ECOLOGICAL RESOURCES CHARACTERIZATION

MIDDLE FORK SNOQUALMIE RIVER
TANNER TO THREE FORKS NATURAL AREA

King County
River and Floodplain Section
Water and Land Resources Division

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MIDDLE FORK SNOQUALMIE RIVER TANNER TO THREE FORKS NATURAL AREA

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September 4, 2013

PRINTED ON RECYCLED PAPER

ACKNOWLEDGMENTS

We would like to thank the following King County staff who participated in this investigation:

- Mark Ruebel, Project Manager
- Clint Loper, Project Oversight
- Phyllis Meyers, Lead Ecologist
- Richelle Rose, Technical Oversight

The following Herrera staff participated in the project:

- Josh Wozniak, Project Manager and Lead Ecologist
- José Carrasquero, Principal Fisheries Biologist
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- Wes Lauer, Senior Geomorphologist
- Mark Ewbank, Project Management Support
- Jennifer Schmidt, GIS Analysis
- Olivia Lau, GIS Graphics

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GLOSSARY OF TERMS

1 Percent Annual Chance Flood. The flood that has a 1 percent chance of being equaled or exceeded in any given year. Also known as a 100-year flood.

Aquatic Habitats. For the purpose of this report, aquatic habitats are water channels that convey river water, groundwater discharged to surface waters, and tributaries. In addition, islands within the primary river channel are categorized as aquatic habitat.

Alluvial Fan. A radially symmetric geomorphic surface created by an alluvial sedimentation. Alluvial fans are usually characterized by active and sometimes unpredictable channel movement and channel avulsions.

Anabranching River. A river that contains multiple mid-channel bars, vegetated islands, and multiple channel courses. Where the riverbed is primarily gravel, anabranching rivers experience relatively frequent and somewhat unpredictable changes in channel position as mid-channel bars form and erode. They are thus sometimes referred to as wandering rivers.

Armor. A relatively coarse layer at the surface of a sedimentary deposit that results from the winnowing of fine material out of the underlying deposit. In the context of bank hardening, it refers to substrate, such as riprap, placed to limit bank erosion.

Avulsion. A rapid change in channel course that results in the abandonment of the original channel. Avulsions can result in the creation of a new channel or, more frequently, in the reoccupation of an old channel that was abandoned by a previous channel avulsion.

Bank Erosion. Fluvial erosion of a riverbank.

Bar. An in-channel sedimentary structure that is elevated relative to the rest of the channel bed and generally has horizontal dimensions that are not significantly larger or smaller than the width of the channel.

Basin. A geographic area that contains and drains to a stream named and noted on common maps or a geographic area that drains to a non-flowing water body, such as a lake or marine area, named and noted on common maps.

Bed Material. Sediment with a size gradation similar to that found on the channel bed. In the study area, bed material consists of sand, gravel, cobble, and boulder-size material.

Bed/Bar Material. Sediment with a size gradation similar to that found on the channel bed or in channel bars. In the study area, bed/bar material probably contains more sand than bed material.

Bedload. Sediment that moves near the channel bed and not high in the water column.

Channel Migration. A change in channel location of a stream or river due to bank erosion or avulsion.

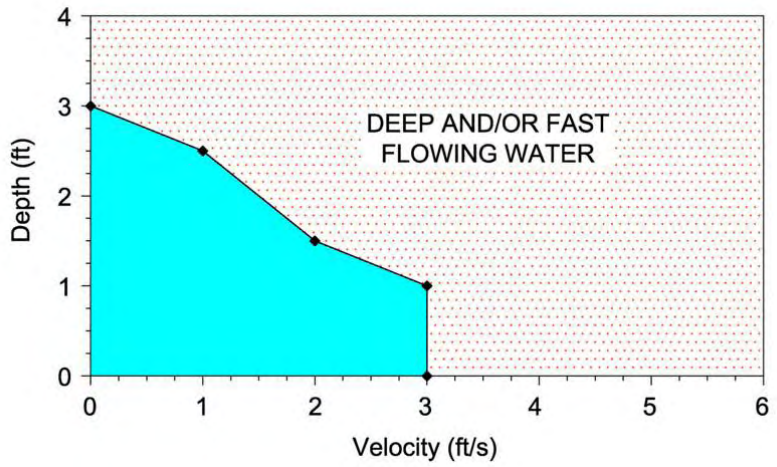
Corridor. The area of a river and surrounding lands that is essential to the storage and conveyance of floodwaters and is integral to natural riverine processes. A river corridor is a larger geographic area that includes one or more river reaches (see **River Reach**).

Debris Flow. A fast-moving slurry of sediment and water and sometimes plant material.

Debris Flow Fan. An alluvial fan formed by debris flow processes. Debris flow fans are present where steep colluvial channels divulge sediment onto a relatively flat alluvial floodplain or terrace. One debris flow fan occurs in the study area, at the base of a steep channel on the west side of Mount Si. Because the debris flow fan is forested, it is not clear how active the fan has been during the historic period.

Delta. A sedimentary structure formed at the transition between a river and standing water such as a lake or the ocean.

Deep and/or Fast Flowing Water – Areas of public safety hazard characterized by water depths greater than 3 feet, flow velocities greater than 3 feet per second, or a combination of depth and velocity greater than a threshold as shown on the figure below (from Pierce County 2010):



Development. Any manmade change to improved or unimproved real estate, including but not limited to buildings and other structures, mining, dredging, filling, grading, paving, extraction or drilling operations, farming, and storage of equipment or materials.

Digital Elevation Model (DEM). A three-dimensional digital representation of the ground (or other) surface based upon a regularly spaced grid of elevation data points.

Distal Floodplain/Fan. Relatively low-elevation areas that lie adjacent to, and slightly above, meandering and wandering river floodplains and relict channels.

Distributary Channel: A channel that conveys flow away from the main channel, usually on an alluvial fan or fan delta.

Embankment. A large glacially derived sedimentary structure. Near the study area, embankment moraines block all or part of the valleys of the Middle Fork Snoqualmie River, South Fork Snoqualmie River, and Cedar River.

Erosion. The wearing away of ground surface as the result of the movement of wind, water, or ice.

Extent. The size of an area affected by a hazard.

Fan Delta. An alluvial fan whose lower limit is a delta.

Flood or **Flooding.** A general and temporary condition of partial or complete inundation of normally dry land areas from the overflow of inland or tidal waters or the unusual and rapid accumulation of runoff of surface waters from any source.

Floodplain Habitats. For the purpose of this report, the different geomorphic and vegetation types in the floodplain are distinguished into different habitat types.

Flood Protection Infrastructure. Structures that provide protection from flood damage, including but not limited to the following:

- Dams or water diversions, regardless of primary purpose, if the structures provide flood protection benefits
- Flood containment structures such as levees, dikes, berms, walls, and raised banks, including pump stations, flood closure devices, and other supporting structures
- Bank stabilization structures, often called revetments

Flood Risk Reduction. An action taken to decrease exposure of people and property to flood or channel migration hazards.

Floodplain. The area potentially subject to inundation due to high river levels. The floodplain encompasses geomorphically active areas near the channel, alluvial fans (whether active or inactive), and low-elevation surfaces that may be flooded by the river. As used in this report, the term does not necessarily distinguish between land surfaces that are currently protected from flooding by flood protection infrastructure and surfaces that have no such protection.

Floodplain Swale. A channel that is usually smaller than the main river channel and crosses a floodplain surface. Floodplain swales are typically mantled by fine-grained silt/clay sediment.

Geomorphology. The study of landforms.

Glacial Outwash. Glacially derived sediment deposited by a fluvial action, usually by meltwater flowing out of the glacier.

Glacial Till. Unsorted sediment deposited directly by a glacier. Usually includes a wide range of sediment sizes, from boulders down to clay. The weight of overlying glacial ice usually consolidates glacial till so that it is relatively resistant to erosion.

Glide. Glide habitats are characterized by moderately shallow water with an even flow that lacks pronounced turbulence. Glides are most frequently located at the transition between a pool and the head of a riffle. The typical substrate is gravel and cobble. Glides are commonly referred to as "runs."

Groundwater Channel. Groundwater channels are often relict river and/or flood channels fed by groundwater, although surface flow from higher terraces can also contribute. They include several subtypes of channels that include but are not limited to the following:

- Channels originating from the exfiltration of main channel surface water (i.e., very shallow groundwater associated with the main river); they are sometimes called backwater channels or sloughs
- Channels fed by the floodplain aquifer (hyporheic zone); they are sometimes called percolation channels
- Channels fed by lateral groundwater supplied from adjacent terraces; they are sometimes called wall-base channels

Some groundwater channels can also be classified as overflow channels. For the purposes of this study, they are classified as groundwater channels if the dominant source of hydrology is from groundwater. The size of groundwater channels will have some seasonal variation though tempered from the range of change associated with the hydrograph. Groundwater channels are typically vegetated and commonly contain upland forests or wetlands (forested, scrub-shrub, emergent, and aquatic bed).

Hazard. An event or physical condition that has the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural loss, damage to the environment, interruption of business, and other types of loss or harm.

Hazard Mitigation. Reduction or alleviation of the loss of life, personal injury, and property damage that could result from a disaster through long- and short-term strategies. Hazard mitigation involves strategies such as planning, policy changes, programs, projects, and other activities.

Headcut. An erosive landform that occurs where water spills across a locally steep drop. Headcuts can migrate upstream when material at the toe is removed by the highly erosive flow at the base of the headcut.

Hillslope. Hillslopes are comprised of the valley walls and convex surfaces at the toe of the valley slopes.

In-channel Island. In-channel islands are composed of floodplain benches that are entirely surrounded by the main channel and/or active side channels. They occupy an elevation at or above typical annual high flows and are commonly inundated by larger floods. They are indicative of active channel formation processes. In-channel islands are typically forested or dominated by shrubs and provide extensive riparian edge habitat.

Inset Floodplain. Floodplain surface, located just above 2-year flood inundation, formed in a setting where channel location is highly constrained by riverbank substrate size. Within this report, inset floodplains occur in subreach MF2, within the radially symmetric alluvial fan.

Large Wood. Large pieces of wood including logs, pieces of logs, root wads of trees, and other large chunks of wood that are in or partially in the channel or floodplain of rivers and streams. The term does not include rooted, standing vegetation. Large wood can stabilize streambeds and riverbanks, provide cover and refuge for fish, and create complex in-stream habitat by forming pools, regulating sediments, and dispersing stream energy.

Lateral migration. Progressive, usually gradual change of position of a geomorphic feature. Channel migration is the lateral migration of a river channel.

Levee. A manmade structure, usually an earthen embankment, designed and constructed to contain, control, or divert the flow of water so as to provide protection from temporary flooding.

Lidar. An acronym for **l**ight **d**etection **a**nd **r**anging, which is a remote sensing method that uses light in the form of a pulsed laser mounted in aircraft to measure ranges (variable distances from the sensor) to the earth's surface. The resultant topographic mapping is typically precise, high-resolution information that can be used cost-effectively in lieu of on-the-ground or other photogrammetric survey data for analysis encompassing large areas.

Meandering River. A sinuous single-thread river. Meandering rivers often are characterized by meander bends that migrate across the floodplain.

Meandering River Floodplain. Floodplain formed by a meandering river. Meandering river floodplains are usually characterized by lateral accretion of point bars and subsequent deposition of suspended sediment. They also usually contain abandoned meander bends or oxbow lakes.

Moraine. A geomorphic feature formed by deposition of sediment at the edge or front of a glacier.

Native Vegetation. Plant species indigenous to the Puget Sound region that reasonably could be expected to occur naturally on a site.

Natural Resource Lands. Lands designated under requirements of the State of Washington Growth Management Act that include the following: 1) agricultural lands with long-term significance for the commercial production of food or other agricultural products, 2) forest lands with long-term significance for the commercial production of timber, and 3) mineral resource lands with long-term significance for the extraction of minerals. The King County Comprehensive Plan designates Agricultural Production Districts, Forest Production Districts, and Mineral Resource Sites.

Open Space. Areas left predominantly in a natural state to create urban separators and greenbelts, sustain native ecosystems, connect and increase protective buffers for environmentally sensitive areas, provide a visual contrast to continuous development, reinforce

community identity and aesthetics, or provide links between important environmental or recreational resources.

Overflow Channel. Overflow channels represent flood swales, often an abandoned mainstem or side channel, carrying surface water and directly connected to the primary channel at their upstream end. Some side channels may have formed or at least been enhanced by head-cutting that was initiated where the side channel reconnects with the main river at its downstream end. For purposes of this study, overflow channels are characterized as hydraulically connected to the primary channel at modeled flows corresponding to flows above 1-year floods, but at or below 2-year peak flows.

Plane Bed Channel. Plane bed channels generally lack regularly repeating bedforms and are characterized by long stretches of relatively featureless bed encompassing glide, riffle, and rapid morphologies. Plane bed channels lack discrete bars, a condition associated with low width-to-depth ratios. Plane bed channels typically exhibit armored bed surfaces dominated by gravel and cobble.

Point Bar. A bar located on the inside of a meander bend.

Pool. Pool habitats are topographic depressions within the channel that include several types formed under a variety of different conditions. Within the main channel of the river, pool-riffle channels are typical, where pools are rhythmically spaced between riffles. Pools are also found in association with bars generated by flow convergence and divergence either freely formed by cross-river flow and sediment transport, or forced by channel bends and obstructions (e.g., large woody debris). Pool types affected by obstructions include backwater pools, trench pools, and lateral scour pools. Substrate size in pools varies from sand to cobble, but it typically is gravel-sized in pool-riffle channels.

Regulatory Floodplain. An area regulated by King County as floodplain through its land use regulations. It includes, but is not limited to, areas identified by the Federal Emergency Management Agency and published on Flood Insurance Rate Maps and additional areas identified by King County as being susceptible to flooding using best available flood information.

Relict Channel. Former river channels, side channels, or floodplain swales that are disconnected from frequent flooding. For the purposes of this study, relict channels are characterized as only showing signs of inundation at modeled flows corresponding to greater than 2-year flood events. Relict channels occur in historic floodplains at higher elevations that are no longer flooded except at extreme flows. These channels are typically entirely vegetated and lack visible signs of flow (e.g., no scour evident).

Revetment. A facing of stone, broken rock, or other material placed on a streambank or slope to minimize erosion by moving water.

Riffle. Riffle habitats are characterized by shallow reaches with moderate current velocity and moderate turbulence. Substrate is usually composed of gravels, cobbles, and boulders. The upper gradient limit for this habitat is approximately 4 percent.

Riparian Area. The area adjacent to flowing water such as rivers, perennial or intermittent streams, seeps, or springs that contains elements of both aquatic and terrestrial ecosystems that mutually influence each other.

River Reach. A length of river through which similar physical or geomorphic conditions exist.

Riverine. Of or produced by a river. Riverine floodplains have readily identifiable channels.

River and Floodplain Management Section. A section within King County's Water and Land Resources Division, Department of Natural Resources and Parks, and funded by the King County Flood Control District and Inter-County River Improvement Fund to conduct the following activities:

- Structural capital improvement projects
- Relocation and elevation projects
- Maintenance and monitoring
- River planning
- Flood hazard education
- Flood warning and emergency response
- Complaint response and enforcement
- Interlocal coordination

Salmonid. Members of the fish family *Salmonidae*, including, but not limited to the following:

- Chinook, coho, chum, sockeye, and pink salmon
- Rainbow, steelhead, and cutthroat salmon (which are also known as trout)
- Brown trout
- Brook, bull trout (which is also known as char), and Dolly Varden char
- Kokanee
- Pygmy whitefish

Sediment. Mineral and rock materials that are eroded, transported, and deposited by rivers, in sizes that range from clay and silt through sand and gravel to cobble and boulders. Sediment may also include waterlogged organic debris.

Sediment Yield. The amount of sediment supplied by a watershed to a given location.

Sediment Transport Capacity. The rate at which a channel could transport sediment without leading to significant net sediment deposition, assuming sediment supply is sufficiently high.

Sedimentation. The deposition of sediment.

Setback Levee. A levee that is set away from a river in a manner to allow the river channel to migrate, increasing the connection between the river and floodplain to accommodate a floodplain that can store and convey flood flows.

Side Channel. Side channels contain a portion of the flow from the main or primary river channel at flows less than 1-year floods, and are partially or entirely surrounded by vegetated or stable island(s). The channel may remain connected at its upstream end through all flows less than bankfull, or it may become disconnected at some point as flows decline. When flowing, the channel is connected to the main channel at its upstream and downstream ends. The primary channel carries the greatest volume of water when there is one (or more) secondary channel with flowing surface water. Side channels can contain a variety of subhabitats including riffles, pools, glides, and bars. They have an unvegetated substrate indicative of regular scour.

Single-thread River. A river channel that ordinarily is characterized by a single main channel course.

Sinuosity. Total channel length divided by straight-line distance (or sometimes along-valley distance) between two points.

Structural Solution. Reduction of flood hazard through physical means, such as dams, levees, revetments, or channelization of rivers and streams.

Suspended Sediment. Sediment that is mixed throughout the water column.

Terrace. Terraces are relatively planar surfaces that do not show evidence of recent reworking by the main river channel and are elevated above any adjacent floodplain.

Tributary. Tributaries are defined as stream systems that flow into the main river channel. Tributaries often flow through side channels of the main stem as they approach their confluence.

Upland Habitats. For this report, upland habitats are the habitat types that are outside the floodplain.

Vashon Ice Sheet. The large ice sheet that advanced through the Puget Sound area approximately 17,000 years ago.

Wandering River. See **Anabranching River**.

Wandering River Floodplain. Floodplain formed by a wandering river. Wandering river floodplains typically contain multiple abandoned channel bars and abandoned channels. In the study area, the transition between wandering river floodplain and distal floodplain/fan surfaces is not always distinct.

Water Resource Inventory Area (WRIA). Area designations formalized under Washington Administrative Code 173-500-040 and authorized under the Water Resources Act of 1971, Revised Code of Washington 90.54. The original WRIA boundary agreements and judgments

were jointly reached in 1970 by Washington's Departments of Ecology, Natural Resources, and Fish and Wildlife. The Washington Department of Ecology is responsible for developing and managing these administrative and planning areas.

Watershed. A land area that drains to a single outlet and is separated from other watersheds by a divide.

INTRODUCTION

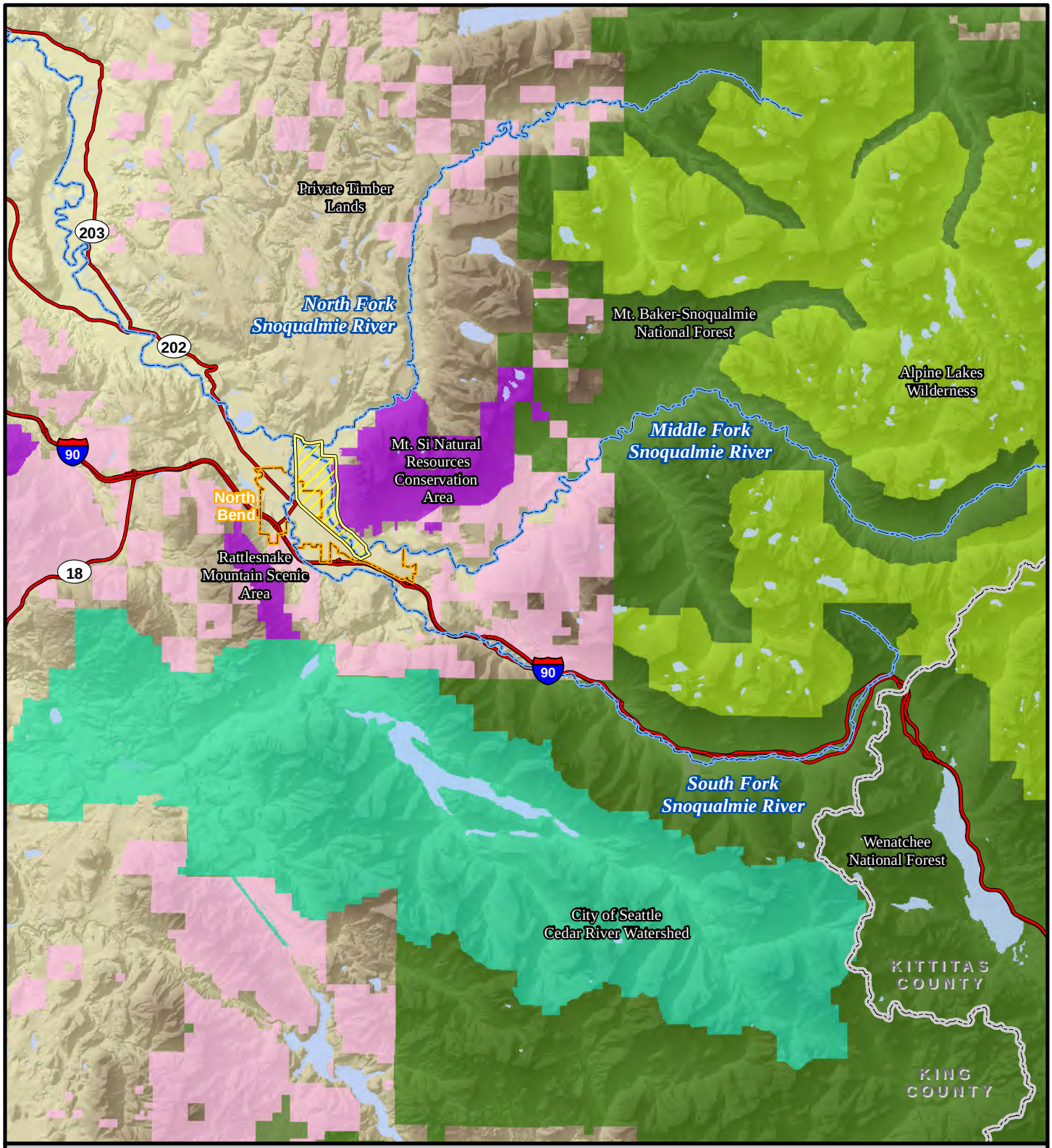
King County is responsible for several flood and erosion protection facilities in a 5-mile reach of the Middle Fork Snoqualmie River between the community of Tanner (upstream) and the Three Forks Natural Area (downstream) near North Bend, Washington. This purpose of this report is to document existing habitat conditions in this study area as part of a comprehensive Corridor Management Plan to reduce flood and erosion hazards in this reach of the river. The Corridor Management Plan will be used by King County to develop a prioritized implementation strategy for near-term and long-term actions for the lower Middle Fork Snoqualmie River with the following objectives:

- Reduce risks to life and property from flood and channel migration/avulsion hazards
- Avoid or minimize adverse environmental impacts of flood hazard management on fish and wildlife habitat and other environmental resources
- Reduce the long-term cost of public flood hazard management

The Middle Fork Snoqualmie River (hereafter referred to as the "Middle Fork") originates in the Cascade Mountains and flows westerly, exiting the mountain valley near the city of North Bend (Figure 1). The study area for this ecological resources characterization of the Middle Fork extends from river mile (RM) 4.25, just upstream of Tanner Landing, downstream to the confluences with the North Fork Snoqualmie River and South Fork Snoqualmie River, including the riparian corridor and adjacent upland habitats. Thirteen flood and erosion protection facilities (levees and revetments) along the river in the study area affect formation and sustenance of fish and wildlife habitat. These facilities are depicted in Figure 2 and listed in Table 1.

The Middle Fork channel and adjacent floodplain areas within the study area are divided into three subreaches based on geomorphic analyses (Perkins 1996; King County 2013a). The subreaches reflect logical breaks between distinct zones of geological features, geomorphic processes and the resultant river channel and floodplain characteristics, aquatic and riparian habitats, and sediment transport and deposition patterns. As shown in Figure 2, these subreaches are named MF2 (from Middle Fork RM 4.25 to RM 1.9), MF1 (RM 1.9 to RM 0.4), and Confluence (from RM 0.4 through the confluence with the South Fork Snoqualmie River). For some portions of this analysis, subreach MF1 was further divided into MF1a (RM 1.9 to RM 1.0) and MF1b (RM 1.0 to RM 0.4). The analysis presented in this report is structured around these subreaches, as each has distinctive characteristics that directly influence ecological resources.

The goals of this study are to document historical and existing ecological resources in the study area, analyze the effects of existing King County-operated flood and erosion protection facilities on those resources, and project how ecological conditions may be affected by different river management strategies and actions. This study was conducted in coordination



Legend

- Alpine Lakes Wilderness
- Cedar River watershed
- National Forest
- Washington Department of Natural Resources
- Natural Resources Conservation Area
- Private timber land
- Study area
- North Bend city limits

Figure 1. Vicinity Map.

N

0 10,500 21,000 42,000

Feet

King County

Prepared for King County by Herrera

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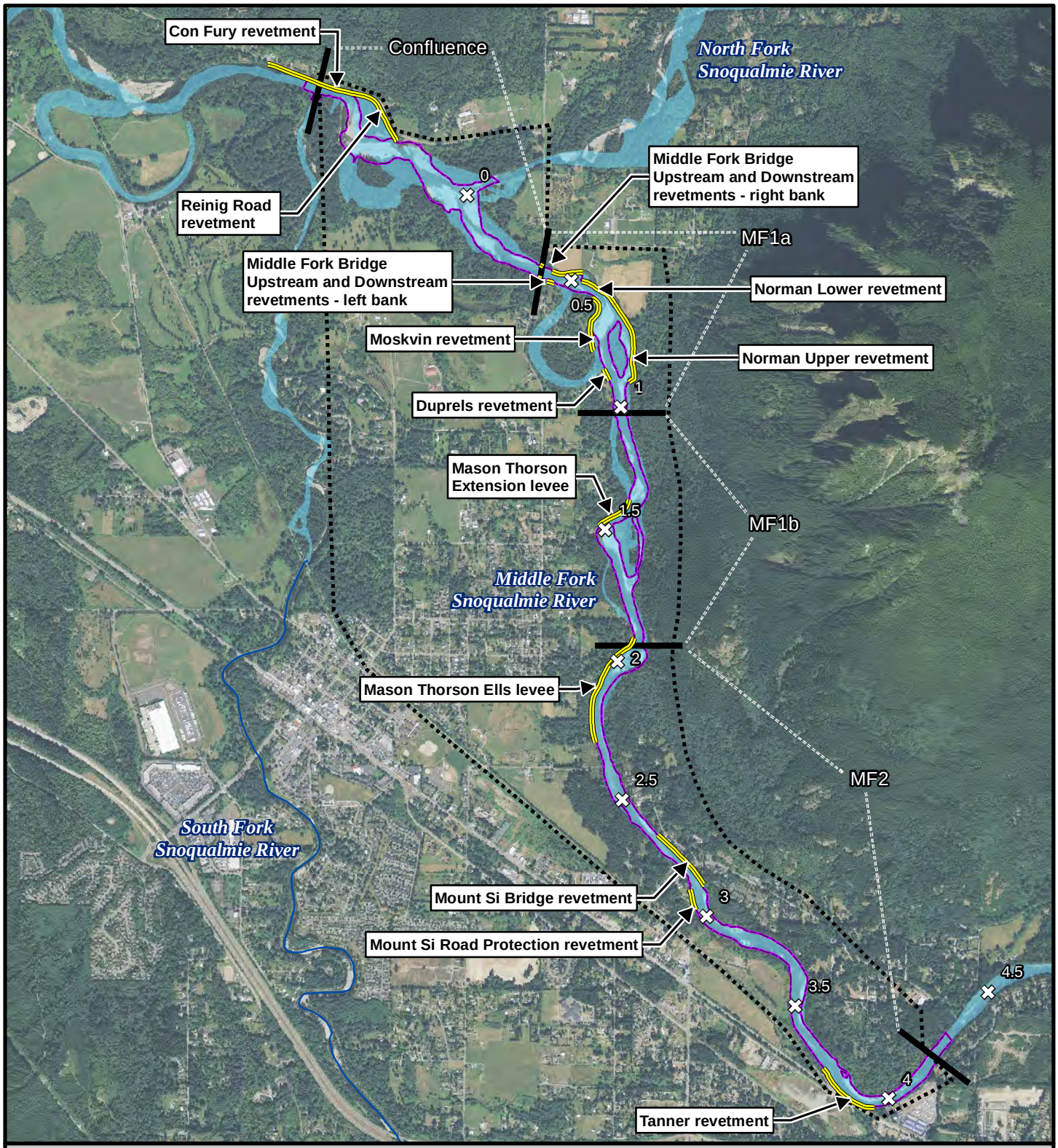

Legend

- River mile
- Levee or revetment
- Subreach boundary
- Project area
- 2010 channel banks
- Channel banks (1942 to 1998)

Figure 2. Channel Bank Positions Digitized from Aerial Photograph for Five Different Periods.

N

0 1,250 2,500 5,000

Feet

King County

Aerial: USDA (2011)

Prepared for King County by Herrera

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with a comprehensive geomorphic assessment of the study area (King County 2013a) and a hydraulic analysis of existing conditions (King County 2013b).

Table 1. Summary of Characteristics of the King County Flood and Erosion Protection Facilities in the Middle Fork Snoqualmie River Study Area.

Facility	Year Built	Bank[a]	Composition	Subreach
Tanner Revetment	circa 1965	Left	Riprap	MF2
Mount Si Bridge Revetment	1964	Right	Riprap	MF2
Mount Si Road Protection Revetment	1964	Left	Riprap	MF2
Mason Thorson Ells Levee	1963, extended in 1969	Left	Riprap	MF2
Mason Thorson Extension Levee	1963	Left	Riprap, with large woody debris integrated during repairs in 2008	MF1b
Duprels Revetment	1973	Left	Rock and soil	MF1a
Moskvin Revetment	1977	Left	Rock and soil	MF1a
Norman Upper Revetment	1965	Right	Rock	MF1a
Norman Lower Revetment	1965	Right	Rock	MF1a
Middle Fork Bridge Upstream Revetments	Circa 1948	Both	Riprap	MF1a
Middle Fork Bridge Downstream Revetments	1984	Both	Riprap	MF1a
Reinig Road Revetment	1966	Right	Riprap	Confluence
Con Fury Revetment	1969	Right	Riprap	Confluence

[a] Bank direction if looking downstream.

The technical approach and methods are described in the next section, followed by results, and then by an overall habitat analysis. The latter section focuses on habitat problems and notes possible restoration actions in the context of future floodplain management. Appendices to this report include oversized tables and figures (Appendix A), photographic documentation (Appendix B), detail on wildlife (Appendix C), and cross-sections through selected areas of the Middle Fork (Appendix D).

METHODS

The analysis of ecological conditions in the study area included several steps:

- Compiling and reviewing existing information on habitats
- Describing and mapping habitats and vegetative cover types, using existing information, remote sensing data, hydraulic model outputs (from a companion task) and field assessments
- Synthesizing the findings to assess historical and current habitats by subreach, including a description of each flood and erosion protection facility and resulting ecological effects

Results are interpreted in the overall analysis of habitat conditions.

Existing Information

The following information sources were used to understand the historical and current conditions in the study area:

- Recent (2011) and historical (1942) aerial photography (1942 is first year of complete aerial photograph coverage at sufficient detail to evaluate changes)
- Lidar data collected in 2010
- Historical information from Snoqualmie Historical Society resources, and historical ground photography
- Soil maps (NRCS 2012) and wetland inventories (USFWS 2012; King County 2012)
- Previous studies of the project area (Perkins 1996; Northwest Hydraulics Consultants 2011; Bethel 2004; Kaje 2009; King County 1999, 2000, 2001; Stohr et al. 2011)

Maps and analysis of the facilities are presented in the *Results* section of this report.

Types of Habitat and Vegetation Cover

Landform and vegetation largely determine habitat types. Dynamic river processes contribute to shaping habitat, for example by creating logjams and sediment deposits used by spawning salmonids. For this reason, the term *geomorphic surface* is used in this document to define habitats. Habitat classification methods and type descriptions are presented in the following sections.

Aquatic, Floodplain, and Upland Habitats

Habitats are classified into three main groups, according to their position in the landscape and pattern of inundation from the Middle Fork: *aquatic habitats, floodplain habitats,* and *upland habitats*. *Aquatic habitats* are in contact with the Middle Fork flow including floodwaters, occupy topographic features created by the Middle Fork (e.g., abandoned oxbows), or both. *Floodplain habitats* are surfaces located higher in elevation than aquatic habitats and were created by fluvial deposition. *Upland habitats* occupy topographic features that were created and shaped primarily by processes other than the river (e.g., mountain hillslopes and debris flow fans).

Table 2 lists the aquatic and upland habitat classifications identified within the Middle Fork Snoqualmie River study area. The habitat classification types are defined in the *Glossary* included in this report.

Table 2. Aquatic and Upland Habitats Identified Within the Middle Fork Snoqualmie River Study Area.

Aquatic Habitats	Floodplain Habitats	Upland Habitats
Primary Channel	Inset floodplain	Hillslope
Riffle	Wandering river floodplain	Debris flow fan
Plane bed channel	Meandering river floodplain	
Glide	Distal floodplain/fan	
Pool	Radially symmetric alluvial fan	
Bar		
Side channel		
In-channel island		
Secondary Channel		
Overflow channel		
Groundwater channel		
Relict channel		
Tributary		

Aquatic habitat types are based on landscape-level processes as described by Stanford (2006), the classification approach used in Ecosystem Diagnosis and Treatment (EDT) as described in Lestelle et al. (2005), channel types and geomorphic units defined by Montgomery and Buffington (1997), and primary channel habitats defined by Bisson et al. (1982).

Geomorphic units and river habitats (e.g., individual pools and riffles) are relatively fine-scale features that vary over the scale of a channel width or less and are usually characterized by relatively homogenous depth, velocity, and substrate properties. Channel types (e.g., pool-riffle channels) describe reach-scale geomorphic patterns that vary over spatial scales of many channel widths. A given channel type can contain several different geomorphic units or habitat types.

Aquatic habitats are divided into two classes: *primary channel* and *secondary channel*. *Primary channel* habitats occur within the area encompassed by the main channel and areas inundated during typical annual high flows (i.e., the 99 percent annual chance flood). They include in-channel islands that may not be inundated by these flows but are surrounded by channels that convey these flows.

Secondary channel habitats are inundated at flows higher than the 1-year recurrence flood (100 percent annual chance flood) up to the 2-year recurrence flood (50 percent annual chance flood), or are hydrologically supported independent of the Middle Fork (e.g., tributaries). Overflow channels are inundated by 2-year recurrence floods. Relict channels were created by a former channel but are inundated only during severe floods (greater than 100-year floods). Groundwater channels are dominated by evidence of groundwater expression. Some features contain the qualities of two or more habitats, but were defined by the habitat that is most prominently evidenced.

Floodplain habitats include features that are flooded at different frequencies. Inset floodplains as well as wandering and meandering river floodplains are inundated at or below a 2-year recurrence flood (50 percent annual chance flood). Distal floodplains in subreach MF1 and the large radially symmetric alluvial fan that underlies much of the area adjacent to subreach MF2 are infrequently flooded. These floodplains are the focus of companion geomorphic and hydraulic assessments conducted as part of the corridor planning effort (King County 2013a,b) and at some point in recent history were directly formed by Middle Fork geomorphic processes. These floodplains are dissected by channels that convey groundwater, which expresses primarily during periods of high flow in the Middle Fork. The complexities of this interaction are discussed in the relevant technical reports (King County 2013a,b).

Aquatic, floodplain, and upland habitats were mapped using features evident in lidar imagery and characterized based on lidar images, flood models (King County 2013b), and aerial photography. Initial mapping was conducted by project ecologists, and reviewed by a senior geomorphologist. Mapped features were revised based on field observations and integrated into a geographic information system (GIS) database. This database was then used to characterize and analyze the study area. Output tables and analysis are presented in the *Results* section.

Vegetation Types

The vegetation community is shaped by the constraints and niches of geomorphic position, river processes, and human-induced changes. The vegetation types used to characterize the study area are summarized in Table 3. For this study, the vegetation types occurring in each aquatic habitat were characterized based on descriptions provided by Collins and Sheikh (2002), Franklin and Dyrness (1988), and Cowardin et al. (1979), as applicable. However, many of the aquatic habitats in the study area remain unvegetated because of active scour, deposition, and bedload movement. The floodplain and upland habitats support a variety of vegetation types.

Table 3. Vegetation Types Identified Within the Middle Fork Snoqualmie River Study Area.		
Vegetation Type	**Description**	**Typical Species**
Upland		
Forests (coniferous, deciduous, and mixed)	Areas dominated by tree species more than 20 feet in height	Douglas-fir, western hemlock, western red cedar, grand fir, red alder, black cottonwood, big-leaf maple, with understories composed of native and/or non-native species
Upland shrubs	Non-wetlands dominated by shrubs	Snowberry, oceanspray, hazelnut, Himalayan blackberry, Scotch broom, willows
Herbaceous uplands	Non-wetlands dominated by grasses and forbs	Pasture grasses, variety of weeds and wildflowers
Wetland		
• Forested	• More than 30% tree cover	• Red alder, black cottonwood, western red cedar, Sitka spruce
• Scrub-shrub	• Less than 30% tree cover, more than 30% shrub cover	• Willows, salmonberry, spiraea
• Emergent	• Less than 30% either tree or shrub cover, more than 30% emergent species.	• Reed canarygrass, sedges, bulrushes, rushes
• Aquatic bed	• Less than 30% tree, shrub, or emergent cover, but vegetated	• Water lilies, smartweeds, pondweeds
Developed		
• Built	• Extensive buildings and roads	• Impervious surfaces, lawns, and landscaped areas
• Forested residential	• Scattered buildings, sparse roads, and extensive tree cover	• Primarily native trees, mixed native and exotic understory, and isolated impervious areas
• Agriculture	• Scattered buildings; sparse roads; and pastures, crop fields, and orchards	• Pasture grasses, crop species, fruit trees, variety of weeds and wildflowers, scattered trees and shrubby areas

Mapping

Preliminary habitat maps were prepared using information sources cited above and initial results of flood modeling (King County 2013b). Geomorphic habitat areas were delineated based on landforms evident in lidar imagery with flood model data superimposed. Habitat areas were characterized and partitioned, as needed, based on features evident in aerial photography and habitat inventory data (WDFW 2012a; WDNR 2012; King County 2010; USFWS 2012). Vegetation typing was based on aerial photography interpretation using 1942 and 2011 imagery. Mapping was refined and habitat areas were further characterized during ground surveys in September and October 2012. Following the field investigations, the maps were revised and the habitat characteristics were compiled for analysis.

Data Synthesis

Data synthesis targeted ecological problems that have been identified in the Middle Fork system within the study area (Stohr et al. 2011; WDFW 2011; Kaje 2009; King County 1999, 2000):

- Elevated water temperature
- Loss of riparian functions
- Insufficient large wood
- Reduced channel and floodplain connectivity
- Reduced high-flow refuge

To evaluate the interaction between the flood and erosion protection facilities and these problems, 2011 conditions in the study area were compared to historical (1942) conditions and to typical reference site conditions. Although many alterations occurred on the landscape prior to 1942, this is the first year of complete aerial photograph coverage at sufficient detail to evaluate changes. The following quantitative analyses were conducted:

- Changes in areas (acres) encompassed by the active river channel and adjacent vegetation types between 1942 and 2011
- Geomorphic habitats and vegetation types (acres) that currently occur within the 2-year recurrence flood interval water surface, within a 150-foot range of the 2-year flood extents (to estimate the riparian zone for purposes of meeting total daily maximum load [TMDL] requirements [Stohr et al. 2011]), and within a buffer of 150 to 300 feet from the extent of the 2-year flood (selected to provided further ecological context; referred to in this document as the outer buffer)
- All habitats (acres) encompassed by the outermost extent of the 10-year recurrence flood inundation
- Tally of downed logs (as evident on 2011 aerial photographs and ground-truthed) as compared to reference data for wood loading in less-managed river systems (Fox and Bolton 2007)
- Maximum and average height (feet) of the tree canopy in mapped forested areas (using second-return data from lidar imagery)

The analysis also included a qualitative assessment of these factors:

- Changes in Middle Fork channel configuration (bank locations and channel connections as evident in aerial photographs) between 1942 and the 2011
- Effects of the flood and erosion protection facilities on geomorphic habitats and vegetation

RESULTS

Synthesis of the review of existing information, mapping, and field investigations is described in the sections below. A geologic and historic context for the study area is summarized first, followed by a summary of the ecological context, and an assessment of historical and current habitat conditions organized by subreach.

Geologic and Historic Context

The landforms in the study area were shaped predominantly by events of the Vashon glaciation during the Pleistocene epoch, and immediately afterward in the Holocene epoch. Many of the major landforms in the study area were deposited during that time by a glacial outwash river probably somewhat wider than the present Middle Fork. The legacy of Pleistocene glaciation continues to affect flooding in the study area and is the subject of a number of studies (Perkins 1996; Tetra Tech 2011; King County 2013a; Bethel 2004; Northwest Hydraulic Consultants 2011). A timeline of more recent prehistoric and historical events affecting the study area is presented in Table A-1, Appendix A.

The Middle Fork and South Fork occupy positions on either side of the City of North Bend. Mountainous hillslopes bound the valley to the east. The Middle Fork is confined within a narrow channel migration zone at the upstream (east) end of the study area in subreach MF2; this confinement is due to the dominance of glacially derived, coarse substrate that is too large to be effectively eroded by the modern river (King County 2013a). As the Middle Fork flows west, the floodplain widens, and the substrates of the bed and banks become increasingly dominated by river alluvium in MF1a and b. Where the Middle Fork runs along the base of Mount Si, Pleistocene sediments have been reworked or are buried under river alluvium deposited near the anabranching or wandering MF1b and MF1a subreaches. Below the point where the channel leaves Mount Si and heads toward its confluence with the South Fork in the Confluence subreach, the valley floor consists of a meandering river floodplain that has been reworked extensively, even during modern times (King County 2013a). Figure 2 presents the locations of the Middle Fork channel since 1942.

The study area is divided into three river subreaches. The upstream subreach, MF2, emerges from the Salal prairie terrace downstream of the Middle Fork Embankment and is a rather steep, entrenched plane bed channel from RM 4.2 to RM 1.9, below which is the transition to subreach MF1. Subreach MF1 is further subdivided. In the upstream subdivision, subreach MF1b (RM 1.9 to RM 1.0), the floodplain character transitions to a radially symmetric alluvial fan built primarily during the Holocene. The river becomes increasingly flat and anabranching, characterized by gravel accumulation, vegetated mid-channel bars, and a less-confined channel. The wandering river and floodplain section extends downstream until approximately RM 1.0, where subreach MF1a begins, and continues to RM 0.4, where the Confluence subreach begins. At that point, the river transitions again to a single-thread

meandering planform with numerous meander scars and abandoned oxbows in the floodplain near the Three Forks area (see Figure 3).

Vegetation patterns and wildlife habitats prior to settlement by immigrants were primarily the result of natural processes. Immigration of non-native people brought extensive forest harvest (see Photo 51, Appendix B), roads, railroads, and larger permanent settlements in the study area. Much of the watershed upstream of the study area was logged, resulting in altered sedimentation and flooding patterns and a sharp reduction in inputs of large wood (Mount Baker-Snoqualmie National Forest 1988; King County 2013a). Much of the large wood currently present in the study area was likely recruited locally from nearby bank erosion.

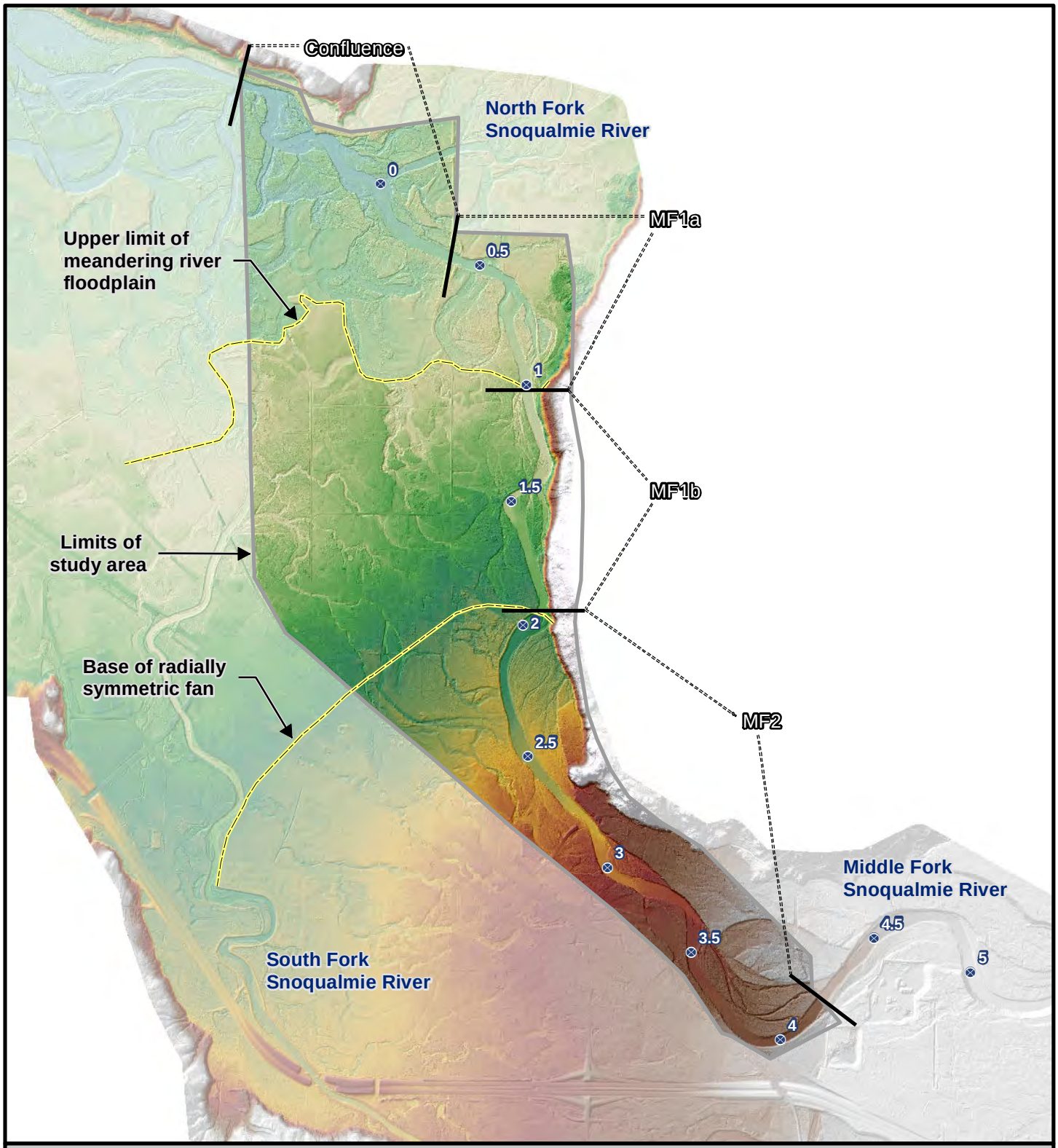
As human development in the watershed continued, modifications to the location of the Middle Fork's channel were undertaken to support adjacent land uses and navigation. The attempts to constrain the Middle Fork began as isolated flood control structures built by landowners. The current flood and erosion protection facilities were put in place as individual projects between 1950 and 1977, transferred to King County jurisdiction in 1990, and repaired and augmented over time (Table 1). County records indicate that wood was actively removed from the channel of the Middle Fork as recently as 1991 (M. Ruebel, project engineer, King County Water and Land Resources Division, Seattle, WA, personal communication [email regarding history of wood removal from Middle Fork Snoqualmie River to J. Wozniak, Herrera Environmental Consultants, Seattle, WA], April 20, 2013.).

Over the time period for which aerial photographs of the study area are available (1942 to 2011), forest cover has decreased and residential development has increased. These changes are discussed in detail below, in the *Assessment of Historical and Current Habitats*. The loss of forest cover influences both terrestrial and aquatic habitats. Decreases in the size and number of trees in the riparian corridor have resulted in reduced cover, reduced shading of the river, and fewer habitat niches. The decrease in both overall volume and piece size of in-channel wood may have changed conditions in the main channel and its laterally connected floodplain habitats; in turn, these changes have resulted in simplified (less complex, extensive, or diverse) habitat features and reduced capacity to buffer upstream pulses of sediment and floodwaters (King County 2013a).

Further development would likely exacerbate problems affecting wildlife movement and habitats in areas adjacent to and within the riparian corridor. Despite these changes, the study area continues to support a wide range of wildlife species and contains extensive areas of high-quality aquatic, floodplain, and upland habitats and vegetation types.

Ecological Context

Occupying a unique location that includes low-elevation river valleys and mid-elevation hillslopes with adjoining high-elevation alpine and subalpine habitats, the Middle Fork study area supports many fish and wildlife species. It also offers multiple migration and dispersal corridors. The riparian corridor of the Middle Fork is partially forested, primarily with native



Legend

River mile

Project area

Elevation (ft)

High : 550

Low : 410

Figure 3. Floodplain DEM and Reach Boundaries.

N

0 0.25 0.5 1

Miles

King County

Prepared for King County by Herrera

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trees, as are those of the North Fork and South Fork of the Snoqualmie River.[1] Between these corridors, forage and cover for wildlife is available in large patches of herbaceous and forested habitats. The habitat quality is augmented by connectivity to extensive forest and wilderness areas (e.g., Mount Si Natural Resource Conservation Area, Mount Baker-Snoqualmie National Forest, Alpine Lakes Wilderness, and private timberlands) (Figure 1). In addition, the Mountains to Sound Greenway connects the study area with the Cedar River watershed and habitats downstream in the Snoqualmie valley.

Species such as mountain goat (*Oreamnos americanus*) that are infrequently observed at low elevations descend from the flanks of Mount Si to drink in the Middle Fork. In addition, wildlife species that are rare in most developed areas (e.g., black bear [*Ursus americanus*], bobcats [*Lynx rufus*], and cougar [*Puma concolor*]) occur here. This richness of wildlife is a unique attribute of the study area, compared to many other low-elevation areas in western Washington. Species inventories from King County (1999, 2000, 2001), Washington Department of Fish and Wildlife (WDFW 2010, 2012b,c), and other wildlife distribution information sources (e.g., Thompson et al. 2011) are compiled in Tables C-1 through C-5 in Appendix C.

A large number of wildlife species also use habitats in the study area and the Middle Fork as a migration corridor. Although certain road systems restrict wildlife movement (e.g., Interstate 90, North Bend Way), passageways underneath bridges provide a potential alternative to the often-lethal direct crossing. The Middle Fork and North Fork provide the highest quality and least-obstructed movement corridors in the vicinity of the study area.

Assessment of Historical and Current Habitats

Quantitative results of the investigations noted in the *Methods* section are presented in a series of tables and figures. Historical (1942) and current (2011) aerial photography of the study area is provided in Figure A-1 (three sheets, Appendix A), with locations of significant change indicated. In 1942, few, if any, levees and revetments had been constructed along the Middle Fork, but the riparian areas and much of the basin had been logged (see Table A-1, Appendix A). While several major roads and railroads had been constructed by 1942, dense residential development had yet to occur.

Current aquatic and upland habitats (geomorphic surfaces) are shown in Figure A-2, Appendix A, with further detail by flood zone provided in Table A-3, Appendix A:

- Within the 2-year recurrence flood interval water surface (the active channel zone)
- Within a zone extending 150 feet beyond the 2-year flood extent (the riparian zone, per the previous TMDL assessment [Stohr et al. 2011])

[1] With well-established and largely uninterrupted riparian cover, the North Fork has little human settlement and is protected in its industrial timberland watershed. The South Fork is substantially leveed and urbanized system from RM 7 to RM 2.

- Within an outer buffer covering 150 to 300 feet from the edge of the 2-year flood extent (to evaluate areas adjacent to but farther from the river)
- Within the inundation extent of the 10-year recurrence flood interval water surface (to provide an assessment of habitats within a greater flood inundation area)

The existing vegetation types within the same areas listed above for Table A-3, Appendix A, are tabulated in Table A-4, Appendix A.

Current vegetation conditions are presented in Figure A-3, Appendix A, with tree height data presented in Figure A-4. [2] Table A-2, Appendix A, provides changes in vegetation between 1942 and 2011, based on features evident in aerial photographs, within an area inundated during the 2-year recurrence interval flood (King County 2013b). The 2-year flood was selected for analysis, as it was a criterion for geomorphic surface mapping (see *Methods* section).

Large wood currently found in the channels of the Middle Fork study area is tallied in Table 4. Habitat and vegetation features are discussed in more detail by subreach in the sections below.

Table 4. Large Wood in the Middle Fork Channel Compared to Reference Site Conditions.

Subreach	Total No. Pieces	Channel Length (m)	No. Pieces per 100 m of Channel	Median Reference No. Pieces per 100 m of Channel[a]	Percent of Median Reference Value
MF2	85	3,700	2.3	106	2
MF1b	177	1,575	11.2	106	11
MF1a	185	1,030	18	106	17
Confluence	889	2,330	38.1	106	36

[a] Per Fox and Bolton (2007)

Subreach MF2

The channel in subreach MF2 is entrenched into the radially symmetric alluvial fan (likely deposited during a glacial retreat period) that constitutes the primary landform in this subreach (see Figure 3). Substrate in the channel is dominated by cobbles and boulders, which are too coarse to be easily eroded by the modern river (King County 2013a). Subreach MF2 is the steepest of those in the study area and has the most confined channel, with extremely high velocities (King County 2013b).

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[2] Figure A-4, Appendix A, presents tree height data (maximum and mean canopy heights) within forested polygons that intersect with the area inundated by the 2-year recurrence interval flood, based on processing of first return and second return data from lidar imagery. This analysis shows the greatest mean canopy heights occur in mapped forested floodplain polygons at RM 2.1 (right bank, 99 feet), at RM 4.2 (right bank, 94 feet), and on the slopes of Mount Si (87 feet). Maximum canopy heights are the greatest (180 to 196 feet) on Mount Si and in the riparian corridor at the lower end of subreach MF2. Maximum heights above 150 feet occur in forested polygons throughout subreach MF1 and the Confluence subreach.

Current aquatic habitats within the 2-year flood limits include pools, riffles, and plane beds (Table A-3, Appendix A). Primary aquatic habitats in the 10-year flood zone are inset floodplains (i.e., narrow zones that have been reworked by lateral channel migration and then colonized by vegetation), pools, riffles, and plane beds. Primary habitats in the riparian zone (150-foot range from 2-year flood limits) include vegetated in-channel islands, inset floodplains, and less flood-prone and less-frequently reworked parts of the prehistoric Middle Fork alluvial fan. The outer buffer area (150 feet to 300 feet from the 2-year flood limit) includes all of the above non-channel habitat as well as several flat terrace surfaces elevated above all flood risk and hillslopes at the base of Mount Si.

Geomorphic aquatic habitat conditions in subreach MF2 have shown minor changes over the study period (1942 to 2011). Minimal channel migration has occurred and floodplains appear to be similar in 1942 and at present. A comparison of features evident on aerial photos from 1942 and those evident on 2011 aerial photos shows a few areas of minor erosion in the vicinity of the Tanner revetments (RM 3.7 and RM 3.5) and the Mount Si Road and Bridge revetments (RM 3.0 to RM 2.8) (Figure A-1, Appendix A, Sheet 3). Near the lower end of the subreach, in the vicinity of the Mason Thorson Ells levee, the main channel has been disconnected from the floodplain on the left bank (looking downstream) by the levee (RM 1.95) (Figure A-1, Appendix A, Sheet 2). Also evident are erosion of a former bar on the left bank, and growth of a mid-channel bar at RM 2.05 to RM 1.95.

In contrast to geomorphic conditions, the vegetation cover in subreach MF2 has changed greatly since 1942 (Table A-2, Appendix A). Portions of the riverfront have been developed as residential areas, and formerly forested areas have been cleared. The forest canopy is primarily native and many areas contain a native understory. Douglas-fir (*Pseudotsuga menzeisii*), black cottonwood (*Populus balsamifera*), and western red cedar (*Thuja plicata)* are common canopy species. However, invasive shrub and herbaceous species are common along roadways and in developed areas, and are encroaching into many areas of the riverbank.

Within the 2-year flood limit, forested areas declined by 45 percent (from 20 acres to 11 acres), herbaceous cover declined sharply (from 6.2 acres to 0 acres), shrub cover increased substantially from 0.8 to 4.8 acres (primarily due to colonization of in-channel islands and bars), and built areas increased by an order of magnitude from 0.1 acres to 1.1 acres).

Within the 150-foot riparian zone, forest increased from 7 acres to 28 acres on the left bank and remained constant on the right bank; changes on the left bank were primarily due to reforestation of Tanner Landing Park (RM 3.5 to RM 3.3) and of properties northwest of Mount Si Bridge (RM 2.8 to RM 2.4). Shrub areas dropped by 70 percent (from 14 acres to 6 acres) and built areas increased 600 percent (from 2.8 acres to 17.8 acres).

Within the 150- to-300-foot outer buffer, total forest cover remained constant, with some loss on the right bank offset by increases on the left bank. Herbaceous cover dropped from 26 acres to 7.5 acres due to reforestation of some farm areas, and shrub cover dropped from 11 acres to 4.3 acres. Built areas increased by an order of magnitude from 1.9 acres to 20 acres. Acreage of vegetation cover types is detailed in Table A-4, Appendix A.

As shown in Table 4, the estimated number of logs in this subreach is farther below reference conditions that that in any other subreach in the study area.

Flood and Erosion Protection Facility Descriptions

Three flood and erosion protection facilities have been constructed in subreach MF2: the Tanner revetment, the Mount Si Road and Bridge revetments, and the Mason Thorson Ells levee. Each is described below.

Tanner Revetment

The Tanner revetment is located on the left bank at RM 3.9 to RM 3.8 (Photo 8, Appendix B) and was constructed in 1965. The channel in this area has been largely stable over the period of historical record. Adjacent areas have shown minimal changes in channel extents, suggesting that the revetment may be limiting lateral channel migration. However, given the resistance of the bank material to erosion by the Middle Fork, the revetment may not have dramatically affected overall channel migration patterns (King County 2013a). The substrate in the channel in the vicinity of the Tanner revetment is dominated by boulders (Photo 1, Appendix B).

The floodplain across the channel from the facility contains a network of side and overflow channels interspersed with in-channel islands. Figure D-1 in Appendix D shows a cross-section through this area, including habitat features and estimated floodwater elevations.

The islands and inset floodplain are forested and contain a variety of native coniferous and deciduous trees (e.g., Douglas-fir, western red cedar, western hemlock [*Tsuga heterophylla*], black cottonwood, red alder [*Alnus rubra*], big-leaf maple [*Acer macrophyllum*]) (Photos 2 and 6, Appendix B). The understory is composed primarily of native shrubs (e.g., serviceberry [*Amalanchier alnifolia*], salmonberry [*Rubus spectabilis*], oceanspray [*Holodiscus discolor*]), and herbs (e.g., blue wild rye [*Elymus glaucus*], sword fern [*Polystichum munitum*]) with a few patches of invasive species such as butterflybush (*Buddleja davidii*), Scotch broom (*Cytisus scoparius*), and Himalayan blackberry (*Rubus armeniacus*). The upstream openings to the side channels contain logjams (Photo 3, Appendix B); these logjams help maintain natural floodplain processes by influencing surface water hydrology as well as the transport and distribution of sediment and wood.

Mount Si Road and Bridge Revetments

The Mount Si Road revetment is on the left bank (RM 3.0 to RM 2.0), upstream of the Mount Si Bridge (Photo 17, Appendix B). The Mount Si Bridge revetment is on the right bank (RM 2.9 to RM 2.65), extending up- and downstream from the Mount Si Bridge (Photo 16, Appendix B). Both revetments are located between RM 2.9 and RM 2.7. Constructed in 1964, the revetments likely reduce local bank erosion upstream and downstream from the Mount Si Bridge. Aside from minor bank erosion and channelization effects of the revetments, aquatic habitats have not changed significantly in the vicinity of the revetments since 1942 (King County 2013a).

In-channel habitats in the vicinity of the revetments include pool/riffle complexes, glides, and plane bed channels. Boulders dominate the riverbed (Photo 10, Appendix B). A bar occurs

on the left bank (RM 2.8), downstream of the Mount Si Bridge. A floodplain and overflow channel complex occur immediately upstream of the Mount Si Bridge revetment on river right (RM 3.2 to RM 2.9) (Figure A-2, Appendix A, Sheet 2). Because the river bend inside of which this feature occurs is significantly smaller than the bend at the Tanner revetment, the extent of the side channel complex is less than that near the Tanner revetment. A network of floodplain channels on river right converges at RM 2.9, immediately upstream of the bridge revetment. Unlike the well-defined secondary channels that cross the floodplain near the Tanner revetment (right bank RM 4.1 to RM 3.4), these channels are shallow and closely spaced, creating an undulating surface with colonnades of trees, primarily western red cedar, that occupy the marginally higher ground above the channels (Photos 14, Appendix B). The remainder of the inset floodplain is forested with black cottonwood, big-leaf maple, red alder, grand fir (*Abies grandis*), Douglas-fir, and western hemlock. Snags and small concentrations of large wood are present but rare.

Sandy substrate is widely distributed throughout this floodplain area (Photo 14, Appendix B). A small side channel flows around a bar colonized with willows (*Salix* spp.) (RM 2.9). Understory cover is noticeably sparse compared to floodplain conditions near the Tanner revetment. This difference can be at least partially attributed to the understory-suppressing effects of western red cedar. Browsing by regular concentrations of elk also reduce understory vegetation. Figure D-2 in Appendix D shows a cross-section through this area, including habitat features and estimated floodwater elevations.

Mason Thorson Ells Levee

The Mason Thorson Ells levee, constructed in 1963 and extended in 1969, is located on the left bank between RM 2.3 and RM 1.9 (Photo 18, Appendix B). While it is not clear whether the banks protected by the levee are particularly erodible, the levee limits lateral left-bank erosion. This phenomenon may reduce local sediment recruitment, and the resulting hydraulic conditions may contribute to sedimentation of the mid-channel bar at RM 2.0 to RM 1.9. The levee affects flow into several overflow channels in the floodplain on the left bank (RM 2.3 to RM 1.9), limiting both flooding in this area and floodwater access to the 120th Street and Reid Slough floodwater channels (King County 2013a). Exposed bedrock on the right bank (RM 1.9) forms a hard, erosion-resistant point.

On the right bank, across the river from the levee is a floodplain containing a network of dendritic channels that converge near the toe of the hillslope to the east (right bank, RM 2.0). Little Si Creek, a tributary to the Middle Fork, flows into the channel along the toe, which empties into the Middle Fork immediately upstream of (and across the channel from) the end of the levee (right bank, RM 2.0). Figure D-3 in Appendix D shows a cross-section through this area, including habitat features and estimated floodwater elevations.

Forests occurring on the floodplain are both coniferous (dominated by western red cedar, western hemlock, and Douglas-fir) and mixed (dominated by the aforementioned conifers as well as black cottonwood, red alder, and big-leaf maple). The left-bank floodplain downstream of the levee (RM 1.9 to RM 1.5) is forested primarily by deciduous species, with scattered Douglas-fir. The in-channel bar (RM 2.0) is partially colonized by willows. Some

snags and large wood occur on the floodplain, and small concentrations of large wood occur in side and overflow channels.

Aquatic habitats and floodplain dynamics on both banks of the river may be affected by the levee. Its construction narrowed the channel and limited the ability of the channel to store bed material in the bar located at the lower end of the levee (left bank, RM 1.9) (Figure A-2, Appendix A, Sheet 2). A portion of the lower end of the floodplain forest has eroded and is now an unvegetated side channel (left bank, RM 1.6). Upstream of the levee, the channel banks appear to have been stable over the available photographic record. The river flow and thalweg are concentrated at the toe of the levee, drawing flow away from the right-bank floodplain. As a result, only flows above the 2-year flood activate most of the overflow channels on the floodplain (right bank, RM 2.4 to RM 2.0). Flow into the left-bank floodplain (RM 1.9 to RM 1.6) is obstructed, limiting floodwater access and eliminating channel-forming scour and deposition patterns. A portion of the main channel on the left bank was isolated from the river by the levee, resulting in a patch of relict channel (left bank, RM 1.9).

Vegetation conditions in the vicinity of the facility have changed since 1942. The most significant changes are those related to channel-forming processes discussed above. In addition, extensive clearing and development on the terraces above the floodplain on river right has reduced forest cover and increased human presence in the river corridor. These factors limit wildlife habitats and reduce potential recruitment of large wood into the channel, which in turn reduces fish habitat complexity.

Subreach MF1

Subreach MF1 contains two finer subunits, MF1b and MF1a. Although still somewhat constrained by the alluvial fan and distal floodplain to the west (see Figure 3), the Middle Fork in the upstream section (MF1b) has developed relatively broad floodplain benches and takes a wandering or anabranching planform morphology characterized by several vegetated mid-channel bars (King County 2013a). Farther downstream in subreach MF1a, the channel slope flattens where the channel leaves the base of Mount Si as it approaches the confluence of the Middle Fork with the North Fork. Compared to subreach MF1b, this shallower slope reduces flow velocity and sediment transport capacity, resulting in a natural zone of alluvial deposition. The reduction in slope and perhaps the movement away from the valley walls historically allowed for the formation of well-defined meander bends in subreach MF1a, creating a broad floodplain and many large oxbow lake features (King County 2013a).

In general, the channel within subreach MF1 has a predominantly cobble surface with some small boulders (Photos 37-40, Appendix B), although grain size becomes much finer in the downstream direction. There is a sharp contrast between the substrate here and the boulder-dominated substrate upstream in subreach MF2. At the lower end of subreach MF1, boulders are nearly absent, and cobbles and gravels dominate the substrate.

Primary aquatic habitats in subreach MF1 are glides and bars, followed by riffles and side channels (Table A-3, Appendix A). Primary aquatic habitats in the 10-year flood zone are overflow channels and floodplains; abandoned meander bends and their associated open-

water habitat are much more prevalent in subreach MF1a than in subreach MF1b. Primary habitats in the riparian zone (150 feet beyond the 2-year flood limits) and outer buffer zone (150 feet to 300 feet beyond the 2-year flood limits) are hillslopes and floodplains. Reduced flow velocities in this subreach relative to subreach MF2 result in less exposure of aquatic life to high-velocity floodwaters. This effect has been somewhat reduced under current conditions, in that flood and erosion protection facilities partially block access to the floodplains. This blockage leads to higher water levels in the main channel and increased flow velocities compared to what would occur without human interference.

Aquatic habitat conditions in subreach MF1 have shown several changes since 1942. In addition to areas of bank erosion (left bank, RM 1.5 and RM 0.9) similar to those seen in subreach MF2, floodwater access to the historical floodplain and channels has been blocked by levees (both banks RM 0.9 to RM 0.8; left bank RM 1.4) (see Figure A-2, Appendix A). This blockage has compromised natural river processes and degraded salmonid habitat. A forested island at RM 1.4 to RM 1.1 has been eroded and the multi-channel threaded complexity present in 1942 has been replaced with a simpler single-channel configuration. Bedrock outcroppings on the right bank at RM 1.3 form an erosion-resistant hard point.

The vegetation cover in subreach MF1 has been modified since 1942 (see Figure A-1 and Table A-2, Appendix A). Portions of the riverfront have been developed as residential areas and formerly forested areas have been cleared, although to a lesser extent than in subreach MF2. Within the inundation area estimated for the 2-year recurrence interval flood, vegetated areas showed little change: forested cover is similar, and herbaceous cover has been reduced but offset by increased shrub cover. The greatest change is a 10 percent reduction in unvegetated channel coverage (from 48.5 acres to 43 acres).

Within the 150-foot riparian zone, the greatest changes are an increase in “agriculture” (likely due to subdivision and development on formerly large pastures) and a 56 percent reduction in river channel area (from 5 acres to 2.1 acres). The latter occurred because blockage of portions of the main channel and floodplain channels has allowed subsequent revegetation.

Within the 150-foot to 300-foot outer buffer, total forest cover remained constant, agriculture area increased from 1.6 to 3.4 acres, and 1.85 acres of pasture were fully developed.

Acreage of vegetation cover types is detailed in Table A-4, Appendix A.

Despite the presence of several persistent logjams, (e.g., near the Upper Norman levee) the estimated number of logs in this subreach is far below reference conditions (14 percent of mean reference values; see Table 4).

Flood and Erosion Protection Facility Descriptions

Nine flood and erosion protection facilities have been constructed in subreach MF1: the Mason Thorson Extension levee, Upper and Lower Norman levees, Moskvin revetment, Duprels revetment, and Middle Fork Bridge revetments (four segments). Each is described below.

Mason Thorson Extension Levee

The Mason Thorson Extension levee is located on the left bank at RM 1.5 to RM 1.4 (Photos 20-22, Appendix B). Composed primarily of riprap, the levee was repaired in 2008, during which time large wood was integrated into the structure (Photo 21, Appendix B). The levee limits lateral left-bank erosion, in turn restricting sediment recruitment, blocking flow into several relict and overflow channels in the floodplain on the left bank (RM 1.4), and limiting flooding in this area. Channel migration, channel formation, and natural floodplain processes have been diminished as a result (King County 2013a).

Aquatic habitats on the right-bank floodplain include significant side channels and a network of connected overflow channels (RM 1.7 to RM 1.4). Deciduous forests occupy the floodplain, and willows have colonized several large bar features. Aquatic habitats on the left bank (downstream of the levee, RM 1.4 to RM 1.0) include a network of relict channels (due to isolation from the levee) and overflow channels. The channels are forested with deciduous species, as are the floodplains above the channels. Aquatic habitats have changed significantly in the vicinity of the facility since 1942. Large unvegetated side channels present in 1942 were revegetated by 2011 (see Figure A-2, Appendix A, Sheet 2).

Upper/Lower Norman Levees; Duprels, Moskvin, and Middle Fork Bridge Revetments

Between RM 0.9 and RM 0.6, the Upper and Lower Norman levees protect the right bank (Photos 40 and 49, Appendix B), while the Moskvin and Duprels revetments stabilize the left bank (Photo 38, Appendix B). The Middle Fork Bridge revetment protects both banks in the vicinity of the bridge, at RM 0.5 to RM 0.4.

These facilities probably originated with channel realignment projects that cut off two historic meander bends. The Moskvin and Duprels revetments isolated a large oxbow lake and wetland complex to the west (RM 0.8 to RM 0.5) and the Upper Norman levee isolated a smaller depression/swale within a relict channel to the east (RM 0.9 to RM 0.8) (see Figure D-7, Appendix D). If the levees and revetments had not been constructed, it is likely that the channel would have maintained a meandering path in this vicinity and downstream to the confluence with the North Fork (King County 2013a). The lateral movement of the channel would have widened the zone over which bed material is able to accumulate, potentially reducing the rate at which overall bed aggradation occurs. The Upper and Lower Norman levees and the Moskvin and Duprels revetments have had the most direct effects on river channel processes, as discussed below. The Middle Fork Bridge revetments reduce local bank erosion but occur in a section of river that is now relatively straight (probably because of the influence of the upstream revetments). The Middle Fork Bridge revetments may modestly preclude channel migration and influence adjacent habitats by limiting recruitment of riverbank sediment and large wood. The position of the bridge also affects hydraulic patterns in the channel, reducing the tendency for the channel to shift laterally between the bridge and the confluence with the North Fork. This lateral shift limitation may reduce the recruitment of large wood into the channel in this area.

Aquatic habitats have changed significantly in the vicinity of the constructed facilities since 1942. The large oxbow feature was the main channel in 1942. What appears to be a small

side channel in the 1942 aerial photograph is the current location of the main channel. The current relict channel feature on the right bank was the outside bend of the main channel. The current channel configuration is significantly straighter and shorter now than in 1942. Channel migration, channel formation, and natural floodplain processes have all been severely diminished as a result of these facilities (King County 2013a).

Aquatic habitats in this area include a large island and bar forested with mature black cottonwoods (Photo 41, Appendix B) and big-leaf maples. The understory is a mixture of native shrubs and herbs (e.g., snowberry [*Symphoricarpos albus*], salmonberry, sword fern) and non-native shrubs and herbs (primarily Himalayan blackberry and reed canarygrass [*Phalaris arundinacea*]). A large apex logjam (Photo 37, Appendix B) is present at the upstream end of the island. The island is separated from the right bank by an active side channel (Photo 36, Appendix B) containing what appear to be groundwater expressions. The Upper Norman levee isolates a relict channel feature (river right) from this side channel. The relict channel is now a large wetland with permanently ponded areas (Photo 42, Appendix B) vegetated with a variety of submerged and emergent native wetland species (e.g., small-fruited bulrush [*Scirpus microcarpus*], aquatic buttercup [*Ranunculus aquatilis*], rushes [*Juncus* spp.], and sedges [*Carex* spp.]), surrounded by scrub-shrub and forested wetlands. This wetland abuts and is contiguous with an extensive forested wetland complex fed by groundwater and surface water flowing off of Mount Si (Photo 43, Appendix B). On the left bank, the oxbow feature mentioned previously contains a large forested wetland whose canopy is dominated by red alder and black cottonwood, with extensive areas of permanent ponding vegetated with submerged, emergent, and scrub-shrub wetland species (Photo 55, Appendix B). Extensive residential development has occurred in this oxbow and vicinity. Deciduous forests dominated by black cottonwood cover the floodplain and contain many large trees (i.e., over 3 feet in diameter and 150 feet tall).

Confluence Subreach

The Confluence subreach is characterized by relatively flat topography, further reduced channel slope, and the confluences with the North Fork and South Forks. The Middle Fork in this area exhibits the characteristics of a meandering river: a broad floodplain, meandering channels, and extensive oxbow features (see Figures 3 and A-2, Appendix A). The substrate is primarily reworked alluvium from the three rivers. Extensive bars and side channels are dominated by gravels and sand (Photo 51, Appendix B), unlike the reaches upstream, which are dominated by boulders (in subreach MF2) and cobbles with some boulders (in subreach MF1).

Primary aquatic habitats in this subreach are associated with overflow channels, glides, and bars (Table-A-3, Appendix A). Primary aquatic habitats in the 10-year flood zone are overflow channel, meandering river floodplain, and relict channel. Primary aquatic habitats in the riparian zone (150 feet beyond the 2-year flood limits) are overflow channel, floodplain formed primarily by river meander migration, and relict channel. Primary habitats in the outer buffer zone (150 feet to 300 feet beyond the 2-year flood limits) are distal fan, meandering river floodplain, and relict channel.

Flow velocities are lower in this subreach than in those upstream, resulting in large areas of relatively quiescent waters in overflow channels and extensive floodplains that inundate during high flows. These conditions provide refuge for aquatic species during flood events.

A comparison of features evident on aerial photos from 1942 and from 2011 shows a reduction in channel sinuosity downstream of the North Fork confluence (see Figure A1, Appendix A, Sheet 1). A large river bend has been reduced in amplitude and the forested floodplain inside the bend has been eroded.

Vegetation conditions in the vicinity of the revetments in this subreach have changed since 1942 (see Table A-2, Appendix A). Forest cover has been reduced in all three zones: within the 2-year flood extent from 37 acres to 11 acres, within the riparian zone (150 feet beyond the 2-year flood extent) from 40 acres to 27 acres, and within the outer buffer (150 feet to 300 feet beyond the 2-year flood extent) from 20 acres to 11 acres. These areas have converted to primarily non-native herbaceous or shrub cover. Tree cover is dominated by black cottonwood. Extensive populations of Japanese knotweed (*Polygonum cusptidatum)* occur along the riverbanks and in the riparian forests. The extent of unvegetated river channel has not significantly changed over this time period.

As is the case for subreaches MF2 and MF1, the estimated number of logs in the Confluence subreach is below reference conditions (36 percent of median reference values). However, it is higher than values in the subreaches upstream.

Flood and Erosion Protection Facility Descriptions

Two flood and erosion protection facilities have been constructed in the Confluence subreach: the Reinig Road and Con Fury revetments. The Reinig Road and Con Fury revetments are composed of rock and are located on the right bank from Middle Fork RM 0 to Snoqualmie River mainstem RM 41.8.

Aquatic habitats include a large side channel on the right bank, against the revetment, and extensive bars of sand and gravel. Flooding in 2008 resulted in major erosion on the left bank, which cut into the floodplain forest and created a large logjam along that bank (Photos 51-53, Appendix B). Deciduous forest (primarily black cottonwood) dominates the floodplain and includes many very large trees (i.e., over 3 feet in diameter and approximately 150 feet tall).

Aquatic habitats have changed significantly in the vicinity of the revetments since 1942. At the upstream end of the facilities (RM 0), the main channel used to abut the right bank until at least 1961, but it has pushed towards the left bank and the mouth of the South Fork. In the previous location of the main channel there is now a large, forested sand and gravel bar (and the side channel noted above). Conditions along the downstream end of the revetments have remained relatively stable since1942.

HABITAT ANALYSIS

This analysis corroborates previous studies (WDFW 2011; King County 1999) describing known problems in the system: elevated water temperature in subreaches MF1a and Confluence (RM 1.0 to RM 0 and Snoqualmie RM 42.5 to RM 41.8), reduced channel and floodplain connectivity, reduced high-flow refuge for salmonids, and degraded riparian vegetation conditions in some areas (e.g., right bank, RM 0.4 to RM 0.7). In this section, these problems are examined more closely to offer guidance on priorities for restoration actions.

The primary habitat limitations in the corridor are detailed below: elevated water temperature, loss of riparian functions, insufficient large wood, reduced floodplain connectivity, and reduced high-flow refuge. River processes functioning at levels typical of intact river systems include flow discharge and sediment transport (King County 2013a).

Elevated Water Temperature

The dominant source of elevated water temperature is thought to be loss of shade from trees on the river. The Snoqualmie River temperature TMDL (Stohr et al. 2011) calls for maintaining or reestablishing mature intact buffers 150 feet wide with trees 150 feet tall in the Middle Fork Snoqualmie River. This condition is not met in the study area, particularly near RM 3.5, RM 1.0, and RM 0.5. Riparian logging; construction of roads, levees, and revetments; residential development; and landscaping have reduced buffer width and height. Temperature modeling in the TMDL indicates that a buffer 150 feet wide is sufficient to inject a layer of cool air over the river and reduce heat exchange with the water.

For tributaries, the TMDL calls for “complete shade.” Buffer widths large enough to create and maintain cooler conditions in smaller streams were not detailed in the TMDL but are optimal (R. Svrjcek, Washington Department of Ecology, personal communication [with P. Meyers, King County], April 8, 2013).

Less hyporheic exchange between the river channel and the underlying alluvial aquifer than in the past may also contribute to elevated water temperature. Hyporheic exchange is driven by local gradients in pressure on the streambed. These gradients are typically derived from large objects such as logjams and boulders that disrupt flow in the channel or by natural large-scale variation in channel morphology (e.g., river bends). Both riverbank hardening and a lack of large wood may limit opportunities for water to exchange through the substrate. Nevertheless, cold groundwater expression was observed in several areas during ground surveys, primarily along the base of Mount Si (at RM 2.0, RM 1.5, and RM 0.9). These expressions could be derived from hyporheic upwelling or from toe slope groundwater discharge of water off of Mount Si. A hyporheic study is needed to definitively characterize the importance of groundwater on stream temperatures.

Loss of Riparian Functions

The provision of shade by trees is one of many riparian ecosystem functions. Other ecologically important riparian functions include allochthonous input of nutrients and small prey organisms to fuel the food web, and provision of physical structure for shelter and reproduction of terrestrial and aquatic species. Riparian vegetation plays a fundamentally important role in river ecosystems by providing food and shelter, as well as shade.

These functions have been reduced by removal of vegetation along the river, and continue to be impaired where flood management facilities are maintained to comply with the vegetation requirements of the US Army Corps of Engineers Public Law (PL) 84-99 program. The amount of vegetation allowed on levees enrolled in the PL 84-99 program is generally limited to trees of 2-inch diameter. This is the case for the Mason Thorson Ells and Extension levees. King County has elected to keep these two levees in the PL 84-99 program to maintain eligibility for federal financial assistance when repairs are needed. Landscaping activities, agricultural activities, roads, and residential development in riparian areas also continue to impair riparian functions in some parts of the corridor.

The decomposition of large pieces of wood is beneficial for building soil and for propagating seedling trees. Where they are present, “nurse logs” support tree regeneration in floodplains and riparian areas. The lack of large wood limits the establishment of conifers (particularly western red cedar, Sitka spruce, and western hemlock), which are especially important for shade in riparian zones. This interaction between large wood, riparian condition, and water temperature exemplifies the relationships that characterize the environmental complexity of the Middle Fork.

Actions to reestablish native vegetation riparian communities, including generating large wood for in-channel habitat, will help restore riparian functions central to food webs.

Insufficient Large Wood

The role of large wood in Pacific Northwest streams is linked to channel processes that benefit salmonids. Woody debris plays an important role in controlling channel morphology, storing and routing sediment and organic matter, and creating fish habitat. In particular, large wood creates habitat heterogeneity; it forces complex hydraulic flows resulting in pools, back eddies, and side channels, and increasing channel complexity. Because it provides nutrients and supports recruitment of insects and macroinvertebrates to the streams, wood functions as an indirect food source for salmonids (Fox and Bolton 2007).

When pools occur at high frequency and volume, they decrease the effective streambed gradient and increase the retention of organic material and nutrients within the system. Most salmonids require pool habitats at one or more life stages, for example to support adult holding and resting as well as juvenile feeding and refuge. The reduction in quality and quantity of pool habitats has been identified as a major source of habitat degradation through large portions of the Pacific Northwest (McIntosh et al. 2000).

Over time, logging, development, and bank hardening have dramatically reduced wood inputs to the river. When large wood is removed from the channel but not replaced, the river becomes straighter, shorter, and more static. Historical evidence and documents indicate that large wood was actively removed from the Middle Fork river channel in the past (Collins et al. 2002; Hill 1970). The scale of this removal is undocumented. However it is almost certain that only a small fraction of the large wood once present remains (see Table 4). Logs large enough to form logjams, referred to as "key pieces," typically occupy at least half the channel width and half the channel depth. Few, if any, logs of this size remain in the study area.

The scarcity of large wood and logjams in contact with the main channel is a major limiting factor for river processes. It is difficult to reestablish such features naturally, especially because extensive timber harvest throughout the Middle Fork watershed has dramatically reduced the number of large trees available for recruitment. The installation of large wood jams at strategic points on the river could help restore natural river processes, particularly floodplain flow and channel activation/creation. When future repairs are needed to flood and erosion protection facilities, large wood could be integrated into the work to improve local habitat conditions.

Reforestation efforts, both in the study area and upstream, would provide a long-term source of large wood for recruitment into the channel, as well as organic inputs (e.g., leaf litter) into the riparian area. Such inputs are critical for populations of macroinvertebrates, a key food resource for salmonids. Eventual reforestation with coniferous trees would provide larger, more durable wood as recruitment material. Finally, acquisition and reforestation of additional property along the Middle Fork corridor would support natural river processes over the long term by providing space for and limiting conflicts related to channel migration and flooding.

Reduced Channel and Floodplain Connectivity

The levees and revetments built along the Middle Fork corridor are intended to confine the river channel and limit damage from erosion or channel migration. The structures do not prevent flooding, but rather change its frequency and intensity in local areas. During high-flow events, swift water concentrates along the sides of the levees and revetments. In contrast, natural systems, particularly those with anabranching or wandering planforms, allow large wood accumulations that activate and stabilize floodplain channels (e.g., right bank at RM 4.1, RM 3.0, RM 1.6, and RM 0.9).

The very nature of channelization is to eliminate alternative flow paths. For example, the Moskvin and Duprels revetments cut off large oxbows formerly linked to the main channel, isolating them and dramatically straightening and shortening the main channel. By limiting lateral channel migration, these facilities may also be responsible for focusing local sediment accumulation. Modifying or removing these facilities could restore natural processes.

Channelization also restricts fish access to sheltered areas in the floodplain, where prey organisms are typically diverse and abundant. Floodplain energy production is a key part of river ecology. In addition, loss of floodplain connection makes in-channel habitat more

hazardous: water velocity is increased and shelter from hard surfaces may be hard to find. Channelization reduces both habitat area (quantity) and complexity (quality). The cumulative impact of channelization is straighter shorter channels and faster water during flood events.

In meandering zones, such as the Confluence subreach, connections between the primary channel and oxbow lakes have been lost. In the MF1b subreach, a split channel section has been reduced to one channel.

The expansion and enhancement of forested riparian buffers will provide long-term sources of large wood. It will also create roughness and complexity during flood events, which in turn support natural river processes, including channel and floodplain connectivity suitable to the geomorphic context. Strategic addition of large wood to the channel could enhance these effects in targeted areas.

Reduced High-Flow Refuge

High-flow refuge is most available in floodplain channels, along well-vegetated riverbanks, and in association with large wood. These conditions are no longer prevalent in the study area. The root causes of reduced high-flow refuge are a combination of the factors described above: uniformity of bank conditions in channelized areas, lack of complexity and small-scale slow-water niches, and inability of the river to recruit wood. Levees and revetments contribute to habitat limitations in the corridor because they interfere with channel migration, channel-forming processes, and natural floodplain processes; locally, they also offer poor riparian cover along their alignments. Concentrating alongside the structural elements of the facilities, flow is channelized and diminished in overbank areas. The net effect is reduced refuge during periods of high flow.

The recommended treatments and associated effects described above to enhance channel and floodplain connectivity would also create habitat for high-flow refuge. In promoting connectivity with these secondary channel habitats, such treatments would provide the areas of reduced velocity that benefit fish and other aquatic species during flood events.

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APPENDIX A

Historical Timeline and Report Figures

Table A-1. Historic Timeline of Major Events in the Middle Fork Watershed.

Date	Climate and Fire	Timber and Wood Management	Hydrology and Geomorphology	Facility Construction and Municipal History	Source
900-1300	Medieval Climate Optimum, warmer climate. Western hemlock zone covers more of watershed to higher elevations than at present.				1
1400-1850	Little Ice Age, cooler and probably drier climate. Expansion of silver fir zone, downward movement of Douglas fir zone.				1
1308	Large fire(s) in Western Washington. Upper Middle Fork Snoqualmie River and Quartz Creek burned.				1
1508	Several fires in southern Pratt River and lower Middle Fork Snoqualmie and Quartz Creek watersheds.				1
1701	Fire in Western hemlock zone outside National Forest boundary, Middle Fork Snoqualmie watershed.				1
1887		Snag removal begins on Snoqualmie River below Snoqualmie Falls			2
~1890		W.C. Weeks shingle mill opens in North Bend			1
1893		Formation of Pacific Forest Reserve			1
1906		Construction of North Bend Lumber Company mill at Edgewick, in South Fork Snoqualmie River watershed. Mill was initially supplied with timber from near base of Mount Si.			3
1908		Large number of snags removed from Snoqualmie/Snohomish River system. Unclear whether removal occurred above Snoqualmie Falls.			2
1908		Formation of Snoqualmie National Forest			1
1909				Incorporation of Town of North Bend	3
1909				Norman Bridge built near site of existing Middle Fork Bridge	4
Nov-1909			Flood on Snoqualmie River. Ungaged on Middle Fork.		5
Apr-1915		Photographic evidence of cleared land on terrace/floodplain at base of Little Mount Si.			6
12/18/1918			Boxley Burst causes flood and sedimentation on South Fork. May have affected Middle Fork.		7, 8
1924				Norman Bridge replaced (near site of existing Middle Fork Bridge)	4
1929		Much of low elevation land adjacent to Middle Fork below Embankment is owned by Weyerhauser Logged Off Land Company, indicating it had been logged prior to 1929.			9
1930s				King County Flood Control Division in conjunction with Federal WPA, maintains staff of over 200 employees.	10
Feb-1932			Flood on Snoqualmie River. Ungaged on Middle Fork.		5
1930s and 1940s		Stand replacing logging begins inside National Forest boundary in Middle Fork watershed. Mostly consists of railroad logging of valley bottoms.			1
1940	Large fire, Pratt river drainage. Timber harvested after fire.				11
1940s		Period of maximum disturbance to canopy within National Forest in Middle Fork Snoqualmie watershed.			1
1940s and 1950s		Timber harvest in Taylor River watershed.			1
between 1942 and			Abandonment of bend above site of Middle Fork Bridge, at site of Norman Levee, RM 0.8 to RM 0.5.		12
between 1942 and 1961			Abandonment of bend below site of existing Middle Fork Bridge, ~1500 ft below confluence with North Fork. South Fork occupies part of this bend in 1961.		12
between 1942 and 1962			Major debris avalanche, Thunder Creek		1
1950				Wood truss bridge (Howe bridge) built near site of existing Middle Fork Bridge.	4
Late 1950s				King County Flood Control Division is reduced in size to 15 employees.	10
1959				River Improvement Fund (RIF) is established from Countywide levy.	10
Nov 1959 and Dec 1959			Two floods on Snoqualmie River. Ungaged on Middle Fork. Washout of 1400 feet of U.S. Highway 10 near North Bend where logjam caused South Fork to cut new channel.		5, 13
1959-1963				Middle Fork left and right bank and bridge revetments built	12
Feb-1961			USGS stream gage installed at Tanner.		14
1961-1962				Mount Si Bridge right bank revetment built.	15
1963				Mason Thorson Ells Levee built	15
1963				Mason Thorson Extension Levee built	12
1964				Mount Si Road protection revetment built.	15
1964				Mount Si Bridge built	15
1964-1965				Tanner Road Revetment installed	15
1965				Upper/Lower Norman Revetment built	15
1966				Reinig Road Revetment built	15
1969				Con Fury Revetment built	15
1969				Mason Thorson Ells Levee Extended	15
1970s		Last large-scale logging of uplands in National Forest (Taylor River)			1
1973				Duprells Revetment built	15
1977				Moskvin Revetment built	15
1976		Designation of Alpine Lakes Wilderness Area			
1980s		Closure of last lumber mill in North Bend			1
12/2/1977			3rd highest recorded discharge at Tanner gage, 30,200 cfs		14
October to November, 1987			Lowest 30-day average discharge on record for Tanner gage. Average discharge = 99.3 cfs.		14
11/24/1990			4th highest recorded discharge at Tanner gage, 30,100 cfs		14
1990s		County ends practice of burning snags. Last record of County involvement in wood burning was fall 1991 on right bank bar at RM 1.7.			15
July to September , 1998			Second lowest 30-day average discharge on record at Tanner gage. Average discharge = 129.2 cfs.		14
11/6/2006			Highest recorded discharge at Tanner gage, 31,700 cfs		14
2008				Mount Si Bridge replaced	15
1/7/2009			2nd highest recorded discharge at Tanner gage, 31,200 cfs		14
September to October, 2012			Third lowest 30-day average discharge on record at Tanner gage. Average discharge = 133.4 cfs.		14

Sources

[1] Mount Baker-Snoqualmie National Forest 1998; [2] Collins and Sheik 2002; [3] http://www.middleforkgiants.com/NBTC.html; [4] King County Department of Construction and Facilities Management 2000

[5] WSE 2013; [6] Ambrose 1915; [7] Mackin 1943; [8] Stein 2000; [9] Kroll Map Company, 1929; [10] King County Surface Water Management Division 1990; [11] Perkins 1996; [12] Air photo record;

[13] Hendricks 1964; [14] USGS Streamgage Record; [15] King County Staff

Table A-2. Comparison of 2011 and 1942 Vegetation Cover Types in the Middle Fork Study Area.

Subreach	Vegetation Type	2011 Within 2-year Flood	1942 Within 2-year Flood	2011 Within 2-year Limits to 150-foot Buffer			1942 Within 2-year Limits to 150-foot Buffer			2011 150-foot Buffer Limits to 300-foot Buffer			1942 150-foot Buffer Limits to 300-foot Buffer		
				Left Bank	Right Bank	Total	Left Bank	Right Bank	Total	Left Bank	Right Bank	Total	Left Bank	Right Bank	Total
CONFLUENCE															
	Deciduous Forest	0.01	x[1]	1.19	0.00	**1.19**	x	x	**x**	1.50	0.00	**1.50**	x	x	**x**
	Mixed forest	1.18	x	12.18	0.00	**12.18**	x	x	**x**	3.22	0.00	**3.22**	x	x	**x**
	Forested Wetland	9.81	x	9.36	4.11	**13.47**	x	x	**x**	3.84	2.49	**6.32**	x	x	**x**
	Forest Total (for comparison to 1942)	***11***	***37.21***	***22.73***	***4.11***	***26.84***	***36.46***	***3.64***	***40.11***	***8.56***	***2.49***	***11.05***	***17.14***	***2.80***	***19.94***
	Herbaceous Upland	1.09	x	9.10	0.29	**9.40**	x	x	**x**	11.16	0.47	**11.63**	x	x	**x**
	Emergent Wetland	0.06	x	3.70	1.55	**5.25**	x	x	**x**	2.42	0.45	**2.86**	x	x	**x**
	Emergent and Aquatic Bed Wetland	20.57	x	2.63	0.00	**2.63**	x	x	**x**	0.00	0.00	**0.00**	x	x	**x**
	Herbaceous Total (for comparison to 1942)	***21.72***	***5.33***	***15.43***	***1.84***	***17.27***	***6.37***	***2.71***	***9.07***	***13.57***	***0.91***	***14.49***	***10.67***	***2.62***	***13.29***
	Upland Shrub	0.00	x	0.00	0.00	**0.00**	x	x	**x**	0.00	0.73	**0.73**	x	x	**x**
	Scrub/Shrub Wetland	2.48	x	1.69	0.75	**0.00**	x	x	**x**	0.44	0.99	**1.43**	x	x	**x**
	Shrub Total (for comparison to 1942)	***2.48***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.44***	***1.72***	***2.16***	***0.00***	***0.00***	***0.00***
	Agriculture	***0.09***	***0.00***	***3.11***	***0.00***	***3.11***	***0.00***	***0.00***	***0.00***	***4.99***	***0.00***	***4.99***	***0.00***	***0.00***	***0.00***
	Unvegetated (river channel)	***10.06***	***8.89***	***0.57***	***0.79***	***1.35***	***0.70***	***1.14***	***1.84***	***1.10***	***0.90***	***2.00***	***0.85***	***0.60***	***1.44***
MF1A															
	Coniferous forest	0.00	x	0.00	0.10	**0.10**	x	x	**x**	0.00	3.49	**3.49**	x	x	**x**
	Deciduous Forest	8.19	x	12.10	0.97	**13.07**	x	x	**x**	4.57	0.00	**4.57**	x	x	**x**
	Mixed forest	1.66	x	5.76	4.72	**10.48**	x	x	**x**	2.76	2.50	**5.26**	x	x	**x**
	Forested Wetland	20.79	x	3.27	3.58	**6.84**	x	x	**x**	0.46	1.32	**1.79**	x	x	**x**
	Forest Total (for comparison to 1942)	***30.64***	***25***	***21.12***	***9.37***	***30.50***	***23.82***	***7.46***	***31.28***	***7.80***	***3.82***	***11.62***	***10.55***	***7.28***	***17.83***
	Emergent Wetland	0.00	***x***	0.00	0.00	**0.00**	x	x	**x**	0.00	0.00	**0.00**	x	x	**x**
	Emergent and Aquatic Bed Wetland	0.00	***x***	0.00	0.00	**0.00**	x	x	**x**	0.00	0.00	**0.00**	x	x	**x**
	Herbaceous Upland	0.23	***x***	2.01	5.84	**7.85**	x	x	**x**	2.82	7.69	**10.51**	x	x	**x**
	Herbaceous Total (for comparison to 1942)	***0.23***	***1.7***	***2.01***	***5.84***	***7.85***	***2.55***	***6.12***	***8.66***	***2.82***	***7.69***	***10.51***	***3.64***	***7.23***	***10.86***
	Shrub	0.04	x	0.00	1.32	**1.32**	x	x	x	0.00	0.38	**0.38**	x	x	**x**
	Scrub/Shrub Wetland	5.84	x	0.22	0.08	**0.30**	x	x	x	0.02	0.26	**0.28**	x	x	**x**
	Shrub Total (for comparison to 1942)	***5.88***	***2.14***	***0.22***	***1.40***	***1.62***	***0.00***	***1.16***	***1.16***	***0.02***	***0.64***	***0.66***	***0.00***	***1.13***	***1.13***
	Agriculture	***0.51***	***0***	***5.99***	***0.00***	***5.99***	***0.16***	***0.00***	***0.16***	***4.45***	***0.00***	***4.45***	***0.91***	***0.00***	***0.91***
	Unvegetated (river channel)	***20***	***30.58***	***0.04***	***0.03***	***0.07***	***2.85***	***1.91***	***4.76***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***

Table A-2, Appendix A (continued). Comparison of 2011 and 1942 Vegetation Cover Types in the Middle Fork Study Area.															
				2011 Within 2-year Limits to 150-foot Buffer			1942 Within 2-year Limits to 150-foot Buffer			2011 150-foot Buffer Limits to 300-foot Buffer			1942 150-foot Buffer Limits to 300-foot Buffer		
Subreach	**Vegetation Type**	**2011 Within 2-year Flood**	**1942 Within 2-year Flood**	**Left Bank**	**Right Bank**	**Total**	**Left Bank**	**Right Bank**	**Total**	**Left Bank**	**Right Bank**	**Total**	**Left Bank**	**Right Bank**	**Total**
MF1B															
	Coniferous forest	0.58	x	0.00	14.81	**14.81**	x	x	x	0.00	15.09	**15.09**	x	x	**x**
	Deciduous Forest	9.67	x	3.45	1.55	**5.00**	x	x	x	0.00	0.00	**0.00**	x	x	**x**
	Mixed forest	4.64	x	21.82	0.00	**21.82**	x	x	x	12.53	0.00	**12.53**	x	x	**x**
	Forested Wetland	2.71	x	0.00	0.56	**0.57**	x	x	**x**	0.00	0.00	**0.00**	x	x	**x**
	Forest Total (for comparison to 1942)	***17.6***	***23.74***	***25.28***	***16.92***	***42.20***	***23.5***	***16.52***	***40.02***	***12.53***	***15.09***	***27.62***	***13.88***	***15.09***	***28.96***
	Emergent Wetland	0.00	x	0.00	0.00	**0.00**	x	x	**x**	0.00	0.00	**0.00**	x	x	**x**
	Herbaceous Upland	0.00	x	0.89	0.00	**0.89**	x	x	**x**	2.01	0.00	**2.01**	x	x	**x**
	Herbaceous Total (for comparison to 1942)	0.00	***0.10***	***0.89***	***0.00***	***0.89***	***2.89***	***0.00***	***2.89***	***2.01***	***0.00***	***2.01***	***4.88***	***0.00***	***4.88***
	Scrub/Shrub Wetland	3.51	x	0.01	0.00	**0.01**	x	x	**x**	0.00	0.00	**0.00**	x	x	**x**
	Shrub Total (for comparison to 1942)	***3.51***	***2.42***	***0.01***	***0.00***	***0.01***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***
	Agriculture	***0.00***	***0.00***	***1.41***	***0.00***	***1.41***	***0.00***	***0.00***	***0.00***	***2.72***	***0.00***	***2.72***	***0.35***	***0.00***	***0.00***
	Built	***1.14***	***0.00***	***0.22***	***0.00***	***0.22***	***0.00***	***0.00***	***0.00***	***1.85***	***0.00***	***1.85***	***0.00***	***0.00***	***0.00***
	Unvegetated (river channel)	***23.97***	***18.37***	***0.24***	***0.34***	***0.58***	***1.65***	***0.21***	***1.86***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***
MF2															
	Coniferous forest	2.86	x	15.89	12.97	**28.86**	x	x	**x**	11.61	11.62	**23.24**	x	x	**x**
	Deciduous Forest	0.24	x	0.00	2.28	**2.28**	x	x	**x**	0.00	0.01	**0.01**	x	x	**x**
	Mixed forest	6.61	x	12.13	30.50	**42.63**	x	x	**x**	9.72	9.17	**18.89**	x	x	**x**
	Forested Wetland	1.46	x	0.00	0.30	**0.30**	x	x	**x**	0.00	0.00	**0.00**	0.00	0.00	**0.00**
	Forest Total (for comparison to 1942)	***11.17***	***20.05***	***28.02***	***46.05***	***74.07***	***7.00***	***49.54***	***56.53***	***21.33***	***20.80***	***42.14***	***11.80***	***29.74***	***41.54***
	Herbaceous Upland	0.00	x	0.94	0.00	**0.94**	x	x	**x**	7.53	0.00	**7.53**	x	x	**x**
	Herbaceous Total (for comparison to 1942)	***0.00***	***6.18***	***0.94***	***0.00***	***0.94***	***27.07***	***0.00***	***27.07***	***7.53***	***0.00***	***7.53***	***26.05***	***0.00***	***26.05***
	Scrub/Shrub Wetland	4.74	x	0.05	0.17	**0.23**	x	x	**x**	0.00	0.00	**0.00**	x	x	**x**
	Upland Shrub	0.05	x	5.75	0.00	**5.75**	x	x	**x**	4.37	0.00	**4.37**	x	x	**x**
	Shrub Total (for comparison to 1942)	***4.79***	***0.79***	***5.80***	***0.17***	***5.98***	***5.31***	***8.83***	***14.15***	***4.37***	***0.00***	***4.37***	***4.64***	***6.33***	***10.97***
	Agriculture	***0.00***	***0.00***	***0.00***	***0.33***	***0.33***	***0.00***	***1.01***	***1.01***	***0.00***	***0.70***	***0.70***	***0.00***	***1.59***	***1.59***
	Forested Residential	***0.02***	***x***	***0.00***	***3.90***	***3.90***	***x***	***x***	***x***	***0.00***	***7.57***	***7.57***	***x***	***x***	***x***
	Built	***1.14***	***0.05***	***9.14***	***8.69***	***17.83***	***2.76***	***0.00***	***2.76***	***11.16***	***8.52***	***19.68***	***1.90***	***0.00***	***1.90***
	Unvegetated (river channel)	***59.22***	***48.85***	***0.21***	***1.35***	***1.56***	***1.97***	***1.13***	***3.10***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***

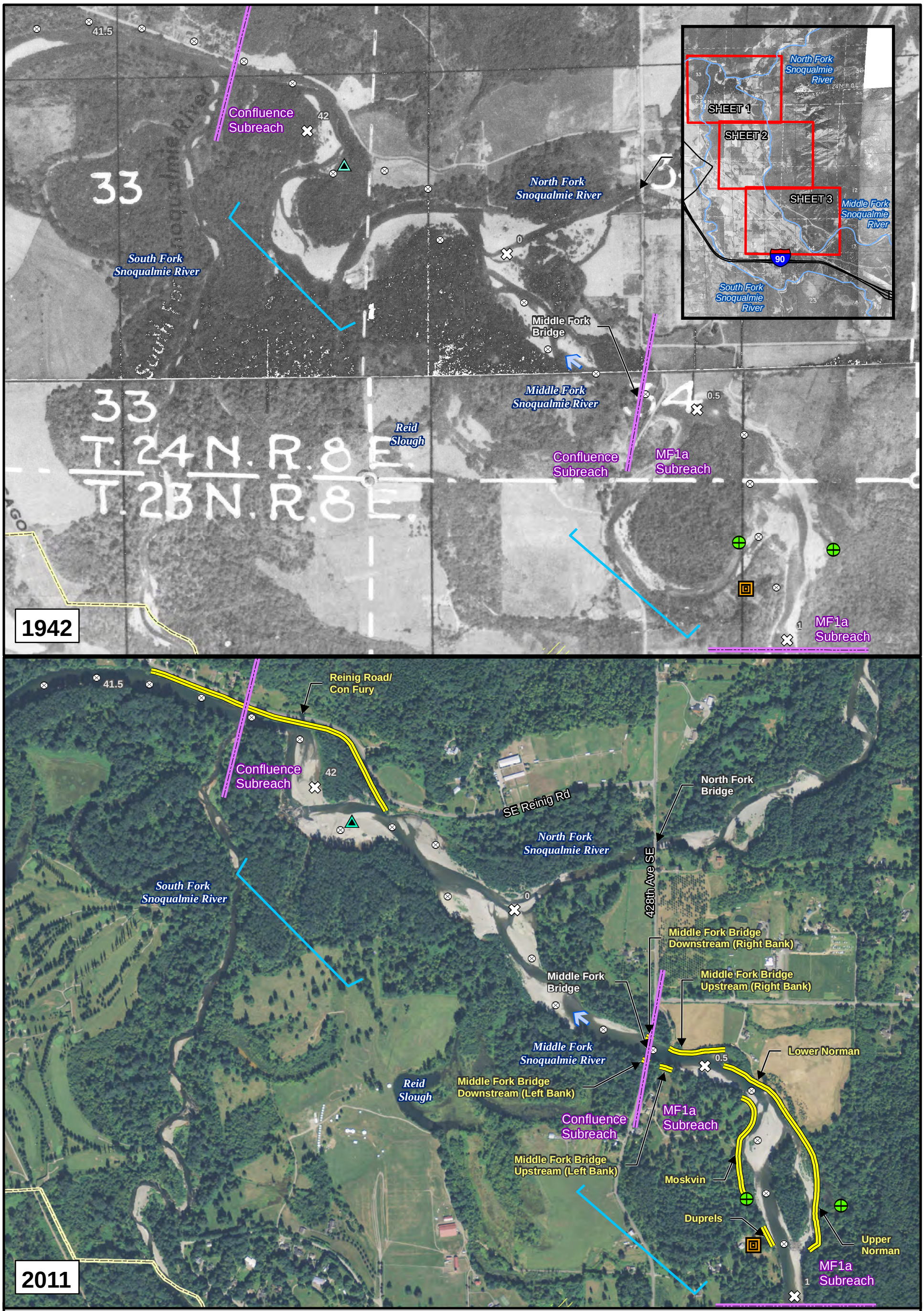
x[1] Indicates habitat categories that are not distinguishable in 1942 aerial photographs. These habitat types were combined into groups for mapping and quantification. For example: Forests were combined in mapping of 1942 features, but were further subdivided (coniferous forest, deciduous forest, forested wetland) for assessing conditions in 2011 aerial photographs.

Table A-3. Summary of Current (2011) Aquatic And Upland (Geomorphic) Habitats in the Middle Fork Study Area.									
				2-year Limits to 150-foot Buffer			150-foot Buffer Limits to 300-foot Buffer		
Subreach	Aquatic/Upland (Geomorphic) Habitat Type	Current Within 2-year Flood	Current Within 10-year Flood	Left Bank	Right Bank	Total	Left Bank	Right Bank	Total
CONFLUENCE									
	Primary Channel								
	Riffle	0.00	0.00	0.08	0.00	**0.08**	0.43	0.13	**0.56**
	Glide	6.07	6.10	0.32	0.00	**0.32**	0.00	0.00	**0.00**
	Pool	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	**0.00**
	Bar	7.57	9.00	1.43	1.69	**3.11**	0.93	0.77	**1.71**
	Side channel	1.68	1.71	0.04	0.04	**0.04**	0.00	0.00	**0.00**
	Secondary Channel								
	Overflow channel	32.91	40.68	8.06	0.19	**8.25**	0.18	0.00	**0.18**
	Relict channel	0.13	19.48	7.30	0.00	**7.30**	5.60	0.00	**5.60**
	Tributary	0.00	0.12	0.92	0.92	**0.92**	0.00	1.33	**1.33**
	Floodplain								
	Meandering River Floodplain	3.05	25.55	24.31	4.66	**28.97**	15.69	3.79	**19.48**
	Distal Floodplain/Fan	0.00	0.16	2.03	0.00	**2.03**	5.83	0.00	**5.83**
MF1A									
	Primary Channel								
	Riffle	4.83	4.83	0.00	0.00	**0.00**	0.00	0.00	**0.00**
	Glide	8.83	8.85	0.02	0.01	**0.03**	0.00	0.00	**0.00**
	Pool	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	**0.00**
	Bar	6.61	6.90	0.24	0.07	**0.30**	0.00	0.00	**0.00**
	Side channel	2.83	2.83	0.00	0.02	**0.02**	0.00	0.00	**0.00**
	In-channel island	4.24	4.38	0.00	0.14	**0.14**	0.00	0.00	**0.00**
	Secondary Channel								
	Overflow channel	19.34	25.62	5.66	0.24	**5.90**	0.49	0.00	**0.49**
	Groundwater channel	3.25	3.64	0.42	0.02	**0.44**	0.00	0.00	**0.00**
	Relict channel	5.24	22.93	0.32	0.96	**1.27**	0.63	0.00	**0.63**
	Tributary	0.00	2.67	0.00	0.00	**0.00**	0.00	0.00	**0.00**
	Floodplain								
	Wandering River Floodplain	0.31	17.34	7.26	0.00	**7.26**	6.33	0.00	**6.33**
	Meandering River Floodplain	3.87	41.64	15.46	12.71	**28.17**	7.63	10.57	**18.20**
	Distal Floodplain/Fan	0.00	0.39	0.00	0.00	**0.00**	0.00	0.00	**0.00**
	Upland								
	Hillslope	0.08	0.33	0.00	2.49	**2.49**	0.00	4.81	**4.81**
MF1B									
	Primary Channel								
	Riffle	5.97	5.98	0.00	0.01	**0.01**	0.00	0.00	**0.00**
	Glide	7.20	7.22	0.02	0.00	**0.03**	0.00	0.00	**0.00**
	Bar	8.81	8.94	0.13	0.04	**0.17**	0.00	0.00	**0.00**
	Pool	3.54	3.59	0.09	0.01	**0.11**	0.00	0.00	**0.00**
	Side channel	4.46	4.67	0.00	0.31	**0.31**	0.00	0.00	**0.00**
	In-channel island	2.24	3.77	0.00	1.55	**1.55**	0.00	0.00	**0.00**
	Secondary Channel								
	Overflow channel	5.77	7.76	2.03	0.00	**2.03**	0.09	0.00	**0.09**
	Relict channel	2.36	14.89	0.49	0.09	**0.58**	1.26	0.00	**1.26**
	Floodplain								
	Wandering River Floodplain	3.88	74.51	25.26	0.00	**25.26**	17.75	0.00	**17.75**
	Meandering River Floodplain	0.24	0.25	0.01	0.00	**0.01**	0.00	0.00	**0.00**
	Distal Floodplain/Fan	0.00	5.99	0.00	0.00	**0.00**	0.00	0.00	**0.00**
	Radially Symmetric Alluvial Fan	0.00	0.05	0.00	0.00	**0.00**	0.00	0.00	**0.00**
	Upland								
	Hillslope	0.61	0.87	0.00	15.25	**15.25**	0.00	15.09	**15.09**

Table A-3. Summary of Current (2011) Aquatic And Upland (Geomorphic) Habitats in the Middle Fork Study Area.									
Subreach	Aquatic/Upland (Geomorphic) Habitat Type	Current Within 2-year Flood	Current Within 10-year Flood	2-year Limits to 150-foot Buffer			150-foot Buffer Limits to 300-foot Buffer		
MF2									
	Primary Channel								
	Riffle	19.74	19.80	0.00	0.00	0.00	0.00	0.02	**0.02**
	Plane bed	10.74	10.83	0.02	0.14	**0.16**	0.00	0.00	**0.00**
	Glide	8.24	8.24	0.00	0.00	0.00	0.00	0.00	**0.00**
	Pool	10.72	10.75	0.00	0.03	**0.03**	0.00	0.00	**0.00**
	Bar	7.28	7.74	0.18	0.43	**0.60**	0.00	0.00	**0.00**
	Side channel	6.47	6.81	0.06	0.01	**0.07**	0.00	0.00	**0.00**
	In-channel island	2.10	8.39		13.45	**13.45**	0.00	0.36	**0.36**
	Secondary Channel								
	Overflow channel	3.26	5.58	0.00	1.70	**1.70**	0.00	0.70	**0.70**
	Floodplain								
	Inset Floodplain	3.07	13.70	0.00	19.75	**19.75**	0.00	8.11	**8.11**
	Wandering River Floodplain	0.00	0.01	0.00	0.49	**0.49**	0.00	0.00	**0.00**
	Radially Symmetric Alluvial Fan	4.47	8.71	42.98	21.27	**64.25**	43.90	23.18	**67.08**
	Upland								
	Hillslope	0.22	0.59	0.00	3.25	**3.25**	0.15	5.27	**5.42**

Table A-4. Summary of Current Vegetation Types in the Middle Fork Study Area.

Subreach	Vegetation Type	Within 2-year Flood	Within 10-year Flood	2-year Limits to 150-foot Buffer			150-foot Buffer Limits to 300-foot Buffer		
				Left Bank	Right Bank	Total	Left Bank	Right Bank	Total
CONFLUENCE									
	Upland								
	Deciduous Forest	0.01	0.28	1.19	0.00	**1.19**	1.50	0.00	**1.50**
	Mixed forest	1.18	15.39	12.18	0.00	**12.18**	3.22	0.00	**3.22**
	Upland Shrub	0.00	0.00	0.00	0.00	**0.00**	0.00	0.73	**0.73**
	Herbaceous	1.09	5.26	9.10	0.29	**9.40**	11.16	0.47	**11.63**
	Wetland								
	Forested Wetland	9.81	33.31	9.36	4.11	**13.47**	3.84	2.49	**6.32**
	Scrub/shrub Wetland	2.48	3.14	1.69	0.75	**2.44**	0.44	0.99	**1.43**
	Emergent Wetland	0.06	9.71	3.70	1.55	**5.25**	2.42	0.45	**2.86**
	Emergent/Aquatic Bed Wetland	20.57	23.19	2.63	0.00	**2.63**	0.00	0.00	**0.00**
	Unvegetated (river channel)	10.06	10.09	0.57	0.79	**1.35**	1.10	0.90	**2.00**
	Developed								
	Agriculture	0.09	2.41	3.11	0.00	**3.11**	4.99	0.00	**4.99**
M1A									
	Upland								
	Coniferous forest	0.00	0.00	0.00	0.10	**0.10**	0.00	3.49	**3.49**
	Deciduous Forest	8.19	24.32	12.10	0.97	**13.07**	4.57	0.00	**4.57**
	Mixed forest	1.66	7.24	5.76	4.72	**10.48**	2.76	2.50	**5.26**
	Upland Shrub	0.04	1.12	0.00	1.32	**1.32**	0.00	0.38	**0.38**
	Herbaceous Upland	0.23	20.99	2.01	5.84	**7.85**	2.82	7.69	**10.51**
	Wetland								
	Forested Wetland	20.79	39.43	3.27	3.58	**6.84**	0.46	1.32	**1.79**
	Scrub/shrub Wetland	5.84	8.75	0.22	0.08	**0.30**	0.02	0.26	**0.28**
	Emergent Wetland	0.00	3.82	0.00	0.00	**0.00**	0.00	0.00	**0.00**
	Emergent/Aquatic Bed Wetland	0.00	0.48	0.00	0.00	**0.00**	0.00	0.00	**0.00**
	Unvegetated (river channel)	*20*	20.04	0.04	0.03	**0.07**	0.00	0.00	**0.00**
	Developed								
	Agriculture	*0.51*	16.18	0.00	0.00	**5.99**	4.45	0.00	**4.45**
M1B									
	Upland								
	Coniferous forest	0.58	0.77	0.00	14.81	**14.81**	0.00	15.09	**15.09**
	Deciduous Forest	9.67	14.56	3.45	1.55	**5.00**	0.00	0.00	**0.00**
	Mixed forest	4.64	30.21	21.82	0.00	**21.82**	12.53	0.00	**12.53**
	Herbaceous	0.00	2.33	0.89	0.00	**0.89**	2.01	0.00	**2.01**
	Wetland								
	Forested Wetland	2.71	11.01	0.00	0.56	**0.57**	0.00	0.00	**0.00**
	Scrub/shrub Wetland	3.51	3.51	0.01	0.00	**0.01**	0.00	0.00	**0.00**
	Emergent Wetland	0.00	0.96	0.00	0.00	**0.00**	0.00	0.00	**0.00**
	Unvegetated (river channel)	23.97	24.35	0.24	0.34	**0.58**	0.00	0.00	**0.00**
	Developed								
	Built	1.14	10.49	0.22	0.00	**0.22**	1.85	0.00	**1.85**
	Agriculture	0.00	40.31	1.41	0.00	**1.41**	2.72	0.00	**2.72**
M2									
	Upland								
	Coniferous forest	2.86	7.56	15.89	12.97	**28.86**	11.61	11.62	**23.24**
	Deciduous Forest	0.24	1.52	0.00	2.28	**2.28**	0.00	0.01	**0.01**
	Mixed forest	6.61	22.61	12.13	30.50	**42.63**	9.72	9.17	**18.89**
	Upland Shrub	0.05	0.23	5.75	0.00	**5.75**	4.37	0.00	**4.37**
	Herbaceous upland	0.00	0.00	0.94	0.00	**0.94**	7.53	0.00	**7.53**
	Wetland								
	Forested Wetland	1.46	1.75	0.00	0.30	**0.30**	0.00	0.00	**0.00**
	Scrub/shrub Wetland	4.74	4.94	0.05	0.17	**0.23**	0.00	0.00	**0.00**
	Developed								
	Built	*1.14*	2.06	9.14	8.69	**17.83**	11.16	8.52	**19.68**
	Forested Residential	*0.02*	0.12	0.00	3.90	**3.90**	0.00	7.57	**7.57**
	Agriculture	0.00	0.00	0.00	0.33	**0.33**	0.00	0.70	**0.70**



Legend

- Reduced channel sinuosity
- Subreach boundary
- Bank erosion
- Channel disconnected from river
- Erosion through floodplain channel
- Increased forest cover
- Areas of major development
- Current flood protection facility location (2011 photo)
- Current City of North Bend boundary
- River mile
- 1/10th river mile
- Middle Fork flow direction

Note: For portions of the study area below the confluence with the North Fork, which serves as the origin for the King County Middle Fork Snoqualmie River channel coordinate system, river miles are based on the King County Snoqualmie River Mile system, which has its origin at the confluence with the Skykomish River.

Figure A-1. Comparison of 1942 and 2011 Aerial Photography (Sheet 1 of 3).

N

0 450 900 1,800 Feet

King County

Prepared for King County by Herrera

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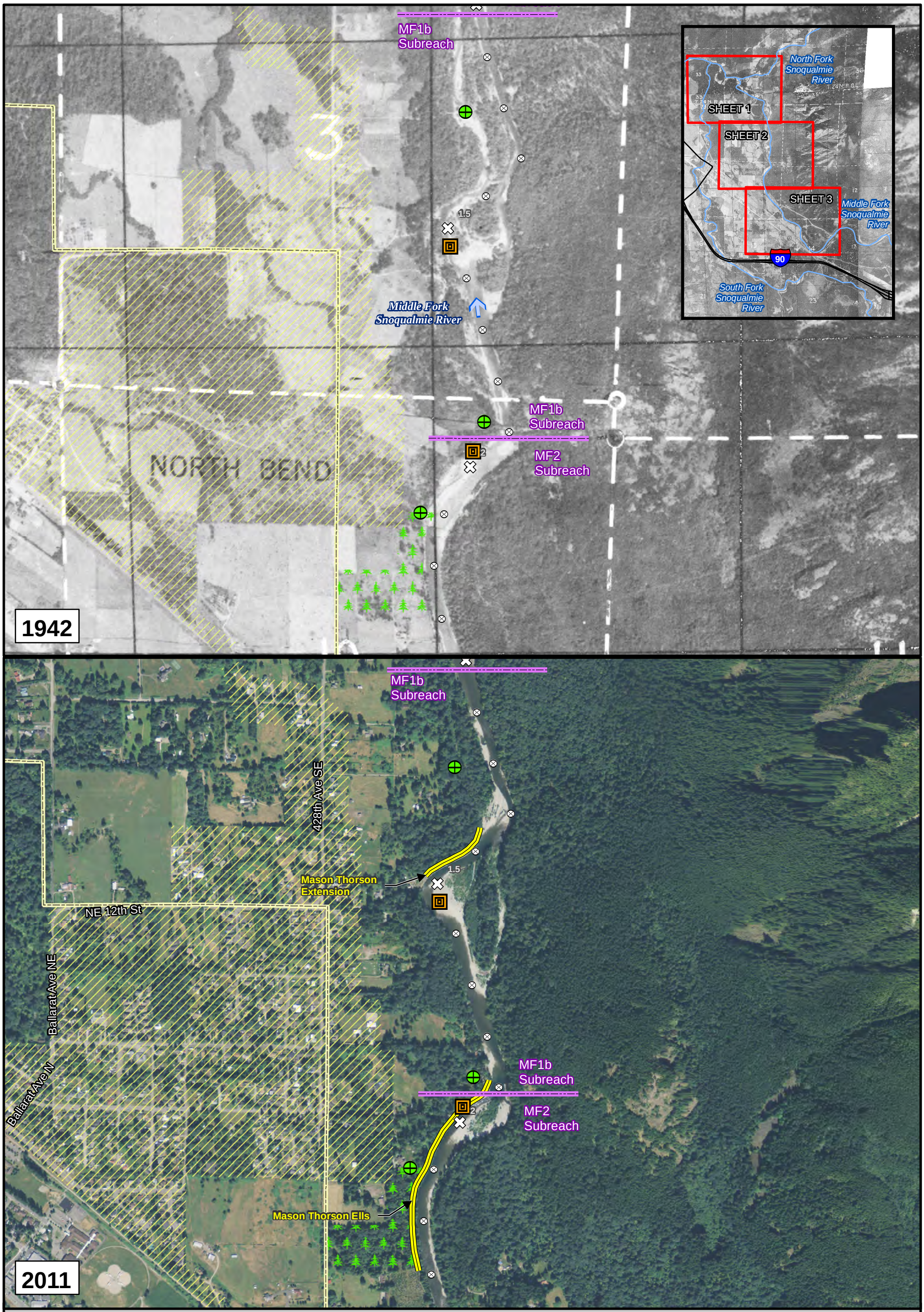

Legend

- Reduced channel sinuosity
- Subreach boundary
- Bank erosion
- Channel disconnected from river
- Erosion through floodplain channel
- Increased forest cover
- Areas of major development
- Current flood protection facility location (2011 photo)
- Current City of North Bend boundary
- River mile
- 1/10th river mile
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Note: For portions of the study area below the confluence with the North Fork, which serves as the origin for the King County Middle Fork Snoqualmie River channel coordinate system, river miles are based on the King County Snoqualmie River Mile system, which has its origin at the confluence with the Skykomish River.

Figure A-1. Comparison of 1942 and 2011 Aerial Photography (Sheet 2 of 3).

N

0 450 900 1,800 Feet

King County

Prepared for King County by Herrera

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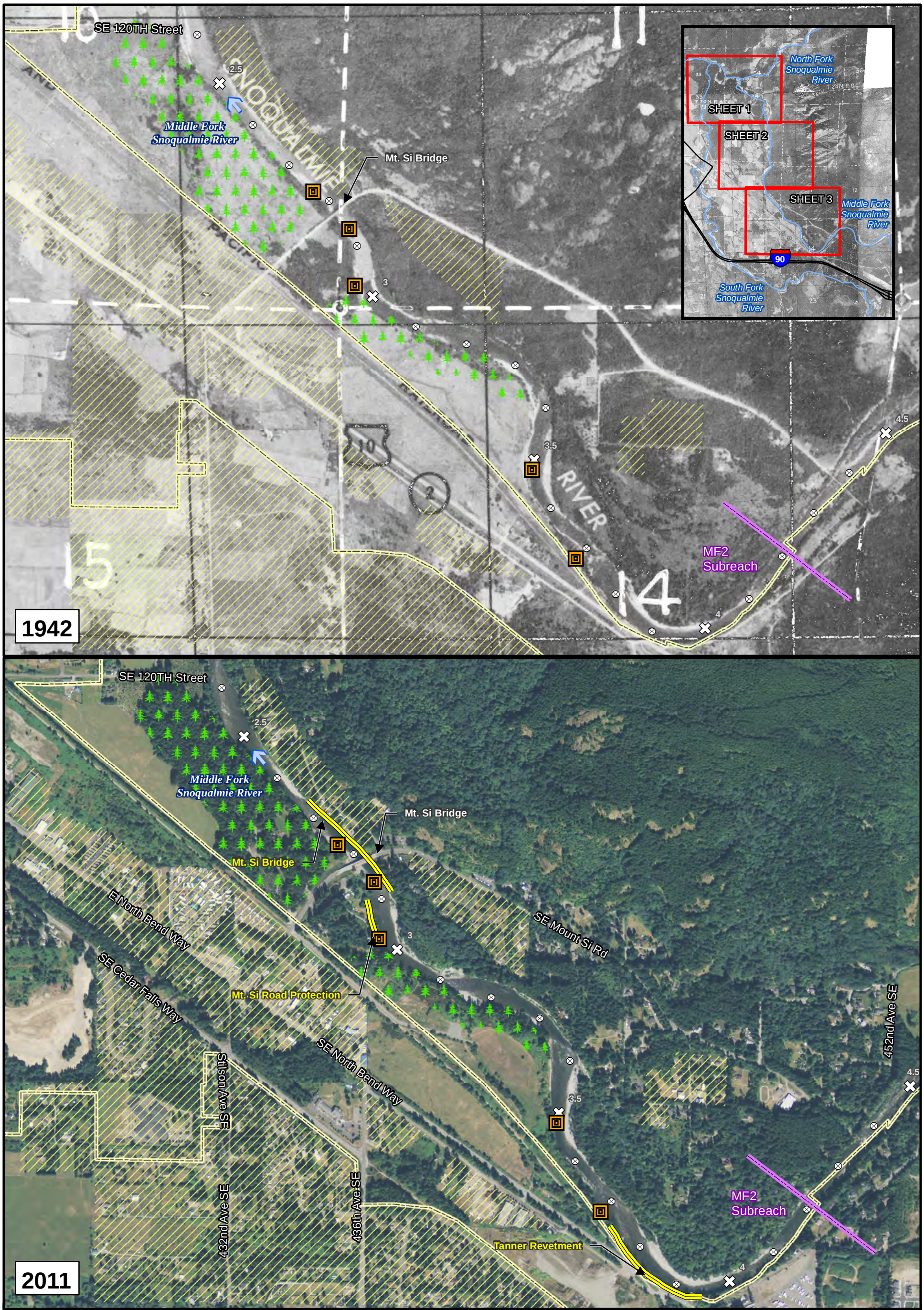


Legend

- Reduced channel sinuosity
- Subreach boundary
- Bank erosion
- Channel disconnected from river
- Erosion through floodplain channel
- Increased forest cover
- Areas of major development
- Current flood protection facility location (2011 photo)
- Current City of North Bend boundary
- River mile
- 1/10th river mile
- Middle Fork flow direction

Note: For portions of the study area below the confluence with the North Fork, which serves as the origin for the King County Middle Fork Snoqualmie River channel coordinate system, river miles are based on the King County Snoqualmie River Mile system, which has its origin at the confluence with the Skykomish River.

Figure A-1. Comparison of 1942 and 2011 Aerial Photography (Sheet 3 of 3).

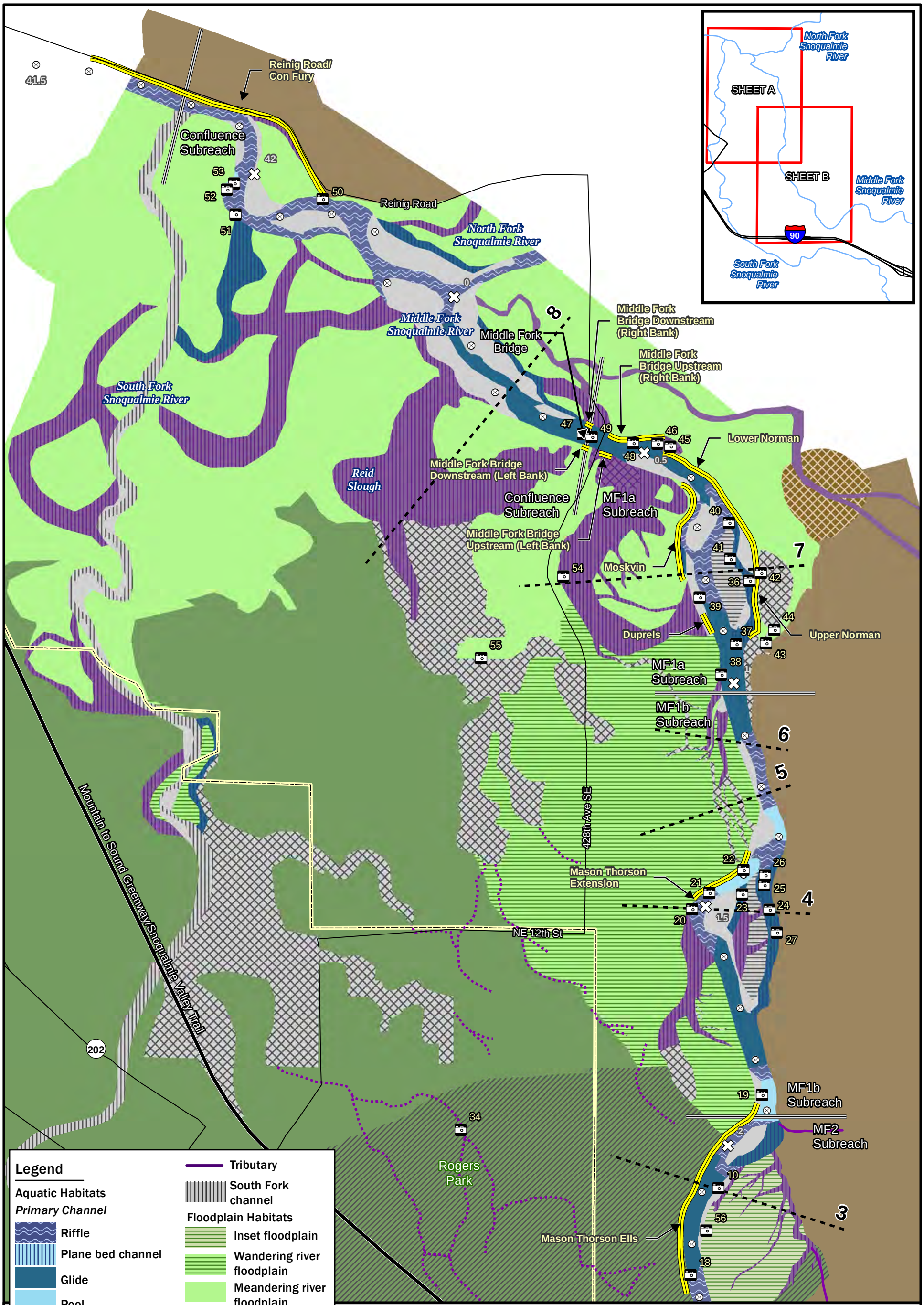
N

0 450 900 1,800 Feet

King County

Prepared for King County by Herrera

K:\Projects\10-04766-016\Project\Ecological_Resources_Assessment\historic_conditions_template.mxd (9/3/2013)



Legend

Aquatic Habitats

Primary Channel

- Riffle
- Plane bed channel
- Glide
- Pool
- Bar
- Side channel
- In-channel island

Secondary Channel

- Overflow channel
- Groundwater channel
- Groundwater channel
- Relict channel
- Tributary
- Tributary
- South Fork channel

Floodplain Habitats

- Inset floodplain
- Wandering river floodplain
- Meandering river floodplain
- Distal floodplain/ fan
- Radially symmetric alluvial fan

Upland Habitats

- Hillslope
- Debris flow fan
- Photo point
- Levee or revetment
- Subreach boundary
- Cross section (see Appendix C)
- City of North Bend boundary
- Mountain to Sound Greenway/ Snoqualmie Valley Trail
- River mile
- 1/10 river mile

Note: For portions of the study area below the confluence with the North Fork, which serves as the origin for the King County Middle Fork Snoqualmie River channel coordinate system, river miles are based on the King County Snoqualmie River Mile system, which has its origin at the confluence with the Skykomish River.

Figure A-2. 2011 Geomorphic Conditions in the Vicinity of the King County Facilities on the Middle Fork Snoqualmie River (Sheet 1 of 2).

N

0 450 900 1,800 Feet

King County

Prepared for King County by Herrera

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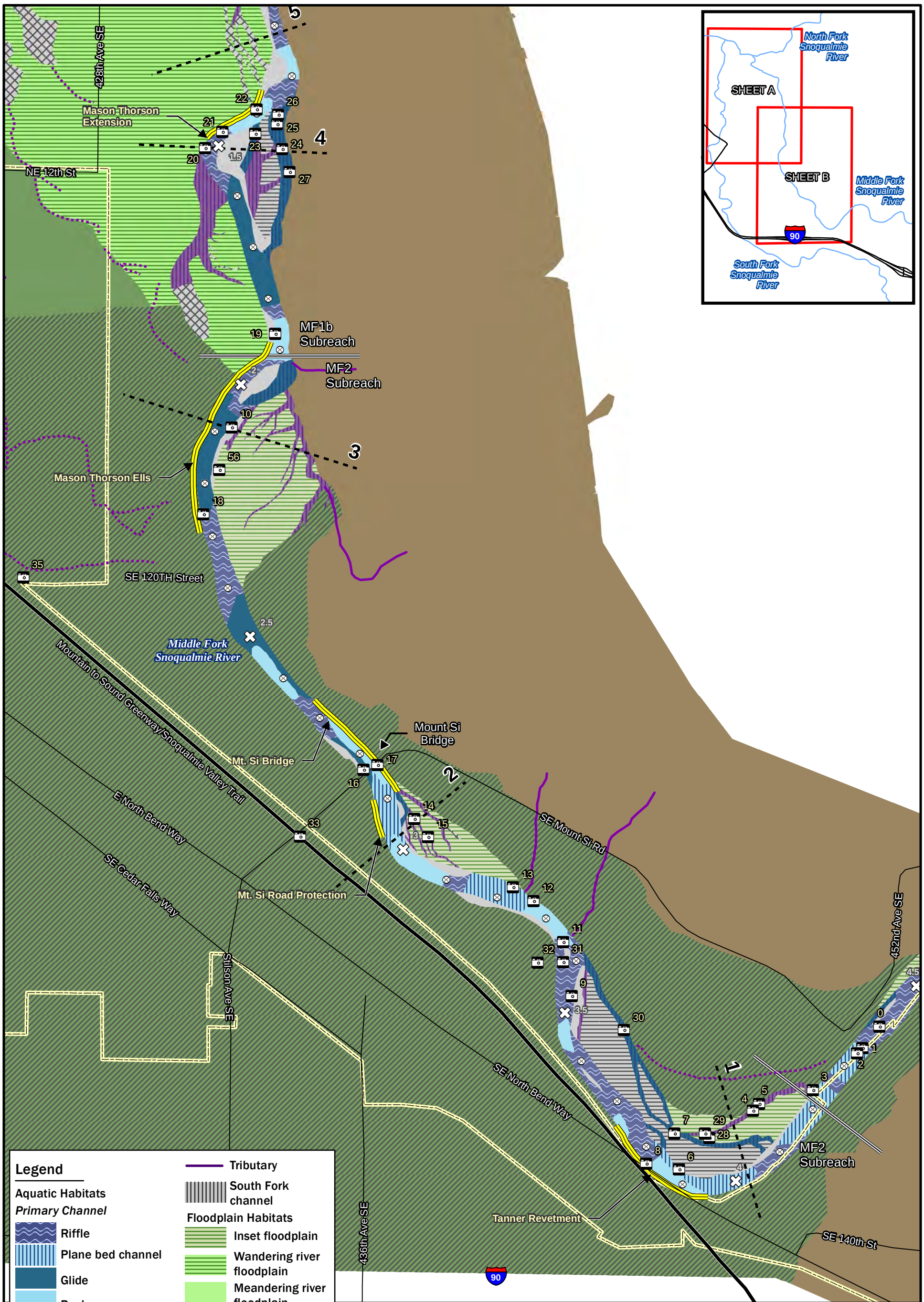
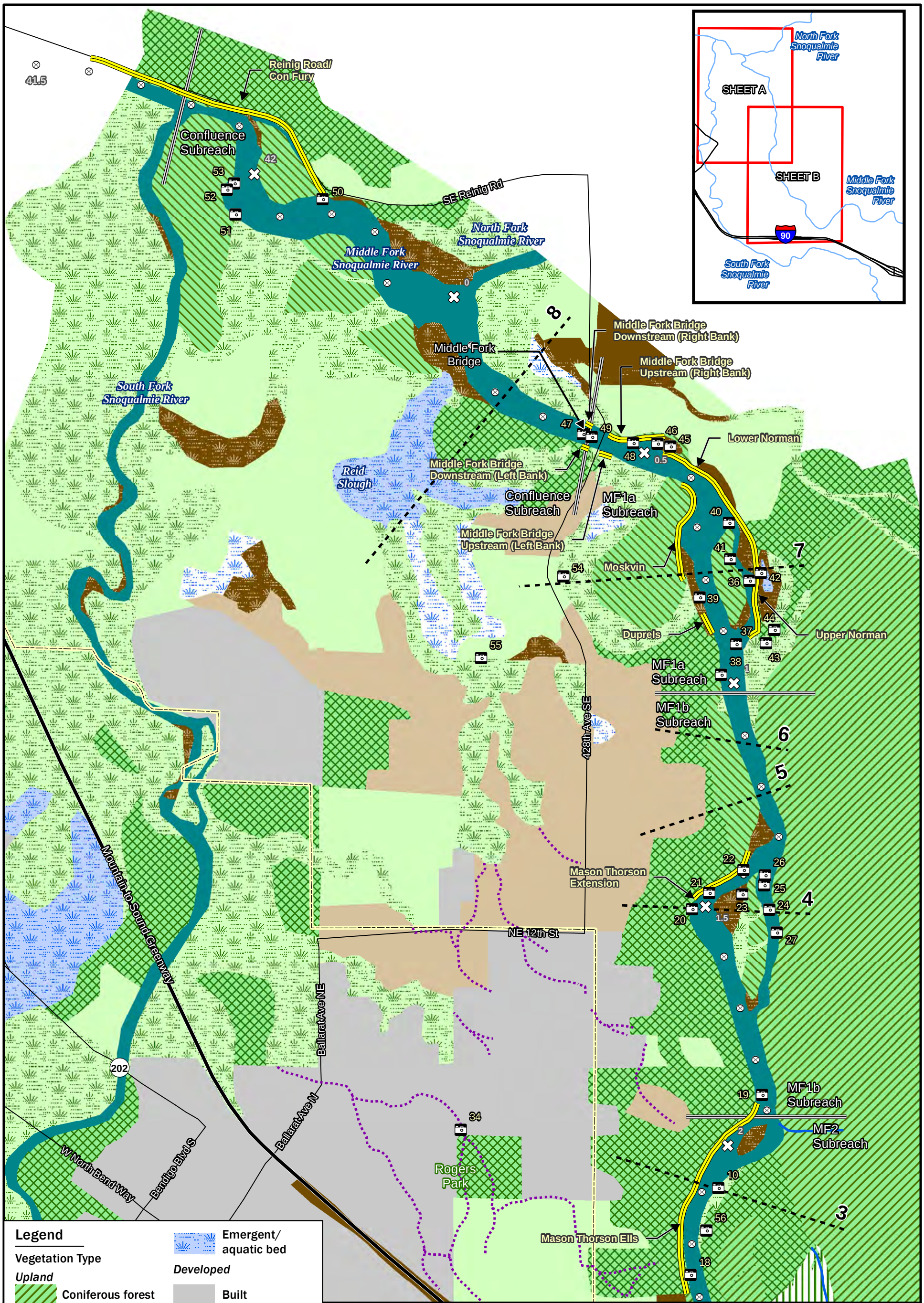


Figure A-2. 2011 Geomorphic Conditions in the Vicinity of the King County Facilities on the Middle Fork Snoqualmie River (Sheet 2 of 2).



Legend

Vegetation Type

Upland
- Coniferous forest
- Deciduous forest
- Mixed forest
- Upland shrub
- Herbaceous upland

Wetland
- Forested
- Scrub-shrub
- Emergent
- Emergent/ aquatic bed

Developed
- Built
- Rural forest
- Rural agriculture
- Unvegetated

Other Features
- Groundwater channel
- Subreach boundary
- Cross section (see Appendix C)
- City of North Bend boundary
- Mountain to Sound Greenway
- Tributary
- Levee or revetment
- Photo point
- River mile
- 1/10 river mile

Note: For portions of the study area below the confluence with the North Fork, which serves as the origin for the King County Middle Fork Snoqualmie River channel coordinate system, river miles are based on the King County Snoqualmie River Mile system, which has its origin at the confluence with the Skykomish River.

Figure A-3. 2011 Vegetation Coverage in the Vicinity of the King County Facilities on the Middle Fork Snoqualmie River (Sheet 1 of 2).

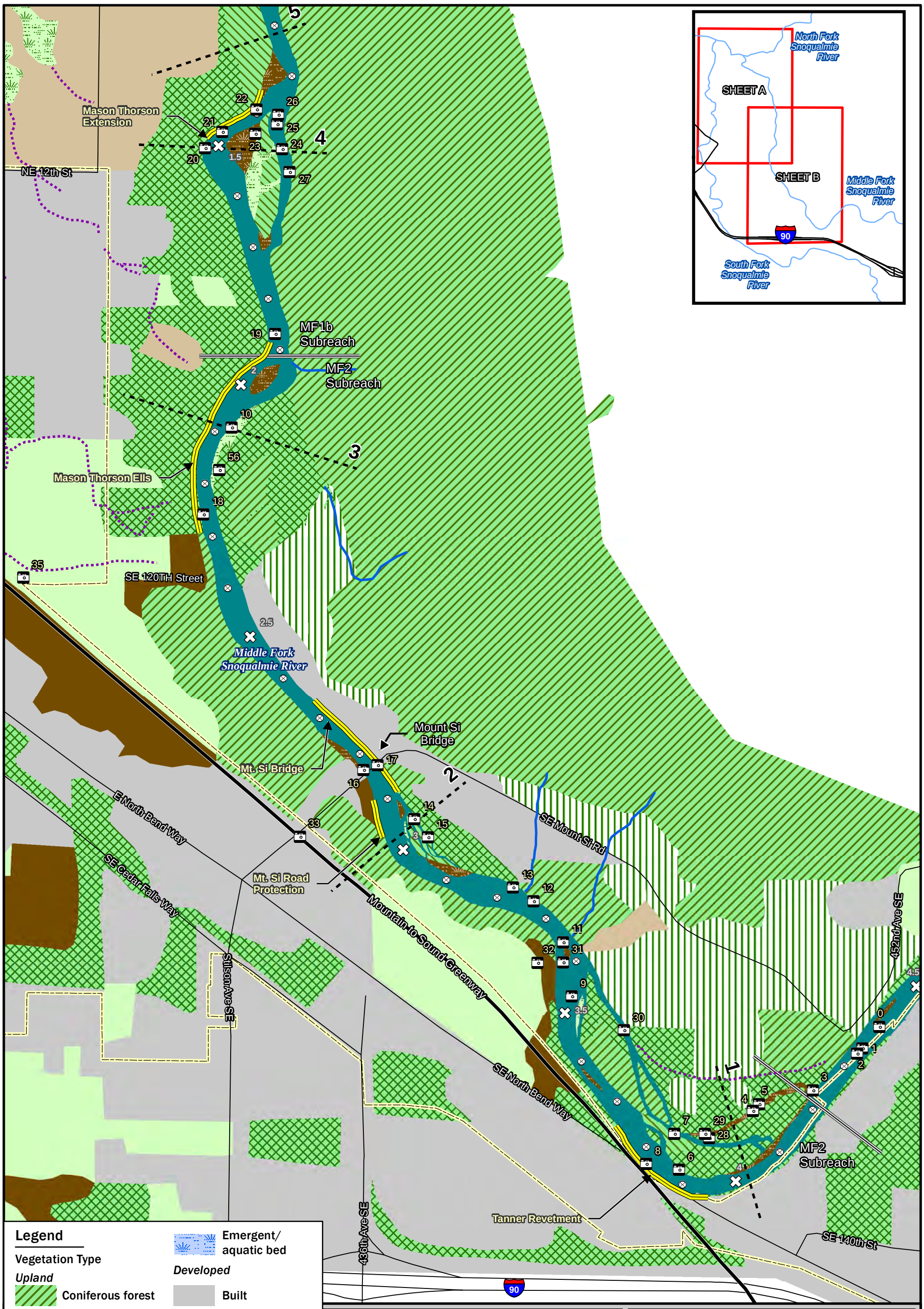
N

0 450 900 1,800 Feet

King County

Prepared for King County by Herrera

K:\Projects\10-04766-016\Project\Ecological_Resources_Assessment\existing_conditions_detail_sheets_vegetation.mxd (9/3/2013)



Legend

Vegetation Type

Upland
- Coniferous forest
- Deciduous forest
- Mixed forest
- Upland shrub
- Herbaceous upland

Wetland
- Forested
- Scrub-shrub
- Emergent
- Emergent/ aquatic bed

Developed
- Built
- Rural forest
- Rural agriculture
- Unvegetated

Other Features
- Groundwater channel
- Subreach boundary
- Cross section (see Appendix C)
- City of North Bend boundary
- Mountain to Sound Greenway
- Tributary
- Levee or revetment
- Photo point
- 1/10 river mile
- River mile

Note: For portions of the study area below the confluence with the North Fork, which serves as the origin for the King County Middle Fork Snoqualmie River channel coordinate system, river miles are based on the King County Snoqualmie River Mile system, which has its origin at the confluence with the Skykomish River.

Figure A-3. 2011 Vegetation Coverage in the Vicinity of the King County Facilities on the Middle Fork Snoqualmie River (Sheet 2 of 2).

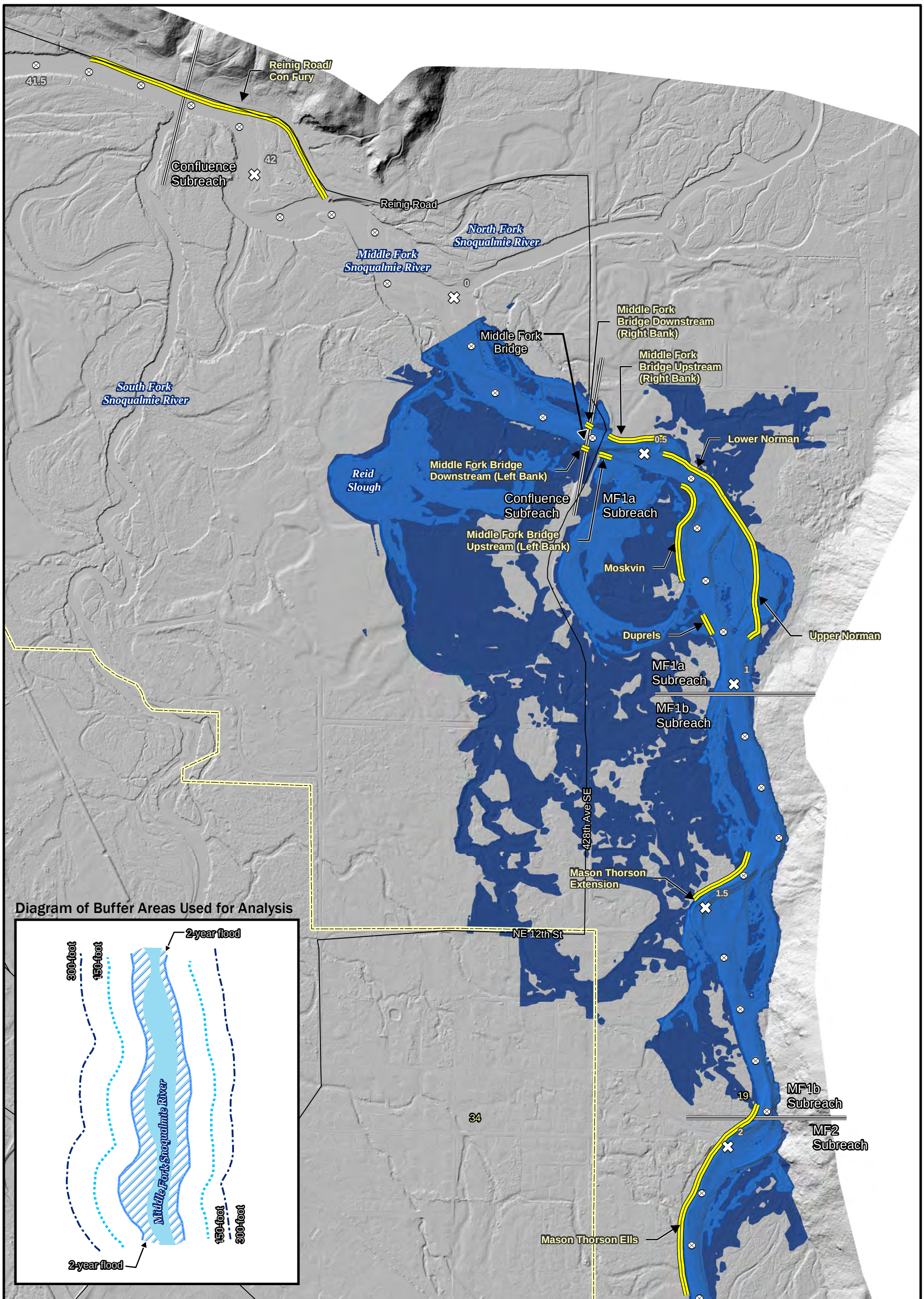
N

0 450 900 1,800 Feet

King County

Prepared for King County by Herrera

K:\Projects\10-04766-016\Project\Ecological_Resources_Assessment\existing_conditions_detail_sheets_vegetation.mxd (9/3/2013)



Legend

- 2-year flood extents
- 10–year flood extents
- Levee or revetment
- Subreach boundary
- City of North Bend boundary
- Mountain to Sound Greenway/ Snoqualmie Valley Trail
- River mile
- 1/10 river mile

Note: For portions of the study area below the confluence with the North Fork, which serves as the origin for the King County Middle Fork Snoqualmie River channel coordinate system, river miles are based on the King County Snoqualmie River Mile system, which has its origin at the confluence with the Skykomish River.

Figure A-4. Extents of 2-Year and 10-Year Flood Inundation Areas and Diagram of Buffer Areas Used for Analysis (Sheet 1 of 2).

N

0 450 900 1,800 Feet

King County

Prepared for King County by Herrera

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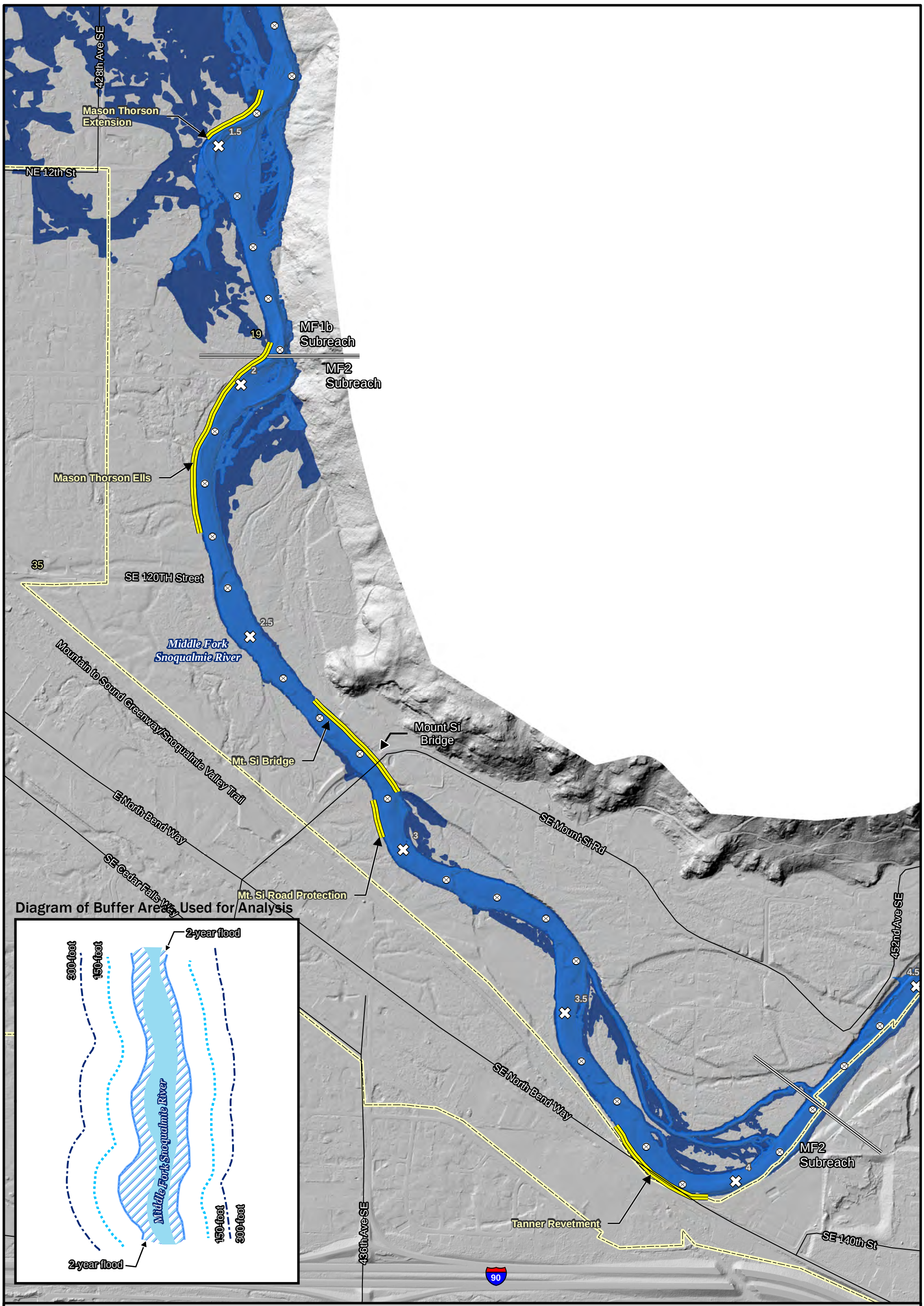

Legend

- 2-year flood extents
- 10–year flood extents
- Levee or revetment
- Subreach boundary
- City of North Bend boundary
- Mountain to Sound Greenway/ Snoqualmie Valley Trail
- River mile
- 1/10 river mile

Note: For portions of the study area below the confluence with the North Fork, which serves as the origin for the King County Middle Fork Snoqualmie River channel coordinate system, river miles are based on the King County Snoqualmie River Mile system, which has its origin at the confluence with the Skykomish River.

Figure A-4. Extents of 2-Year and 10-Year Flood Inundation Areas and Diagram of Buffer Areas Used for Analysis (Sheet 2 of 2).

N

0 450 900 1,800 Feet

King County

Prepared for King County by Herrera

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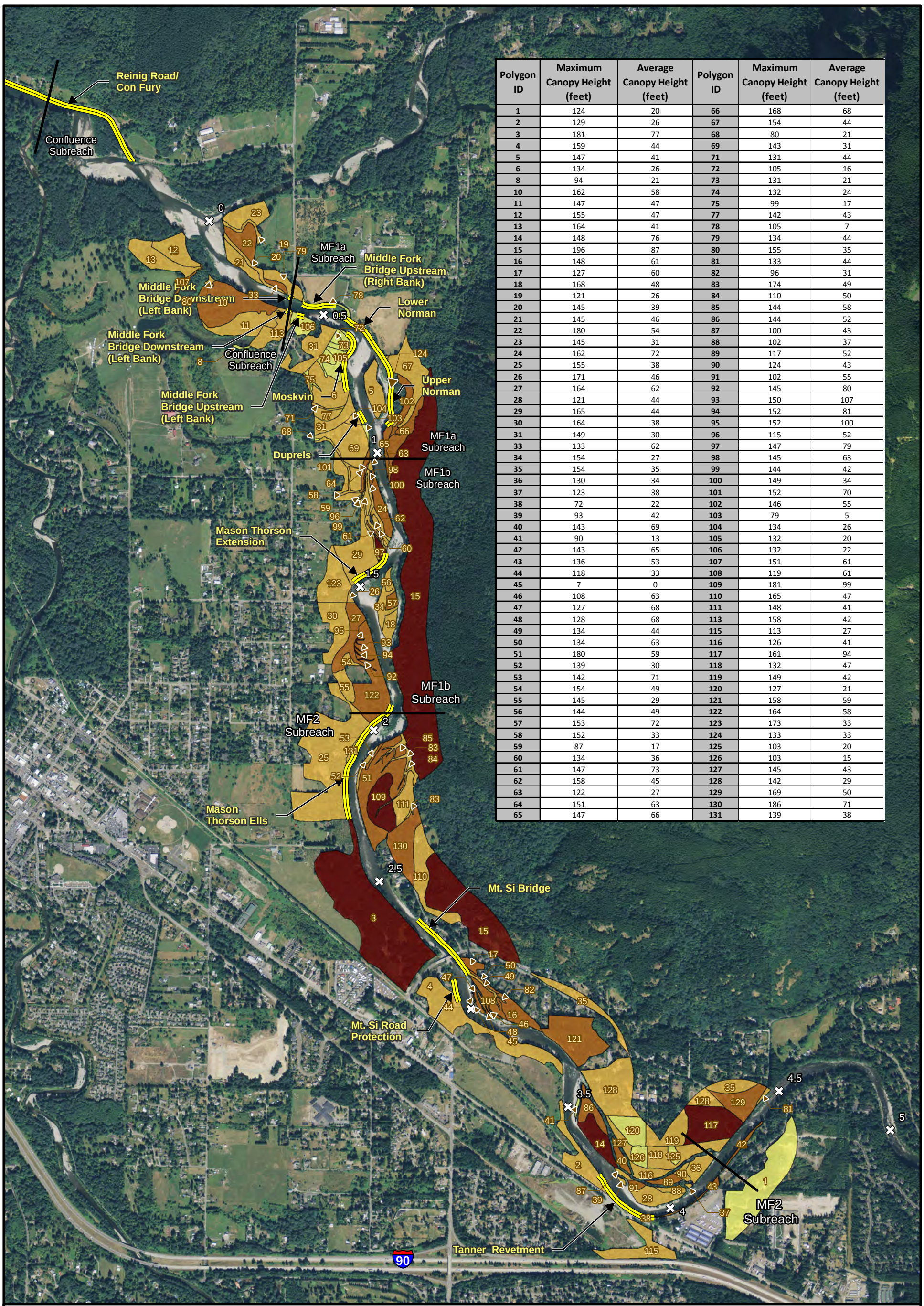

Polygon ID	Maximum Canopy Height (feet)	Average Canopy Height (feet)	Polygon ID	Maximum Canopy Height (feet)	Average Canopy Height (feet)
1	124	20	66	168	68
2	129	26	67	154	44
3	181	77	68	80	21
4	159	44	69	143	31
5	147	41	71	131	44
6	134	26	72	105	16
8	94	21	73	131	21
10	162	58	74	132	24
11	147	47	75	99	17
12	155	47	77	142	43
13	164	41	78	105	7
14	148	76	79	134	44
15	196	87	80	155	35
16	148	61	81	133	44
17	127	60	82	96	31
18	168	48	83	174	49
19	121	26	84	110	50
20	145	39	85	144	58
21	145	46	86	144	52
22	180	54	87	100	43
23	145	31	88	102	37
24	162	72	89	117	52
25	155	38	90	124	43
26	171	46	91	102	55
27	164	62	92	145	80
28	121	44	93	150	107
29	165	44	94	152	81
30	164	38	95	152	100
31	149	30	96	115	52
33	133	62	97	147	79
34	154	27	98	145	63
35	154	35	99	144	42
36	130	34	100	149	34
37	123	38	101	152	70
38	72	22	102	146	55
39	93	42	103	79	5
40	143	69	104	134	26
41	90	13	105	132	20
42	143	65	106	132	22
43	136	53	107	151	61
44	118	33	108	119	61
45	7	0	109	181	99
46	108	63	110	165	47
47	127	68	111	148	41
48	128	68	113	158	42
49	134	44	115	113	27
50	134	63	116	126	41
51	180	59	117	161	94
52	139	30	118	132	47
53	142	71	119	149	42
54	154	49	120	127	21
55	145	29	121	158	59
56	144	49	122	164	58
57	153	72	123	173	33
58	152	33	124	133	33
59	87	17	125	103	20
60	134	36	126	103	15
61	147	73	127	145	43
62	158	45	128	142	29
63	122	27	129	169	50
64	151	63	130	186	71
65	147	66	131	139	38

Legend

Average canopy height (feet)

- 0 to 25
- 25 to 50
- 50 to 75
- > 75
- Levee or revetment
- Subreach boundary
- River mile
- 21 Forested polygon number

Figure A-5. Tree Height Data Derived from 2010 LiDAR Imagery.

N

0 750 1,500 3,000 Feet

King County

Aerial: USDA (2011)
Prepared for King County by Herrera

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APPENDIX B

Photographic Documentation

Geomorphic Assessment: Middle Fork Snoqualmie River Corridor Photographic Log

Photo Number	Photo Description
1	View of Boulder-dominated substrate
2	View of Forests, Boulder substrate
3	Logjam at channel entrance
4	Cobbles in overflow channel
5	Elk prints
6	Floodplain forest
7	Sand and Gravels in side channel
8	Tanner Revetment
9	Vegetated bar and floodplain forest
10	Boulders in channel, large cobbles on bar
11	Vegetated bar
12	Eroding terrace and conifer forest
13	Terrace composition
14	Shallow overflow channels and red cedar
15	Overflow channel and racked debris
16	Mt. Si Bridge Revetment Left Bank
17	Mt. Si Bridge Revetment Right Bank
18	Mason Thorson Ells Levee
19	Mason Thorson Ells Levee
20	Upper Mason Thorson Extension
21	Mason Thorson Extension LWD Integrated
22	Lower Mason Thorson Extension
23	Gravels and Cobbles in side channel
24	Groundwater and residual pool
25	Groundwater expression, sand and gravel
26	Groundwater flow into channel, spawning substrate

Photo Number	Photo Description
27	Groundwater, pool, sedges
28	Large snag in floodplain forest
29	Large cobbles and boulders with moss
30	Large cobbles in side channel
31	Bar, eroding terrace, reveg project on terrace
32	Restoration area, raptor platform, elk exclosure
33	Mountain to Sound Greenway
34	Relict channel in neighborhood
35	Pasture
36	Side channel, vegetated bar, Upper Norman Revetment
37	Large apex jam and cobble bar
38	View of overflow channel exit
39	View of old channel entrance
40	Norman Upper Revetment
41	Deciduous forest on in-channel island
42	Emergent and aquatic bed wetland
43	Red cedar wetland
44	Red-legged frog in forested wetland
45	Wetland in backwater slough
46	Vegetated sand bar island
47	Downstream of MFS bridge, gravel deposits
48	Gravel and cobble bars, isolated logs
49	MFS bridge and Lower Norman revetments
50	Large deposits of sand and small gravel, bank erosion
51	Downed logs and bank erosion
52	Logjam and scour
53	Logjam and sand deposition
54	Forested wetland in overflow channel
55	Forest wetland in relict channel
56	Riparian forest, perches and logjam
	Old Covered Bridge (permission for use pending)

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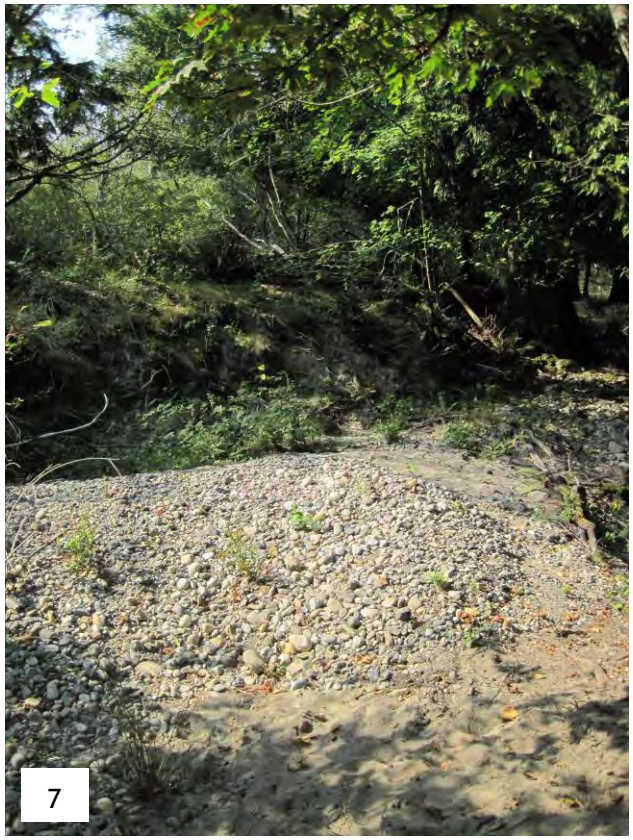
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APPENDIX C

Wildlife Species Tables

Table C-1: Mammals That May Occur in the Middle Fork Project Study Area						
C.ommon Name	**Scientific Name**	**State Status**	**Federal Status**	**Preferred Habitat Type**	**Present in Project Area?**	**Basis for Presence**
Beaver	*Castor canadensis*	N	N	Riparian areas, ponds, and lakes	Yes	Sign, Observed in the vicinity
Big Brown Bat	*Eptesicus fuscus*	N	N	Highly adaptable. Can roost in buildings, bridges, and trees. Wide range of foraging habitats.	Yes	Observed in the vicinity
Black bear	*Ursus americanus*	N	N	Wide range of forested and open habitats	Yes.	Sign, Observed in the vicinity
Bobcat	*Felis rufus*	N	N	Wide range of forested and open habitats, especially brushy riparian areas	Yes	Observed in the vicinity
Boreal Red Backed Vole	*Clethrionomys gapperi*	N	N	Damp forests, bogs, and other wetlands	Yes	Observed in the vicinity
California Myotis	*Myotis californicus*	N	N	Forested areas	Yes	Observed in the vicinity
Columbian black-tailed deer	*Odocoileus hemionus columbianus*	N	N	Occurs from the crest of the Cascades west to the ocean, preferring brushy, logged lands, meadows, and forests.	Yes	common species, sign observed
Eastern Cottontail Rabbit	*Sylvilagus floridanus*	N	N	brushy areas, lawns	Yes	Observed in the vicinity
Coyote	*Canis latrans*	N	N	Wide range of habitats from grassland to forest	Yes	Observed in the vicinity
Deer Mouse	*Peromyscus maniculatus*	N	N	Wide range of habitats from grassland to forest and developed areas	Yes	Observed in the vicinity
Douglas Squirrel	*Tamiasciurus douglasii*	N	N	conifer, mixed-conifer, and subalpine forests	Yes	Observed
Elk in their historic range	*Cervus Elaphus*	N	N	Elk habitat includes productive grasslands, meadows, or clearcuts, interspersed with closed-canopy forests.	Yes. Resident and Winter Migratory elk range includes entire project area.	PHS, direct observation of sign
Fisher	*Martes pennanti*	SE	FC	Dense, mesic forests at low to mid-elevations. Very few in WA due to habitat loss.	Unlikely, but possible in dense forest	No barriers, but very low population numbers

Gray Wolf	*Canis lupus*	SE	FE	Intact wilderness habitats away from human habitation.	Unlikely, but possible; former range includes project area	Large distance (over 50 miles) to closest confirmed sighting. Wide-ranging species and no passage barriers to preclude occurrence. Tends to avoid developed areas.
Grizzly Bear	*Ursus arctos*	SE	FT	Intact wilderness habitats away from human habitation.	Unlikely, but possible; former range includes project area	Large distance (over 50 miles) to closest confirmed sighting. Wide-ranging species and no passage barriers to preclude occurrence. Tends to avoid developed areas.
Little Brown Myotis	*Myotis lucifugus*	N	N	Flexible roosting requirements. Must be near water body for foraging.	Possible.	Suitable habitat exists
Long-eared Myotis	*Myotis evotis*	N	N	Forests with old growth characteristics and nearby rocky cliffs	Possible.	Some isolated patches of forest with OG features occur, but are small and fragmented.
Long-legged Myotis	*Myotis volans*	N	N	Coniferous forest near waterbodies	Possible.	Suitable habitat exists
Long-tailed Meadow Vole	*Microtus longicaudus*	N	N	Wide range of habitats from grassland to forest	Likely	This is a common widespread species with suitable habitat in study area.
Long-tailed Weasel	*Mustela frenata*	N	N	Open areas, including fields, meadows, and alpine areas.	Likely	Abundant suitable habitat exists.

Lynx	*Lynx canadensis*	ST	FT	Intact wilderness habitats away from human habitation.	Unlikely, but possible; former range includes project area	Large distance (over 100 miles) to closest confirmed sighting. Wide-ranging species and no passage barriers to preclude occurrence. Tends to avoid developed areas.
Marsh Shrew	*Sorex bendirei*	N	N	Marshy areas along slow-moving streams and wetlands	Yes	Observed in the vicinity
Marten	*Martes americana*	N	N	Coniferous forests, most of WA except Columbia Basin;	Possible.	Likely occurs in forested slopes of Mt. Si. May use other portions of the project area in search of food or as movement corridor
Masked Shrew	*Sorex cinereus*	N	N	Forests	Yes	Observed in the vicinity
Mink	*Mustela vison*	N	N	Near water, including rivers.	Yes	Observed in the vicinity
Mountain beaver	*Aplodontia rufa*	N	N	Forested areas and adjoining habitats	Yes.	Burrows observed in several locations
Mountain goat	*Oreamnos americanus*	N	N	Mountane areas of WA including West Cascades. North Pacific Maritime Mesic Subalpine Parkland, North Pacific Montane Massive Bedrock Cliff and Talus, Northern Rocky Mountain Subalpine Woodland and Parkland, North Pacific Alpine and Subalpine Bedrock and Scree	Yes	Documented occurences on Mt. Si and migration to Middle Fork to drink water.
Mountain Lion	*Felis concolor*	N	N	Forested and brushy habitats and along margins of open habitats	Yes	Observed in the vicinity
Muskrat	*Ondatia zibethica*	N	N	Streams, wetlands, and lakes with suitable forage (cattails and rushes)	Yes	Observed in the vicinity
Northern Flying Squirrel	*Glauconys sabrinus*	N	N	Coniferous forests	Yes	Observed in the vicinity

Norway Rat	*Rattus norvegicus*	N	N	Wide range of habitats, often near developed areas	Yes	Observed in the vicinity
Opposum	*Didelphis marsupialis*	N	N	Wide range of habitats	Yes	Observed in the vicinity
Oregon Vole	*Microtus oregoni*	N	N	Openings in moist coniferous forest and	Yes	Observed in the
Porcupine	*Erethizon dorsatum*	N	N	Range of habitats, primarily forests	Yes	Observed in the
Raccoon	*Procyon lotor*	N	N	Wide range of habitats	Yes	Observed in the vicinity
Red Fox	*Vulpes vulpes*	N	N	Open habitats with brushy shelter	Yes	Observed in the
River Otter	*Lutra canadensis*	N	N	Riparian areas, ponds, and lakes	Yes	Observed in the vicinity
Short-tailed Weasel	*Mustela erminea*	N	N	Forests and riparian areas	Yes	Observed in the vicinity
Shrew-mole	*Neurotrichus gibbsi*	N	N	Areas with abundant leaf litter, rotting vegetation and downed logs	Yes	Observed in the vicinity
Silver Haired Bat	*Lasionycteris noctivagans*	N	N	Forests, farms, and developed areas	Yes	Observed in the vicinity
Snowshoe hare	*Lepus americanus*	N	N	Forests and dense brushy areas	Likely	Fairly common, widely distributed
Spotted Skunk	*Spilogale putorius*	N	N	Forests, brushy areas, and farms	Yes	Observed in the vicinity
Striped Skunk	*Mephitis mephitis*	N	N	Streamside woodlands, and semi-open areas	Yes	Observed in the vicinity
Townsend Chipmunk	*Tamias townsendii*	N	N	Forests with dense cover	Yes	Observed
Townsend's Mole	*Scapanus townsendi*	N	N	Cultivated fields and open brushlands	Yes	Observed in the
Townsend's Vole	*Microtus townsendii*	N	N	Moist fields and sedge meadows	Yes	Observed in the
Townsend's Big-Eared Bat*	*Corynorhinus townsendii*	SC	FCo	Lowland conifer/hardwood forests and riparian wetlands on west side of Cascades. Always in association with water.	Possible.	Suitable habitat exists
Trowbridge Shrew	*Sorex trowbridgei*	N	N	Mature forests with abundant forest litter	Yes	Observed in the vicinity
True-coast Mole	*Scapanus orarius*	N	N	Meadows, forests and brushy areas	Yes	Observed in the vicinity
Vagrant Shrew	*Sorex vagrans*	N	N	Forests with nearby water	Yes	Observed in the vicinity
Water Shrew	*Sorex palustris*	N	N	Alongside flowing streams with undercut, well-rooted banks	Yes	Observed in the vicinity
Water Vole	*Microtus richardsoni*	N	N	Along waterways, primarily sub-alpine streams and lakes	Yes	Observed in the vicinity

Wolverine	*Gulo gulo*	SC	FC	Intact wilderness habitats away from human habitation in alpine and subalpine habitats of the Cascades, Blue Mountains, and Rocky Mountains.	Unlikely	Large distance (over 50 miles) to closest confirmed sighting. Wide-ranging species and no passage barriers to preclude occurrence. Tends to avoid developed areas.

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Table C-2: List of Amphibians Potentially Occurring in the Middle Fork Project Study Area							
Common Name	**Scientific Name**	**Type**	**State Status**	**Federal Status**	**Preferred Habitat Type**	**Present in Project Area?**	**Basis for Presence Determination**
Ensatina	*Ensatina eschscholtzii*	Amphibian	N	N	Forested areas with well rotted downed wood and snags.	Yes	Documented occurrence
Larch Mountain Salamander	*Plethodon larselli*	Amphibian	SS	FCo	Inhabits steep, forested (e.g., Douglas-fir and mixed hardwoods) or nonforested slopes associated with talus, scree, gravelly soils, or other rocky substrates where interstitial spaces exist between the rock and soil. In some areas of the Cascade Mountains in Washington, habitats include old-growth coniferous forests without significant exposed rocky areas.	Possible	Suitable habitats present
Long-toed salamander	*Ambysto mamacrodactylum*	Amphibian	N	N	Ponds and slow-moving water with submerged vegetation for egg mass attachment and foraging	Yes	Documented occurrence
Northwestern salmander	*Ambystoma gracile*	Amphibian	N	N	Ponds and slow-moving water with submerged vegetation for egg mass attachment and foraging	Yes	Documented occurrence
Pacific giant salamander	*Dicamptodon ensatus*	Amphibian	N	N	Ponds and slow-moving water for foraging. Forested streams for breeding.	Possible	Suitable habitats present
Rough-skinned newt	*Taricha granulosa*	Amphibian	N	N	Ponds and slow-moving water with submerged vegetation for egg attachment and foraging	Yes	Documented occurrence
Van Dyke's Salamander	*Plethodon vandykei*	Amphibian	SC	FCo	Rocky, steep walled stream valleys with mature to old growth forested cover.	Possible	Suitable habitats present
Western redback salamander	*Plethodon vehiculum*	Amphibian	N	N	Forested areas with well rotted downed wood and snags.	Yes	Documented occurrence
Bullfrog	*Rana catesbiana*	Amphibian	N	N	Ponds and slow-moving water with submerged vegetation for egg mass attachment and foraging	Possible	Suitable habitats present
Cascades Frog	*Rana cascadae*	Amphibian	N	N	Ponds, lakes, and shorelines in mountain meadows	Unlikely, but possible.	preference for high elevation habitats

Northern Red-legged frog	*Rana aurora*	Amphibian	N	N	Occurs widely west of the Cascade Mountains. forests, damp meadows, marshes, ponds, lakes, and streamsides. During rainy seasons, they are occasionally found on land away from water.	Yes	Observed, Documented occurrence
Oregon Spotted Frog	*Rana pretiosa*	Amphibian	SE	FC	Highly aquatic, inhabiting marshes and marshy edges of ponds, streams, and lakes. Usually occur in shallow, slow moving waters with abundant emergent vegetation and a thick layer of dead and decaying vegetation on the bottom. Active February through October	Possible	Suitable habitats present
Tailed Frog	*Ascaphus truei*	Amphibian	N	N	Cold, rocky mountain stream with forested cover.	Possible	Suitable habitats present
Western toad	*Bufo boreas*	Amphibian	SC	FCo	Breeding sites are in still or barely moving water, typically ponds and small lakes, streams, rain pools, and ditches. Often found at the water's edge or basking on partially submerged logs in the spring and early summer, more terrestrial habitats later in year, although often in damp areas or near water. May use groundsquirrel and gopher holes for winter hibernation.	Yes	Documented occurrence

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SM: State Monitor Species.

Table C-3: List of Birds Potentially Occurring in the Middle Fork Project Study Area							
Common Name	**Scientific Name**	**State Status**	**Federal Status**				
American bittern	*Botaurus lentiginosus*	N	N				
American Coot	*Fulica americana*	N	N				
American Crow	*Corvus brachyrhynchos*	N	N				
American Dipper	*Cinclus mexicanus*	N	N				
American Goldfinch	*Carduelis tristis*	N	N				
American Robin	*Turdus migratorius*	N	N				
American White Pelican	*Pelecanus erythrorhynchos*	SE	N				
American Wigeon	*Anas americana*						
Bald Eagle	*Haliaeetus leucocephalus*	SS	FCo				
Band-tailed pigeon	*Columba fasciata*	N	N				
Band-tailed Pigeon	*Columba fasciata*	N	N				
Barn Owl	*Tyto alba*	N	N				
Barn Swallow	*Hirundo rustica*	N	N				
Barred Owl	*Strix varia*	N	N				
Barrow's Goldeneye	*Bucephala islandica*	N	N				
Belted kingfisher	*Ceryle alcyon*	N	N				
Bewick's Wren	*Thryomanes bewickii*	N	N				
Black scoter	*Melanitta nigra*	N	N				
Black-Backed Woodpecker	*Picoides arcticus*	SC	N				
Black-capped Chickadee	*Parvus atricapilus*	N	N				
Black-headed grosbeak	*Pheucticus melanocephalus*	N	N				
Black-throated Gray Warbler	*Dendroica nigrescens*	N	N				
Blue Grouse	*Dendragapus obscurus*	N	N				
Blue-winged teal	*Anas discors*	N	N				
Blue-winged Teal	*Anas discors*	N	N				
Brewer's Blackbird	*Euphagus cyanocephalus*	N	N				

Brown Creeper	*Certhia americana*	N	N				
Brown-headed Cowbird	*Molothrus ater*	N	N				
Bufflehead	*Bucephala albeola*	N	N				
Bushtit	*Psaltriparus minimus*	N	N				
California Gull	*Larus californicus*	N	N				
California Quail	*Callipepla californica*	N	N				
Canada Goose	*Branta canadensis*	N	N				
Cassin's Finch	*Carpodacus cassinii*	N	N				
Cedar Waxwing	*Bombycilla garrulus*	N	N				
Chipping sparrow	*Spizella passerina*	N	N				
Cinnamon Teal	*Anas cyanoptera*	N	N				
Cliff Swallow	*Huirundo pyrrhonota*						
Common Goldeneye	*Bucephala clangula*	N	N				
Common Goldeneye	*Bucephala clangula*	N	N				
Common Loon	*Gavia immer*	SS	N				
Common Merganser	*Mergus merganser*	N	N				
Common Raven	*Corvus corax*	N	N				
Common Sandpiper	*Actitis hypoleucos*	N	N				
Common Snipe	*Gallinago gallinago*	N	N				
Common yellow throat	*Geothylpis trichas*	N	N				
Cooper's Hawk	*Accipiter cooperii*	N	N				
Dark-eyed Junco	*Junco hyemalis*	N	N				
Downy Woodpecker	*Picoides pubsescens*	N	N				
Dusky Flycatcher	*Empidonax oberholseri*	N	N				
Eared Grebe	*Podiceps nigricollis*	N	N				
European Starling	*Sturns vulgaris*	N	N				
Evening Grosbeak	*Coccothraustes vespertina*	N	N				
Flammulated Owl	*Otus flammeolus*	SC	N				
Fox sparrow	*Passerella iliaca*	N	N				
Gadwall	*Anas strepera*	N	N				
Golden Eagle	*Aquila chrysaetos*	SC	N				

Golden-crowned Kinglet	*Regulus satrapa*	N	N				
Golden-crowned Sparrow	*Zonotrichia atricapilla*	N	N				
Great Blue Heron	*Ardea herodias*	N	N				
Great Horned Owl	*Bubo virginianus*	N	N				
Greater Yellowlegs	*Tringa melanoleuca*	N	N				
Green Heron	*Butorides virescens*	N	N				
Green-winged Teal	*Anas crecca*	N	N				
Hairy Woodpecker	*Picoides villosus*	N	N				
Hairy Woodpecker	*Picoides villosus*	N	N				
Hammond's Flycatcher	*Empidonax hammondii*	N	N				
Harlequin duck	*Histrionicus histrionicus*	N	N				
Hermit Thrush	*Catharus guttatus*	N	N				
Hermit warbler	*Dendroica occidentalis*	N	N				
Hooded merganser	*Lophodytes cucullatus*	N	N				
Horned Grebe	*Podiceps auritus*	N	N				
House Finch	*Carpodacus mexicanus*	N	N				
House Wren	*Troglodytes aedon*	N	N				
Hutton Vireo	*Vireo huttoni*	N	N				
Killdeer	*Charadrius vociferus*	N	N				
Lazuli bunting	*Passerina amoena*	N	N				
Lesser Scaup	*Aythya affinis*	N	N				
Lesser Yellowlegs	*Tringa flavipes*	N	N				
Lewis' Woodpecker	*Melanerpes lewis*	SC	N				
Lincoln's sparrow	*Melospiza lincolnii*	N	N				
Long-billed Dowitcher	*Limnodromus scolopaceus*	N	N				
MacGillivray's warbler	*Oporornis tolmiei*	N	N				
Mallard	*Anas platyrhynchos*	N	N				
Marbled Murrelet*	*Brachyramphus marmoratus*	ST	FT				
Marsh Wren	*Cistothorus palustris*	N	N				
Merlin	*Falco columbarius*	SC	N				
Merlin	*Falco columbarius*	N	N				
Mountain chickadee	*Poecile gambeli*	N	N				
Mountain Chickadee	*Parus gambeli*	N	N				

Mourning Dove	*Zenaida macroura*	N	N				
Northern .Rough-winged	*Stelgidopteryx*	N	N				
Northern Flicker	*Colaptes auratus*	N	N				
Northern Goshawk*	*Accipiter gentilis*	SC	FCo				
Northern Oriole	*Icterus galbula*	N	N				
Northern Pintail	*Anas acuta*	N	N				
Northern Pygmy Owl	*Glaucidium gnoma*	N	N				
Northern Saw-whet Owl	*Aegolius acadicus*	N	N				
Northern Shoveler	*Anas clypeata*	N	N				
Northern Spotted Owl	*Strix occidentalis*	N	N				
Northwestern Crow	*Corvus caurinus*	N	N				
Olive-sided Flycatcher	*Contopus cooperi*	N	N				
Orange-crowned Warbler	*Vermiuora celata*	N	N				
Oregon Vesper Sparrow	*Pooecetes gramineus affinis*	SC	FCo				
Osprey	*Pandion haliaetus*	SM	N				
Pacific-slope Flycatcher	*Empidonax difficulis*	N	N				
Peregrine Falcon*	*Falco peregrinus*	SS	FCo				

Pied-billed Grebe	*Podilymbus podiceps*	N	N				
Pileated Woodpecker	*Dryocopus pileatus*	SC	N				
Pileated Woodpecker	*Drycopus pileatus*	N	N				
Pine Siskin	*Carduelis pinus*	N	N				
Purple Finch	*Carpodacus purpureus*	N	N				
Purple Finch	*Carpodacus purpureus*	N	N				
Purple Martin	*Progne subis*	SC	N				
Red Crosbill	*Loxia curvirostra*	N	N				
Red-breasted Merganser	*Mergus serrator*	N	N				
Red-breasted Nuthatch	*Sitta canadensis*	N	N				
Red-breasted Sapsucker	*Sphyrapicus thyroides*	N	N				
Red-eyed Vireo	*Vireo olivaceus*	N	N				
Redhead	*Aythya americana*	N	N				
Red-tailed Hawk	*Buteo jamaicensis*	N	N				
Red-winged Blackbird	*Agelaius phoeniceus*	N	N				
Ring-billed Gull	*Larus delawarensis*	N	N				
Ring-necked Duck	*Aythya collaris*	N	N				
Ring-Necked Pheasant	*Phasianus colchicus*	N	N				
Ruby-crowned Kinglet	*Regulus calendula*	N	N				
Ruddy Duck	*Oxyura jamaicensis*	N	N				
Ruffed grouse	*Bonasa umbellus*	N	N				
Ruffed Grouse	*Bonasa umbellus*	N	N				
Rufous Hummingbird	*Selasphorus rufus*	N	N				
Rufous-sided towhee	*Pipilo erythrophthalmus*	N	N				
Sandhill Crane	*Grus canadensis*	SE	N				
Savannah sparrow	*Passerculus sandwichensis*	N	N				
Sharp-shinned Hawk	*Accipiter striatus*	N	N				
Short-billed Dowitcher	*Limnodromus griseus*	N	N				
Song sparrow	*Melospiza melodia*	N	N				
Sooty grouse	*Dendragapus fuliginosus*	N	N				
Sora	*Porzana carolina*	N	N				

Spotted Owl*	*Strix occidentalis*	SE	FT				
Spotted Sandpiper	*Actitis macularia*	N	N				
Steller's Jay	*Cuanoatta stelleri*	N	N				
Streaked Horned Lark	*Eremophila alpestris strigata*	SE	FC				
Sturns vulgaris	*Vireo solitarius*	N	N				
Swainson's Thrush	*Catharus ustulatus*	N	N				
Townsend's Warbler	*Dendroica townsendi*	N	N				
Tree Swallow	*Tachycineta bicolor*	N	N				
Varied Thrush	*Ixoreus naevius*	N	N				
Vaux's Swift	*Chaetura vauxi*	N	N				
Vaux's Swift*	*Chaetura vauxi*	SC	N				
Violet-green Swallow	*Tachycineta thalassina*	N	N				
Virginia Rail	*Rallus limicola*	N	N				
Warbling Vireo	*Vireo gilvus*	N	N				
Weaver Finches	*(Passeridae)*	N	N				
Western Grebe	*Aechmophorus occidentalis*	SC	N				
Western Grebe	*Aechmophorus occidentalis*	N	N				
Western Meadowlark	*Sturnella neglecta*	N	N				
Western Sandpiper	*Calidris mauri*	N	N				
Western Screech-owl	*Otus kennicottii*	N	N				
Western tanager	*Piranga ludoviciana*	N	N				
Western Wood Pewee	*Contopus sordidulus*	N	N				
White-crowned Sparrow	*Zonotrichia leucophrys*	N	N				
White-winged scoter	*Melanitta fusca*	N	N				
Willow Flycatcher	*Empidonax traillii*	N	N				
Wilson's warbler	*Wilsonia pusilla*	N	N				
Winter Wren	*Troglodytes troglodytes*	N	N				
Wood duck	*Aix sponsa*	N	N				

Yellow Warbler	*Dendroica petechia*	N	N				
Yellow-billed cuckoo	*Coccyzus americanus*	SC	FC				
Yellow-rumped warbler	*Dendroica coronata*	N	N				

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SC: State Candidate, defined in WDFW Policy M-6001 to include fish and wildlife species that the Department will review for

Table C-4: Fish Species in the Middle Fork Project Study Area					
Common Name	**Scientific Name**	**State Status**	**Federal Status**	**Present in Project Area?**	**Criteria for presence determination**
Bull trout	*Salvelinus confluentus*	SC	FT	Possible	Rare, norturnal species that is difficult to survey. Suitable habitat is present
Coastal resident/searun cutthroat	*Oncorhynchus clarki clarki*	N	N	Yes	Documented occurrence
Dolly varden	*Salvelinus malma*	N	N	Possible	Suitable habitat is present.
Rainbow trout	*Oncorhynchus mykiss*	N	N	Yes	Documented occurrence
River lamprey	*Lampetra ayresi*	SC	FCo	Possible	in King County
Mountain whitefish	*Prosoplum williamsoni*	N	N	Yes	Documented occurrence
Eastern brook trout	*Salvelinus fontinalis*	N	N	Yes	Documented occurrence
Three-spined sticklebacks	*Gasterosteus aculeatus*	N	N	Yes	Documented occurrence
Largemouth bass	*Micropterus salmoides*	N	N	Yes	Documented occurrence
Sculpin	*Cottus sp.*	N	N	Yes	Documented occurrence

Table C-5: Reptiles That May Occur in the Middle Fork Project Study Area						
Common Name	**Scientific Name**	**State Status**	**Federal Status**	**Preferred Habitat Type**	**Present in Project Area?**	**Criteria for presence determination**
Alligator lizard	*Elgaria coerulea*	N	N	Grassy, brushy or rocky openings within forested landscapes. They have also been observed along road corridors and near lake edges. They can persist in low to moderately developed landscapes where they are typical seen in rock retaining walls, rock piles, woody debris and along building foundations.Inhabits low gradient and low elevation rivers, lakes, and reservoirs. They prefer shallow water in mud, sand, or fi ne gravel.	Possible	Suitable Habitat is present
Common garter snake	*Thamnophis sirtalis*	N	N	Foung in grassy, brushy or rocky openings within forested landscapes, near riparian areas and other water sources	Yes	Documented Occurrence
Northwestern garter snake	*Thamnophis ordinoides*	N	N	Foung in grassy, brushy or rocky openings within forested landscapes, near riparian areas and other water sources	Yes	Documented Occurrence

Western fence lizard	*Weaver Finches Snake*	N	N	In the Puget Trough, they occur along shorelines with accumulations of driftwood. They have also been found in sunny, rocky areas, as well as an oak stand with rubbish piles,	Possible	Suitable Habitat is present
Western pond Turtle	*Actinemys marmorata*	SE	FCo	Inhabits slow moving streams, lakes, ponds and wetlands.	Unlikely	Extremely rare species with closest known populations over 50 miles away
Western Terrestrial Garter	*Thamnophis elegans*	N	N	Foung in grassy, brushy or rocky openings within forested landscapes, near riparian areas and other water sources	Yes	Documented Occurrence

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Table C-6: Rare or Listed Insect Species That May Occur in the Middle Fork Project Study Area								
Common Name	**Scientific Name**	**Type**	**State Status**	**Federal Status**	**Preferred Habitat Type**	**Present in Project Area?**	**Basis for presence Determination**	
Bog Idol Leaf Beetle (formerly known as Long-horned Leaf Beetle)	*Donacia idola*	Beetle	SC	none	downed woody debris	Possible	Suitable Habitat is present	
Hatch's Click Beetle	*Eanus hatchii*	Beetle	SC	FCo	North-facing basalt talus. Endemic: only known in King County (historically also SnoCo, but no longer)	Unlikely	No significant areas of north-facing talus	
Johnson's Hairstreak	*Mitoura johnsoni*	Butterfly/ Moth	SC	none	Dependent on lowland coniferous forests that contain dwarf mistletoes of the genus Arceuthobium, which occur mainly on western hemlock (Tsuga heterophylla) and occasionally on true firs (Abies spp.). Peak conditions for this butterfly exist in old-growth and late successional second-growth, lowland forests. Younger forests that contain dwarf mistletoe may also support species. Have been recorded in King County in suitable habitat: lowland coniferous forests that contain dwarf mistletoes of the genus Arceuthobium.	Possible	Suitable Habitat is present	
Valley Silverspot	*Speyeria zerene bremnerii*	Butterfly/ Moth	SC	FCo	Found in prairies of the Puget Trough, and open island prairies with a dominance of original vegetation. May be in King Co	Possible	Suitable Habitat is present	

Status Codes:
FE: Federal Endangered
FT: Federal Threatened
FC: Federal Candidate
FCo: Federal Species of Concern
SE: State Endangered, defined in WAC 232-12-297, Section 2.4, to include "any wildlife species native to the state of Washington that is seriously threatened with extinction throughout all or a significant portion of its range within the state."
ST: State Threatened, defined in WAC 232-12-297, Section 2.5, to include "any wildlife species native to the state of Washington that is likely to become an endangered species within the foreseeable future throughout a significant portion of

its range within the state without cooperative management or removal of threats."

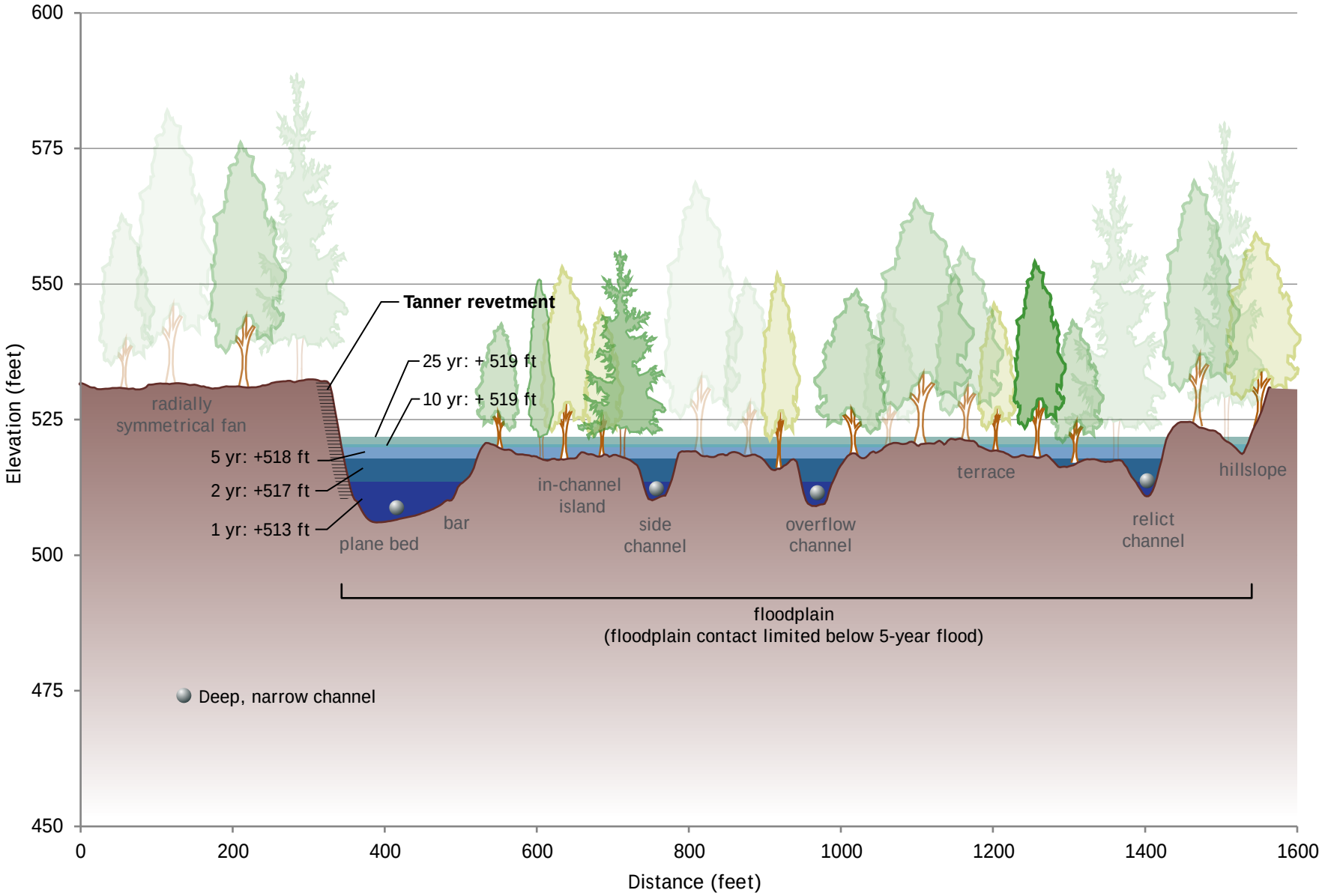
SS: State Sensitive, defined in WAC 232-12-297, Section 2.6, to include "any wildlife species native to the state of Washington that is vulnerable or declining and is likely to become endangered or threatened throughout a significant portion of its range within the state without cooperative management or removal of threats."

SC: State Candidate, defined in WDFW Policy M-6001 to include fish and wildlife species that the Department will review for possible listing as State Endangered, Threatened, or Sensitive. A species will be considered for designation as a State Candidate if sufficient evidence suggests that its status may meet the listing criteria defined for State Endangered, Threatened, or Sensitive.

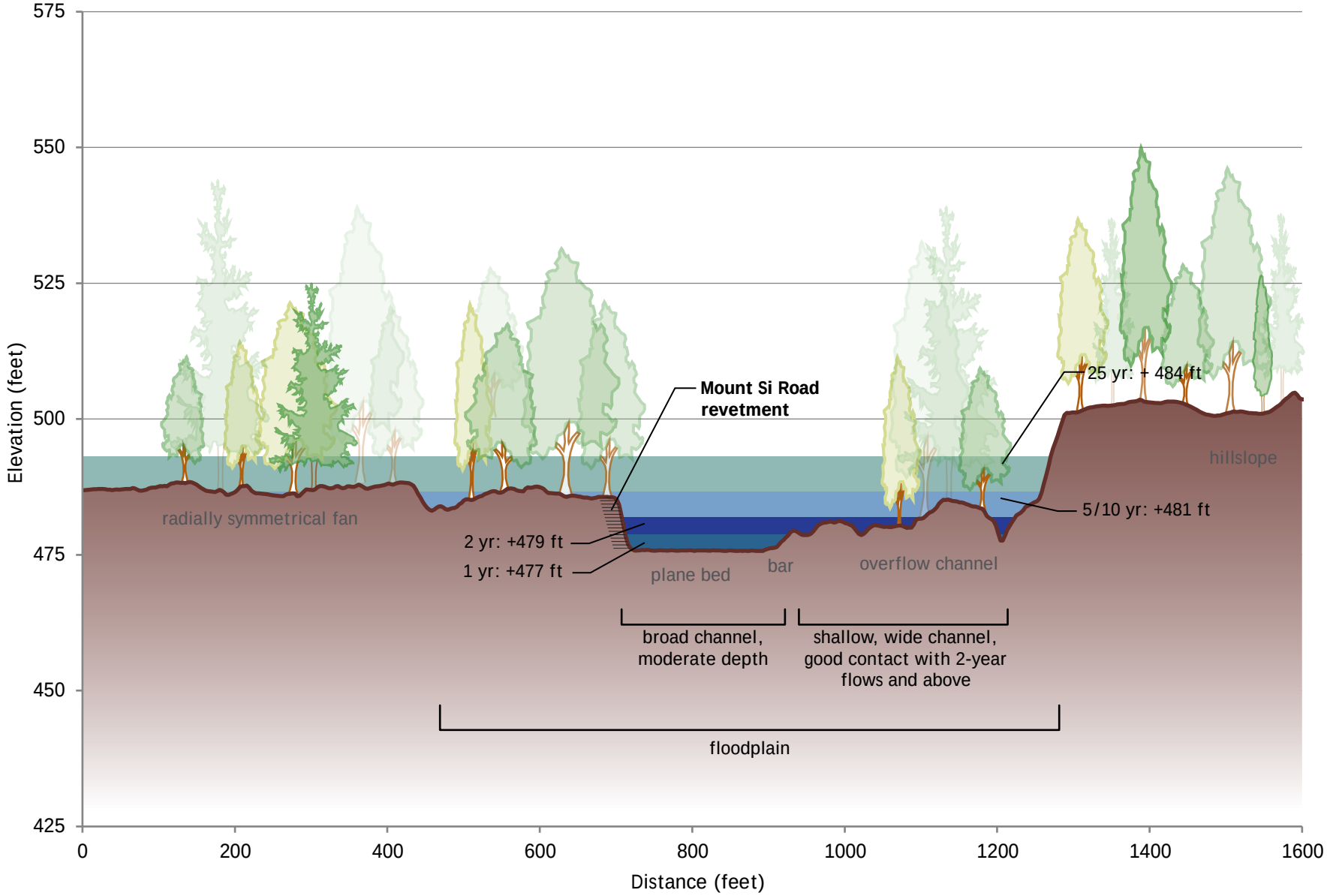
APPENDIX D

Cross-sections

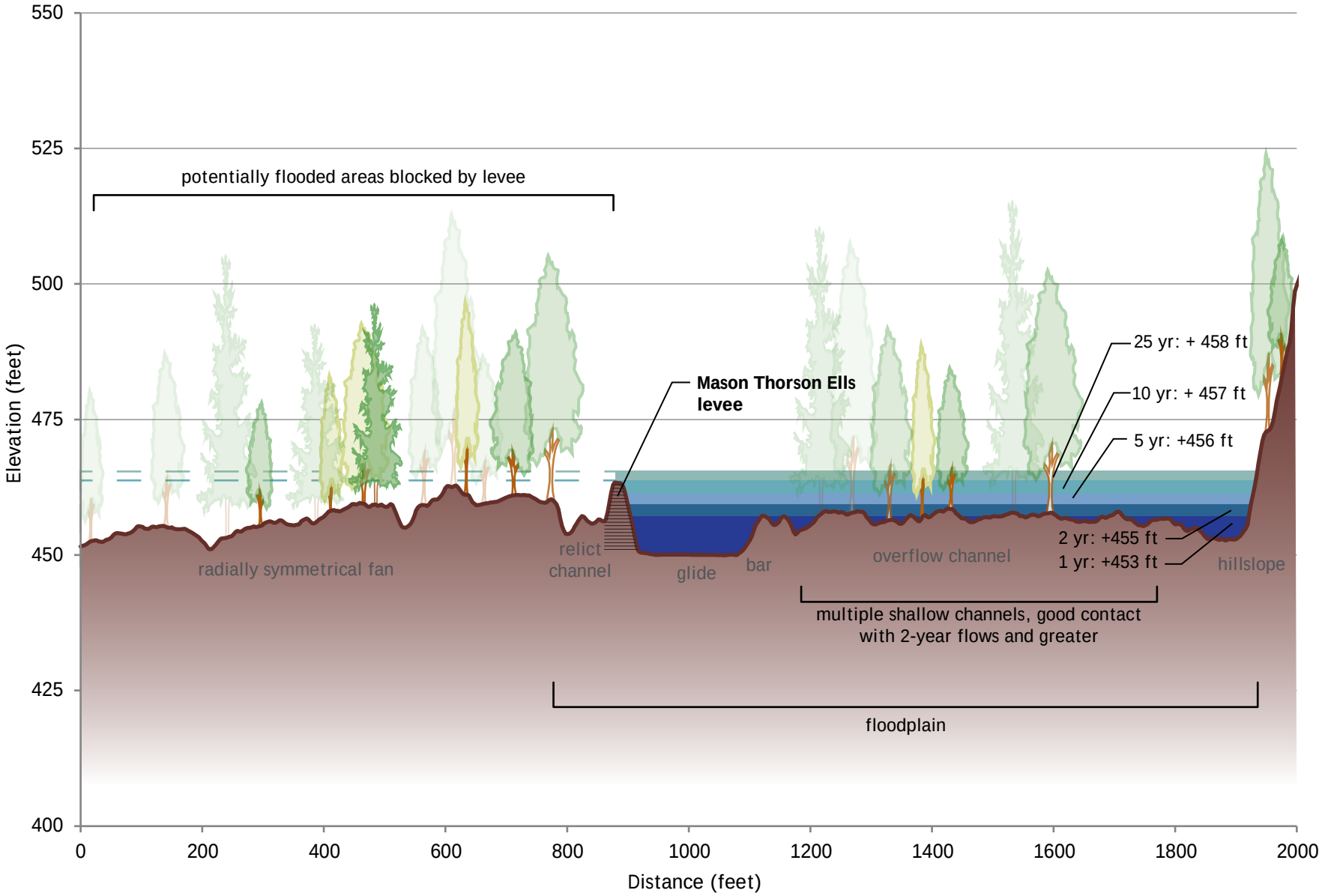
D-1


600
575
550
525
500
475
450
Elevation (feet)
0
200
400
600
800
1000
1200
1400
1600
Distance (feet)
Tanner revetment
25 yr: + 519 ft
10 yr: + 519 ft
5 yr: +518 ft
2 yr: +517 ft
1 yr: +513 ft
radially symmetrical fan
plane bed
bar
in-channel island
side channel
overflow channel
terrace
relict channel
hillslope
floodplain
(floodplain contact limited below 5-year flood)
Deep, narrow channel

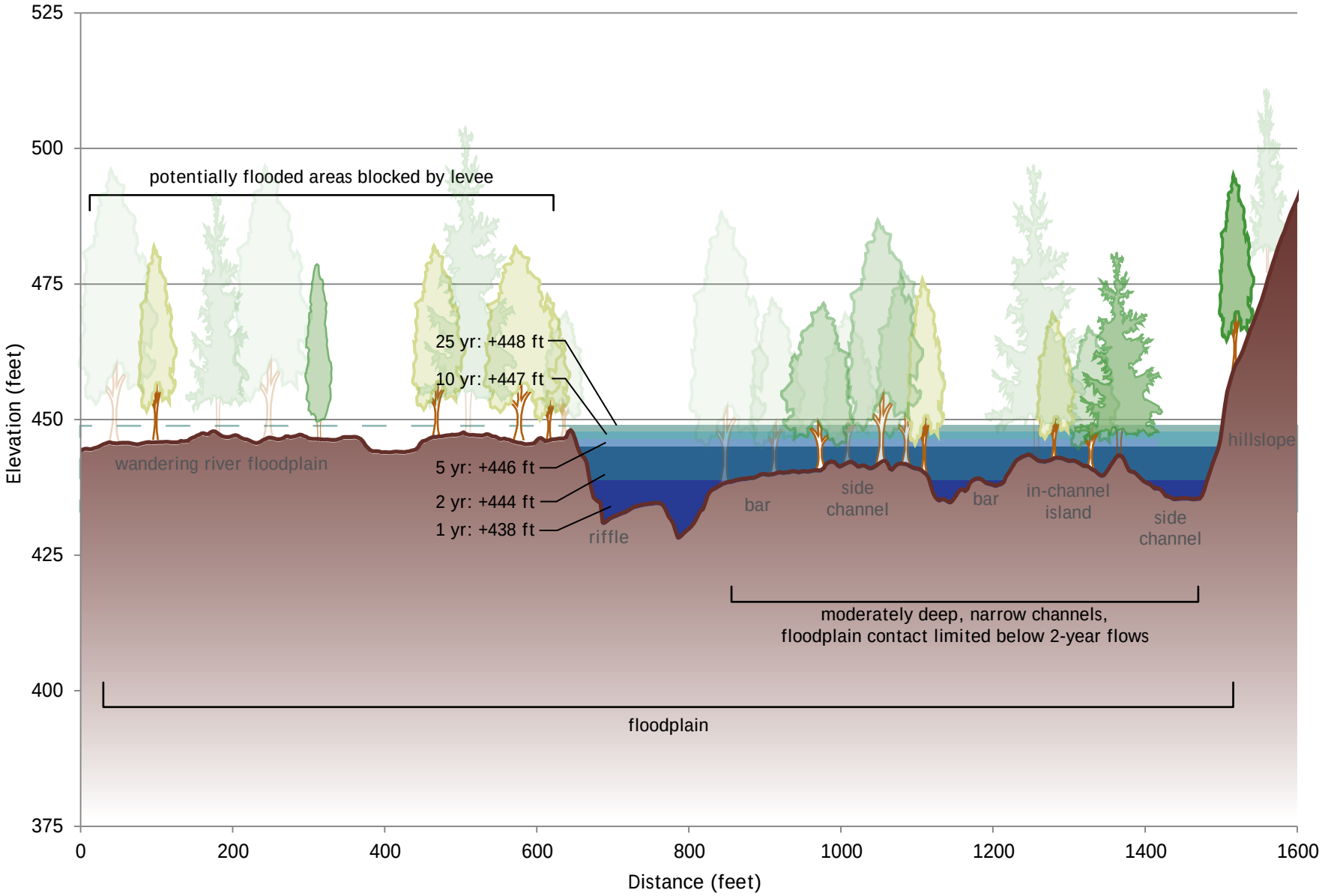
D-2


575
550
525
500
475
450
425
Elevation (feet)
0
200
400
600
800
1000
1200
1400
1600
Distance (feet)
Mount Si Road revetment
25 yr: + 484 ft
hillslope
5/10 yr: +481 ft
radially symmetrical fan
2 yr: +479 ft
1 yr: +477 ft
plane bed
bar
overflow channel
broad channel, moderate depth
shallow, wide channel, good contact with 2-year flows and above
floodplain

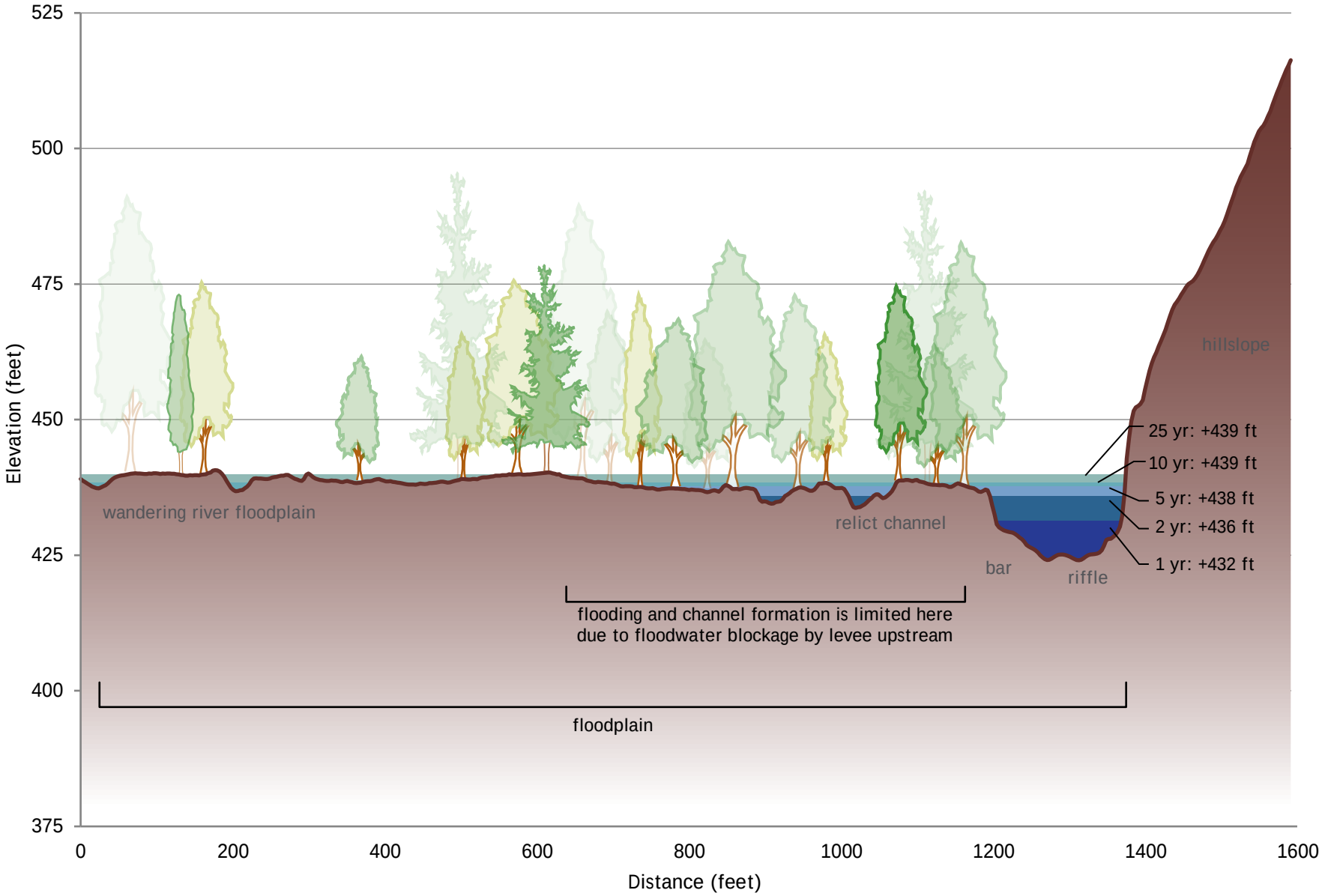
D-3


550
525
500
475
450
425
400
Elevation (feet)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance (feet)
potentially flooded areas blocked by levee
Mason Thorson Ells levee
25 yr: + 458 ft
10 yr: + 457 ft
5 yr: +456 ft
2 yr: +455 ft
1 yr: +453 ft
radially symmetrical fan
relict channel
glide
bar
overflow channel
hillslope
multiple shallow channels, good contact with 2-year flows and greater
floodplain

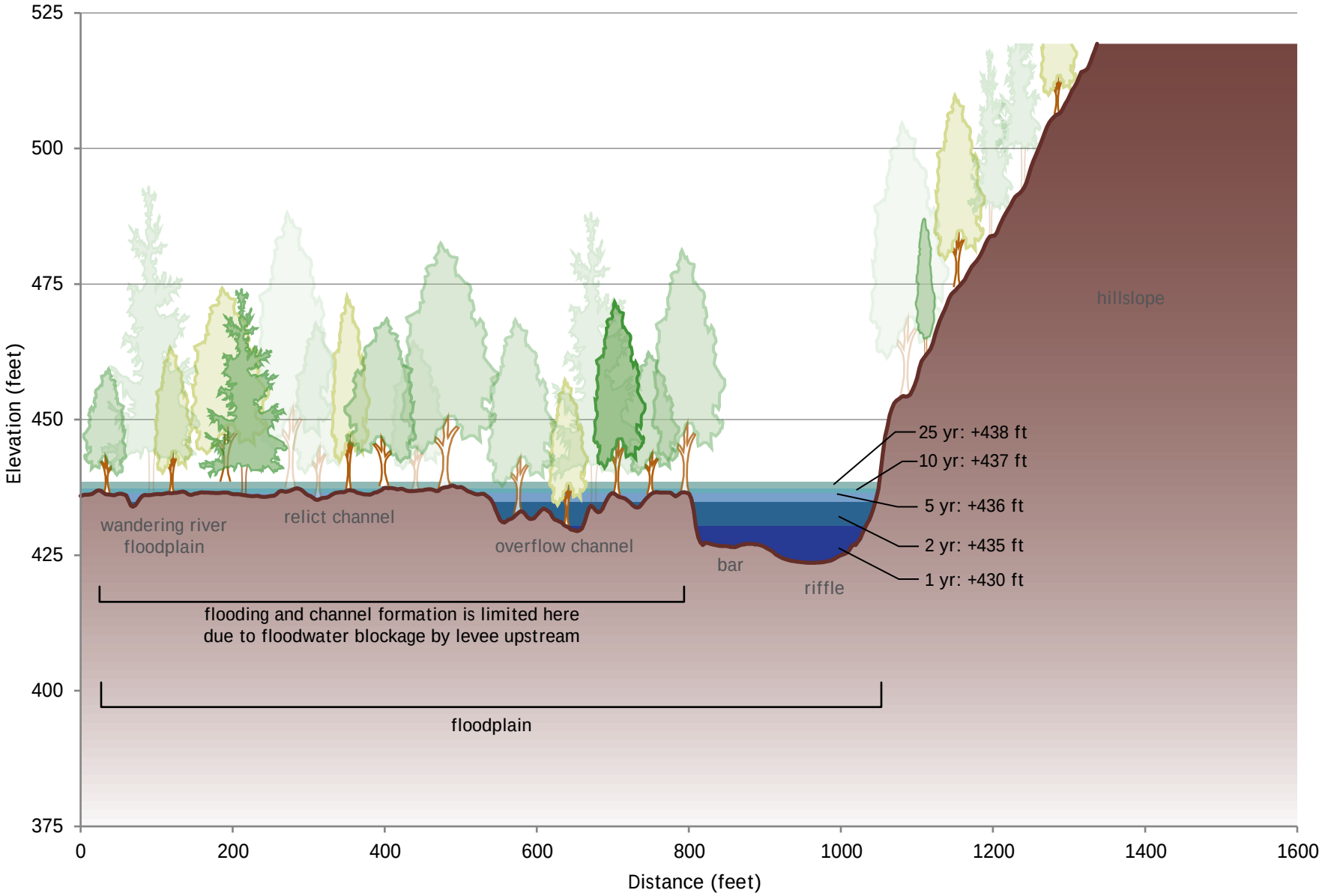
D-4


525
500
475
450
425
400
375
Elevation (feet)
0
200
400
600
800
1000
1200
1400
1600
Distance (feet)
potentially flooded areas blocked by levee
25 yr: +448 ft
10 yr: +447 ft
5 yr: +446 ft
2 yr: +444 ft
1 yr: +438 ft
wandering river floodplain
riffle
bar
side channel
bar
in-channel island
side channel
hillslope
moderately deep, narrow channels,
floodplain contact limited below 2-year flows
floodplain

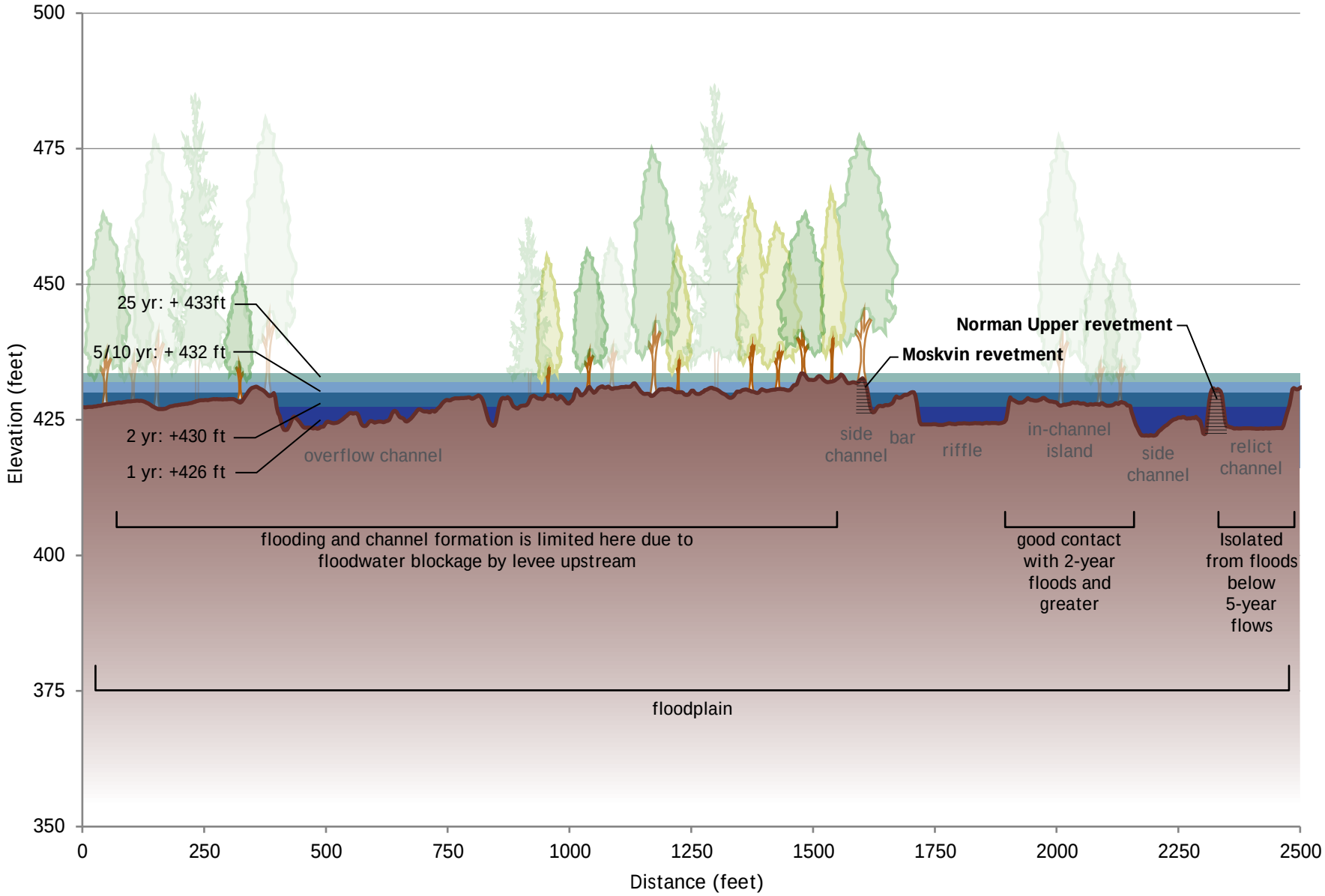
D-5


525
500
475
450
425
400
375
Elevation (feet)
0
200
400
600
800
1000
1200
1400
1600
Distance (feet)
hillslope
25 yr: +439 ft
10 yr: +439 ft
5 yr: +438 ft
2 yr: +436 ft
1 yr: +432 ft
wandering river floodplain
relict channel
bar
riffle
flooding and channel formation is limited here
due to floodwater blockage by levee upstream
floodplain

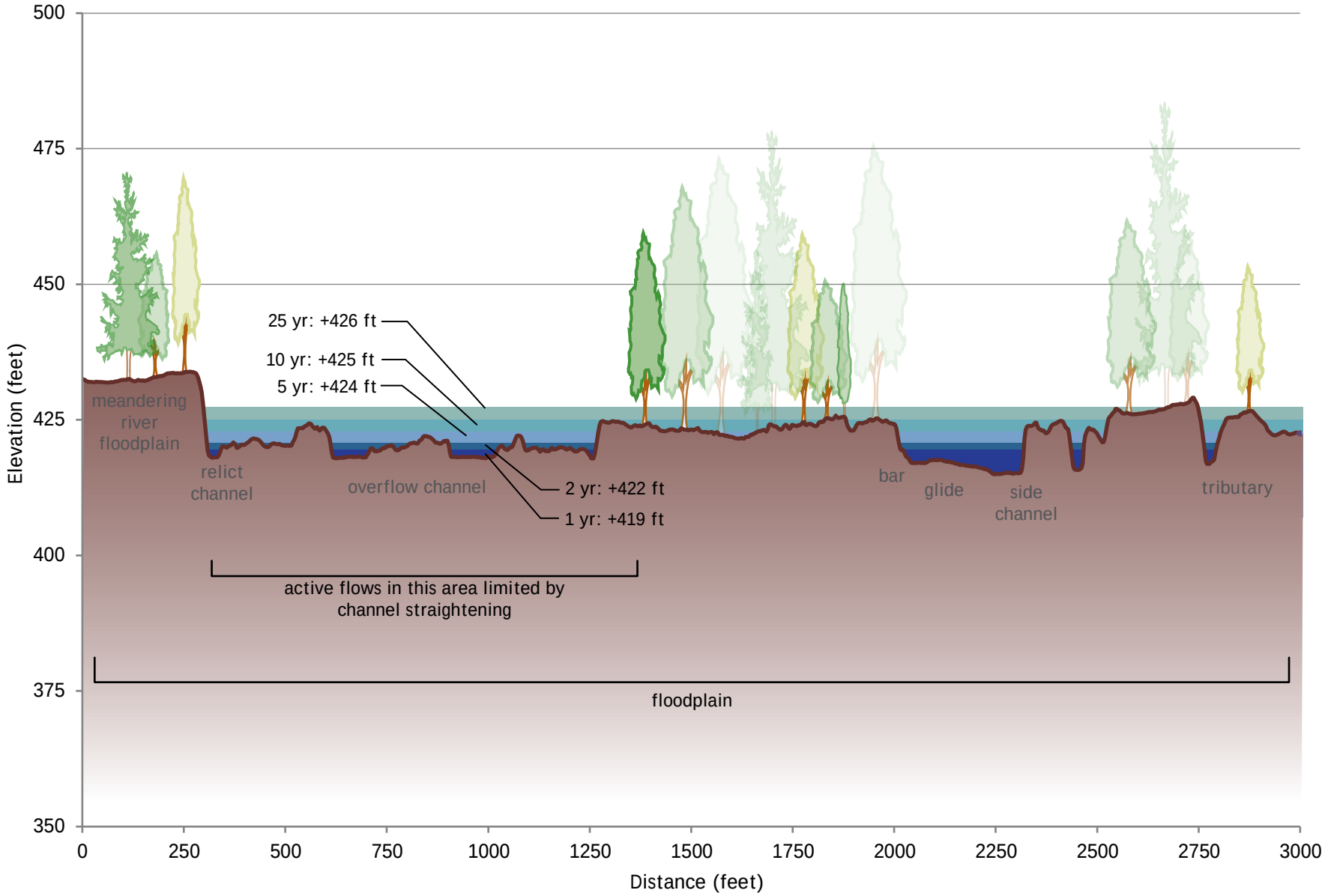
D-6


525
500
475
450
425
400
375
Elevation (feet)
0
200
400
600
800
1000
1200
1400
1600
Distance (feet)
hillslope
25 yr: +438 ft
10 yr: +437 ft
5 yr: +436 ft
2 yr: +435 ft
1 yr: +430 ft
wandering river floodplain
relict channel
overflow channel
bar
riffle
flooding and channel formation is limited here due to floodwater blockage by levee upstream
floodplain

D-7


500
475
450
425
400
375
350
Elevation (feet)
25 yr: + 433ft
5/10 yr: + 432 ft
2 yr: +430 ft
1 yr: +426 ft
overflow channel
Norman Upper revetment
Moskvin revetment
side channel
bar
riffle
in-channel island
side channel
relict channel
flooding and channel formation is limited here due to floodwater blockage by levee upstream
good contact with 2-year floods and greater
Isolated from floods below 5-year flows
floodplain
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
Distance (feet)

D-8


500
475
450
425
400
375
350
Elevation (feet)
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
Distance (feet)
25 yr: +426 ft
10 yr: +425 ft
5 yr: +424 ft
2 yr: +422 ft
1 yr: +419 ft
meandering river floodplain
relict channel
overflow channel
bar
glide
side channel
tributary
active flows in this area limited by channel straightening
floodplain