Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

Kitsap County, Washington

July 31, 2014

Prepared for:

THE SUQUAMISH TRIBE

Funded by:

U.S. Environmental Protection Agency
EPA Puget Sound Capacity Grant
Grant Number PA-00J29001

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1 Introduction

1.1 OVERVIEW

The Chico Creek watershed covers 16.3 square miles in eastern Kitsap County (Figure 1) and supports the natural production of native salmonid populations including chum, coho, steelhead, and cutthroat trout. The watershed and adjacent nearshore areas have long supported the Suquamish people and these areas are geographically important to the Tribe's cultural history. The natural land cover of the region was historically dominated by old-growth lowland forests which played an important role in maintaining ecological integrity and resilience. The watershed contains localized areas of high quality habitats that are identified as important salmonid refugia (May and Peterson, 2003); however, the area is part of a developing region where human land use practices have impacted the natural processes that are critical to the regulation of geomorphic and ecosystem functions. Timber harvest, mining, road construction, and residential/commercial development have altered watershed processes in the basin and limit salmonid productivity (Haring, 2000).

1.2 PURPOSE AND SCOPE

The Suquamish Tribe has sponsored this assessment with the support of funding provided by the U.S. Environmental Protection Agency (Grant ID Number PA-00J29001). Natural Systems Design, Inc. (NSD) and ICF International prepared the assessment report under contract to, and in collaboration with, the Suquamish Tribe.

The purpose of this assessment is to develop a plan that identifies protection and restoration strategies that prioritize specific actions to maintain and/or improve salmonid habitat conditions and ecological resilience in the Chico Creek watershed. The scope of work outlined to develop this plan included specific tasks to:

- Synthesize findings from previous studies and existing information;
- Assess trends in watershed conditions and alterations to habitat forming processes;
- Identify threats and impacts to ecological processes and habitat conditions;
- Evaluate stream segments with respect to the degree they meet "properly functioning conditions";
- Evaluate land use patterns and current regulatory protections;
- Summarize the status of previously identified protection and restoration actions;
- Recommend and prioritize additional habitat protection and restoration strategies and actions; and
- Identify critical data gaps to be addressed in future investigations.

This report synthesizes information compiled from technical assessments of the Chico Creek watershed and provides recommendations for protection and restoration strategies and actions that will maintain and/or improve watershed, riparian, floodplain and stream habitat conditions for salmonids. The report is organized according to the following sections:

- Section 2 provides an overview of general watershed characteristics;
- Section 3 describes the distribution and status of salmonid populations;
- Section 4 characterizes habitat forming processes, human alterations, and effects on salmonid habitats;
- Section 5 identifies habitat protection and restoration strategies to address impairments caused by alterations to watershed processes.

- Section 6 identifies data gaps and makes recommendations for future work.

The following materials are included as appendices to supplement discussion in the body of the report:

- Appendix A presents a GIS map collection produced at a scale of 1:6,000 and overlay of key features in the watershed, including recommended protection and restoration actions, on a topographic basemap derived from the LIDAR DEM;
- Appendix B presents the same GIS map collection as in Appendix A, but with a basemap displaying recent aerial imagery of the watershed; and
- Appendix C summarizes a list of recommended protection and restoration actions by subbasin.

1.3 BACKGROUND AND PREVIOUS STUDIES

Stakeholder groups have been working to protect critical areas and restore habitat conditions in the Chico Creek watershed and have identified a need for further assessment of the habitat-forming processes to support salmonid recovery planning efforts in the basin.

This report builds upon findings of previous assessments and planning efforts completed for the Chico Creek watershed. Early scientific investigations describing the regional geologic and hydrologic characteristics were developed by the U.S. Geological Survey (Sceva, 1957) and the State of Washington Department of Conservation and Development, Water Resources Division (Garling and Molenaar, 1965). Understanding of the geologic history of the Kitsap Peninsula has since been advanced with high resolution mapping of geologic features and landforms derived from LIDAR based Digital Elevation Models (DEMs) (Haugerud, 2009; Tabor et al., 2011).

Haring (2000) compiled information on fish distribution and salmonid habitat limiting factors in eastern Kitsap County. Findings included an inventory of multiple fish passage barriers in the Chico Creek watershed and a qualitative assessment of floodplain and channel conditions and have been ranked as good, fair, or poor. Limited floodplain connectivity and poor habitat conditions are described for many channel segments in the watershed including Chico Creek downstream of the railroad trestle, Dickerson Creek downstream of the railroad crossing, and in Kitsap Creek downstream of the lake. Key limitations in these segments include a lack of channel complexity, few pools, low amount of wood, bank hardening, and loss of riparian vegetation. Floodplain, channel, and riparian conditions in localized areas of the watershed, notably Lost Creek and Wildcat Creek, are generally described as good.

May and Peterson (2003) identified and characterized potential salmonid habitat conservation areas, or "refugia". The study assigned Chico Creek an overall watershed score of 71%, or Category A (Excellent) and described the watershed as a "*priority refugia with natural ecological integrity*". While not necessarily pristine, this category identifies areas that generally have properly functioning conditions. Chico Creek's high overall score is a function of the quality and spatial extent of the Wildcat and Lost Creek sub-watersheds. The Lost Creek tributary scored 81% and Wildcat scored 76%, both of which are Category A (Excellent). The mainstem of Chico Creek (59% at the river mouth to 64% upstream), Dickerson (73%), and Kitsap (70%) creeks were determined to be Category B streams defined as habitat which is generally in good condition and able to support natural salmonid production despite past disturbance that has altered ecological processes.

Kitsap County Department of Natural Resources initiated a planning effort in 2001 to evaluate watershed responses to human land use activities representing a range of potential development scenarios (Alternative Futures Analysis). A Watershed Advisory Committee defined four alternative futures: (1) Planned Trend, (2) Development, (3) Conservation, and (4) Moderate. A Technical Working Group utilized analytical tools to assess the specific impacts of the alternative scenarios on terrestrial habitats (Linders et al., 2003), geomorphology and stream channel conditions (Segura Sossa and Booth, 2003), water quality, water quantity, riparian processes (Roberts, 2003), and aquatic habitats (Nelson, 2003). The Alternative Futures Analysis concluded that all of the potential scenarios, to a varying degree, result in adverse impacts to natural resources. They found that there are no policies in place, such as those promoting low-impact developments, that would protect watershed resources to the level needed to avoid increased degradation of the conditions assessed.

In 2004, the Suquamish Tribe, in partnership with Kitsap County, the Washington Department of Fish and Wildlife (WDFW), and other entities, developed a planning document that outlined habitat restoration opportunities along the lower 1 mile of Chico Creek downstream of the Chico Way NW bridge (Chico Watershed Alliance, 2004). Several action items that were identified in the 2004 document have been implemented in recent years or are in development including floodplain channel reconnection, riparian restoration on the Kitsap Golf and Country Club as well as continued property acquisition and restoration planning in the estuary. The present assessment will summarize the status of restoration and protection actions identified in the 2004 plan and build upon the previous work to identify additional protection and restoration opportunities in the watershed beyond the lower mainstem corridor considered in 2004.

Additional assessments of watershed processes and habitat conditions have been conducted in recent years to address specific planning or resource management issues. Shanz and Park (2006) conducted a Washington State Department of Transportation (WSDOT) assessment of debris blockages at the SR3 culvert and channel changes in the reach immediately upstream. The Ueland Tree Farm, LLC (UTF) contracted a series of assessments (Parametrix, 2007; Parametrix, 2009) to characterize subbasin conditions and evaluate the potential impacts of proposed mining activities to water resources in the affected area (primarily within the Dickerson Creek subbasin). Kitsap County contracted a stream and wetland characterization (GeoEngineers, 2011) to support design planning for the Dickerson Creek Culvert Replacement and Floodplain Restoration Project. One goal of the study was to provide restoration guidance on the number and placement locations of large wood within Dickerson Creek using baseline information from Fox and Bolton (2007). The key difference between the project area and reference reach (lower Lost Creek) is the quantity of instream wood.

At least ten years has passed since the completion of the Limiting Factors Analysis, Salmonid Refugia, Alternative Futures Analysis, and Chico Watershed Alliance reports, and a status update is warranted to synthesize findings of more recent assessments and consider recent changes in the watershed. Land use practices have continued to alter watershed processes, multiple flood events have occurred, including large floods in 2007 and 2009 that triggered geomorphic change resulting in damage to infrastructure in the floodplain. Additionally, several habitat restoration projects have been implemented since completion of the 2003 assessment, and a number of property acquisitions or easements have been secured that are intended to protect habitat conditions. As such, a comprehensive watershed planning document is needed to coordinate targeted habitat protection and restoration strategies and to prioritize actions for implementation.

The Puget Sound Salmon Recovery Plan (Shared Strategy for Puget Sound, 2007) was adopted by the federal government in early 2007 and is a part of the larger Puget Sound Partnership Action Agenda. The chapter from that plan focusing on salmon recovery planning for the East Kitsap region classifies Chico Creek as a “Tier 1 stream” and identifies it as a high priority for habitat protection and restoration.

A "Chico Creek Protection and Restoration Plan" is identified as a near-term action item in the 2012 update to the West Sound Local Integration Organization (LIO) Action Agenda. This assessment aims to address the need for continued protection and restoration and guide the development of planning strategies for future habitat protection and restoration actions in the Chico Creek watershed.

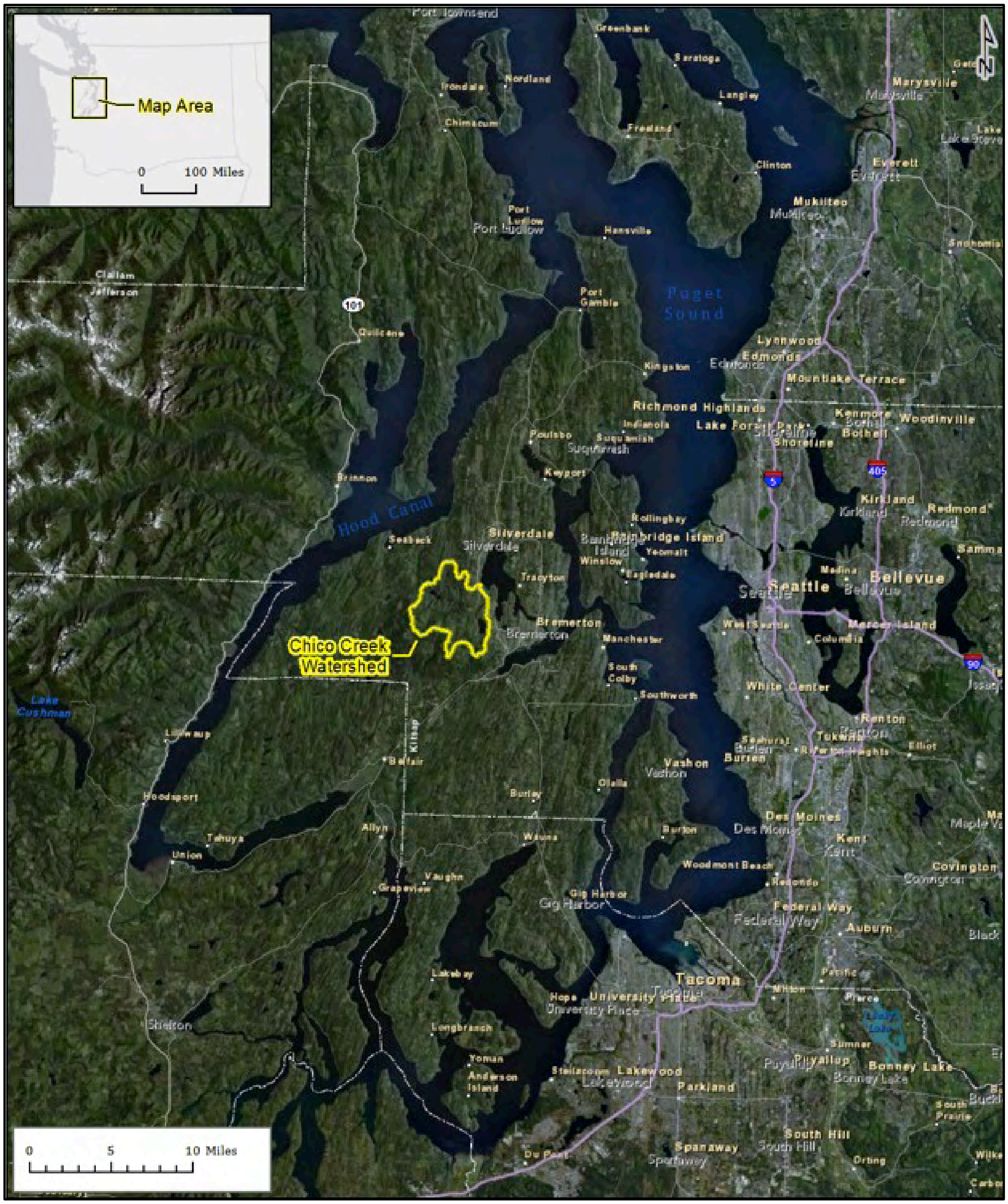


Figure 1. Vicinity map showing locations of the Kitsap Peninsula and the Chico Creek watershed.

2 WATERSHED CHARACTERISTICS

The Chico Creek watershed encompasses an area of 16.3 square miles in eastern Kitsap County (Table Figure 1). The climate, geology, land use, and physiography of the drainage basin collectively determine the magnitude and variability of streamflow in the river channels as well as the quantity and character of the sediment supply. The watershed characteristics of the Chico Creek basin are summarized below to describe the prevailing physical conditions driving habitat forming processes.

2.1 DRAINAGE NETWORK

The Chico Creek watershed drainage network is comprised of the mainstem channel, tributary streams, and two large lakes formed by natural processes (Figure 2). In total, there are 50 miles of mapped stream channels in the watershed, 22 miles of which are classified as fish habitat according to the Washington Department of Natural Resources (WDNR) forest practices fish habitat water type dataset. The principal tributary streams include Kitsap Creek (drainage area [A_d] = 2.9 square miles), Dickerson Creek (A_d = 2.1 square miles), Lost Creek (A_d = 3.0 square miles), and Wildcat Creek (A_d = 6.3 square miles). Kitsap Lake, within the Kitsap Creek subbasin, inundates an area of 230 acres with a maximum depth of approximately 25 ft. Wildcat Lake, within the Wildcat Creek subbasin, covers an area of 103 acres with a maximum depth of approximately 30 ft. Kitsap Creek, Dickerson Creek, and Wildcat Creek subbasins include extensive wetland areas that play an important role moderating the infiltration, storage, and delivery of flow in the hydrologic system. The largest of the wetland areas, the Newberry Wetlands, covers an area of 140 acres in the Wildcat Creek subbasin and is managed as part of the Newberry Hill Heritage Park by Kitsap County.

Table 1. Subbasin characteristics for the Chico Creek watershed.

	A_d (mi^2)	*Topographic Relief (ft)*	*Annual Mean Precipitation (in)*
Chico Creek Subbasin	1.9	588’	54”
Kitsap Creek Subbasin	2.9	653’	56”
Dickerson Creek Subbasin	2.1	1286’	62”
Lost Creek Subbasin	3.0	1401’	65”
Wildcat Creek Subbasin	6.3	1135’	56”
Watershed Total	16.3	38%	59”

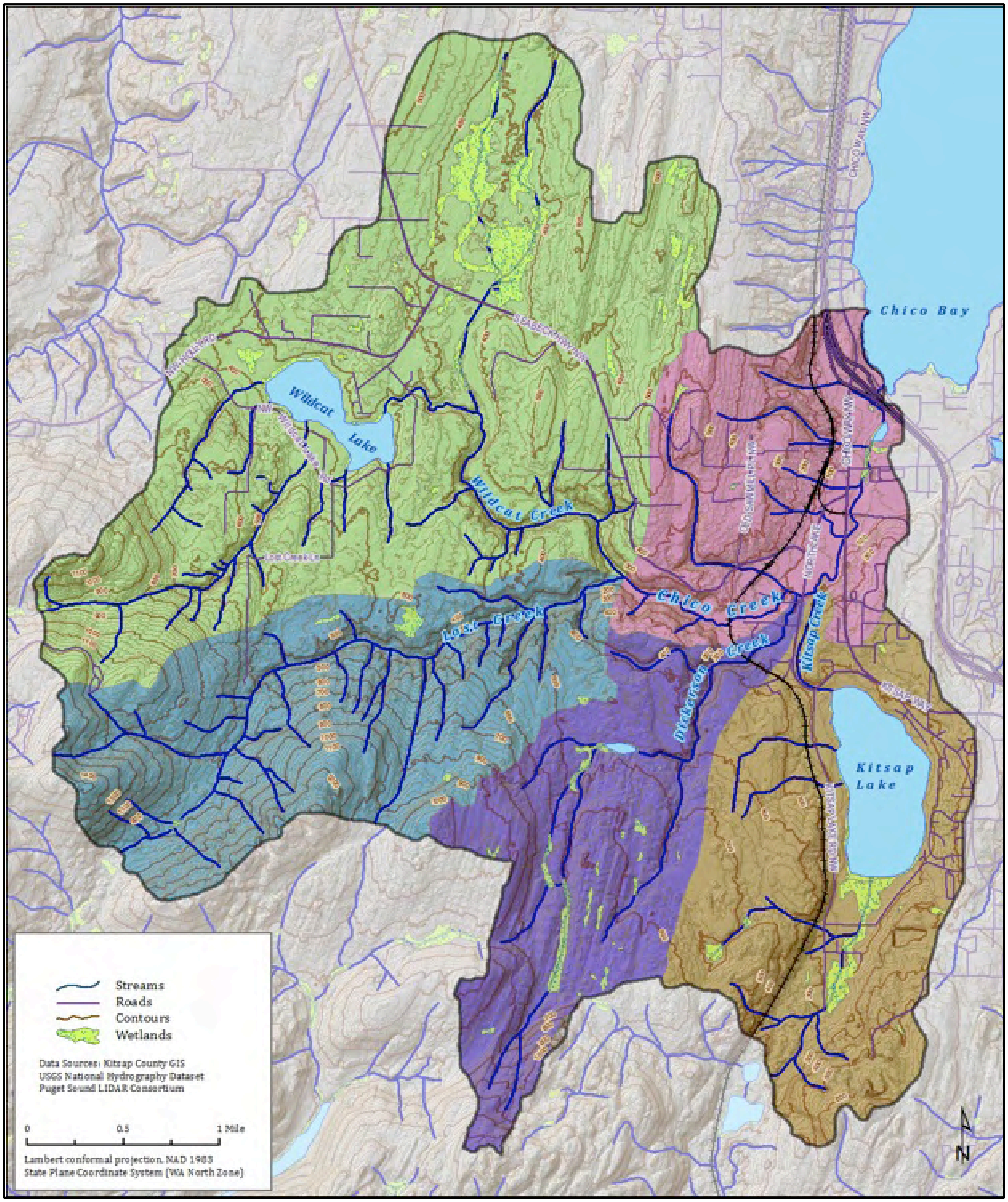


Figure 2. Key hydrologic features and subbasins of the Chico Creek watershed.

2.2 GEOLOGIC HISTORY AND LANDFORMS

The Chico Creek watershed is located within the Puget Lowland of Washington State and has been transformed over time by tectonic, glacial, and fluvial processes that defined the watershed boundary and shaped the landforms which are present today. Topographic relief (range between minimum and maximum elevation values) of the watershed is approximately 1,500 ft (Figure 2). The watershed is characterized by the following set of physiographic zones that are defined by topographic relief, surficial geology, and geomorphic function:

- Bedrock dominated uplands;
- Fluted glaciated surfaces (plateau);
- Steep slopes along incised valleys or ravines; and
- Alluvial flats (floodplain and associated terrace features).

Surficial geology of the watershed includes Eocene aged (formed 33.9 – 56 million years ago) volcanic rocks and a variety of unconsolidated glacial deposits (Figure 3). The areas of shallow bedrock, primarily basalt of the Crescent formation, are located in the higher elevations of the watershed where extensions of Green Mountain and Gold Mountain form the divide in the upper Dickerson, Lost, and Wildcat Creek subbasins. A broad plateau underlain by glacial deposits covers an extensive area of the watershed and is distinguished by the relatively flat upland region ranging in elevation between 350 and 500 ft above sea level. The most recent ice sheet advance, known as the Vashon Stade of the Fraser Glaciation, covered the Puget Lowland in ice beginning approximately 18,000 years before present (b.p.) and retreated from the region by approximately 15,000 years b.p. (Booth, 1994; Porter and Swanson, 1998). Ice thickness was approximately 3,000 ft at the present day location of Seattle and increased to over 5,500 ft near the U.S.-Canadian border (Armstrong et al., 1965). Glacial deposits accumulated in the Chico Creek watershed include areas of glacial till deposited by ice, and outwash which was sorted or redeposited by glacial meltwater. In general, these deposits are divided such that the plateau in the Wildcat Creek subbasin and the northern portion of the Lost Creek subbasin are underlain by deposits classified as till, and areas of the plateau in the southern portion of Lost Creek, Dickerson Creek, and Kitsap Creek subbasins are underlain by deposits classified as outwash (Figure 3).

Haugerud (2009) mapped geomorphic features in the Kitsap Peninsula using LIDAR-based topographic data (Figure 4). The geomorphic map identifies landforms in the Chico Creek watershed at a much higher resolution compared to previous geologic mapping. Haugerud (2009) delineates subareas within the glaciated surface and includes:

- Fluted glaciated surfaces characterized by elongated ridges, 30 to 100 ft in height;
- Outwash flats composed of sediment deposited by glacial meltwater and primarily graded to the base level formed by inundation of glacial Lake Russell (elevation 340 to 400 ft above sea level); and
- Kettle/Kame surfaces marked by irregular topography with closed depressions formed as deposits settled around stagnant ice during a period of glacial melt.

Post-glacial incision by fluvial processes has dissected the upland plateau and formed the network of alluvial valleys which drain to Chico Creek. Many of the alluvial valleys are flanked by steep slopes, some exceeding a gradient of 60 percent. The hillslope areas are generally composed of unconsolidated glacial deposits and are susceptible to mass-wasting processes including colluviation, debris flows, and landslides (Haugerud, 2009). Present day stream channels forming the drainage network of the Chico Creek watershed are actively carving the alluvial valleys over time. Longitudinal profiles of the modern

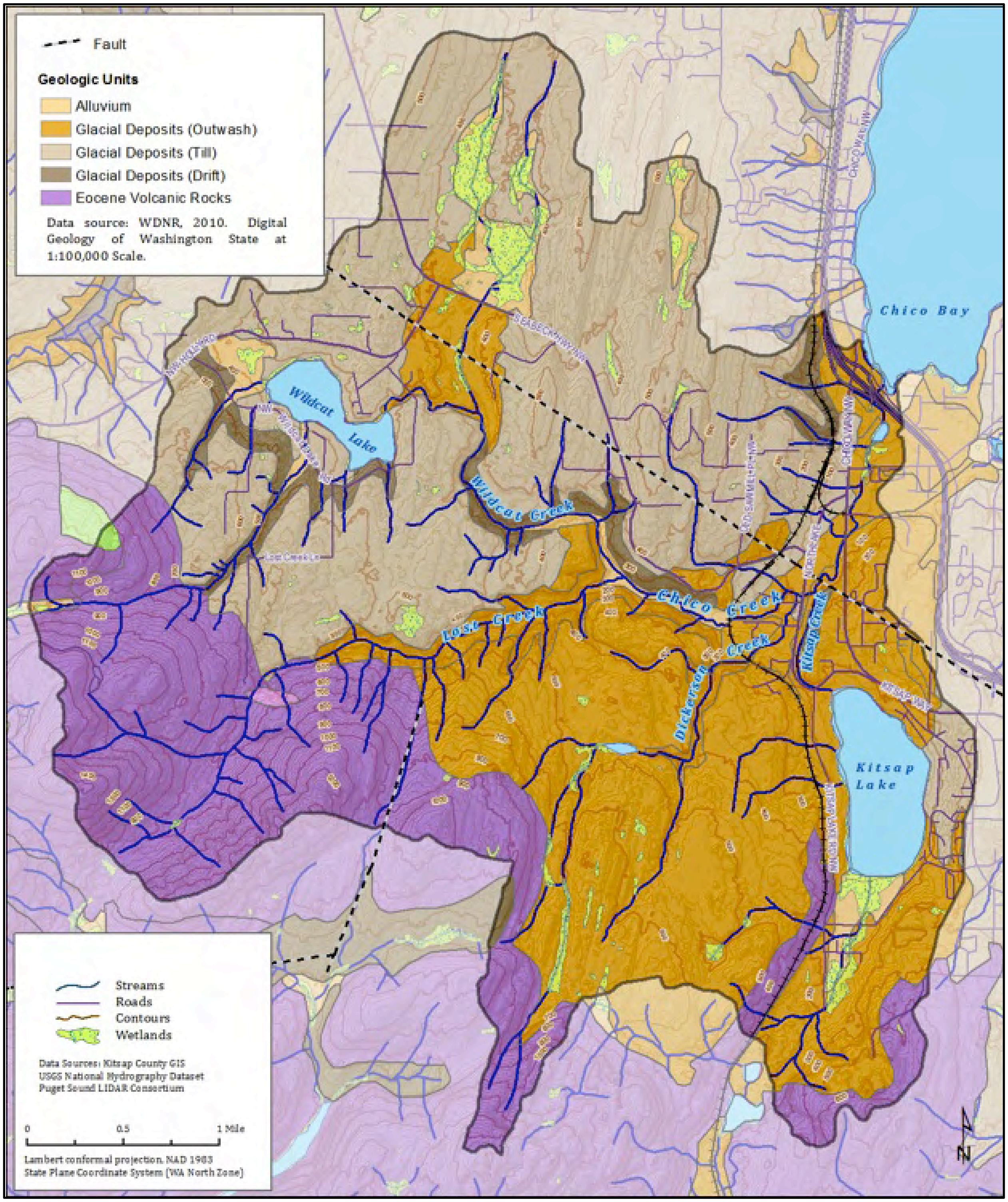


Figure 3. Surficial geology of the Chico Creek watershed (source: WDNR, 2010).

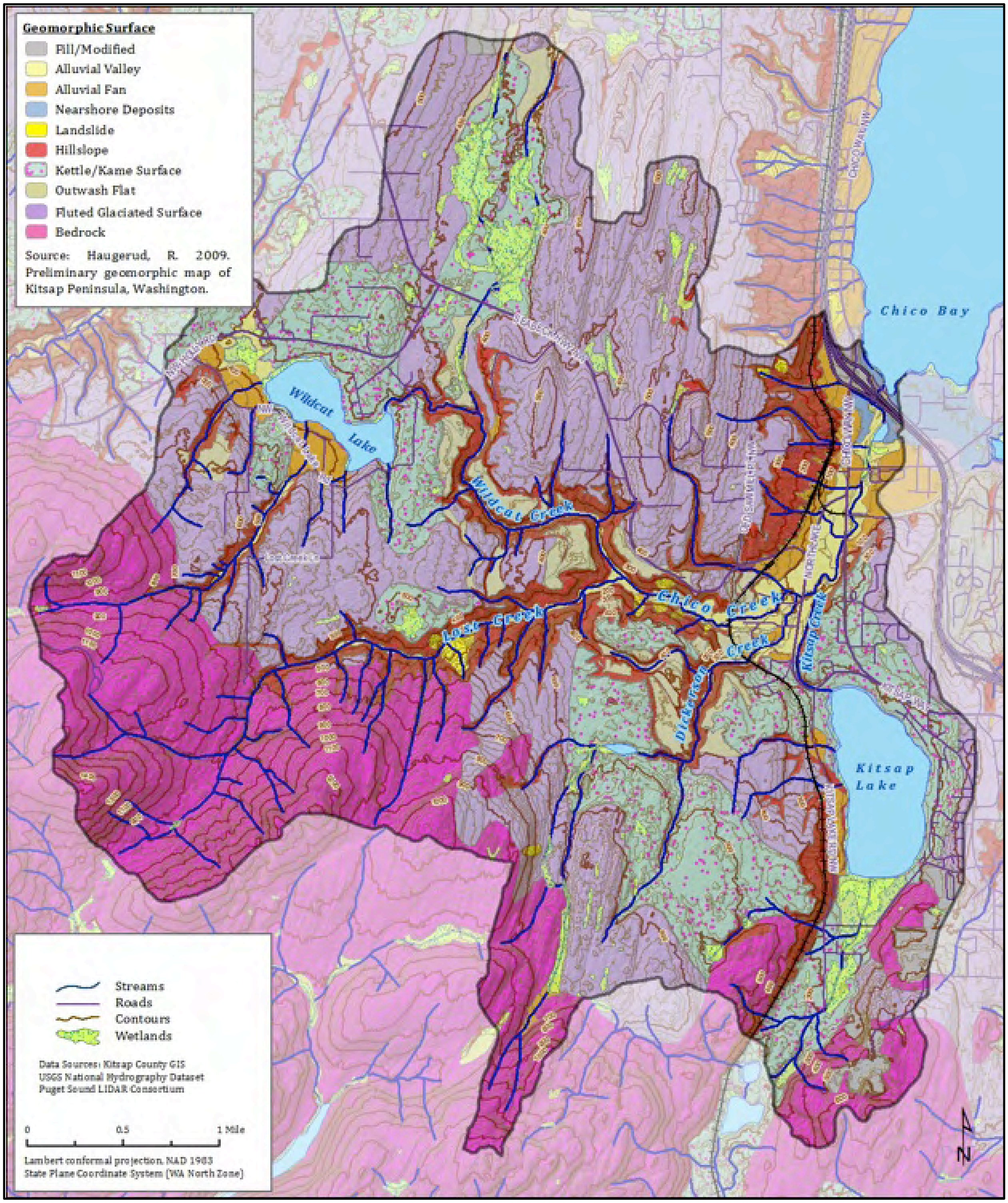


Figure 4. Geomorphic map of the Chico Creek watershed (source: Haugerud, 2009).

stream network show that the main channels of Chico Creek and lower segments of Kitsap, Dickerson, Lost, and Wildcat creeks have developed relatively uniform channel gradients ranging between 1 and 2 percent slope (Figure 5). Localized influences of bedrock (basalt) outcrops influence the middle segments of channel profiles in Dickerson and Lost Creeks marked by steepened gradients (falls or steep cascades).

Alluvial flats are generally limited to the lower portions of the watershed in locations that are dominated by fluvial processes such as sediment transport and channel migration. The alluvial valley containing the mainstem channel of Chico Creek includes multiple terrace surfaces that formed as alluvial floodplains but have since been disconnected from the stream by channel incision or uplift. The highest surfaces in the valley include terraces that formed in response to tectonic uplift associated with large earthquakes (Atwater, 1999; Haugerud, 2009; Sherrod, 2001). There are additional terraces, however, that likely represent more recent floodplain surfaces which have been disconnected by historic channel incision associated with human alterations of the landscape. Alluvial fans are also evident in the landscape at tributary confluences and along valley walls where steep, confined tributaries join broader, less confined valleys. Alluvial fans are characterized by moderately sloping surfaces (gradients generally between 2 and 5%), are conic in shape, and prone to debris-flow processes and infrequent, but potentially hazardous, flood events.

2.3 CLIMATE AND HYDROLOGY

Climatic characteristics of the Chico Creek watershed are typical of the Puget Lowland region with summers that are generally cool and relatively dry and winters are mild, wet, and cloudy. Climatic normals (1981-2010) compiled for a nearby monitoring station in Bremerton illustrate the seasonal variations of temperature and precipitation for the region (Figure 6). Mean monthly temperatures at Bremerton range between 40° F in December to 67° F in August. Monthly means of minimum temperatures drop to 35° F in December.

Precipitation patterns are strongly seasonal with mean values of total precipitation at Bremerton ranging from less than 1 inch in July to 10 inches in December. Typically, the majority of precipitation for a given year falls during the months between November and February. Precipitation falls almost exclusively in the form of rainfall as opposed to snow. Snowfall in the lowland areas is infrequent and accumulations typically melt within days of snowfall events. Snowfall at the Bremerton monitoring station averages about 5 inches per year with annual totals ranging between 0 and 40 inches. Higher elevations in the watershed can receive greater amounts of snowfall; however, hydrologic regimes are rainfall dominated in all areas of the Chico Creek watershed.

Precipitation is driven by the movement of frontal systems and the easterly passage of moisture laden air masses from the Pacific Ocean. Rainfall is typically moderate in intensity and spread out over a relatively long duration rather than focused in intense downpours (Table 2). Spatial variations of precipitation reflect the influence of the rain shadow effect created by the Olympic Mountains to the west and a more localized effect driven by orographic uplift of the Green and Gold Mountain region in the upper portions of the Chico Creek watershed. At a course-scale, precipitation in Kitsap County decreases from south to north, where the rain shadow effect is greatest. Mean annual precipitation at Bremerton was 56 inches during the period 1981-2010. Within the Chico Creek watershed, precipitation increases with elevation and is greatest in the upper regions of Dickerson, Lost, and Wildcat Creek subbasins. Spatial modeling of precipitation data, accounting for orographic effects driven by topographic relief (Daly et al., 2008) predicts an increase in mean annual precipitation to a maximum value exceeding 70 inches in the upper watershed (Figure 7).

Interannual and interdecadal variations of climatic characteristics in the Pacific Northwest are strongly related to variations in the strength and location of the Aleutian Low, a low pressure cell centered over the Gulf of Alaska that directs onshore movement of moist air masses into the Pacific Northwest. Two important factors affecting climatic patterns in the Pacific Northwest are the El Nino Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) (Mantua et al., 1997). El Nino conditions are typically associated with warmer, drier winters in the Pacific Northwest while the opposite condition, La Nina, is more typically associated with cooler and wetter winter conditions (Redmond and Koch, 1991). The PDO is a more persistent climatic pattern that oscillates between warm and cool phases. The warm phase of the PDO has a similar effect as El Nino on climate of the Pacific Northwest (warm, dry winters) and the cool phase of the PDO tends to favor cooler, wetter winters (Mantua et al., 1997).

Streamflow characteristics in the Chico Creek watershed are strongly related to the timing and magnitude of precipitation. Flows in Chico Creek begin the hydrologic year (starting in October) relatively low, increase during winter months, and recede during the drier period between March and September (Figure 8). Peak flows respond quickly to precipitation events; the winter season hydrograph is characterized by a relatively flashy series of peak flow events. Flood frequency statistics calculated using USGS guidelines (U.S. Interagency Advisory Committee on Water Data, 1982) on the annual maximum series at the USGS gaging station are summarized in Table 3. Flow duration statistics reveal that daily streamflow values generally range between 1 and 100 cfs with a median value, exceeded 50% of the time in the period of record, of 14 cfs (Figure 9).

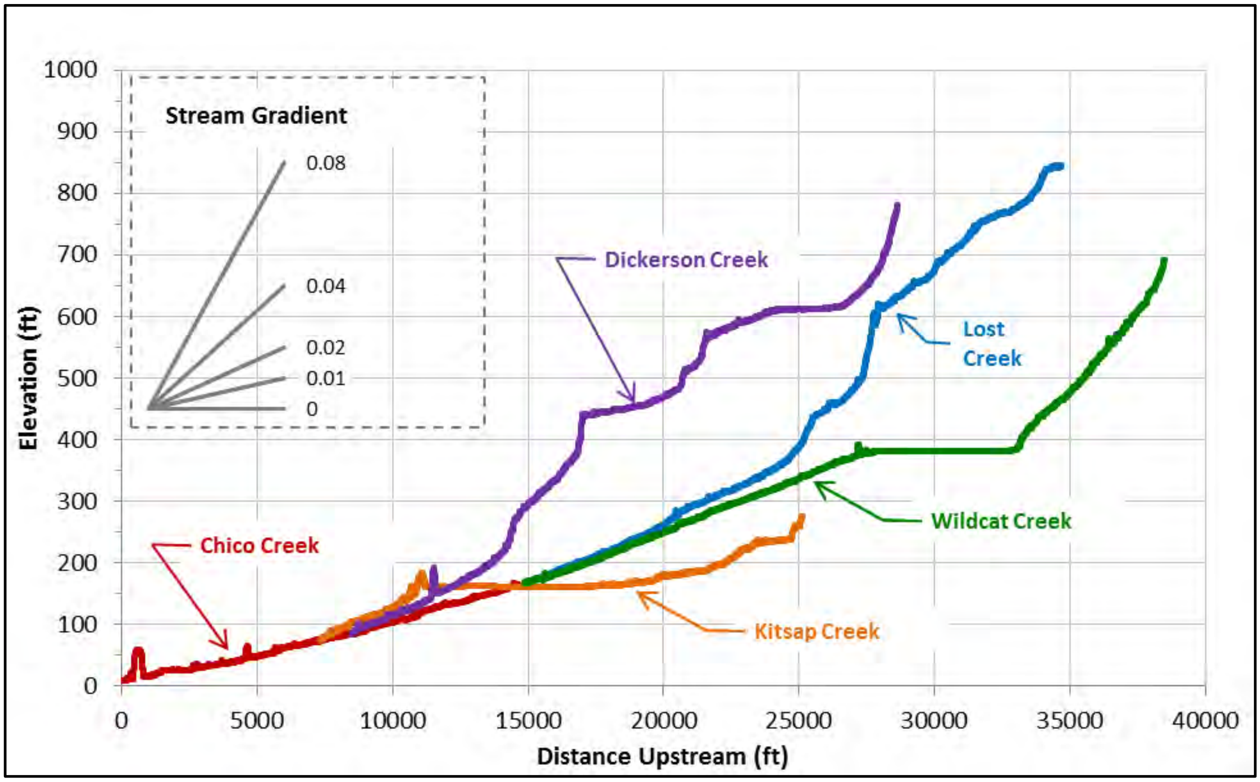


Figure 5. Longitudinal profiles of the primary stream network in the Chico Creek watershed.

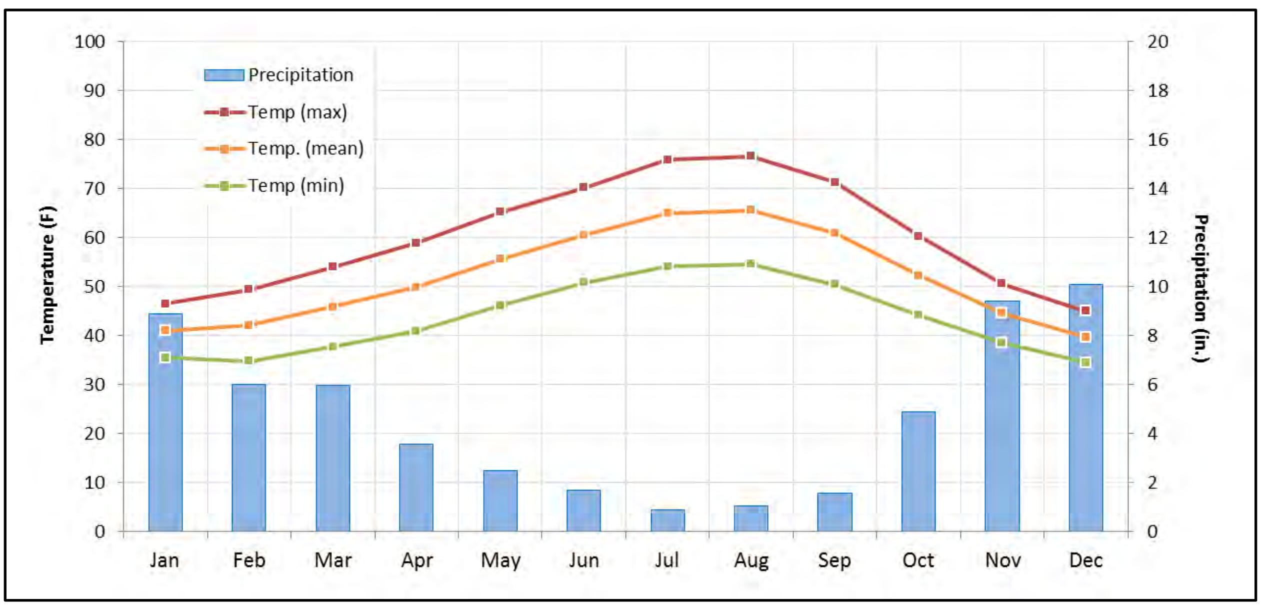


Figure 6. Climograph of mean monthly temperature and precipitation totals for the period 1981-2010 at Bremerton, WA (NOAA COOP Station: 450872).

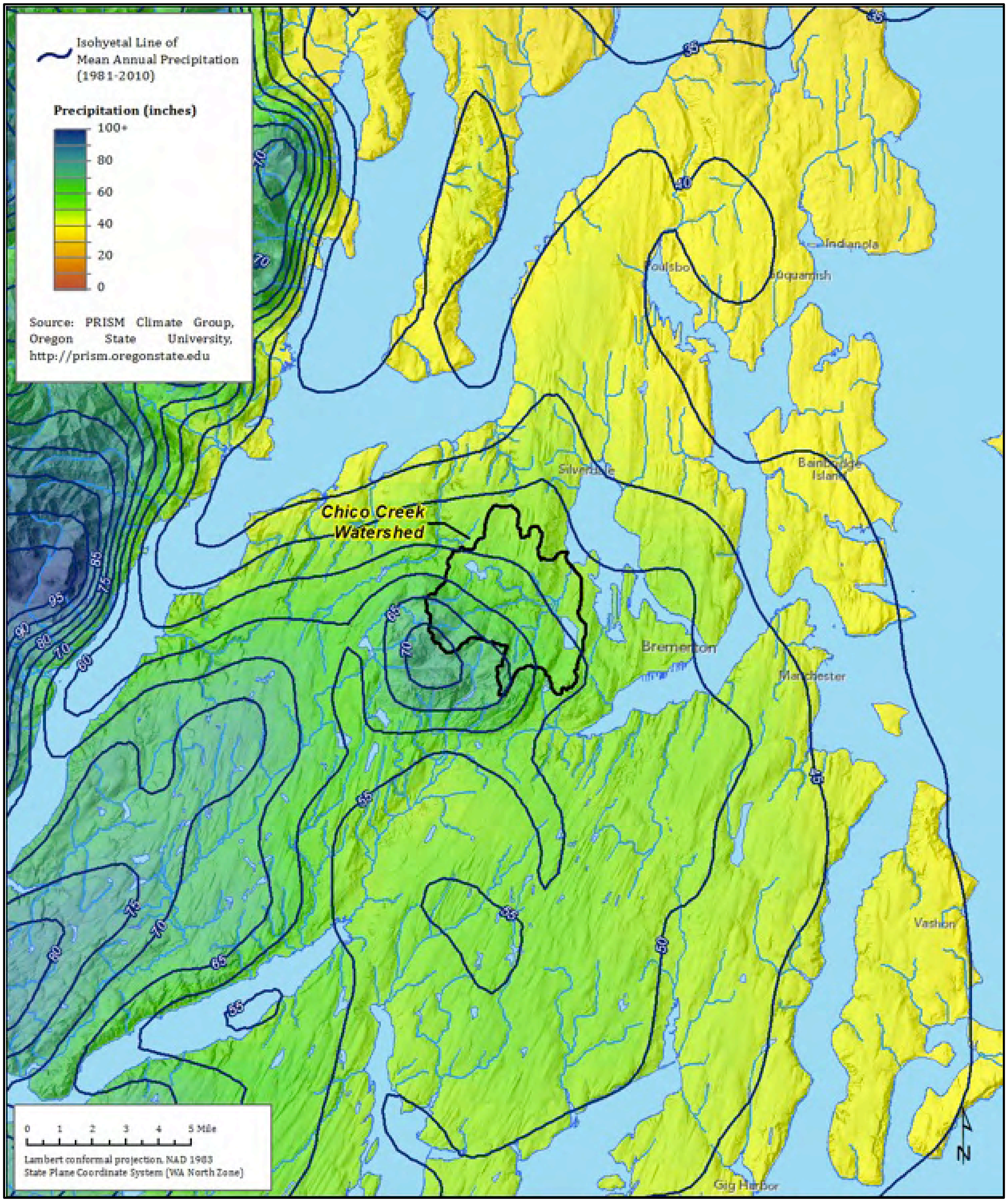


Figure 7. Isohyetal map of mean annual precipitation 1981-2010 (source: PRISM Climate Group, Oregon State University).

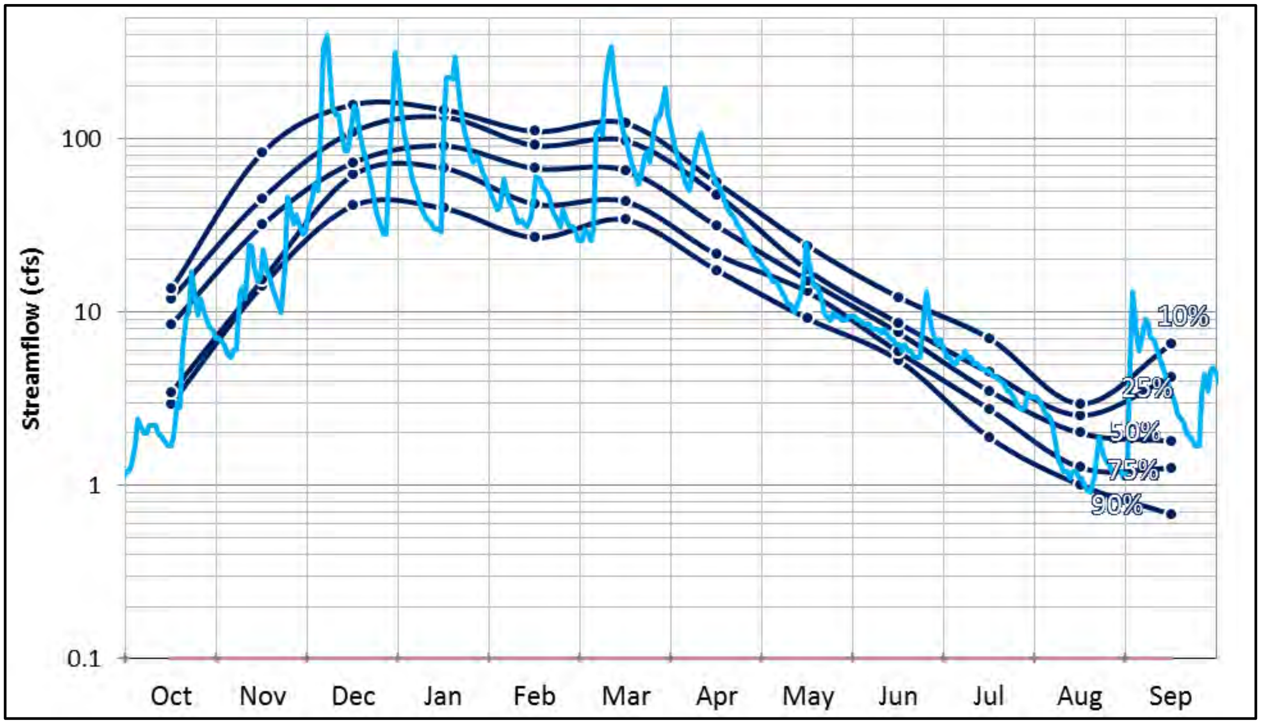


Figure 8.Seasonal distribution of streamflow for Chico Creek at NW Golf Club Hill Rd (USGS station # 12072000; 1947-50, 1961-74). Dark blue lines depict the exceedance percentiles for a given month. The lighter blue line shows daily fluctuations from an example hydrograph (WY 1971) for reference.

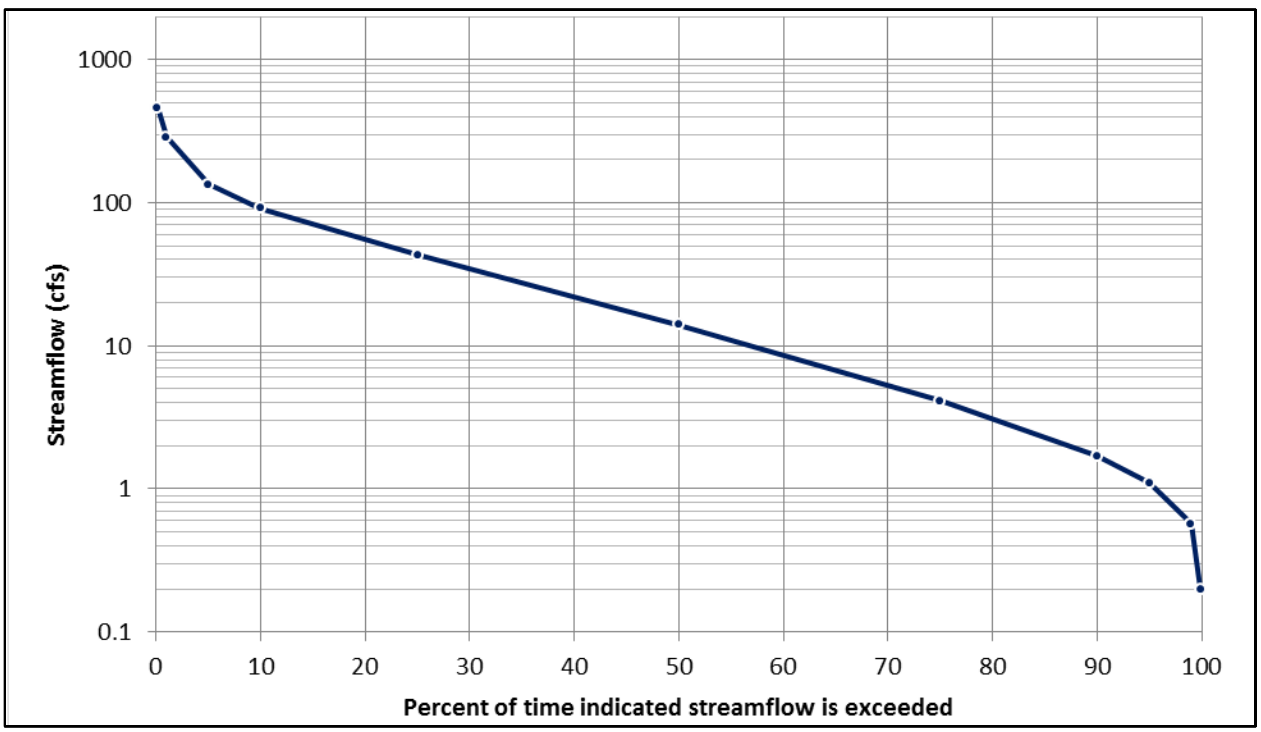


Figure 9. Flow duration curve based on mean daily streamflow (1947-50, 1961-74); Chico Creek at NW Golf Club Hill Rd (USGS station # 12072000).

Table 2. Summary of precipitation intensity, duration, and frequency for the Chico Creek watershed (Miller et al., 1973). Units of precipitation values are inches.

	Duration		
Frequency	***1-hr***	***6-hr***	***24-hr***
2-yr	0.5	1.4	3.2
5-yr	0.6	1.8	3.7
10-yr	0.7	2	4.2
25-yr	0.8	2.4	5
50-yr	0.9	2.6	5.5
100-yr	1.0	2.8	6

Table 3. Flood frequency statistics (1962-79); Chico Creek at NW Golf Club Hill Rd (USGS station # 12072000).

Recurrence Interval (yrs)	***Peak Streamflow (cfs)***
1.01	205
1.25	331
2	432
5	564
10	647
25	749
50	822
100	894

2.4 SOILS AND NATURAL LAND COVER

The natural land cover of the Puget Lowland region was characterized by vast expanses of late seral (mature) coniferous forest composed primarily of western hemlock (*Tsuga heterophylla*), Douglas fir (*Pseudotsuga menziesii*), and western redcedar (*Thuja plicata*) (Franklin and Dyrness, 1988). Hardwood species were generally rare in upland forests; however, hardwoods were abundant in valley bottom areas prone to frequent disturbance (Collins et al., 2003). The natural forest cover is important to the regulation of hydrologic, geomorphic, and ecologic processes in the watershed. The original forests were cleared by timber harvest practices early in the settlement period and areas of the Chico Creek watershed have been harvested numerous times since the mid- to late-1800s. There is one known remaining example of relatively mature timber in the watershed that is part of a conservation area known as the Mountaineers Foundation Rhododendron Preserve.

Soil characteristics generally reflect the prevailing climate, geologic history, and distribution of parent materials (e.g., weathered rock, glacial deposits, and alluvium). The distribution of soil types in the Chico Creek watershed is characterized by a majority of soil units classified as silty gravel (Figure 10). The most widely distributed soil series in the watershed is the Alderwood series, a moderately well drained soil that develops from a parent material of glacial deposits. The typical pedon of these soils is described as (McMurphy, 1980):

- A surface layer (O horizon) composed of organic materials (e.g., needles, leaves, bark, wood);
- A thin topsoil (A horizon) characterized as very gravelly sandy loam with a granular structure;
- A subsurface (B horizon) characterized as very gravelly loam with a subangular blocky structure; and
- An underlying substratum (C horizon) composed of weakly silica-cemented glacial sediments.

The silica-cemented substratum forms a hardpan layer that ranges in depth between 20 to 40 inches below the ground surface (McMurphy, 1980). The hardpan layer restricts infiltration and limits the water holding capacity of these soils. Soils of the Alderwood series are classified as hydrologic soil group D, indicating a high potential for surface runoff (Figure 11).

Soils in the upper portions of the watershed located at higher elevations underlain by bedrock are most commonly grouped as part of the Kilchis series. The Kilchis soils have similar characteristics as the Alderwood series for the O, A, and B horizons; however, the Kilchis soils lack the C horizon and form directly from fractured bedrock (basalt). Depth to bedrock is shallow and ranges between 16 and 20 inches (McMurphy, 1980). Given that shallow bedrock restricts infiltration, the Kilchis soils are also mapped as hydrologic soil group D (Figure 11).

Localized areas of silty sand occur to the east of Wildcat Lake; in the upper portions of the Chico Creek subbasin (between the Navy Railroad and the upstream junction with Lost/Wildcat Creeks); in the middle Dickerson Creek subbasin; and in the upper segments of the Kitsap Creek subbasin. These soils develop from glacial outwash and lack the hardpan layer described for soils in the Alderwood series and are typically mapped as hydrologic soil group A, indicating a relatively low potential for surface runoff (Figure 11). Soils in the lower watershed, including the valley of mainstem Chico Creek, lower Dickerson Creek, and Kitsap Creek, are classified as silt. Areas of peat are mapped in the areas surrounding Kitsap Lake, Wildcat Lake and the Newberry Wetlands.

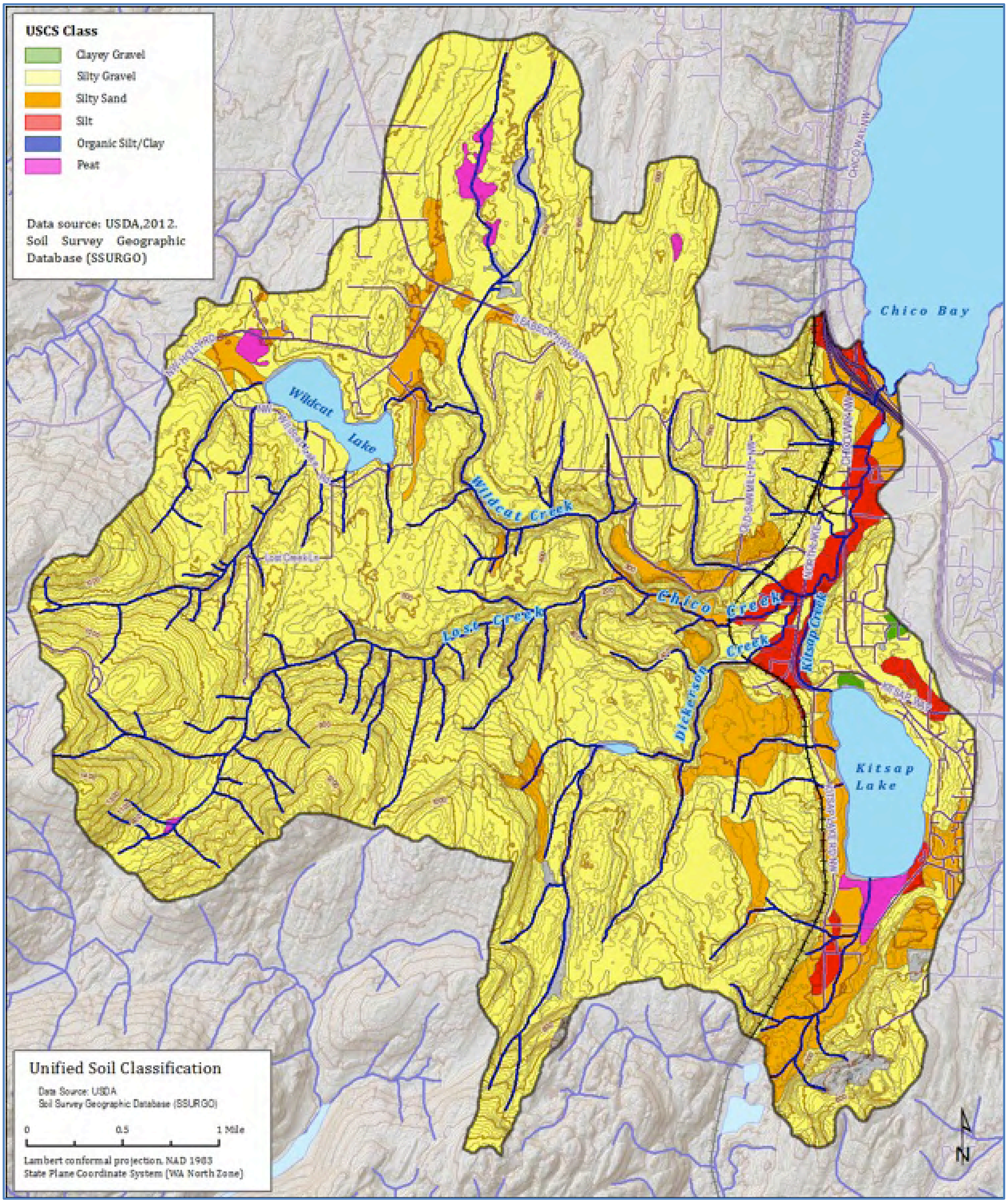


Figure 10. Soil map of the Chico Creek watershed with Unified Soil Classification System designations (Source: USDA, 2012).

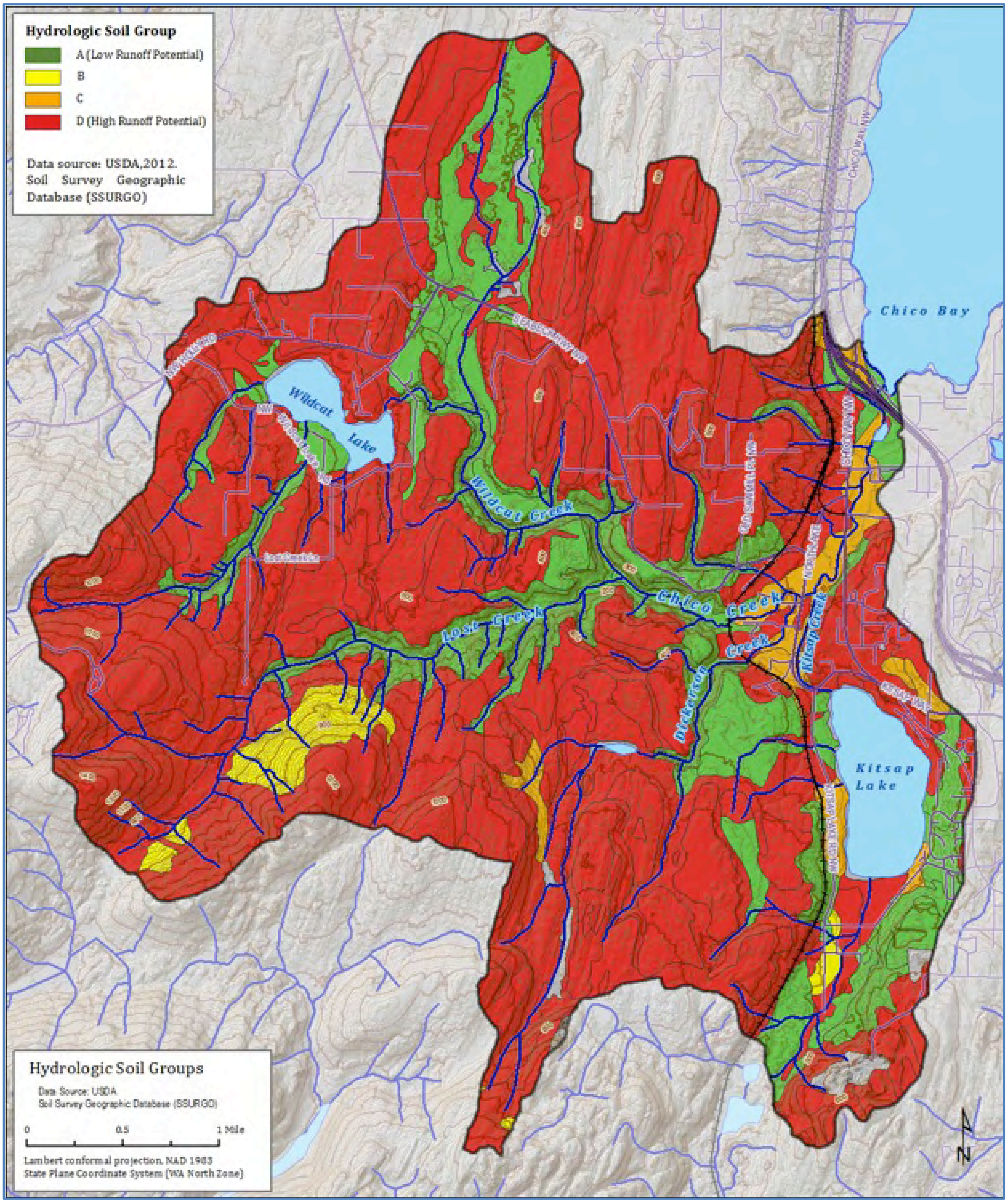


Figure 11. Hydrologic soil groups in the Chico Creek watershed (Source: USDA, 2012).

2.5 LAND USE AND DEVELOPMENT HISTORY

The Suquamish people have long occupied the Chico Creek Watershed and Dyes Inlet. The oldest radiocarbon dates from excavated archaeological sites in the inlet prove that people have been in the region since at least 1,200 years ago. Numerous ethnographic place names documented along the shorelines of Dyes Inlet demonstrate the importance of the area to the Suquamish. A variety of resources could be found in the Dyes Inlet area, especially from Chico Creek. Salmon and shellfish, the dietary staples of the Suquamish people, were easily procured from the vicinity. Chico Creek was known as Spe'w1L, meaning "to whistle" (Waterman ca. 1920). A Suquamish winter village, known as spewl, was near the mouth of Chico Creek and had at least one shed-roofed house (Snyder 1968:132). Suquamish informants described how "salmon were caught in the stream and deer hunting was good especially around Kitsap Lake" (Snyder 1968:132).

A contemporary aerial view of the existing land cover characteristics reveal extensive human land use impacts in the Chico Creek watershed (Figure 12). Although approximately 70 percent of the watershed land area is forested, the forests are primarily managed for timber production and generally lack many of the characteristics associated with the late seral forests that covered the region prior to the period of Anglo-American settlement in the mid-1800s. Existing land cover of the watershed includes substantial areas characterized by scrub/shrub lands (areas of recent timber harvest) and developed areas dominated by residential and commercial land uses. Satellite-based land cover classifications for 1992 and 2011 are mapped for the Chico Creek watershed in Figure 13 and Figure 14. Recent land cover changes were calculated for each subbasin by extracting the difference between the 1992 and 2011 classifications (Table 4).

Developed areas cover only about 11 percent of the watershed; however, localized areas are more intensively developed. The Lower Chico Creek and Kitsap Creek subbasins are the most developed areas of the watershed, characterized as 36 and 22 percent developed, respectively (Figure 15). Kitsap County experienced a nearly threefold increase (198%) in population during the period 1960-2010 and planning level population forecasts predict an additional 28% increase over the period 2010-2040 (State of Washington Office of Financial Management, 2012). Land development patterns in the Chico Creek watershed show a large number of parcels in the Lower Chico and Kitsap Creek subbasins that were developed during the period between 1950 and 1980; while areas in the Wildcat Creek subbasin and the plateau region above Lower Chico Creek experienced more recent development since 1980 (Figure 16). Developed areas increased by 2.2% over the entire watershed between 1998 and 2011 with the most intensive development during this period occurring within the Chico Creek subbasin (8.3% increase; Table 4)

Land ownership in the Chico Creek watershed is distributed between private ownership and multiple public agencies (Figure 17). Collectively, 39 percent of the land area in the Chico Creek watershed is in public ownership with the Lost Creek and Wildcat Creek subbasins having the greatest relative area in public ownership (Table 5). The largest land management unit in the watershed is the Green Mountain State Forest composed primarily of State trust lands managed by WDNR. Kitsap County retains ownership of a mosaic of parcels totaling about 8 percent of the watershed area including key parcels such as the Newberry Hill Heritage Park, Erlands Point Park, and streamside parcels near NW Golf Club Hill Road and at the confluence of Chico Creek with Dickerson Creek. Federal lands include the Camp Wesley Harris Naval Reservation in the northern part of the watershed and the Camp McKeon Naval Recreation Center along the western shore of Kitsap Lake. The U.S. Navy also owns a railroad right of way that is oriented north-south and crosses Kitsap Creek (upstream of Kitsap Lake), Dickerson Creek, and Chico Creek, in addition to multiple tributary channels in the watershed. The City of Bremerton manages a park at the south end of Kitsap Lake and owns municipal lands along the ridgeline in the Lost Creek, Dickerson Creek, and Kitsap Creek subbasins.

The largest private land owners/ownership groups in the watershed are the Ueland Tree Farm (LLC) and the Mountaineers Foundation. The Ueland Tree Farm encompasses over 1,300 acres in the Chico Creek watershed (13 percent of the total watershed land area) and is the majority land owner (73 percent) of the Dickerson Creek subbasin. The Mountaineers Foundation own and manage a conservation area (Kitsap Rhododendron Preserve) spanning over 400 acres in the center of the watershed including areas of mature forest conditions highlighting the ecological potential of the watershed area if resources are managed to maintain the integrity of key watershed processes.

Kitsap County (2012) recently adopted a Comprehensive Plan to guide development policies in the region and fulfill mandates set by the State of Washington Growth Management Act (GMA). The plan produced a map designating land use patterns based on a 20-year vision of physical, economic, and community development (Figure 18). The relative portion of subbasin areas designated for individual land use classes is summarized in Table 6. The primary land use categories that are mapped in the Chico Creek watershed area include:

- Forest Resource Lands, maintaining availability for significant resource production (e.g., timber harvest) while permitting residential uses at an appropriate low density as long as they do not interfere with timber management and harvesting activities (maximum of 1 dwelling unit [du]/40 acres [ac]);
- Rural Wooded, allowing for forest resource use and limited residential uses (1 du/20 ac);
- Rural Residential, promoting low density residential development with a maximum of 1 du/5 ac; and
- Incorporated City.

Additional land use classifications mapped for smaller relative areas (<5 percent of the watershed) include:

- Public Facility;
- Military;
- Tribal;
- Urban Reserve, intended to allow rural development in areas that may be suitable for inclusion in the UGA in the future (maximum of 1 du/10 ac).
- Mineral Resource Lands, a zone overlay intended to protect sand, gravel, and rock deposits of commercial significance;
- Rural Commercial; and
- Rural Industrial.

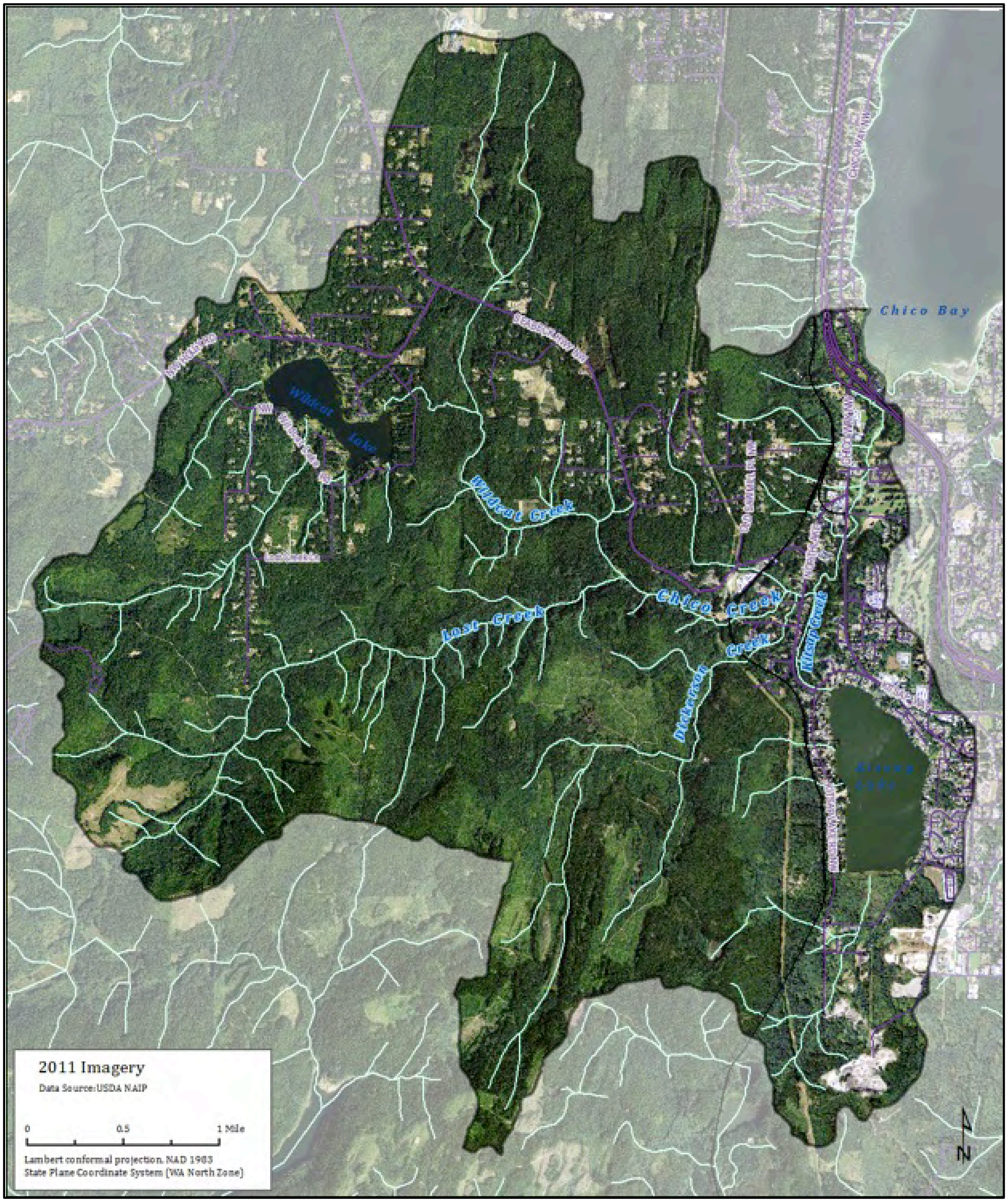


Figure 12. 2011 aerial imagery of the Chico Creek watershed.

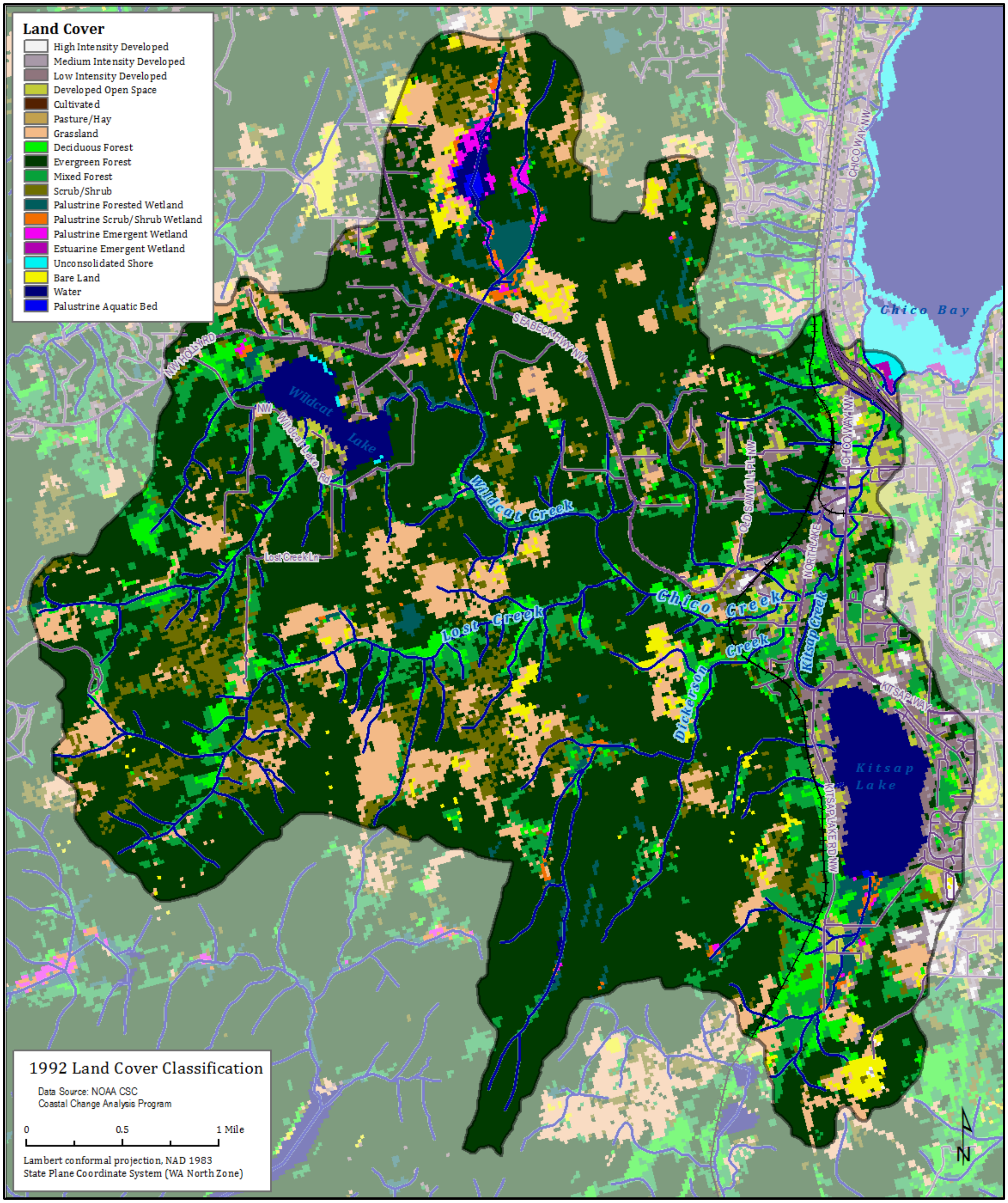


Figure 13. 1992 land cover classification for the Chico Creek watershed (NOAA Coastal Change Analysis Program).

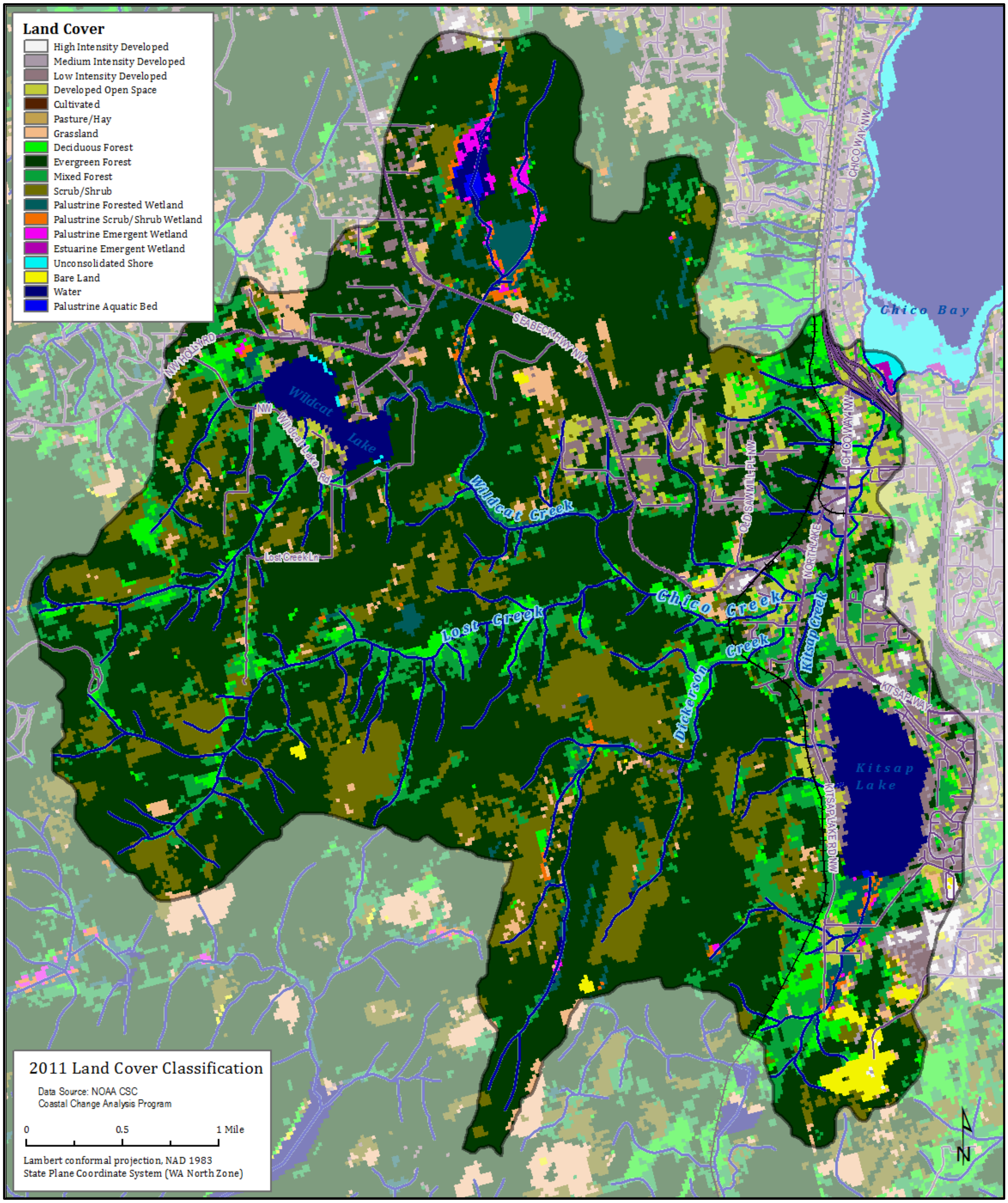


Figure 14. 2011 land cover classification for the Chico Creek watershed (NOAA Coastal Change Analysis Program).

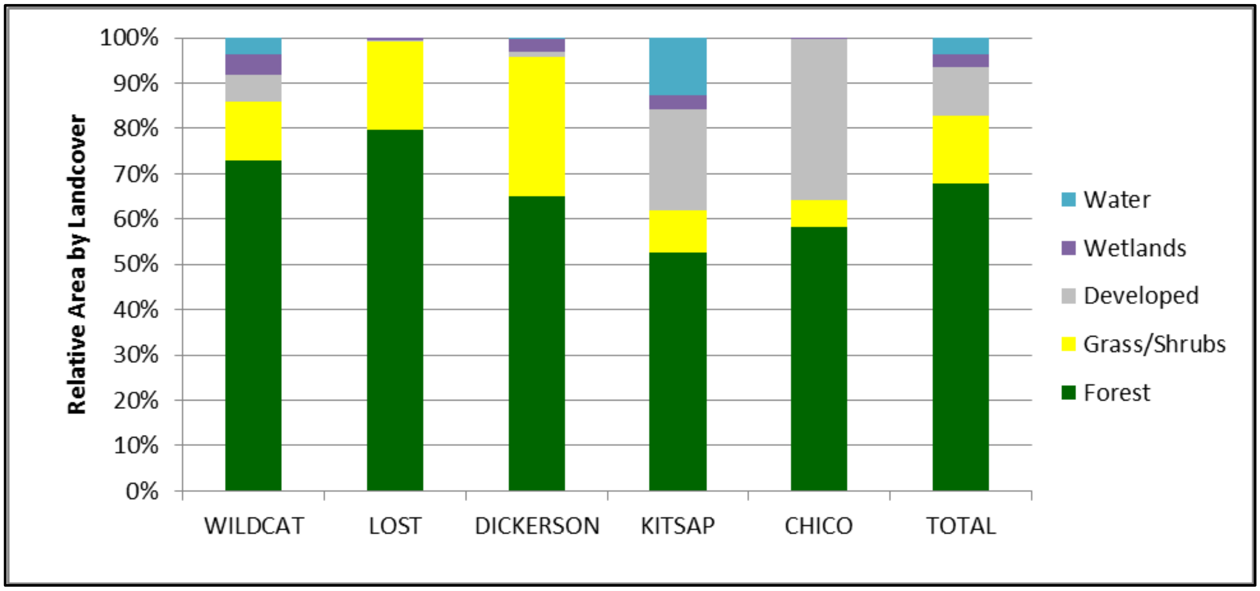


Figure 15. Summary of 2011 land cover characteristics by subbasin (source: NOAA Coastal Change Analysis Program).

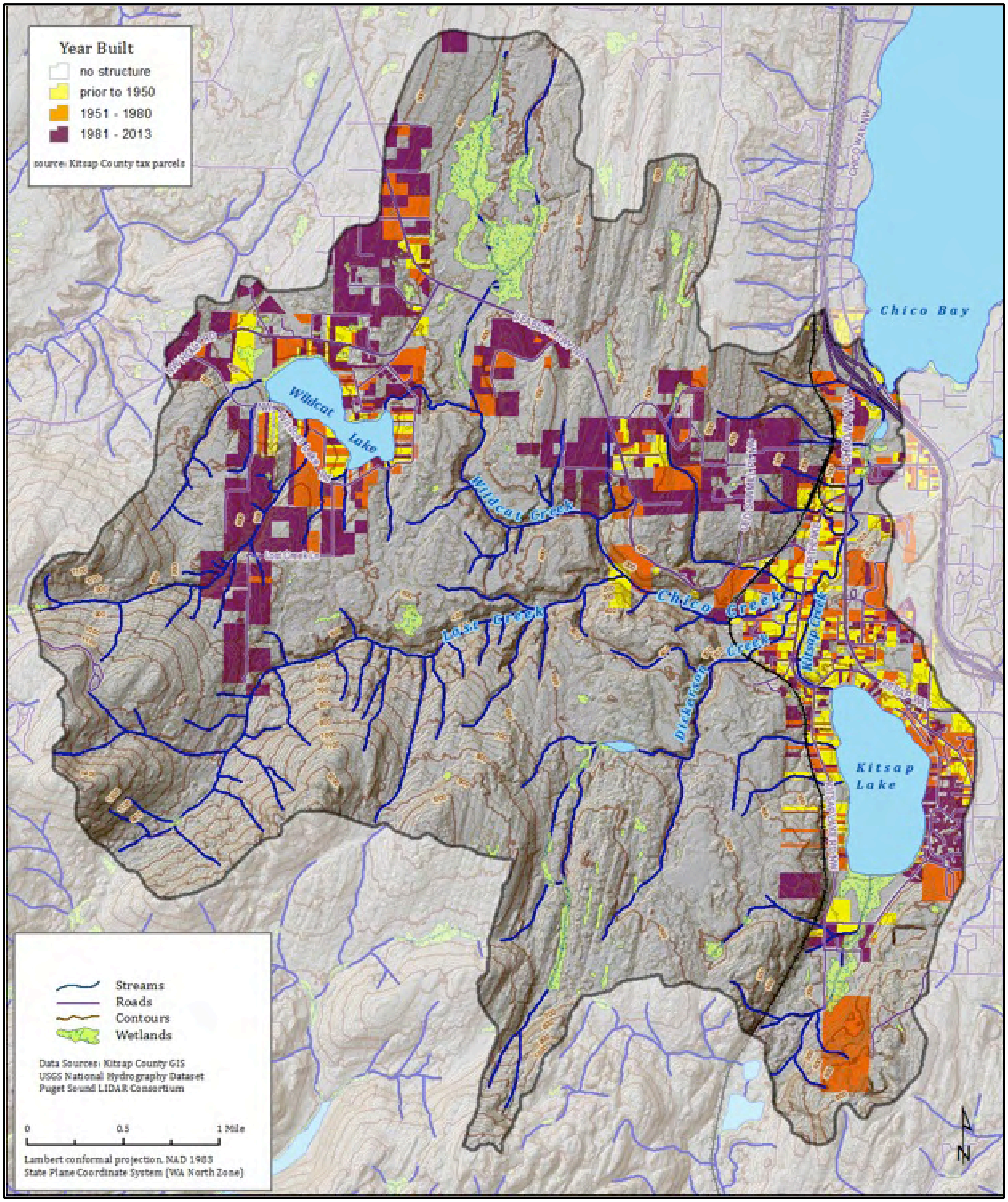


Figure 16. Map of development history in the Chico Creek watershed derived from tax records (source: Kitsap County, 2012).

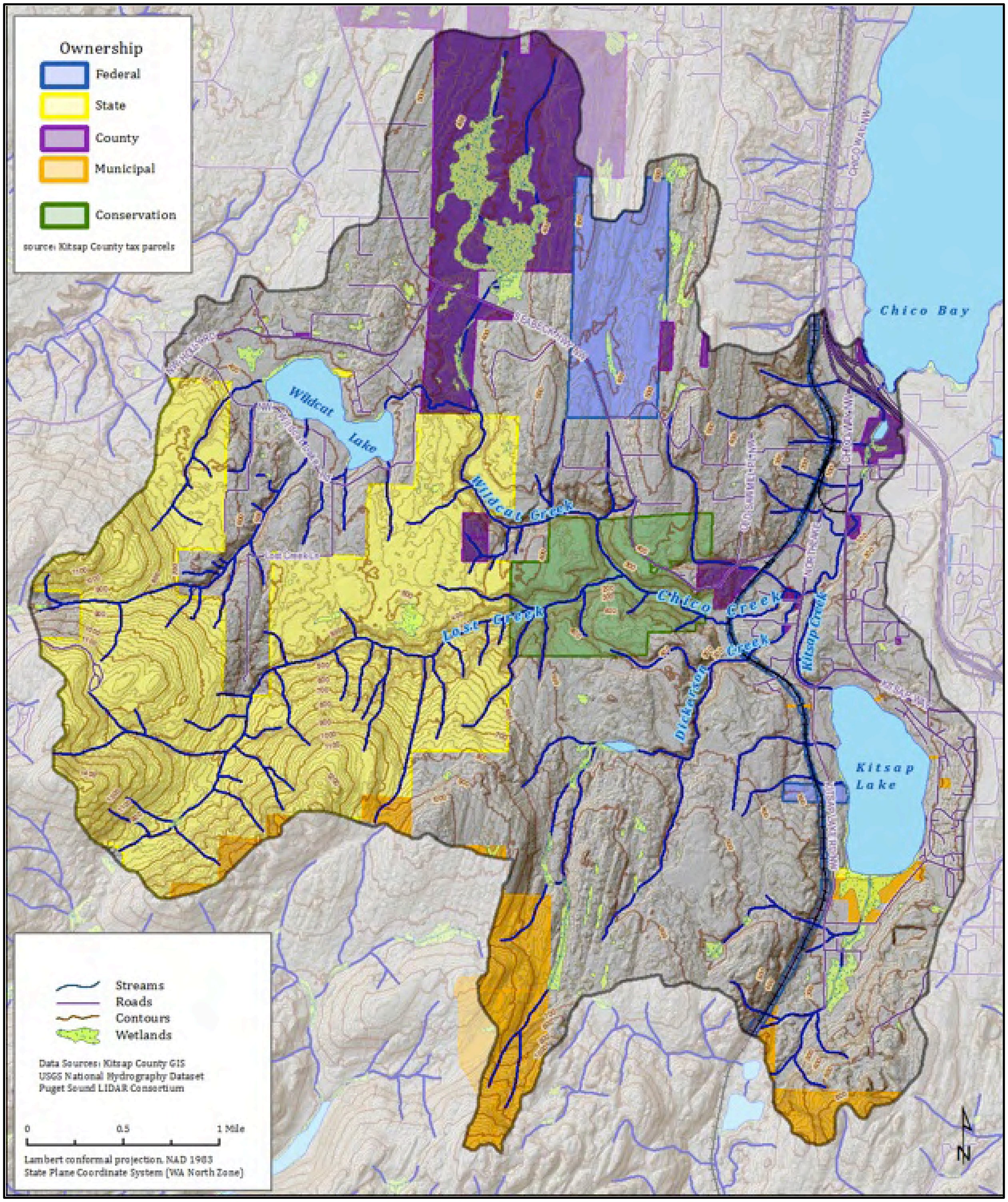


Figure 17. Public land ownership and conservation areas in the Chico Creek watershed (source: Kitsap County, 2012).

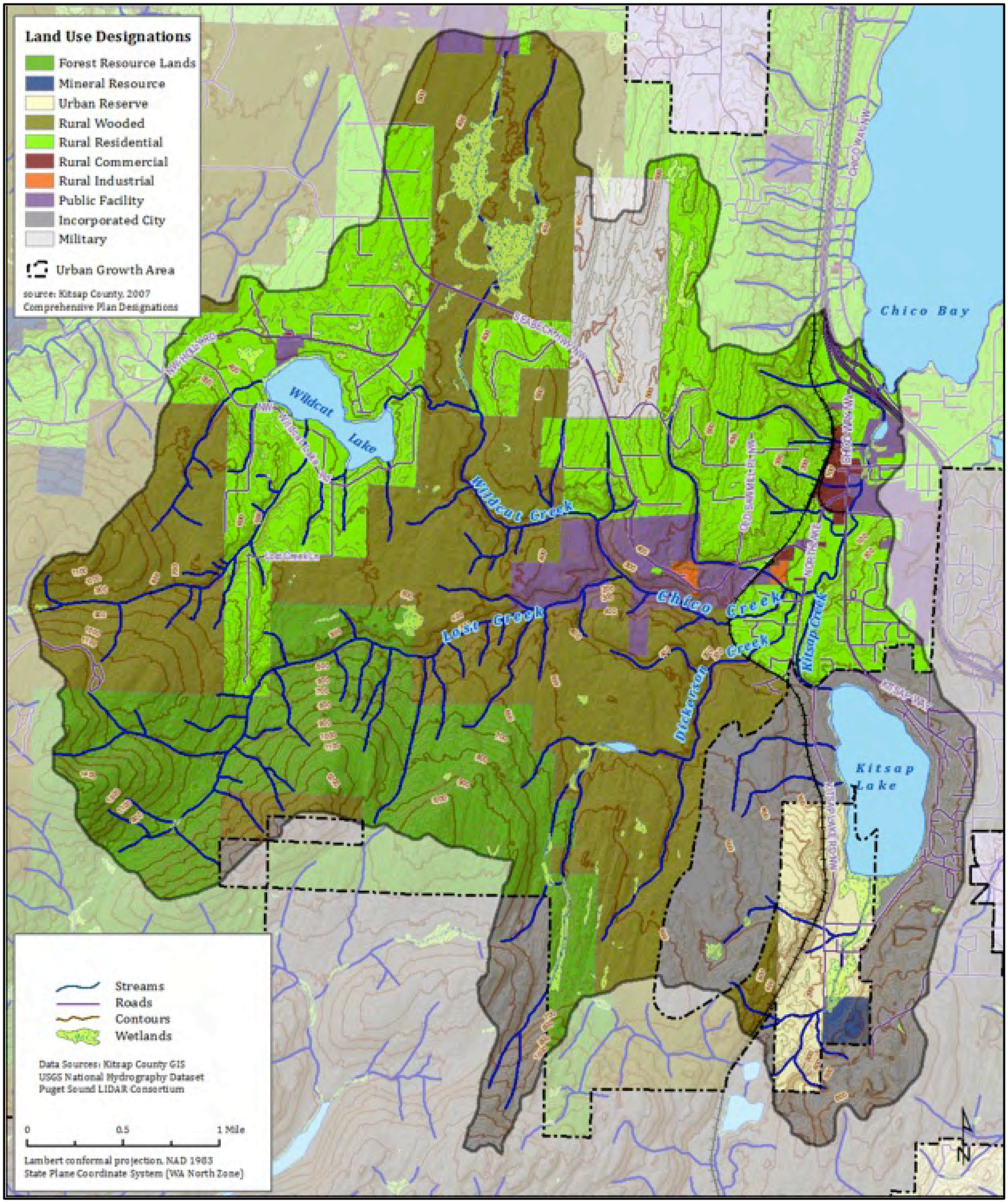


Figure 18. Land use designations in the Kitsap County Comprehensive Plan.

Table 4. Summary of land cover changes between 1992 and 2011 (Source: NOAA Coastal Change Analysis Program).

	Chico Creek	Kitsap Creek	Dickerson Creek	Lost Creek	Wildcat Creek	Watershed Total
Forest	-7.2%	-2.7%	-20.3%	11.1%	2.6%	-1.0%
Grass/Shrub	-1.1%	0.7%	20.1%	-11.1%	-4.8%	-1.2%
Developed	8.3%	2.0%	0.1%	0.0%	2.1%	2.2%
Wetlands	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Water	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5. Summary of public lands in the Chico Creek watershed as a percentage of total land area (source: Kitsap County, 2012 tax parcels).

	Chico Creek	Kitsap Creek	Dickerson Creek	Lost Creek	Wildcat Creek	Watershed Total
Federal	2.9%	3.3%	0.3%	0.0%	8.6%	4.3%
State	0.0%	0.3%	0.0%	75.7%	23.2%	22.9%
County	5.6%	1.3%	0.1%	0.0%	18.2%	7.9%
City	0.0%	6.2%	16.9%	2.7%	0.0%	3.9%
Total	8.5%	11.1%	17.4%	78.4%	50.1%	39.0%

Table 6. Land use designations in the Kitsap County Comprehensive Plan.

	Chico Creek	Kitsap Creek	Dickerson Creek	Lost Creek	Wildcat Creek	Watershed Total
Rural Wooded	4.9%	4.4%	52.9%	28.4%	49.0%	32.5%
Rural Residential	73.4%	5.9%	3.0%	3.0%	36.9%	24.9%
Forest Resource Lands	0.0%	0.0%	23.9%	63.6%	0.1%	15.0%
Incorporated City	0.0%	55.7%	19.5%	1.1%	0.0%	12.8%
Public Facility	16.0%	0.1%	0.6%	3.9%	2.5%	3.7%
Lake	0.0%	13.0%	0.0%	0.0%	2.8%	3.4%
Military	0.1%	0.0%	0.0%	0.0%	8.7%	3.4%
Urban Reserve	0.0%	18.7%	0.0%	0.0%	0.0%	3.4%
Rural Commercial	4.3%	0.0%	0.0%	0.0%	0.0%	0.5%
Mineral Resource	0.0%	2.1%	0.0%	0.0%	0.0%	0.4%
Rural Industrial	1.3%	0.0%	0.0%	0.0%	0.0%	0.2%

3 SALMONID DISTRIBUTION AND POPULATION STATUS

This section summarizes existing information describing the life history characteristics, abundance, and distribution of the salmonid populations known to utilize habitat areas in the Chico Creek watershed. The potential extent of fish habitat in the watershed was modeled as part of the WDNR forest practices water typing (Figure 19). WDNR water typing maps, however, have been found to underestimate the upstream extent of salmonid habitat and field surveys have found that many streams are mapped incorrectly (Wild Fish Conservancy, 2013).

3.1 CHUM SALMON

Chum salmon is the most abundant salmon species in Chico Creek, with spawning escapements (i.e., the number of adults that successfully escape the terminal fishery and reach Chico Creek) exceeding 100,000 fish in some years. The Chico Creek chum run is the most abundant among Kitsap Peninsula streams. The large amount of marine nutrients returning to Chico Creek each fall provide essential nutrients to the watershed contributing to the productivity of salmonids, other wildlife, and riparian forests (Bilby et al. 2003) in the watershed. Chico Creek chum salmon also are an important cultural resource to the local area, providing opportunities for the community to view salmon migrations and spawning, and supporting active tribal and sport fisheries. Chum salmon in the Chico watershed, and salmon more broadly, remain central to the Suquamish Tribe’s economy, sustenance, and way of life.

LIFE HISTORY

Chum salmon have a very short freshwater residency, typically migrating to sea soon after emergence (Salo, 1991). Their ocean residence can range from two to four years for a total age at return from three to five years. Within Puget Sound there are three races of chum salmon: summer, fall, and winter, based on their river entry and spawn timing. Fall chum are the most numerous and widespread race of chum in Puget Sound. Summer chum occur in several Hood Canal streams, a few streams along the eastern portion of the Strait of Juan de Fuca, and in Blackjack, Curley, and Ollala creeks in closer proximity to Chico Creek (Kassler and Shaklee, 2003). Winter chum are most common in the Nisqually River. Chico Creek chum typify the fall-timed race with a majority of adults entering the river from mid-October to mid -November. The migration extends later with some adults entering in early winter.

Spawn timing is fairly uniform across the watershed and predominantly occurs throughout the month of November; however, there are fish spawning earlier and later that may be very important for certain years. Adult chum move through lower Chico Creek in early- to mid-November downstream of the Navy Railroad Trestle, and within a week to 10 days later (mid-late-November) mass spawning typically occurs in the tributaries (Kitsap, Dickerson, Lost and Wildcat). Spawn timing may be influenced by fish passage barriers and flow conditions associated with the weather (J. Oleyar, pers. comm.). These barriers may delay fish movement, and consequently, spawn timing may vary from year to year. Fish that enter streams later are known to spawn soon after arrival.

Little is known about timing of fry emergence in Chico Creek, but it likely begins in February and extends into May. Data from other watersheds in Puget Sound suggest that most chum salmon fry move quickly out of the system after emergence (e.g. Simenstad, 2000). Juvenile chum are observed in the Chico watershed during smolt trapping in April – June (J. Oleyar, pers. comm.). Limited surveys of the Chico estuary have found chum smolts present from early April – early June (Suquamish Tribe 2003). Once chum fry leave the Chico estuary, it is assumed that they follow patterns observed for other chum populations and inhabit shallow nearshore areas and non-natal estuaries until they reach a larger size (Salo 1991, Simenstad 2000).

Degraded habitat conditions that affect chum salmon productivity and abundance in the Chico watershed include migration barriers that exclude or delay fish access to spawning areas, and a lack of adult resting/holding pools that increase competition for space among pre-spawn adults, thereby increasing energetic demands prior to spawning. Degraded and reduced quantity of riffle and glide spawning habitat (substrate size, mobility, and quantity of fine sediment) affects egg incubation survival and capacity. This is likely caused by artificially confined channels and the loss of floodplain habitat (particularly in Chico and Dickerson creeks downstream of the railroad grade), leaving the mainstem channel more vulnerable to bed scour during fall/winter storms when incubation occurs.

Abundance

Table 7 shows abundance of Chico Creek chum salmon spawning and local area catch (Suquamish Tribe, unpublished data). The 10 year (2004 to 2013) average stream escapement is 34,480 fish. During this period escapement has ranged from approximately 16,000 fish to over 90,000 fish. The column reporting Chico terminal run is the estimate of chum salmon returning to Chico Creek including fish harvested in Chico Bay by tribal fisheries. The 10 year average terminal run to Chico Creek is 46,940 fish, and the terminal run in 2007 exceeded 127,000 fish. The Area 10E catch includes marine harvest of chum salmon from approximately Port Orchard to Bainbridge Island, of which Chico Creek is assumed to comprise approximately 90% (Zischke, pers. comm. 2013). The 10 year average annual harvest of chum salmon for the 10E area is approximately 15,000 fish.

Chico Creek is a significant contributor to South Puget Sound chum salmon. The Washington Department of Fish and Wildlife (WDFW) reports annual abundance of chum salmon returning to South Puget Sound including Area 10E streams from run reconstruction (WDFW 2013). Reported hatchery contribution to the South Puget Sound run was subtracted from the total run. From 1990 to 2009 the annual average wild run returning to South Puget Sound streams was 475,000 fish. The average contribution of Chico Creek averaged almost 20% of the total run.

Distribution

The following is a summary of adult chum salmon distribution based on conversations and unpublished data provided by the Suquamish Tribe. See Figure 20 for mapped known distribution of chum salmon and barriers to migration. Chum salmon spawning occurs in multiple locations in the watershed, with dense spawning often in Kitsap Creek from the confluence with Chico Creek up to about RM 0.5. Most chum are then unable to access habitat past the bedrock chutes and culvert under Northlake Way just downstream of Kitsap Lake. Other productive chum spawning reaches are in Chico Creek from the Navy Railroad Trestle crossing upstream 0.6 miles to the confluence of Lost and Wildcat creeks, and in the lower 1.7 miles of Lost Creek and lower 1.9 miles of Wildcat Creek.

Chum salmon distribution in Chico Creek is affected by complete and partial migration barriers, some of which are not barriers (or affect movements to a lesser degree) for other salmonids (specifically, coho and steelhead). Chum adults are strong swimmers, but they are not considered capable leapers (Salo 1991), and their distribution typically stops or is impeded at the first significant barrier. Natural barriers limiting distribution include steep cascades and falls in tributary streams. Man-made barriers are noted in the WDFW Fish Passage Barrier Inventory and mapped in Appendices A and B. Suquamish Tribe monitoring of chum behavior and distribution in Chico Creek has observed an effect of fish barriers on chum migration timing and abundance. For example, a mitigation project that removed several riprap rocks from the channel in 2012 in the vicinity of the Navy Railroad Trestle on Chico Creek resulted in a noticeable increase in chum salmon movement to primary spawning areas upstream of the trestle.

Table 7. Chico Creek adult chum salmon abundance, 1974-2013 (Suquamish Tribe, unpublished data).

Year	Chico Cr Terminal Runsize	Chico Creek Escapement	Chico Bay Harvest	Area 10E Harvest
1974	18,200	18,200		
1975	1,560	1,560		
1976	6,950	6,950		
1977	16,170	16,170		
1978	68,680	68,680		
1979	3,425	3,425		
1980	44,329	31,693		12,636
1981	17,858	15,020		2,838
1982	12,279	5,722		6,557
1983	8,439	8,154		285
1984	25,392	19,982		5,410
1985	21,448	14,370		7,078
1986	15,978	11,150		4,828
1987	30,667	19,169		11,498
1988	49,919	27,953		21,966
1989	14,129	4,800		9,329
1990	16,714	6,100		10,614
1991	38,734	27,913		10,821
1992	66,750	33,000		33,750
1993	48,337	23,000		25,337
1994	56,923	32,000		24,923
1995	52,724	35,000		17,724
1996	32,803	32,000	803	13,832
1997	3,250	3,250	0	1,652
1998	108,371	108,371	0	5,755
1999	45,657	45,657	0	3,543
2000	6,229	6,229	0	541
2001	48,877	48,877	0	2,703
2002	80,565	72,410	8,155	13,094
2003	92,230	*75,000*	17,230	19,263
2004	31,796	31,000	796	4,848
2005	22,060	22,000	60	5,92
2006	81,179	71,602	9,577	9,707
2007	127,785	93,307	34,478	39,200
2008	19,285	15,696	3,589	5,654
2009	26,682	26,682	0	213
2010	28,270	20,628	7,642	8,447
2011	10,033	10,033	0	590
2012	30,075	25,650	4,425	4,560
2013	31,181	28,197	2,984	0
Average All Years	**36,548**	**29,165**	**4,986**	**9,994**
10 yr Average (2004-2013)	**40,835**	**34,480**	**6,355**	**7,381**

Chum spent less time holding downstream and spawn timing may have advanced after removal of the passage impediments.

Lower Chico Creek (SR3 to Navy Railroad Trestle)

Lower Chico Creek from SR3 to the Navy Railroad Trestle serves primarily as a migration corridor for adult chum. However, the reach between Golf Club Hill Road and the confluence with Kitsap Creek supports more chum spawning than the reach downstream of Golf Club Hill Rd. There are some sections, particularly starting at Chico Way and upstream, with rip-rapped banks and concentrated flows that may impede fish passage.

From the confluence with Kitsap Creek upstream to the Navy Railroad Trestle, Chico Creek typically supports a moderate amount of chum spawning. Similar to some downstream sections, this reach is heavily armored through residential areas affecting habitat quality and chum use. Concentrated flows from bank armoring may impede fish passage through this section and incubating salmon eggs may be more prone to bed scour. Riprap banks extend upstream to the Navy Railroad Trestle at approximately RM 2.

Upper Chico (Navy Railroad Trestle to Wildcat/Lost Creek confluence)

Chico Creek upstream of the Navy Railroad Trestle (RM 2.0) to the confluence with Lost and Wildcat Creeks (RM 2.6) has the highest density of chum spawning. Spawning habitat is of high quality (ideal size for spawning and low percent fine sediment) and is extensive through this section of Chico Creek.

Kitsap Creek and Kitsap Lake

Kitsap Creek from its confluence with Chico Creek upstream to about RM 0.5 (about 0.1 mile downstream of Northlake Way Road) is used extensively by spawning chum salmon. However, just downstream of Northlake Way Road the channel steepens and chum passage is impeded by a series of bedrock chutes and old pipes that span the channel. This defines the upstream extent for most chum spawning in Kitsap Creek, although some adult chum pass upstream and possibly into Kitsap Lake (which is within a few hundred ft of Northlake Way Rd.). The culvert under Northlake Way is also failing and has a long, steep pitch further impeding chum passage above this location. A map from ca. 1960 indicates that the relatively steep section of Kitsap Creek immediately downstream of Northlake Way may have been more sinuous and perhaps less steep prior to reconfiguration of the road crossings. This evidence is corroborated from examination of LIDAR-based topography in this vicinity (S. Todd, pers. comm.).

Dickerson Creek

Dickerson Creek downstream of David Road is heavily riprapped and currently serves primarily as a migration corridor for chum salmon to spawning areas between David Road and passage barriers at log weirs (RM 0.45) that have failed downstream of the Navy Railroad crossing. The log weirs, placed in the channel several years before, began to fail during and following the December 2007 flood event; chum salmon had not been observed upstream of this point until fall 2013 by which time the channel had started to erode around the last step weir. The process is expected to continue, thus allowing for easier access for chum. The channel appears to be head-cutting through this section, and passage remains a challenge for chum despite the recent weir breach (Oleyar, pers. comm.). The Navy Railroad crossing, located a short distance upstream of the failed log weirs, also poses fish passage problems for chum, particularly during high flows or if sediment and woody debris is blocking the upstream end of the two undersized culverts beneath the railroad grade.

Lost Creek

Chum spawning in Lost Creek is typically heavy from the mouth (and confluence with Wildcat Creek) upstream to RM 1.7. Beyond this point, Lost Creek is steeper and suitable spawning substrate is less available. Chum salmon have been reported upstream to a natural bedrock barrier at RM 1.9 on Lost Creek, but most return downstream to spawn.

Wildcat Creek and Lake

Chum spawning in Wildcat Creek is heavy from the confluence with Lost Creek upstream to RM 1.9. Chum passage may be affected in some years by several large log jams between RM 0.9 and 1.9. A few chum salmon have been observed entering Wildcat Lake, which indicates the downstream log jams are not always impassable barriers (Oleyar, pers. comm.). In 1999, fish weir screens operated by WDFW were removed between Wildcat Lake and Wildcat Lake Road allowing fish to access the lake. The culvert crossing at Wildcat Lake Road was considered a passage barrier for chum for many years. In 2011 Kitsap County replaced the undersized perched culvert with a wider bottomless concrete arched culvert and adult chum can now more easily access the stream reach between Wildcat Lake Road and Wildcat Lake.

3.2 COHO SALMON

Coho salmon are most often associated with small streams and rivers and use a wide variety of habitat during their freshwater residence (Sandercock, 1991). Numerically, adult chum salmon are far more abundant than coho in the Chico Creek watershed, at least during the past several decades when records have been kept. Coho abundance was likely much higher in pre-development times when floodplain habitat was more available, particularly in the lower watershed. Presumably, an abundance of beaver would also have created extremely productive pond and wetland rearing conditions for coho. Coho are likely the most abundant juvenile salmonid in the watershed during the summer and winter months.

LIFE HISTORY

Coho typically have a three year life cycle (Sandercock 1991). The commonly held belief is that juvenile coho spend one year in freshwater before migrating to sea in the spring. However, new information indicates a more complex suite of life history patterns exhibited by coho, including the use of estuarine habitat or direct seaward migration by 0 age coho. Koski (2009) reviewed several studies to better understand the role that these “nomadic” coho play in population resiliency, and suggests that estuarine habitats may have a significant role in the recovery of depressed coho populations. Miller and Sadro (2003) reported spring movement of 0 age coho to downstream estuarine habitats for a coastal Oregon stream, where most fry resided through the summer and returned upstream to freshwater to overwinter. Roni et al. (2012) reported juvenile coho leaving a Strait of Juan de Fuca stream in the fall of their first year. They reported that over 50% of the juveniles from a given brood year were fall migrants (migrated to sea between early October and end of December). These studies did not report how well these alternative life histories survived to adult. These life history patterns and other reported patterns of movement in freshwater (Lestelle et al., 1993) highlight the importance of high quality habitat for coho salmon throughout the Chico Creek watershed.

Puget Sound coho typically spend one year at sea before returning to spawn in the fall and early winter. Chico Creek coho river entry timing is from early/mid-October to early December. Spawning occurs from November to January, with peak spawning from late-November to mid-December (Oleyar, pers. comm.).

Juvenile coho may remain close to their natal site throughout their freshwater residence or they may move in the spring or fall to find suitable summer or overwinter habitat. Fry dispersal to downstream areas is a common pattern seen across the range of the species (Sandercock 1991). Fall movement of fingerlings is in response to fall freshets and cooler temperatures to seek more suitable overwinter habitat, particularly floodplain channels, wetlands, and ponds.

Smolt trapping during the 1980s in Lost and Wildcat Creeks indicated coho smolt seaward migration from mid-March to late June (Lenzi, 1983; Lenzi, 1985; Lenzi, 1987). Peak downstream movement was typically from late April to late May. Migration timing and rate of migration can be affected by smolt size (Quinn 2005). Mean fork length of smolts sampled in Wildcat Creek and Lost Creek in 1985, 1986 and 1987 was similar (1985: 106.0 mm versus 109.7 mm, 1986: 97.8 mm versus 97.0 mm, and 1987: 105.6 mm versus 98.6) (Lenzi 1987). However, there was not as distinct a pattern of large size early in the season for smolts sampled from Lost Creek and the maximum size of smolts sampled was not as great as reported for Wildcat Creek. Weekly maximum size of smolts sampled from Wildcat Creek often exceeded 160 mm, whereas maximum size of smolts sampled from Lost Creek rarely exceeded 140 mm (Lenzi 1987). These larger smolts may be the few fish that were able to rear in Wildcat Lake or juveniles that were able to find high quality rearing habitat downstream of the lake. Smolt trapping from 2011-2013 (Suquamish Tribe, unpublished data) shows, on average, larger smolts in Wildcat Creek than in Lost Creek. This larger average size may be attributed to improvements in fish access to Wildcat Lake in recent years (removal of fish screens in 1999 and Wildcat Lake Road culvert replacement in 2011) allowing greater access to the lake for both adult and juvenile coho.

Throughout their freshwater residence coho are strongly associated with slow water and areas with high channel complexity and physical cover (in-channel wood, vegetated banks, and side channels). Sandercock (1991) summarized a variety of studies that showed the effects of low and high flow on coho survival. Summer low flow is found to be a significant limiting factor for coho smolt production in Puget Sound streams (Zillges, 1977). Low flow affects the quantity of habitat in the stream, and is also correlated with increased water temperature and potentially greater competition and predation with other salmonids. High winter flows can displace juvenile coho and disrupt habitats essential to coho survival. High quality overwinter habitats include streams with ponds adjacent to the channel, slow moving side channels, backwater pools, and beaver ponds. Lakes also may be an important overwinter habitat as evidenced by WDFW observations from Lake Symington on Big Beef Creek (Baranski, 1989).

ABUNDANCE

The abundance of adult coho in the Chico watershed is not as well-known as for chum salmon. The recent five year average annual number of spawners is thought to be a few hundred fish (Oleyar pers. comm.). Annual counts performed by Suquamish Tribe survey crews of post-spawning dead coho (carcass counts) for the watershed (Suquamish Tribe, unpublished data) provide an estimation of a minimum escapement as not all coho are recovered during these surveys. Although they are imperfect indicators of inter-annual trends in abundance as carcass recovery rates likely vary across years due to effects of fall freshets, the surveys are useful as indicators of patterns of distribution in the watershed. Live counts of adult coho are also reported for the same years but are not included in this summary as they would include the same fish counted over multiple survey dates.

The number of dead coho ranged from 26 fish in 2010 to 346 fish in 2003 with an average of 148 fish (Table 8). Carcass counts were highest in Wildcat Creek, followed by Lost Creek, Chico Creek mainstem, Dickerson Creek, and Kitsap Creek, generally reflecting the relative availability of high quality spawning habitat in these tributaries.

Coho smolt abundance was estimated leaving Wildcat and Lost Creeks by the WDFW from 1979 to 1987 (Baranski 1989) and more recently (2011 – 2013) by the Suquamish Tribe (Suquamish, unpublished data). Average abundance from Lost Creek was 2,355 and 1,449 smolts for the early and more recent periods, respectively (Table 8). The number of smolts leaving Wildcat Creek averaged 3,873 fish for the early period and 3,309 fish for the more recent period. These numbers provide an estimate of total smolt emigration from upstream of the trap (i.e., counts were expanded for periods the traps were not operating). However, they are likely not the total contribution of the streams to smolt production from Chico Creek as a portion of each brood year likely moved downstream of the traps as 0 age fish in the spring or fall. In addition, Kitsap and Dickerson creeks support coho, but are not monitored for smolt production.

Baranski (1989) classified Wildcat Creek as not having a lake accessible to coho. This is probably because early smolt estimates were when adult coho were thought to be prevented from accessing Wildcat Lake by a fish screen structure located for several decades just downstream of the lake outlet. The purpose of this structure was to restrict downstream movement of non-native trout planted in Wildcat Lake. Anecdotal reports from long-time residents living around Wildcat Lake indicate that in some years at least, a small percentage of returning adult coho were able to make their way into the lake presumably by leaping over the fish screens (Oleyar, pers. comm.). Coho access to Wildcat Lake was restored in 1999 by removal of the fish screens. In addition, the culvert replacement at Wildcat Lake Road in 2011 is thought to have improved access to the lake for coho, as well as other anadromous species out-migrations from the lake in spring. Data from the Suquamish Tribe and WDFW suggests that coho residing in Wildcat Lake grow fast and may smolt at a large size. The Suquamish Tribe has observed some very large coho smolts in their out-migrant trap (fish ~200 mm in length), suggesting that these fish reared in Wildcat Lake. Scale-age analysis confirms that 2 year old smolts are out-migrating, further evidence of coho rearing in Wildcat Lake (Oleyar, pers. comm.).

Smolt estimates show a fair amount of inter-annual variability in abundance (Table 9). However, variability in abundance was slightly less in Wildcat Creek than Lost Creek for the early period and more so in the later period. Variability in abundance can be a result of differences in adult abundance and environmental variability affecting survival and distribution of juveniles in the watershed. The greater inter-annual variation in smolt abundance from Lost Creek may be related to differences in channel gradient, floodplain confinement, and hydrologic characteristics in this stream compared to Wildcat Creek. Channel gradient and confinement is slightly higher in Lost Creek. Furthermore, Wildcat Lake and the extensive Newberry Wetlands in Wildcat Creek likely moderate low summer flow and peak winter flow characteristics in this stream. Adult coho carcass counts in Lost Creek vary more than in Wildcat Creek, which may be an indication of greater variation in spawner abundance or simply differences in ability to observe carcasses among years due to effects of flow and visibility. Fewer adult coho spawners have been observed in Lost Creek since the December 2007 flood event. One suggestion is that this may be a result of numerous landslides and bed scour effects in the Lost Creek system associated with that event and subsequent floods (Oleyar, pers. comm.).

Table 8. Adult Coho Post Spawn Carcass Counts in Chico Creek by Tributary, 2003-2013 (Suquamish Tribe, unpublished data).

Year	Chico Mainstem	Kitsap Creek	Dickerson Creek	Lost Creek	Wildcat Creek[1]	Total
2003	23	0	19	118	186	346
2004	61	6	21	8	40	136
2005	42	0	3	8	9	62
2006	6	0	6	56	91	159
2007	26	3	5	6	19	59
2008	7	0	84	45	155	291
2009	6	0	23	13	30	72
2010	9	3	1	1	12	26
2011	55	14	36	36	180	321
2012	15	3	15	2	25	60
2013	18	0	21	9	44	92
Average	**24.4**	**2.6**	**21.3**	**27.5**	**71.9**	**147.6**
Coefficient of Variation	**0.81**	**1.62**	**1.10**	**1.29**	**0.96**	**0.79**

Table 9. Smolt abundance measured at the mouth of Lost and Wildcat Creeks by WDFW from 1979 to 1987 (Baranski 1989) and 2011 to 2013 (Suquamish Tribe, unpublished data).

Year	Lost Creek	Wildcat Creek
1979	3,633	5,941
1980	1,936	2,158
1981	4,743	4,193
1982	1,587	3,763
1983	3,026	5,540
1984	1,949	2,964
1985	2,496	5,317
1986	1,213	3,598
1987	613	1,386
2011	1,198	3,228
2012	1,102	3,152
2013	2,046	3,546
Average (1979- 1987)	**2,355**	**3,873**
Coefficient of Variation	**0.54**	**0.40**
Average (2011 - 2013)	**1,449**	**3,309**
Coefficient of Variation	**0.36**	**0.06**

[1] Wildcat Creek includes fish counted in a Wildcat Lake tributary stream, which is spot checked for spawners (and not every year).

Distribution

Coho spawning occurs mostly in the same general locations as chum spawning and also higher in the watershed (upper Chico Creek, Lost Creek and Wildcat Creek, and Dickerson Creek above the Navy Railroad crossing at RM 0.5). See Figure 21 for mapped known distribution of coho salmon and identified barriers to migration. The following sections are summaries of adult coho salmon distribution based on conversations and unpublished data provided by the Suquamish Tribe (Oleyar, pers. comm.).

Lower Chico Creek (SR3 to Navy Railroad Trestle)

Coho are rarely observed spawning in this reach. This is primarily a migration corridor to the upper watershed. It is very likely that this section of Chico Creek historically would have been key overwinter habitat for juvenile coho that dispersed downstream in the fall. Currently in-channel conditions are not as favorable for overwinter residence, because historic off-channel habitat has been largely isolated or lost due to armoring, diking, and fill associated with residential, commercial, and transportation infrastructure.

Upper Chico (Navy Railroad Trestle to Wildcat/Lost Creek confluence)

Coho are observed spawning in the section upstream of the Navy Railroad Trestle in mainstem Chico Creek. Coho are not likely affected by passage impediments to the same extent as chum in this reach.

Kitsap Creek and Kitsap Lake

Coho have been observed spawning in the uppermost section of Kitsap Creek, just below Kitsap Lake and have also been observed spawning at the outlet of the lake. Coho appear to avoid the lower section of Kitsap Creek (an area with high chum densities). Spawning upstream of Kitsap Lake is thought to occur, but is not well documented. There may also be coho spawning along the shore of Kitsap Lake associated with springs, but this occurrence is poorly documented.

Dickerson Creek

Most coho spawning occurs between RM 0.4 and 0.9, above the Navy Railroad crossing. When passage (influenced by weather and adequate stream flows) is favorable, considerable numbers of adult coho can be present in upper Dickerson (total dead count in 2008 was 84 fish, Table 7). Passage is impeded by an impassable bedrock falls at RM 1.1 (Oleyar, pers. comm.).

Lost Creek

Coho are observed spawning throughout Lost Creek, but most spawning occurs between RM 1.0 and a natural barrier at RM 1.9. The moderate stream gradient of Lost Creek and channel confinement suggests that fall and winter freshets might displace some juvenile coho downstream to overwinter and complete their freshwater residence. Juvenile coho may also continue to move downstream and enter saltwater as documented elsewhere by Roni et al (2012). Thus, Lost Creek is considered both an important area supporting the entire freshwater lifecycle and likely an important source area for fry and parr dispersal to downstream habitats in Chico Creek.

Wildcat Creek

Coho are observed spawning throughout Wildcat Creek, with most of the activity occurring between RM 3.5-5.0. Coho have been observed spawning at the outlet from Wildcat Lake in most years. The channel between Wildcat Lake outlet and Wildcat Lake Road culvert was dry with pockets of standing water in late summer 2013 (Todd, pers. comm.). The frequency, persistence into the fall, and extent downstream of these dry channel conditions may affect adult migration into Wildcat Lake, juvenile redistribution in the fall, and quantity of coho habitat and should be investigated. There is a tributary to Wildcat Creek at approximately RM 4.2 where coho are observed spawning in the lower 0.2 to 0.3 miles during most years. This tributary is the outlet from the Newberry Wetland complex, upstream of Seabeck Highway. In some years, this tributary appears to have flows, at least seasonally, similar to the flow of Wildcat Creek at their confluence. Downstream of Seabeck Highway, this tributary flows through a series of beaver pond habitats before joining Wildcat Creek. It is assumed that coho can access the wetlands and channels upstream of the Seabeck Highway crossing. However, the extent to which adult and juvenile coho use the tributary from the Newberry Wetland complex and can access the wetlands and channels upstream of Seabeck Highway should be investigated.

Similar to that described for Lost Creek above, Wildcat Creek is an important area supporting the entire coho freshwater lifecycle and likely an important source area for fry and parr dispersal to downstream habitats in Chico Creek.

Wildcat Lake and Tributaries

Coho have been observed spawning along the lakeshore near the outlet to Wildcat Creek, possibly in places of spring-water upwelling (J. Oleyar, pers. comm.). Coho also are known to spawn in the largest tributary to Wildcat Lake (unnamed tributary to the south, opposite the lake outlet) where they have historically been observed spawning downstream of the culvert under Wildcat Lake Road. The stream flows through an undersized concrete drop-culvert, which delays or stops upstream coho migration. The full extent of coho use in Wildcat Lake and its tributaries is unknown, and should be investigated. The culvert just downstream of the lake outlet was repaired in 2011, providing better adult and juvenile access to the lake and headwater tributaries as well as access for juvenile out-migration downstream.

3.3 STEELHEAD TROUT

In May 2007 the Puget Sound steelhead Distinct Population Segment (DPS) was listed as a threatened species under the Endangered Species Act (ESA). Chico Creek and its major tributaries (Kitsap, Dickerson, Lost, and Wildcat Creeks) are included in National Oceanic and Atmospheric Administration's (NOAA) proposed critical habitat designation for the Puget Sound Steelhead DPS (U.S. Office of the Federal Register, 2013). The Puget Sound Steelhead Technical Review Team's (PSSTRT) draft analysis of historic population structure for the Puget Sound DPS does not identify the Chico Creek winter steelhead population as an independent population (Puget Sound Steelhead Technical Recovery Team, 2013); rather, the PSSTRT considers Chico Creek steelhead as one of many small inter-dependent populations that make up a larger distinct independent population (DIP) for the area.

We know little about current and historic use of the Chico watershed by steelhead. Current use and potential for improving productivity and abundance of Chico steelhead should be investigated more closely, particularly given the 2007 ESA listing and the need to develop regional and watershed recovery plans for Puget Sound.

LIFE HISTORY

Puget Sound steelhead exhibit one of the most complex suites of life history strategies among the anadromous Pacific salmonid species. Puget Sound steelhead usually spend 1 to 3 years in freshwater, with the greatest proportion typically spending two years (Busby et al. 1996). Consequently, steelhead rely heavily on freshwater habitats and are present in streams year round. It is likely that juvenile steelhead interact with other salmonids in the watershed, including feeding on chum salmon fry when abundant.

As in other Puget Sound streams, winter run steelhead likely return as adults to Chico Creek from December to April. In most Puget Sound streams spawning occurs from January to mid-June. In the Chico watershed, spawning probably occurs between February and May, with peak spawning thought to occur from mid-April through May (Oleyar, pers. comm.). Prior to spawning, maturing adults hold in pools or in side channels to avoid high winter flows. Steelhead tend to spawn in moderate to high-gradient sections of streams and may spawn higher in the watershed compared to other salmonids.

Movement patterns of juvenile steelhead in Chico Creek likely follows observations from other streams. Fry emergence can be protracted depending on spawn timing; fry from fish spawning in mid-May would emerge sometime in late June to early July depending on temperatures during egg incubation. Steelhead and rainbow trout require about 85 d at 4°C and 26 d at 12°C to reach 50% hatch (Bjornn and Reiser, 1991). Steelhead fry would be emerging as flows are approaching summer lows in Chico Creek. Newly emerged fry occupy shallow riffles and stream margins until large enough to move into deeper water in late summer. Steelhead juveniles are not as dependent on pools as coho. Juvenile steelhead seem to occupy nearly all habitat types in the main channel. Preferring the interstitial space in the substrate to hide, juvenile steelhead do not tend to use off-channel ponds. Larger, older steelhead in smaller tributaries of Chico Creek likely move out to overwinter in the mainstream Chico Creek.

ABUNDANCE

Steelhead trout are in decline throughout Puget Sound. Recent abundance of Puget Sound steelhead has been estimated at only 1% to 4% of historical levels, with abundance estimates for the period 1980 to 2004 of 22,000 fish, compared to historical (1895) abundance of 485,000 to 930,000 fish (Gayeski et al., 2011). Hard et al. (2007) estimated a lower peak historical abundance ranging between 327,592–545,987 fish using slightly different methods.

Since the 1980s, there has been a significant decline in abundance across all Puget Sound streams (Hard et al (2007). The Puget Sound Partnership and WDFW are coordinating a research effort to investigate marine survival as a common factor affecting Puget Sound populations.

There are no quantitative estimates of winter steelhead in the Chico Creek watershed, but their abundance is assumed to be chronically low at least in recent decades. A few individuals are observed, but remain rare and spring surveys are not routinely conducted (Oleyar, pers. comm.).

DISTRIBUTION

See Figure 22 for mapped known distribution of steelhead and identified barriers to migration. The few observations of adult steelhead and redds suggest they distribute throughout much of the watershed (Oleyar, pers. comm.). Steelhead redds were observed in Dickerson Creek upstream of the Navy Railroad crossing around 1999-2001, and juveniles have been observed moving downstream in both Lost and Wildcat creeks during smolt trapping in recent years (Oleyar, pers. comm.).

3.4 OTHER SPECIES

Other salmonids known to use the Chico watershed include Chinook salmon and cutthroat trout.

The Puget Sound Technical Recovery Team (TRT) did not identify any independent Chinook populations originating from East Kitsap streams, including Chico Creek. However, Chinook adults are occasionally observed in the estuary downstream of Kittyhawk Road during August-October (Oleyar, pers. comm.). Also, in limited sampling, juvenile Chinook have been captured in the Chico estuary from early June to mid-September. The majority of these fish had their adipose fins clipped, indicating they were of hatchery origin (Suquamish Tribe 2003). Most Chinook that use East Kitsap streams, including Chico Creek, appear to be from one of the Suquamish Tribe's hatchery programs (at Gorst Creek and Grover's Creek) or from hatcheries at Minter Creek, White River (Puyallup), or other hatcheries. During years of particularly abundant salmon runs, wild Chinook may use smaller streams such as Chico Creek (Haring 2000). The hatchery Chinook that are found in Chico Creek most likely originate from the Gorst Creek facility that is closest to Chico Creek (Oleyar, pers. comm.).

Little is known of the abundance and distribution of cutthroat trout in the Chico watershed. A few cutthroat are observed in Chico Creek, but they remain rare, and spring spawning surveys are not routinely conducted (Oleyar, pers. comm.). However, adults are consistently caught each year in the out-migration traps in both Lost and Wildcat Creeks. Cutthroat are also observed upstream of Kitsap Lake, where coho also reside (O'Sullivan, pers. comm.).

Besides salmonids, several additional fish and aquatic species, including sculpin and lamprey, are also observed in the watershed. Brook lamprey have been observed in the mainstem Chico Creek and in the smolt traps in lower Lost and Wildcat creeks. Crayfish, a crustacean, has also been observed in both Lost and Wildcat creeks (Oleyar, Suquamish Tribe unpublished data).

3.5 FISH INTRODUCTIONS TO THE CHICO CREEK WATERSHED

Like many streams in western Washington, Chico Creek and its tributaries, including Wildcat and Kitsap lakes, has a history of fish releases into its waters. From 1980 until 1999, the Suquamish Tribe used Netarts incubators to raise and release unfed native Chico Creek chum salmon (up to several hundred thousand eggs/year) into a segment of Dickerson Creek (between David Road and the Navy RR grade) that was blocked by downstream culvert barriers during that time. The intent of this effort was to jump-start the local chum population (P. Dorn, Suquamish Tribe, personal communication).

The Washington Department of Fish and Wildlife (WDFW) released surplus coho produced from Minter Creek Hatchery into many Puget Sound streams, including 130,000 into Dickerson Creek in 1982 (P. Dorn, Suquamish Tribe, unpublished data). Short and long-term impacts of these fish releases on native salmonid populations are unknown.

Non-native warmwater fish species have likely been present in Kitsap and Wildcat lakes for many decades, planted to support recreational fisheries. The impact of these non-native species on coho and other native fish is largely uncertain. For example, a study in the late 1990s that included Wildcat Lake indicated that largemouth bass in the lake may be important predators to wild juvenile coho salmon (Bonar et al., 2005). However, at the time of the study, the ability of coho to access Wildcat Lake was restricted by fish screens just downstream of the outlet of Wildcat Lake, as well as the culvert at Wildcat Lake Road. The screens were removed in 1999 and the culvert was replaced in 2011, both contributing to improved access to the lake for coho as well as other fish species. Abundance of anadromous fish has probably increased subsequent to the improvements to fish passage at the culvert and the former screen. How largemouth bass or other introduced fish species in Wildcat Lake may currently (post passage improvement) affect native coho, steelhead, or other species has not been determined. The effect of introduced fish species in Kitsap Lake on native fish is also poorly understood.

The Washington Department of Fish and Wildlife (WDFW) has planted non-native rainbow trout into both Kitsap and Wildcat lakes to support a "put and take" recreational fishery for many decades. The Suquamish Tribe (Suquamish) is concerned that these stocking practices have potential negative impacts for native salmonids in the Chico Watershed, and that out-planting of these non-native fish is inconsistent with policy identified in the WDFW Statewide Steelhead Management Plan (WDFW 2008), which specifies that “hatchery-origin rainbow trout shall not be released in anadromous waters”.

Additional information is needed to understand the following potential impacts to native salmonid populations resulting from past and continued out-planting of non-native trout in Kitsap and Wildcat Lakes:

1. Impacts of lake harvest targeting non-native trout on native steelhead, coho salmon, and cutthroat trout (i.e., incidental catch);
2. Ecological impacts associated with competition for food and habitat; and
3. Genetic interactions

To address these concerns and data needs, Suquamish recommends the following near-term actions:

1. Adipose fin clipping of all trout planted into Wildcat Lake;
2. Phase-out of fingerling trout plants over the next 3 years (beginning in 2014);
3. Decrease in numbers of catchable trout plants (commensurate with increase in fish size);
4. Increase monitoring to include creel surveys of the lakes throughout the fishing season; and
5. Consideration of gear/species restrictions to better protect native salmonid populations

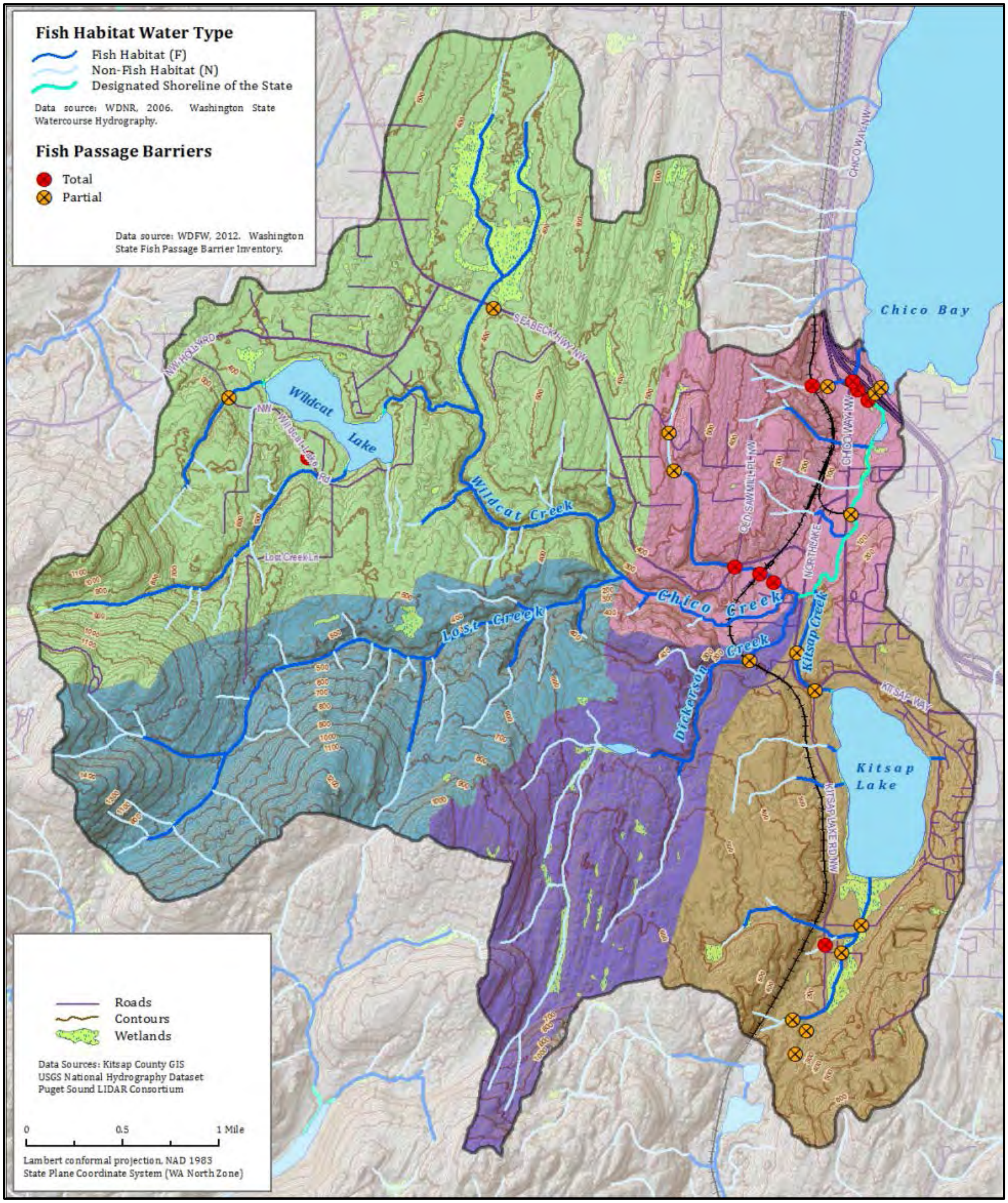


Figure 19. Map of water typing (WDNR, 2006) and inventory of fish passage barriers (WDFW, 2012).

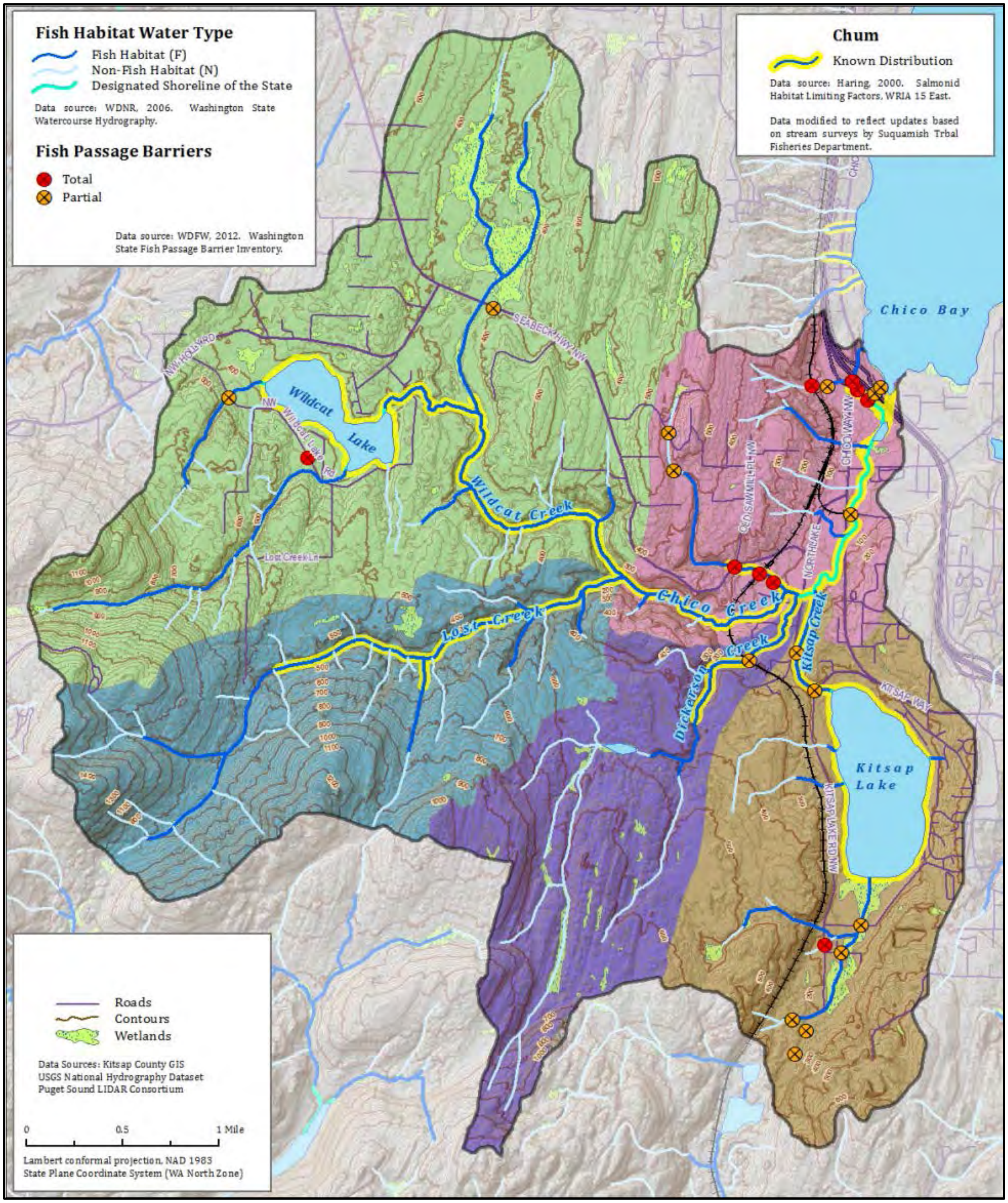


Figure 20. Map of the known distribution of chum salmon (source: Haring, 2000 and updates from the Suquamish Tribal Fisheries Department).

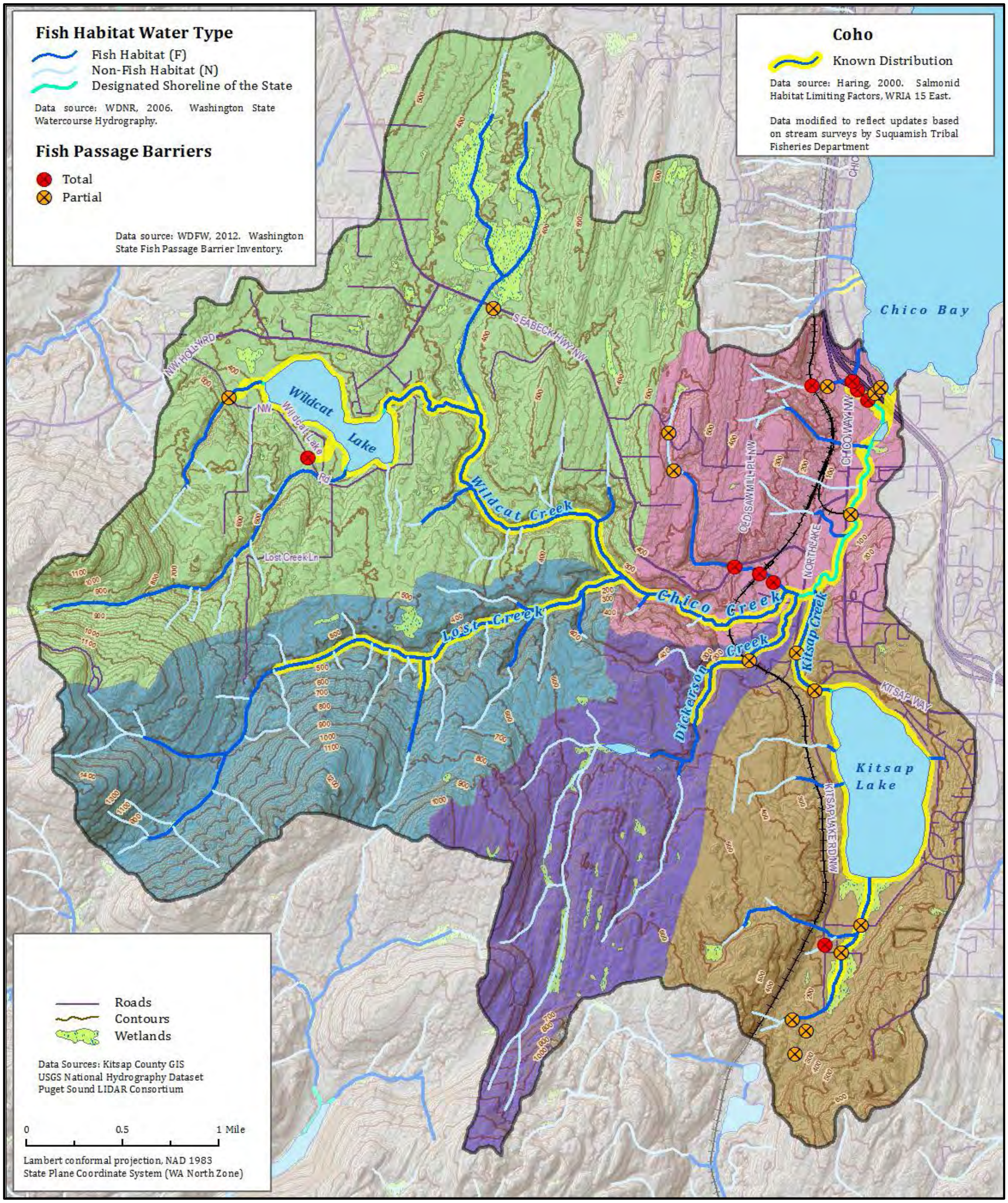


Figure 21. Map of the known distribution of coho salmon (source: Haring, 2000 and updates from the Suquamish Tribal Fisheries Department).

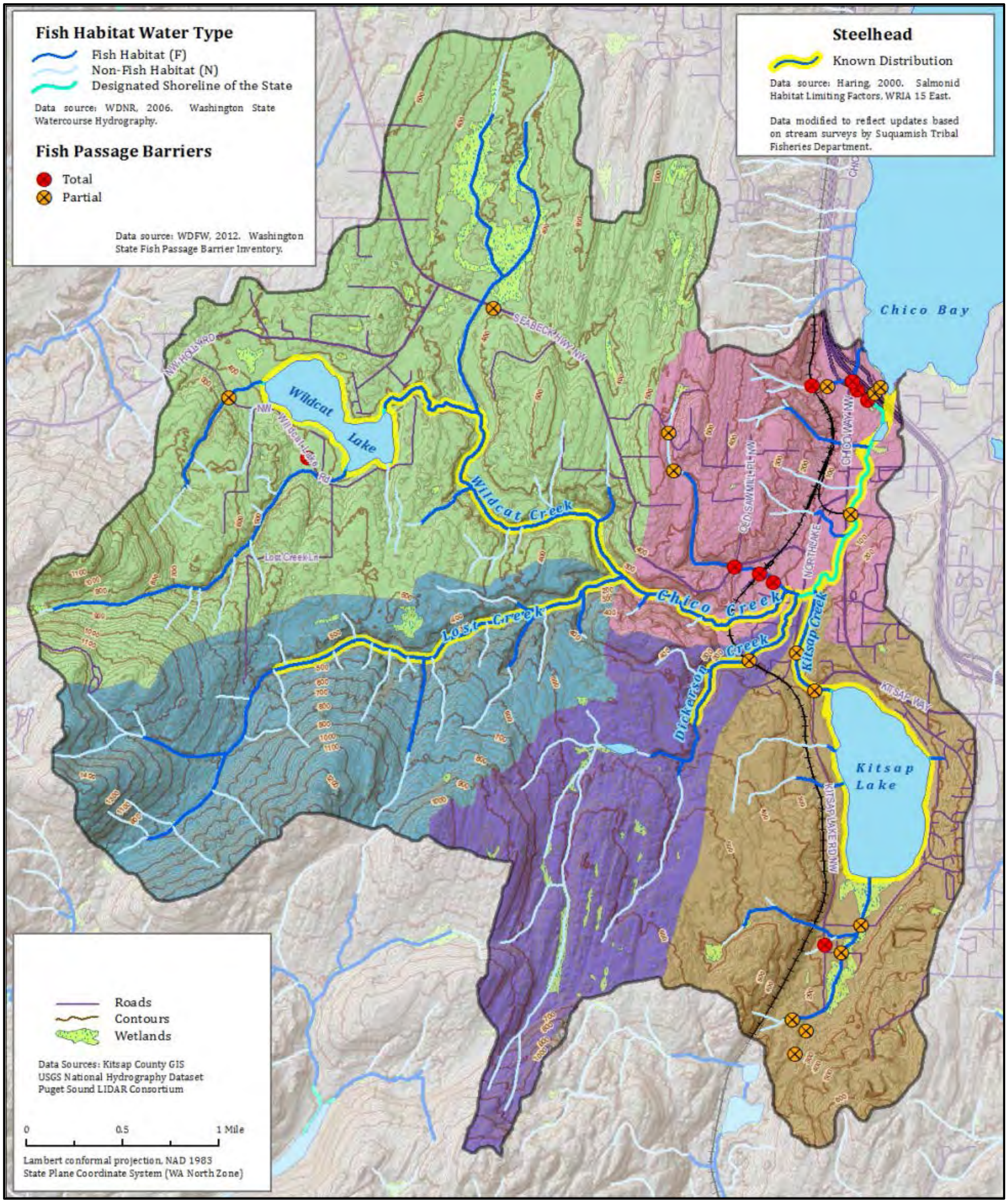


Figure 22. Map of the known distribution of steelhead trout (source: Haring, 2000 and updates from the Suquamish Tribal Fisheries Department).

4 Watershed Processes and Habitat Effects

One of the key roles that watershed assessments can provide in salmon recovery planning is to evaluate land use effects on the habitat-forming processes (Beechie et al., 2003). This section summarizes findings from a series of assessment tasks that used a coarse-scale approach based on a combination of existing data sources, spatial data (GIS), and limited field reconnaissance to evaluate alterations to the following suite of watershed processes and indicators in the Chico Creek watershed:

- Hydrologic Regime;
- Sediment Regime;
- Riparian Corridors and Wetlands;
- Large Woody Material;
- Floodplain Connectivity;
- Fish Passage and Access; and
- Water Quality

4.1 HYDROLOGIC REGIME

The hydrologic regime of a river system is characterized by the quantity, timing, and variability of streamflow. The natural flow regime plays a critical role in regulating both physical and biological processes that sustain ecological integrity within the stream corridor (Poff et al., 1997). Riparian plants, aquatic insects, and fish all have specific adaptations to the natural flow regime of a given stream (Lytle and Poff, 2004). Pacific salmon, for example, have life history characteristics (e.g., migration, spawning, egg incubation, and juvenile rearing) that are adapted to a specific range of suitable habitat conditions which are affected by hydrologic regime (Waples et al., 2008). As such, human activities that alter flow regimes and shift prevailing conditions outside of the natural range and variability pose a threat to the long term resilience of native salmonid populations in the Chico Creek watershed.

While all components of the hydrologic regime are important to the maintenance of ecological habitats, assessments of watershed alterations to the hydrologic regime often focus on changes to high (flood) and low (base) flow characteristics of a given stream. Flood flows exert a controlling influence on watershed processes (e.g., sediment transport, channel migration, and wood recruitment) that collectively define channel morphology (Costa and O'Connor, 1995; Wolman and Leopold, 1957) and affect the distribution of aquatic and riparian habitats (Bunn and Arthington, 2002). The level of impairment to the natural hydrologic regime in the Chico Creek watershed was assessed with an approach that evaluated changes in land use indicators and reviewed existing data from the hydrologic record (precipitation and streamflow).

Land Use Indicators of Hydrologic Alteration

The natural land cover of the Chico Creek watershed was characterized by a distribution of plant communities associated with late-seral coniferous forest (Franklin and Dyrness, 1988). The original forest vegetation has since been replaced by less mature plant communities and non-vegetated artificial surfaces (e.g., roads, parking lots, and buildings) driven by widespread impacts of human land use activities. Forest practices such as timber harvest and road construction have significant impacts on the natural hydrologic regime. Clearcut logging, in particular, can alter rainfall-runoff relationships and result in an increase to peak flow magnitudes compared to pre-disturbance conditions (Jones and Grant, 1996). The moderate magnitude, relatively high frequency events (recurrence intervals between 1 and 5 years), have been shown to be the most sensitive to forest practices (Beschta et al., 2000). This is significant given that the moderate magnitude floods are generally considered to be the dominant channel forming discharge in alluvial streams (Wolman and Miller, 1960). Analysis of hydraulic geometry relationships in the Pacific Northwest show the prevailing bankfull discharge to approximate the 1.2 year recurrence interval peak flow (Castro and Jackson, 2001). Hydrologic alterations that affect the frequency and duration of flows at or near bankfull can be expected to result in geomorphic responses such as channel incision and/or widening.

Forest practices in the Chico Creek watershed have resulted in a mosaic of land cover characteristics that vary with age since last harvested. Present forest management practices in the Chico Creek watershed are primarily managed by the two largest landowner groups: Washington State Department of Natural Resources (DNR) and Ueland Tree Farm. Both entities have Forest Stewardship Council (FSC) certification which holds landowners to a higher management standard that includes more sustainable forest practices than used in previous decades. In general, this implies that present forest management practices have lessened the environmental impacts associated with timber harvest. However, historical legacy of past logging which clearcut large swaths of forest has left a substantial impact on the landscape.

Land cover data from the 1992 and 2011 classifications were analyzed to delineate areas of hydrologically immature vegetation (Figure 23). This coarse scale assessment considered any land area classified as developed, grassland, or shrubland as hydrologically immature. A key assumption in the analysis is that grasslands and shrublands are not widely distributed in the natural land cover patterns of the region and areas classified as such are likely to be areas of recent timber harvest. Areas which were classified as shrubland in 1992 but forest in 2011 were grouped into the hydrologically immature category as the forest is assumed to be less than 30 years in age. The hydrologic maturity dataset was updated with a digitized polygon representing recent timber harvest in the Lost and Wildcat Creek subbasins delineated from a 2013 aerial image (*source: Google Earth*).

Results of the hydrologic maturity analysis were compiled to characterize the relative area of hydrologically mature vegetation for each subbasin. An estimated 62% of the cumulative watershed area is classified as hydrologically mature with the remaining 38% classified as immature due to land clearance for development or forest practices since 1992. The distribution of hydrologically mature areas showed relatively little variation between individual subbasin areas; ranging between 68% mature in the Wildcat Creek subbasin and 57% mature in the Lost Creek subbasin (Table 10). Basin-wide, the relative immaturity of forest vegetation suggests that land use impacts are likely to alter rainfall-runoff relationships and increase peak flows in the basin. Previous assessments of other developing regions in the Puget Lowland identified 65% forest cover as a plausible threshold for rural watersheds on moderately sloped till soils, below which the 2-year recurrence interval peak flow begins to exceed the pre-disturbance 10-year recurrence interval flow and trigger downstream channel instability (Booth et al., 2002).

Given that the Chico Creek watershed is located within a developing region, the hydrologic impacts of urbanization and residential development are also a concern for alterations to hydrologic regime. Urban development alters rainfall-runoff relationships and increases the flashiness (higher peaks, lower baseflows) of the hydrologic regime for a given stream (Booth, 1991; Booth and Jackson, 1997; Konrad et al., 2005). Hydrologic impacts driven by urbanization are related to decreases in ecological productivity and biodiversity in aquatic systems (Klein, 1979). Currently, relatively developed areas of the Chico Creek watershed are clustered around the lower portions of the watershed adjacent to Chico, Kitsap, and Dickerson creeks, and the lakeshore areas of the Kitsap and Wildcat Creek subbasins. The hydrologic impacts related to land use development were assessed based on the relative portion of impervious surface areas in each subbasin, as derived from existing data in the USGS National Land Cover Database, representing land cover classifications from 2006.

The impervious surface data were analyzed to compile a summary of Total Impervious Area (TIA) for each subbasin area. The cumulative watershed area is estimated to contain 3.7% TIA. The most developed subbasins in the watershed, Chico Creek and Kitsap Creek, have 12.1% and 7.6% TIA, respectively (Table 11). Watershed assessments in other regions of the Puget Lowland have found declining ecosystem health for subbasin areas exceeding 10 to 15% TIA (Booth and Reinelt, 1993). Impacts to stream processes and ecological health are still observed at < 10% TIA; however, this value marks a transition above which "good" ecological conditions are no longer observed. Based on these criteria, the Chico Creek subbasin can be classified as impaired. The Kitsap Creek subbasin also has relatively high TIA and large areas with hydrologically immature forest; however, impacts to the hydrologic regime may be moderated by Kitsap Lake.

Table 10. Hydrologically mature vegetation as a relative percent of subbasin land area.

	Mature	*Immature*
Wildcat Creek Subbasin	68%	32%
Lost Creek Subbasin	57%	43%
Dickerson Creek Subbasin	62%	38%
Kitsap Creek Subbasin	59%	41%
Chico Creek Subbasin	59%	41%
Watershed Total	62%	38%

Table 11. Total impervious areas (TIA) as a relative percentage of subbasin area in the Chico Creek watershed (USGS, 2006).

	TIA
Wildcat Creek Subbasin	2.2%
Lost Creek Subbasin	0.1%
Dickerson Creek Subbasin	0.4%
Kitsap Creek Subbasin	7.6%
Chico Creek Subbasin	12.1%
Watershed Total	3.7%

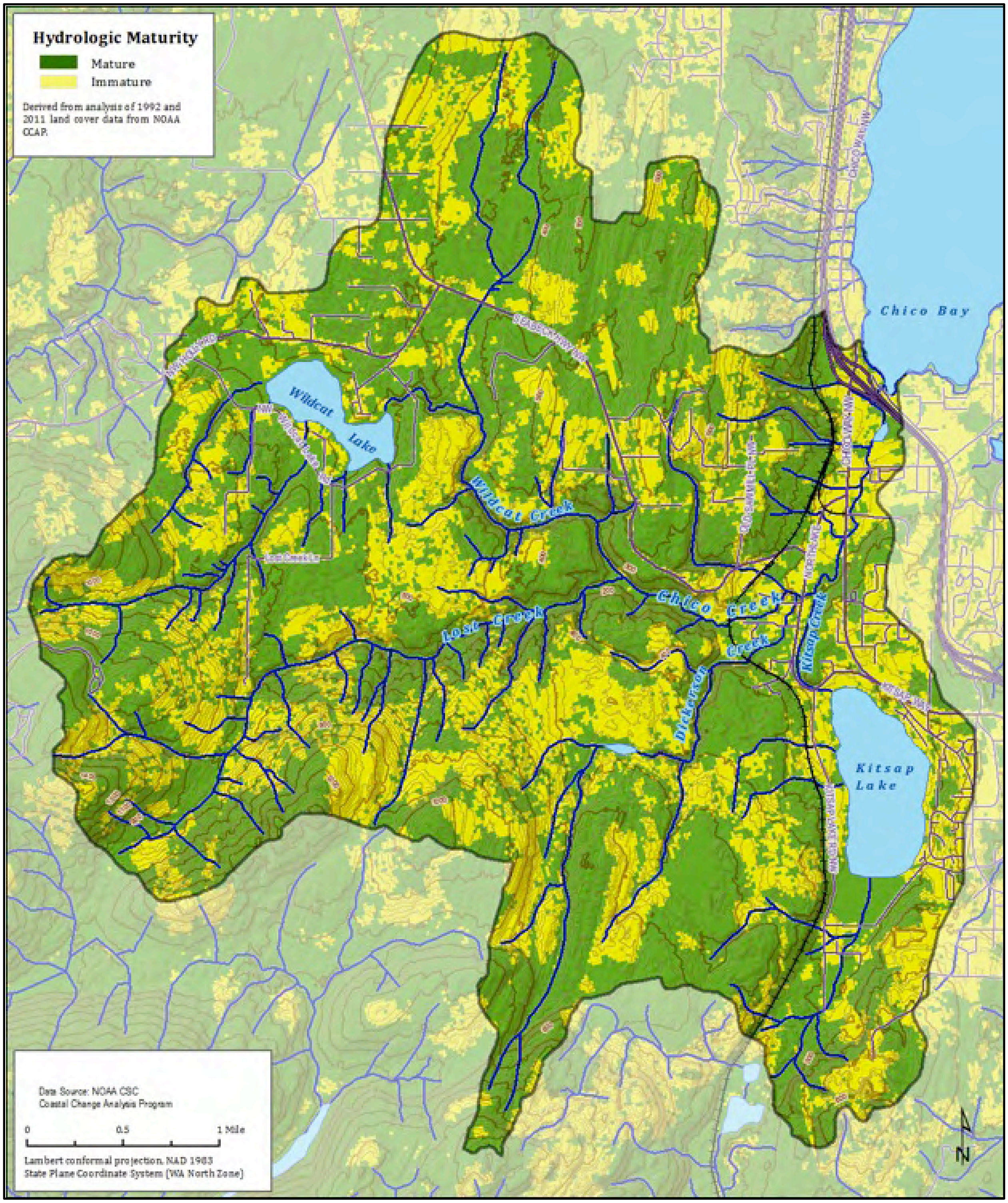


Figure 23. Map of hydrologic maturity in the Chico Creek watershed derived from analysis of 1992 and 2011 landcover data and updated to include areas of timber harvest evident from 2013 aerial imagery in Google Earth.

HYDROLOGIC RECORD

A long term record of precipitation data has been collected as part of the National Weather Service Cooperative Network for the station at Bremerton, WA (Station ID: 450872). The station at Bremerton is not located within the Chico Creek watershed but is approximately 1 mile from the watershed boundary and reasonably representative of the precipitation record in the study area. The precipitation record at Bremerton compiles data for the period 1948-present and is relatively complete; however there are periods of missing data. As such, the data are useful for compiling information on seasonal and interannual variability (Figure 6) but are not complete for use in evaluation of statistical trends without further processing and analysis.

Streamflow measurements have been collected at multiple locations in the Chico Creek watershed over varying time periods since the late 1940’s (Table 12). The U.S. Geological Survey (USGS) operated a stream gaging station on Chico Creek at NW Golf Club Hill Road for a short period during water years (WY) 1947-50 and then again from WY 1960-74. The USGS has been making discrete field measurements at the gage site 2-3 times a year during the summer low flow period since 2011. Kitsap Public Utility District (KPUD) maintains a network of streamflow gaging stations that includes 5 locations in the Chico Creek watershed, 3 of which are actively monitored. The earliest gaging by KPUD collected measurements from a site located on the Kitsap Golf & Country Club property just downstream of NW Golf Club Hill Road and was discontinued in 2009. Although the KPUD gaging record at this site spanned a period of 15 years, there are considerable gaps of missing data during this period. Chico Creek is presently gaged at a site located upstream at Taylor Road. The Taylor Road site was initially monitored for a short period from 2001-03 and then restarted in 2012. The site at Taylor Road excludes inflow from Kitsap Creek and Dickerson Creek, and therefore, is not directly comparable to previous monitoring data for Chico Creek. The gaging records on Kitsap Creek (at outlet of Kitsap Lake), Dickerson Creek (at David Road), and Wildcat Creek (at outlet of Wildcat Lake) support the present understanding of the streamflow characteristics in the tributary channels. There has been no streamflow gaging in the Lost Creek watershed; however, Roberts et al. (2008) collected instantaneous measurements of streamflow in the lower reaches of Lost Creek from 2002-2006. Additional instantaneous measurements have been collected in lower Wildcat Creek; however, these data have not been compiled (Roberts, personal communication).

Collectively, this hydrologic record presents data that quantifies the seasonal and interannual variability of flows for Chico Creek and its primary tributaries. The period of record for streamflow observations on tributary channels is not a sufficient length of time to support a quantitative analysis of long term trends. The combined period of record for Chico Creek at NW Golf Club Hill Rd totals 31 years; however the KPUD record from more recent years has periods of missing data. One could use the combined flow records of these two stations for evaluation of hydrologic change over the period 1948-present; however, the gaps in the datasets and potential for different operating procedures between the two agencies (USGS and KPUD) create additional uncertainty in any results of such analysis.

The hydrologic record for the Chico Creek watershed was reviewed to identify whether changes in the hydrologic regime can be identified from existing streamflow data. Such an evaluation is limited in that the period of record for streamflow information is relatively short and does not include any data to characterize watershed conditions prior to large scale timber harvest practices in the watershed. An evaluation of the hydrologic changes between the 1962-1979 data collected by USGS and the 1992-2008 data collected by KPUD explored temporal changes in the annual maximum peak flow for Chico Creek during recent decades. Note that data from the 1960s and 1970s does not represent natural watershed conditions given that intensive forest practices likely altered watershed conditions during the period prior to the 1960s. The USGS time series of annual peak flow has a continuous record over an 18 year period. The KPUD gaging record has periods of missing data. Any year for which daily maximum values were missing for more than 2 days in any month during the period November-March was excluded from the time series. Results show a general decrease in peak streamflow between the two time periods (Figure 24). The 2-year recurrence interval flood (equaled or exceeded once every 2 years, on average) calculated based on the 1962-1979 USGS time series, was exceeded in only 1 out of 13 years gaged by KPUD during the period 1992-2008. The two stations were located in the same general vicinity and there are no significant tributary inflows that could account for such a difference. Peak flow estimates are generally made by extrapolation of a rating curve produced from lower flows and it is possible that the difference is partially attributed to uncertainty derived from such extrapolation to estimate peak discharge. It is also possible that the degree of hydrologic alteration has decreased with time and that during the 1960s and 1970s watershed conditions were prone to greater peak flow magnitudes given widespread forest clearing from timber harvest. Land cover data prior to 1992 was not compiled for this analysis.

Low summer baseflows are also an important measure of the hydrologic regime of the Chico Creek watershed. Extreme low flows can result in dewatering of localized subreaches and the fragmented habitat for aquatic species. Data from the USGS gaging station reveals that flows along mainstem Chico Creek receded to less than 1 cfs for a period of approximately 2 weeks per year, on average (Figure 9). Additional instantaneous measurements of summer baseflows have been made in the upper watershed and recorded baseflows ranging from 0.001 to 0.003 cms in Wildcat Creek and 0.012 cms in Lost Creek (Roberts et al., 2008).

Existing data in the hydrologic record from more recent gaging by KPUD were reviewed to evaluate potential changes in the flow duration curve of Chico Creek. The data from KPUD were missing considerable periods of the summer baseflow period for multiple years, limiting the ability to calculate baseflow statistics for recent years. Historic trends in baseflow have not been assessed. It can be concluded from the hydrologic record that the hydrologic regime of the Chico Creek watershed is sensitive to watershed changes that may alter baseflow given the known occurrence of low flows that limit availability of salmonid habitat (Haring, 2000). Establishing a permanent streamflow gaging station in Chico Creek at a location where a stable rating curve can be developed and maintained is critically important to monitoring impacts to both peak flow and baseflow conditions.

Table 12. Summary of streamflow monitoring in the Chico Creek watershed.

Stream Name/Station	Agency	Record length (yrs)	Period of record
Chico Creek #12072000	USGS	16	1948-50, 1962-74
Chico Creek mainstem	KPUD	15*	1991-96*, 2001-09*
Chico Creek at Taylor Rd	KPUD	5*	2001-03*, 2012-present
Kitsap Creek at lake outlet	KPUD	8	2001-05, 2011-present
Dickerson Creek at David Rd	KPUD	4*	2001, 2003-05*
Wildcat Creek at lake outlet	KPUD	13*	2001-present*

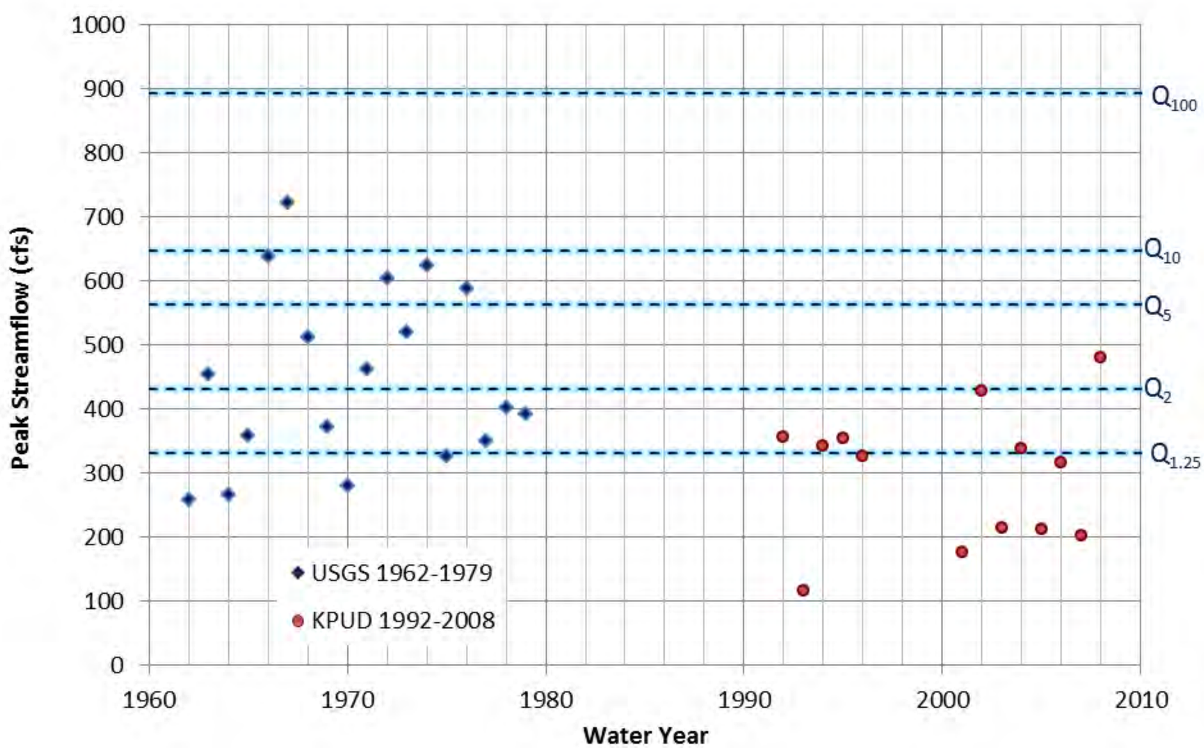


Figure 24. Annual peak streamflow for Chico Creek combining data from the USGS gaging station (#12072000) and the KPUD station. Dashed horizontal lines indicate estimated flood magnitudes for recurrence intervals between 1.25 and 100 years based on analysis of the 1962-79 time period.

SUBBASIN VARIATION

Spatial variation of watershed characteristics (e.g., geology, physiography, climate, vegetation) and land use impacts contribute to hydrologic response of individual subbasin areas. A coarse scale assessment of subbasin variation was evaluated using spatial (GIS) data from the Washington State Department of Ecology's (Ecology) Puget Sound Characterization Project (Stanley et al., 2012). Ecology's assessment of hydrologic processes quantified a range of hydrologic parameters for seven Assessment Units (AU) corresponding to the primary tributary subbasins in the watershed. The Chico Creek subbasin was divided into three units delineated as a coastal lowland unit, Lower Chico Creek (subbasin draining areas downstream of the confluence with Dickerson Creek), and Upper Chico Creek (subbasin draining areas upstream of the confluence with Dickerson Creek), including the tributary channel draining the plateau region to the north of Chico Creek and discharging to the mainstem just upstream of Dickerson Creek. Key parameters assessed for each AU include:

- Water Delivery, driven largely by precipitation patterns;
- Surface Storage, including depressional wetlands, lakes, and floodplain areas;
- Groundwater Recharge, enhanced by surface soils characterized by high permeability; and
- Groundwater Discharge, identified as areas where floodplains intersect permeable geologic deposits or slope breaks delineating an area of hydric soils extending into a lower gradient area.

Results of Ecology's assessment were compiled from a GIS database of AUs located in Water Resource Inventory Area (WRIA) 15. Initial results were developed to characterize the variability between AUs and identify areas most important to specific hydrologic parameters and the overall importance to water flow in the basin (Table 13, Figure 25). Kitsap Creek ranked highest in terms of overall importance to water flow with key factors scoring high in Kitsap Creek, including surface storage and groundwater recharge and are strongly related to the contributions of large depressional wetlands and Kitsap Lake. Dickerson Creek was characterized as moderate-high for overall importance to water flow and scored highly for groundwater recharge but slightly below (moderate-high) Kitsap Creek for surface storage. The Upper Chico Creek AU ranked moderate-high and includes areas ranked highly important for recharge and moderate-high for groundwater discharge. The Wildcat Creek AU ranked as moderately important with a moderate-high importance for groundwater recharge and low importance for surface storage. These results appear to underestimate the importance of key features in the Wildcat Creek AU such as Wildcat Lake and the Newberry Hill wetland complex area. A finer scale analysis would likely rank subareas within the Wildcat Creek AU as highly important for parameters such as surface storage and groundwater recharge. The Lost Creek AU ranked low in importance to water flow, likely related to the generally confined nature of the floodplain, limited presence of depressional wetlands, and areas of shallow bedrock with little potential for groundwater recharge. Observations from instantaneous streamflow measurements verify that Lost Creek has a "flashier" flow regime when compared to Wildcat Creek. Note, however, that summer baseflow contributions from Lost Creek generally exceed the baseflow contributions coming from Wildcat Creek (Roberts, personal communication).

A second phase of Ecology's assessment characterized the level of degradation to water flow processes driven by land use impacts in the watershed. Results show a clear linkage between degradation and the spatial pattern of development in the basin (Table 14, Figure 26). Assessment of degradation to water flow processes primarily reflects the distribution and intensity of urban and residential development in the watershed. The Chico Creek AUs in the lower watershed showed the highest level of degradation, followed by the Upper Chico and Kitsap Creek AUs which are classified as moderate-high for degradation. Wildcat Creek is classified as moderate, and Lost Creek and Dickerson Creek are both classified as low with respect to degradation. This characterization may underestimate potential impacts driven by timber harvest in upper parts of the watershed, particularly Lost and Dickerson Creeks.

Table 13. Assessment of hydrologic importance for key parameters in the Chico Creek watershed (Stanley et al., 2012).

	Delivery	*Surface Storage*	*Recharge*	*Discharge*	*Overall Importance*
Coastal Lowland	M	MH	H	H	H
Lwr Chico	M	M	MH	MH	M
Upr Chico	M	M	H	MH	MH
Kitsap	M	H	H	MH	H
Dickerson	M	M	H	H	MH
Lost	M	L	MH	L	L
Wildcat	M	L	MH	L	M

Key: L = Low; M = Moderate; MH = Moderate-High; and H = High Importance.

Table 14. Assessment of hydrologic degradation for key parameters in the Chico Creek watershed (Stanley et al., 2012).

	Delivery	*Surface Storage*	*Recharge*	*Discharge*	*Overall Degradation*
Coastal Lowland	H	H	H	H	H
Lwr Chico	H	H	H	H	H
Upr Chico	MH	H	H	MH	MH
Kitsap	MH	MH	H	M	MH
Dickerson	M	M	L	L	L
Lost	L	L	L	L	L
Wildcat	M	M	M	M	M

Key: L = Low; M = Moderate; MH = Moderate-High; and H = High Importance.

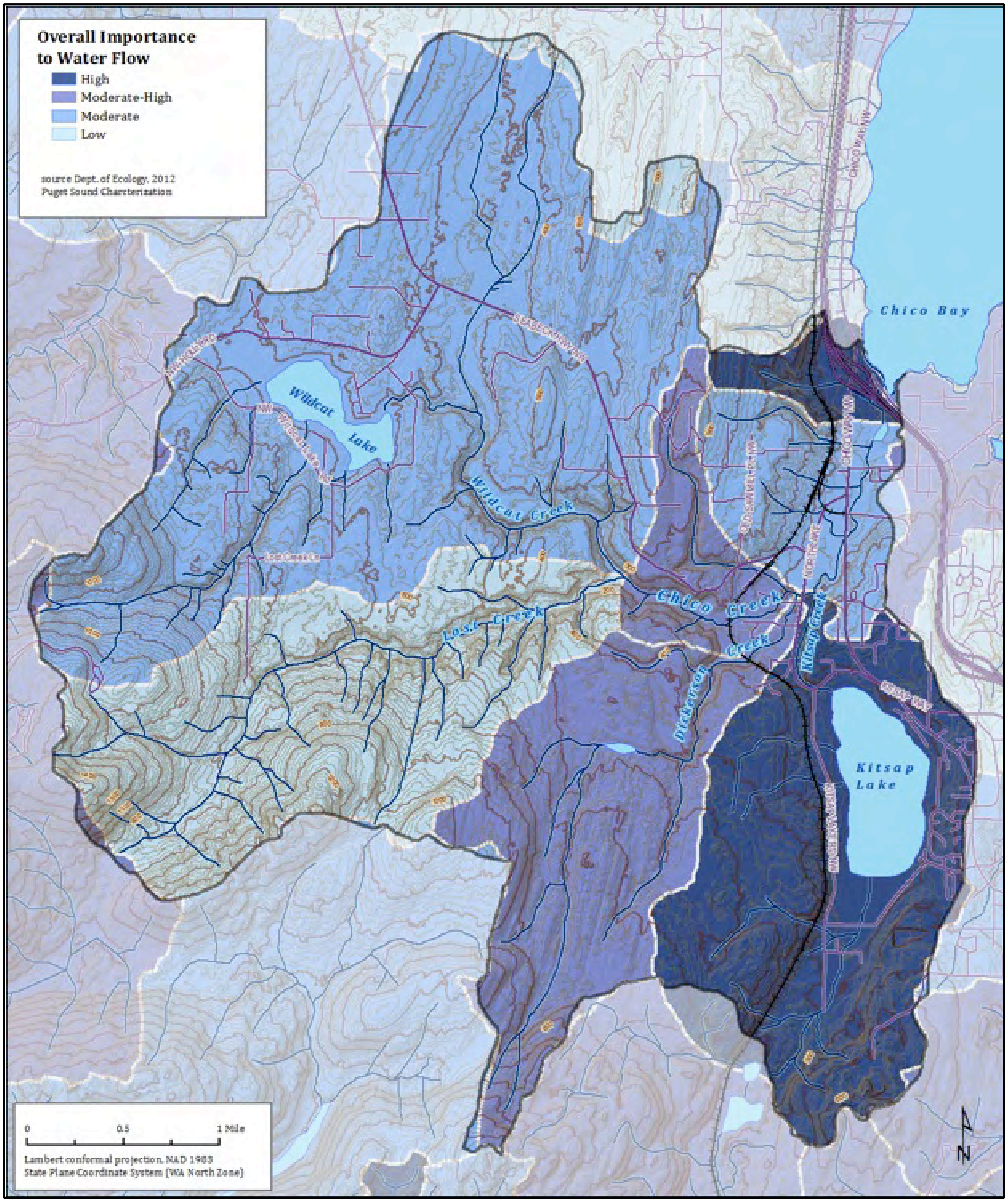


Figure 25. Map of the overall importance to water flow derived from the Puget Sound Characterization for WRIA 15 (Stanley et al., 2012).

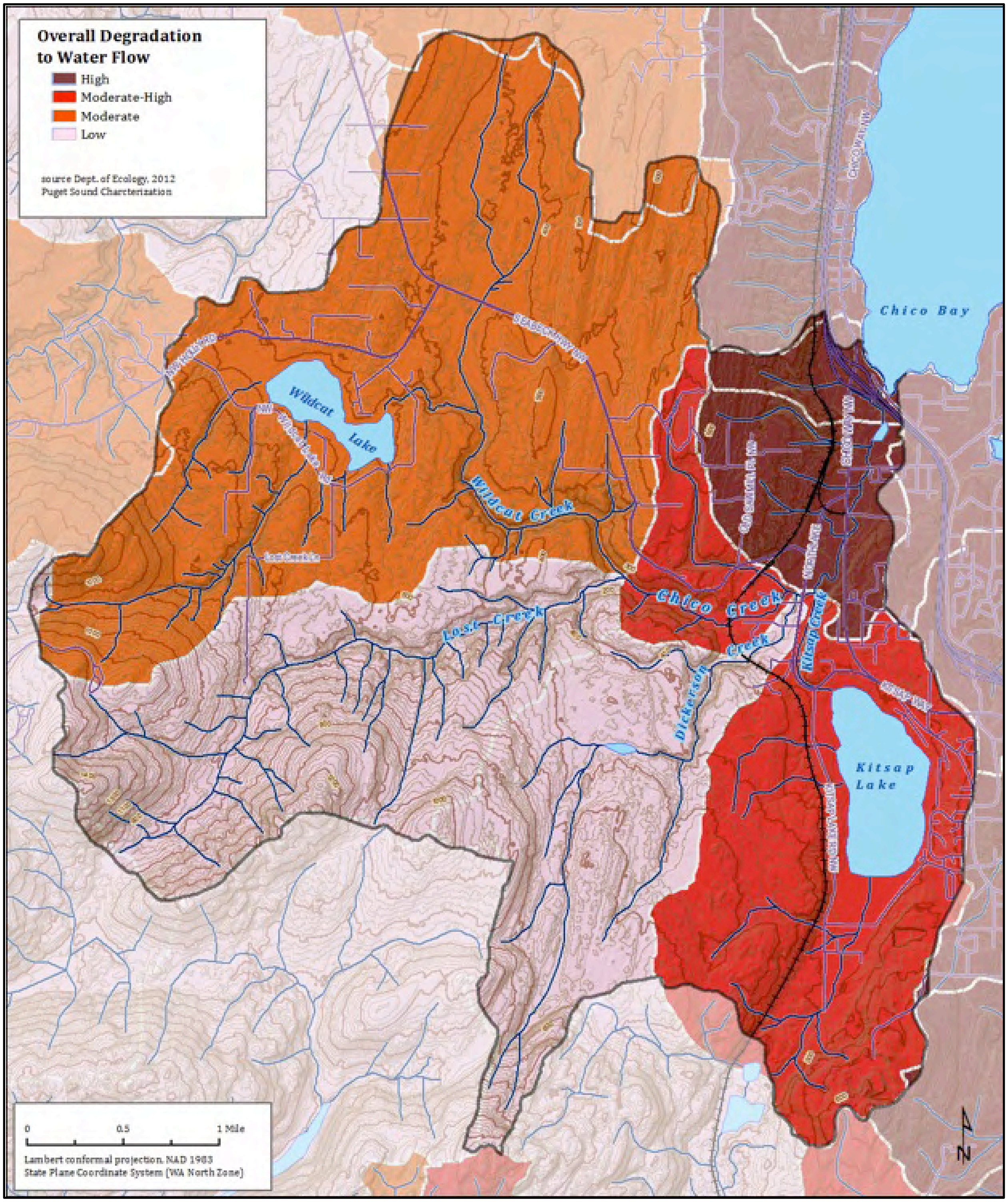


Figure 26. Map of the overall degradation to water flow derived from the Puget Sound Characterization for WRIA 15 (Stanley et al., 2012).

ANTICIPATED HYDROLOGIC EFFECTS OF CLIMATE CHANGE

A brief review of long term climatic trends was conducted using the climatic record at Seattle, WA that has been analyzed as part of the United States Historical Climatology Network (USHCN) to account for periods of missing data and adjust for biases or other irregularities that would affect trend analysis (Menne et al., 2013). The Seattle monitoring location is the closest station to the Chico Creek watershed in the USHCN and determined to be a reasonable representation of the surrounding region. Time series plots of temperature and precipitation at Seattle suggest increasing trends in both annual mean temperature and precipitation for the period 1890-2010 (Figure 27). The historical trends at Seattle correspond to a 1.1° F increase in annual mean temperature and a 5% increase in annual precipitation over the period of record.

Hydrologic models of historical and future impacts of climate change have identified important differences between watersheds that are rainfall-dominated, snowfall-dominated, or transitional. Model results show that the hydrologic regime of watershed areas in the transitional or snowfall-dominated zones are most affected by climate change (Cuo et al., 2011; Elsner et al., 2010). Given that rain-on-snow events in western Washington are generally limited to elevations above 1,200 ft in (Harr, 1986), only a small portion of the Chico Creek watershed would be influenced by such changes. Assessment of watershed areas in lowland regions that have rainfall-dominated flow regimes show that land cover changes have dominated climatic signals in historical trends (Cuo et al., 2009).

Atmospheric research on potential impacts of projected climate changes does raise some concern for lowland basins such as the Chico Creek watershed. Regional climate models for the western United States indicate consistent and significant increases in the intensity of extreme winter precipitation events (Dominguez et al., 2012). Research shows potential linkages between warming ocean temperatures and climatic patterns that shift the position of the Aleutian Low northward and result in increased precipitation intensity over the Pacific Northwest (Salathé, 2006). Essentially all extreme flood events in western Washington are driven by atmospheric processes which concentrate warm, moist air from tropical regions and deliver large amounts of precipitation to the Pacific Northwest in atmospheric river (AR) events known as the “Pineapple Express” (Neiman et al., 2011). Modeling of projected climate changes shows predicted increases in the intensity of extreme AR episodes and a lengthening of the peak season within which ARs occur (Dettinger, 2011), supporting the argument for future increases in rainfall intensity. Mass et al. (2011) documented historical increases in the frequency and magnitude of extreme precipitation events along the Washington Coast. Climate model simulations for the Pacific Northwest show a large increase in water vapor under future climate conditions and increased frequency of AR events. Such increases in precipitation intensity could have large implications for the hydrologic regime in the Chico Creek watershed. For example, the December 2007 storm event affecting Kitsap County peaked on December 3 with a 24-hour rainfall total of 7.6 inches at Bremerton. The predicted 100-year, 24-hour rainfall total for Bremerton is 5.5 inches. The intense precipitation produced peak flows that triggered substantial geomorphic changes in Chico Creek (e.g., sediment transport, bank erosion, wood recruitment) and damaged infrastructure located within the stream corridor. A long term trend of increased precipitation intensity could be expected to alter flood frequency relations in the region and have related impacts on geomorphic and ecologic processes.

Dry season conditions may also be affected by projected climate changes in the region. Potential watershed hydrologic effects from increases in air temperature include (Mote et al., 2014):

- Increased evaporation from Kitsap Lake, Wildcat Lake, and large depressional wetlands;
- Increased evapotranspiration from trees and other vegetation;
- Decreased soil moisture; and
- Increased susceptibility to drought and fire.

Such changes are linked with an overall tendency toward a future hydrologic regime characterized by higher flood peaks and lower base flows. The anticipated effects of future climate change, therefore, intensify the overall impacts driven by land use activates in the watershed and further suggest a need to increase stream resilience to future watershed changes.

Habitat Effects

Review of land use indicators in the Chico Creek watershed suggests that hydrologic regime is moderately impaired due to forest clearance and urbanization. Past timber harvest practices have likely driven accelerated peak flows in the Chico Creek watershed with associated increases in sediment transport capacity in downstream reaches. Such increases in peak flow and sediment transport capacity, due to historical land use activities, have important implications for channel stability and have resulted in disconnection of side channel and floodplain habitats due to channel incision. Accelerated peak flows have direct impacts on salmonids by increasing scour depth during floods. Even minor increases in bed scour driven by accelerated peak flows can decrease embryo survival in salmon redds (Montgomery et al., 1996).

Habitat conditions during periods of base flow are also affected by changes in hydrologic regime. The Chico Creek watershed was likely characterized by low base flow conditions under the natural flow regime. As such, relatively small changes in land cover characteristics that reduce the rate of infiltration and groundwater recharge (due to increases in surface runoff) during the wet season can result in negative habitat effects due to reduced base flows in the dry season. Sections of Wildcat Creek, for example, have been observed to dewater during late summer as flow is entirely subsurface. Habitat effects during base flow conditions are exacerbated in reaches lacking in large wood and devoid of pool habitats.

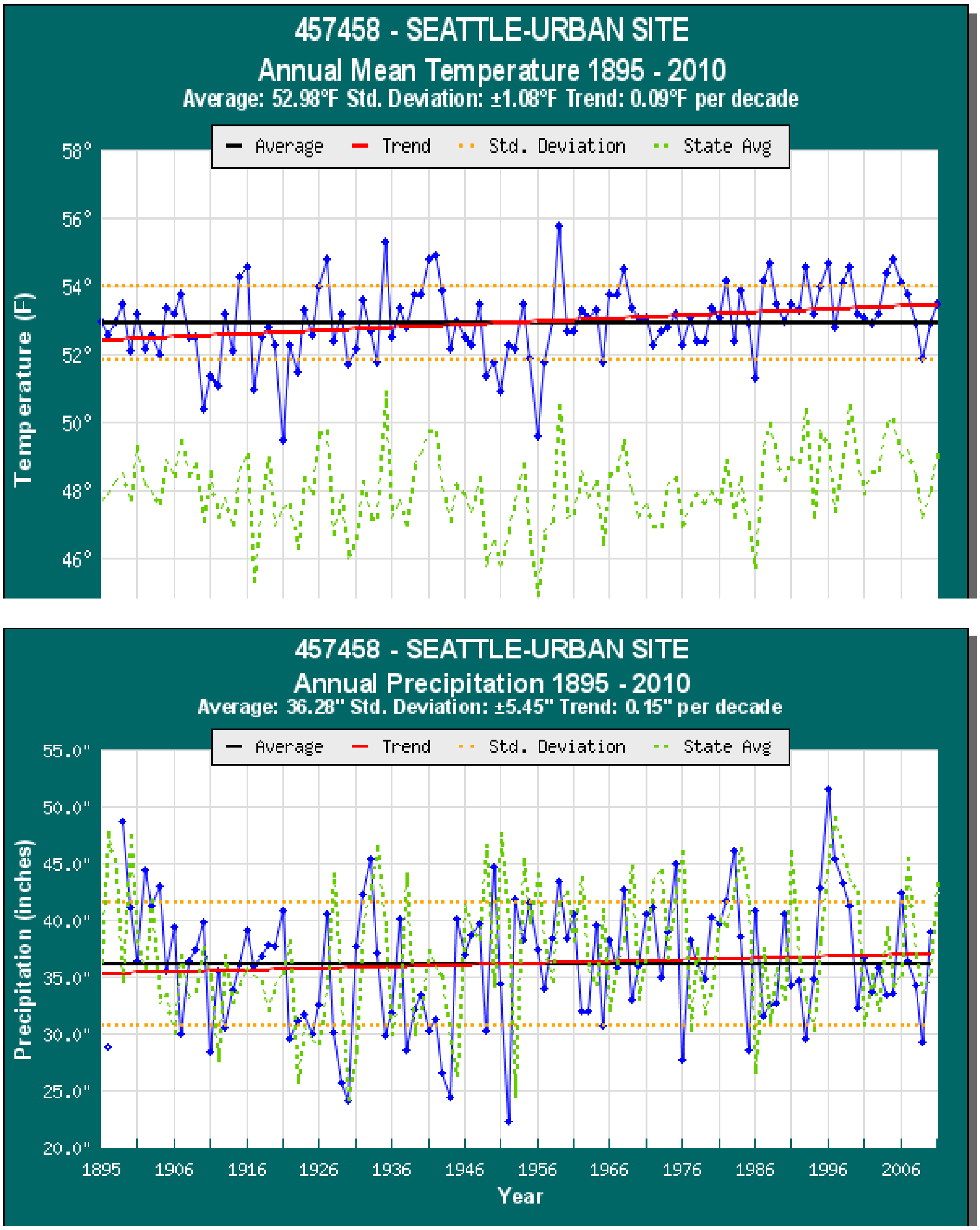


Figure 27. Long term trends in temperature (top) and precipitation (bottom) for the period of record 1895-2010 at Seattle, WA (Office of the Washington State Climatologist, 2013).

4.2 SEDIMENT REGIME

The sediment regime of alluvial rivers is characterized by the spatial and temporal variations in the geomorphic processes that drive sediment supply, transport, and deposition in the channel network. The various inputs, outputs, and storage of sediment over time can be integrated to develop a sediment budget identifying linkages between the prevailing processes driving the sediment regime (Dietrich et al., 1982). Land use activities in the Chico Creek watershed have triggered important changes in the sediment budget and contributed to resulting changes in the quality, quantity, and resilience of salmonid habitats in the stream corridor. Key factors affecting these processes include:

- Changes in sediment input from hillslope areas or upstream sources;
- Changes in the prevailing flow regime; and
- Changes in the roughness characteristics of the channel.

This assessment of sediment related processes in the Chico Creek watershed focuses on describing historical changes in land use indicators and the related impacts on the stream corridor.

SOURCES AND SINKS

Watershed contributions of sediment to the alluvial channel network are episodic in nature and driven by variations in both natural (climatic, geologic) and human induced (land use) disturbances. Three key mechanisms driving sediment supply to the channel network include:

- Surface erosion;
- Mass wasting processes; and
- Erosion of the channel bed and bank material in upstream channel reaches.

Surface erosion is driven by entrainment of soil particles by overland flow. Sediment production from surface erosion is generally limited to fine-grained materials (sand sized particles and smaller). Factors affecting rates of sediment production from surface erosion include soil characteristics, topographic relief, and vegetation. Land disturbances which increase soil exposure to raindrop impact or overland flow are associated with human induced increases in sediment production. In developing regions of a watershed, sediment yield from upland areas tend to follow a cyclical trend with rapid increases during periods of intense land clearance for construction, then tapering off as land surfaces become dominated by paved areas (Wolman, 1967). Sediment supply to stream reaches downstream of developed areas can remain elevated as increased surface runoff from paved areas accelerates erosion of the channel bed and banks (Allmendinger et al., 2007; Trimble, 1997). In forested areas of the watershed, surface erosion is accelerated by the clearance of vegetation for timber harvest and by road construction. Forest roads increase surface runoff rates by compaction of the ground surface (Reid and Dunne, 1984) and interception of shallow subsurface flow (Megahan and Clayton, 1983; Wemple and Jones, 2003). Surface erosion attributed to roads in forested basins can increase sediment production by over an order of magnitude (MacDonald and Coe, 2008). Sediment production from forest roads is strongly correlated to the volume of traffic usage with heavily used road segments producing 130 times as much sediment as abandoned road segments (Reid and Dunne, 1984).

Mass wasting is the downslope movement of sediment under the influence of gravity and includes a variety of hillslope processes such as soil creep, debris flows, and landslides. Slope failures are prone to occur when the gravitational forces exceed the resisting forces of the sedimentary deposit. In the Chico Creek watershed, mass wasting processes are most dominant in areas of steep topography and unconsolidated sediment (Figure 28). Hillslope areas composed of glacial materials are particularly vulnerable (Montgomery and Dietrich, 1994). Mass wasting processes are capable of contributing rapid pulses of sediment to the channel network and can be an important component of sediment production in headwater channels that have strong connections with hillslope processes (Gomi et al., 2002) . Land use impacts from forest clearing dramatically accelerate shallow landsliding and accelerate rates of sediment delivery to the channel network (Montgomery et al., 2000; Sidle et al., 1985).

Sediment produced by instream erosion of bed and bank materials is a natural component of the fluvial system. Alterations to prevailing watershed conditions that distribute the natural balance of sediment supply and transport capacity can trigger a geomorphic response such as incision or aggradation and can affect the sediment budget by either increasing or decreasing the net export of sediment from a given reach. Headwater reaches of forested watersheds in the Puget Lowland are typically areas of high transport capacity and act as conduits in transporting excessive sediment load to lower gradient reaches in downstream areas that are more responsive to watershed alterations (Montgomery and Buffington, 1998). The presence of sediment sinks also affect the overall response to watershed changes. Two large lakes, Kitsap Lake and Wildcat Lake, form sediment sinks that limit the downstream conveyance of sediment. Wildcat Lake, in particular, receives inputs from relatively steep channels draining areas that are prone to instability (Figure 28). Kitsap Lake watershed is more urbanized, but sediment production is largely trapped within the lake; therefore, the area of sediment production that tends to reach the stream reach downstream of the lake is more limited. Kitsap Lake therefore dampens high flows and sediment transport in lower Kitsap Creek (downstream of the lake).

Watershed Alterations

Land use activities in the Chico Creek watershed have affected key factors influencing the sediment regime. The land use indicators highlighted in the section on hydrologic regime have concurrent effects on the sediment regime. Given the substantial increases in sediment loading associated with forest roads (Reid and Dunne, 1984), spatial data were analyzed with GIS tools to calculate the density of roads for each subbasin area. Results show the highest road densities in the Chico Creek subbasin (most developed) with road densities in tributary subbasins between 5 and 6 miles of road per square mile of watershed area (Table 15). For reference, existing guidelines for salmon habitat by the National Marine Fisheries Service (1996) characterize watersheds with road densities greater than 3 mi/mi^2 as "not properly functioning", while "properly functioning condition" was defined as less than or equal to 2 mi/mi^2.

Although road densities are considered high throughout much of the Chico watershed, improvements have been made in the way forest roads are constructed and maintained, with efforts in more recent years to avoid and minimize constructing roads in steep unstable terrain, or that cross or run adjacent to streams. Recommended actions should include identifying and prioritizing options to decommission roads that occur in steep unstable terrain, and removing road crossings of streams and sections of road that occur in close proximity to stream channels. These cumulative actions should help reduce forest road contributions to sedimentation in the watershed. Two of the largest forest landowners in the Chico watershed (WDNR and Ueland Tree Farm) manage the majority of their properties under Forest Stewardship Certification (FSC), which generally implies that more sustainable forest practices are in place now than during past decades, including less impacting methods of forest road construction and maintenance, as well as smaller harvest patch sizes.

Water quality assessment as part of Department of Ecology’s Puget Sound Watershed Characterization (Stanley et al., 2012) utilized the Non-Point Source Pollution and Erosion Control Tool (N-SPECT) to model degradation to sediment processes in a GIS. This coarse-scale screening tool focuses primarily on surface erosion and calculates changes in sediment yield derived from alterations to surface runoff and a soil erodibility factor linked to land use. Results show high levels of degradation to sediment processes in the Kitsap and Lower Chico Creek AUs where land use impacts have been most extensive (Figure 29). Note that Kitsap Lake acts as a sediment sink that buffers the downstream transport of sediment produced in the upper watershed of that subbasin. The Lost Creek and Upper Chico Creek AUs show moderate-high levels of degradation to sediment processes. Field reconnaissance of tributary areas in the Lost Creek subbasin identified areas where accelerated runoff has triggered erosion and channel incision that deliver large volumes of sediment to downstream reaches (Figure 30).

Ecological Impacts

The evaluation of land use indicators (e.g., hydrology, sediment, riparian characteristics, wood, and floodplain connectivity) suggests an overall increase in sediment production from the Chico Creek watershed due to land clearance and road construction. Human induced increases in sediment supply raise concerns for impacts to salmonid habitat in downstream reaches. Increased sediment supply from disturbed landscapes can potentially lead to aggradation of the channel bed and fill pools (Lisle, 1982). The coarse-scale review conducted for this assessment did not identify specific reaches where substantial aggradation is a concern for habitat. In fact, a general trend toward channel incision is a larger concern suggesting that human caused increases in sediment supply are overwhelmed by concurrent increases in peak flow magnitudes and sediment transport capacity. The frequency and depth of pool habitats are a limiting factor for salmonids in the Chico Creek watershed (Haring, 2000). It is likely that the relative contribution of sediment supply is small compared to the effect of reduced wood loading on pool habitat. Concerns related to changes in sediment production are more focused on negative effects of increasing contributions of fine sediment to the channel. Large increases in fine sediment can result in negative effects for salmonid habitats such as filling of backwater habitats and pools and intrusion of fine sediments into salmon redds. McHenry et al. (1994) studied the effect of fine sediment on redds in Olympic Peninsula streams and report that almost no steelhead or coho eggs survive if more than 13% fine sediment (<0.85 mm) intrudes into the redd.

Table 15. Road density by subbasin area (source: WDNR, 1996. 1:24,000 scale transportation data).

	Road Length (mi)	***A_d (mi^2)***	***Road Density (mi/mi^2)***
Chico Creek Subbasin	14.6	1.9	7.6
Kitsap Creek Subbasin	15.0	2.9	5.1
Dickerson Creek Subbasin	12.5	2.1	5.9
Lost Creek Subbasin	17.6	3.0	5.8
Wildcat Creek Subbasin	36.5	6.3	5.8
Watershed Total	96.3	16.3	5.9

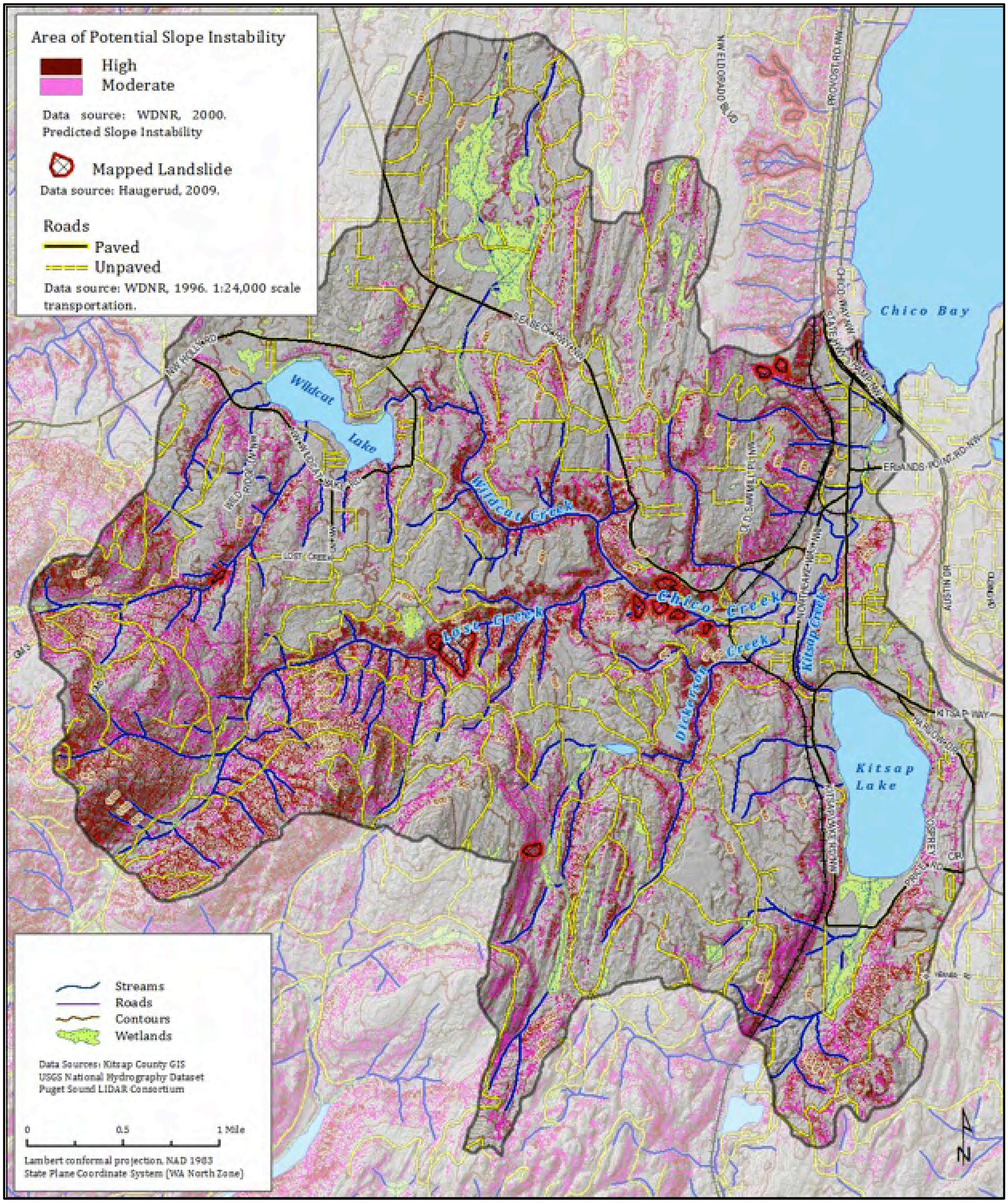


Figure 28. Predicted slope instability and landslide deposits in the Chico Creek watershed. Mapped landslides are from Haugerud (2009). Potential slope instability is derived from SHALSTAB model output (Montgomery and Dietrich, 1994).

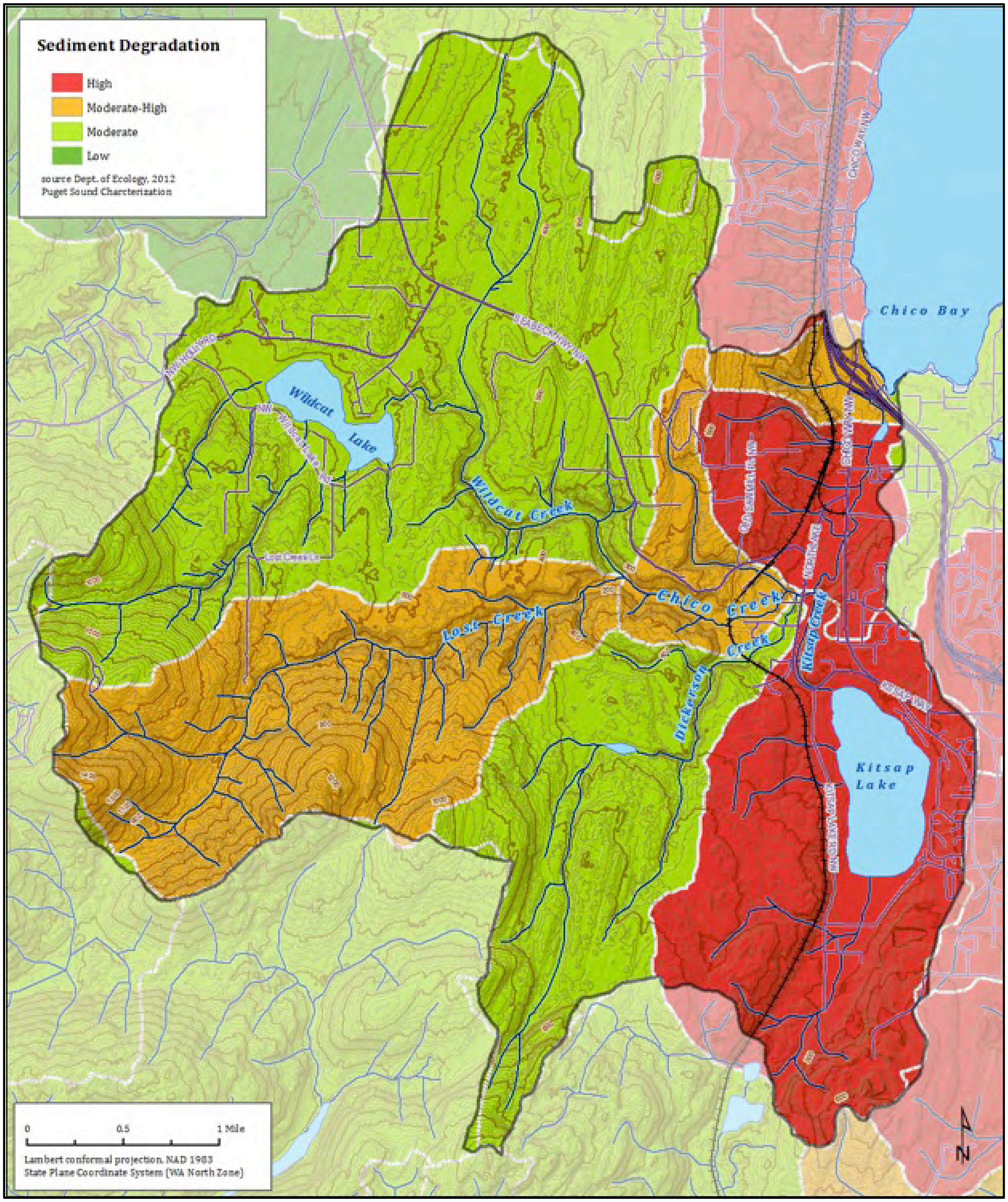


Figure 29. Map of the degradation to sediment processes derived from the Puget Sound Watershed Characterization for WRIA 15 (Stanley et al., 2012).

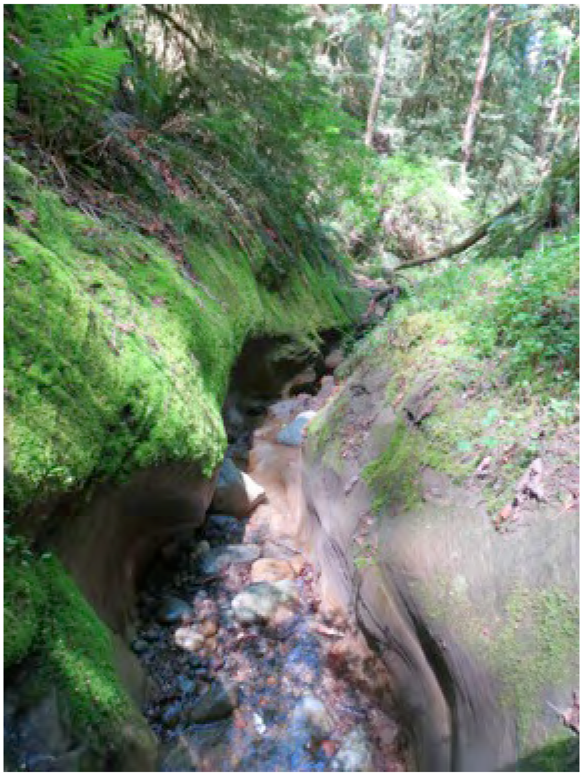


Figure 30. Photo of moderately steep, forested channel segment that has incised a narrow ravine in response to accelerated surface runoff. Much of the small watershed of this right bank tributary to Lost Creek was clearcut and had road construction in the 1990s and in about 2004. In 2009 the Ueland Tree Farm donated a conservation easement for part of the subbasin to the Mountaineers Foundation to protect this riparian corridor and stream into the future. The parcel was purchased by the Mountaineers Foundation in 2012 with a donation from the Suquamish Tribe under EPA's National Estuary Program. Photo taken May 2013 by Steve Todd

4.3 RIPARIAN CORRIDORS AND WETLANDS

The riparian corridor provides an important linkage across the landscape between terrestrial influences and aquatic habitat conditions. The species, diversity, density, structure, and width of the riparian corridor all affect the influence of riparian conditions on stream habitat conditions and on the integrity and resiliency of aquatic communities. Riparian corridor trees shade the streams, provide allochthonous organic matter that feeds benthic invertebrates, resist erosion, slow flood flows, and provide the source of most large woody debris (LWD) recruitment to streams (Décamps et al., 2009). Clearing and fragmentation of the riparian corridor reduces LWD recruitment, altering habitat forming processes and the nature and number of pools. Alterations in tree and shrub species diversity and community composition changes the frequency, nature, and seasonality of allochthonous organic material input to the stream. Consequent changes in benthic invertebrate communities affect foraging opportunities and the bioenergetics of juvenile salmonids rearing in streams and estuaries. Clearing and development of the riparian zone negatively affects riparian functions, including stream temperatures, wildlife habitat, sediment retention, and possibly also groundwater recharge (Baird et al., 2005; Haring, 2000; Naiman and Bilby, 2001)

Wetlands similarly link aquatic and terrestrial habitats, providing rearing, breeding, and foraging habitat functions for fish and wildlife, as well as water quality/erosion and sediment reduction functions. Wetlands affect the hydrologic functions related to reducing and holding floodwaters and sustaining seasonal base flow in adjacent streams.

Nearly all the Chico Creek watershed, including the riparian zones, has been harvested for timber at least one time since the mid-late 1800's. Urbanization in the lower watershed, coupled with a continuous cycle of timber harvest, replanting, and regrowth has created a patchwork of development, and second, third, and fourth growth forests (Nelson, 2003).

ANALYSIS METHODS

The condition of the riparian corridor was assessed based on a combination of information presented in past studies (Roberts, 2003; Segura Sossa and Booth, 2003). Additionally, LiDAR-derived maps from 2000 indicating tree height (Puget Sound LiDAR Consortium), a GIS analysis completed by NSD of land cover classifications, and the Roberts (2003) LWD recruitment potential rankings were evaluated. Field data on tree species, diversity, size, and degree of floodplain development collected on February 12, 2013 during limited field reconnaissance were also utilized. Riparian conditions and the presence of large wetland areas were assessed based on these sources for the area within a 1,000 foot wide corridor (delineated 500 feet in each direction from the centerline of stream channel). Note that this corridor is not intended as a regulatory buffer but rather a unit of analysis to evaluate existing land cover classes and various ecological functions including, but not limited to: wood recruitment, shading of streams, channel migration and flooding, water quality protection, mass wasting processes, and riparian wildlife habitat within relatively close proximity to streams and wetlands. The 1,000 foot wide corridor is a distance consistent with the zone of analysis used by Roberts (2003).

The land cover classification process differentiated cover into classes and determined percent of the riparian corridor for each class (Table 16). Developed areas of the riparian zone included the areas of low to high intensity development, pasture/hay, and developed open space categories. These categories are indicative of clearings, managed grass, and residential development. Forested areas included areas classified as deciduous, coniferous, and mixed forests. Total area of wetlands included palustrine wetlands categorized as being forested, scrub-shrub, or emergent. Aquatic bed/lacustrine fringe wetland was separated out from total wetlands as this category is ecologically distinct, occurring along the inner shoreline of Wildcat Lake and Kitsap Lake.

Using these data, the riparian corridor condition was qualitatively categorized as functioning, moderately impaired, or impaired based on the following indicators of riparian condition (Segura Sossa and Booth, 2003):

- Prevalence of multi-aged stands of trees
- Prevalence of conifers
- LWD recruitment potential (Figure 31)
- Degree of shading of channel
- Degree of vegetation and soil disturbance on immediately adjacent lands

These factors were assessed where possible during the limited field reconnaissance, and using aerial photo interpretation for areas not field assessed. Other factors considered within the riparian analysis zone included prevalence of native tree and shrub species, prevalence of invasive plant species, and presence or connections with large wetland areas. Data on these factors was derived from notes and photos collected during the limited field reconnaissance.

It was not within the scope of this analysis to conduct a detailed field assessment of riparian conditions along each stream, a comprehensive wetland inventory, a correlation of riparian conditions with site specific data on fish use or benthic macroinvertebrate communities, or to collect detailed information on tree heights or in-channel LWD counts. Of these data gaps, collection of more detailed information on riparian conditions along stream reaches identified as important for salmonid rearing and spawning, and compiling a comprehensive inventory of wetlands within the riparian zone would support a more detailed analysis of watershed and riparian conditions. Note that Roberts and Bilby (2009) measured riparian forest plots in the Chico Creek watershed and documented characteristics such as basal area, stem density, and canopy cover for floodplains, terraces, and hillslope areas. More detailed review of these data and additional measurement is warranted to refine understanding of riparian conditions in the watershed.

Chico Creek Estuary

Riparian Corridor Characteristics and Large Woody Debris Recruitment Potential

Currently, the mouth of Chico Creek is a single, narrow and armored channel, with limited formation of a natural dendritic tidal channel network at the estuary. The estuary has been extensively modified by fill placement and construction of SR 3 which bisects the estuary and realigned the channel in the 1960s. The outlet channel shifted between 1994 and 2005 from a western orientation, closer to the shoreline in 1994, to a very straight configuration extending straight out from the culvert in 2005. Aerial photos reveal that this channel deepened and widened in 2006 and particularly in 2009, with the channel now trending to the northeast. Note that the Chico Creek estuarine channel was modified in 2008 by placement of rock weirs to assist fish passage through culverts at Kittyhawk Drive and some of the observed deepening may be related to this work.

The Chico Creek estuary was not categorized in the Roberts (2003) analysis for large woody debris recruitment potential. Riparian conditions are moderately impaired, being confined to a narrow band of mixed conifers and deciduous trees along the sides and toe of the slope along SR 3 and adjacent to private property with a narrow band of intertidal marsh fringing the mudflats of the estuary. Based on interpretation of 2012 aerial photos, approximately 1,200 ft of the western shoreline is densely forested, as is approximately 750 ft of the eastern shoreline. Deciduous trees dominate, but some large conifers (Douglas fir) are also present. Large woody debris recruitment potential is low, based on the absence of large conifers along the shoreline. Shoreline development encroaches immediately adjacent to the left bank of the channel with a consequent reduction in the density and diversity of riparian plants, particularly trees such as Hooker's willow (*Salix hookeriana*), shore pine (*Pinus contorta* var. *contorta*) and Pacific madrone (*Arbutus menziesii*) which would typically be present along the upper shoreline above MHHW. Foot traffic along the creek outlet to the bay has also degraded the riparian plant community immediately adjacent to the channel.

Historic Conditions and Alterations

The lower mile of Chico Creek is of critical importance in that its habitat conditions influence access to more than 17 miles of upstream spawning and rearing habitat for wild salmonids. Historically, this reach of Chico Creek was an alluvial channel that meandered across a wide, unconstrained glacial valley. The channel widened further at its confluence with Chico Bay into a naturally dendritic channel with associated tide flats and intertidal saltmarsh; this channel may have historically moved across a broader extent of the estuary (Haring, 2000). Shoreline development associated with SR 3 and adjacent residential development has altered riparian vegetation along the estuary, reducing large trees, particularly conifers, and reducing the diversity of native tree and understory species. Much of the vegetation is currently dominated by invasive species such as Himalayan blackberry (*Rubus armeniacus*), knotweed (*Polygonum* spp.), Scotch broom (Cytisus *scoparius*), and English ivy (*Hedera helix*).

Habitat Effects

Although estuarine conditions are generally characterized as currently good for salmonids, the culverts at SR 3 and Kittyhawk Drive limit the extent of tidal influence and form a partial (tide dependent) barrier to salmonid access (Haring, 2000). This constriction also reduces habitat diversity and limits the extent of the functional riparian zone immediately adjacent to the channel and its influence on important estuarine habitat. Channel migration and braiding was likely more pronounced prior to the installation of SR 3 and Kittyhawk Drive (May and Peterson, 2003). The riparian zone was also likely wider, but still with limited floodplain connectivity due to the steep bluffs fringing the estuary. These road crossings have reduced the extent of estuarine influence in the creek thereby creating a more abrupt transition zone farther downstream. Recruitment of wood to the estuary is severely degraded due to the fragmented riparian corridor and the barrier formed by SR 3.

Lower Chico Creek (SR 3 to Navy RR Crossing)

Riparian Corridor Characteristics and Large Woody Debris Recruitment Potential

This reach has experienced a loss of connectivity between the floodplain and the channel, including degraded riparian conditions in terms of diversity of native species, density of plants, size and type of trees, and related capacity of the riparian zone to provide foundational wood to the stream. Riparian conditions are poor, particularly in the area from SR 3 to the Chico Way bridge, due to encroachment of development in the floodplain, a lack of native, mature trees and low diversity in the riparian community (May and Peterson, 2003).

Land cover classification of the riparian zone of lower Chico Creek indicates impaired conditions, with only 16.1% of the riparian zone between SR 3 and the Chico Way bridge forested (with 12.4% of the total being coniferous forest) while approximately 73.1% is developed (Figure 14; Table 16). In contrast, between the Chico Way bridge and the railroad trestle, 34% of the riparian zone is forested (mostly mixed forest), 24.7% is in a scrub-shrub stage, and 33% of the riparian zone is developed. Large woody debris recruitment potential was categorized as medium to low (Roberts 2003). Only the area between Golf Club Hill Road and Chico Way NE (i.e., Keta Park reach) and the area between Chico Way NE and the confluence with Dickerson Creek were categorized as having high large woody debris recruitment potential in this reach of lower Chico Creek (Figure 31).

Extensive fill and re-grading necessary to construct SR 3 across the mouth of Chico Creek physically eliminated the riparian zone through excavation to provide gravel for the highway fill. This removed the native riparian plant community, including the adjacent historically forested floodplain and associated wetlands, created large pits in the floodplain along the right side of the channel, and shifted the channel alignment to the west into a more linear configuration. A dike constructed to separate the new channel from the pits also modified the floodplain and riparian zone (Shanz and Park, 2006).

Lower Chico Creek, prior to major floods in 2002 and 2009 and significant channel avulsion, was channelized and the stream was contained to the west side of the historic floodplain (Haring, 2000). In 2002 the channel avulsed, returning the creek to the west side of its historic floodplain. During this same period, the outlet channel downstream of SR 3 has deepened, lengthened, and straightened (see description of Chico Creek estuary). Stream bedload in conjunction with major flood and depositional events has resulted in the filling of the floodplain pond upstream of SR 3.

The channel avulsion and bedload processes have geomorphically restored the excavated areas to their original alluvial floodplain condition; however, a functional riparian community has not been restored. The left bank is dominated by red alder (*Alnus rubra*) and Himalayan blackberry, with the occasional Douglas fir (*Pseudotsuga menziesii*) tree, but provides virtually no shade to the channel along this reach. Along the right bank, a young riparian community is beginning to re-establish, particularly in the area downstream of Erland's Point Road and adjacent to the right bank in Erland's Point Park. In this area, the riparian community is dominated by young trees and shrubs interspersed with areas of extensive sand and fine gravel accumulation. The channel is branched and flows through and around these areas. The riparian community provides some shade and canopy over these braided areas, as well as input of organic material to the stream. Invasive knotweed species, butterfly bush (*Buddleia* spp.) and Scotch broom are also present in disturbed areas abandoned by the channel.

The riparian community observed in February 2013 was composed predominately of young red alder trees, ranging in diameter from approximately 2 to 4 inches, interspersed with an understory of reed canarygrass (*Phalaris arundinacea*). Native and invasive emergent species fringe the edges of the channel in some places along the right bank, predominately reed canarygrass, soft rush (*Juncus effusus*), and yellow-flag iris (*Iris pseudacorus*). Native species include cattails and small-fruited bulrush (*Scirpus microcarpus*). Recent foraging and tree cutting by beaver was noted, as were desiccated chum salmon carcasses and bones throughout the riparian floodplain. Salmon carcasses provide an important source of nutrients to riparian zones (Bilby et al., 1996; Cederholm et al., 1999; Wipfli et al., 1998), supplying nitrogen to riparian vegetation which in turn provide allochthonous organic material to the stream and its benthic food web (Roberts and Bilby, 2009).

The riparian condition of the portion of Chico Creek between Erland's Point Road and Golf Club Hill Road was characterized as poor (Haring, 2000), but this area has recently received restoration projects in 2008 and 2011 to remove failing log weirs, widen the channel, contour the floodplain, and install wood structures. Riparian plants were installed along the edges of the channel, primarily willows. Extensive browse, possibly by beaver, was noted in February 2013 in this area. Beaver browse can cause willows to send up multiple shoots, sometimes creating denser riparian vegetation and more shade along the stream channel. However, heavy and repeated browse can also eliminate riparian plants, particularly in areas where the plants are not well established. Note that browse (by beaver or other species) is not the cause of habitat degradation in this reach but rather a constraining factor to revegetation in the area cleared by past land use practices. The riparian condition in the golf course reach thus remains impaired, with no shading and little organic material supplied to the stream.

The portion of Chico Creek between Golf Club Hill Road and Chico Way NE (i.e., Keta Park reach) has a narrow riparian corridor confined mostly to the area immediately adjacent to the stream banks. Although the riparian classification by Roberts (2003) classified much of this reach as having high LWD recruitment potential, riparian condition is generally considered impaired (Shanz and Park, 2006). This area does provide a relatively dense zone of vegetation along the channel compared to the areas downstream, and thus some shading and organic matter input functions for the stream. The riparian community along this stretch of Chico Creek is dominated by approximately 12 to 20-inch diameter at breast height (DBH) red alder trees, with patches of native understory including salmonberry (*Rubus spectabilis*), western crabapple (*Malus fusca*), and Nootka rose (*Rosa nutkana*), with higher areas of sword fern (*Polystichum munitum*), trailing blackberry (*Rubus ursinus*), and Oregon grape (*Mahonia nervosa*).

The portion of Chico Creek between Chico Way NE and the confluence of Dickerson Creek at approximately Taylor Road and Northlake Way NE also has a narrow riparian corridor, ranging from approximately 50 to 150 ft wide, dominated mainly by red alder, with some areas still supporting mature Douglas fir, western red cedar, and big-leaf maple (*Acer macrophyllum*) trees near the confluence with Kitsap Creek. Single family residences are present in the floodplain, with yards largely cleared of riparian vegetation. Canopy closure averages less than 50 percent along much of this area and invasive English ivy is a dominant component of the riparian zone and stream banks. Extensive bank erosion and channel incision limits riparian functions by isolating the riparian zone and floodplain from the channel, particularly in the area downstream of the confluence of Chico Creek and Kitsap Creek.

Young red alder stands characterize the riparian zone of Chico Creek between NW Taylor Road and NW David Road, upstream to the Navy railroad trestle. In many places the vegetated riparian zone is less than 50 ft wide, with the stream straight and incised, particularly the 1,000 ft downstream of the trestle where the riparian community is currently degraded, lacking diversity and structure. While scattered western red cedar trees, up to 36 inches in diameter, occur on the floodplain, the vast majority of the riparian zone is composed of young red alder trees, with little to no shrub understory. Additionally, there is little to no canopy closure present along much of the channel in this area.

Historic Conditions and Alterations

Historically, lower Chico Creek likely flowed through extensive forested floodplain wetlands associated with anabranching alluvial channels (i.e., diffuse flow through multiple small channels rather than a single channel) (Shanz and Park, 2006). These wetlands would typically have been dominated by a mixture of willows (*Salix* spp.), red alder, black cottonwood (*Populus balsamifera*), and possibly Sitka spruce (*Picea sitchensis*), and western red cedar (*Thuja plicata*), with the deciduous trees along the more active channels where seasonal high flows were common. The Sitka spruce and western red cedar trees would typically have been in more geomorphically stable areas that accumulated fine organic material and had soils with longer periods of near surface soil saturation.

Habitat Effects

An assessment of lower Chico Creek concluded that this reach has poor quality stream habitat, partially as a result of poor riparian condition and lack of large woody debris (Roberts, 2003). Quantity of wood and reach habitat scores (a combined score based on qualitative and quantitative assessments of channel stability, channel complexity, streambed cementation, and riparian condition) were the lowest across all the areas evaluated in the reach assessment. Habitat scores for all components were nearly uniformly low for all lower Chico Creek reaches. Channel conditions are poor due to lack of pools, wood, and riparian vegetation. There are few pools for adult resting and juvenile rearing and the effects of these degraded habitats are more significant during high flow events. Isolation of the channel from the floodplain and riparian zone also reduces the input of organic matter into the stream and thus reduces the supply of food for benthic macroinvertebrates and rearing salmonids.

Despite a reduced and somewhat isolated riparian zone, water quality in this reach is generally good, with potentially some negative effects due to stormwater runoff from nearby roads (Haring, 2000) . Kitsap County (2003) reported a 7 day average daily maximum (7 DADmax) temperature of 18.2° to 21.7° C. Several years of stream temperature measurements recorded in more recent years by the Suquamish Tribe in this reach corroborates these relatively high temperatures (Todd, pers. comm.).

This portion of Chico Creek is also listed by Ecology as impaired by high water temperatures and of concern for fecal coliform contamination due to the proximity of residential septic systems (Shanz and Park, 2006).

Upper Chico (from Navy RR Crossing up to the Wildcat/Lost Creek confluence)

Riparian Corridor Characteristics and Large Woody Debris Recruitment Potential

Upstream of the railroad trestle, riparian condition improves, with a wider riparian zone, denser vegetation, and fewer invasive species. Land cover classification of the riparian zone of upper Chico Creek indicates moderately impaired conditions upstream of the railroad trestle, with 75.3% of the riparian zone being forested (with 56% of the total being mixed forest) and approximately 23.4% in a scrub/shrub stage (Table 16; Figure 14). A narrow primarily forested riparian zone is dominated by big-leaf maple and red alder trees, with the occasional western red cedar and black cottonwood. Large woody debris recruitment potential was categorized as high throughout most of this area (Figure 31), with the exception of the more recently cut over left bank for approximately 0.5 mile upstream of the Navy railroad trestle (Roberts, 2003).

Native understory shrub species include salmonberry, Indian plum (*Oemleria cerasiformis*), red elderberry (*Sambucus racemosa*), beaked hazelnut (*Corylus cornuta*), willow, and thimbleberry (*Rubus parviflorus*), as well as sword fern, Pacific bleeding heart (*Dicentra formosa*), lady fern (*Athyrium filix-femina*), Cooley's hedge-nettle (*Stachys cooleyae*), and creeping buttercup (*Ranunculus repens*). Dense areas of invasive Himalayan blackberry, English ivy, and Japanese knotweed are also present throughout the understory and along the stream banks (GeoEngineers, 2011).

Historic Conditions and Alterations

GeoEngineers (2011) assigned a Rosgen stream type of C4 (riffle/pool with a well-developed floodplain, meanders, and point bars; wide with a width/depth ratio greater than 12; channel moderately entrenched and floodplain active during large storms) to Chico Creek upstream of the Dickerson Creek confluence. Historically, this reach was likely a 'wood-dominated' channel with wood playing a large role in forming pools and channel/floodplain interactions; however land-use has resulted in the elimination of much of the wood in the channel. This reach would have been surrounded by a mature forested riparian area containing conifers such as western red cedar and Sitka spruce providing key pieces of large wood to the stream. GeoEngineers (2011) reported little wood in the channel currently, with a series of log sill weirs near Taylor Road and some cobble weirs near Northlake Way.

Habitat Effects

Moving upstream from approximately the Navy railroad trestle, Chico Creek transitions from an unconfined, low gradient channel with a narrow and fragmented riparian corridor to a more confined steeper channel with a more intact native riparian corridor (Kitsap County 2003). This location also marks a transition from the hillslope geology of the upper basin to the alluvial valley geology of the lower portions of the stream (Figure 4).

Habitat characterizations of Chico Creek upstream of the Navy railroad trestle at RM 2.0 to the Lost/Wildcat confluence describe this reach as providing quality habitat for spawning, egg incubation, and resident juvenile salmonids (Haring, 2000). Segura Sossa and Booth (2003) reported higher quantities of wood and reach habitat scores (a combined score based on qualitative and quantitative assessments of channel stability, channel complexity, streambed cementation, and riparian condition), consistent with properly functioning riparian habitat.

KITSAP CREEK (AND KITSAP LAKE)

Riparian Corridor Characteristics and Large Woody Debris Recruitment Potential

Large wetland complexes are located at the southern (upstream) end of Kitsap Lake and are formed by the confluence of flows from the lake's tributaries. In addition to potentially providing rearing habitat for salmonids, these wetlands attenuate runoff during storms and provide water storage and water quality improvement functions for the lake. Kitsap Lake also moderates the effect of peak storm flow and sedimentation/bed scour in Kitsap Creek (Haring, 2000).

The shoreline of Kitsap Lake is heavily developed with houses, with much of the lakeside riparian vegetation replaced with bulkheads, lawns, and landscape plants (Haring, 2000).

Downstream of the lake (downstream of Northlake Way), the riparian condition along Kitsap Creek is reported as good on the east side of the creek; however, the west side of the creek is developed with houses and associated armoring with little to no riparian vegetation for part of the reach (Shanz and Park, 2006, Haring 2000). This reach of Kitsap Creek is listed by Ecology as impaired by high water temperatures (Shanz and Park, 2006, Haring 2000).

Land cover classification of the riparian zone of Kitsap Creek indicates moderately impaired riparian conditions downstream of the lake, with 51.9% of the riparian zone being forested (with 46.9% of the total being mixed forest), while approximately 28.1% is developed (Table 16, Figure 14). Upstream of the lake, the riparian zone is also moderately impaired, with approximately 23% of the riparian zone being forested (14.2% of which is coniferous), 12.2% developed, and 37.2% wetland (mostly scrub-shrub wetland). The riparian zone surrounding Kitsap Lake is 63.8% aquatic bed wetland and 26.2% developed. Large woody debris recruitment potential was categorized as low along the left bank of the channel downstream of the lake, with areas of high potential along the right bank (Roberts, 2003) (Figure 31). Recruitment potential was not categorized upstream of the lake, but appears to be relatively low due to the extensive areas of wetland and deciduous forest upstream of the lake.

Historic Conditions and Alterations

Historically, Kitsap Lake and its headwater wetlands upstream of the lake likely provided high quality rearing habitat for coho prior to the installation of the fish screen barrier at the lake outlet, and may function again in that capacity now that the barrier has been removed. Lacustrine fringe wetlands and a forested riparian zone likely occurred around the lake prior to shoreline development and would have provided important organic matter input, bank stability, and wood that supported important rearing habitat for salmonids.

Habitat Effects

The glacial deposits (kettle/kame) in the upper headwaters of Kitsap Creek (Figure 4) create areas where depressional and riverine wetlands can form within the riparian zone and provide cool groundwater and low flow hydrologic support to the creek, thereby improving instream habitat. The degree to which this potential cooling effect is muted by high water temperatures in the lake is unknown.

There are few pools to support rearing juveniles and resting adults in Kitsap Creek downstream of the lake and large wood is scarce (Segura Sossa and Booth, 2003). Upstream of RM 0.1 the stream is confined, the riparian zone is steep and narrow and spawning substrates are not as abundant. The lower 0.1 miles of Kitsap Creek is heavily utilized by spawning chum salmon and egg incubation survival is likely high because of relatively stable and clean spawning substrate.

The potential for Kitsap Lake to support juvenile coho residence is strongly affected by shoreline development and associated water quality. Kitsap County (2003) reported a 7 day average maximum (7 DADmax) temperature of 25.4°C in Kitsap Creek. The lake's shallow depth and extensive shoreline development and limited riparian vegetation likely contribute to its elevated summer temperatures, despite the potential for temperature moderation that may be provided by its headwater wetlands. These water temperature conditions likely constrain or possibly prevent the use of lower Kitsap Creek by juvenile salmonids during late spring/summer months.

Dickerson Creek

Riparian Corridor Characteristics and Large Woody Debris Recruitment Potential

Land cover classification of the riparian zone of Dickerson Creek from its junction with Chico Creek upstream to the Navy Railroad culverts indicates impaired conditions, with only 32.4% of the riparian zone being forested (with 16.8% of the total being coniferous forest), while approximately 35.8% of the riparian zone is scrub-shrub/recently cutover vegetation, and 24.9% is developed (Table 16, Figure 14) In contrast, upstream of the railroad culverts to the first natural falls/grade break (approximately 2,000 ft upstream), the riparian zone is less impaired, with 74.3% of the riparian zone being forested (a nearly even mixture of coniferous and mixed forest), 21.6% scrub-shrub, and 0% developed. Upstream of the falls, the riparian zone is functioning, with extensive wetlands comprising approximately 26.7% of the riparian zone and forested areas 63% (nearly all mixed forest). Large woody debris recruitment potential was categorized by Roberts (2003) as generally low downstream of the railroad culverts, and along the left bank upstream of the culverts. Recruitment potential may be higher immediately adjacent to the stream channel along the left bank upstream of the culverts (Figure 32). Only the right bank downstream of the railroad culverts and scattered portions of the riparian zone upstream of the falls were categorized as having high large woody debris recruitment potential (Roberts, 2003) (Figure 31).

The riparian community in the lower portion of Dickerson Creek downstream of the Navy railroad culverts is narrow (approximately 25 to 50 ft on average) and constrained by residential development, a condition similar to the riparian zone along nearby portions of Chico Creek. The riparian zone is more mature and diverse, however, with a mixture of approximately 24 inch diameter red alder, 36 inch diameter western red cedar, and approximately 20 inch diameter big-leaf maple trees. The understory along the stream banks is a mixture of invasive species, such as Himalayan blackberry and English ivy, and patches of native sword fern. Canopy closure in the narrowest portions of the stream averages approximately 30%. Large wood is present in the channel, particularly just downstream of the railroad culverts, creating pools and instream habitat structure. However, only three key pieces of wood were documented during stream surveys in the 1,000 ft reach of Dickerson Creek from 300 ft upstream of David Road NW downstream 700 ft to NW Taylor Road, compared to an estimated median of 36 key pieces in a lower reach of the same length along Lost Creek (GeoEngineers, 2011).

Upper Dickerson Creek (upstream of the Navy RR crossing) has a more extensive riparian zone that is in better condition (Shanz and Park, 2006). Upper Dickerson has been considered a critical contributing area for water quality and quantity (May and Peterson, 2003); intact riparian zone functions (e.g. sediment retention, shade, allochthonous organic matter input) likely contribute to the quality of in-stream habitat in this reach and may also contribute complimentary functions such as LWD and allochthonous organic matter to downstream reaches (May and Peterson, 2003). The quantity of wood and overall habitat quality scores are much higher upstream of the Navy railroad crossing and are comparable to conditions reported in Lost Creek (Segura Sossa and Booth, 2003).

Historic Conditions and Alterations

GeoEngineers (2011) classified lower Dickerson Creek as a Rosgen stream type C4: riffle/pool with a well-developed floodplain, meanders, and point bars; wide with a width/depth ratio greater than 12; channel moderately entrenched and floodplain active during large storms. Historically, this reach was likely a ‘wood-dominated’ channel, with wood playing a large role in forming pools and channel/floodplain interactions. This reach would likely have been surrounded by a mature forested riparian zone containing conifers such as western red cedar and Sitka spruce providing key pieces of large wood to the stream. Such wood would have had a strong effect on channel forming processes, including floodplain/channel connectivity and floodplain habitats. Most of the upper reaches of the Dickerson Creek watershed supported coniferous forest in 1992 (Figure 13); however, these reaches were subsequently logged and converted to early seral stage forest/scrub shrub habitats (Figure 14). The powerline right of way has eliminated riparian structure and destabilized slopes adjacent to the stream, supplying fine sediments directly to the channel during storms and mass wasting events (Nelson, 2003).

Habitat Effects

An impassable natural falls at approximately river mile 1.1 limits the upstream distribution of salmonids (Haring, 2000). The Navy railroad crossing culverts at RM 0.5 form a complete barrier to wood transport from the riparian zones of the upper watershed to lower Dickerson Creek. The road culvert at Taylor Road crossing also limits wood transport.

The extensive wetland system in upper Dickerson Creek may help support cool water temperatures and maintain base flow downstream of the wetlands. Studies have shown that wetlands in urban areas can increase the residence time of runoff and reduce the water temperature before it enters streams (Jones and Hunt, 2010).

In contrast, timber harvest within the riparian corridor in the upper portions of Dickerson Creek may alter the dynamics of flood flows and hyporheic recharge by reducing the retention of flood flows, increasing sediment loads, and reducing large woody debris recruitment potential for decades into the future. While the glacial outwash geology of the upper headwater areas (Figure 4) creates a supply of gravels to the creek, clearing in the riparian zone can also increase fine sediment delivery to the lower reaches, which can reduce habitat suitability for salmonids.

Lost Creek

Riparian Corridor Characteristics and Large Woody Debris Recruitment Potential

Land cover classification of the riparian zone of Lost Creek indicates moderately impaired riparian conditions overall, with 63% of the riparian zone being forested (with 51.1% of the total being mixed forest), while approximately 28.6% is scrub-shrub/cutover areas (mostly in the upper reaches); 0% of the riparian zone is developed (Table 16, Figure 14). Wetlands also comprise approximately 8.5% of the riparian zone (mostly forested wetland). Large woody debris recruitment potential was categorized as a patchwork of both low potential areas along much of the reach, and high potential areas such as the Rhododendron Preserve near the confluence with Chico Creek (Roberts, 2003) (Figure 31).

The riparian zone is functioning and densely vegetated with native species throughout the 300-acre portion of the corridor preserved within the Rhododendron Preserve. Much of the valley and surrounding upland forests preserved in this area are mature to old-growth forest (Haring, 2000). Big-leaf maple, Douglas fir, western hemlock, western red cedar, and red alder are the dominate trees, with a dense and diverse understory including salmonberry, Indian plum, red elderberry, vine maple (*Acer circinatum*), devil's club (*Oplopanax horridus*), Oregon grape, trailing blackberry, sword fern, foamflower (*Tiarella trifoliata*), and lady fern. Individual Douglas fir, western hemlock, western red cedar, and big-leaf maple trees exceed 30 inches in diameter throughout the riparian zone and on the surrounding upland slopes.

Upstream of the Rhododendron Preserve, historical logging practices removed the larger trees from the riparian zone (Shanz and Park, 2006). The upper reaches of Lost Creek flow through active commercial timber lands, but riparian conditions are generally characterized as good (May and Peterson, 2003). The no-cut zone along the stream channel has preserved a diverse riparian community within the active floodplain of the stream that is dominated by a mixture of species including native conifer western hemlock, western red cedar, Douglas fir, and big-leaf maple trees, with subdominate red alder trees. The understory is composed of sword fern, salmonberry, Nootka rose, and salal (*Gaultheria shallon*), with Pacific rhododendron (*Rhododendron macrophyllum*) also present. The riparian zone in this area provides shade and canopy closure over the stream channel, and contributes organic matter to the stream. A natural cascade at approximately RM 1.9 limits the upstream extent of fish passage in Lost Creek.

Headwater wetlands dominated by willow, red-osier dogwood (*Cornus sericea*), and slough sedge (*Carex obnupta*) also contribute organic matter, attenuate runoff during storms, and provide storage that supports cool base flows during summer low flow conditions in the creek. Small streamside seeps were observed in these headwaters, collecting water from adjacent low portions of the floodplain and contributing cool water to the stream channel.

Historic Conditions and Alterations

Lost Creek was characterized as a Rosgen Type C4 wood-dominated channel (GeoEngineers, 2011). The lower reach of Lost Creek within the Rhododendron Preserve was used as a reference condition to determine wood restoration objectives for lower Dickerson Creek. The lower reach of Lost Creek within the Rhododendron Preserve is likely a good reference for habitat and riparian conditions in much of Chico Creek as this area has experienced comparatively minor land-use modifications while the creek flows through mature forest and some old growth forest areas. Wood counts indicate numerous key pieces, above expected median values for western Washington streams of comparable size (GeoEngineers, 2011). Habitat scores were high for all sections of lower Lost Creek.

Logging has influenced the reaches of Lost Creek and its tributaries upstream of the Rhododendron Preserve, with much of its upper watershed having been logged prior to 1992 (Figure 13); the upper reaches are now transitioning from early to mid-seral stage forest/scrub-shrub habitats (Figure 14). This watershed consequently has a large number of logging roads, some crossing the riparian zone, which can deliver fine sediments directly to the stream.

Habitat Effects

The wetlands and seeps that characterize the Lost Creek subbasin likely contribute to ideal summer water temperatures for juvenile salmonids. The functional riparian zone near the confluence of Lost and Chico Creeks contributes large wood, provides shade, and supports the formation of instream habitat for salmonids. However, the patchwork of intact riparian areas and cutover/harvested areas in the upper basin compromises the connectivity of the riparian corridor in terms of wildlife habitat functions. Because of the bedrock and hillslope geology of the steep upper headwater areas (Figure 4), forest clearing can rapidly increase erosion and sediment delivery to the lower reaches, which can alter spawning gravels and reduce rearing habitats for salmonids.

WILDCAT CREEK (FROM CONFLUENCE WITH LOST CREEK TO WILDCAT LAKE)

Riparian Corridor Characteristics and Large Woody Debris Recruitment Potential

Land cover classification of the riparian zone of Wildcat Creek indicates functional to moderately impaired riparian conditions downstream of the lake, with 74.3% of the riparian zone being forested (with nearly all of the total being mixed forest), while approximately 17.1% is wetland (mostly scrub-shrub wetland) and 0.8% is developed (Table 16, Figure 14). Upstream of the lake, the riparian zone is also functional to moderately impaired, with approximately 48.5% of the riparian zone being forested (38.4% of which is mixed forest), 16.9% scrub-shrub/cutover, 0% developed, and 37.6% wetland (mostly forested wetland).

Large woody debris recruitment potential along Wildcat Creek downstream of the lake was categorized as a mixture of low and high potential areas (Roberts, 2003), although 2011 land classification shows most of this area as coniferous forest (Figure 31). Recruitment potential was not categorized upstream of the lake or along the main tributary stream, but these areas appear to have a moderate to low recruitment potential due to the mixture of coniferous forest and formerly cutover areas upstream of the lake.

Riparian conditions are generally described as good along Wildcat Creek upstream to Wildcat Lake, with the creek flowing through several large logjams and beaver ponds which provide habitat complexity (Haring, 2000; May and Peterson, 2003; Shanz and Park, 2006).

Large wetland complexes form the headwaters of the tributaries to Wildcat Creek. Approximately 175 acres of palustrine wetlands (Newberry Wetlands) lie north of Seabeck Highway, with another approximately 40 acres of wetland south of the highway. These wetlands are located in a long, broad basin extending north-south on either side of the highway. As contributors to the headwaters of Wildcat Creek, these wetlands likely attenuate runoff during storms and provide storage that supports cool base flows during summer low flow conditions in the creek.

Historic Conditions and Alterations

Logging along Wildcat Creek has been very limited, with the exception of the lands along the eastern tributaries south of Seabeck Highway, which was relatively intact forest in 1992 (Figure 13), but have since been cleared and developed into large lot residences (Figure 14). A recent timber harvest cleared approximately 50 acres on the upland to the west of Wildcat Creek in 2013. These recent practices have likely affected the quantity of wood and will ultimately affect in-stream habitats such as pools in Wildcat Creek and its tributaries.

Habitat Effects

Because of the glacial till and hillslope geology of the lands surrounding Wildcat Creek and its tributaries (Figure 4), land clearing and development of the riparian zone and adjacent forested areas reduces the erosion control capacity of the landscape and reduces this function of the riparian zone. Summer water temperatures supported by areas with an intact riparian zone, are likely near ideal for juvenile salmonids.

Wildcat Lake, Its Tributaries, and Headwater Wetlands

Riparian Corridor Characteristics and Large Woody Debris Recruitment Potential

Land cover classification of the riparian zone of the tributary stream flowing into the south end of Wildcat Lake indicates moderately impaired riparian conditions. The riparian zone is 62.2% forested, largely as mixed forest, 22.3% scrub-shrub/cutover, and 15.4% forested wetland (Table 16, Figure 14).

The shoreline of Wildcat Lake is moderately developed, with some remaining high quality riparian areas, but also bulkheads, lawns and landscaping in place of native riparian vegetation (Haring, 2000). The lacustrine fringe of Wildcat Lake itself is also moderately impaired, with 26.2% of the riparian zone developed, 5.5% forested, and 62.8% fringed with aquatic bed wetland. In contrast, the riparian zone of the tributary stream flowing through the Newberry wetland complex upstream of Seabeck Highway is functioning, being approximately 69% forested, mostly mixed forest, and 25.5% wetland (an interspersion of emergent, scrub-shrub, and forested wetland types).

Large woody debris recruitment potential was not categorized for the tributaries to Wildcat Creek (Roberts, 2003), but it appears to be relatively moderate due to the extensive areas of forested wetland and mixed forest areas along the Newberry wetland tributary and the tributaries upstream of the lake (Figure 31).

The upper tributaries to Wildcat Creek, upstream of the lake, flow through commercial timber land. Riparian zone harvest restrictions have preserved a narrow riparian community along the stream channel that is currently composed of 16 to 20 inch red alder and big-leaf maple trees with scattered western red cedar and western hemlock trees and an understory of sword fern, salmonberry, and salal, with red huckleberry and trailing blackberry present on old stumps. The riparian zone in this area provides shade and canopy closure over the stream channel, and contributes organic matter to the stream.

Historic Conditions and Alterations

Logging has influenced the upper reaches of Wildcat Creek and its tributaries (Figure 13); the upper reaches are now transitioning from early and mid-seral stage forest/scrub shrub habitats (Figure 14).

Habitat Effects

Because of the steep slopes, glacial till, bedrock, and hillslope geology of the tributary areas upstream of Wildcat Lake (Figure 4), logging and clearing of the riparian zone and adjacent forested areas reduces the erosion control function of the riparian zone, increasing sediment delivery to the lake and reducing habitat suitability in these headwater streams for salmonids. Historical timber harvest practices have also likely affected the quantity of wood and thus in-stream habitats such as pools in the upper tributaries.

A moderately impaired riparian zone in the stream reaches upstream of the lake increases sediment delivery to the lake and reduces habitat suitability for salmonids in the stream by altering wood delivery, pool habitat formation, and support of the food web provided by the input of organic matter into streams.

Occasional coho spawning has been observed in the tributaries upstream of Wildcat Lake (Oleyar, pers. comm.). Habitat conditions and potential fish barriers in these tributaries are data gaps at this time.

Table 16. 2011-era Land Cover Classes in 500-ft Riparian Corridor.

	Chico Creek			Kitsap Creek			Dickerson Creek			Lost Creek	Wildcat Creek				
Cover Class in 500-foot Riparian Zone	SR3 to Chico Way Bridge	Chico Way Bridge to Railroad Trestle	Upstream of Trestle	Kitsap Creek	Upper Kitsap Creek	Kitsap Lake	Junction with Chico to Railroad Culverts	Railroad Culverts to Falls	Above the Falls	Lost Creek	Wildcat Creek	Upper Wildcat	Tributary to Wildcat	Newberry Tributary	Wildcat Lake
High Intensity Developed	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Medium Intensity Developed	6.0%	0.4%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Low Intensity Developed	13.6%	2.9%	0.0%	1.2%	0.2%	3.4%	0.6%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
Open Space Developed	21.7%	18.5%	0.0%	25.6%	4.1%	19.1%	15.6%	0.0%	0.8%	0.0%	0.7%	0.0%	0.0%	1.9%	7.1%
Pasture/Hay	31.8%	11.4%	0.0%	1.2%	8.0%	3.5%	8.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.9%
TOTAL DEVELOPED	73.0%	33.2%	0.0%	28.1%	12.2%	26.2%	24.9%	0.0%	0.8%	0.0%	0.8%	0.0%	0.0%	1.9%	12.0%
Deciduous Forest	0.2%	5.2%	2.1%	0.6%	1.3%	0.1%	0.0%	0.0%	2.5%	0.7%	1.7%	6.3%	1.0%	4.8%	1.5%
Evergreen Forest	12.4%	9.5%	17.2%	4.3%	14.2%	1.5%	16.8%	32.0%	2.9%	11.1%	1.3%	3.8%	9.0%	0.0%	0.6%
Mixed Forest	3.5%	19.3%	56.0%	46.9%	7.5%	3.8%	15.6%	42.3%	57.6%	51.1%	71.2%	38.4%	52.1%	64.2%	28.6%
TOTAL FORESTED	16.1%	34.0%	75.3%	51.9%	23.0%	5.3%	32.4%	74.3%	63.0%	63.0%	74.3%	48.5%	62.2%	69.0%	30.7%
Palustrine Forested Wetland	0.9%	7.9%	1.4%	3.4%	3.4%	0.2%	6.4%	4.1%	18.5%	8.5%	4.1%	34.3%	15.4%	8.0%	3.2%
Palustrine Scrub/Shrub Wetland	1.4%	0.0%	0.0%	0.0%	27.2%	0.9%	0.0%	0.0%	6.9%	0.0%	13.0%	0.3%	0.1%	9.0%	0.6%
Palustrine Emergent Wetland	0.0%	0.0%	0.0%	0.0%	6.5%	0.1%	0.0%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%	8.5%	0.0%
TOTAL WETLAND	2.3%	7.9%	1.4%	3.4%	37.2%	1.1%	6.4%	4.1%	26.7%	8.5%	17.1%	34.6%	15.5%	25.5%	3.8%
Palustrine Aquatic Bed Wetland	0.9%	0.0%	0.0%	1.5%	0.0%	62.8%	0.0%	0.0%	0.7%	0.0%	0.4%	0.0%	0.0%	0.0%	44.8%
Grassland	0.5%	0.2%	0.0%	0.0%	0.0%	0.1%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%
Scrub/Shrub	7.1%	24.7%	23.4%	15.1%	23.5%	4.5%	35.8%	21.6%	8.3%	28.6%	7.4%	16.9%	22.3%	2.4%	5.6%
Unconsolidated Shore	0.0%	0.0%	0.0%	0.0%	1.6%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%
Bare Land	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%
Water	0.0%	0.0%	0.0%	0.0%	2.4%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

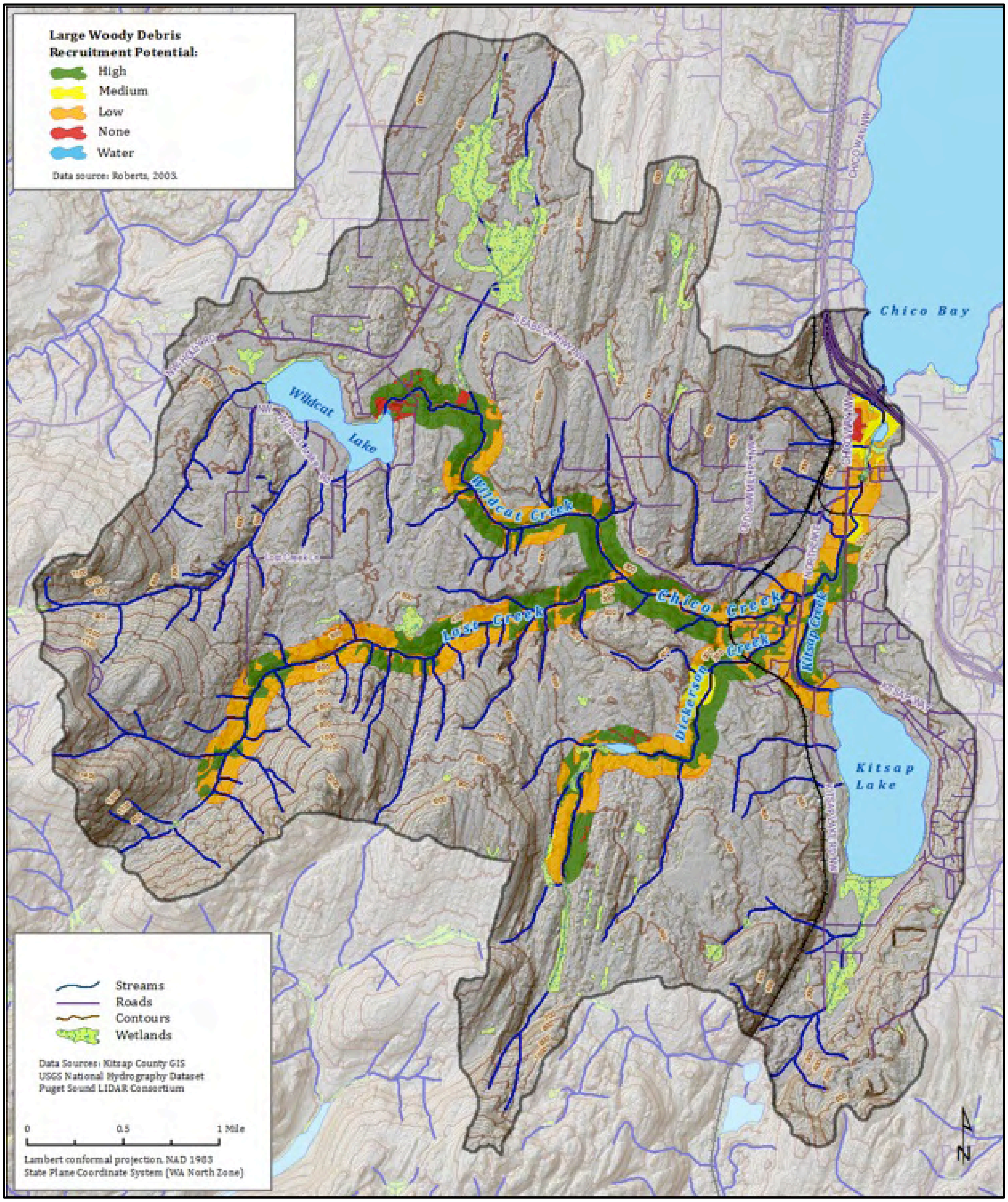


Figure 31. Map of large wood recruitment potential in the riparian corridor (source: Roberts, 2003).

4.4 LARGE WOODY MATERIAL

The natural processes driving the recruitment, transport, and accumulation of wood in the stream corridor are critically important in the formation and maintenance of salmonid habitats. Historical reconstruction of habitat distributions in alluvial valleys of Puget Lowland rivers shows dramatic transformation from a wood-dominated landscape with abundant off channel habitat (e.g., side channels and floodplain wetlands) to a simplified landscape with widespread human alteration of the stream corridor (Collins et al., 2003). Wood recruitment was reviewed previously in the discussion of riparian corridors (Section 4.3). This section presents a coarse-scale review of changes in wood abundance and the geomorphic and ecologic response to historical changes in the Chico Creek watershed.

Relation to Geomorphic and Ecologic Processes

Flow interacts with wood to create distinctive hydraulic patterns that drive processes of scour and deposition to form complex arrangements of channel features including pools and bar areas (Abbe and Montgomery, 1996). Wood pieces interact to develop stable structures within the channel that can be grouped into specific types based on the configuration of logs and resulting geomorphic function (Abbe and Montgomery, 2003). Large wood plays an important role in the partitioning of shear stress across the channel bed (Manga and Kirchner, 2000) and increases sediment storage capacity by trapping material within depositional features in the alluvial channel and floodplain (May and Gresswell, 2003). The abundance of instream wood has important effects on the distribution of aquatic habitats. For example, mean pool spacing decreases and pool frequency increases with increasing levels of wood loading (Montgomery et al., 1995). In the Queets River system of Washington's Olympic Peninsula, a relatively intact forest river protected within Olympic National Park, 70% of all surveyed pools were formed by wood accumulations in the channel (Abbe and Montgomery, 1996). Instream wood is an important driver of channel complexity and contributed to increased tendency for multi-thread (anabranching) channel patterns in Puget Lowland streams prior to widespread disturbance and wood removal simplified stream corridors (Abbe and Montgomery, 2003; Collins et al., 2002). Wood increases hyporheic exchange between surface water and the alluvial aquifer, thus moderating temperature fluctuations and affecting other water quality parameters (Hester and Doyle, 2008).

Wood Abundance and Loading

Current wood abundance in Puget Lowland rivers is estimated to be one or two orders of magnitude less than the conditions that prevailed prior to the period of European settlement beginning in the mid-1800s (Collins et al., 2002). Widespread timber harvest of streamside forests and direct intervention via wood removal has greatly diminished the abundance of wood in lowland rivers. The removal of trees large enough to remain stable when recruited to the channel is critical as these 'key pieces' are necessary to initiate and stabilize wood jams that can trap and retain smaller pieces (Abbe and Montgomery, 1996; Abbe and Montgomery, 2003). Overall, wood abundance in Chico Creek has been substantially reduced by human land use and management activities throughout the majority of the watershed. However, there are localized areas that have maintained natural wood recruitment processes, and as such, have much greater wood loading compared to more disturbed reaches in the watershed (Figure 32).

Two existing data sources aid in the assessment of wood abundance in the Chico Creek watershed. Segura Sossa and Booth (2003) present stream survey information including wood tallies for 41 discrete segments spanning 6 miles of channel in Chico Creek and its primary tributaries (Kitsap, Dickerson, Lost, and Wildcat creeks). Minimum size criteria for wood counts were 1 meter in length and 10 cm in diameter. Results of the 2002 stream surveys show very low wood abundance throughout Chico Creek, Kitsap Creek, and in lower reaches of Dickerson Creek (Figure 33). Higher wood abundance was noted in localized areas such as the portion of Chico Creek within the Mountaineers Foundation Rhododendron Preserve and in the segment of Dickerson Creek upstream of the Navy railroad. No data were available for most of Lost and Wildcat Creeks to quantify wood abundance.

GeoEngineers (2011) conducted wood surveys as part of a stream and wetland characterization to support design of the Dickerson Creek culvert replacement project. The surveys tallied wood abundance in the lower reaches of Dickerson Creek (Chico Creek confluence to just upstream of David Road) as well as a reference reach selected in Lost Creek within the Kitsap Forest Reserve property. Results of the 2011 wood surveys are summarized in Table 17. Data show that channel segments in the forested areas with active wood recruitment in Lost Creek have greater than 6 times the wood abundance of the more developed part of the watershed represented by lower Dickerson Creek. Fox and Bolton (2007) present wood reference quantities based on field surveys in unmanaged streams and identify a management target of about 38 pieces/100m for small channels (width < 6m) in Western Washington and 63 pieces/100m for channels in the bankfull width class between 6 and 30 m. Outside of the limited area of stream channel in the Kitsap Forest Reserve, the wood abundance of surveyed stream channels in the Chico Creek watershed is generally poor (Figure 33). Note, however, this is not based on a comprehensive survey of wood along Lost, Wildcat, Chico, Dickerson, and Kitsap creeks. Based on anecdotal observations, there may be other segments of Lost and Wildcat Creeks that show higher wood loading (Todd, pers. comm.).

Table 17. Comparisons of instream wood abundance between lower Dickerson Creek and a reference area in Lost Creek. Data source: GeoEngineers (2011).

Reach	*Length (m)*	*# wood Pieces*	*Pieces/ 100m*	*# Key Peices*	*Key Pieces/ 100m*
Dickerson 1 (confluence to Taylor Rd)	305	13	4	0	0
Dickerson 2 (Taylor Rd to David Rd)	210	41	19	2	1
Dickerson 3 (upstream of David Rd)	90	2	2	1	1
Dickerson Creek Total	**605**	**56**	**9**	**3**	**<1**
Lost 1 (upstream of Wildcat Ck confluence)	150	88	59	6	4
Lost 2 (upstream of Lost 1)	150	75	50	17	11
Lost 3 (upstream of Lost 2)	30	28	93	4	13
Lost Creek Total	**330**	**191**	**58**	**27**	**8**

Habitat Effects

The widespread loss of wood from the stream corridor in the Chico Creek watershed has resulted in extensive impacts to salmonid habitat. The loss of in-stream roughness and physical complexity has triggered substantial channel incision in the lower watershed which has produced a fundamental change in the distribution and characteristics of aquatic habitats. A key impact has been the transformation of what was likely a broad alluvial floodplain with numerous side channels, floodplain wetlands, and backwater areas into a narrow, confined corridor lacking off channel habitat features. Channel incision and related simplification of the stream corridor has negative effects on the availability and quality of salmonid habitats (discussed below in section on floodplain connectivity). Other habitat effects directly linked to the loss of instream wood include a decrease in the frequency and depth of pool habitats in the watershed (Abbe and Montgomery, 1996; Abbe and Montgomery, 2003; Montgomery et al., 1995), removal of cover for juvenile salmonids, and associated declines in the periphyton and invertebrate communities (Coe et al., 2009). Further, lack of instream wood limits opportunities for hyporheic exchange and exacerbates water quality concerns related to high summer temperatures (Hester and Doyle, 2008). Localized areas in which active wood recruitment is maintained (e.g., Kitsap Forest Reserve) have adequate wood loading to support resilience of stream habitats (Figure 34).

Figure 32. Photograph comparison of a reach lacking channel complexity due to deficiency of wood in Chico Creek upstream of Taylor Road (left) and a reach with active wood recruitment and increased channel complexity in Wildcat Creek (right). Photos by Shawn Higgins, NSD (left) and Steve Todd, Suquamish Tribe (right).

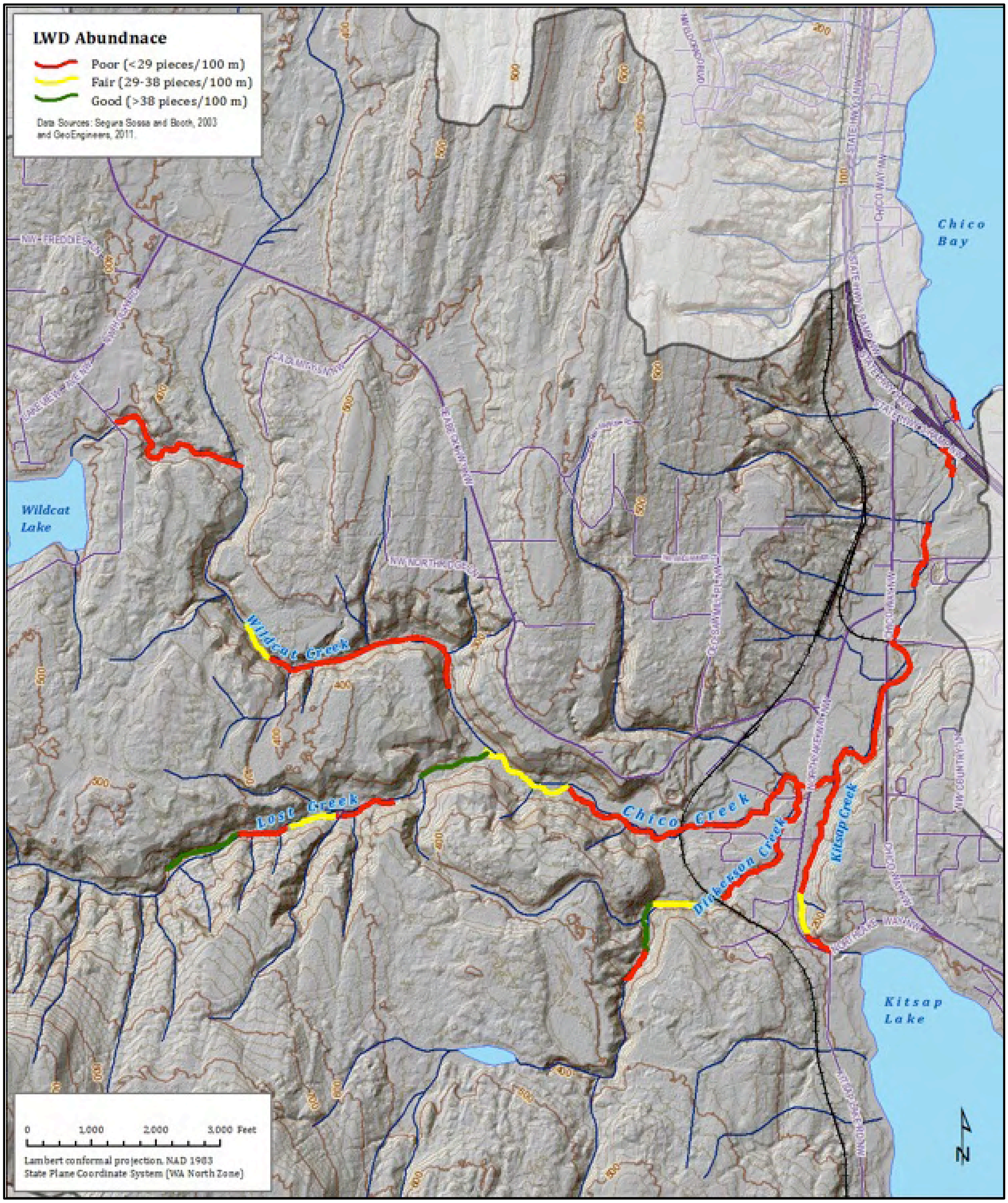


Figure 33. Map of wood abundance derived from 2002 field survey data (Segura Sossa and Booth, 2003) and additional survey of lower Lost Creek in 2011 (GeoEngineers, 2011).

Figure 34. Example of forested channel segment in a tributary to Wildcat Lake that has retained wood despite widespread timber harvest in the contributing watershed approximately 50 years earlier. The stream has logs buried in the bed about every 25 ft, on average, and a floodplain surface that is engaged multiple times a year. The wood has maintained a pool-riffle channel in a moderate gradient segment that would otherwise be scoured to bedrock given history of forest practices in the contributing subbasin area. Photo source: Tim Abbe (NSD).

4.5 FLOODPLAIN CONNECTIVITY

The existing condition of floodplain areas in the Chico Creek watershed is directly related to the historical impacts to the flow, sediment and wood regimes described above. In addition, some floodplain areas have been lost or disconnected by filling to support land use development. This section elaborates on how land use practices have altered floodplain connectivity in the watershed and identifies where channel-floodplain interactions have been most altered and where they remain relatively intact. Floodplain connectivity was assessed primarily through review of topographic data in the LiDAR-based DEM.

CHANNEL STABILITY

Over time, alluvial rivers adjust their channel geometry (i.e., width, depth, slope) to develop a balance between sediment supply and sediment transport capacity. Mackin (1948) described this condition for a graded stream as *"one in which, over a period of years, slope is delicately adjusted to provide, with available discharge and with prevailing channel characteristics, just the velocity required for the transport of the load supplied from the drainage basin"*. Stable channels are not static; they migrate laterally and fluctuate vertically with localized changes in flow, sediment, and wood recruitment. The concept of channel stability refers to the condition whereby a stream can respond to disturbance and maintain consistent cross-sectional, planform, or profile characteristics.

The balance that maintains channel stability can be disturbed by alterations to either the sediment load delivered from upslope areas or the sediment transport capacity. Transport capacity is generally a product of the channel slope and prevailing hydrologic regime. As such, watershed changes that increase peak flow magnitudes tend to increase sediment transport capacity. Such increases are exacerbated by reductions in wood loading or other changes that reduce the partitioning of shear stress along the channel boundary and increase the proportion of the shear stress available to erode the channel bed (Manga and Kirchner, 2000).

The cumulative effects of historical impacts in the Chico Creek watershed have produced episodes of channel incision that have lowered the streambed and disconnected former floodplain areas. In a fairly extensive area of the lower watershed, the former floodplain is now elevated above the stream channel and has become a terrace surface that is inundated if at all by only extreme floods, depending on location and amount of incision. The effect of past channel incision is most pronounced along the lower mainstem of Chico Creek between SR 3 and the Navy railroad trestle.

The channel segments which have functional floodplain areas correspond to locations for which wood abundance is highest and have the most active wood recruitment. Beginning at a point about 1,500 ft upstream of the railroad trestle, the floodplain widens approximately threefold. Floodplain connectivity is relatively good in the Chico Creek segment within the Mountaineers Foundation Rhododendron Preserve and in upstream reaches until the channel is naturally confined by hillslope areas in the Lost Creek and Wildcat Creek subbasins. Incision along the lower mainstem is illustrated by the downstream decrease in the width of the 100-year floodplain delineated on FEMA flood maps (Figure 35). There is no geologic explanation for the floodplain corridor to narrow in downstream reaches. If anything, the increases in flow downstream of the Dickerson and Kitsap Creek confluences would result in wider floodplain areas under natural or undeveloped conditions.

Dickerson Creek and Kitsap Creek have confluences within the incised segment of the mainstem Chico Creek. As such, the lower segments of these tributaries have incised to cut down to the base level imposed by the mainstem channel. The incision along Dickerson Creek has been checked, in part, by grade control created by the culverts at Taylor Road and David Road. The channel segment upstream of David Road has a similar gradient as that of the segment below, but is perched approximately 4 ft higher (Figure 36). This vertical offset represents a minimum value of historical channel incision downstream of David Road. The actual magnitude of incision due to historical land use practices is likely much greater as early land use practices had likely cleared the area and channelized the stream prior to installation of the culvert.

Potential losses of floodplain habitats in incised channel reaches are illustrated by the map of relative floodplain elevations (Figure 37). The existing channel segment in lower Dickerson Creek is flanked by high banks that are 6 to 8 ft above the low flow channel. For reference, predicted bankfull depth is less than 2 ft based on regional hydraulic geometry relations (Castro and Jackson, 2001). The simulated condition in the right hand panel of Figure 37 shows a threefold increase in floodplain width associated with aggradation of the stream bed by 4 ft. This simulated condition represents a potential distribution of floodplain habitats prior to channel incision driven by land use activities in the watershed.

Channel Migration

In addition to vertical adjustments, alluvial stream channels migrate laterally in response to episodic disturbance driven by variations in flow, sediment, and wood recruitment. Bank erosion and lateral channel migration are natural processes that play an important role in the creation and maintenance of aquatic habitats (Florsheim et al., 2008). These processes enable the stream to dissipate energy and respond to fluctuations in the watershed inputs from upstream sources while maintaining variability of channel characteristics to provide a mosaic of habitat features (Gregory et al., 1991). Stable channels are characterized by a relative balance between the erosion on one side of the channel where boundary shear stress exceeds the critical shear stress of the bank material and deposition on the other side where flow separation limits sediment transport capacity. Over time, stable channels migrate laterally yet maintain relatively consistent channel geometry (Leopold and Maddock, 1953).

Channel migration in unstable channels, like the incised channel system represented by lower segments of Chico Creek and its tributaries, is part of a series of processes by which alluvial channels adjust to the imbalance between sediment supply and transport capacity. In this regard, it is important to consider the evolution of channels in the Chico Creek watershed and temporal changes in channel-floodplain interactions. Conceptual models of channel evolution for incised channel segments (Schumm et al., 1984; Simon and Hupp, 1986) highlight a series of characteristic channel adjustments in which a stream channel degrades and then widens, resulting in bank erosion that undercuts the former floodplain surface (which has been disconnected from the channel and thus converted to terrace). Cluer and Thorne (2013) recently expanded on these concepts to develop a stream evolution model as a cyclical, rather than linear, series of adjustments that includes a precursor stage acknowledging the natural tendency for frequent anabranching channel segments particularly in forested regions where instream wood accumulations drive important morphologic processes (Abbe and Montgomery, 1996; Abbe and Montgomery, 2003). Incised channel segments in the lower Chico Creek watershed have progressed from stage 0 to stage 4 in the Cluer and Thorne (2013) stream evolution model (Figure 38). Over time, the natural tendency for these channels is to widen via bank erosion until a quasi-equilibrium is developed and an inset floodplain forms below the historic floodplain surface (Figure 38). The widespread application of bank armoring structures (Figure 39) has arrested this process and thus limits the ability of the stream to restore nature processes on its own.

Delineation of a channel migration zone (CMZ) should be part of future planning efforts in the Chico Creek watershed to facilitate the natural progression of channel evolution and address the widespread loss of floodplain connectivity in the lower watershed. A planning level CMZ was delineated by the Washington Department of Ecology as part of an assessment to support Kitsap County's Shoreline Management Plan Update (Kitsap County Department of Community Development, 2013). This planning level CMZ generally encompasses the 100-year floodplain in lower Chico Creek (Figure 35). Note that the regulatory floodplain mapped in Figure 35 is much narrower than would be expected under natural conditions due to confinement triggered by historical channel incision. It appears as though this planning level CMZ is based on the potential for channel migration under existing (incised) conditions where natural processes are limited by bank armoring. Note that restoration strategies for the lower Chico Creek watershed should envision a broader zone of channel migration based on future opportunities to remove bank armor and restore the function provided by instream wood accumulations. The CMZ needs to consider the potential for future increases in wood loading that can trigger aggradation of the channel bed, increase lateral migration rates, and increase connectivity with potential avulsion pathways in the floodplain area (Brummer et al., 2006; Rapp and Abbe, 2003).

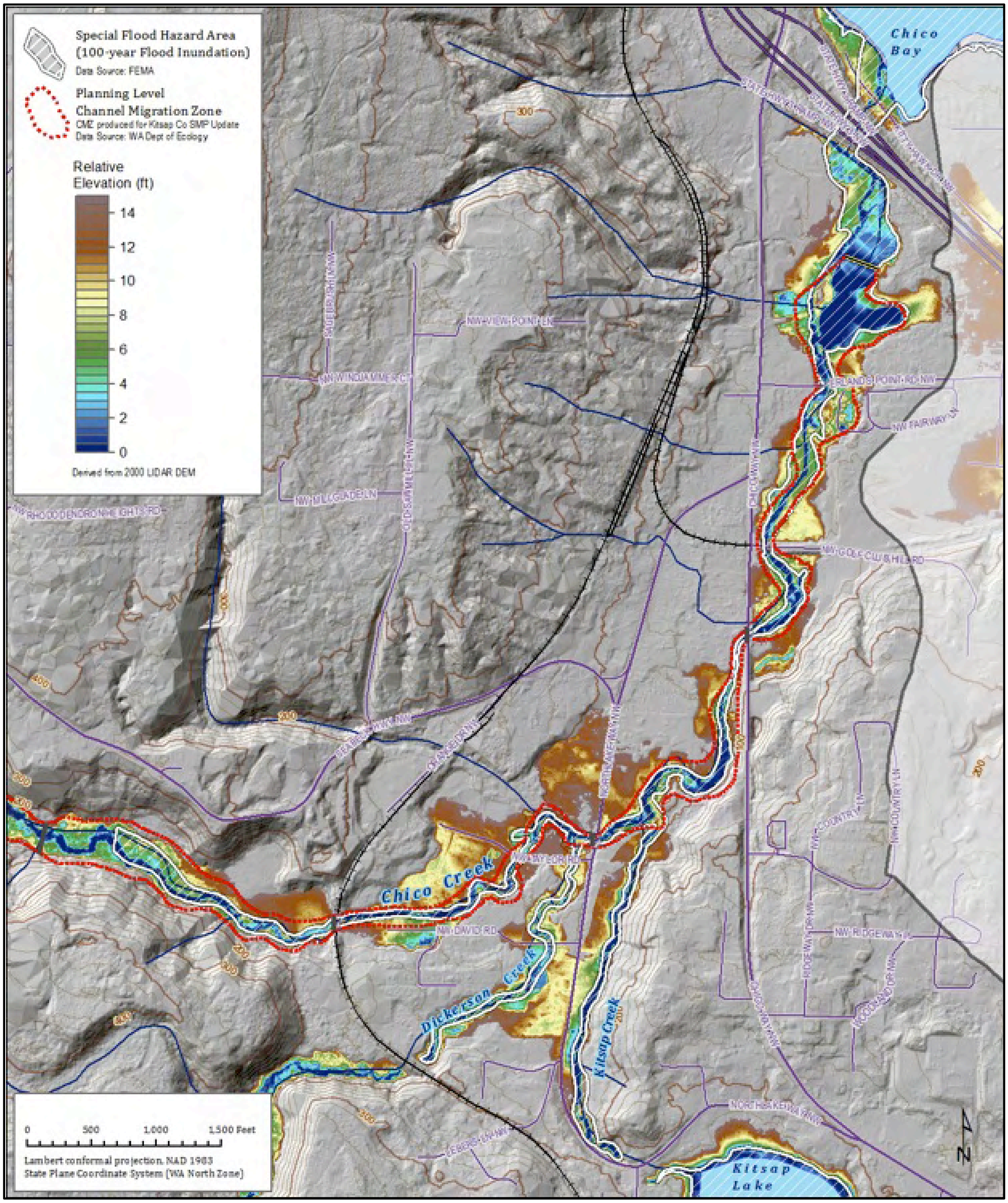


Figure 35. Map of the 100-year floodplain area (FEMA) and planning level channel migration zone (WA Dept of Ecology) for lower segments of Chico Creek, Kitsap Creek, and Dickerson Creek.

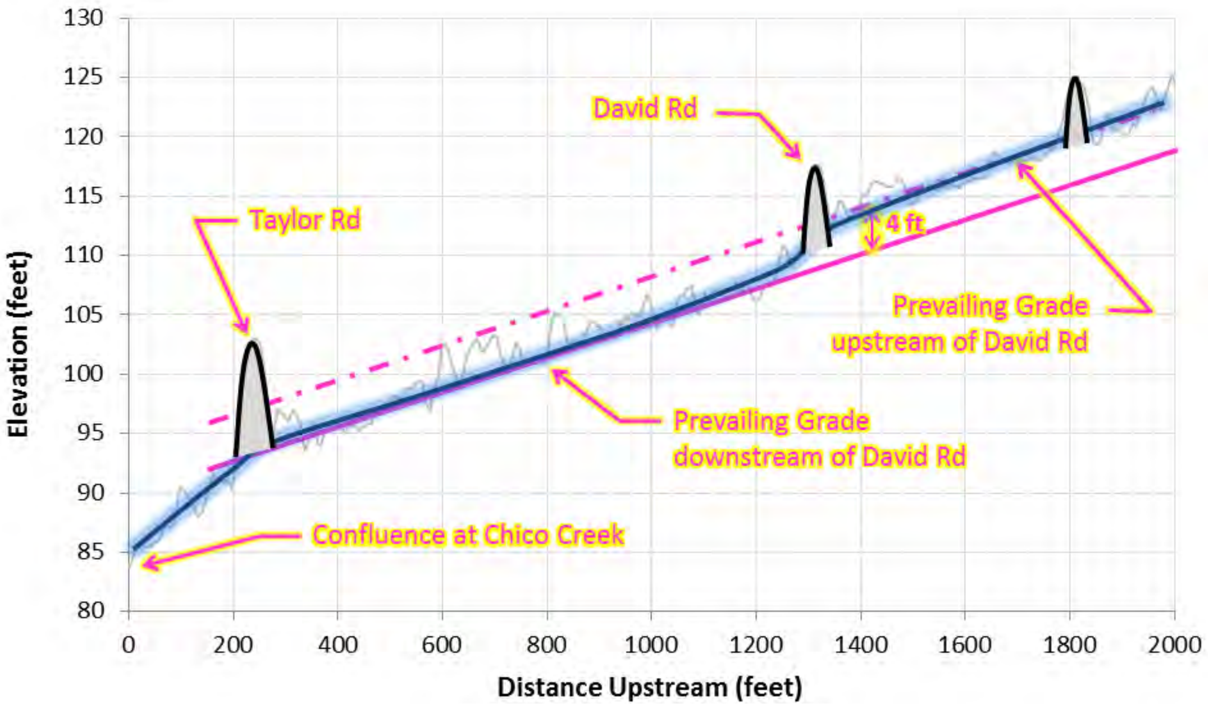
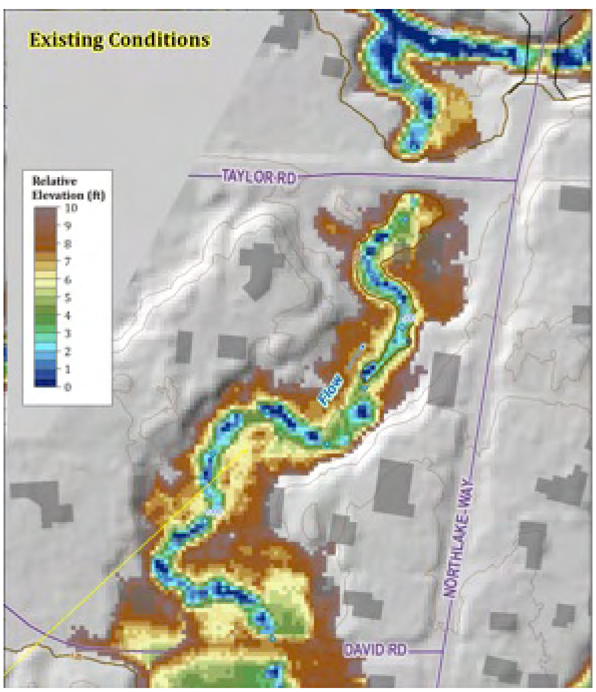


Figure 36. Longitudinal profile of the lower 2,000 ft of Dickerson Creek. Existing culverts function as grade control structures in the incised channel system. An estimated vertical offset of approximately 4 ft represents a minimum value of channel incision. Topographic data from 2000 LIDAR DEM.



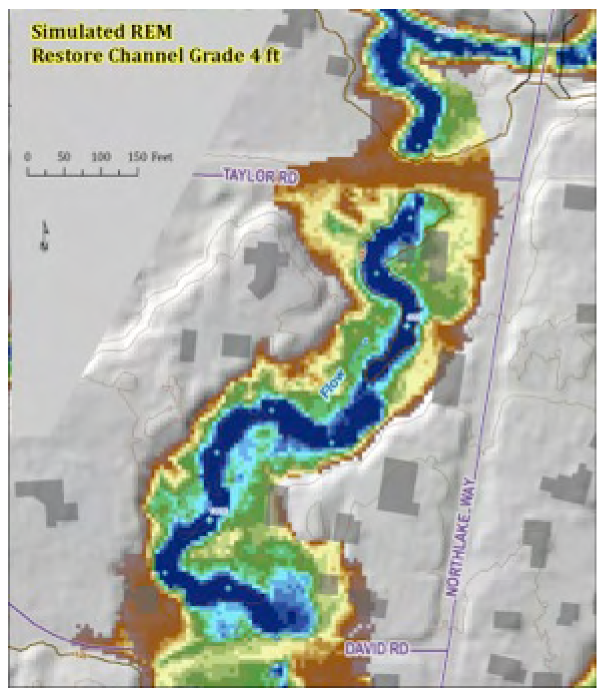


Figure 37. Map of relative elevation model (REM) comparing existing and potential future (simulated) conditions assuming aggradation of the channel bed downstream of David Rd. to restore pre-incision grade and reconnect abandoned floodplain habitats. Relative elevations between 0 and 3 ft correspond to active floodplain areas. Data are derived from 2000 LiDAR DEM.

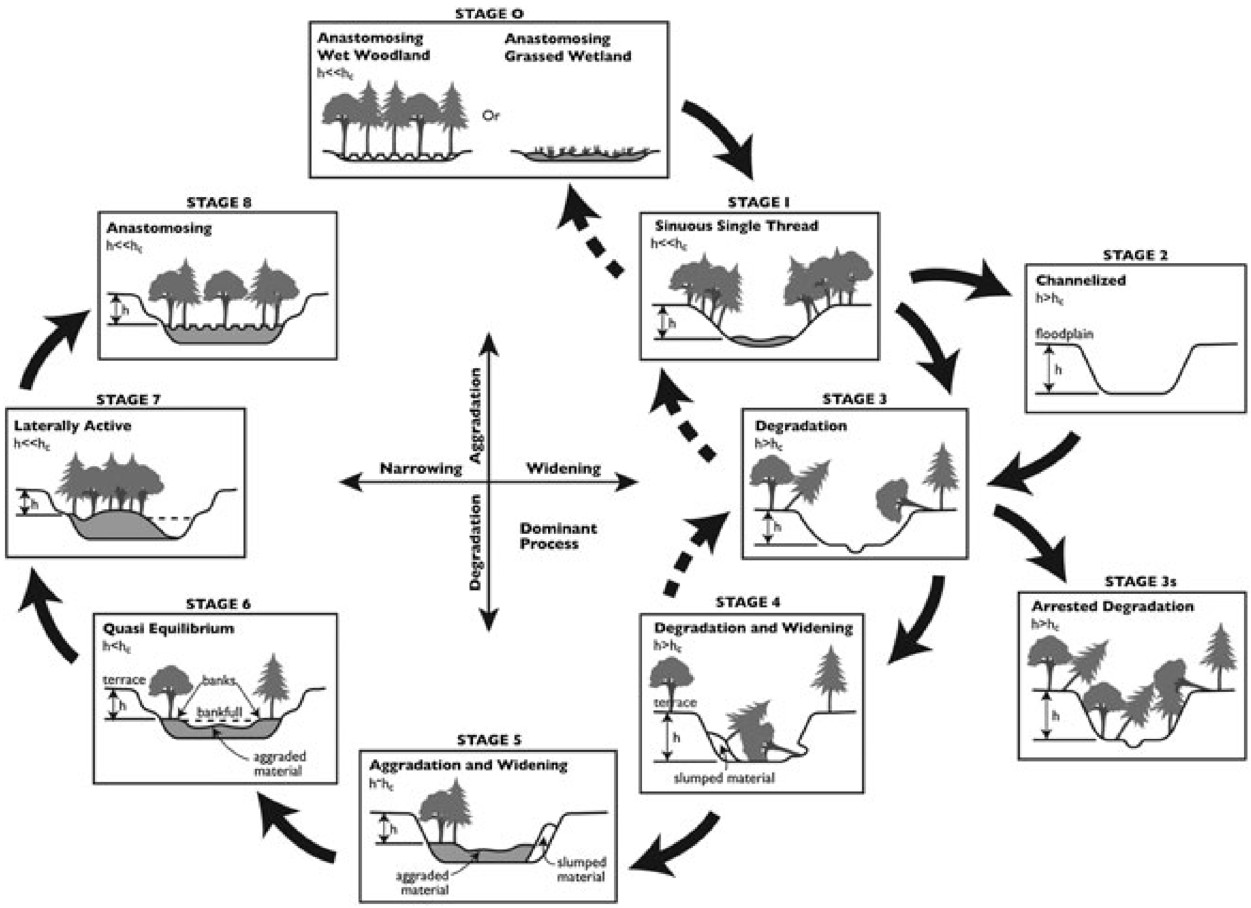


Figure 38. Diagram of the Stream Evolution Model (Figure 4 in Cluer and Thorne, 2013)

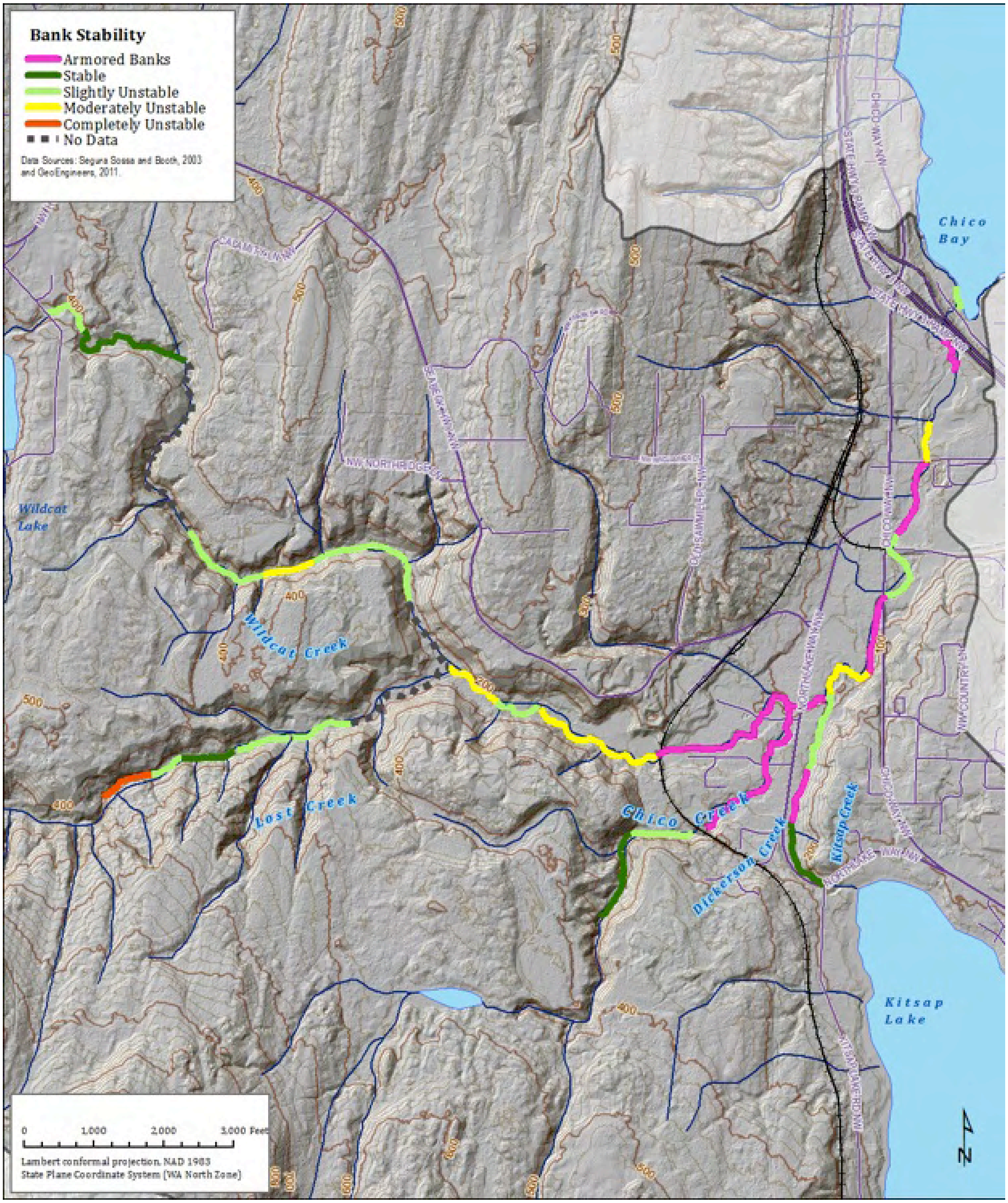


Figure 39. Map of bank stability and channel segments armored by bank protection derived from 2002 field survey data (Segura Sossa and Booth, 2003).

4.6 WATER QUALITY

This assessment reviewed existing data and information to identify stream reaches in the Chico Creek watershed that are impaired and evaluated the effect of known impairments on salmonid habitat and survival. The assessment of water quality is guided by the standards published by the Washington Department of Ecology (2012b). The current EPA-approved Water Quality Assessment (Washington Department of Ecology, 2012a) fulfills the State's obligation under sections 303(d) and 305(b) of the Clean Water Act. Figure 40 depicts all water bodies in the Chico Creek watershed listed as Category 5 in the current water quality assessment, traditionally known as the 303(d) list. Category 5 water bodies have violated water quality standards for one or more pollutants and require a total maximum daily load (TMDL) assessment.

CHICO CREEK

Existing water quality impairments identified in the 303(d) listings for Chico Creek include:

- Temperature (downstream of confluence with Kitsap Creek),
- Fecal coliform bacteria, and
- Dissolved oxygen (confluence with Dickerson Creek to the confluence with Lost/Wildcat Creeks).

Temperature monitoring data collected in Chico Creek by the Suquamish Tribe are summarized to show the 7-day average of daily maximum (7DADM) for the period 2002-2012 in Figure 41. Every year in the period of record exceeded water quality standards for Core Summer Salmonid Habitat criteria of 16° C. The maximum 7DADM temperature in the period of record was 21.7° C recorded in 2009. The listing for fecal coliform bacteria was based on samples collected from 2003-2005 and was likely associated with source areas in the Kitsap Lake subbasin (see below). Ongoing monitoring of fecal coliform bacteria by the Kitsap County Health District shows that bacteria levels in Chico Creek meet health standards and indicate an improving trend (Kitsap Public Health District, 2012).

KITSAP CREEK AND KITSAP LAKE

Existing water quality impairments identified in the 303(d) listings for Kitsap Creek downstream of Kitsap Lake include:

- Temperature, and
- Dissolved oxygen.

Monitoring data from the Suquamish Tribe were collected in Kitsap Creek in only two years of the recent period (2002-2003). 7DADM temperatures from the two years of data greatly exceeded water quality standards for Core Summer Salmonid Habitat criteria of 16° C (Figure 42). In 2002, the maximum 7DADM exceeded 25° C.

Water quality in Kitsap Lake has degraded with development of residential land uses in the contributing watershed. Parameters that have violated water quality standards include:

- Fecal coliform bacteria,
- Phosphorus, and
- Toxics (PCBs).

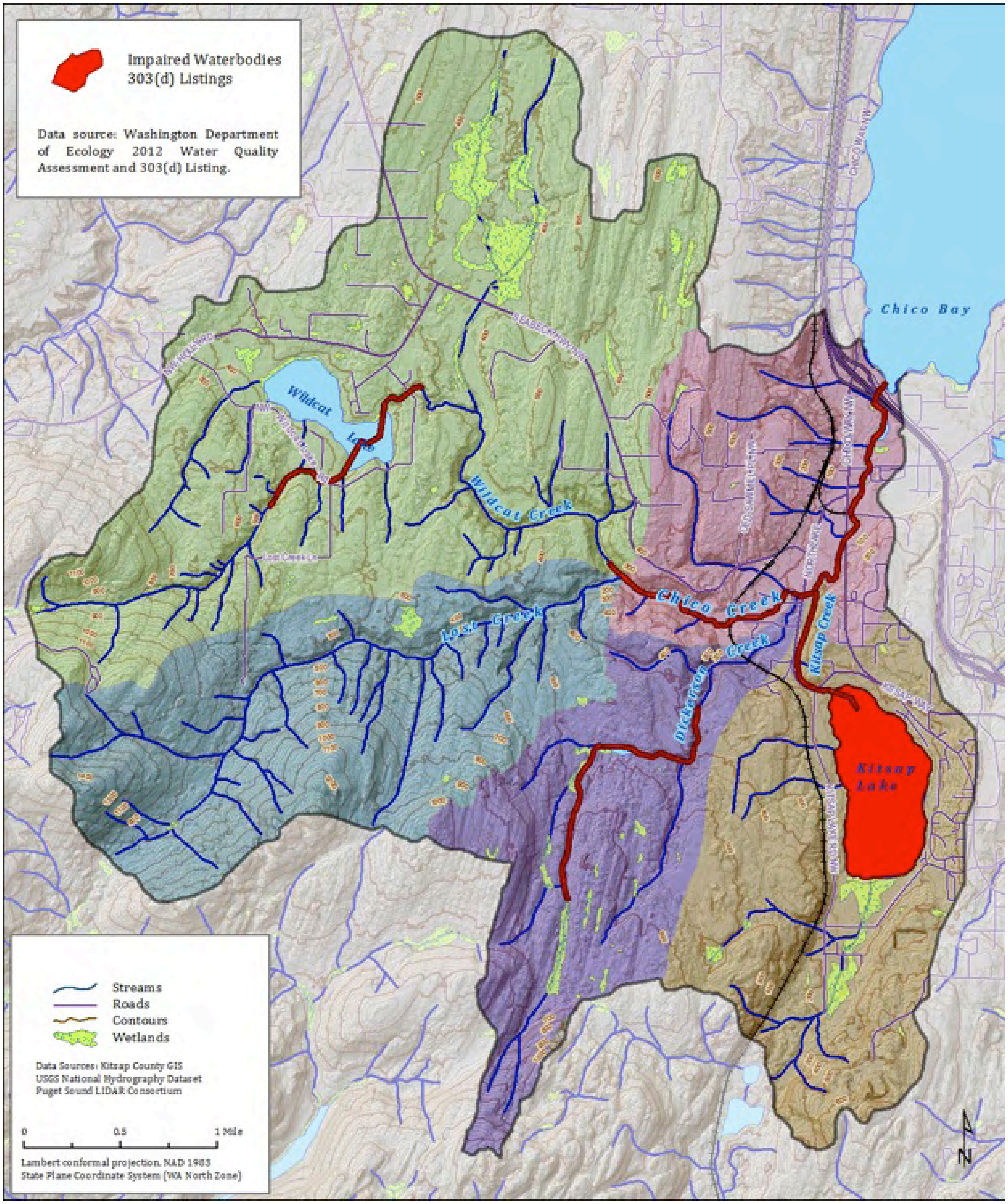


Figure 40. Map of 303d listed waters in the Chico Creek watershed.

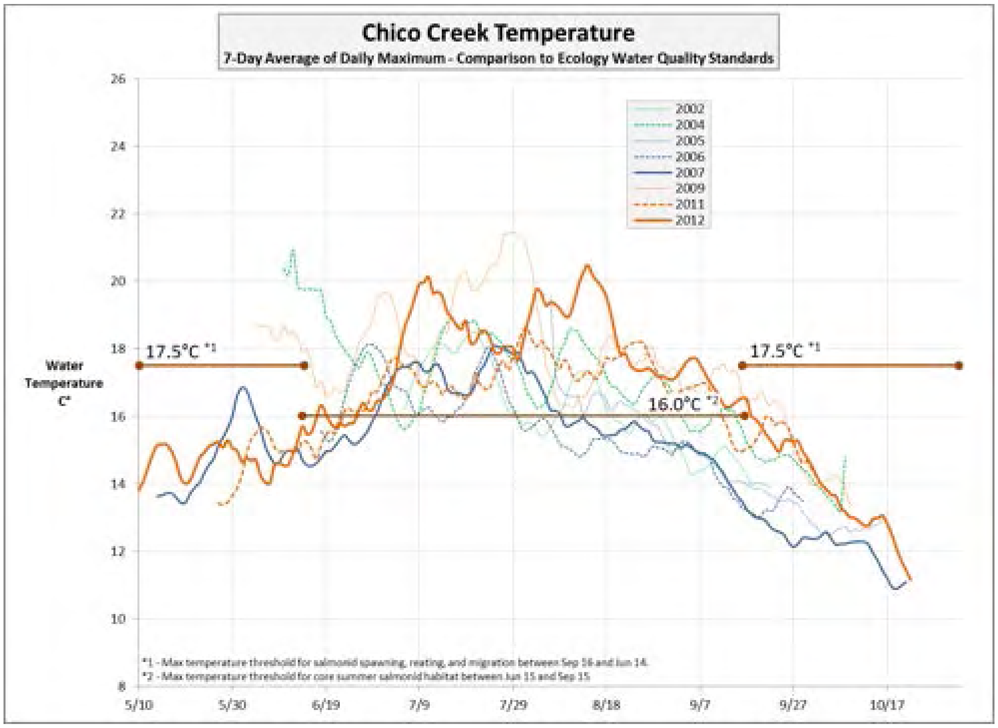


Figure 41. Time series plots of temperature monitoring data for Chico Creek (source: Suquamish Tribe).

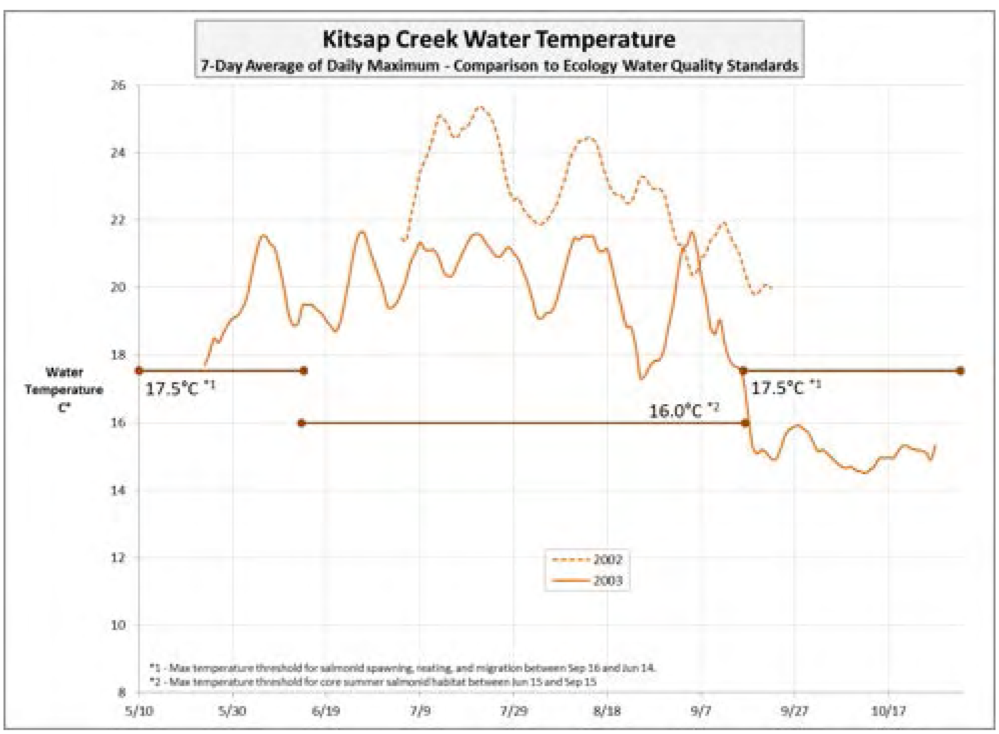


Figure 42. Time series plots of temperature monitoring data for Kitsap Creek (source: Suquamish Tribe).

The Kitsap Public Health District completed a pollution identification and correction (PIC) project to address water quality concerns in Kitsap Lake and identified failing onsite sewage systems were degrading water quality, including three systems discharging directly to the lake (Fohn, 2005). All of the identified failing systems were corrected. Ecology has since developed a TMDL and water quality implementation plan to address fecal coliform bacteria in all subbasins draining to Dyes Inlet and Sinclair Inlet (Lawrence, 2012). Monitoring data from Kitsap Public Health District (2012) showed that Kitsap Lake met water quality standards for fecal coliform bacteria in 2012; however, the lake is still eutrophic with elevated nutrient levels and is susceptible to potentially toxic algae blooms. The category 5 (303(d)) listing for PCBs is based on samples of cutthroat and rainbow trout fillets sampled in 2002 that exceeded the National Toxics Rule criterion.

Dickerson Creek

Existing water quality impairments identified in the 303(d) listings for Dickerson Creek identify temperature as the only parameter exceeding water quality standards (Figure 40). The Category 5 listing for Dickerson Creek is based on unpublished data submitted by Port Blakely Tree Farms during the period 1999-2003 for the segment upstream of the Navy Railroad crossing. Data show relatively high variability between stations with 7DADM values ranging from a maximum of 22.9° C at station DI3 to a minimum of 15.4° C at station DI5. More recent data from the Suquamish Tribe collected over the period 2002-2011 several hundred ft upstream from the Navy railroad crossing show that for nearly all years stream temperature remains below the Summer Core Salmonid Habitat criteria of 16° C (Figure 43).

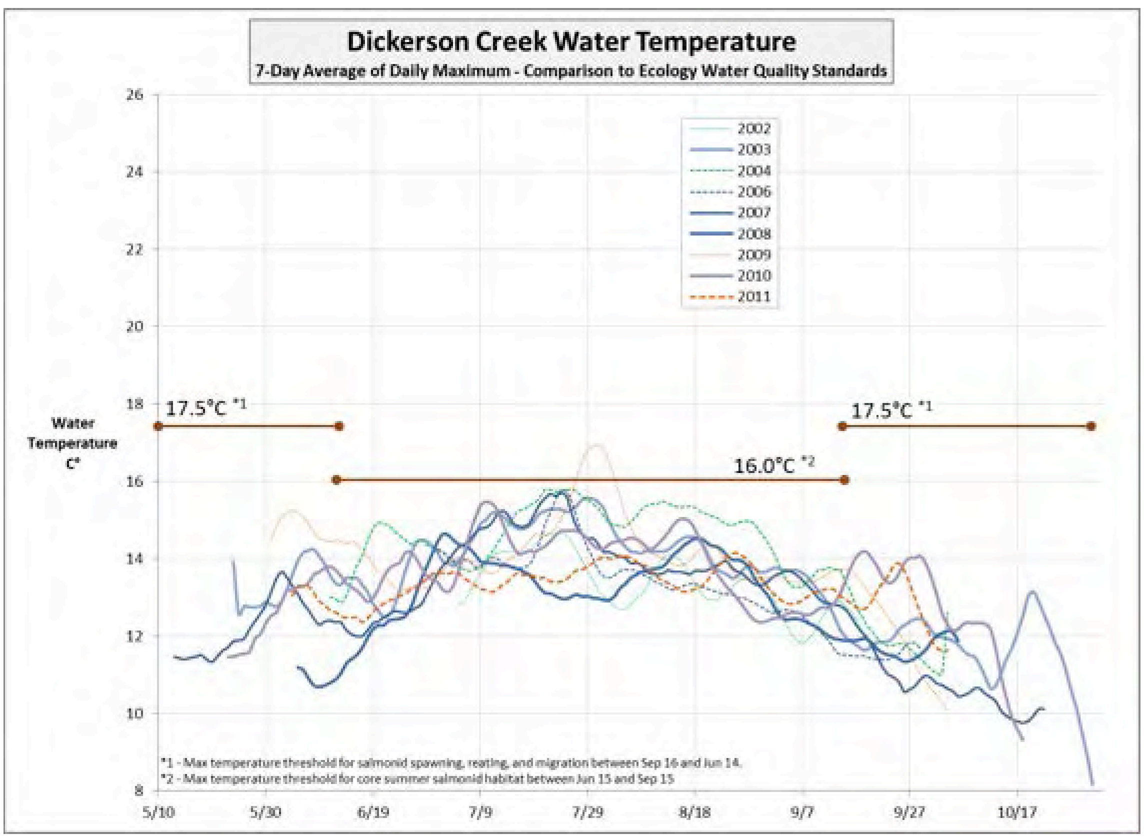


Figure 43. Time series plots of temperature monitoring data for Dickerson Creek (source: Suquamish Tribe).

Lost Creek

There are no channel segments in the Lost Creek subbasin on the 303(d) listing. Monitoring data from the Suquamish Tribe show relatively cool summer temperatures that consistently meet the Summer Core Salmonid Habitat criteria for the period 2002-2012 (Figure 44).

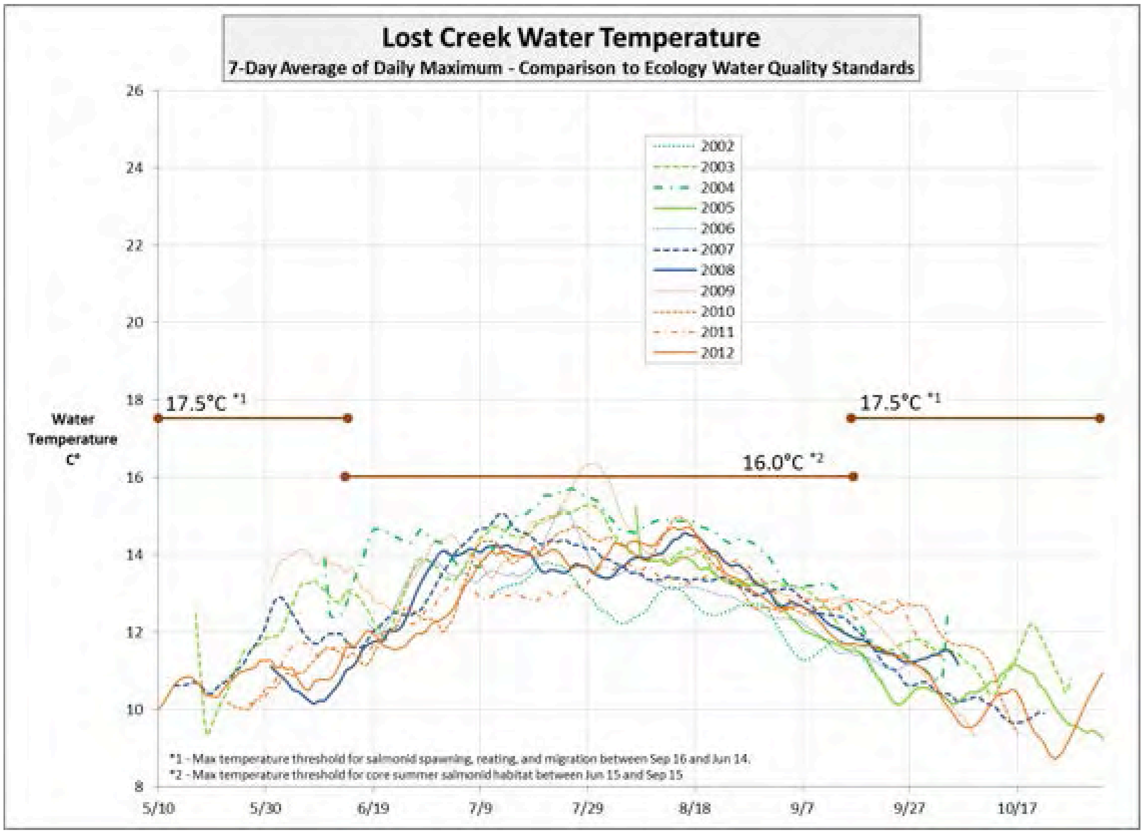


Figure 44. Time series plots of temperature monitoring data for Lost Creek (source: Suquamish Tribe).

WILDCAT CREEK AND WILDCAT LAKE

Stream channel segments upstream and downstream of Wildcat Lake, and Wildcat Lake, are on the 303(d) listing for fecal coliform bacteria (Figure 40). Monitoring data from the Suquamish Tribe at a location a short distance upstream of the confluence with Lost Creek show summer temperatures exceed the Summer Core Salmonid Habitat criteria for some periods during some years (Figure 45). The relative increase in summer water temperatures compared to Lost Creek is likely attributed to the absorption of solar radiation on the surface of Wildcat Lake. Monitoring of Wildcat Lake by the Kitsap Public Health District (2012) shows that water quality met standards for fecal coliform bacteria in 2012.

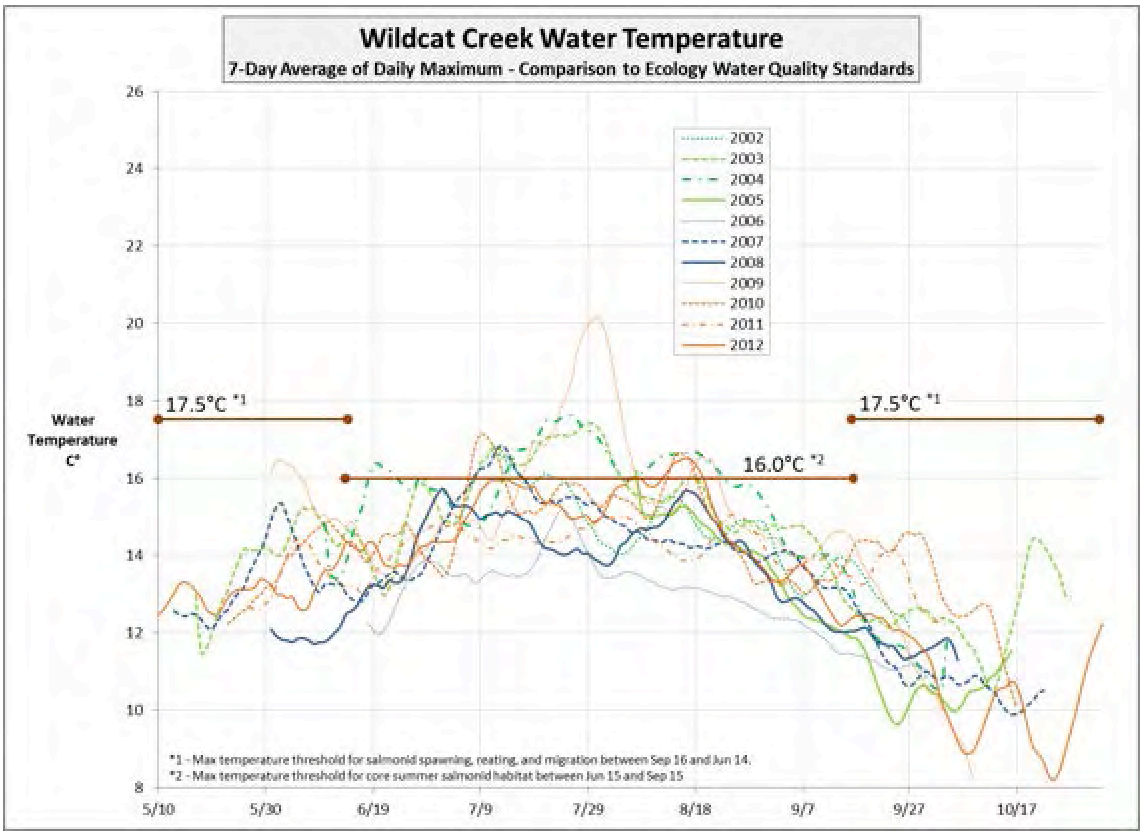


Figure 45. Time series plots of temperature monitoring data for Wildcat Creek (source: Suquamish Tribe).

ANTICIPATED EFFECTS OF CLIMATE CHANGE

Anticipated increases in summertime air temperature under projected climate scenarios for the Pacific Northwest could raise additional water quality concerns for the Chico Creek watershed. Monitoring data collected by the Suquamish Tribe show that water temperature in Kitsap Creek and lower Chico Creek consistently exceed the threshold of 16° C for Core Summer Salmonid Habitat set by the Department of Ecology. Monitoring data from Dickerson, Lost, and Wildcat Creeks show summer temperatures typically 1-2° C less than the 16° C threshold. Projected changes in water temperature from the Washington Climate Change Impacts Assessment estimate a >2° C increase in summertime water temperature for many gaging stations in western Washington (Mantua et al., 2010). Increases in water temperature could therefore result in increased stress on salmonids that utilize freshwater habitat for rearing (e.g. coho and steelhead).

4.7 SUMMARY

The above assessment of watershed processes and indicators was utilized to evaluate stream segments with respect to the degree they meet “properly functioning conditions”. Stream segments were classified as either: impaired, moderately impaired, or functioning for individual components of the watershed assessment. A segment was classified as “functioning” for a given parameter if the available data indicated that human activities were not limiting potential contributions to habitat-forming processes or indicators. A designation of “impaired” was applied where the available data suggested clear impacts related to human activities in the watershed. Stream segments that had been clearly impacted for a given parameter, but retain some of their natural potential were classified as “moderately impaired”. Results of the evaluation are summarized in Table 18 and used in identification of protection and restoration actions for the Chico Creek watershed. Future implementation of protection and restoration actions should aim to move indicators from impaired toward functioning.

Table 18. Summary of reach-scale evaluations of watershed processes and indicators in the Chico Creek watershed.

Reach Description	River Stationing (ft)		Slope (%)	Confinement (*artificial)	← Watershed-Scale Indicators →			← Reach-Scale Indicators →			
	Downstream	Upstream			Hydrology	Sediment	Water Quality	Riparian	Wood	Floodplain Connectivity	Fish Passage
Chico Creek											
Estuary to Erlands Point Rd	0	3,400	0.7	Unconfined	Impaired	Moderately Impaired	Impaired	Impaired	Impaired	Impaired	Impaired
Erlands Point Rd to Chico Way	3,400	5,600	1.0	Moderately Confined*	Impaired	Moderately Impaired	Impaired	Impaired	Impaired	Impaired	Moderately Impaired
Chico Way to confluence with Dickerson Creek	5,600	8,500	1.0	Confined*	Impaired	Moderately Impaired	Impaired	Impaired	Impaired	Impaired	Functioning
Confluence with Dickerson Creek upstream past RR trestle	8,500	12,000	1.4	Confined*	Impaired	Moderately Impaired	Functioning	Impaired	Impaired	Impaired	Functioning
Just upstream of RR trestle to confluence of Lost/Wildcat Cr.	12,000	14,800	1.2	Unconfined	Impaired	Moderately Impaired	Functioning	Functioning	Moderately Impaired	Functioning	Functioning
Kitsap Creek											
Confluence with Chico Creek to change in valley confinement	0	1,850	2.1	Confined*	Moderately Impaired	Moderately Impaired	Impaired	Moderately Impaired	Impaired	Impaired	Functioning
Relatively unconfined valley compared to up/downstream	1,850	2,750	1.6	Moderately Confined*	Moderately Impaired	Moderately Impaired	Impaired	Impaired	Impaired	Impaired	Impaired
Confined valley upstream to Kitsap Lake	2,750	4,000	2.6	Confined	Moderately Impaired	Moderately Impaired	Impaired	Moderately Impaired	Impaired	Impaired	Moderately Impaired
Upstream of Kitsap Lake to Reba Way	10,000	12,400	0.5	Unconfined	Moderately Impaired	Moderately Impaired	Unknown	Functioning	Unknown	Functioning	Moderately Impaired
Reba Way to Archie Ave	12,400	14,500	0.9	Unconfined	Moderately Impaired	Moderately Impaired	Unknown	Functioning	Unknown	Functioning	Functioning
Upstream of Archie Ave	14,500	16,100	2.7	Moderately Confined	Moderately Impaired	Moderately Impaired	Unknown	Functioning	Unknown	Functioning	Moderately Impaired

Description	River Stationing (ft)		Slope (%)	Confinement (*artificial)	Watershed-Scale Indicators			Reach-Scale Indicators			
	Downstream	Upstream			Hydrology	Sediment	Water Quality	Riparian	Wood	Floodplain Connectivity	Fish Passage
Dickerson Creek											
Confluence with Chico Creek to David Rd	0	1,300	2.4	Confined*	Impaired	Moderately Impaired	Functioning	Moderately Impaired	Impaired	Impaired	Moderately Impaired
David Rd to RR crossing	1,300	3,000	1.7	Moderately Confined*	Impaired	Moderately Impaired	Functioning	Moderately Impaired	Impaired	Impaired	Moderately Impaired
RR crossing to cascades	3,000	5,500	2.7	Unconfined	Impaired	Moderately Impaired	Functioning	Moderately Impaired	Moderately Impaired	Functioning	Functioning
Cascades to falls	5,500	8,500	4.7	Confined	Impaired	Moderately Impaired	Functioning	Functioning	Unknown	Functioning	Functioning
Falls to change in valley confinement	8,500	12,000	1.3	Unconfined	Moderately Impaired	Moderately Impaired	Functioning	Functioning	Unknown	Functioning	Functioning
Confined valley segment	12,000	15,500	3.6	Confined	Moderately Impaired	Moderately Impaired	Functioning	Functioning	Unknown	Functioning	Functioning
Wetland	15,500	18,000	0.3	Unconfined	Moderately Impaired	Moderately Impaired	Functioning	Functioning	Unknown	Functioning	Functioning
Headwater channel	18,000	20,000	6.7	Moderately confined	Moderately Impaired	Moderately Impaired	Functioning	Functioning	Unknown	Functioning	Functioning
Lost Creek											
Confluence with Chico Creek to upstream end of forest reserve	0	4,000	1.8	Unconfined	Moderately Impaired	Impaired	Functioning	Functioning	Functioning	Functioning	Functioning
WDNR property downstream of falls/cascades (upstream of forest reserve)	4,000	10,000	2.4	Moderately Confined	Moderately Impaired	Impaired	Functioning	Moderately Impaired	Moderately Impaired	Functioning	Functioning
Confined segment with falls/cascades	10,000	13,000	7.7	Confined	Moderately Impaired	Impaired	Functioning	Moderately Impaired	Unknown	Functioning	Functioning
Upstream of falls	13,000	18,500	3.1	Moderately Confined	Moderately Impaired	Impaired	Functioning	Moderately Impaired	Unknown	Functioning	Functioning

Description	River Stationing (ft)		Slope (%)	Confinement (*artificial)	← Watershed-Scale Indicators →			← Reach-Scale Indicators →			
	Downstream	Upstream			Hydrology	Sediment	Water Quality	Riparian	Wood	Floodplain Connectivity	Fish Passage
Wildcat Creek											
Confluence with Chico Creek to tributary (Newberry Hill wetlands)	0	9,300	1.6	Moderately Confined	**Moderately Impaired**	**Moderately Impaired**	**Functioning**	**Moderately Impaired**	**Functioning**	**Functioning**	**Functioning**
Tributary confluence to Wildcat Lake	9,300	13,000	1.6	Moderately Confined	**Moderately Impaired**	**Moderately Impaired**	**Functioning**	**Moderately Impaired**	**Functioning**	**Functioning**	**Functioning**

5 Protection and Restoration Strategies and Actions

Changes in hydrologic and geomorphic processes by human land use activities have negatively impacted aquatic and riparian habitat for salmonids in the Chico Creek watershed. The quantity and quality of habitat is limited by the following factors:

- Barriers to fish passage at road and railroad stream crossings;
- Low abundance of stable wood (provides hydraulic refugia, cover, and sediment retention);
- Insufficient wood recruitment from riparian areas;
- Lack of pool habitats and channel complexity;
- Low summer base flows;
- Limited floodplain connectivity due to channel incision, artificial fill and bank protection (e.g. riprap);
- Limited availability of side channel/off channel habitats;
- High peak flows in confined channel segments with poor spawning or rearing capacity; and
- Water quality impairments (primarily high summer water temperature);

The development of strategies for the protection and restoration of habitat forming processes, structures, and functions within the Chico Creek watershed are based on the assessment of watershed- and reach-scale processes and indicators presented above. Collectively, the recommended strategies aim to foster resilience to future disturbance in the watershed (including changes driven by natural variability and human impacts). Such resilience will ensure the continued productivity of chum salmon and help recover populations of coho and steelhead in the watershed. Key components of the recommended strategy are summarized as follows:

1. Dedicate land within a stream corridor for the provision of riparian processes, flood conveyance and storage, and geomorphic processes such as channel migration;

2. Restore and/or protect forest conditions within the stream corridor;

3. Manage forestry practices and development in upland areas outside of the stream corridor to ensure at least 65% of the land area in any subbasin remains forested with hydrologically mature vegetation;

4. Improve fish passage at road and railroad crossings that pose barriers to fish passage (e.g., decommission roads, install wider bridge spans, replace culverts with bridges or larger culverts);

5. Remove artificial constraints (e.g., fill, revetments) to floodplain connectivity and channel migration; and

6. Restore in-stream habitat conditions and reverse channel incision through placement of wood.

Recommended strategies were developed to guide both long-term and short-term protection and restoration actions in the watershed. The long-term objective is to restore the dynamic channel processes necessary to support a sustainable and resilient stream, floodplain, and riparian ecosystem. The core long-term recommendation is establishing a viable stream corridor that encompasses a restored floodplain, the channel migration zone, and a riparian corridor. Ensuring there is land adjacent to the stream where the channel is enabled to migrate over time and riparian forests are enabled to mature, is a crucial part of the overall management strategy to protect and restore salmonid habitat in the Chico Creek watershed. The benefits of establishing the corridor are not limited to the ecosystem, but would greatly reduce or eliminate flood hazards and have economic benefits as well.

A planning level stream corridor was delineated to assist with the identification of protection and restoration actions. This stream corridor was delineated to incorporate critical areas surrounding stream and wetland features in addition to adjacent hillslope areas that are directly connected to fluvial landforms in the watershed. The delineated corridor is overlaid with basemap information in Appendix A. The corridor approximates the boundary defined in the Critical Areas Ordinance for Kitsap County; however, the boundary included in the maps appended to this assessment is intended for planning purposes only and does not constitute a regulatory zone.

Protection of undeveloped land areas within the designated stream corridor is important to prevent further impacts to habitat-forming processes and will, in the long term, be more cost effective than implementing future restoration projects after lands have been developed. Other areas in which the stream corridor has been developed will likely require habitat restoration actions and continued protections to support salmonid recovery and ensure resilience to future watershed disturbance.

After protection, the most important and cost-effective recommendation is the addition of large wood to prevent further channel incision and improve habitat. Actions such as wood placement will be beneficial to enhance habitat conditions during the time required for restoration of natural processes (e.g., channel migration, growth of riparian forests, and wood recruitment), but most would be concurrent with actions to protect lands (by working with existing landowners, conservation easements, and/or acquisitions) within the stream corridor to ensure long term resilience of salmonid habitats in the Chico Creek watershed.

Recommended actions for the protection and restoration of salmonid habitat in the Chico Creek watershed are presented in tabular form as Appendix C and summarized below by subbasin. We recommend a hierarchical approach for prioritizing actions based on probability of success, response time, and longevity (Roni et al., 2002; Roni et al., 2008). Highest priority is given to protecting functioning habitats that are not impaired by floodplain modifications (e.g., levees or bank protection) and have an intact forested riparian corridor. Next, actions are prioritized that reconnect isolated habitats either by reconnecting off-channel areas via levee removal or by removing or replacing culverts and other artificial structures that restrict fish passage to upstream areas. The third level of prioritization includes actions that remove artificial structures impairing channel migration (e.g. bank armoring). Note that removal of bank armoring in the Chico Creek watershed is often constrained by residential development and other private property in the stream corridor. As such, working with willing landowners to remove bank armoring, negotiation of conservation easements, and/or land acquisition must be considered as part of the restoration strategy. Once constraints have been removed from the floodplain, the next priority is replanting riparian forests to restore riparian processes such as wood recruitment and providing shade in areas that have been previously cleared or where non-native invasive plant species are currently predominant. Finally, once factors impairing floodplain and riparian processes have been addressed, instream enhancement projects such as wood placement can be successful to restore channel complexity in the intermediate period while riparian forests are developing in the stream corridor. Note that wood placement is a critical near term action in much of the Chico Creek watershed given the widespread impacts of historical land uses. The prioritization framework does not imply that wood placement is unimportant, but rather that wood placement alone will not restore the watershed without restoring floodplain and riparian processes concurrently to enable natural processes such as channel migration and provide for future sources of wood recruitment, shade, organic inputs, water quality protection, and riparian wildlife habitat.

5.1 CHICO CREEK

The valley bottom along Chico Creek is among the most intensively developed parts of the watershed and habitat forming processes are generally impaired throughout all segments of Chico Creek from the estuary to about 1,500 ft upstream of the Navy railroad trestle. The remaining 2,500 ft from this point upstream to the confluence with Lost and Wildcat Creeks is in relatively good condition and protected under current management as part of the Mountaineers Foundation Rhododendron Preserve.

Channel incision along much of Chico Creek has lowered the channel bed and created a narrow, confined floodplain in reaches that likely had a broad, unconfined floodplain prior to disturbance. Disconnection of floodplain surfaces by channel incision reduced flood hazards to property adjacent to the stream channel and thus enabled residential and commercial development within the stream corridor. The natural geomorphic response to channel incision, however, typically involves widening of the channel via bank erosion until a new floodplain can be developed within the incised channel corridor. This natural response is constrained in many of the incised reaches as landowners have armored streambanks with riprap to protect infrastructure from erosion hazards. Removal of this bank armor is essential to restoration of habitat forming processes in Chico Creek; however, such actions requires negotiation of conservation easements and/or land acquisition to facilitate removal of bank armoring without increasing risk to existing infrastructure. A key step in this process is an analysis of the channel migration zone, or erodible corridor, within which the stream can be expected to migrate over time in response to fluctuations of watershed inputs including water, sediment, and wood (Rapp and Abbe, 2003).

Actions completed in the Chico Creek stream corridor since the 2004 Watershed Alliance report include the following:

- Acquisition of key parcels for restoration at the mouth and estuary of Chico Creek;
- Coordination of easements necessary to modify the road alignment in preparation for the anticipated removal of the existing Kittyhawk Drive;
- Design for removal of the box culvert at Kittyhawk Drive;
- Conceptual design for replacement of existing culverts at SR 3 with a bridge;
- Design and construction of channel/floodplain enhancements on the segment crossing the Kitsap Golf and Country Club;
- Acquisition of the streamside parcel upstream of NW Golf Club Hill Road (Time Oil property) by Kitsap County in 2007;
- Watershed-wide survey and treatment to control knotweed in Chico Creek;
- Invasive vegetation removal and riparian planting on County property upstream of NW Golf Club Hill Road;
- Feasibility assessment to evaluate alternatives to relocate NW Golf Club Hill Road and conceptual design plans to replace the existing culvert with a bridge;
- Implementation of noxious weed removal, native vegetation planting, and wood placement on private property funded through the Kitsap Conservation District; and
- Removal of numerous angular riprap rocks obstructing the channel at the U.S. Navy railroad crossing.

There are several restoration opportunities in the Chico Creek mainstem corridor that are near term priority actions that directly address the causes of habitat impairment, have landowner support, and a high likelihood to obtain funding in the near future. These near term priority actions include the following:

- Remove Kittyhawk Drive NW road prism within floodplain/estuary;
- Replace SR 3 culvert with bridge;
- Restore stream, floodplain, and riparian functions on County property at Erlands Point Park;
- Replace NW Golf Club Hill Rd culvert with bridge;
- Restore stream, floodplain, and riparian functions on County property upstream of NW Golf Club Hill Road (Keta Park);
- Wood placement from Chico Way NW to the Kitsap Forest Reserve (upstream of RR trestle) to prevent further incision and increase channel complexity;
- Remove the private driveway just downstream of Navy RR trestle and create alternative access without stream crossing;
- Replace the Navy RR trestle with new structure that allows for channel migration and habitat-forming processes; and
- Remove the floodplain fill (abandoned road grade) upstream of Navy RR trestle.

Note that restoration actions in the more developed areas of the stream corridor are constrained by existing land use patterns. Full restoration of habitat forming processes in these segments is not feasible without first dedicating land within the stream corridor for restoration and removing or setting back the infrastructure encroaching into the corridor. Land areas within the stream corridor between Chico Way NW and the Navy railroad trestle are fragmented into small parcels, many of which have been developed for residential land uses since the 1930s or 1940s. Working with willing landowners to the extent possible, including the establishment of conservation easements, and/or coordination of land acquisition in the stream corridor through these areas is necessary to restore dynamic processes; however, negotiations of these landowner agreements are viewed as long term management actions. We recommend that stakeholders engage landowners to discuss the restoration strategy and identify any willing sellers to help target initial funding for acquisition. The list of long term priority actions in the Chico Creek stream corridor includes the following:

- Replace the Erlands Point Road NW bridge to widen the crossing and remove fill material from the floodplain;
- Restore floodplain upstream of Erlands Point Road (Shadden Lane NW development);
- Realign NW Golf Club Hill Road and remove artificial fill along existing right of way (abandoned RR grade);
- Replace/modify road crossing at Chico Way NW to remove fill and reconnect side channel habitat;
- Restore stream corridor riparian, channel migration zone, and floodplain between Chico Way NW and Northlake Way NW;
- Replace the Northlake Way NW bridge to widen the crossing;
- Restore stream corridor riparian, channel migration zone, and floodplain between Northlake Way NW and NW Taylor Road;
- Replace the NW Taylor Road bridge to widen the crossing; and
- Restore stream corridor riparian, channel migration zone, and floodplain between NW Taylor Road and the Navy RR trestle.

Key actions identified in the Chico Creek mainstem corridor are summarized below.

C1. Kittyhawk Drive culvert and road fill removal

Note: at the time of report finalization Kittyhawk culvert and road prisms were being removed.

Problem: The existing stream crossing at Kittyhawk Drive is comprised of a double box culvert spanning a distance of 18 ft beneath a fill prism extending 12-15 ft above the channel (Figure 46). The culverts and road fill restrict natural channel migration processes and limit the downstream transport of sediment and wood. During periods of high discharge, flows are concentrated in the culverts and create a velocity barrier to fish passage.

Approach: This action will restore fish passage and channel migration processes by removing the double box culvert and eliminating the stream crossing at Kittyhawk Road. The fill prism will be excavated along a 380-ft segment of the road embankment and the site will be graded to enhance connectivity with floodplain and tidal marsh along nearshore areas of the estuary. Key parcels have been acquired on both sides of channel. Easements have been coordinated to facilitate re-alignment of the road and to provide access to properties that currently depend on the stream crossing. HDR (2009) prepared design plans for the culvert removal project and project construction is anticipated in 2014.

The double box culverts at SR 3, located immediately upstream of the Kittyhawk Drive culvert, constrain floodplain/upper estuarine habitat-forming processes in the reach and are also a partial barrier to fish passage. Much of the habitat benefit gained from removal of the Kittyhawk Drive culvert is dependent upon future action to address constraints at the SR 3 stream crossing.

Figure 46. Photo of double box culvert at Kittyhawk Drive (view upstream). Photo taken from Habitat Work Schedule, credit unknown.

C2. SR 3 culvert replacement

Problem: The existing stream crossing at SR 3 is comprised of two parallel 8 x 8 ft box culverts spanning a distance of 400 ft beneath a fill prism extending 40-50 ft above the channel. The culverts restrict natural channel migration processes and limit the downstream transport of sediment and wood. The culvert is partially baffled, however, portions of the bottom are smooth and assumed to be a fish passage barrier at low flow. During periods of high discharge, flows are concentrated in the culverts and create a velocity barrier to fish. WDFW (2009) estimated a velocity of 8 ft per second (fps) for the fish passage design flow (10% exceedance), a velocity well above the WDFW passage criteria of 2 fps.

Approach: The action is to restore fish passage by replacing the existing box culverts with a bridge. Shanz and Park (2006) previously assessed reach conditions and determined that a 50 ft wide span would likely meet WDFW stream simulation requirements; however, a 200 ft wide span would be needed to facilitate natural channel migration processes. Barnard (2009) prepared a conceptual design plan for realignment of the Chico Creek channel and assumed a 200 ft wide span for the bridge replacement.

Bridge design should be coordinated with removal of floodplain constraints and instream habitat enhancement in the reach upstream of SR 3 (Erlands Point Park).

C3. Erlands Point Park Floodplain Restoration

Problem: Upstream of the SR 3 culverts Chico Creek was historically channelized (probably in the early 1960s during construction of SR 3 crossing) into a straight alignment along the west side of the valley and confined by a 4-ft high levee that disconnected the channel from the floodplain. Gravel was extracted from the east half of the valley to fill an embankment as part of SR 3 construction. Gravel pits were left as ponded areas in the disconnected floodplain. A metal debris rack was installed in the channelized segment approximately 800 ft upstream of the culverts to prevent debris from blocking the double box culvert at SR 3. The debris rack was a barrier to fish passage when blocked with wood transported from upstream and required frequent maintenance by WSDOT to remove material accumulated during storm events. A channel avulsion in the early 2000s resulted in split flow with a majority of the streamflow being redirected into the gravel pit areas and bypassing the debris rack channel (Figure 47). Sediment has since accumulated in the pond area as the channel rebuilds a floodplain within the former gravel pit.

Approach: This action will restore habitat-forming processes within a 2,100 ft channel segment owned and managed by Kitsap County (Erlands Point Park). Project components include removal of existing floodplain constraints (levee, metal debris rack), riparian forest restoration, and instream habitat enhancements. Wood placements should be incorporated to create stable hard points to establish an anabranching corridor characteristic of low gradient forested alluvial channels. Barnard (2009) prepared a conceptual design plan as part of the scoping report for planned replacement of the double box culvert at SR 3. This project should be coordinated with the planned culvert replacement downstream at SR 3.

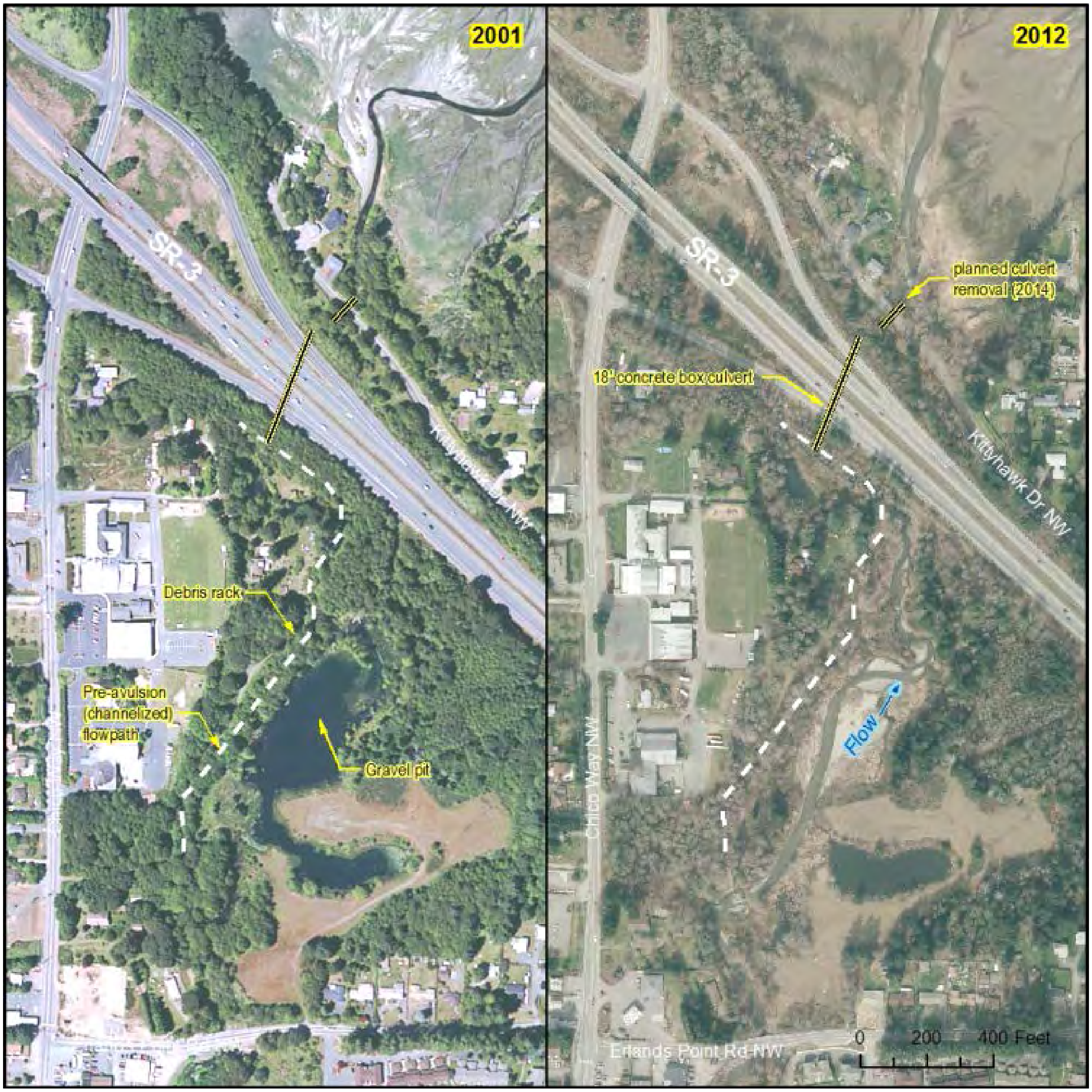


Figure 47. Aerial photo comparison showing recent channel changes in the reach between Erlands Point Road and SR 3.

C4. Erlands Point Road bridge replacement

Problem: Artificial fill brought in to construct the road embankment encroaches into the floodplain on both sides of channel (Figure 48 and Figure 49). The bridge crossing confines the stream corridor and restricts habitat-forming processes.

Approach: The action will replace Erlands Point Road bridge with a wider span and reduce floodplain constriction. Fill material composing the existing road embankment would be removed. The property immediately upstream includes residential development on artificial fill that encroaches into the stream corridor and impairs natural processes. The bridge project should be coordinated as part of a more comprehensive project that includes channel and floodplain constraints created by residential development along Shadden Lane NW.

Figure 48. Bridge crossing at Erlands Point Road. View is looking downstream. Photo by Shawn Higgins (NSD), October 23, 2012.

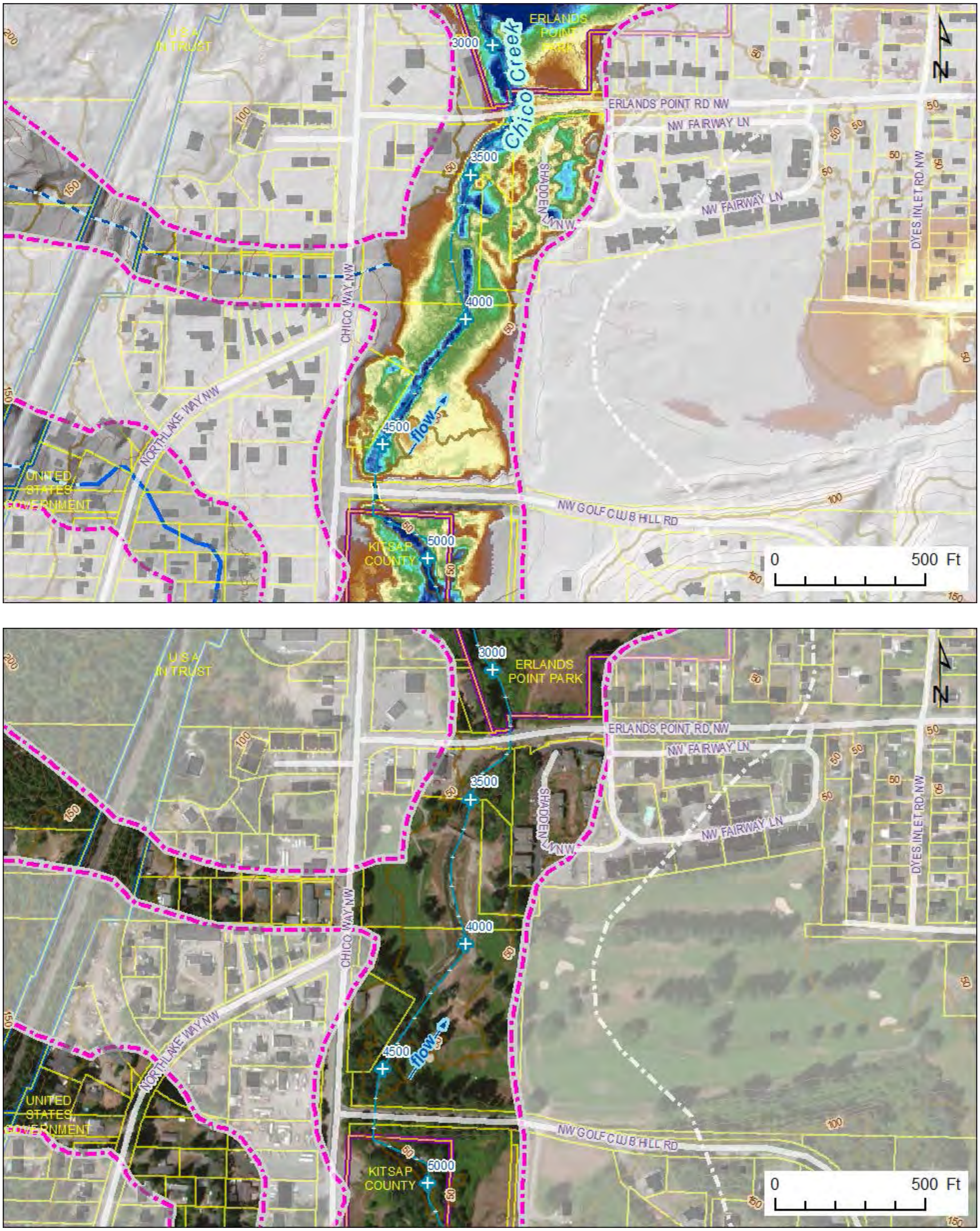


Figure 49. Excerpt from geomorphic map (top panel, Appendix A) and aerial imagery (bottom panel, Appendix B) highlighting the stream corridor (dashed pink line) between Erlands Point Road NW and NW Golf Club Hill Road. Note artificial confinement by road fill at Erlands Point Rd NW and NW Golf Club Hill Road.

C5. Floodplain Restoration upstream of Erlands Point Road (Kitsap Golf & Country Club and Shadden Lane development)

Problem: The stream channel has incised due to loss of in-channel wood and has disconnected adjacent floodplain areas. Channel incision has artificially lowered water surface elevations of flood discharges and enabled development of the historic floodplain for residential land use. The property along the right bank upstream of Erlands Point Road was cleared for construction of a new road (Shadden Lane NW) in 2006 and apartment buildings were constructed in 2007 (Figure 49). This development is not compatible with restoration of reach-scale processes in Chico Creek and is an example of the type of development that should be prevented by protecting undeveloped parcels within the stream corridor. Artificial fill has been placed in the floodplain at the upstream end to create a levee directing flow into the pedestrian crossing at the Kitsap Golf & Country Club. The floodplain encroachments have isolated potential off-channel habitat, restricted habitat-forming processes such as channel migration and wood recruitment, and will require ongoing maintenance to protect infrastructure from channel migration and flood hazards. Instream habitat conditions are impaired by lack of channel complexity and artificially low wood abundance.

Approach: This action will remove artificial constraints to channel migration and reconnect floodplain areas. Property in the stream corridor should be dedicated for maintenance of habitat-forming processes by working with willing landowners and negotiation of conservation easement and/or land acquisition. Fill materials to be removed include the levee on the Kitsap Golf & Country Club property and the infrastructure associated with the housing development along Shadden Lane NW. Instream habitat conditions will be addressed through strategic wood placements that will increase abundance of pool habitats, provide cover, increase channel complexity, and increase hydraulic roughness.

Recent development along Shadden Lane NW will pose significant challenges to restoration of riparian processes and instream habitat conditions through this segment because infrastructure has been placed directly on top of the pre-incision floodplain surface. As such, negotiation and coordination with property owners will be required. Future wood recruitment and restoration of channel migration processes may require future modification to the pedestrian bridge on the Kitsap Golf & Country Club property.

C6. NW Golf Club Hill Road culvert replacement

Problem: The road prism for NW Golf Club Hill Road follows the alignment of a former railroad grade that constricts the floodplain near river station 4600 (Figure 49). Topographic characteristics of this segment reveal a natural floodplain width of approximately 500 ft. Artificial fill placed for the road embankment is approximately 20 ft high, 120 ft in the downstream direction, and restricts the floodplain to a narrow opening with a triple box culvert with openings 12 ft in width (Figure 50). The culvert was identified as a partial barrier to fish passage in WDFW's (2012) Fish Passage Barrier Inventory. Channel incision downstream of the culvert had previously undermined a series of weirs and produced a headcut that extended to the culvert outlet. The headcut was addressed as part of recent channel/floodplain modifications on the Kitsap Golf & Country Club property; however, the culvert remains a significant floodplain constriction and continues to restrict habitat-forming processes in the reach.

Approach: Two main alternatives have been evaluated to address problems at this reach: 1) replace the existing triple box culvert with a bridge, or 2) realign NW Golf Club Hill Road to connect with Chico Way upstream and thus enable complete removal of the stream crossing at NW Golf Club Hill Road. Kitsap County and the Kitsap Conservation District completed a feasibility assessment to evaluate alternatives to relocate NW Golf Club Hill Road in 2012. The conclusion was that all alternatives to relocate the road out of the stream corridor were not feasible because access routes could not be coordinated to cross private properties to the north of Chico Creek. The recommended approach in the conceptual design developed as part of the feasibility study is to replace the existing triple box culvert with a bridge crossing approximately 100 ft in width. This approach will help address fish passage issues and aid in restoration of habitat-forming processes; however, this approach will retain most of the artificial fill confining the floodplain in this channel segment. Conceptual design of a new bridge crossing was prepared as part of the feasibility assessment by Kitsap County and the Kitsap Conservation District. The Suquamish Tribe has sponsored a project to advance designs for the bridge crossing using grant funding awarded from the SRFB in 2014. The recommended long term solution is to pursue alternatives to realign NW Golf Club Hill Road and remove the old railroad grade that fills approximately 400 linear ft of the floodplain surface.

Property ownership constrains opportunities to realign NW Golf Club Hill Road. Furthermore, the floodplain constriction created by the railroad grade protects the downstream property (Kitsap Golf & Country Club) from flooding and channel migration hazards. Removal of this fill and restoration of natural processes through this channel segment will likely require negotiation of conservation easements with the golf course. Culvert replacement work should be coordinated with important and complementary actions to restore in-stream and floodplain habitat upstream of the culverts, extending approximately 1,000 ft to NW Chico Way. A project that replaces the Golf Club Hill Rd. culverts but fails to restore reach-scale processes would continue to put the 1000 ft of degraded stream channel upstream at risk of incision and further degradation.

C7. Floodplain restoration upstream of NW Golf Club Hill Road (Keta Park)

Problem: Past impacts to reach-scale processes in this channel segment have resulted in channel incision and disconnection of floodplain habitats. Key factors degrading habitat conditions include: floodplain constriction at the triple box culvert for NW Golf Club Hill Road, loss of roughness elements such as instream wood, and impairment of riparian processes such as wood recruitment and shade. Existing habitat conditions are characterized by a lack of channel complexity (few pools, limited refugia), low abundance of instream wood, loss of side-channel and off-channel habitats, and poor riparian conditions (Figure 51).

Approach: This action will restore floodplain connectivity and instream habitat conditions by removing artificial fill confining the stream corridor, strategic placement of large wood, creation of side-channel and off-channel habitats, and restoration of riparian forest conditions. Kitsap County acquired the 4.5 acre parcel upstream of NW Golf Club Hill Road (Time Oil property) in 2007 using grant funding awarded by the SRFB. The Suquamish Tribe has sponsored a project to design the floodplain and instream habitat enhancements in conjunction with the design for replacement of the NW Golf Club Hill Road culverts using additional grant funding awarded from the SRFB in 2014. This action should be coordinated with channel/floodplain modifications with replacement of the triple box culvert downstream at NW Golf Club Hill Road. Design will also need to coordinate with private landowners along the east side of Chico Creek.

Invasive plant removal and restoration planting of native conifers, a community project currently underway by the Chico Creek Task Force, could help re-establish a coniferous forest to the riparian zone in the Keta Park reach (as described further under Restoration Strategies). This effort would be most successful if conducted in the proper sequence after floodplain re-contouring is completed as part of the public park envisioned for this area and if the trees are carefully planted in shaded areas of the existing canopy which is dominated by hardwoods, shrubs, and non-native plants. Side channel construction could also restore some riparian habitat to this portion of the stream and support an increased supply of allochthonous (i.e., leaf litter) organic matter. A historically appropriate mixture of riparian zone species would include western red cedar, Sitka spruce, willow, black cottonwood, salmonberry, and sword-fern.

Figure 50. Photo of the triple box culvert at NW Golf Club Hill Road (view upstream). Photo taken November 2012 by Shawn Higgins, NSD.

Figure 51. Photo of Chico Creek upstream of NW Golf Club Hill Road (view downstream). Photo taken February 2013 by Steve Todd, Suquamish Tribe.

C8. Chico Way NW bridge replacement and side channel reconnection

Problem: Artificial fill constricts the floodplain and restricts habitat-forming processes in the upstream and downstream reaches. The Chico Way bridge was damaged in the December 2007 flood and replaced with a new structure in 2009. The investment in this new structure likely limits opportunity to replace the bridge for several decades until the structure is nearing the end of its design expectancy or is damaged in future flood events. Unfortunately, the new bridge continues to confine the stream corridor. In addition, an isolated side channel feature in the floodplain, approximately 700 ft in length, is disconnected at the upstream end by fill placed for the Chico Way NW road embankment and is disconnected at the downstream end by past incision (Figure 52).

Approach: This action will open up the floodplain to reduce constriction and aid in the restoration of habitat-forming processes in upstream and downstream reaches. The crossing should be constructed with a longer span and/or additional bridges to enable reconnection of floodplain habitats including potential to restore connectivity with approximately 700 ft of right bank side channel habitat. The two parcels are owned by the same landowner and have a combined value of approximately $300,000 as assessed in the 2012 tax records. Acquisition of these properties for conservation of habitat forming processes was explored as part of an earlier feasibility assessment for realignment of NW Golf Club Hill Road. The landowner was not interested in selling property at the time (2012), however, we recommend that stakeholders continue engaging with landowners should future opportunities to acquire the parcels become feasible. Instream habitat enhancement will require strategic wood placements to increase channel complexity and restore natural stream grade through the incised segment. Floodplain areas will be graded at the upstream and downstream ends to reconnect the side channel.

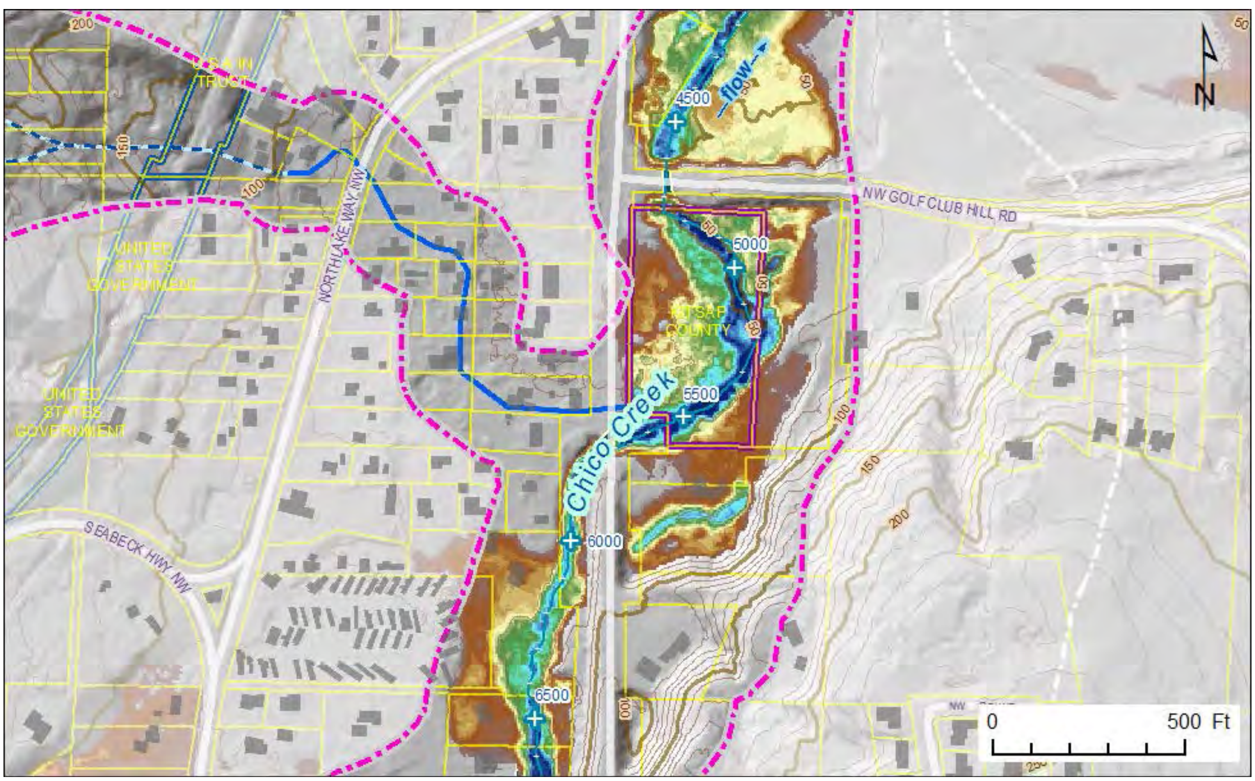


Figure 52. Excerpt from geomorphic map (Appendix A) highlighting the stream reach between NW Golf Club Hill Road and Chico Way NW.

C9. Floodplain restoration between Chico Way NW and Northlake Way NW

Problem: Habitat conditions are degraded from past impacts that have resulted in an incised channel lacking in wood and characterized by low channel complexity with few pool habitats. The geomorphic response to channel incision includes a tendency to widen and erode channel banks. This response, which is the process by which the stream would restore habitat-forming processes in the absence of further disturbance, is constrained by residential development and bank armoring practices to protect infrastructure that has encroached into the stream corridor (Figure 53). One house located along the left bank near the confluence with Kitsap Creek was destroyed in response to bank erosion during the December 2007 flood. Two other properties in this reach were sites of bank protection projects funded in part by the NRCS Emergency Watershed Protection (EWP) and Kitsap County (Figure 54).

Approach: This action will restore instream habitat conditions and floodplain connectivity with strategic wood placements designed to increase channel complexity and restore natural stream grade control. Limited wood placements to increase channel complexity could be implemented in the short term; however, such an approach would not restore habitat-forming processes. Short term efforts to enhance habitat conditions should focus on localized areas where the channel has eroded into the terrace surface and a small inset floodplain is developing. A more holistic approach to process-based restoration will require substantial volumes of wood to reverse the effects of past incision and restore floodplain connectivity. Multiple houses are located within the stream corridor along the left bank and pose constraints to restoration of reach-scale processes through this segment. Restoration of riparian processes will require removal of bank armor and revegetation of the riparian forest. The long term approach to restoration of the stream corridor through this segment will require coordination with willing landowners in negotiating conservation easements and/or acquisition of 12-15 properties between Chico Way NW and Northlake Way NW. Land acquisition will be complicated by the need to coordinate with numerous landowners. Acquisition of key parcels to facilitate restoration is estimated at approximately $1.5 M based on 2012 tax records.

Figure 53. Photo of incised channel conditions, armored banks, and road fill (at left) in Chico Creek upstream of Chico Way NW (view upstream). Photo taken December 2011 by Steve Todd, Suquamish Tribe.

Figure 54. Photo of incised channel and riprap bank protection along the left bank downstream of Northlake Way. Photo taken in Oct. 2012 by Shawn Higgins (NSD).

C10. Northlake Way bridge replacement

Problem: At present, the bridge span is not a problem as the channel is confined within the incised corridor that downcut below the pre-settlement floodplain in response to human land use activities in the watershed. Planned restoration actions in upstream and downstream reaches, however, will result in a more dynamic channel system and aggrade the bed over time as the channel erodes into the terrace surface and sediment transport capacity is reduced by additional hydraulic roughness and expanded cross-sectional area. The future condition, assuming natural processes are restored in adjacent reaches, may require design of a wider bridge span in this location.

Approach: Design a bridge span that enables dynamic channel processes connecting upstream and downstream reaches.

C11. Floodplain restoration between Northlake Way NW and NW Taylor Road

Problem: Habitat conditions are degraded from past impacts that have resulted in an incised channel (Figure 55) lacking in wood and characterized by low channel complexity with few pool habitats. The relatively flat surface on the inside of the 90 degree bend upstream of the Dickerson Creek confluence represents the pre-settlement floodplain surface prior to channel incision.

Approach: This action will aim to restore floodplain connectivity, riparian processes, and instream habitat conditions. The primary mechanism for past channel incision has been removal of instream roughness due to loss of instream wood and impairment of riparian processes. Restoration actions should include targeted wood placements to increase channel complexity and restore natural stream grade. Kitsap County acquired 4 parcels totaling 4.8 acres along the right bank of Chico Creek in 2010, including the triangular land area between Chico Creek, Taylor Road, and Dickerson Creek. Additional acquisition of property along the left bank will be required to facilitate restoration of riparian processes and ensure wood placements do not create flood hazards to adjacent landowners. The 3 parcels recommended for acquisition total approximately 4 acres and have an assessed value of about $600,000 per 2012 tax records.

C12. NW Taylor Road bridge replacement

Problem: At present, the bridge span is not a problem as the channel is confined within the incised corridor that cut down below the pre-settlement floodplain in response to human land use activities in the watershed. Planned restoration actions in upstream and downstream reaches, however, will result in a more dynamic channel system and aggrade the bed over time as the channel erodes into the terrace surface and sediment transport capacity is reduced by additional hydraulic roughness and expanded cross-sectional area. The future condition, assuming natural processes are restored in adjacent reaches, may require design of a wider bridge span in this location.

Approach: Design a bridge span that enables dynamic channel processes connecting upstream and downstream reaches.

C13. Floodplain restoration between NW Taylor Road and the Navy RR trestle

Problem: Habitat conditions are degraded from past impacts that have resulted in an incised channel lacking in wood and characterized by low channel complexity with few pool habitats (Figure 56). The geomorphic response to channel incision includes a tendency to widen and erode channel banks. In the absence of further impacts to floodplain and riparian processes, such erosion can be part of an evolving trajectory that could restore habitat-forming processes in the reach. This response is constrained, however, by residential development and bank armoring that protects infrastructure within the stream corridor. There are houses adjacent to this channel segment within 40 ft of the stream bank on both sides of the channel. A private driveway crosses the stream immediately downstream of the Navy RR trestle and has undermined footings due to channel incision. Bank armoring efforts include a recent project adjoining the church property on the left bank upstream of Taylor Road completed as part of the project funded by NRCS EWP and Kitsap County in response to erosion that occurred during the December 2007 flood.

Approach: This action will aim to restore floodplain connectivity, riparian processes, and instream habitat conditions. The primary mechanism for past channel incision has been removal of instream roughness due to loss of instream wood and impairment to riparian processes. Restoration actions should focus on restoring the riparian forest conditions and include targeted wood placements to increase channel complexity and restore natural stream grade. Properties within the stream corridor should be dedicated to maintenance and provision of habitat-forming processes. Landowner negotiations should consider opportunities to establish conservation easements and/or land acquisition to facilitate restoration in the stream corridor. Key parcels intersecting the preliminary corridor boundary in this segment include 10 parcels totaling 6.5 acres (5 along David Road and 5 along Taylor Road) with an assessed value of $1.6 M per 2012 tax records. Additional negotiation should focus on opportunities to provide alternative access to property on the north side of the creek and removing the existing driveway crossing. The property along the south side of the channel (right bank) includes low-lying areas on the south side of David Road that could provide opportunities for floodplain connectivity and off-channel habitat.

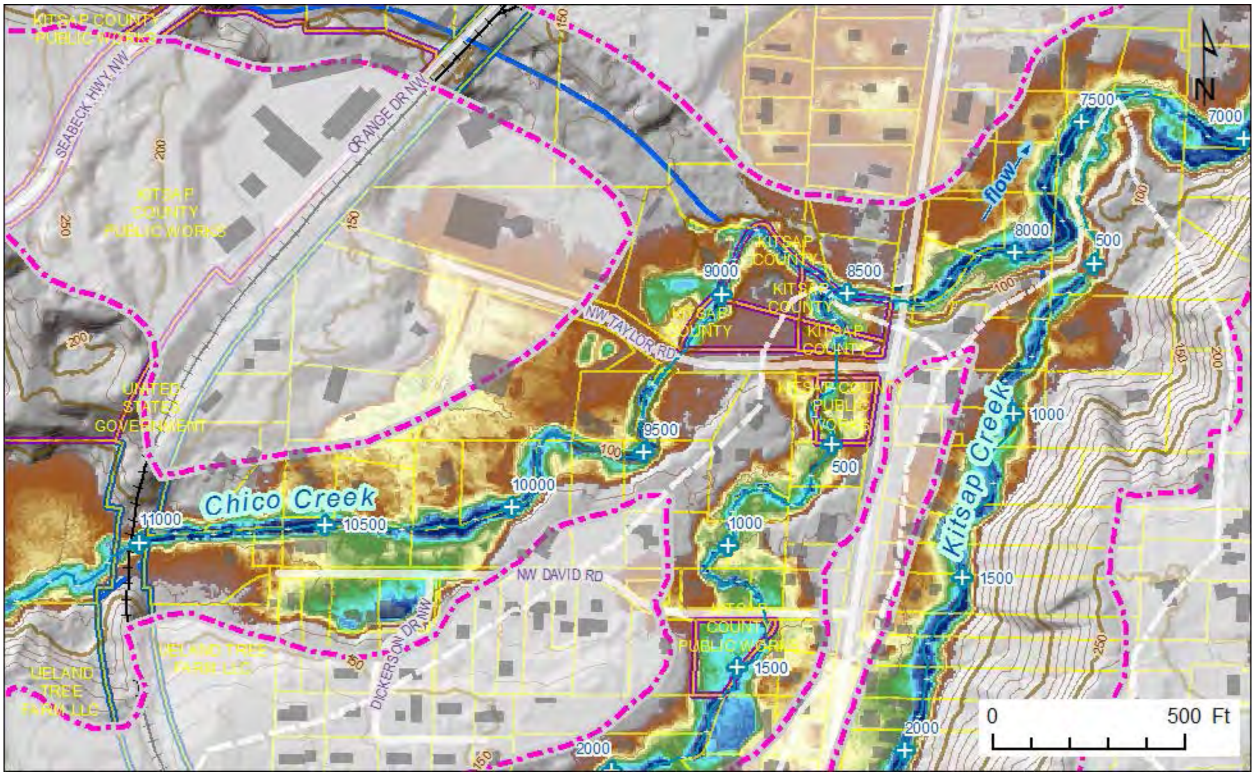


Figure 55. Excerpt from geomorphic map (top, Appendix A) and aerial imagery (bottom, Appendix B) highlighting the stream corridor (dashed pink line) between Chico Way NW and the Navy RR trestle as well as the lower reaches of Kitsap and Dickerson Creeks.

Figure 56. Photo of channel and riparian conditions in Chico Creek between Taylor Road NW and the Navy RR Trestle (view upstream). Photo taken August 2012 by Steve Todd, Suquamish Tribe.

C14. Replace Navy RR trestle

Problem: The Navy RR trestle was constructed in the 1940s of creosote-treated timber. Support piles occur within the stream channel, and trestle approaches are on fill that constrict the valley and constrain habitat-forming processes (Figure 57).

Approach: The trestle should be replaced with a longer span that accommodates channel migration and establishment of a wider stream corridor through this incised channel segment.

Figure 57. U.S. Navy RR trestle crossing at Chico Creek.

C15. Floodplain restoration upstream of Navy RR trestle

Problem: The river channel is incised due to past impacts to reach scale processes. Riparian processes are impaired by residential development along the left bank in the stream corridor for the channel segment extending approximately 900 ft upstream. Instream habitat conditions are impaired by lack of wood, limited channel complexity and few pool habitats. There is artificial fill from an abandoned road grade that constrains the channel immediately upstream of the railroad trestle.

Approach: This action will aim to restore floodplain connectivity, riparian processes, and instream habitat conditions. Restoration actions should focus on removal of artificial fill along the abandoned road grade constricting the channel at RS 11100, restoring riparian forest conditions, and targeted wood placements to increase channel complexity and restore natural stream grade. Restoration of riparian processes will require negotiation of conservation easements or acquisition of the streamside parcel along the northern (left) bank. The parcel totals 6 acres and has an assessed value of $240,000 per 2012 tax records. This action is constrained, in part, by channel confinement at the Navy RR trestle. The channel reach upstream of this segment flows through parcels that are part of the Mountaineers Foundation Rhododendron Preserve, where riparian conditions are more intact, instream wood is more abundant, and a broader floodplain exists due to the lack of bank protection.

5.2 KITSAP CREEK

The long term strategy throughout the Kitsap Creek subbasin should include working with willing landowners on habitat enhancement, negotiation of conservation easements, and/or acquisition of land areas within the stream corridor and removal of features constraining floodplain processes such as riprap along the channel bank and houses on the disconnected floodplain surface. Concurrent with negotiations to dedicate land within the stream corridor to protection and restoration of habitat-forming processes, we recommend near term actions that focus on addressing fish passage issues, enhancement of riparian conditions, and increasing channel complexity with wood placement. Note, however, that implementation of the long term strategy (restoring floodplain processes in the stream corridor) is essential for the long term sustainability of restoration actions.

Specific actions recommended in the Kitsap Creek subbasin are summarized below.

K1. Instream habitat enhancement at the confluence with Chico Creek

Problem: The tributary confluence with Chico Creek is impaired by bank protection and past impacts to riparian processes including loss of mature forest, large instream wood, and presence of invasive non-native plant species.

Approach: Large wood placements to create additional complexity near the tributary confluence will improve habitat conditions in the near term while concurrent efforts to set back constraints to floodplain processes can be implemented.

K2. Floodplain restoration along lower Kitsap Creek (to change in confinement near RS 2500)

Problem: Habitat forming processes are impaired in the lower reaches of Kitsap Creek by lack of floodplain connectivity due to channel incision, lack of large wood, and armored bank protection. Residential development encroaches into the stream corridor with some houses located on the former floodplain surface (converted to terrace by incision) less than 20 ft from the streambank (Figure 55). Riparian conditions are impaired throughout the area of residential development, mainly along the left (west) bank. The restoration strategy in these reaches is constrained by the existing land use pattern. The stream channel lacks wood and has few pools.

Approach: Near term actions to prevent further channel incision and increase channel complexity should focus on wood placement to replace the functions previously provided by large trees recruited to the channel. Concurrent efforts should be made to work with willing landowners to enhance habitat, negotiate conservation easements, and/or acquire property in the stream corridor to enable removal of floodplain constraints such as bank protection and houses from floodplain and replant the riparian forest which has been cleared along much of the left bank.

K3. Improve fish passage at stream crossing for private road near RS 2400

Problem: A private driveway spanning the channel near RS 2400 (see Appendices A and B) is a partial barrier to fish passage, and may impede the transport of sediment and large wood (Figure 58).

Approach: Replace the crossing with a wider culvert or bridge span, or remove road crossing from the floodplain.

Figure 58. Photo of partial barrier to fish passage in Kitsap Creek at RS 2400 (view upstream). Photo taken August 2012 by Steve Todd, Suquamish Tribe.

K4. Enhance instream habitat in the confined valley segment downstream of Kitsap Lake

Problem: The channel is incised by impaired wood recruitment and confined by steep banks on both sides. This segment is less impacted by residential development compared to the downstream segment; however, natural wood recruitment is not fully functional.

Approach: Wood placement to increase channel complexity.

K5. Improve fish passage at the Northlake Way NW stream crossing

Problem: The stream is confined within a narrow culvert passing through the road embankment at Northlake Way (Figure 59). The culvert is identified by WDFW fish passage barrier inventory as a complete barrier; however, there are known observations of adult coho making it upstream to the lake (Haring, 2000). As such, the culvert is considered a partial barrier.

Approach: Replace the crossing with a bridge.

Figure 59. Photo of partial barrier to fish passage in Kitsap Creek at Northlake Way NW (view downstream). Photo taken August 2012 by Steve Todd, Suquamish Tribe.

K6. Remove infrastructure from outlet of Kitsap Lake

Problem: Fish screens at the outlet of Kitsap Lake previously restricted anadromous fish passage. The screens were removed in 1999; however, the concrete pieces that supported the screens remain in the channel (Figure 60). At times, this infrastructure has been altered by local residents to control the lake level without authorization. Such action results in rapid drawdown of streamflow in downstream segments of Kitsap Creek.

Approach: Remove infrastructure from the channel at the lake outlet to prevent future manipulation of lake levels.

Figure 60. Existing infrastructure at outlet of Kitsap Lake (photo by S. Todd, August 2013).

K7. Floodplain restoration upstream of Kitsap Lake (Kitsap Lake Road to Reba Way)

Problem: Compared to other parts of the Chico Creek watershed, the floodplain through this segment is relatively intact. There is a 1,000 ft long segment between W. Kitsap Lake Road and W. Reba Way in which floodplain and riparian processes are impaired by residential development that has cleared part of the riparian forest along the west side of the valley. Both stream crossings are identified as partial barriers to fish passage.

Approach: The long term strategy should include restoration of the floodplain forest in the segment that has been cleared for development. In the near term, fish passage should be addressed by replacing culverts at W. Kitsap Way and W. Reba Way with wider culverts or bridge spans that do not restrict fish passage.

K8. Floodplain restoration upstream of Reba Way

Problem: The floodplain through this reach is relatively intact; however, there are active mining activities that encroach into the stream corridor.

Approach: Protect the stream corridor from mining or development. All permits for mining activities should be reviewed for compliance with existing regulations.

The access road to Kitsap Quarry currently crosses Kitsap Creek with at least one culvert that is a partial barrier to fish passage on its own and a complete barrier when screened with a home-made beaver deceiver. Potential future restoration activities could include either removal or relocation of the road that results in fewer impacts.

5.3 DICKERSON CREEK

The lower reaches of Dickerson Creek downstream of the Navy railroad grade have been impacted by channel incision and continued impairment to floodplain processes by residential development. Channel segments upstream of the railroad grade have been impacted by past timber harvest but have not been developed and are in the recovery process. The large scale or cumulative conversion of existing forestlands in the Chico watershed to more intensive uses including but not limited to residential, commercial, industrial, or mining may pose a threat to watershed processes, with the potential to compromise or undermine existing and future efforts to otherwise improve watershed and habitat conditions. Restoration strategies to prioritize in the Dickerson Creek subbasin include removing constraints to floodplain processes, enhancing channel complexity with functional wood placements, and protection of the stream corridor where functioning floodplain habitat is available.

D1. Floodplain restoration from David Road to confluence with Chico Creek

Problem: This lower reach of Dickerson Creek is severely incised due to land use impacts, the loss of large wood, and floodplain disconnection. Riparian areas have been cleared and the channel lacks pools and complex cover necessary to provide resilient habitat.

Approach: Actions will include stable wood placements to force pools, provide cover and trap sediment to reconnect the channel with adjacent floodplain areas. Work should be coordinated with efforts to increase wood loading to Chico Creek as lower Dickerson Creek will need to match grade at the invert of the mainstem Chico Creek channel. The culverts presently control grade and limit further upstream incision. As such, some form of grade control will need consideration as part of the project to prevent further impairment of instream habitat from incision. Approximately 3 acres of the Dickerson stream corridor at the confluence with Chico Creek were acquired by Kitsap County in 2010. The County is currently completing design of the Dickerson Creek culvert replacement and stream restoration project with final design plans anticipated in 2014 to replace culverts at David and Taylor Roads, and to restore floodplain and riparian areas in the stream corridor.

D2. Floodplain restoration from David Road to failing log weirs

Problem: The floodplain upstream of David Road is relatively intact compared to the lower segment; however, the stream corridor is impaired from residential development set back only 60-80 ft from the channel and past clearing of the riparian forest.

Approach: Short term actions in this segment include wood placements to increase channel complexity. In the long term strategy, opportunities should be explored to work with willing landowners on habitat enhancement, conservation easements, and/or property acquisitions to support dedication of the stream corridor for floodplain and riparian processes.

Figure 61. Photo of incised channel segment on Dickerson Creek downstream of failed log weirs (view downstream). Note box at toe of right bank is exposed septic basin. Photo by Tim Abbe, NSD (2/12/2013).

D3. Floodplain restoration from log weirs to Navy RR culverts

Problem: Channel incision has resulted in an entrenched channel and disconnected adjacent floodplain areas (Figure 61). Log weirs were previously constructed to maintain grade control in the incised channel segment downstream of the Navy RR culverts. The log weirs were damaged in the December 2007 flood and created a fish passage barrier for several years until 2013 when the channel eroded around the end of the logs (Figure 62). There is fill (abandoned road) isolating about half of the potential floodplain area beginning 500 ft downstream of the railroad grade.

Approach: Functional wood is needed in this channel segment to increase channel complexity and help aggrade the bed to reconnect floodplain areas that have been disconnected by channel incision. Failure of the previously installed log weirs highlights the need to support natural floodplain processes such as channel migration and the importance of treating the entire stream corridor rather than fixing the stream within its artificially confined (induced by incision) channel. Removal of the fill materials along the abandoned road alignment will restore connectivity to potential off channel habitat.

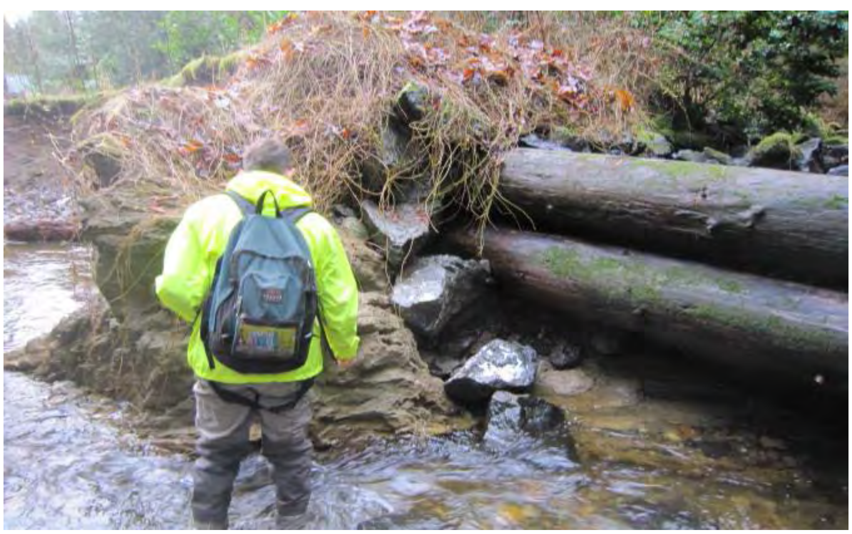


Figure 62. Photos of log weirs on Dickerson Creek downstream of Navy railroad in 2007 (Upper; photo by Jon Oleyar, Suquamish Tribe) and in February 2013 (Lower; photo by Paul Dorn, Suquamish Tribe). Note erosion around failing weir in 2013.

D4. Replace stream crossing at Navy railroad

Problem: The U.S. Navy railroad crossing at Dickerson Creek is constructed on artificial fill that rises 40 ft above the valley floor. Two metal culverts pass through the railroad embankment. The culvert outlets are perched due channel incision downstream. A fish ladder maintains passage to one of the culverts (Figure 63); however, the culverts are assumed to be velocity barriers during high flows and also pose passage problems during low flows. The crossing restricts conveyance of sediment and wood from upstream reaches. Sediment and wood accumulate on the upstream side of the railroad grade during floods and are removed from the channel by the Navy's routine maintenance (Figure 64).

Approach: Replace the crossing with a bridge or trestle to enable transport of sediment and wood downstream, and to improve fish passage.

Figure 63. Photo of Dickerson Creek at the Navy railroad culverts. View upstream; February 2013 (photo by Paul Dorn, Suquamish Tribe).

Figure 64. Photos of Dickerson Creek at the Navy railroad, view looking downstream. Upper photo from October, 2012 (photo by Tim Abbe, NSD). Lower photo from December 2010 shows blockage of the 48" diameter culverts (photo by Jon Oleyar, Suquamish Tribe).

D5. Protection of floodplain and riparian processes upstream of the Navy RR culverts

The Dickerson Creek subbasin area upstream of the Navy railroad is nearly entirely owned by the Ueland Tree Farm. There is greater than 2,500 ft of anadromous fish habitat upstream of the railroad and, while not pristine, the floodplain area through this segment of the stream corridor is relatively intact and there is no development. Protection of the functioning floodplain habitat in this area is an important part of the restoration strategy for Dickerson Creek. Riparian forests have been previously harvested but are in the process of recovery. One exception is an approximately 200 ft long segment upstream of the railroad where the forest is cut along the right of way for overhead powerlines crossing the channel.

There is a series of two natural falls on upper Dickerson Creek (at river station 6,000 and 9,000 ft, respectively) connected by a confined channel segment. Immediately upstream of the upper falls is a low concrete dam. Beyond this point, the channel gradient declines and the valley expands to include substantial wetland areas. These wetlands are important for moderating the hydrologic regime and augmenting summer low flows in lower Dickerson and Chico Creeks.

Protection of floodplain and riparian areas in the upper Dickerson subbasin should be coordinated with management from Ueland Tree Farm, the primary landowner. Ueland Tree Farm prepared a Preliminary Conservation Plan in 2007 (Figure 65). In 2009 Ueland Tree Farm granted a conservation easement to the Mountaineers Foundation to protect its conservation values. We recommend implementation of the other “proposed conservation areas” shown in this plan including the unconfined floodplain area between the railroad grade and the lower falls, and potentially additional riparian corridors upstream of this point. Actions to protect riparian functions within the stream corridor throughout these valley segments are consistent with the FSC Forest Management Plan for the Ueland Tree Farm property.

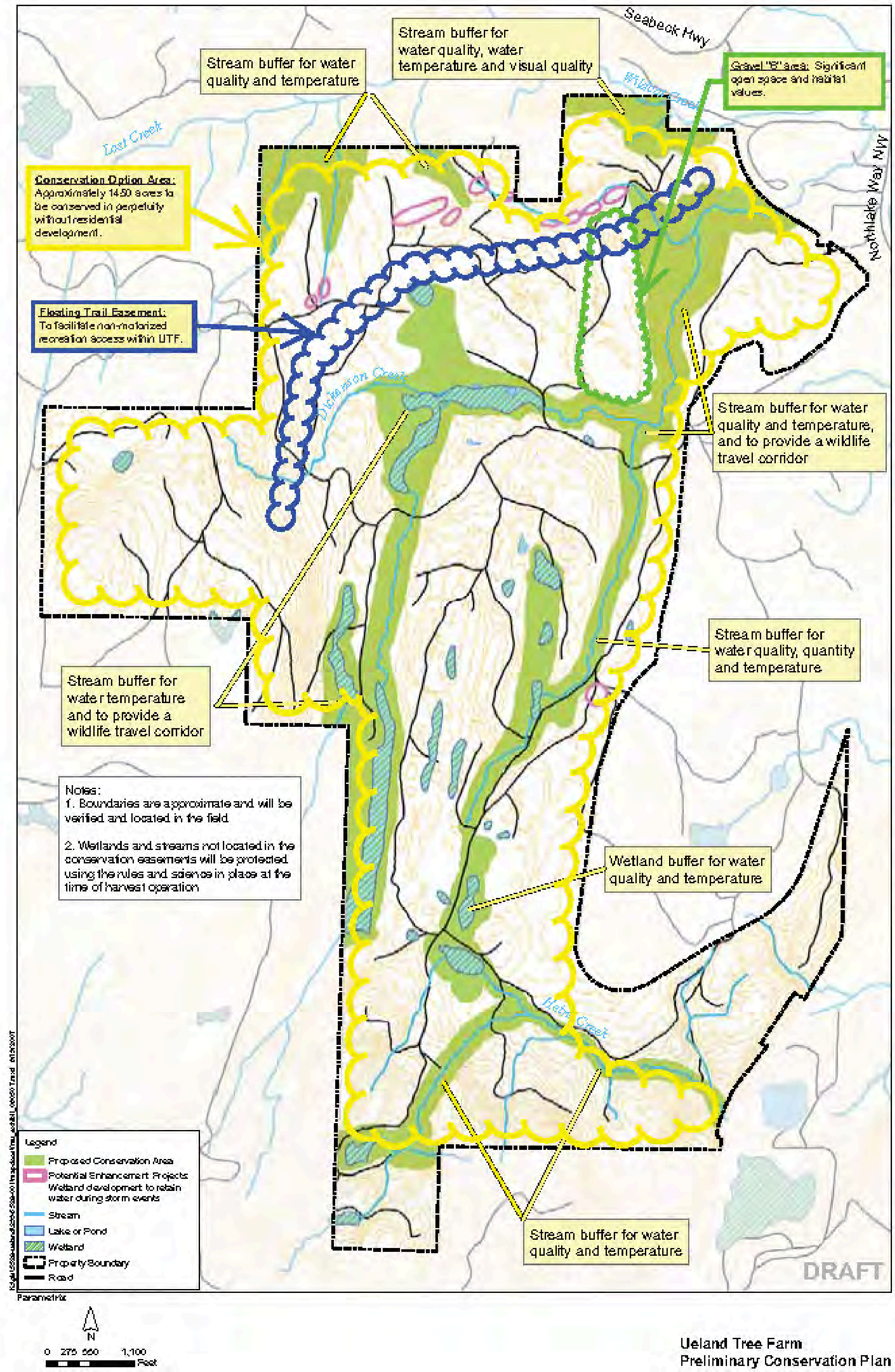


Figure 65. Draft map from Ueland Tree Farm's 2007 Preliminary Conservation Plan. Note that map does not reflect the 2012 purchases by the Mountaineers Foundation.

5.4 LOST CREEK

The lower 4,000 ft of the stream corridor along Lost Creek is within the boundary of the Mountaineers Foundation Rhododendron Preserve and has relatively intact floodplain and riparian processes. The forest within the reserve is relatively mature and includes several old growth trees that provide excellent example of the size of timber that previously were recruited to the valley bottom prior to clearance of the original riparian forests. This channel segment is considered protected from future impacts under the current management strategy for the property.

Headwater tributaries along the south side of the corridor in lower Lost Creek are part of the Ueland Tree Farm property.The Mountaineers Foundation purchased three parcels from the Ueland Tree Farm in 2012 with a donation from the Suquamish Tribe using grant funding from the EPA National Estuary Program. The two parcels to the west include substantial portions of tributaries to Lost Creek that were protected in 2009 by a conservation easement to the Mountaineers Foundation from the Ueland Tree Farm. The conservation easement still protects the top of the plateaus of both tributaries (Appendix A, Sheet 9 of 21).

Property upstream of RS 4000 is owned by WDNR as part of the Green Mountain State Forest. Past impacts from logging are evident in the forest composition and from areas of recent landslide activity triggered by removal of the forest from steep hillslope areas. The stream corridor through this segment is in the process of recovering from past impacts and should be protected from future timber harvest and road construction.

There is an approximately 1,000 ft long segment in the upper portion of the Lost Creek subbasin under private ownership. The stream corridor in this segment intersects properties along Lost Creek Lane NW. These properties are located just upstream of an abandoned road crossing on the WDNR property which has been removed. The restoration and protection strategy should include coordination with the property owners in this segment to dedicate land in the stream corridor to restore the riparian forest and protect the land through conservation easements or land acquisition.

5.5 WILDCAT CREEK

Overall, the stream corridor along Wildcat Creek is in relatively good condition compared to lower portions of the Chico Creek watershed. The restoration strategy should aim to protect segments of the corridor that are currently functioning through negotiation of conservation easements or acquisition of key parcels. Localized areas of floodplain and riparian impacts should be restored. Key recommended actions in the Wildcat Creek subbasin include:

W1. Floodplain Restoration through the homestead area of the Mountaineers Foundation Rhododendron Preserve

Problem: The riparian forest has been cleared along the lower 500 ft of Wildcat Creek (at the confluence with Lost Creek) as part of an abandoned homestead that is now part of the Rhododendron Preserve (Figure 66). The channel is slightly incised, has unvegetated banks, and is lacking in channel complexity due to impairments to natural wood recruitment.

Approach: Re-establishing native forest is crucial to the long term restoration of the stream corridor. Recent efforts to remove abandoned buildings from the property create opportunity to re-plant riparian vegetation. The addition of large wood to the stream will not only increase the number of pools and cover, but raise water elevations and improve floodplain connectivity. Minor excavation work can restore ephemeral side channels and wetlands along the left bank floodplain that were filled when the site was farmed. Beavers have been very active in the area and restoration designs at this site (as well as some other locations in the watershed) will need to consider how beavers utilize the area and alter the channel, floodplain, and riparian characteristics of the stream corridor. The site may be ideal for public access where visitors can see a very rare Puget Lowland stream in near-pristine condition (upstream of homestead) and see a locally impacted area in the process of being restored.

Figure 66. Photo of the homestead area along Wildcat Creek at the confluence with Chico and Lost Creeks (photo taken Oct. 2013 by Tim Abbe, NSD).

W2. Protect corridor through privately owned parcels upstream of Mountaineers Foundation Rhododendron Preserve

Problem: There is an approximately 3,500 ft long segment along Wildcat Creek, between the Rhododendron Preserve and WDNR properties that is under private ownership. Future timber harvest and/or development may impair riparian and other habitat-forming processes within the corridor. The stream corridor should be protected to maintain habitat forming processes in this segment.

Approach: Coordinate with landowner groups to establish conservation easements for the entire stream corridor, and/or pursue land acquisition for conservation purposes.

W3. Protect corridor at confluence with tributary from Newberry Hill wetlands

Problem: There is an approximately 500 ft long segment along Wildcat Creek at the tributary junction and additional 800 ft of tributary channel that is under private ownership, and therefore is at risk of future timber harvest and development that could impair habitat-forming processes within the corridor. The stream corridor should be protected to maintain habitat forming processes in this segment.

Approach: Coordinate with landowner groups to establish conservation easements for the entire stream corridor, and/or pursue land acquisition for conservation purposes.

W4. Stream and wetland road crossings in Newberry Hill Heritage Park

Problem: There are stream and wetland crossings in Newberry Hill Heritage Park upstream of Seabeck Highway that may impair hydrologic processes and could be barriers to fish passage. The existing culvert at Seabeck Highway constricts the stream corridor and is a partial barrier to fish passage.

Approach: Coordinate with stakeholder groups to implement the 2011 Newberry Hill Heritage Park Road Maintenance Plan. Further assessment may be needed to evaluate existing infrastructure and hydrologic characteristics of the wetland complex. This includes evaluation of potential replacement or rmodification of the culvert at Seabeck Highway to address fish passage impairment that isolates the upstream wetland areas.

W5. Culvert replacements for NW Wildcat Lake Road

Problem: There are two culverts crossing fish-bearing tributaries to Wildcat Lake on the road. One, located approximately 500 ft northwest of Schulz Rd NW, is identified by WDFW (2012) as a total barrier to fish passage. The second, approximately 500 ft west of the junction with Wild Ridge Ln NW, is identified by WDFW (2012) as a partial barrier. Both culverts block large areas of habitat for coho and/or steelhead. These habitat areas are now more accessible to fish following replacement of a previous passage barrier located downstream of the lake at NW Wildcat Lake Rd in 2011.

Approach: Replace the passage barrier crossings with wider culverts or bridges.

6 DATA GAPS AND RECOMMENDATIONS FOR FUTURE WORK

This assessment aimed to identify protection and restoration strategies that prioritize specific actions to maintain and/or improve salmonid habitat conditions and ecological resilience in the Chico Creek watershed. Assessment of watershed impairments was based primarily on review of previous studies and by GIS analysis of existing information. Further refinement and expansion of this study is warranted to include more detailed investigation and to address data gaps identified in the assessment.

Additional work needed to refine the assessment of salmonid habitat and watershed impairment includes:

- Targeted stream typing to map the full extent of fish habitat in the Chico Creek watershed;
- Coordination of a stakeholder group including major forest landowners (e.g., UTF, WDNR) to prioritize long-term management of harvest, roads, and invasive plants;
- Investigation of the current use, and potential for improving productivity and abundance of steelhead in the watershed;
- Investigation of the full extent of coho use in Wildcat Lake and its tributaries and further assessment of habitat conditions and passage barriers in the tributary streams;
- Inventory and evaluation of fish, wildlife, and hydrologic characteristics of headwater tributaries and wetlands.
- In particular, evaluation of fish usage in the Newberry wetland complex;
- Further assessment of wood loading and recruitment (re-survey reaches sampled in 2002 and expand the survey to include additional tributary reaches;
- Field assessment of tributary streams and evaluation of tributary stream crossings at roads (initial field reconnaissance identified tributary stream crossings to be sensitive to potential problems where the channel has incised downstream of the grade control created by the culverts);
- Reactivation of USGS gaging station in Lower Chico Creek and establishment of a rating curve at a stable location to address gaps in hydrologic record not recorded by KPUD monitoring.
- Detailed sediment budget;
- Field assessment of riparian conditions and a comprehensive inventory of wetlands within the riparian zone;
- Delineation and adoption of a channel migration zone to guide planning efforts; and
- Investigation of historic and current base flows in the Chico Creek watershed with respect to habitat limitations for summer rearing salmonids (coho, steelhead, cutthroat).

Additional tasks to advance the protection and restoration strategies presented in this assessment include:

- Further work to evaluate biological benefits and ranking factors for specific action items
- Refinement of conceptual designs to estimate project costs; and
- Development of a prioritization matrix.
- Form a Chico Watershed Stakeholder group to prioritize and implement actions recommended in this report.

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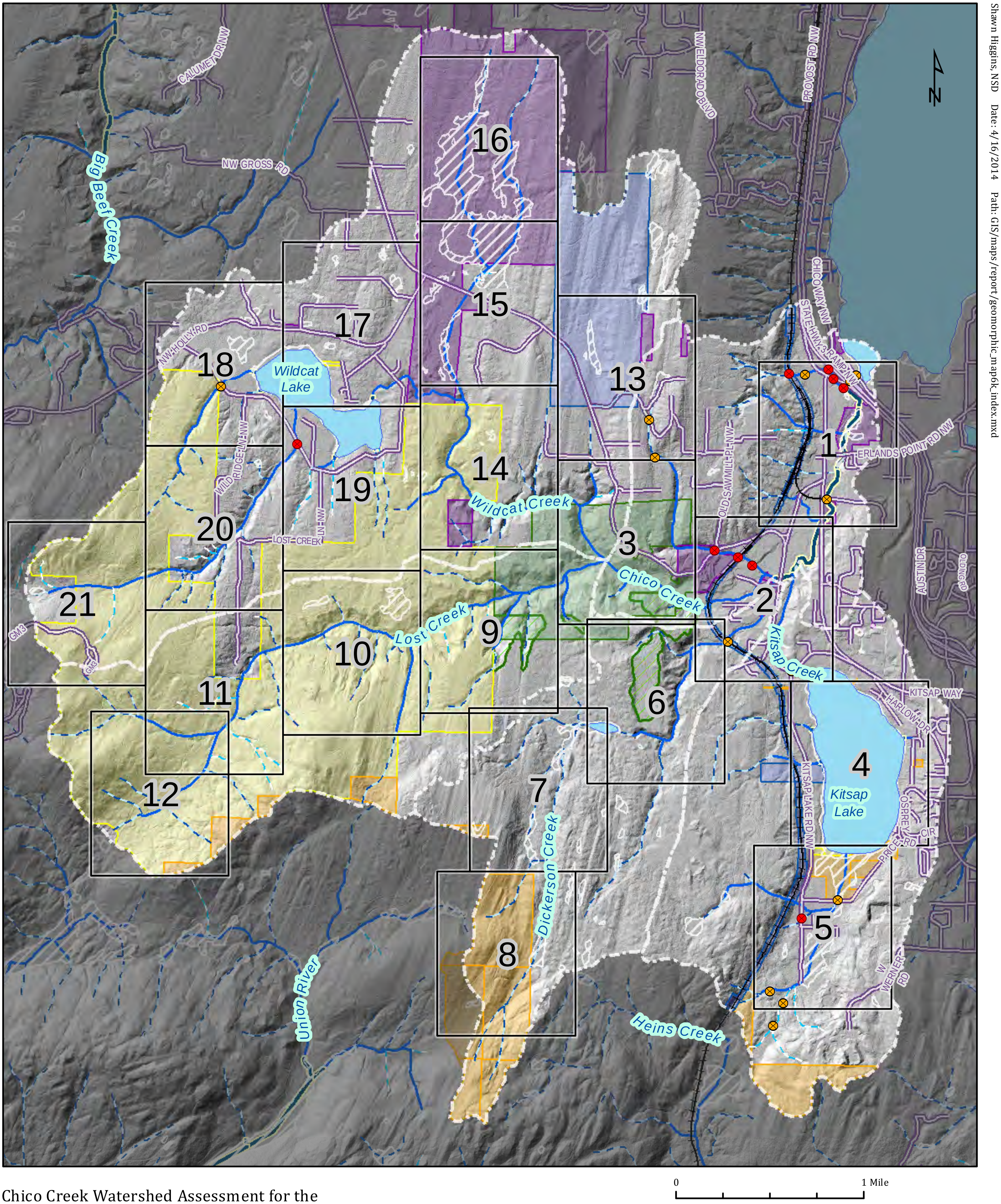
APPENDIX A

Geomorphic Maps with Recommended Actions



Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

Index Sheet for 1:6,000 Scale Geomorphic Map Series

Legend

Passage Barriers

Partial

Total

source: WDFW, 2012. Washington State Fish Passage Barrier Inventory

River stationing (100 ft interval)

Fish Habitat Water Type

Fish Habitat (F)

Non-Fish Habitat (N)

Shoreline of the State (S)

Unknown (U)

source: WDNR, 2006. Washington State Watercourse Hydrography

Inland Water Bodies

Lakes
source: USGS National Hydrography Dataset

Wetland Areas
source: Kitsap County

Stream Corridor

The stream corridor was delineated to incorporate critical areas surrounding stream and wetland features and associated hillslope areas that are directly connected to fluvial landforms in the watershed. Corridor boundaries are mapped for planning purposes only and do not constitute a specific regulatory zone.

Transportation

Road

Railroad

sources: Kitsap County and WDNR

Property Ownership

Parcel Boundaries

source: Kitsap County

Ownership Type

Federal

State

County

Municipal

Conservation Area

Valley Bottom Topography

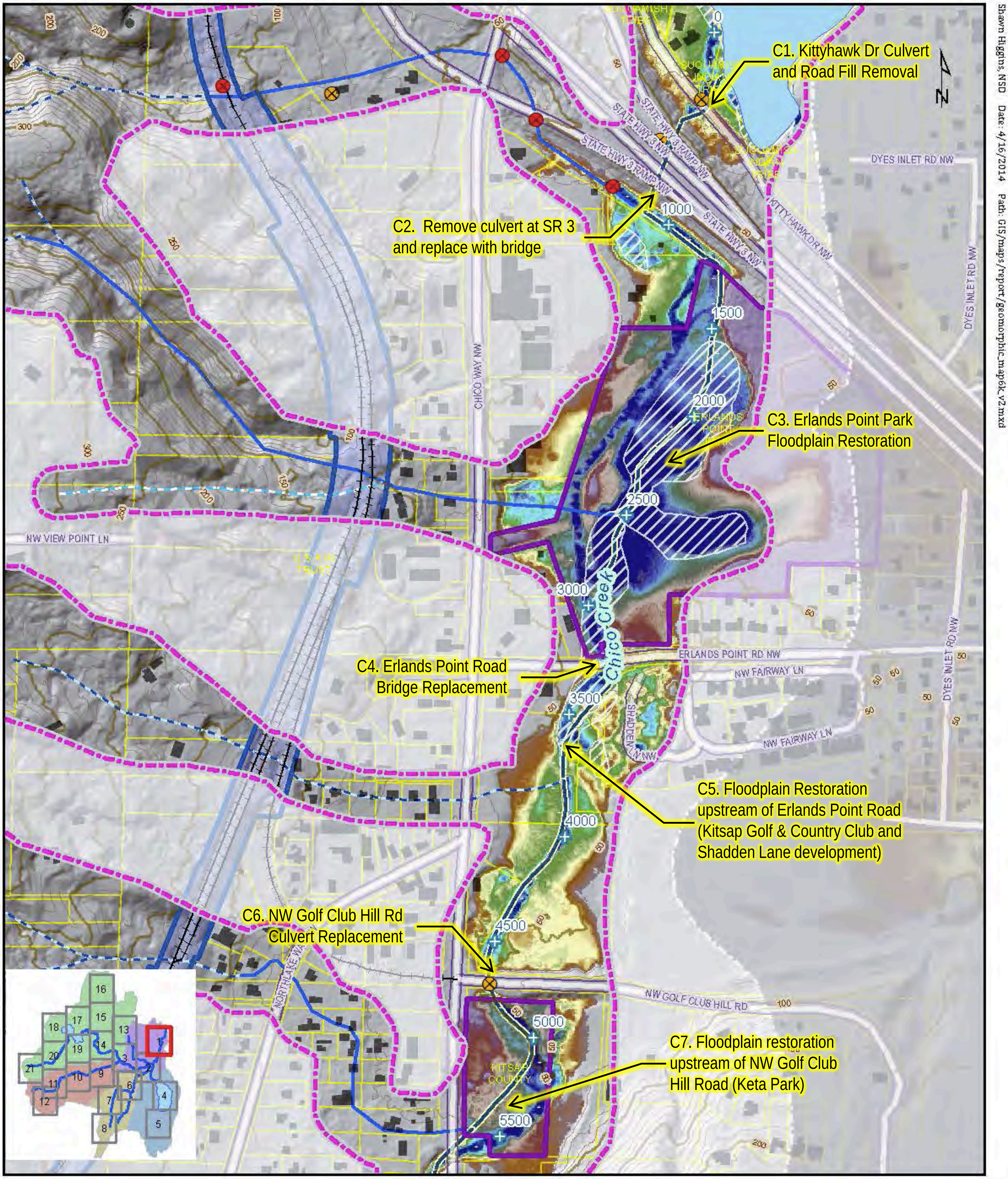
Relative Elevation (ft)

14
12
10
8
6
4
2
0

2000 LIDAR DEM

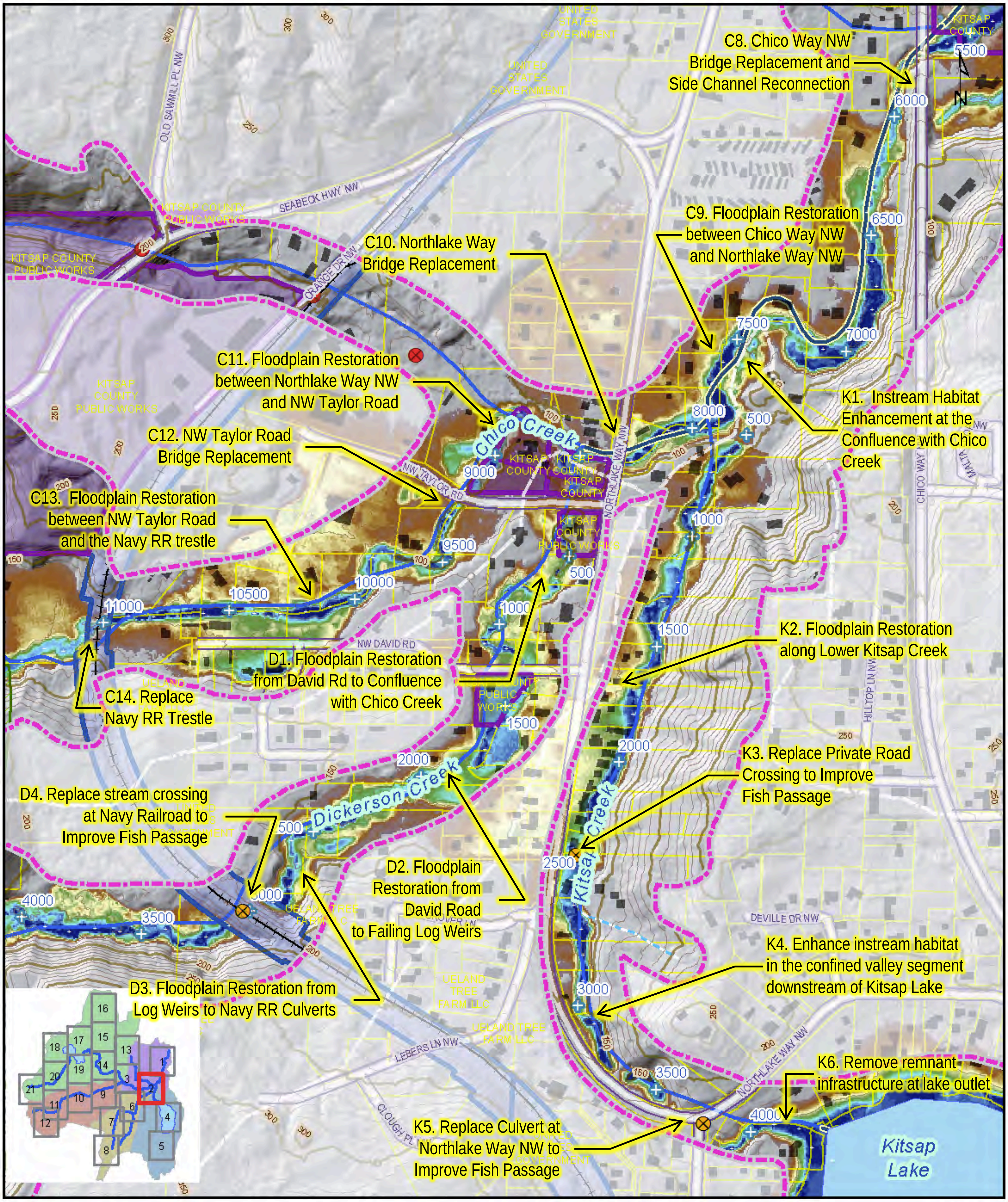
source: Puget Sound LIDAR Consortium

Relative elevation is derived from the difference between bare earth ground surface elevations and and a reference plane representing the channel gradient (based on low flow water surface elevation in the adjacent stream channel).



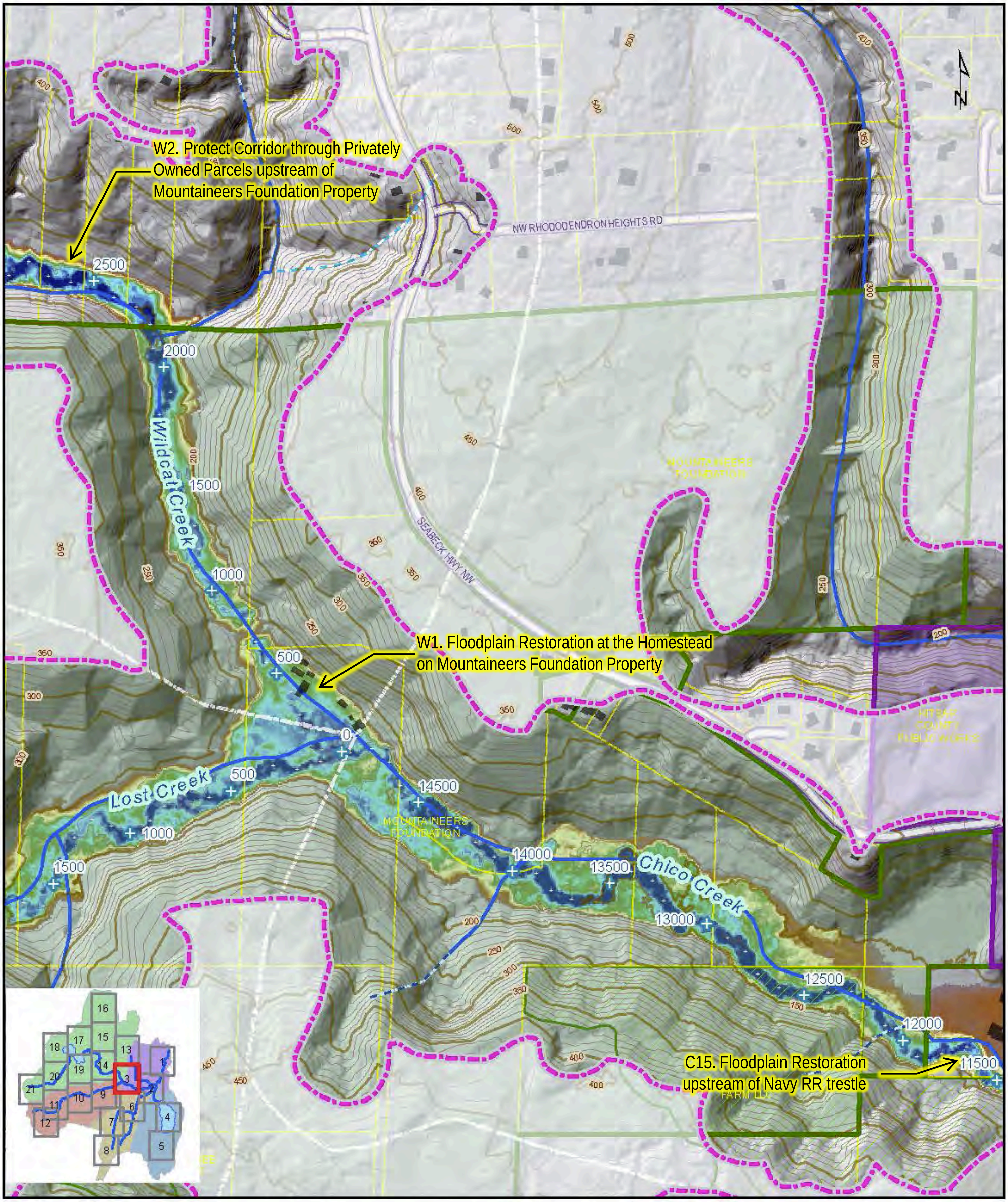
Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

Geomorphic Map: Sheet 1 of 21



Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

Geomorphic Map: Sheet 2 of 21



0 500 1,000 Feet

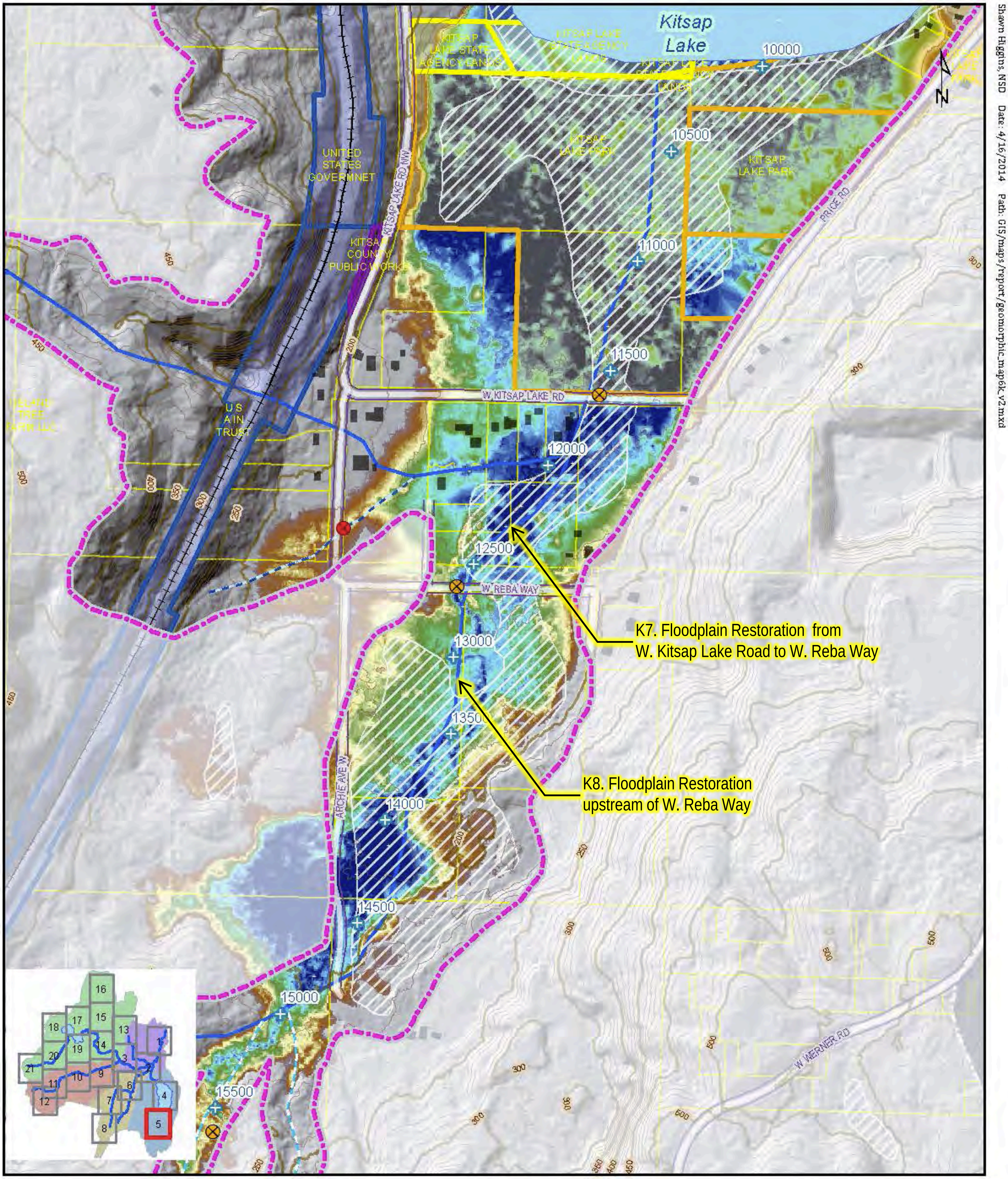
Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

Geomorphic Map: Sheet 3 of 21

Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/geomorphic_map6k_v2.mxd

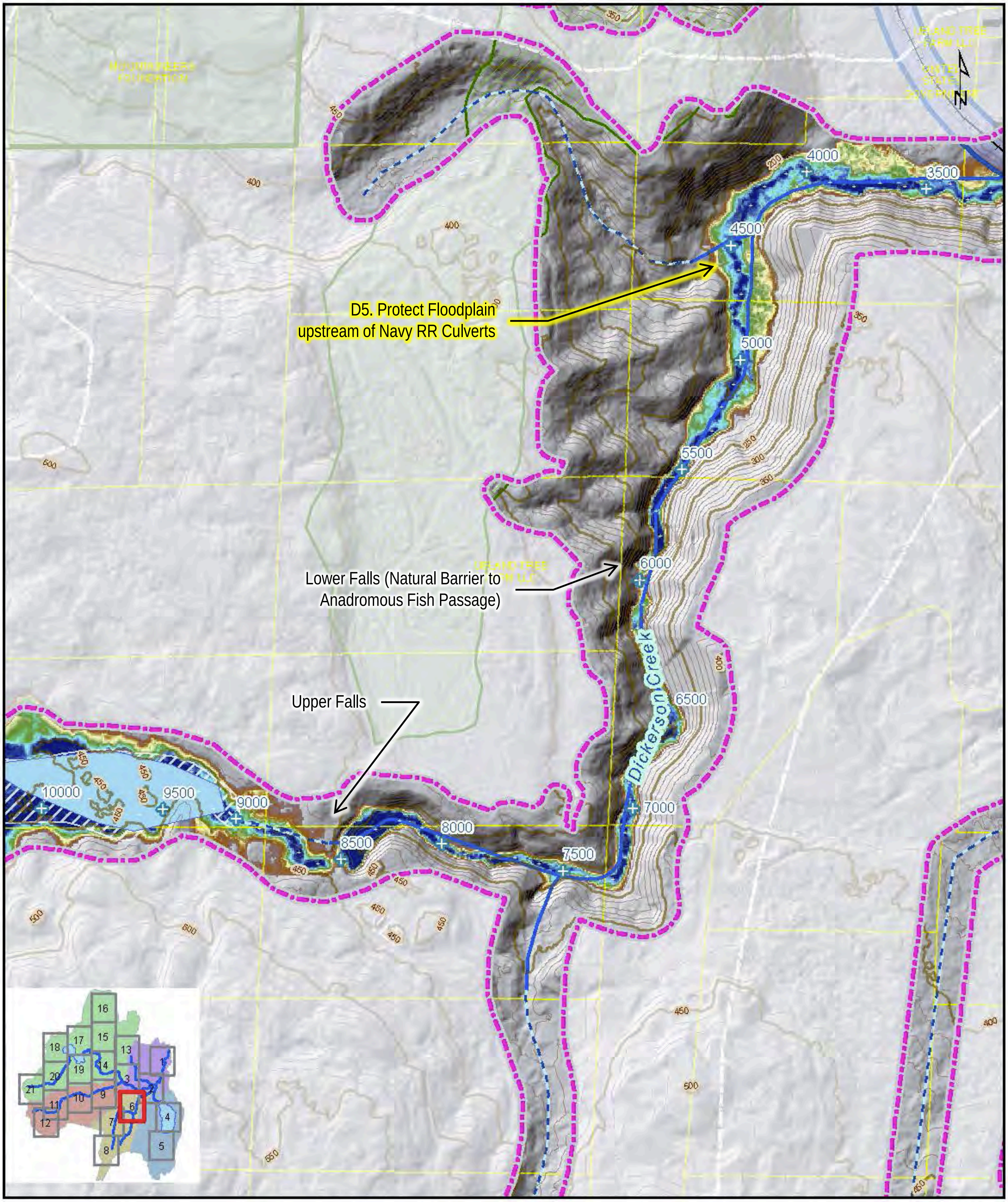
Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

Geomorphic Map: Sheet 4 of 21



Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

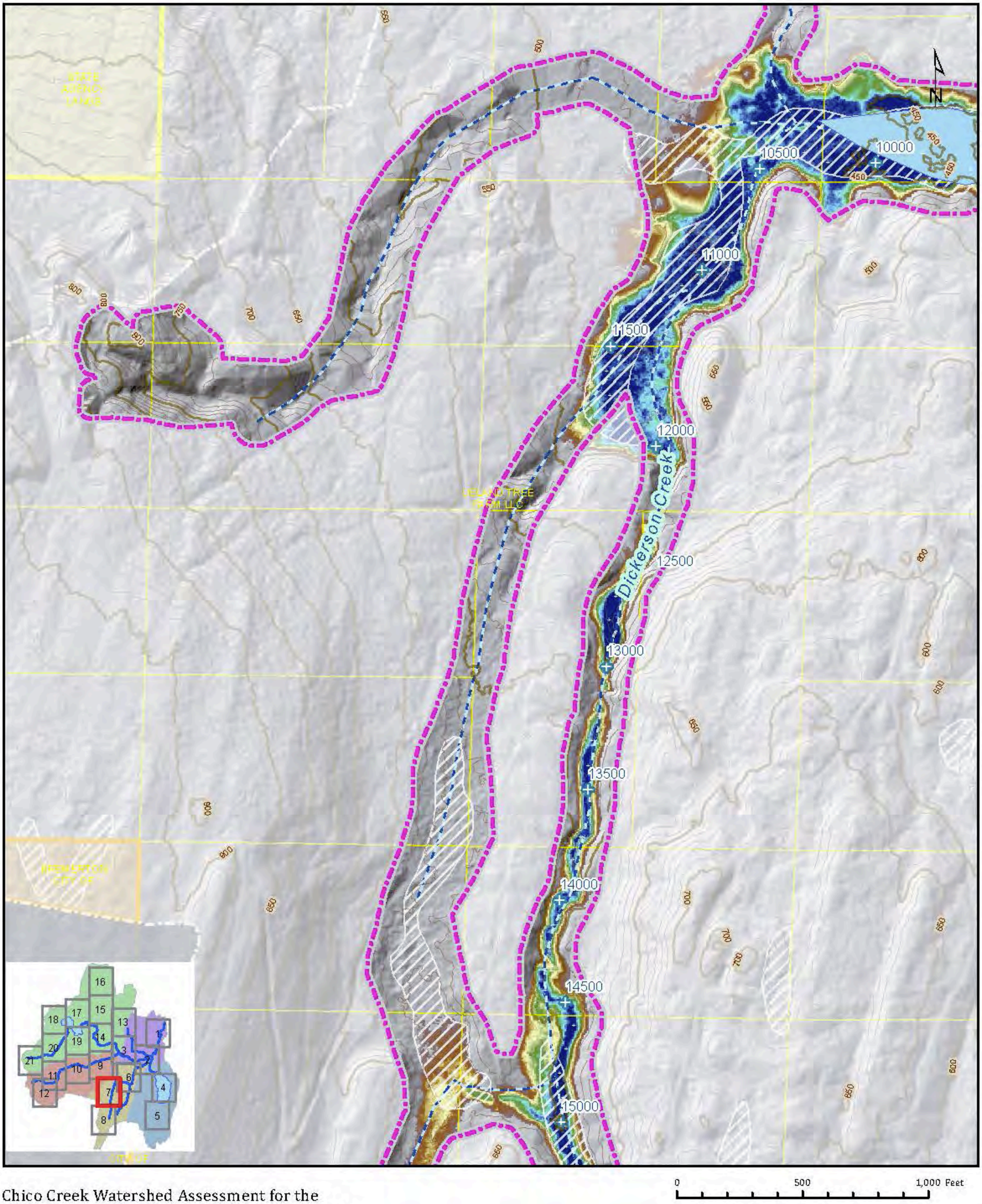
Geomorphic Map: Sheet 5 of 21



0 500 1,000 Feet

Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

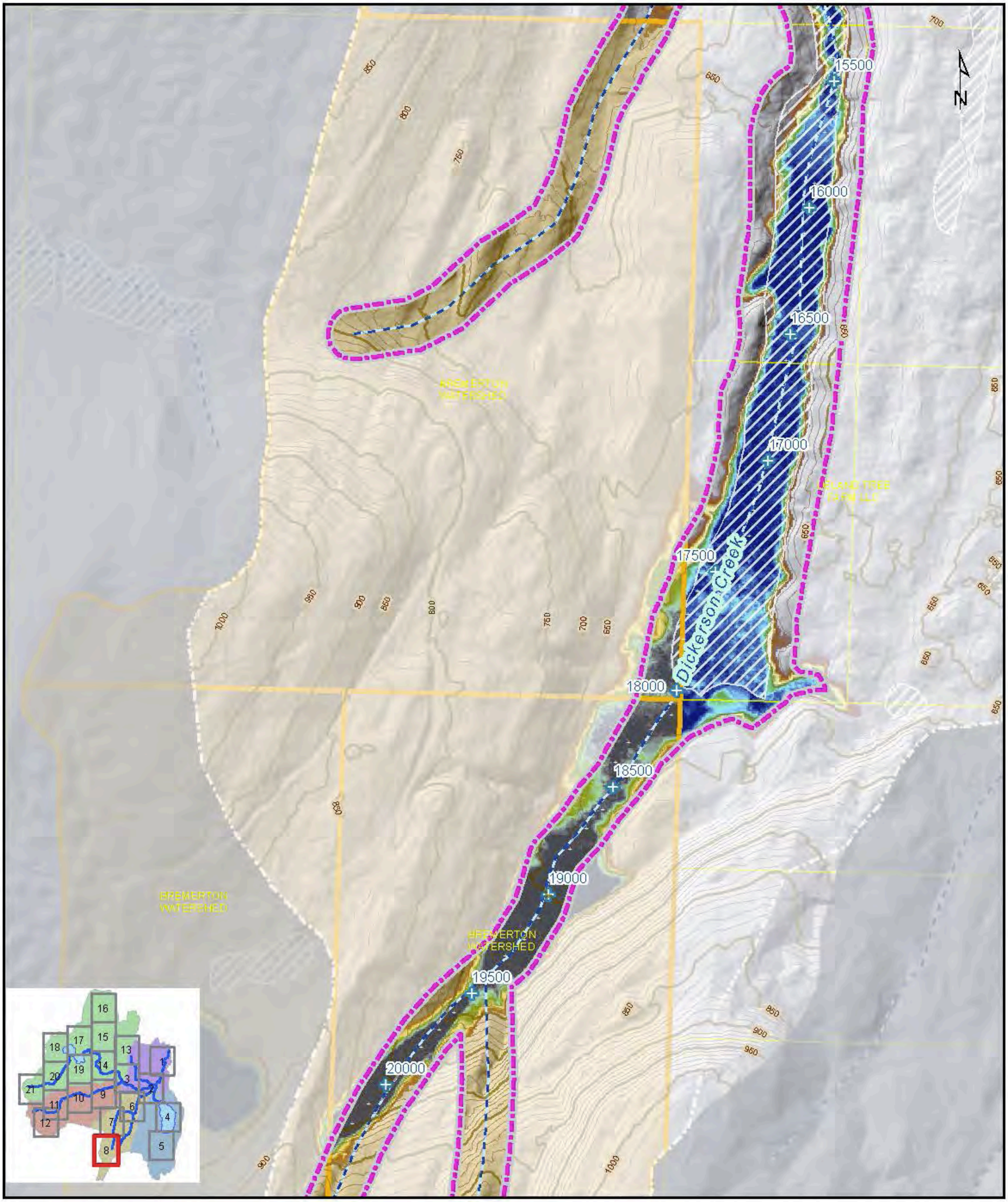
Geomorphic Map: Sheet 6 of 21



Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/geomorphic_map6k_v2.mxd

Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

Geomorphic Map: Sheet 7 of 21

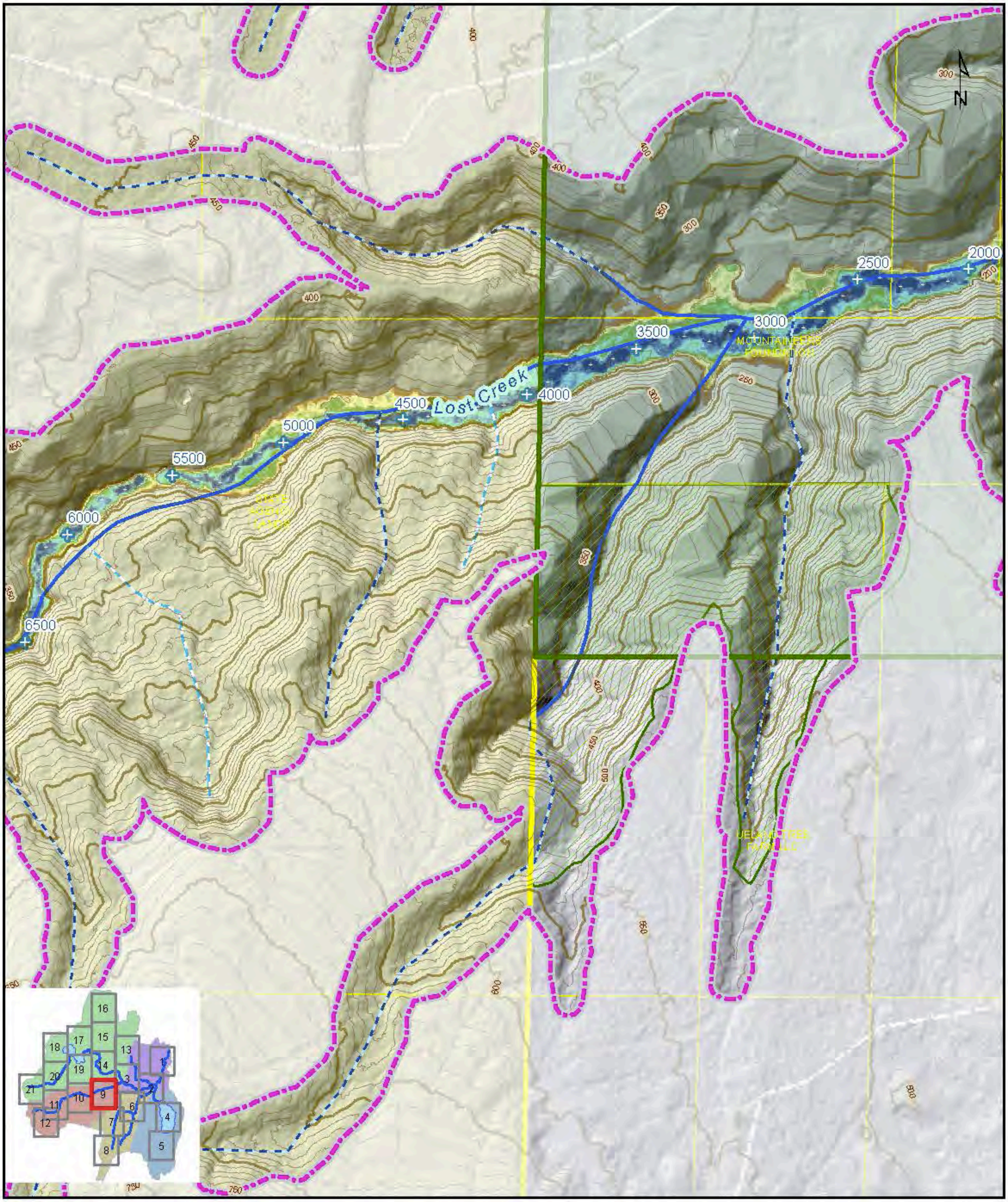


Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/geomorphic_map8_v2.mxd

Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

Geomorphic Map: Sheet 8 of 21

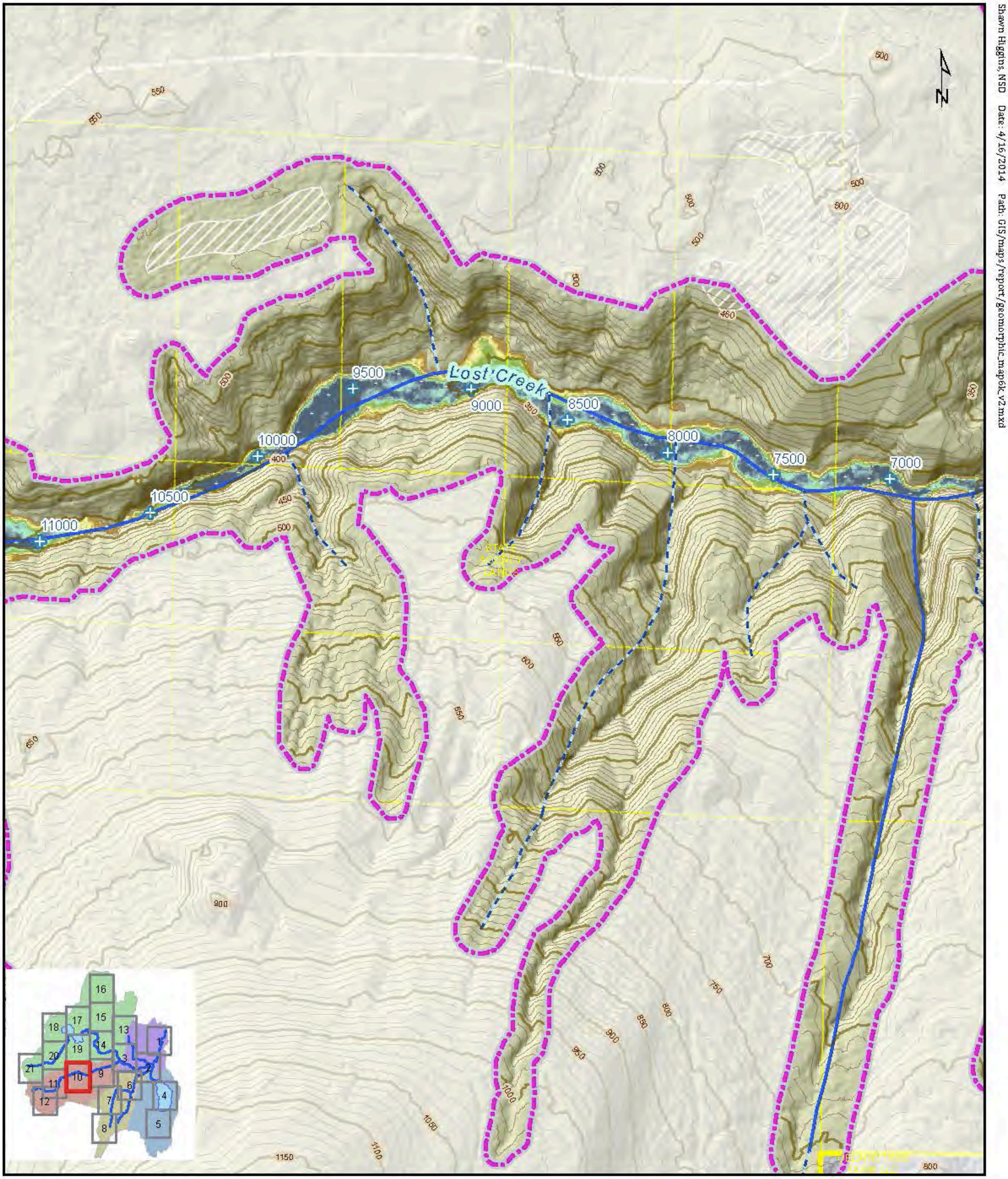
Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/geomorphic_mapek_v2.mxd



0 500 1,000 Feet

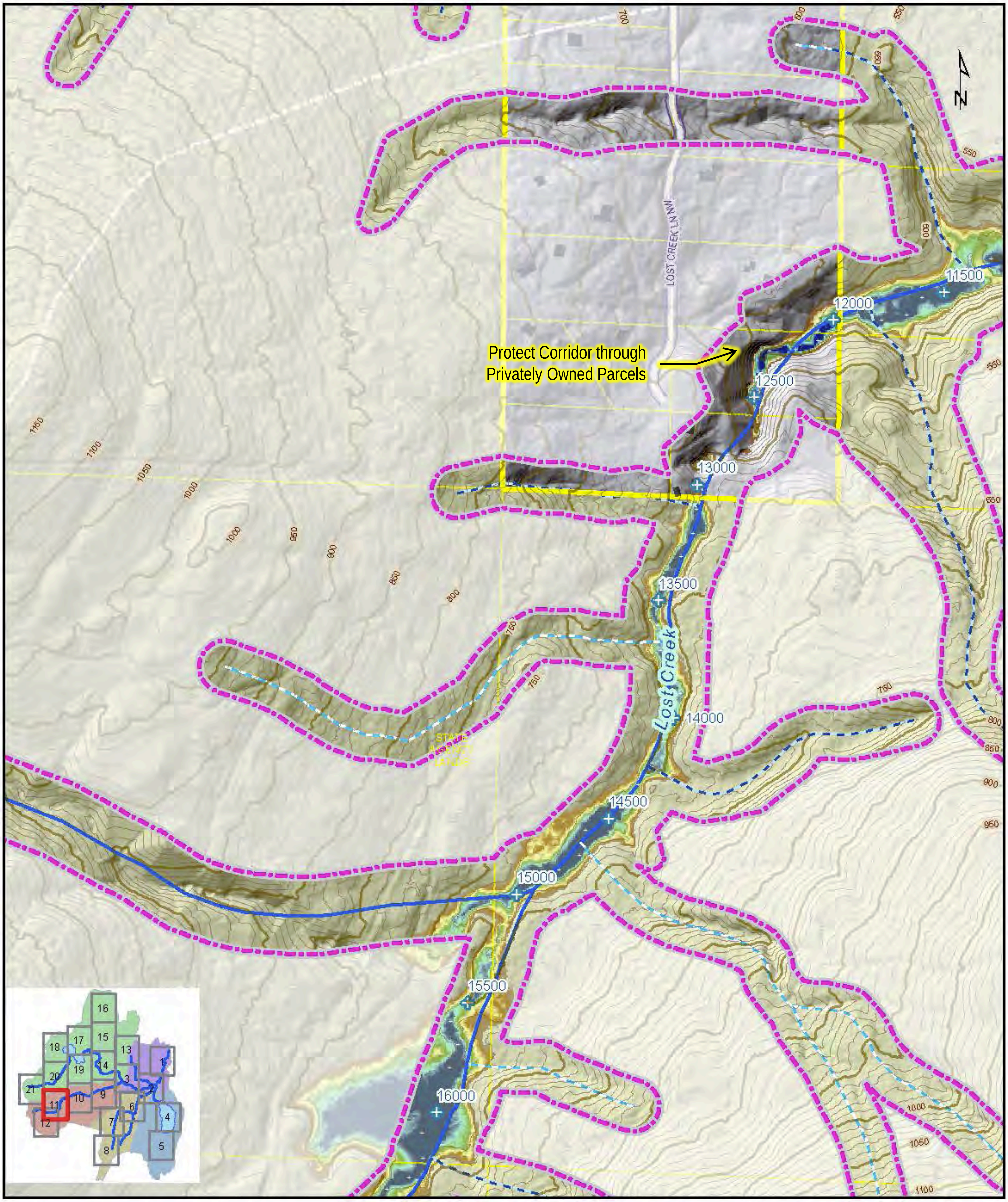
Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

Geomorphic Map: Sheet 9 of 21



Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

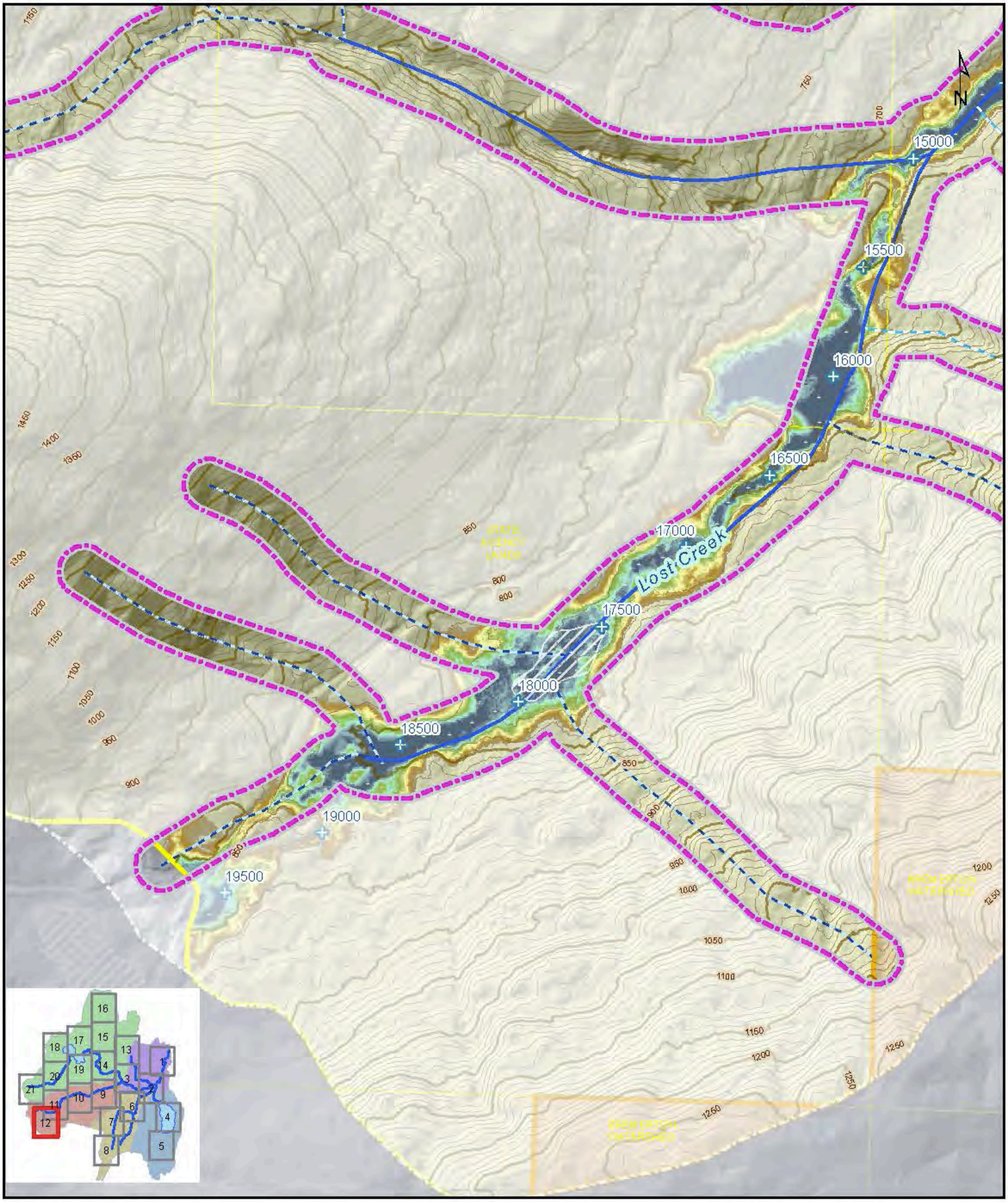
Geomorphic Map: Sheet 10 of 21



0 500 1,000 Feet

Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

Geomorphic Map: Sheet 11 of 21



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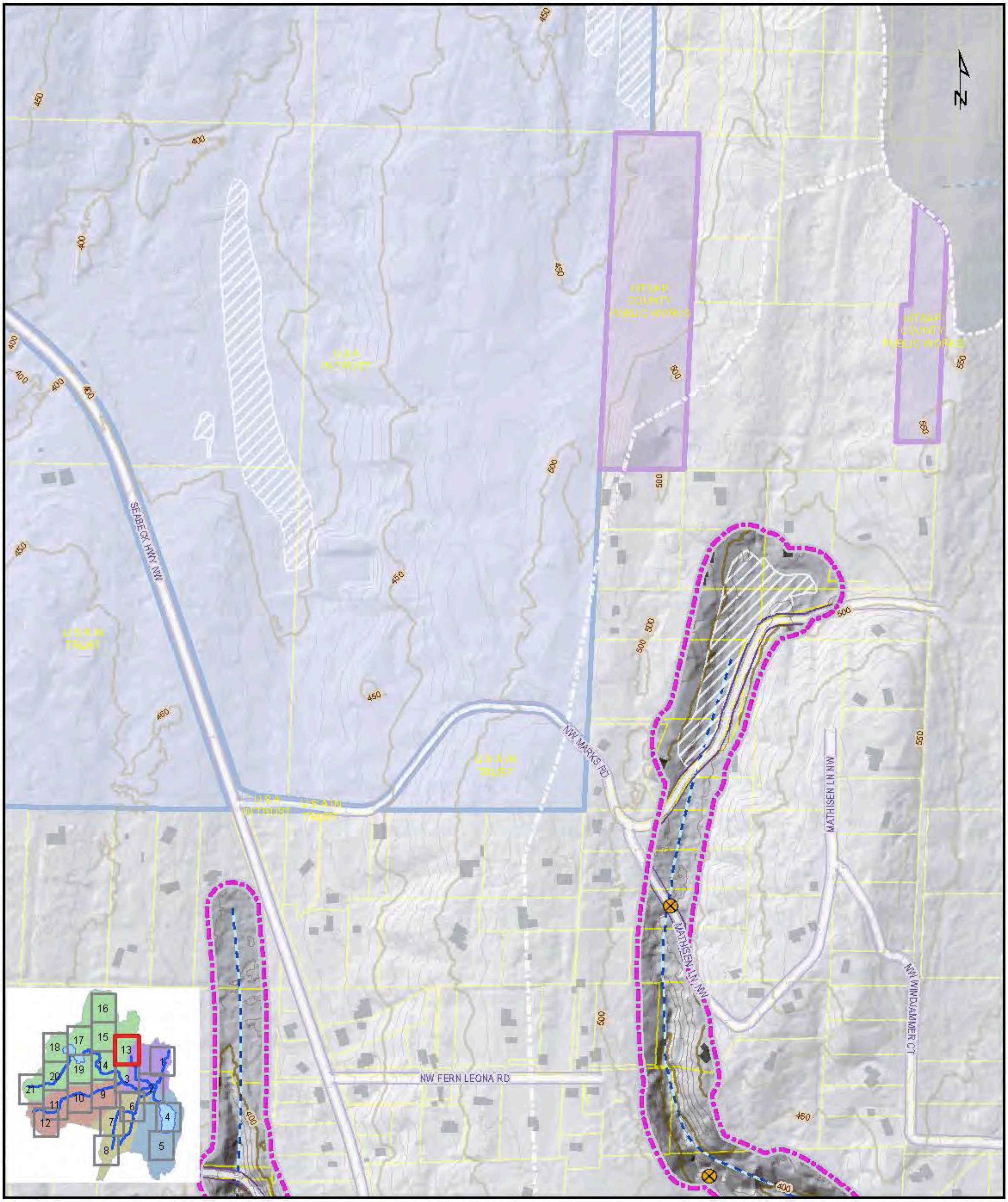
0 500 1,000 Feet

Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

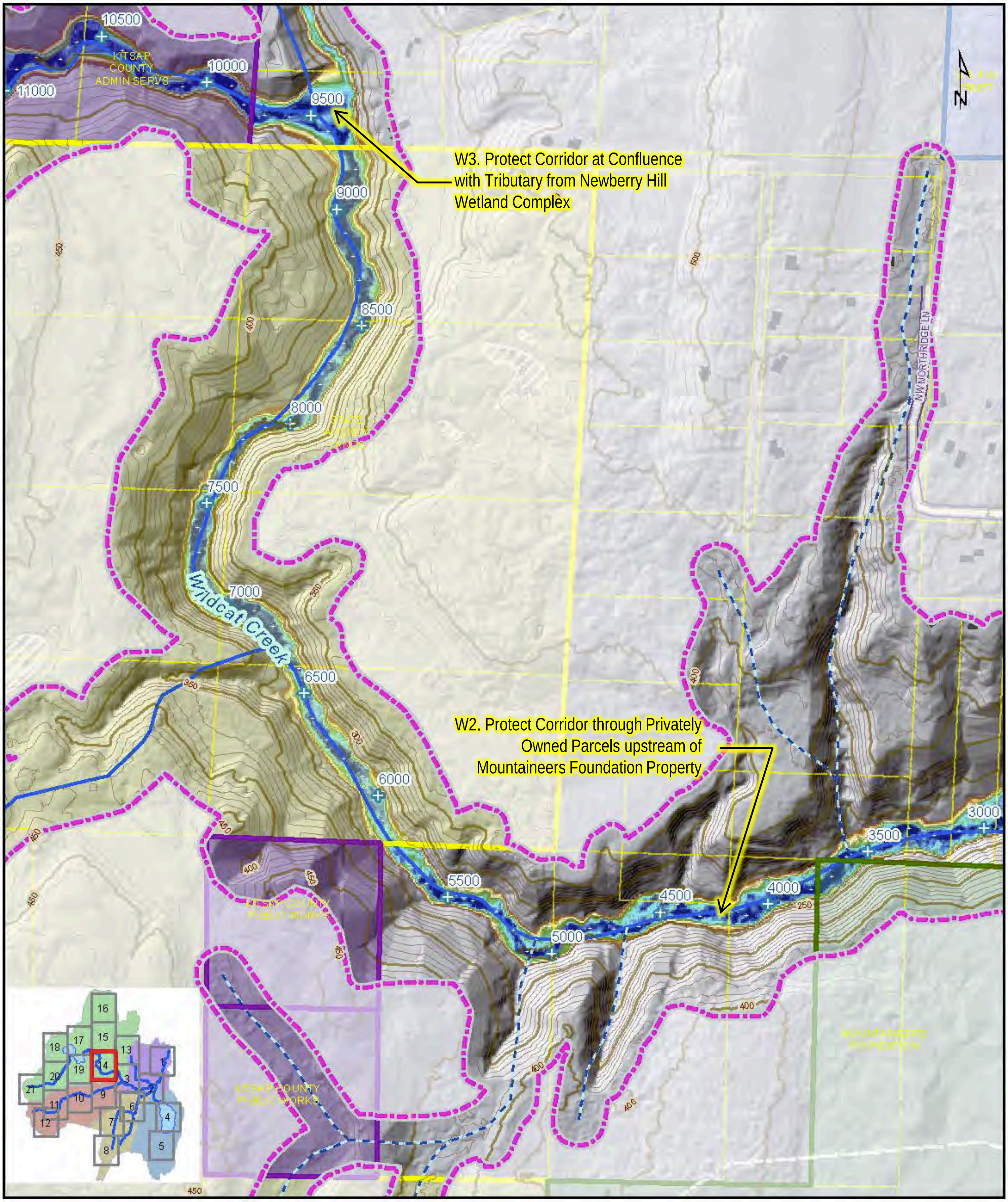
Geomorphic Map: Sheet 12 of 21



Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/geomorphic_map6k_v2.mxd

Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

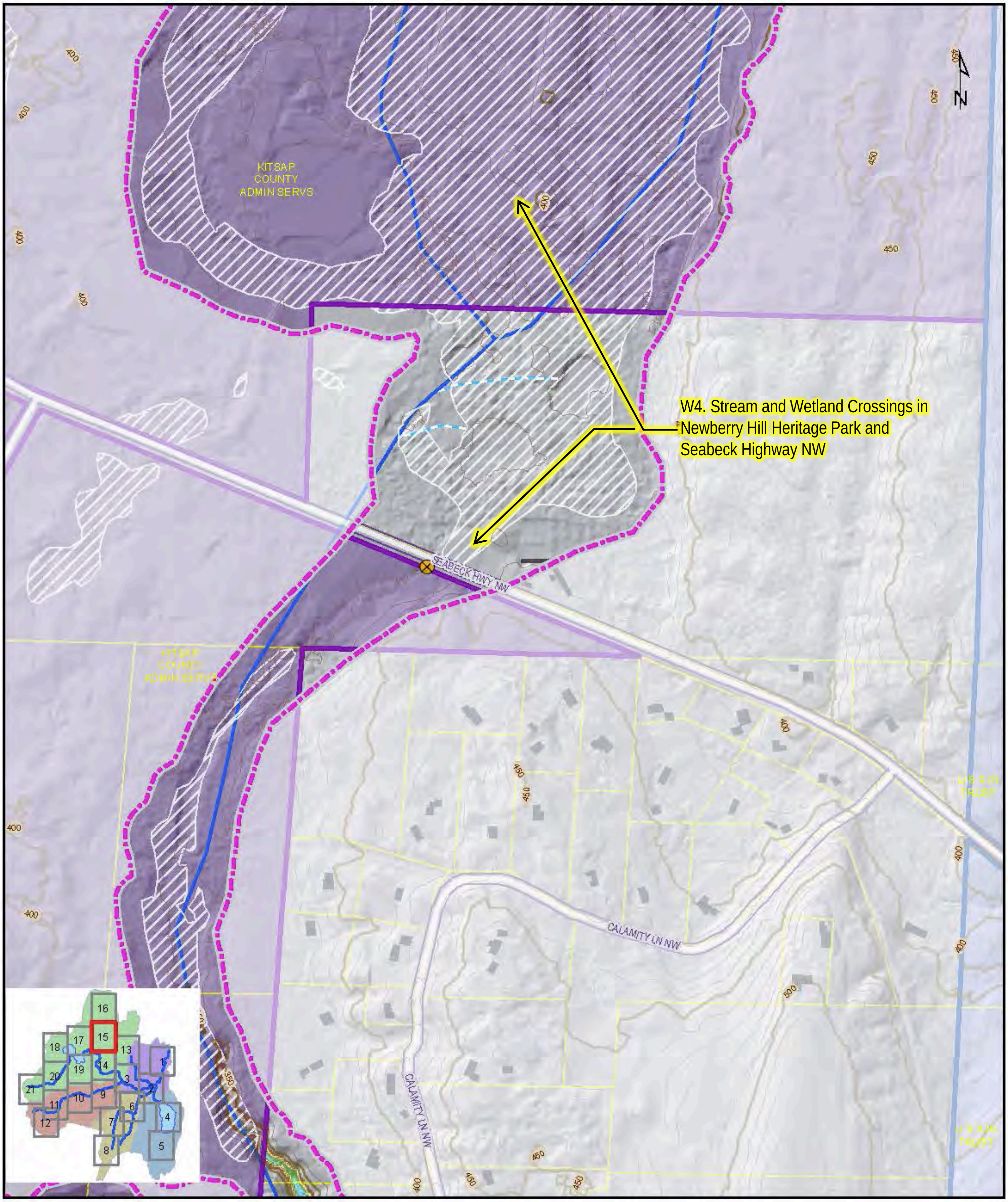
Geomorphic Map: Sheet 13 of 21



Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/geomorphic_map6k_v2.mxd

Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

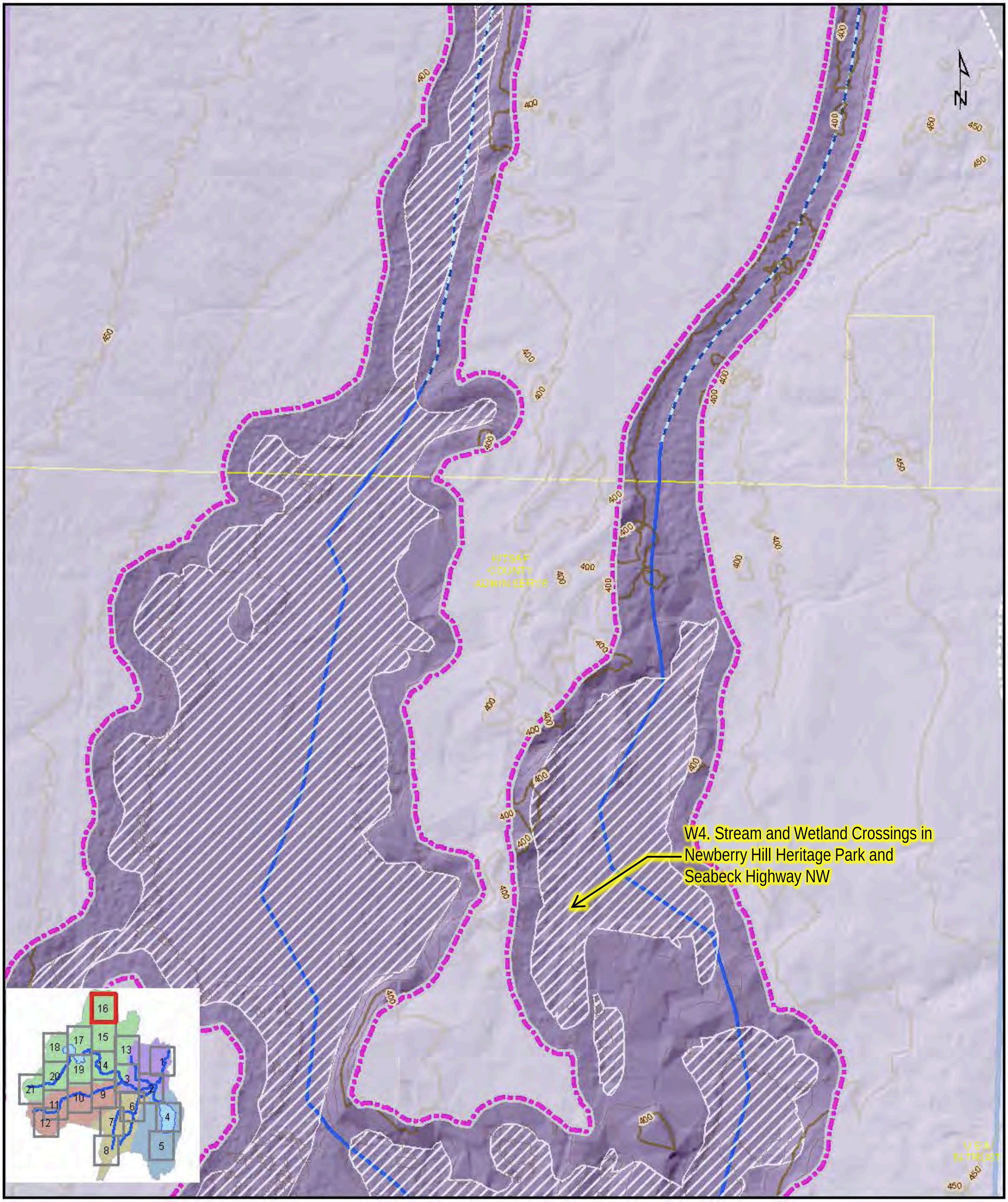
Geomorphic Map: Sheet 14 of 21



Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/geomorphic_map6k_v2.mxd

Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

Geomorphic Map: Sheet 15 of 21



0 500 1,000 Feet

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Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

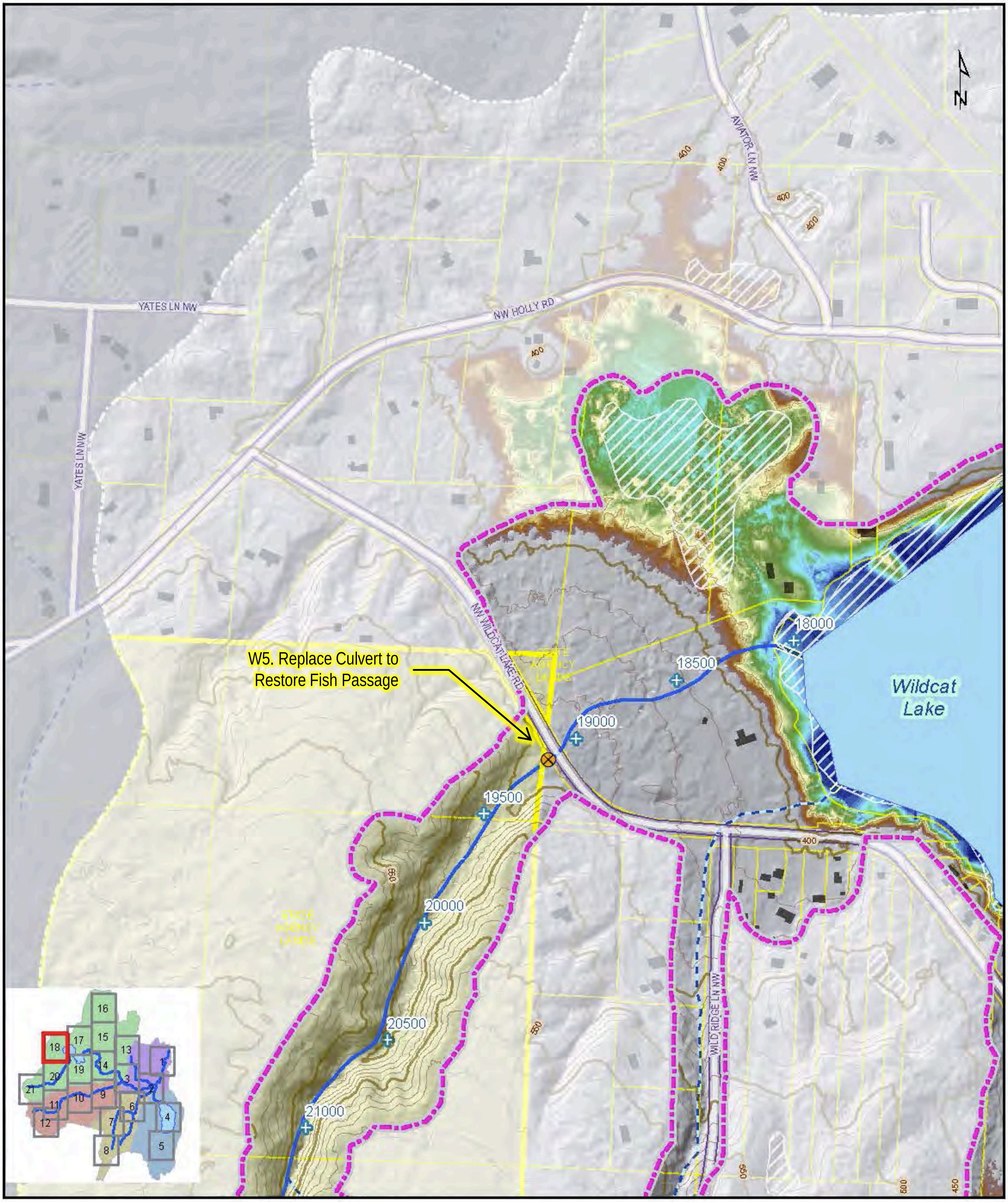
Geomorphic Map: Sheet 16 of 21

0 500 1,000 Feet

Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/geomorphic_map6k_v2.mxd

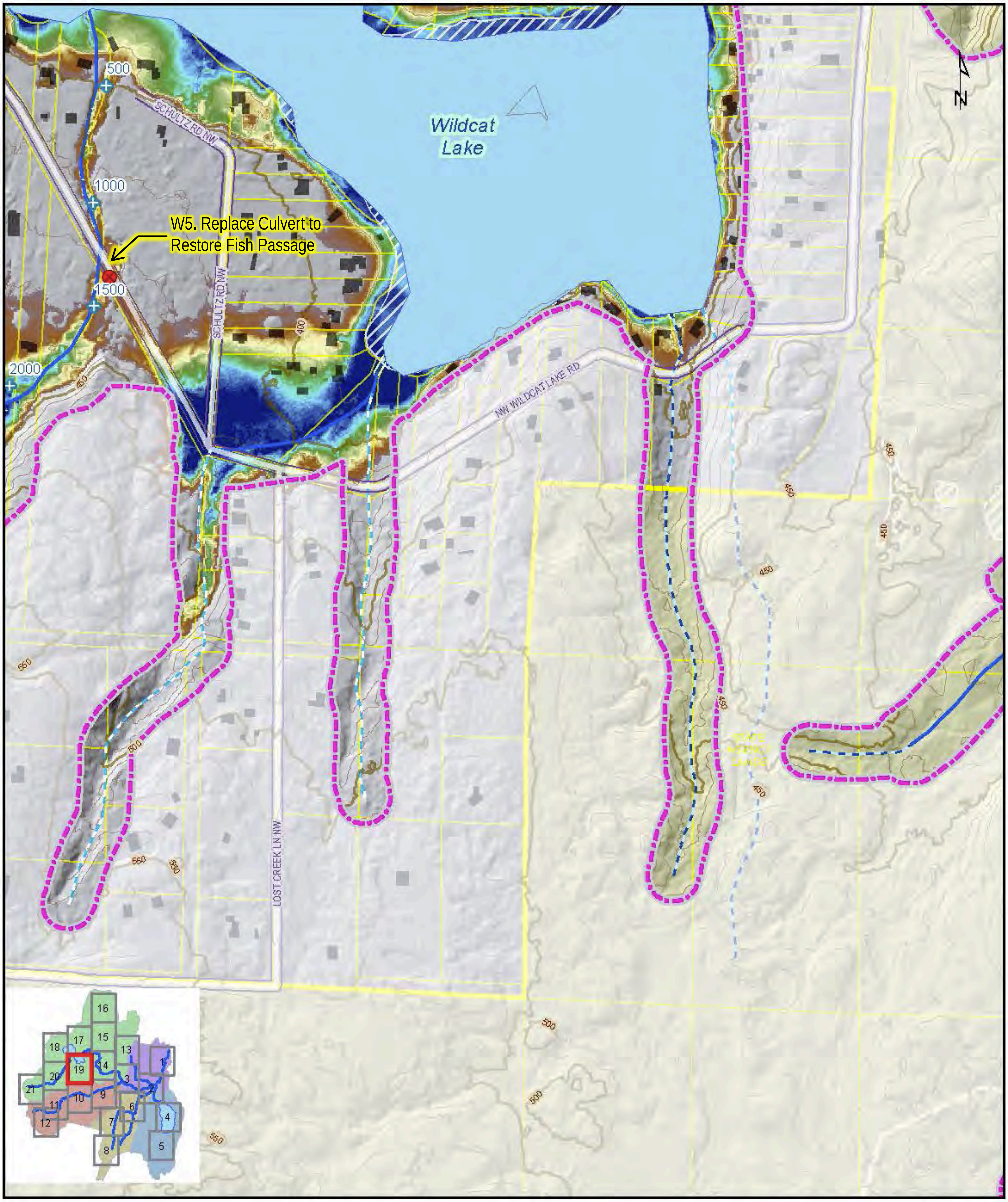
Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

Geomorphic Map: Sheet 17 of 21



Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

Geomorphic Map: Sheet 18 of 21



0 500 1,000 Feet

Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

Geomorphic Map: Sheet 19 of 21

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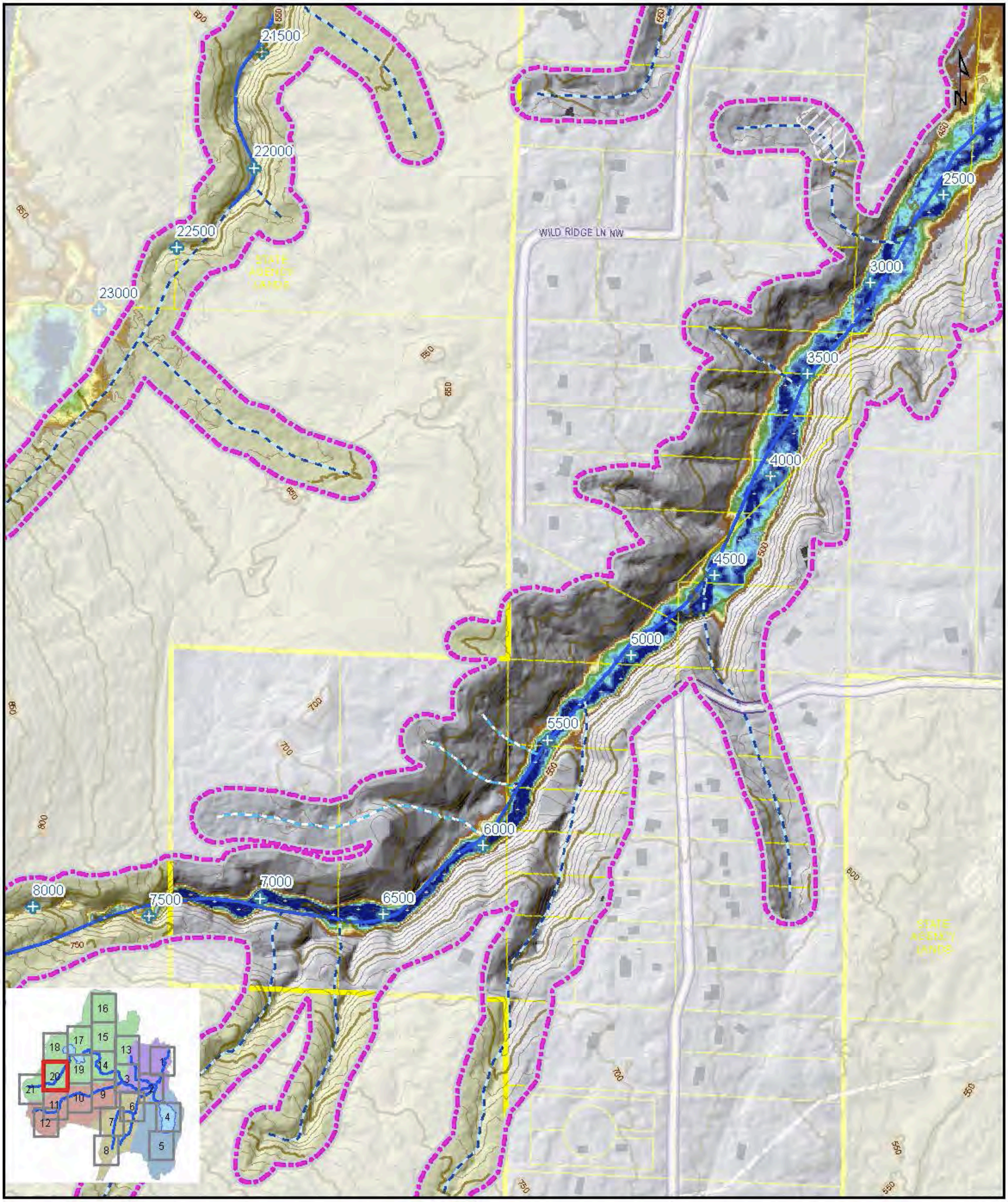

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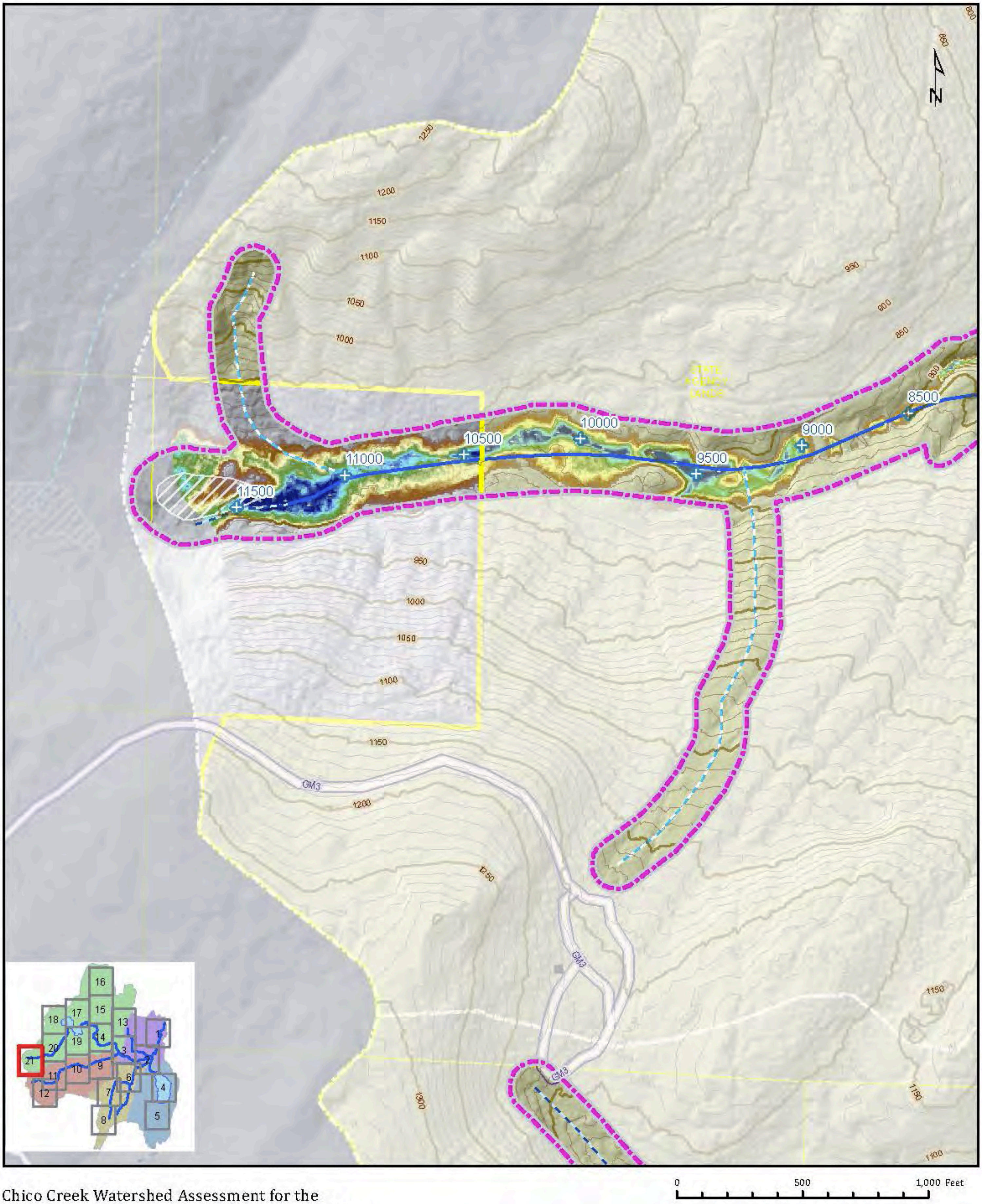
0 500 1,000 Feet

Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

Geomorphic Map: Sheet 20 of 21



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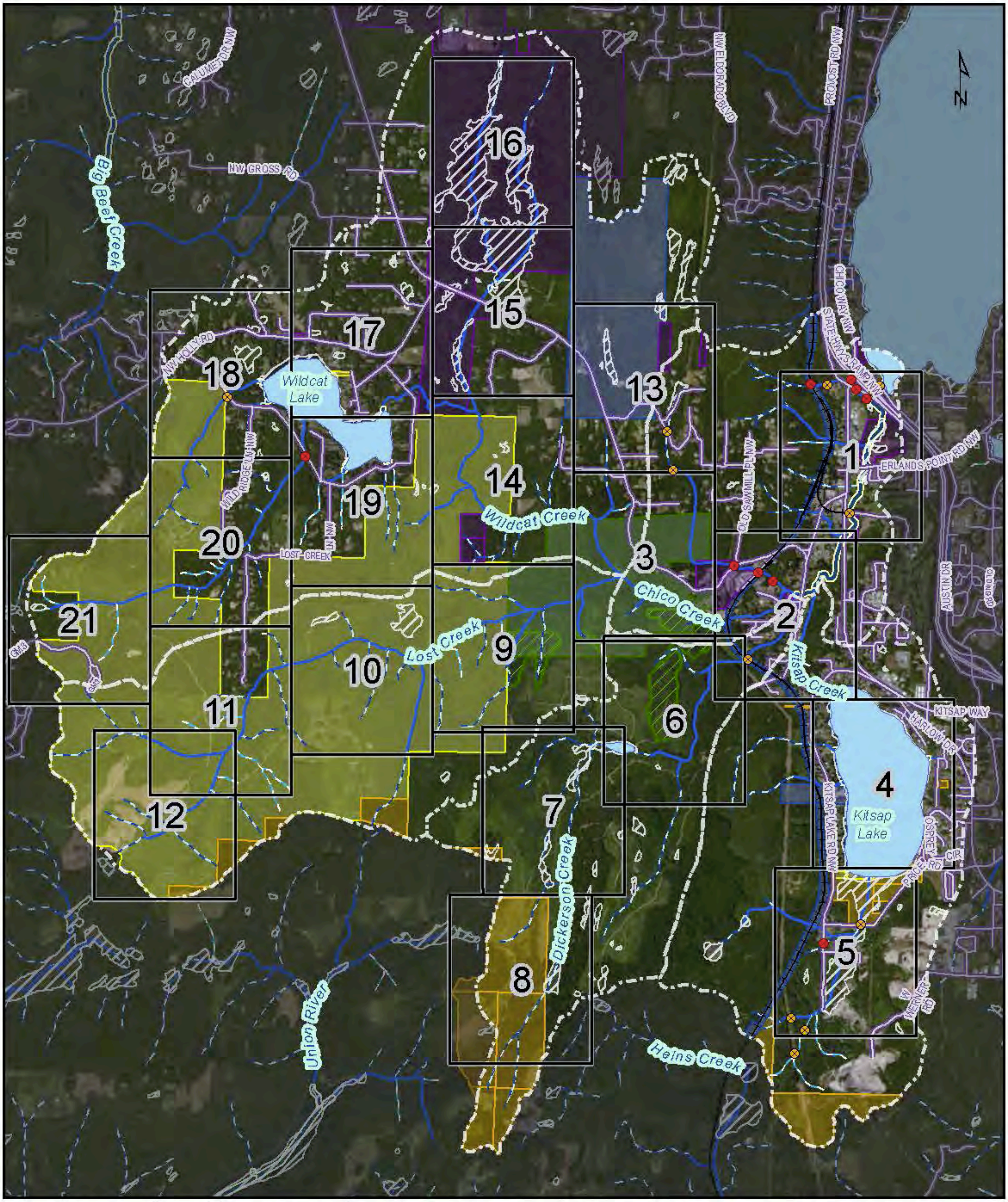
Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

Geomorphic Map: Sheet 21 of 21

APPENDIX B

Aerial Photo Maps with Recommended Actions



Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/imagery6k_index.mxd

0 1 Mile

Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

Index Sheet for 1:6,000 Scale 2012 Imagery

Legend

Passage Barriers

Partial

Total

source: WDFW, 2012. Washington State
Fish Passage Barrier Inventory

River stationing (100 ft interval)

Fish Habitat Water Type

Fish Habitat (F)

Non-Fish Habitat (N)

Shoreline of the State (S)

Unknown (U)

source: WDNR, 2006. Washington State
Watercourse Hydrography

Inland Water Bodies

Lakes
source: USGS National Hydrography Dataset

Wetland Areas
source: Kitsap County

Stream Corridor

The stream corridor was delineated to incorporate critical areas surrounding stream and wetland features and associated hillslope areas that are directly connected to fluvial landforms in the watershed. Corridor boundaries are mapped for planning purposes only and do not constitute a specific regulatory zone.

Transportation

Road

Railroad

sources: Kitsap County and WDNR

Property Ownership

Parcel Boundaries

source: Kitsap County

Ownership Type

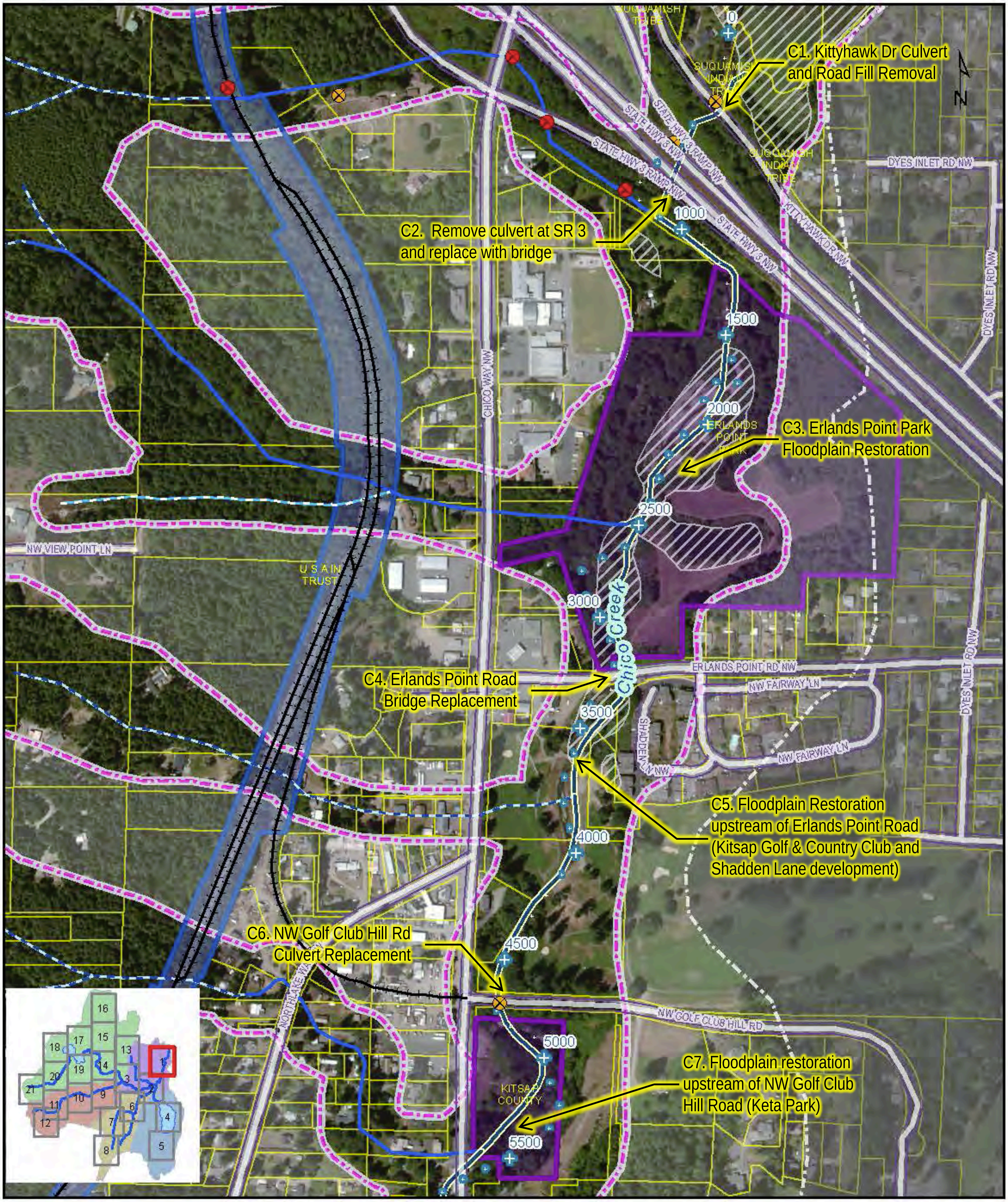
Federal

State

County

Municipal

Conservation Area

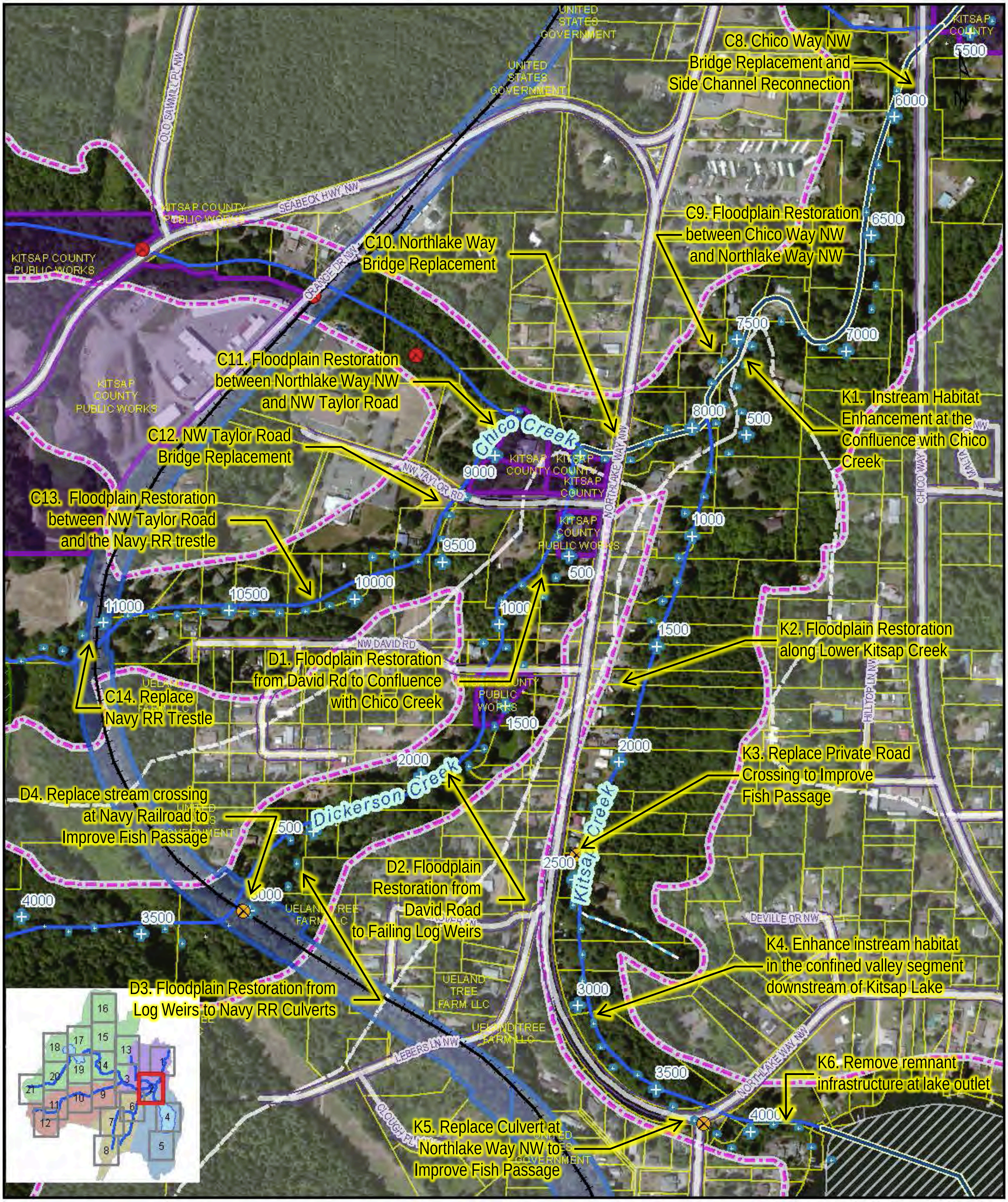


Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/imagery6k_v2.mxd

Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

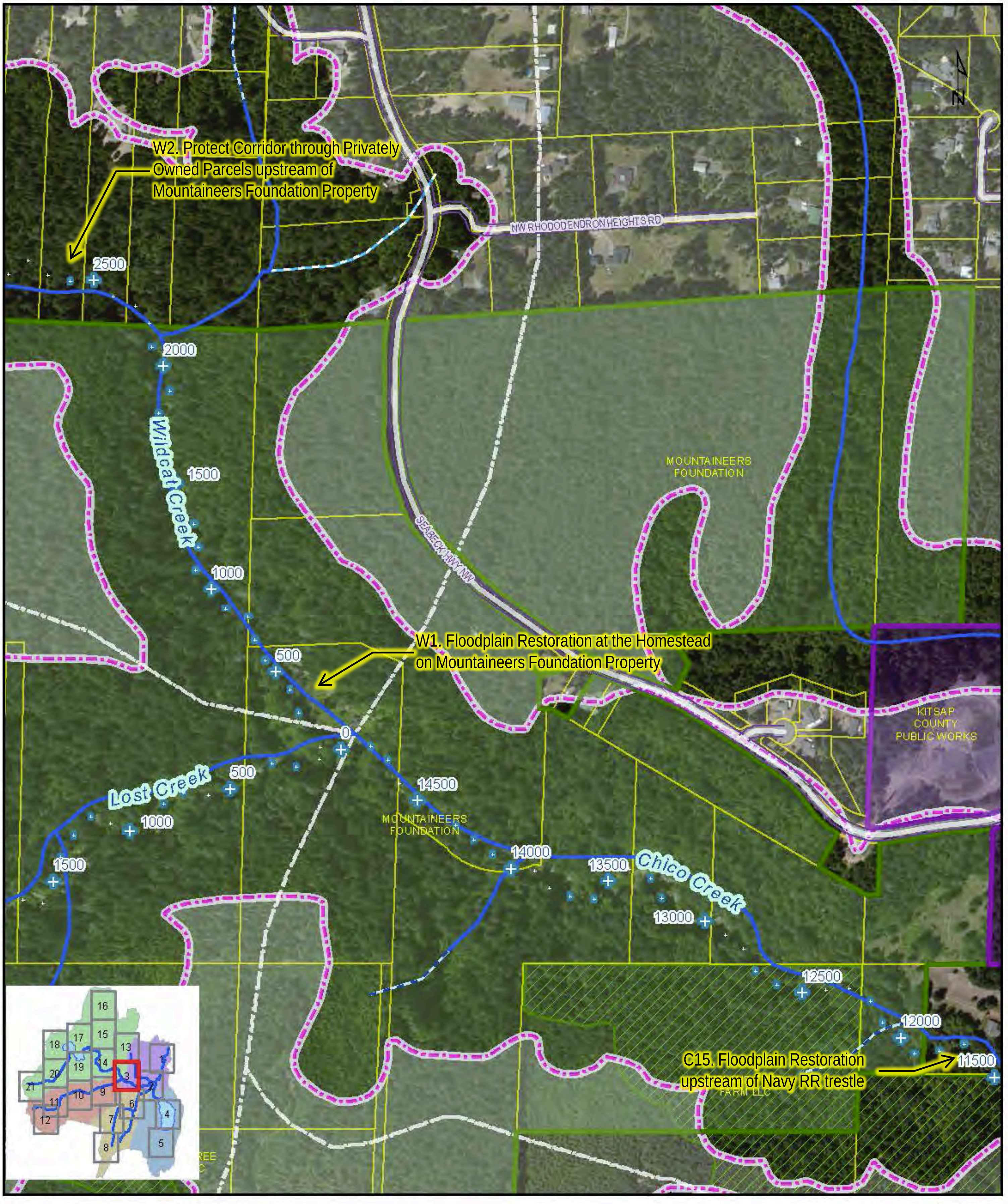
2012 Aerial Imagery: Sheet 1 of 21

Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/imagery6k_v2.mxd



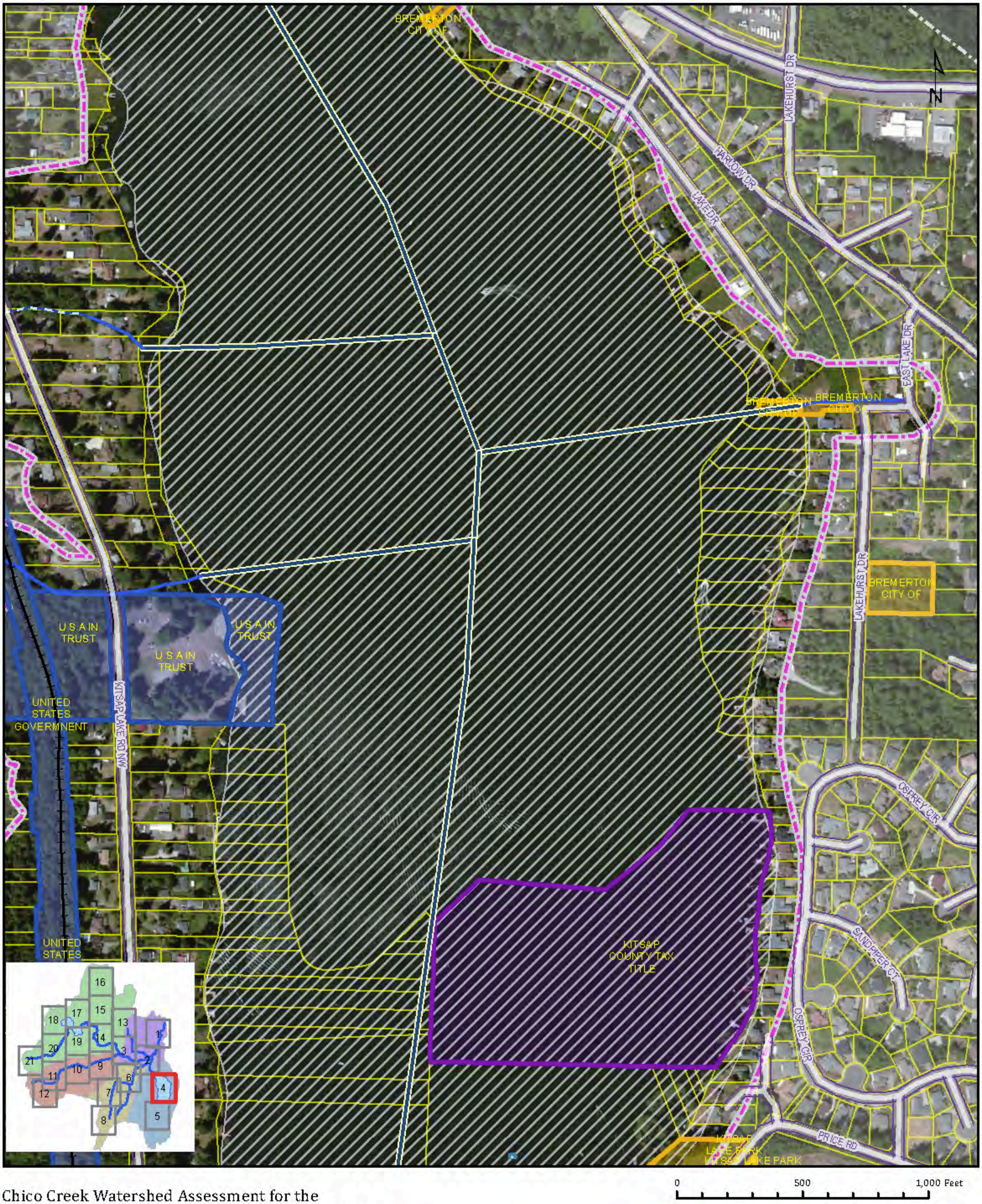
Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

2012 Aerial Imagery: Sheet 2 of 21



Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

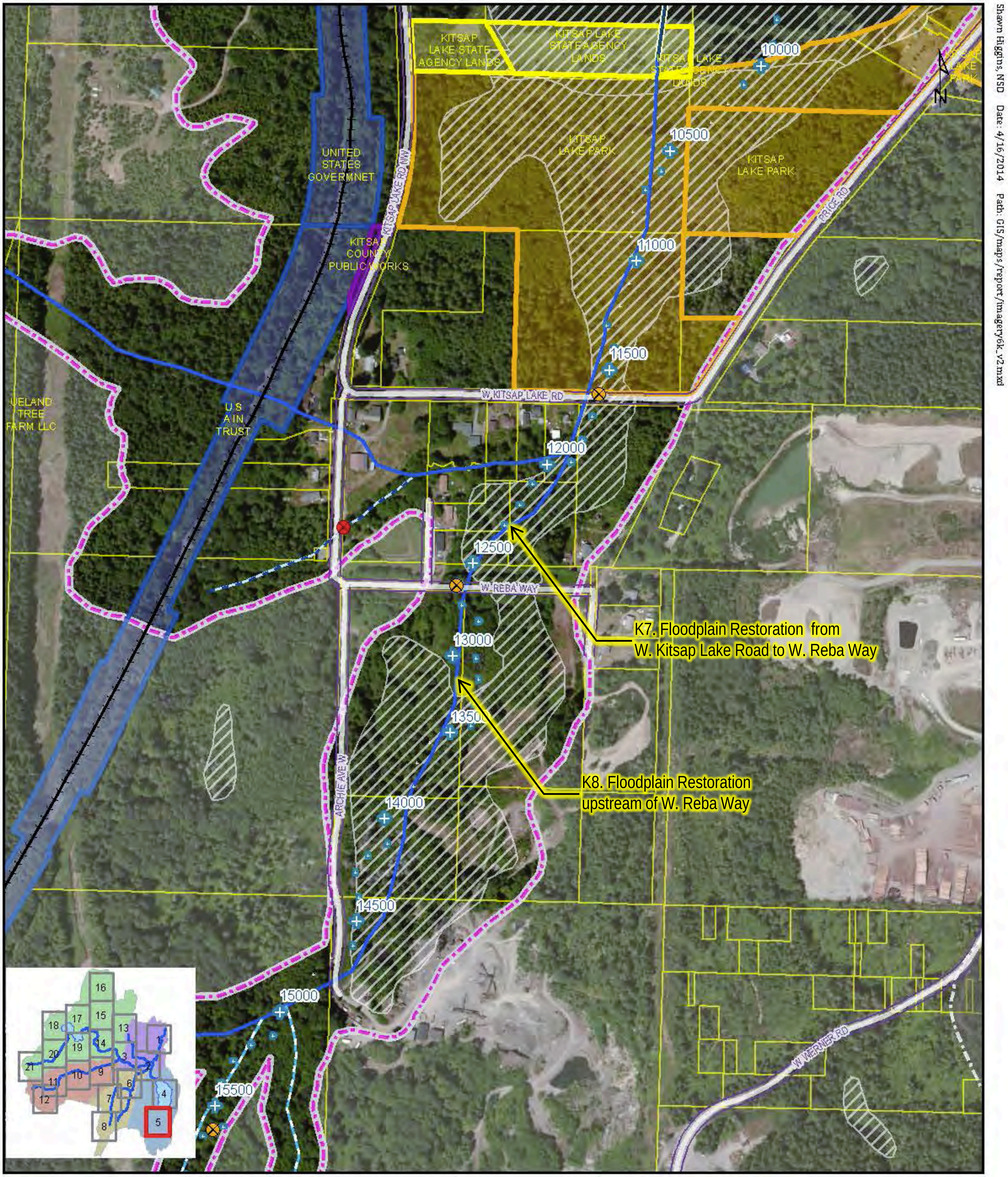
2012 Aerial Imagery: Sheet 3 of 21



Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/imagery6k_v2.mxd

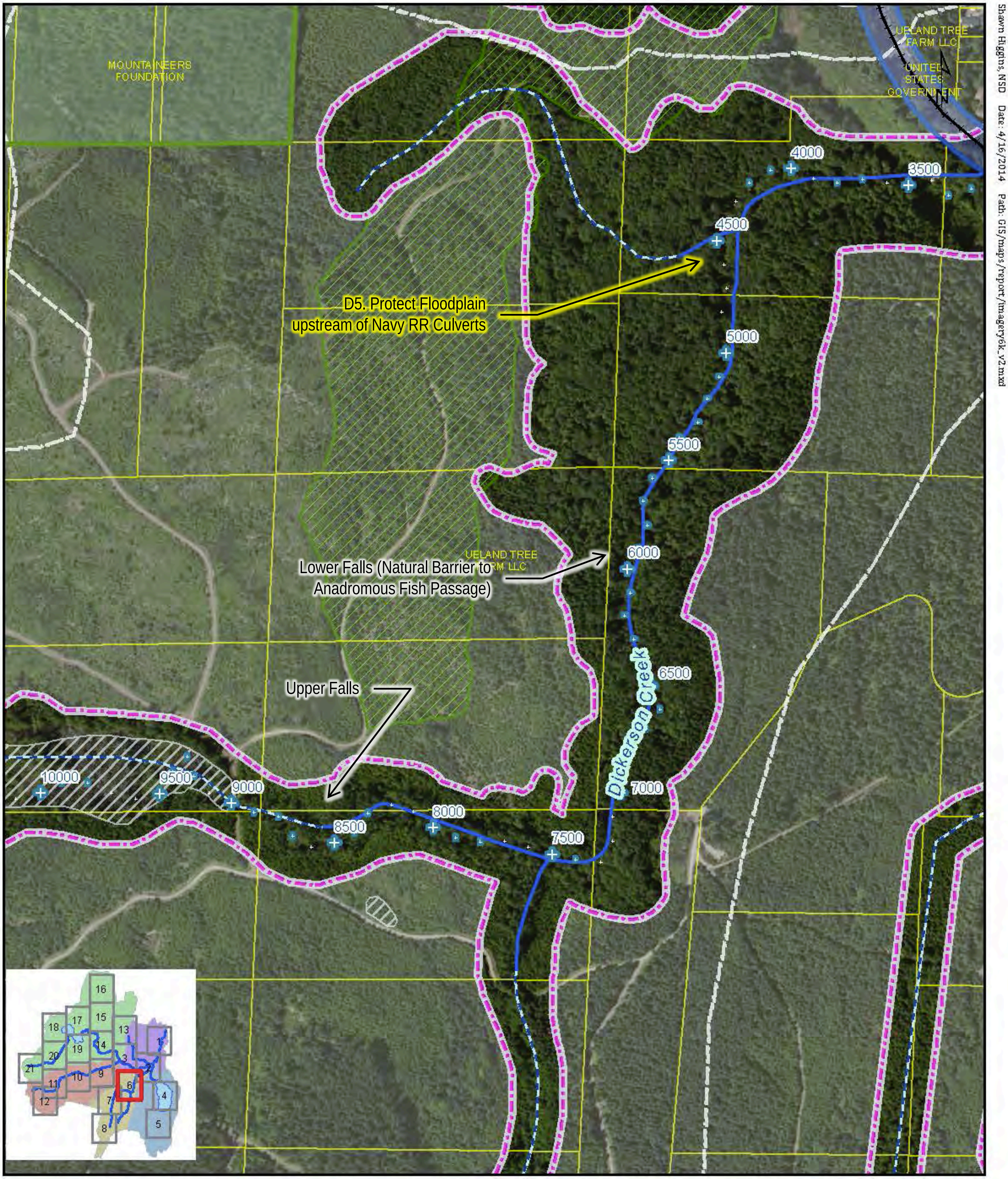
Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

2012 Aerial Imagery: Sheet 4 of 21



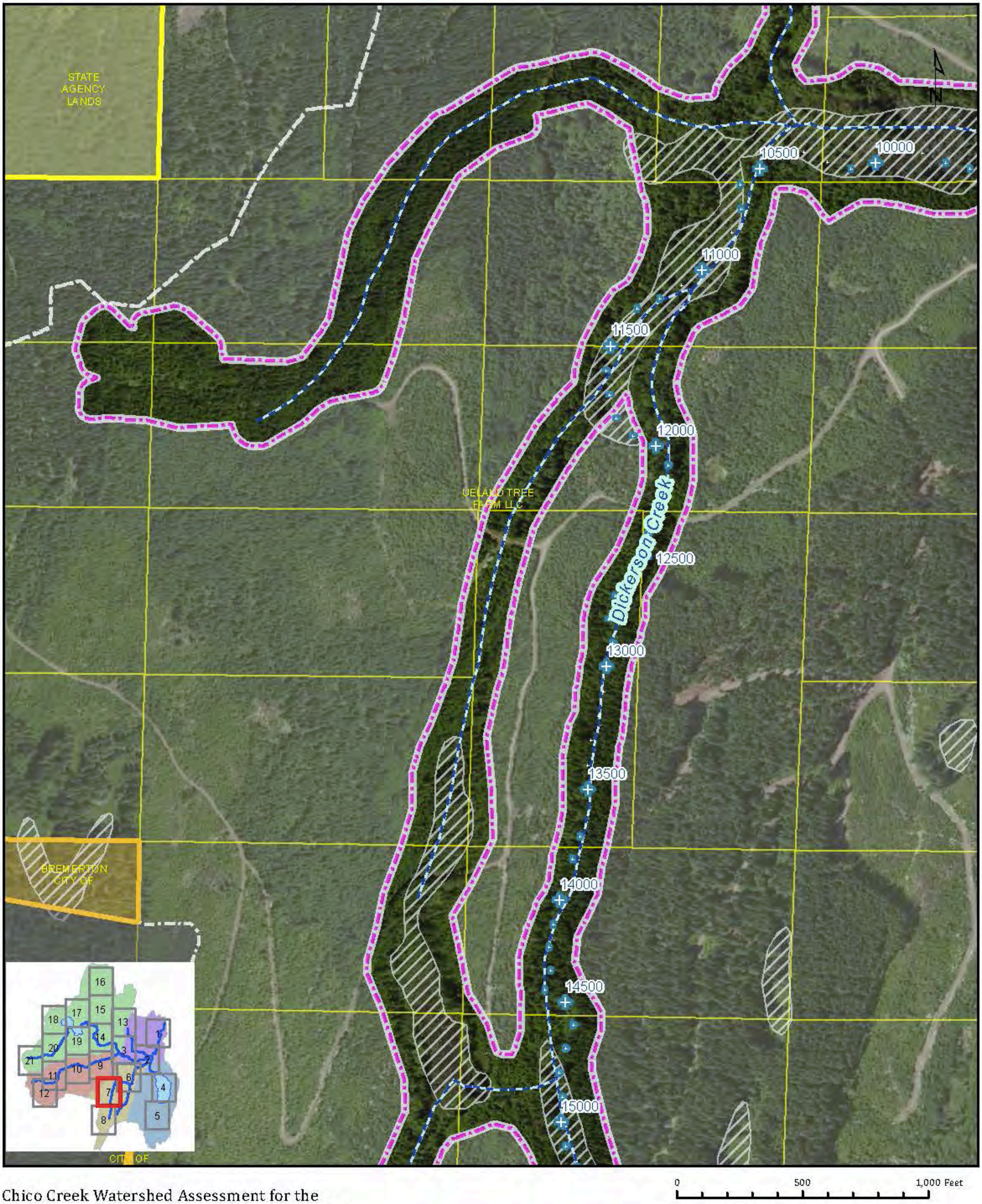
Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

2012 Aerial Imagery: Sheet 5 of 21



Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

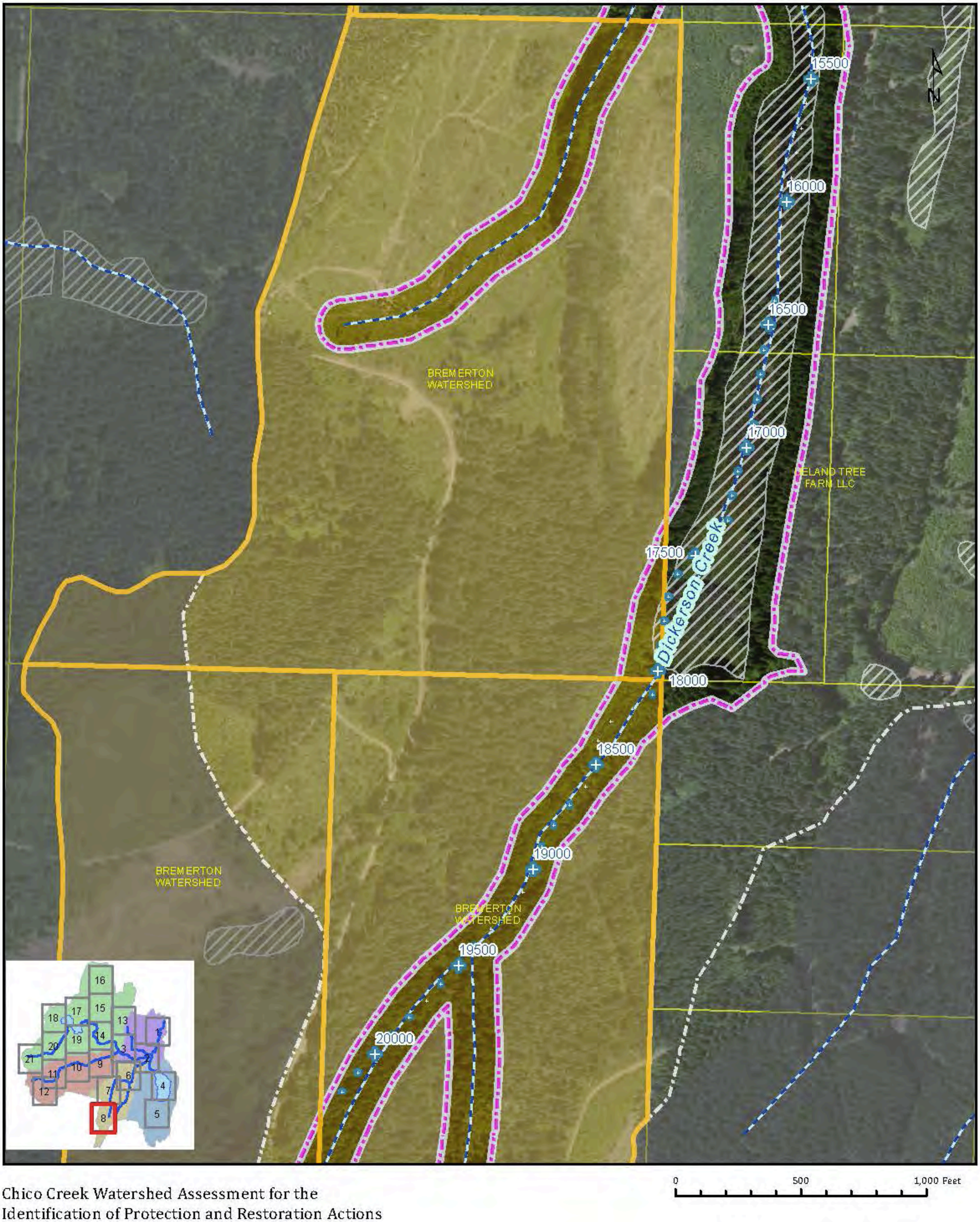
2012 Aerial Imagery: Sheet 6 of 21



Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/imagery6k_v2.mxd

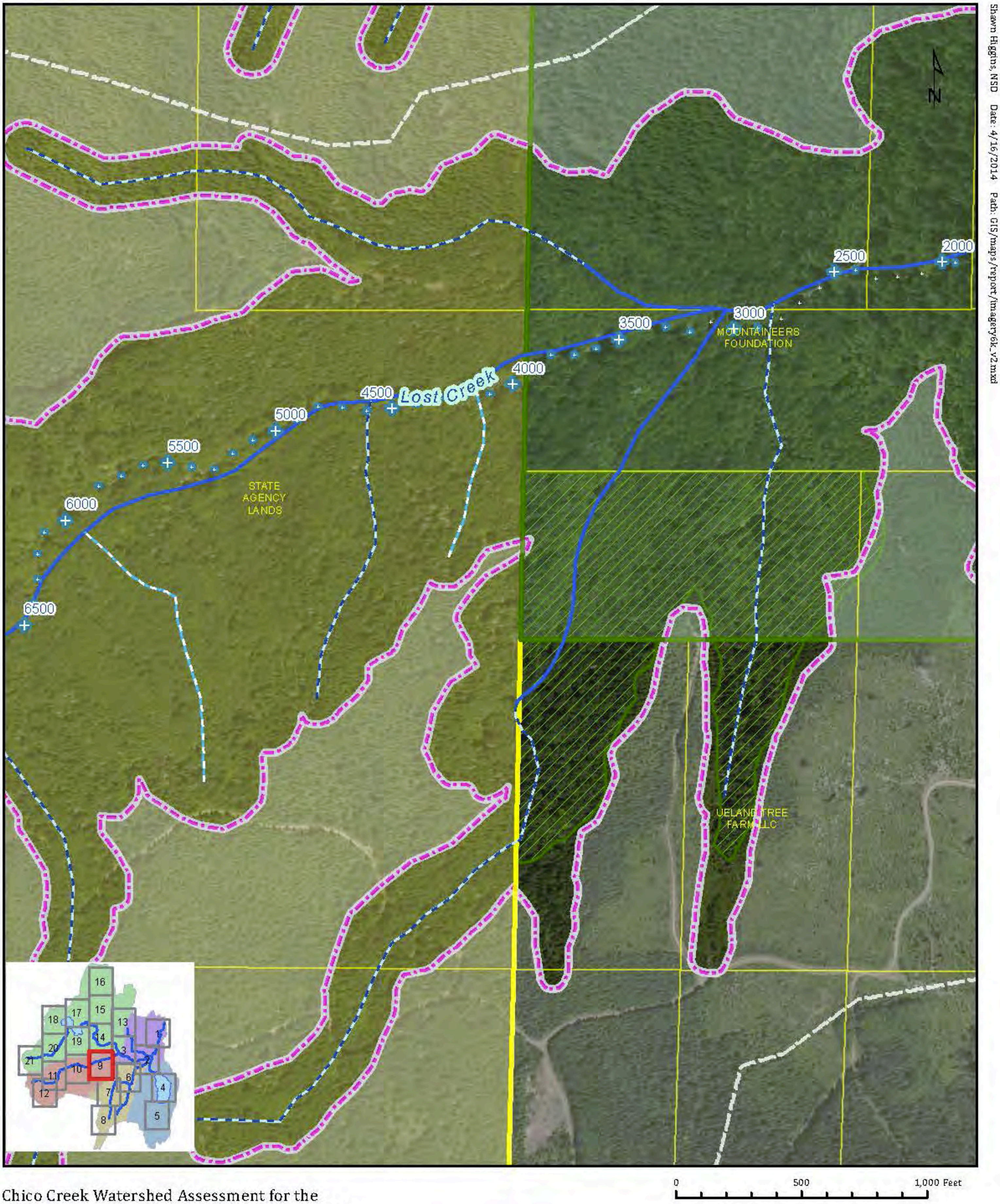
Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

2012 Aerial Imagery: Sheet 7 of 21



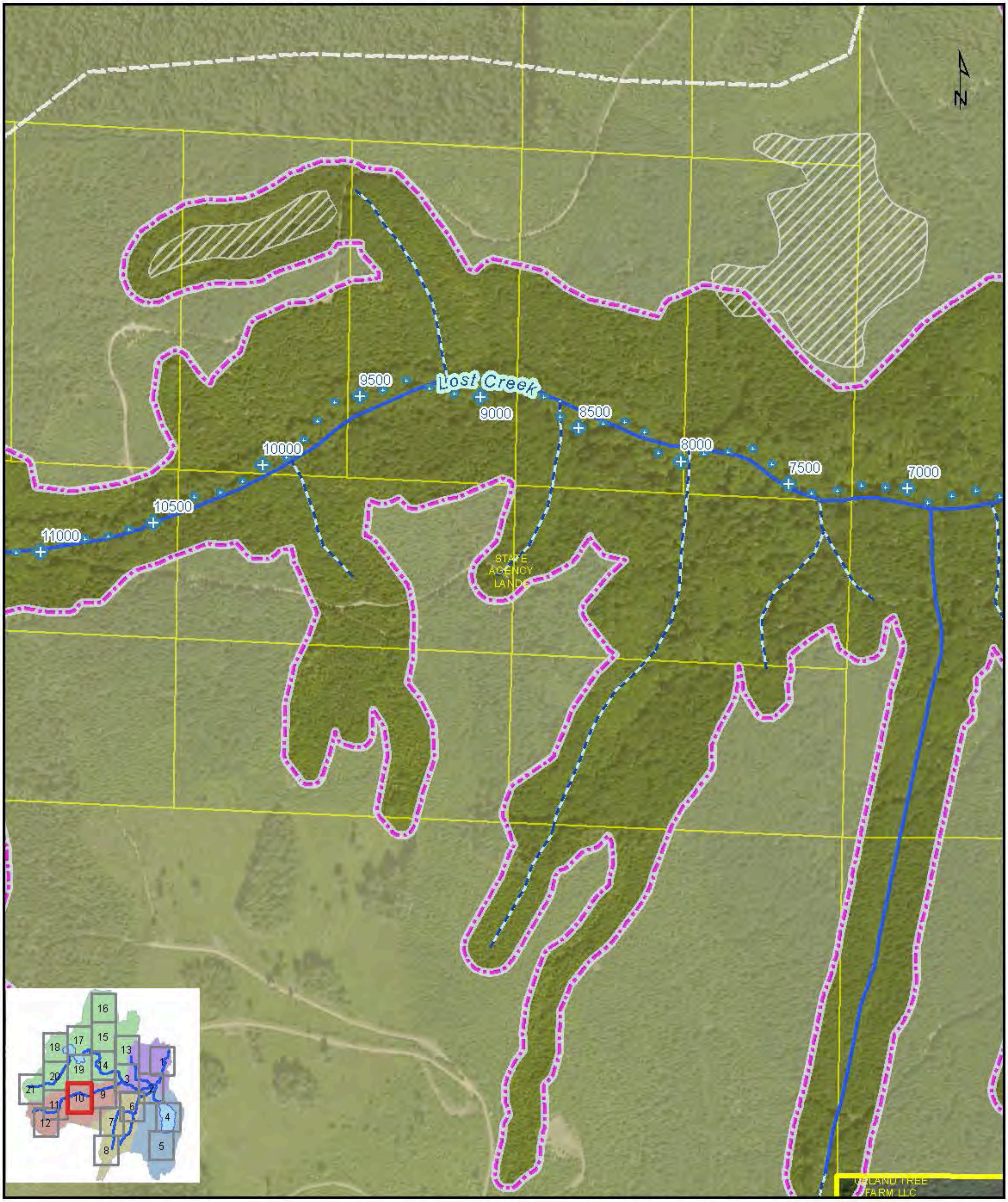
Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

2012 Aerial Imagery: Sheet 8 of 21



Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

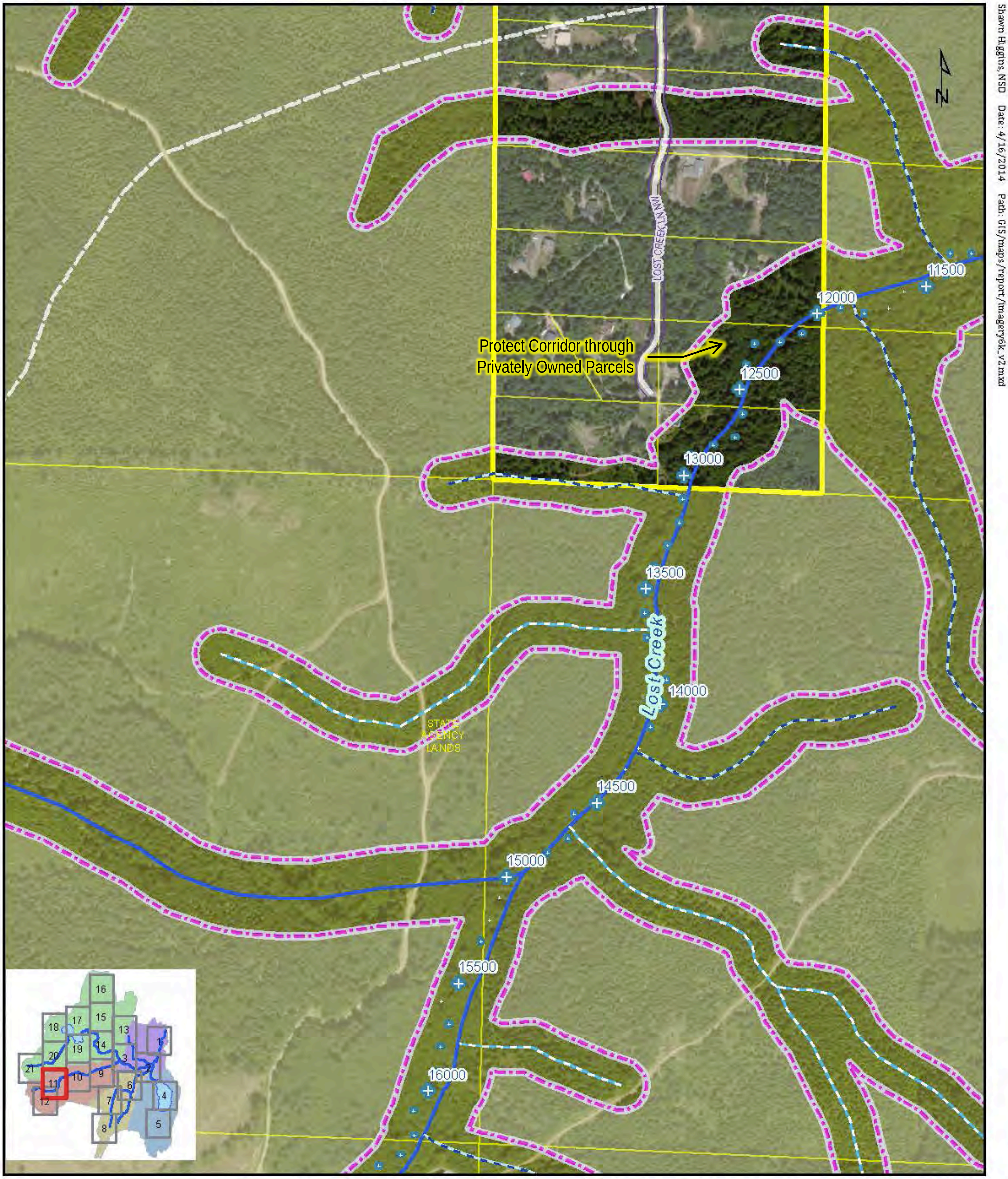
2012 Aerial Imagery: Sheet 9 of 21



Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/imagery6k_v2.mxd

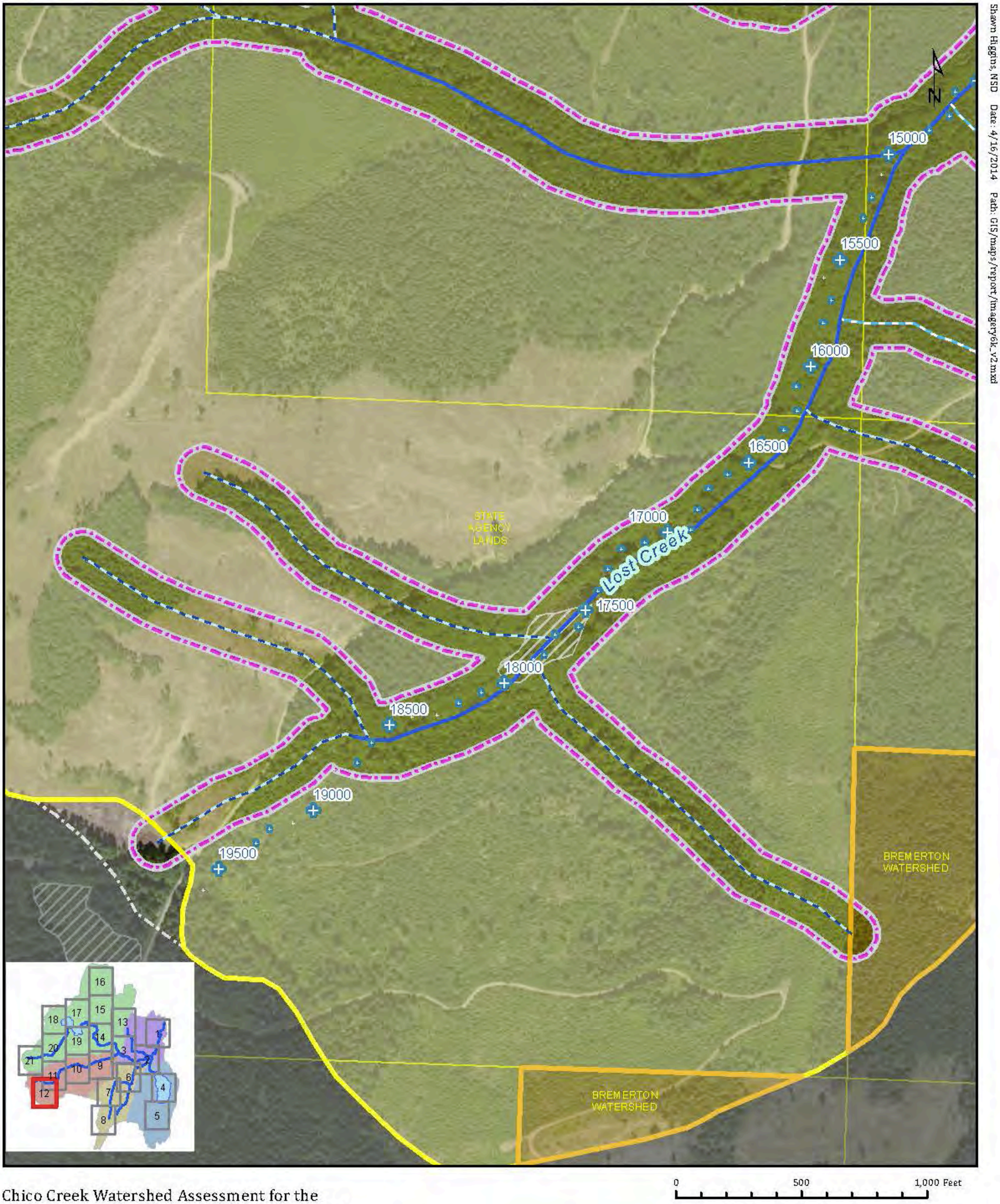
Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

2012 Aerial Imagery: Sheet 10 of 21



Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

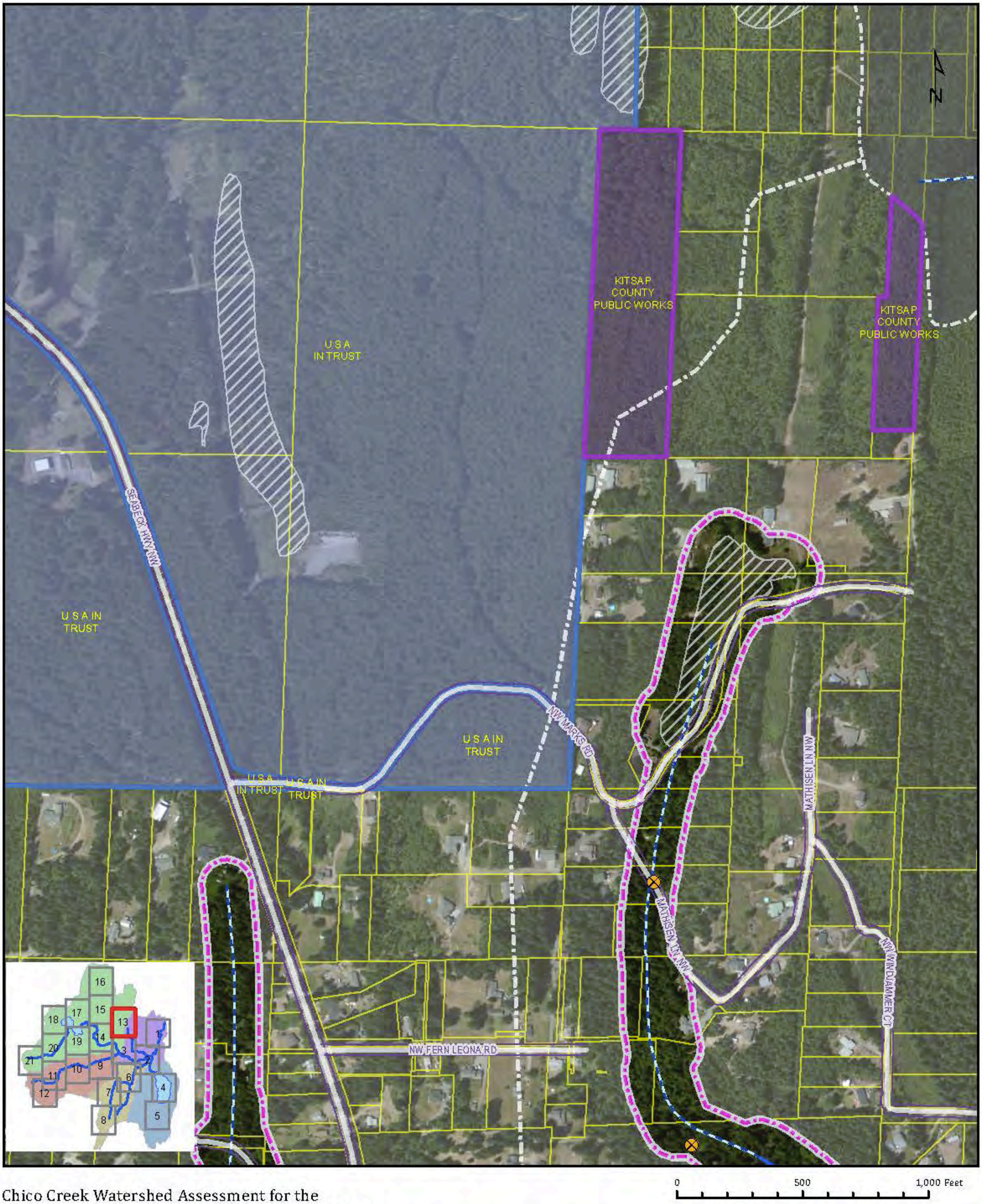
2012 Aerial Imagery: Sheet 11 of 21



Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

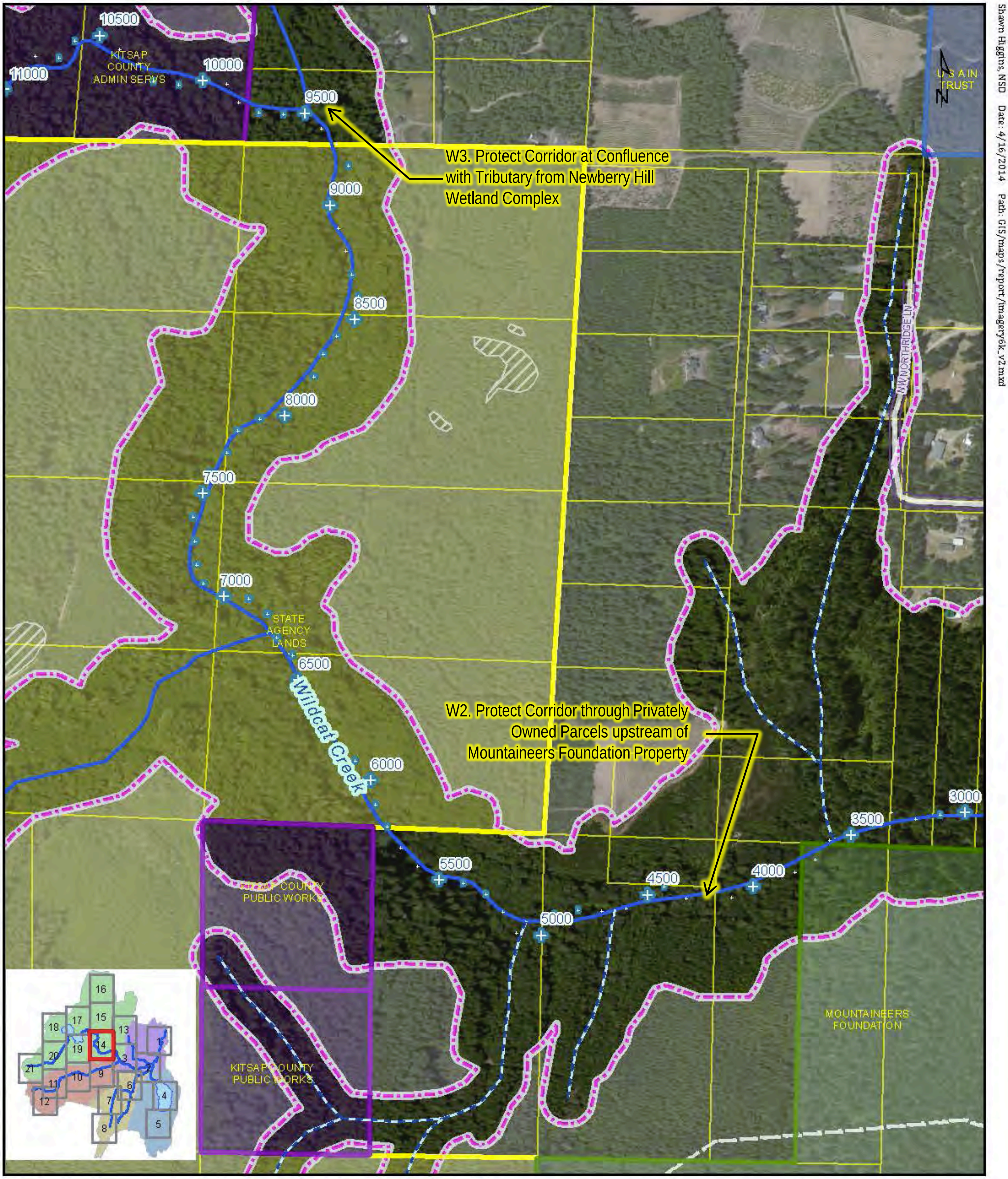
2012 Aerial Imagery: Sheet 12 of 21

Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/imagery6k_v2.mxd



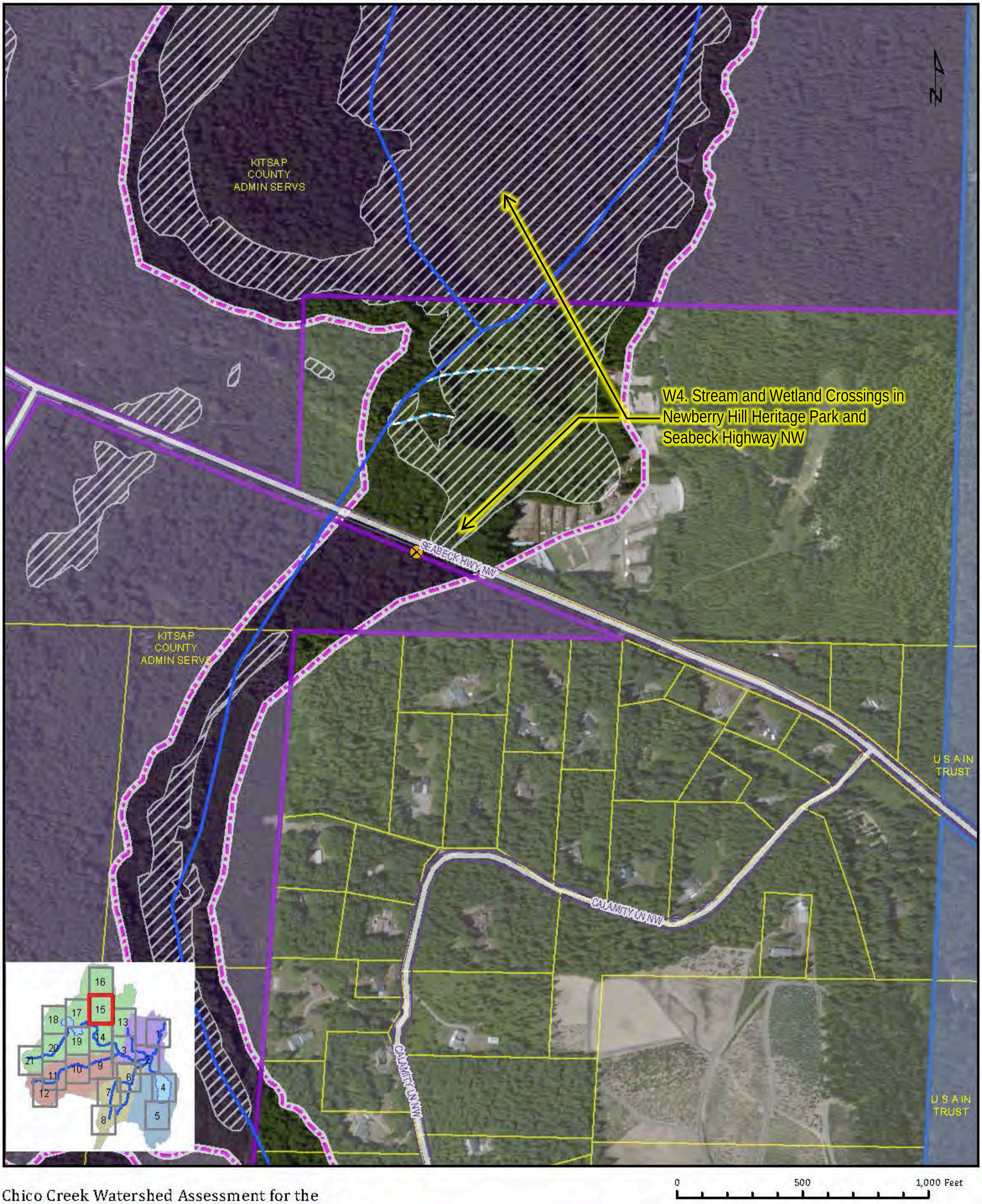
Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

2012 Aerial Imagery: Sheet 13 of 21



Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

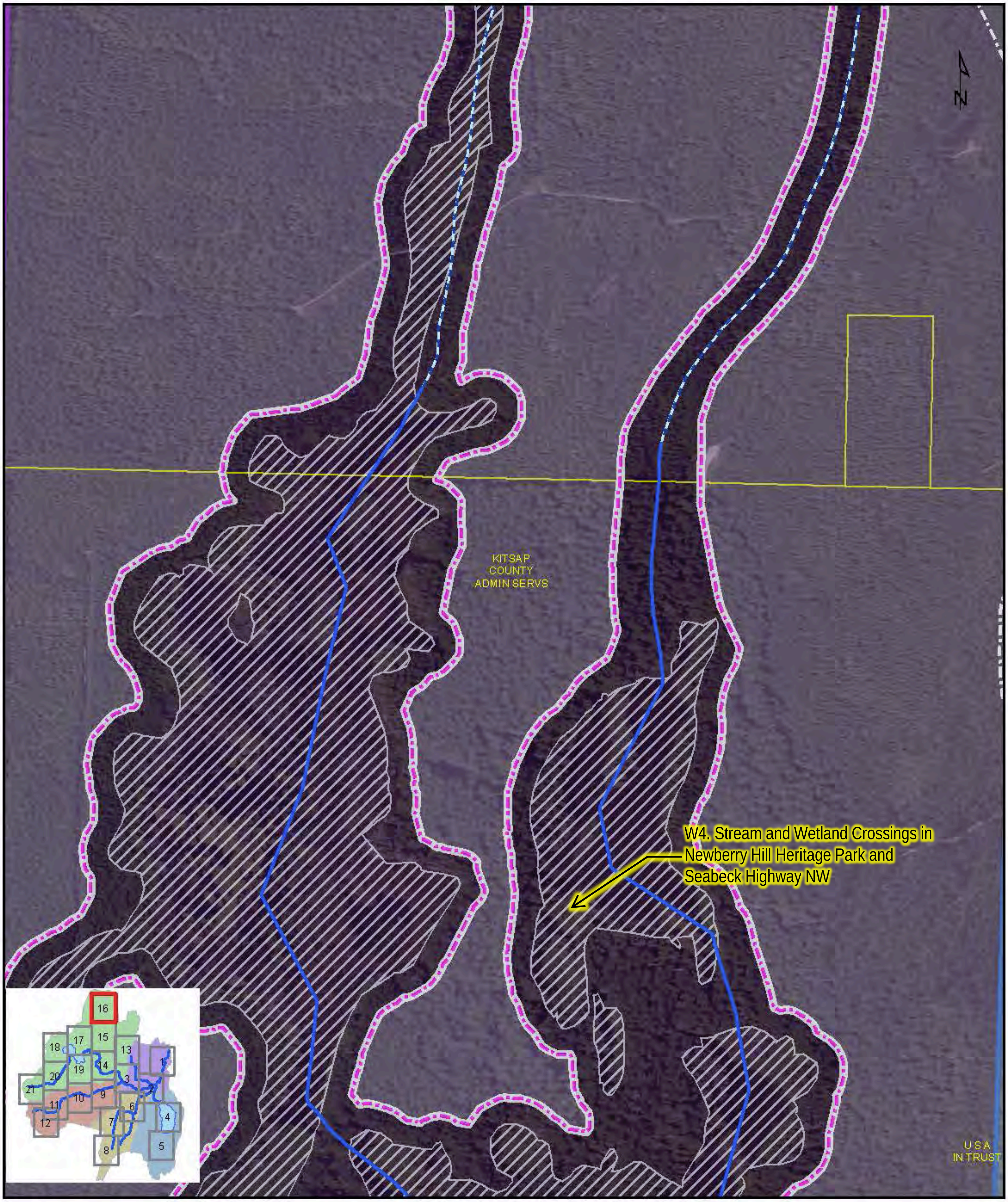
2012 Aerial Imagery: Sheet 14 of 21



Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/imagery6k_v2.mxd

Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

2012 Aerial Imagery: Sheet 15 of 21

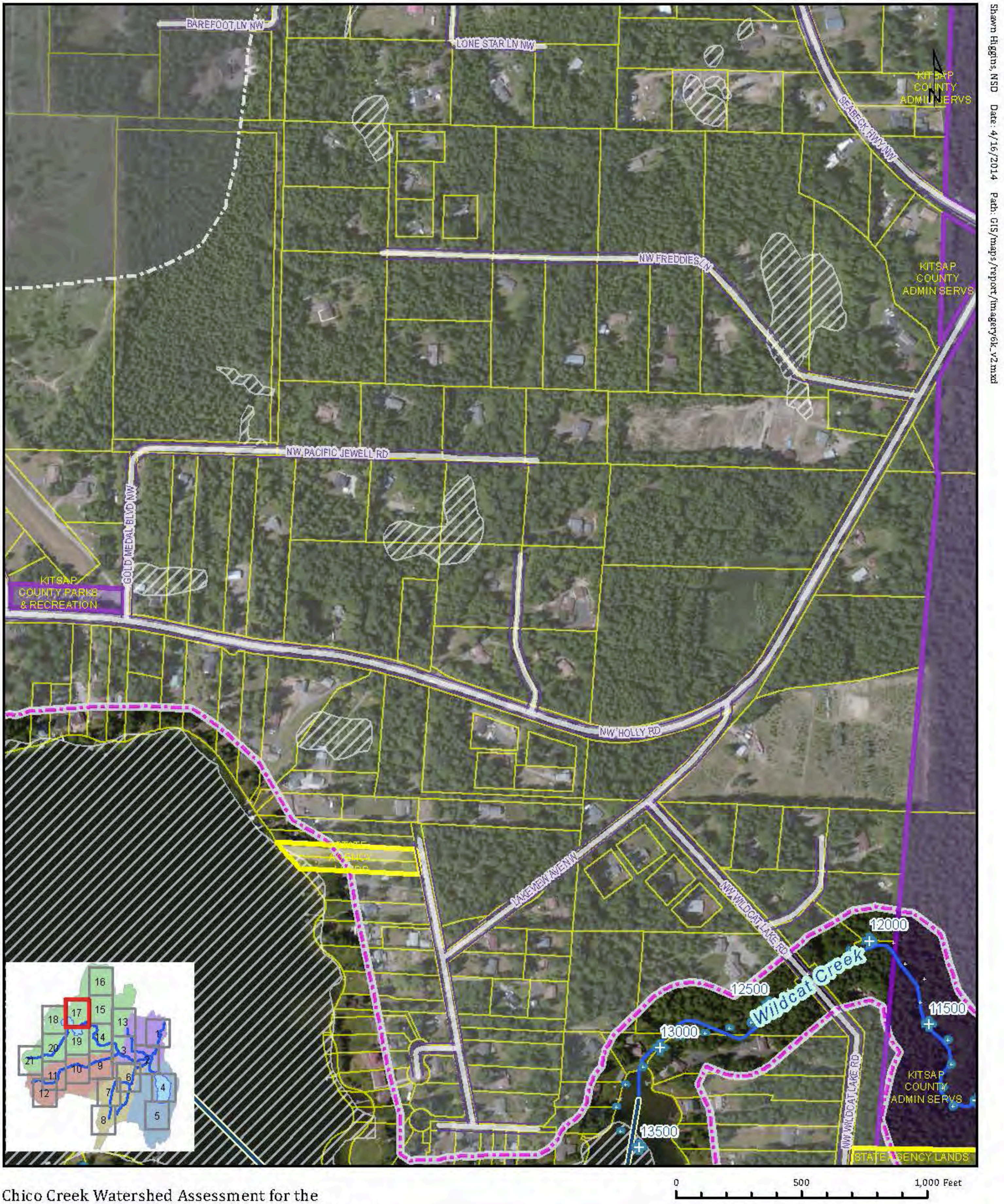


Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/imagery6k_v2.mxd

0 500 1,000 Feet

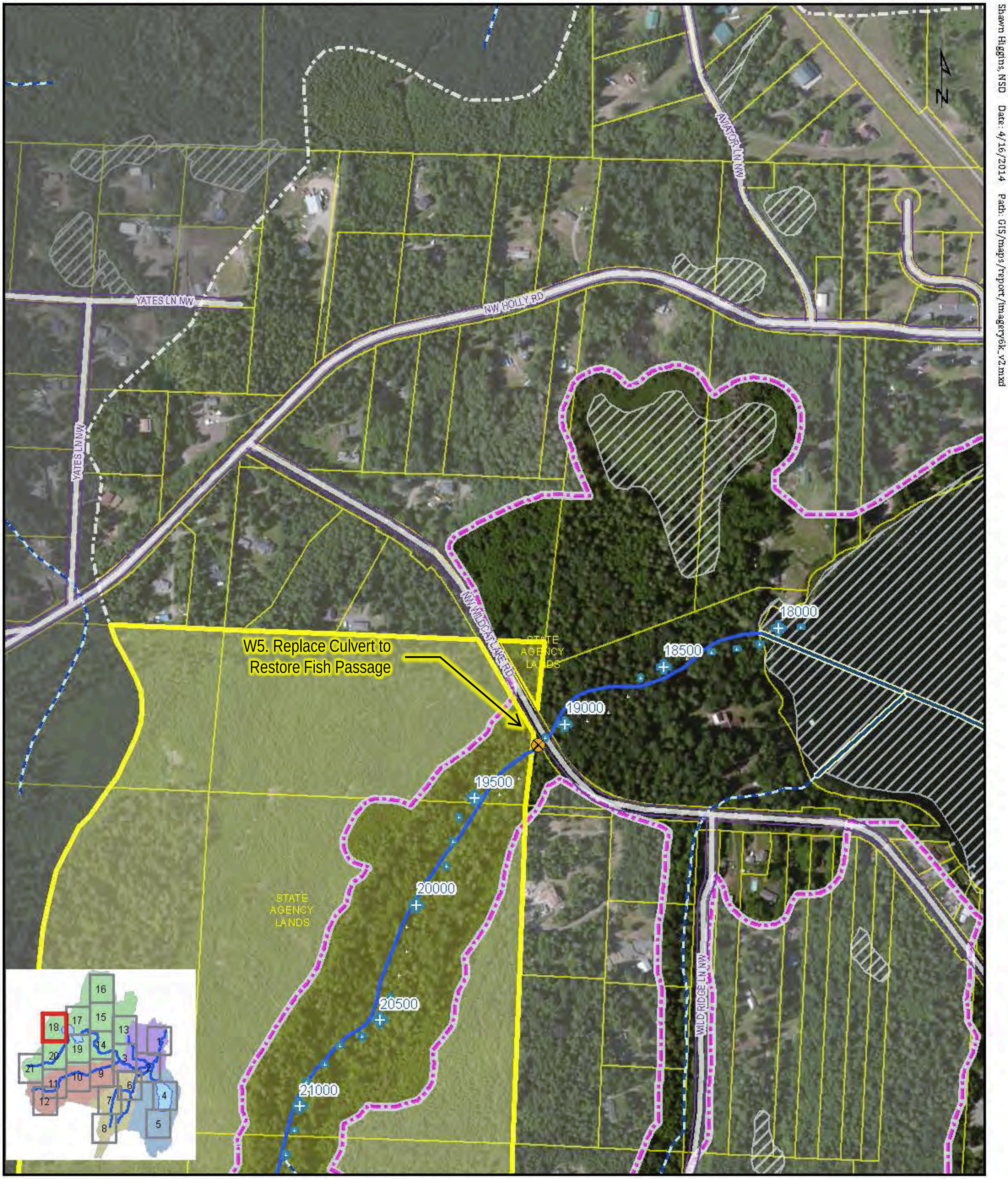
Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

2012 Aerial Imagery: Sheet 16 of 21



Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

2012 Aerial Imagery: Sheet 17 of 21



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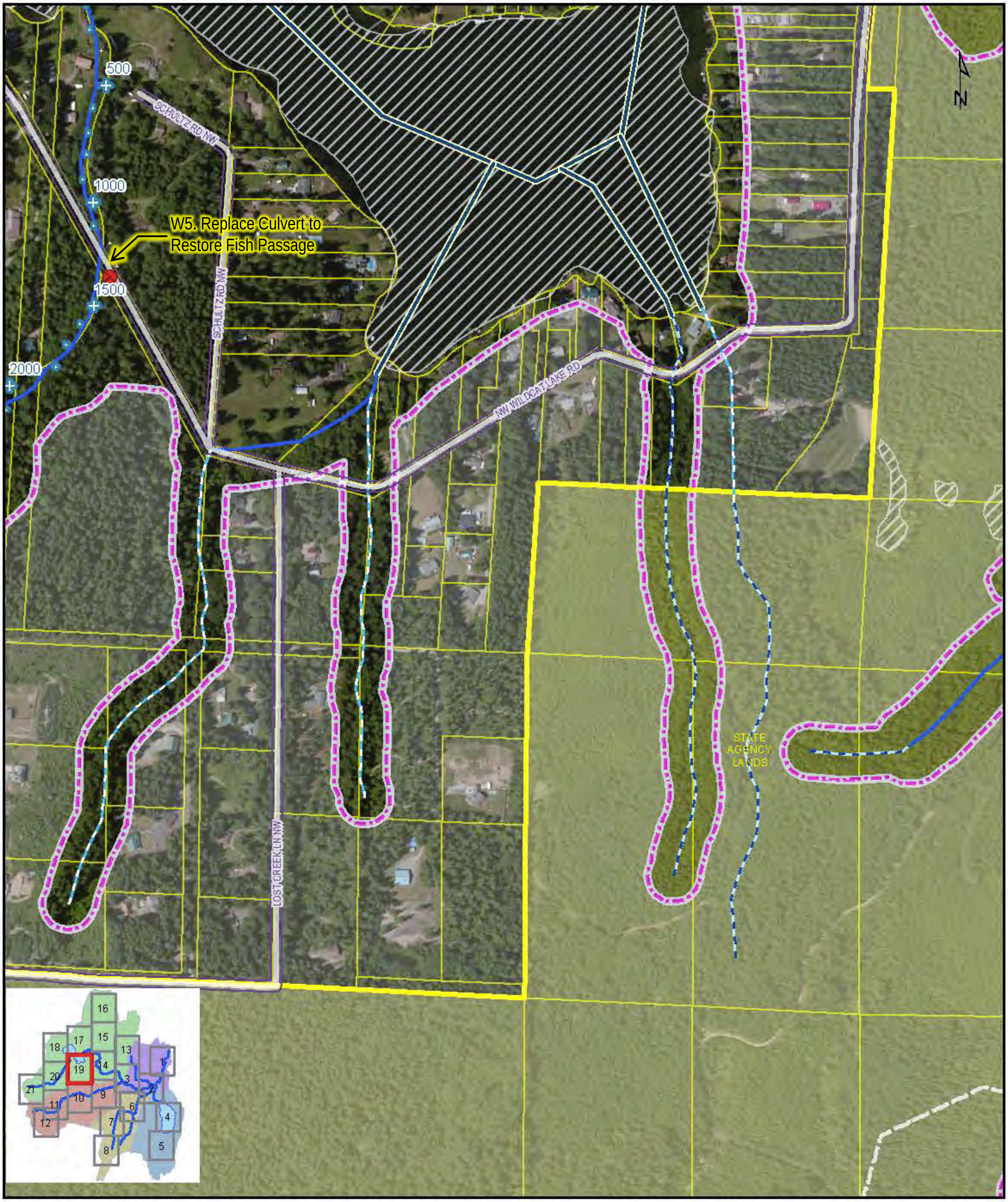

Shawn Higgins, NSD Date: 4/16/2014 Path: GIS/maps/report/imagery6k_v2.mxd

Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions

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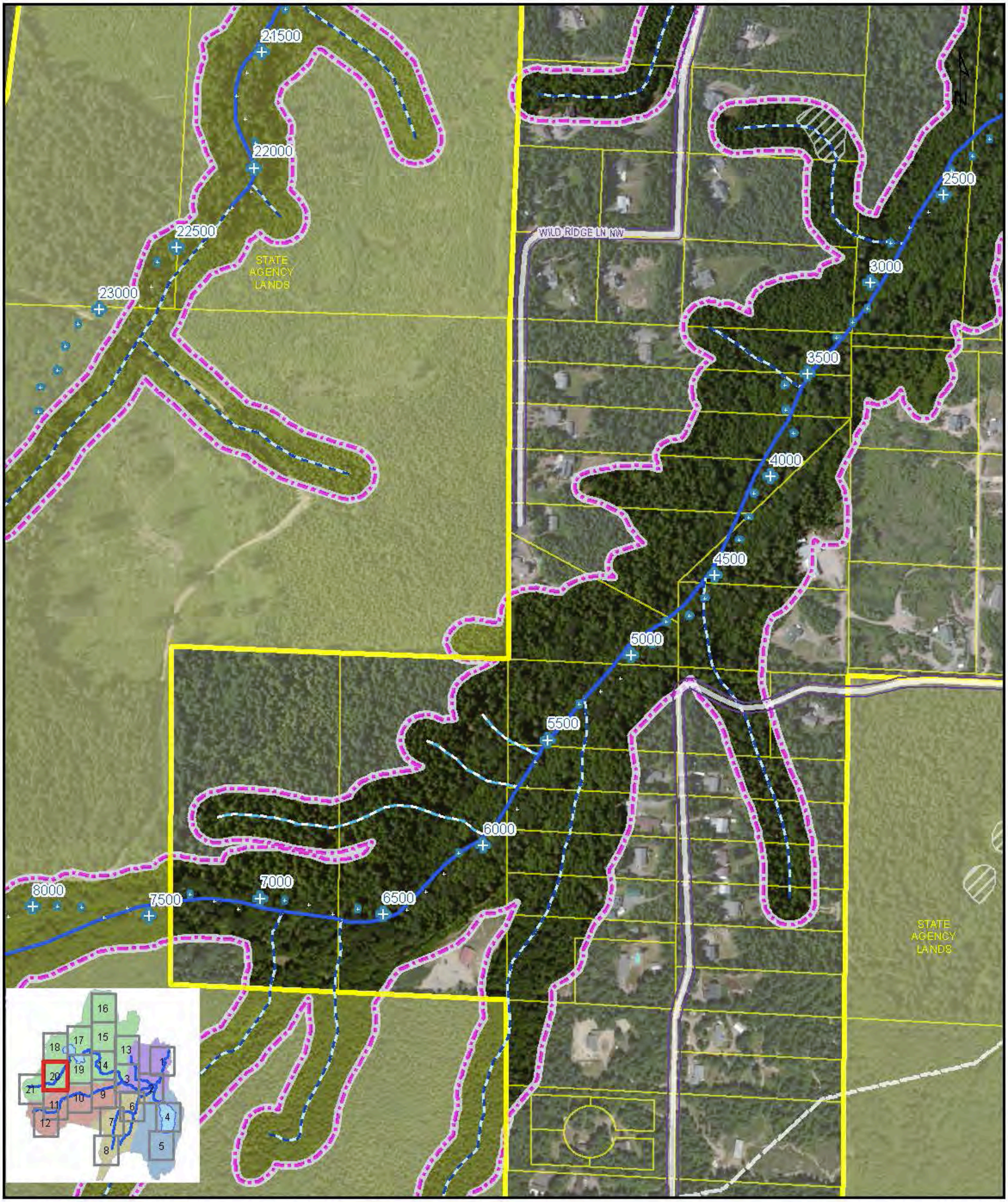

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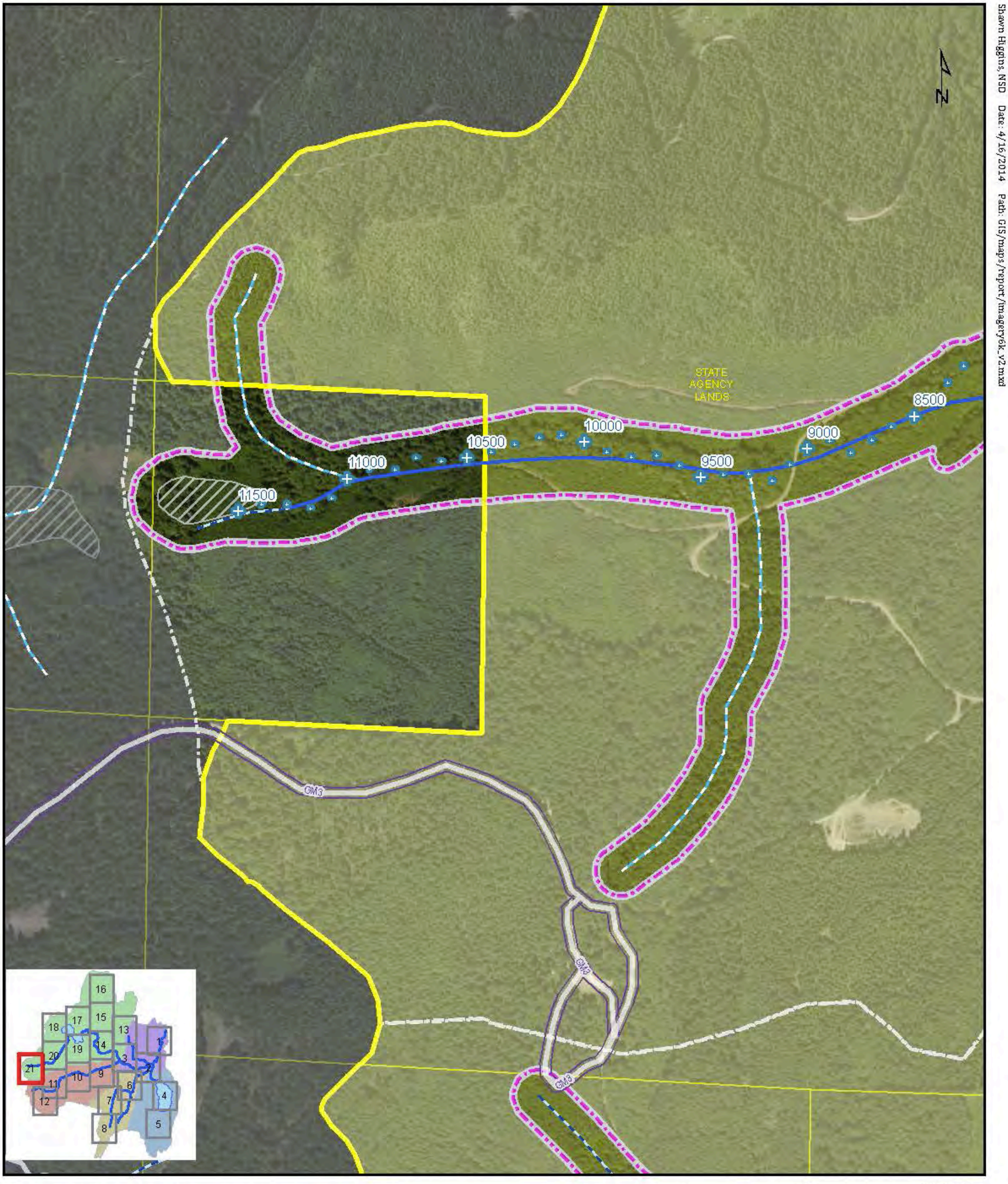

Chico Creek Watershed Assessment for the
Identification of Protection and Restoration Actions

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APPENDIX C

Summary of Recommended Actions

Stream	River Station (ft)		Recommended Restoration Actions						
	From	To	Protect functioning floodplain	Corridor acquisition	Replace stream crossing	Remove features restricting floodplain	Restore riparian processes	Restore instream habitat	Notes
Chico	250	400			☑	☑	☑	☑	Remove Kittyhawk Drive crossing and related road fill; Restore riparian forest and nearshore area; Wood placement to increase channel complexity
Chico	400	1000			☑	☑		☑	Replace SR 3 crossing with larger culverts or bridge and remove excess fill
Chico	1000	3200				☑	☑	☑	Erlands Point Park; Remove levees and debris rack from channelized segment; Plant riparian forest; Re-meander main channel through developing floodplain within former gravel pits; Wood placements to increase channel complexity and form anabranching channel pattern
Chico	3200	3300		☑	☑	☑	☑	☑	Widen bridge span or construct additional bridge for Erlands Point Road NW crossing; Remove excess fill material from floodplain and replant riparian forest
Chico	3300	3700		☑	☑	☑	☑	☑	Channelization along west side of valley with artificial fill on either side. Recent development along Shadow Ln NW on east side of corridor with levee confiinh floodplain; Needs grade control unless corridor can be widened to meander channel
Chico	3700	4500	☑						Protect corridor established throgh golf course
Chico	4550	4750		☑	☑	☑	☑	☑	Fill for NW Golf Club Hill Road extends across entire valley with creek confined to narrow box culverts. Need new bridge or remove road entirely; grade control will be essential if culverts are removed
Chico	4750	5550		☑	☑	☑	☑	☑	County owned property is opportunity for restoration (Keta Park); Additional aquisition of stream corridor needed along east side of stream; Wood placements needed for channel complexity and grade control (critical following removal of box culvert downstream).
Chico	5550	6000		☑	☑	☑	☑	☑	Chico Way NW: road fill blocks almost entire valley, cutting off floodplain. Relict channelon private property in east side of corridor; Restore grade control and reconnect relict channel. Additional bridge or longer span is needed to open up floodplain.
Chico	6000	6300		☑		☑	☑	☑	Entrenched (incised) segment blocked to the east by fill for Chico Way NW. Wood placements needed for grade control; Aquire land in stream corridor and remove riprap from from along left bank to open up floodplain.
Chico	6300	6500		☑		☑	☑	☑	Small inset floodplain on west (left) side of creek; Remove bank protection and increase floodplain connectivty with wood placement.
Chico	6500	7300		☑		☑	☑	☑	Incised reach up to confluence with Kitsap Creek. Needs grade control and wood in short-term, establish corridor in long-term; Potential for side channel enhancement project between RS 7100 and 7300

Chico	7300	8300		☑		☑	☑	☑	Bank erosion in 2007 flood destroyed building (STA 7300) led to more rock revetments. Inset floodplain reach upstream to Northlake Way with good restoration potential, especially with Kitsap Creek confluence
Chico	8300	8400		☑	☑	☑	☑	☑	Northlake Way bridge: additional span to provide floodplain conveyance and ioen floodplain corridor when bank protection can be removed from upstream/downstream reaches.
Chico	8400	8600		☑		☑	☑	☑	Dickerson confluence reach. Park on right bank of Chico and Dickerson creek is old floodplain surface disconnected by channel incision. Restore grade control with wood placentmen to increase floodplain connectivity and remove riprap.
Chico	8600	9250		☑		☑	☑	☑	Incised and entrenched reach in need of grade control and re-connected floodplain
Chico	9250	9350		☑	☑	☑	☑	☑	Taylor Way bridge: additional span to provide floodplain conveyance and ioen floodplain corridor when bank protection can be removed from upstream/downstream reaches.
Chico	9350	10000		☑		☑	☑	☑	Incised reach that experienced bank erosion in 2007 that could have widened flooplain but bank was armored
Chico	10000	11000		☑		☑	☑	☑	Incised reach up to US Navy Trestle ("bowling alley" reach), with terrace on right bank offering great restoration potential to re-establish floodplain
Chico	11000	12000		☑	☑	☑	☑	☑	US Navy Trestle, abuttments cut-off about 60% of original valley bottom; Remove abandoned road grade upstream of trestle; add wood
Chico	12000	12500		☑		☑	☑	☑	Textbook incision reach approaching Navy Trestle. Grade control needed to raise channel at least 5 feet. Channel confined to about 25% its original floodplain
Chico	12500	14000		☑		☑	☑	☑	Moderate incision with almost all of valley bottom intact, channel needs to be raised to fully connect
Chico	14000	14925	☑					☑	Upper most reach of Chico to confluence of Lost and Wildcat Creeks. Good condition, just needs more in-stream wood; Potnetial for grater connectivity with off channel habitats with increased wood loading.

Stream	River Station (ft)		Recommended Restoration Actions						
	From	To	Protect functioning floodplain	Corridor acquisition	Replace stream crossing	Remove features restricting floodplain	Restore riparian processes	Restore instream habitat	Notes
Kitsap	0	500		☑			☑	☑	Confluence with Chico Creek; Wood placement to increase channel complexity
Kitsap	500	2400		☑		☑	☑	☑	Incised channel segment; Remove bank[protction and houses from floodplain; Replant riparian forest; Wood placements to provide grade control and restore floodplain connectivity
Kitsap	2400	2400		☑	☑	☑	☑	☑	Remove culvert for private road
Kitsap	2400	3700		☑				☑	Wood placements to increase channel complexity
Kitsap	3700	4000		☑	☑	☑	☑	☑	Replace crossing at NW Northlake Way to widen the floodplain and ensure fish passage
Kitsap	4000	4200		☑		☑	☑	☑	Remove infrastuctrure previously used to support fish screens and restrict anadromous passage at the lake outlet.
Kitsap	10000	11500	☑	☑					Upstream of Kitsap Lake; Low gradient wetland complex; Much of stream corridor is protected as part of Kitsap Lake Park;
Kitsap	11500	12600	☑	☑	☑	☑	☑		Relatively intact floodplain; Development along west side encroaches into floodplain and impairs riparian processes; Stream crossings at W Kitsap Lake Rd and W Reba Way are partial barriers to fish passage.
Kitsap	12600	15000	☑	☑		☑	☑		Relatively intact floodplain; Mining activities encroach into floodplain on east side of valley

Stream	River Station (ft)		Recommended Restoration Actions						
	From	To	Protect functioning floodplain	Corridor acquisition	Replace stream crossing	Remove features restricting floodplain	Restore riparian processes	Restore instream habitat	Notes
Dickerson	0	1400		☑	☑	☑	☑	☑	Severe incision and disconnected floodplain downstream of David Rd. County plans to replace culverts; Wood placements needed to restore grade currently checked by existing culverts; Remove bank protection structures from corridor
Dickerson	1400	2500		☑		☑	☑	☑	Relatively intact floodplain; Functional wood needed; Remove bank protection structures from corridor
Dickerson	2500	2950		☑		☑	☑	☑	Incised segment where WDFW log weirs failed and channel cut down ~ 5 ft; Functional wood needed; Remove bank protection structures from corridor; Remove levee at RS 2500 to reconnect floodplain habitat
Dickerson	2950	3100			☑				Undersized culverts beneath Navy Railroad grade need to be replaced
Dickerson	3100	3400	☑					☑	Establish conservation easement with Ueland Tree Farm; Transmission line crossing, lack of wood due to clearing beneath lines
Dickerson	3400	7000	☑						Upper watershed: Establish conservation easement with Ueland Tree Farm to protect streamside forests and creek corridor.

Stream	River Station (ft)		Recommended Restoration Actions						
	From	To	Protect functioning floodplain	Corridor acquisition	Replace stream crossing	Remove features restricting floodplain	Restore riparian processes	Restore instream habitat	Notes
Lost	0	4000	☑						Mountaineers propoerty
Lost	4000	12000	☑						WDNR property
Lost	12000	13000	☑	☑					Aquire stream corridor for restoration/protection of the riparian forest
Lost	13000	18500	☑						WDNR propoerty

Stream	River Station (ft)		Recommended Restoration Actions						
	From	To	Protect functioning floodplain	Corridor acquisition	Replace stream crossing	Remove features restricting floodplain	Restore riparian processes	Restore instream habitat	Notes
Wildcat	0	500					☑	☑	Homestead at Mountaineers propoerty; Add stable wood; Potential for off-channel habitat creation
Wildcat	500	2300	☑						Mountianeers property
Wildcat	2300	5800	☑	☑					Aquire stream corridor upstream of Mountaineers property
Wildcat	5800	9300	☑						WDNR propoerty
Wildcat	9300	9800	☑	☑					Aquire stream corridor at tributary confluence
Wildcat	9800	12000	☑						County ownership
Wildcat	12000	13000	☑	☑		☑	☑	☑	Protect stream corridor, riparian processes impaired by development along south side of channel at lake outlet. Add stable wood to increase channel complexity.