Lower Carpenter Creek - Upper Hill Ditch Sediment Assessment and Conceptual Management Alternatives

Submitted to Skagit County Public Works
March 29, 2019

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March 29, 2019

Submitted To: Kara Symonds
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1800 Continental Place
Mount Vernon, WA 98273
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Subject: **Lower Carpenter Creek – Upper Hill Ditch Sediment Assessment and Management Alternatives**

Dear Ms. Symonds,

Element Solutions is pleased to present the following Lower Carpenter Creek – Upper Hill Ditch Sediment Assessment and Conceptual Management Alternatives study. This study was compiled using information provided by you, the client, review of public information, on-site investigation of the subject area, and the professional judgment of environmental professionals. The work included scientific assessment and mapping to determine the sediment composition, transport, and depositional processes within the Carpenter Creek watershed and the project reach. This report is intended to provide you and other project stakeholders with an improved understanding of the physical processes responsible for sedimentation within the project reach, and presents a range of management alternatives to help address multiple project objectives. The results of our analysis are summarized within the report, and may be used to advise future planning and decision making regarding sediment management in the project reach.

Should you have any questions concerning this assessment, please contact us at (360) 671-9172 or at ppittman@elementsolutions.org.

Sincerely,

Paul Pittman, MS, LEG
Earth and Environmental Sciences Manager - Principal

Table of Contents

1 Introduction

1.1 Introduction

The Lower Carpenter Creek - Upper Hill Ditch study area is a managed watercourse in the Fisher/Carpenter Creek watershed, an approximately 25.5 square mile area in WRIA #3 that drains into the South Fork of the Skagit River in southwest Skagit County (Figure 1). The Fisher/Carpenter Creek watershed was described in the 2006 Skagit Conservation District (SCD) *Characterization of the Fisher and Carpenter Creek Watershed of Skagit and Snohomish Counties, Washington* (SCD, 2006). This report described the physical characteristics of the watershed in anticipation of future planning and management activities to address water quality impairments in the basin. The Fisher and Carpenter creeks basin is a federal Clean Water Act Section 303(d) listed water body that has regularly exceeded Washington State Department of Ecology (WDOE) total maximum daily load (TMDL) allocations for temperature and fecal coliform. The characterization was followed in 2008 by the SCD *Feasibility Study of Proposed Water Quality, Stream Flow and Habitat Improvement Activities in the Fisher and Carpenter Creek Watershed of Skagit and Snohomish Counties, Washington (SCD, 2008)*, which identified specific watershed management objectives and feasible alternatives for "improving water quality, providing more consistent stream flows, and supporting fish and wildlife habitat" throughout the watershed.

Past watershed management activities conducted in the Hill Ditch vicinity largely were conducted to address conveyance; however, habitat, conveyance, and water quality impairments identified nearly a decade ago continue to be problematic, and the Hill Ditch system remains "the main detractor of overall good quality fish habitat within these reaches" (SCD, 2006). Sedimentation, low channel complexity, a riparian corridor devoid of forest or shrub vegetation and dominated by invasive reed canarygrass, persistent back-watering during high flow conditions, and localized flooding continue to plague Hill Ditch and the surrounding properties. Despite the recent realignment of two alluvial fans at the southern extent of the project reach (Sandy and Johnson creeks) to address sedimentation downstream from the Upper Hill Ditch study area, frequent maintenance dredging is still required to maintain conveyance throughout the system. These channel maintenance activities conflict with salmonid habitat management objectives, and recently the Washington Department of Fish and Wildlife (WDFW) requested an evaluation of potential management alternatives that could reduce the need for detrimental channel maintenance activities in Hill Ditch.

1.2 Study and Project Areas

The "***Study Area"*** is defined as the contributing watersheds above Hill Ditch at the bridge crossing at Kanako Lane near East Stackpole Road. This downstream point is identified as the "***Area of Interest***" and defines the lower boundary of the study area. The ***"Project Area"*** is a reach of Lower Carpenter Creek – Upper Hill Ditch that extends from the bridge crossing at East Hickox Road to the Area of Interest (Figure 2).

1.3 Purpose

The purpose of this assessment was to (1) evaluate sediment source areas, transport, and depositional processes in a reach of the Lower Carpenter Creek - Upper Hill Ditch and (2) identify management alternatives that could reduce the frequency and/or extent of routine maintenance

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dredging in the channel to lessen the economic cost and habitat impacts associated with sediment management in the reach. Management alternatives also considered secondary benefits: water quality and habitat. Water quality and/or habitat improvement components were preferentially explored in recognition of the myriad agencies and stakeholders involved in managing the Lower Carpenter Creek – Upper Hill Ditch drainage area, which is situated in both Skagit County Dike District (DD) 3 and Skagit County Drainage Utility management areas. In-stream work in the watershed is also regulated by WDFW, WDOE, the United States Army Corps of Engineers (ACOE), and local tribal governments, who co-manage fisheries resources and provide auxiliary review and comment during the regulatory process.

Potential management alternatives were conceptualized following desktop and field analyses of the historic and contemporary channel geomorphology and hydrologic conditions observed throughout the Carpenter Creek watershed. Identified alternatives were compared for relative benefits and costs using evaluation criteria, and recommended alternatives were identified based on their potential to have the greatest benefit and least cost.

1.4 Work Program Methods

Our work plan was developed collaboratively with Skagit County Public Works, who assisted in contextualizing the management challenges presented in Lower Carpenter Creek - Upper Hill Ditch by identifying problem areas across the study reach and providing invaluable perspective for gauging management alternative feasibility. Specific work program task items included:

Task 1: Kickoff Meeting

A kickoff meeting for the Lower Carpenter Creek – Upper Hill Ditch Sediment Assessment was held in July, 2017 with representatives from Element Solutions and Skagit County Public Works. Information from previous correspondence between WDFW, DD 3, and other stakeholders was shared at this meeting.

Task 2: Desktop Assessment

Element performed desktop-based remote sensing imagery and air photo analysis to evaluate the following conditions:

- Watershed basin area, slopes, and contributing waters
- Stream networks, basins, and floodplain areas
- Erosional areas and potential sediment sources
- Vegetation cover
- Geology
- Geomorphology
- Land use
- Stream gradients

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The desktop analysis was used to provide background information for comprehensive watershed-scale understanding of the physical processes related to sediment transport and deposition in Lower Carpenter Creek – Upper Hill Ditch, which aided in the identification of potential long-term management solutions targeting the sources, rather than the symptoms, of sedimentation in the study reach. The desktop analysis also included a detailed review of previous studies, plans, data and records, and anecdotal information obtained during the outreach process.

Task 3: Field Assessment

The field assessment included a surficial reconnaissance of publicly accessible portions of the project reach and contributing watershed areas to observe and qualitatively evaluate sediment transport processes throughout the reach. Element evaluated shallow soil and sediment composition to the extent feasible, using a 48-inch steel soil probe, shovel, and hand augur; representative sediment samples were collected from the active channel bed and overbank floodplain area for field measured grain-size analysis. No additional water quality testing or monitoring were performed.

Task 4: Documentation of Methods, Findings, and Recommendations

Conceptual management alternatives were identified in collaboration with Skagit County following stakeholder engagement, desktop and field analysis, and a team review of the study findings. Reasonable physical, legal, and economic management constraints were considered at each phase of alternative development. A relative concept alternatives analysis was subsequently performed using the pro/con evaluation method, whereby alternatives were compared by evaluating the potential planning-level costs and benefits, implementation feasibility, and potential implementation consequences. A preferred alternative was selected that best addresses stakeholder objectives, and recommendations for further evaluation and plan development were summarized within the report conclusion.

2 Watershed Characteristics

2.1 Watershed Physiography

The 25.5 square mile Carpenter Creek watershed is located at the eastern lateral extent of the historic Skagit River delta, where the Skagit River alluvial plain meets the foothills of the North Cascades at the valley margin. Holocene progradation of the Skagit River delta has caused the mouth of the Skagit River to migrate several miles to the west of the project reach. Although lowland areas of the watershed (including the Lower Carpenter Creek – Upper Hill Ditch project reach) retain the relatively flat floodplain morphology that is characteristic of the Skagit River valley, the upland watershed area exhibits the mountainous, hummocky topography associated with the Darrington-Devils Mountain Fault Zone (DDMFZ). This shear zone of faulted and uplifted bedrock that is characterized by left-lateral strike slip master faults which roughly bisect the watershed from east to west. The bedrock structure of the DDMFZ largely controls regional drainage patterns in the Carpenter Creek watershed; small first-order streams enter second- or third-order tributaries in the upper watershed area, which then flow roughly east to west sub-parallel to the northwest-trending fault lines of the DDMFZ. Several of these streams (including

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Sandy and Johnson creeks immediately south of the study area) discharge as alluvial fans directly onto the Skagit River floodplain.

2.2 Sub-Basin Characterization

SCG (2008) divided the Carpenter Creek watershed into a total of six sub-basins. The Lower Carpenter Creek – Upper Hill Ditch project area, which extends from East Hickox Road in the north to East Stackpole Road in the south (Figure 2), is located in both the Lake Ten Creek sub-basin (No. 4) and the Sandy Creek sub-basin (No. 5), and receives contributing drainage from the Stackpole Creek sub-basin (No. 1) to the northwest, the Carpenter Creek sub-basin (No. 2) to the north, and the English Creek sub-basin (No. 3) to the northeast. Sub-basin channel morphology is described in detail in Section 6.4 of SCD (2008).

Water Quality Monitoring Program

Working in collaboration with the Skagit County Public Works Monitoring Program, the SCD developed and implemented a water quality monitoring program for non-point source pollution parameters (including temperature, dissolved oxygen, fecal coliform, and turbidity) in the Carpenter Creek Watershed in fall of 2005. The so-called Fisher/Carpenter Stream Team established monitoring sites at a total of twelve locations, four of which were in or proximate (immediately upstream or downstream) to the project area; the list below provides the site numbers, designated WRIA identification, and site name for each of these sampling locations, listed from south to north:

- Site 9 – UMJC – Johnson Creek
- Site 10 – UMSC – Sandy Creek
- Site 11 – UM10 – Ten Lake Creek
- Site 12 – GPCC – Carpenter Creek

Sampling was performed at bi-weekly to monthly intervals over the monitoring period, which extended from October 2005 through June 2006. The following conclusions were synthesized from the monitoring parameter data provided in the SCD (2008):

- The highest summer water temperatures (~22°C) were recorded at Site 9 – UMJC – Johnson Creek, the monitoring station located immediately downstream from the southern extent of the project reach; this was attributed to the lack of vegetative cover in the reach and low surface water and groundwater flows in the streams and ditches in the basin (SCD, 2006).
- Dissolved oxygen (DO) levels were below the minimum standard (8 mg/L) in 18% of the samples obtained across the watershed; 24% of these failing samples were collected at Site 7 – UBCC – Carpenter Creek (Hill Ditch), a very low gradient reach in the Hill Ditch system that is located downstream from the project area. The DO impairments were attributed to low summer base flows, bacterial decomposition, and lack of shading vegetation.
- A single spike in fecal coliform (FC) concentration was recorded at the Site 11 – UM10 – Ten Lake Creek monitoring station in August 2005, while excess FC concentrations (at or above 100 cfu) were also recorded during several sampling events at the Site 12 – GPCC –

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Carpenter Creek location. However, the degree of FC impairment generally appeared to increase from north to south across the watershed, with the most frequently elevated FC concentrations observed in the southernmost Site 1 – BRFC – Fisher Creek monitoring station.

- A significant spike in turbidity (148 NTU) was observed in January 2005 at the Site 9 – UMJC – Johnson Creek monitoring station following periods of heavy rainfall that prompted a county-wide flood watch (SCD, 2006); SCD attributes the spike to "extreme aggrading of the (Johnson Creek) channel by sediment inputs from historic logging in its sub-basin, a situation that requires continual dredging in order to prevent flooding."

In summary, while the water quality monitoring period was limited in duration and may not be fully representative of contemporary environmental conditions across the reach, the data from the 2008 SCD report indicate that the project reach has historically experienced seasonal temperature impairments due to lack of shade and cool water inflows in Upper Hill Ditch, as well as episodic spikes in turbidity downstream from the project reach during flooding events on Johnson Creek. Subsequent management activities to address aggradation and flooding in the Johnson Creek alluvial fan may have since altered these conditions. The data did not appear to show significant DO or FC water quality impairments in or immediately adjacent to the project area at the time of the study, although water samples obtained at monitoring stations elsewhere in the watershed routinely failed to meet Washington State water quality standards for one or both of these parameters.

2.3 Historical Land Use

Anecdotal evidence supported by remote sensing and orthophoto image analysis of the watershed suggests that prior to European settlement of the region, the Lower Carpenter Creek / Upper Hill Ditch project area was a stream system in the foothills that discharged into a large wetland complex. There is no discernable channel outlet from this wetland complex in the historical mapping or evident on the lidar topography; however, the wetland likely would have been inundated during flooding events on the Skagit River. Agricultural development began in earnest in the watershed with the establishment of the diking and drainage districts in the early 1900s and has been the predominant land use on the floodplain. Prior to agriculture, the Cedardale township was a logging hub that supported ten different logging camps operated by the English Logging Company (SDC, 2008). The foothills of the study area were primarily forestry land use until the later part of the twentieth century when residential developments began replacing that land use.

2.4 Contemporary Land Use

The series of dikes and ditches that form the structural backbone of the modern Hill Ditch drainage system were constructed by local drainage districts in the early 1900s to channel the water from Stackpole, Carpenter, Lake Ten, Sandy, Johnson, and Bulson creeks into the original mouth of Fisher Creek, with the goal of increasing productive agricultural land area and reducing the potential for flooding in the Conway vicinity. The 1937 historical air photo shows the historic alignment of Upper Hill Ditch being comparable to that of the modern drainage system, while subsequent historical air photos show a gradual increase in cultivated agricultural lands and a decrease in forest canopy vegetation adjacent to the study reach, as well as the introduction of

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various anthropogenic channel modifications in contributing drainages as road and infrastructure development occurs throughout the watershed. At the time of the 2008 SCD watershed characterization, 91% of the land use in the Fisher/Carpenter Creek watershed was described as Rural, Forest, or Agricultural, and the total impervious surface area in the watershed (roads, roofs, and driveways) comprised roughly 3% of the total watershed area (as determined from 2002 aerial photography). In the five sub-basins contributing to the project reach, impervious surfaces accounted for the following percentages of the total sub-basin area, respectively (SCD, 2006):

Sub-basin	*Percent Impervious*
Stackpole	4%
English	0%
Carpenter	2%
Lake Ten	5%
Sandy	0%

The limited new residential development can be observed through comparative analysis of 2004 aerial photographs and contemporary 2016 satellite imagery of the contributing sub-basins. The changes are not likely to have significantly increased the impervious surface area calculations reported in SCD (2006; Figures 3 and 4). It should be noted that while the increase in impervious surfaces within these basins may be a relatively low number, poorly managed stormwater management systems can disproportionately increase the sediment transport processes within a system by increasing both sediment transport capacity and loading.

3 Lower Carpenter Creek – Upper Hill Ditch Desktop Analysis

3.1 Study Area Location and Physiography

The total length of Carpenter Creek is roughly 6,400 linear feet; the stream becomes Hill Ditch, a managed watercourse, near East Hickox Road bridge at an elevation of approximately 80 feet (all elevations NAVD 88 vertical datum). By the East Stackpole Road, Hill Ditch is at an elevation of approximately 14 feet. South of the culvert crossing at Cascade Ridge Road, the watercourse in an unlined ditch adjacent to East Bacon Road for approximately 3,900 feet (i.e., about 64% of the total stream reach length). Hill Ditch outlets into the Skagit River at Fisher Slough.

3.2 Geology

The mapped geology within the contributing basin of Carpenter Creek and the area of interest consists of bedrock overlain by Pleistocene glacial deposits and Holocene unconsolidated sediments (Figure 5). The glacial deposits dominate the surface geologic conditions. The glacial deposits are susceptible to a high rate of erosion relative to the bedrock geology. The bedrock geology is predominantly found only in the upper elevations of the contributing basin and more prominent in the southern contributing areas, particularly in Ten Mile Creek sub-basin.

3.3 Geomorphology

The contributing basin of the study area is predominantly steep, mountainous terrain subject to erosion and hillslope processes (Figure 6). In general, the upper watershed areas of the study area

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are erosional areas with incised channel networks that are actively transporting sediment to the lower gradient, unconfined valley bottom. One exception to this generalization is a mid-basin depositional area on Carpenter Creek located northeast of the quarry. This mid-basin depositional area captures and stores sediment, effectively reducing the sediment delivery to the valley bottom. Below this depositional reach is a steep, incised reach which is actively incising and providing a source of sediment to the lower reaches of Carpenter Creek and Hill Ditch. Lakes within the upper and mid-reaches of the contributing areas also offer longer term sediment deposition. Sediment may also store in-channel when gradient and confinement conditions are suitable, or were large woody debris accumulate. These sediment storage areas are often temporary over the long-term time frame. The ultimate depositional reach is the valley bottom. An alluvial fan landform exists at the mouth of Carpenter Creek. The size of the Carpenter Creek alluvial fan is small relative to the watershed size and compared to the adjacent tributaries' alluvial fans. It is likely that the depositional areas in the mid-basin of Carpenter Creek influences this condition. An expanded discussion on sediment transport is provided in Section 4.

3.4 Habitat

Carpenter Creek and Hill Ditch provide habitat for salmonids (Figure 7). Table 1 itemizes the species presence and distribution data from Salmonscape. In general, the upper reaches of Carpenter Creek likely provide the greatest quality and quantity of spawning habitat, whereas the lower reaches likely provide habitat suitable for rearing and holding. Ten Mile Creek has been identified as a 303(d) listed water for DO impairment.

Table 1: Documented salmonid use

Species presence and distribution, Carpenter Creek, Hill Ditch [1/]					
Species/run	**Species**	**Runtime**	**Distribution Type**	**Use Type**	**Life History**
Dolly Varden/ Bull Trout	Bull Trout	Unknown or not Applicable	Presumed	Presence	Unknown
Rainbow Trout	Rainbow Trout	Unknown or not Applicable	Documented	Presence	Unknown
Pink Odd Year	Pink Salmon	Odd Year	No Gradient Barrier	Presence	Anadromous
Fall Chum	Chum Salmon	Fall	Documented	Presence	Anadromous
Winter Steelhead	Steelhead Trout	Winter	Documented	Presence	Anadromous
Fall Chinook	Chinook Salmon	Fall	Documented	Presence	Anadromous
Kokanee	Kokanee Salmon	Unknown or not Applicable	Documented	Presence	Adfluvial
Coho	Coho Salmon	Unknown or not Applicable	Documented	Rearing	Anadromous
Resident Coastal Cutthro	Cutthroat Trout	Unknown or not Applicable	Documented	Presence	Unknown
Sockeye	Sockeye Salmon	Unknown or not Applicable	Documented	Presence	Anadromous
Summer Steelhead	Steelhead Trout	Summer	Documented	Presence	Anadromous
[1/] Salmonscape March 11, 2019. LLID 1223439483217					

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4 Project Reach Stream Analysis

4.1 Instream Sediment Characterization

Sediment enters the project reach through one or more of the following pathways:

1) Inter-basin (upstream) sediment inputs – Sediment transported through the Carpenter Creek sub-basin, which receives contributing drainage from the Stackpole and English sub-basins, enters the project reach at the East Hickox Road crossing.

2) Intra-basin sediment inputs – Sediment may enter the project reach directly from the Lake Ten sub-basin, a natural fluvial system that enters a ditched drainage network at Cascade Ridge Road south of the Martin-Marietta Pacific Quarry and empties into the Hill Ditch system at Bacon Road.

3) Local sediment inputs – Sediment may enter the project reach through the many private ditches that discharge into the Lower Carpenter Creek - Upper Hill Ditch system from the east along Bacon Road; overland flow across steep erodible surfaces adjacent to the ditch, such as gravel driveways, also contributes sediment to the reach during heavy precipitation events.

4) Downstream sediment inputs – A portion of the sediment-laden discharge from the Sandy Creek alluvial fan is diverted into the Hill Ditch system through a ditch and 6" PVC culvert at the Kanako Lane / East Stackpole Road Crossing; backwatering conditions are known to occur in this low-gradient reach of Upper Hill Ditch, which would allow sediment to enter the reach at the crossing and could even support fine sediment transport upstream from the crossing during certain flow conditions.

Sediment that is recruited into a stream network can be characterized as either suspended load or bedload sediment based on its mobility. For this analysis, we define suspended sediment as fine-grained sediment that is transported through the project reach. Suspended sediment is a source for turbidity and results in water quality impairments, but does not reduce the conveyance of the system in this reach. We define bedload sediment as coarser sediment that occurs within channel of the project reach for significant duration of time. Bedload sediment delivered to the project reach may either transport slowly through the project reach or be stored indefinitely. Bedload sediment can provide some habitat function, but reduces conveyance. Historic dredging efforts were to address bedload sediment that influenced conveyance.

The primary focus of this sediment analysis is bedload sediment as it relates to conveyance impacts and channel maintenance. However, we discuss suspended sediment to a lesser extent as it relates to water quality impairments. It should be noted that in lower gradient reaches downstream of the project reach, the fine-grained sediment may transition to bedload sediment and could contribute to conveyance issues.

To understand the sediment processes influencing management of the project reach, we identified potential significant bedload sediment source areas within the contributing watershed using both desktop and field analysis and characterized the observed sediment deposition

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processes (Figure 8). In addition, we discuss potential downstream sediment processes and contributing watershed changes that may influence the project reach in the future.

The project reach transitions from a transport reach to a depositional reach. The project reach has been divided into three segments based on depositional characteristics (Figure 9) summarized in Table 2. The upper segment of the project reach, beginning at about the Hickox Road crossing, has a distinct gradient break and decrease in channel confinement (Profile Graph 1). The channel confinement in the **Upper Segment** is natural at the Hickox Road crossing, but by Cascade Ridge Drive, the natural channel confinement transitions into what appears to be confinement that is a result of historic hydromodification. Below Cascade Ridge Drive is the beginning of what is a managed watercourse (Hill Ditch). Confinement is the result of a levee on the right bank and a hillslope on the left bank. The **Middle Segment** of the project reach is characterized as a decreasing gradient and a narrow floodplain occurring between the levee (Stackpole Road) and the hillslope (Profile Graph 2; Table 1). Hill Ditch generally flows tight up against Stackpole Road. Digital Elevation Model (DEM) analysis reveals a sink and low gradient areas on the left bank floodplain in this segment. This floodplain is known to flood often. The Middle Segment is an area of recurring channel maintenance dredging. The **Lower Segment** is marked by a significant decrease of channel gradient and increased channel confinement (Profile Graph 3). The flow velocity in the Lower Segment, and therefore the transport capacity for bedload, is greatly reduced and during times of flooding can be backwatered with no velocity.

The data measurements and observations we collected to inform our sediment analyses are tabulated in Table 2. They included both field and desktop measurements.

Table 2 - Project Reach Characteristics

Location	Attribute	Measurement
Upper Segment		
	Segment Length	2,098 feet
	Slope (%)	2.6%
Middle Segment		
	Segment Length	2,316 feet
	Slope (%)	0.6%
Lower Segment		
	Segment Length	1,952 feet
	Slope (%)	0.1%

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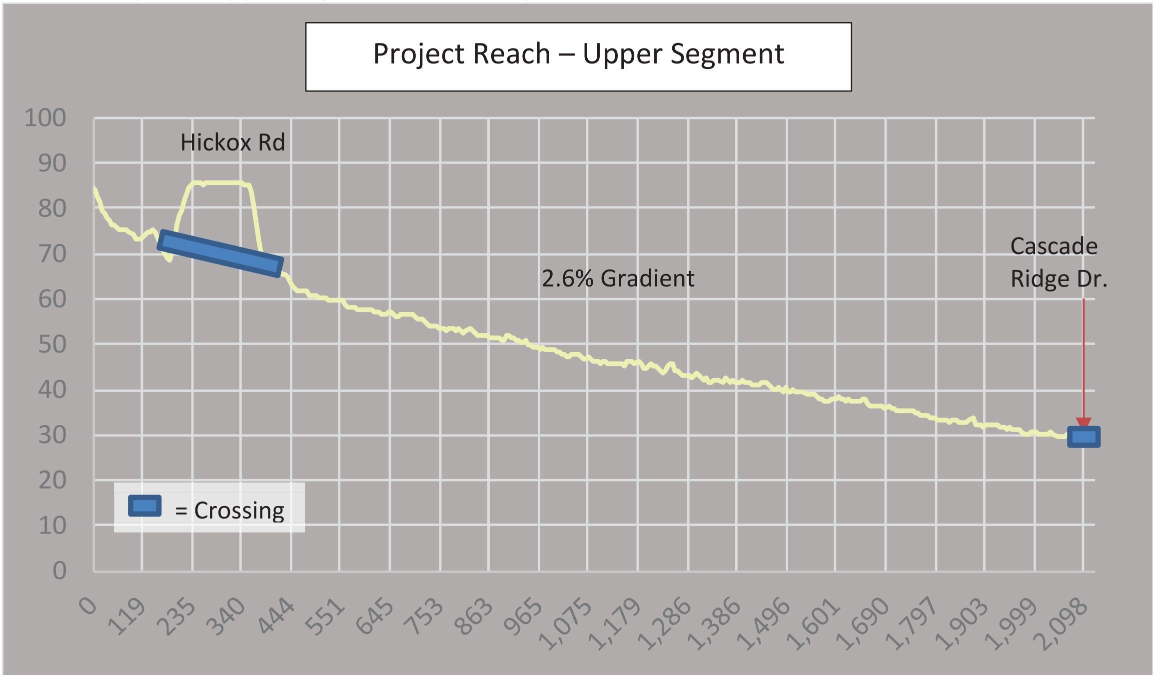
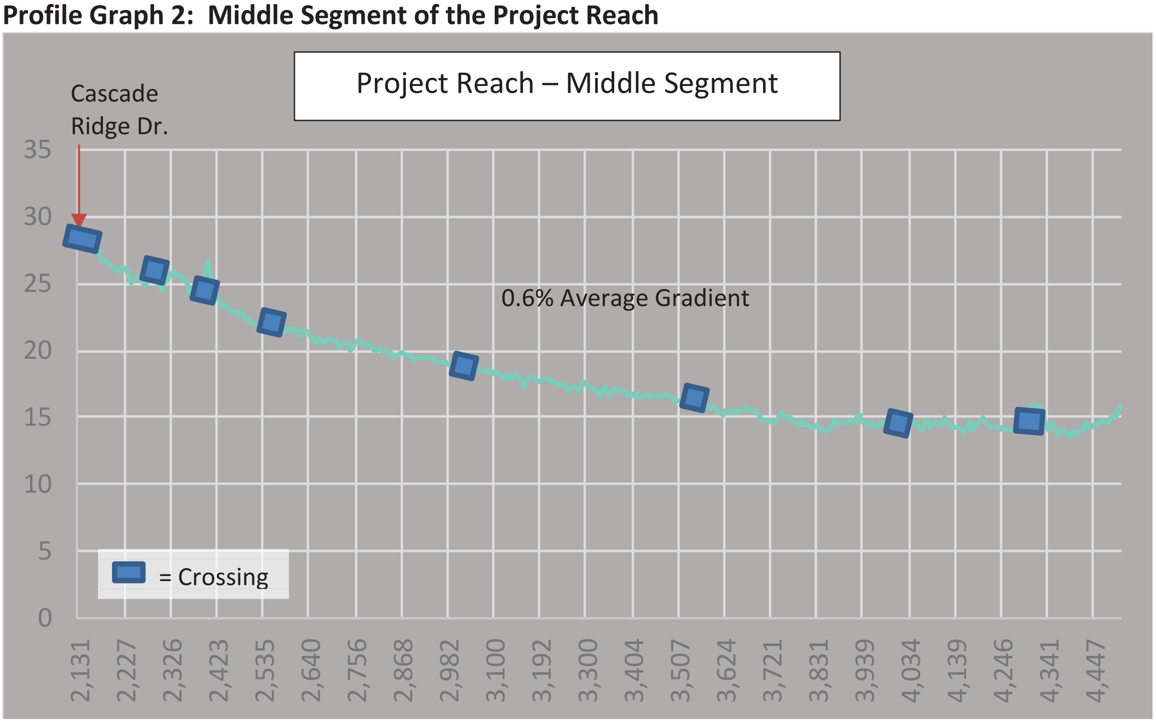
Profile Graph 1: Upper Segment of the Project Reach



Profile Graph 2: Middle Segment of the Project Reach



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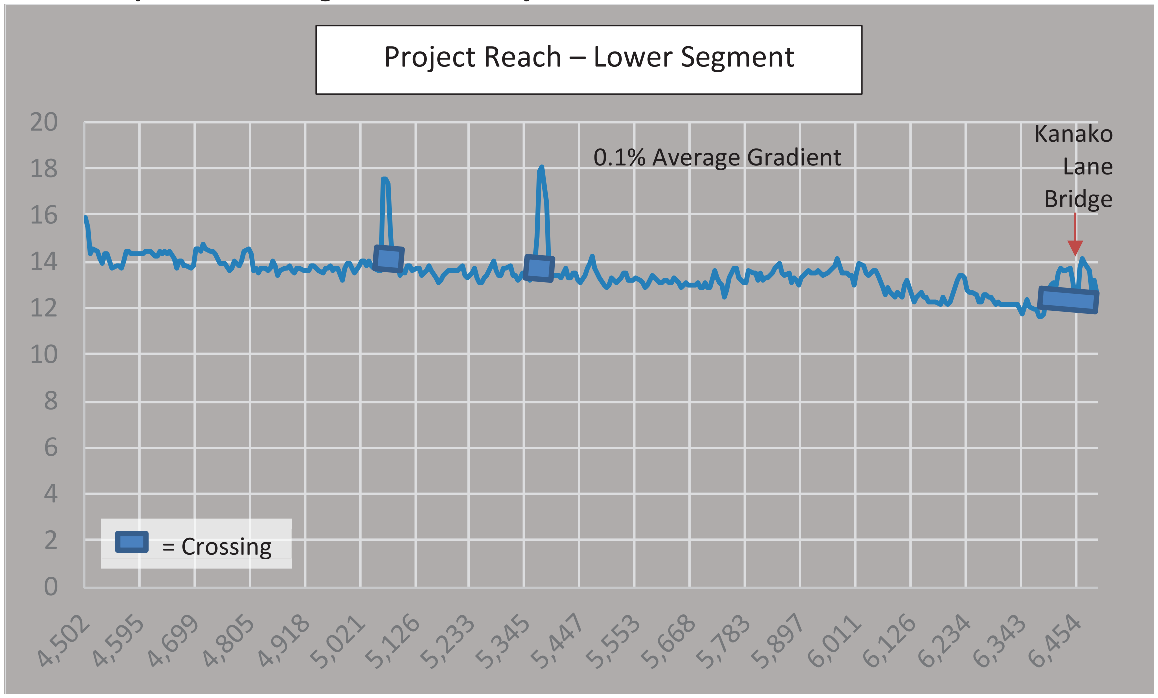
Profile Graph 3: Lower Segment of the Project Reach



4.2 Sediment Sources

This sediment source desktop analysis identified potential areas where sediment can enter into the stream network and be transported to the project reach. Stream sediment can be produced by the following physical processes:

- Incision
- Channel expansion and migration
- Mass wasting
- Surface water overland flow (stormwater)

The geology, channel morphology, slope and land use of the watershed influence sediment source areas and stream recruitment potential.

Bedload Sediment

Within the subject watershed, the upper watershed of Carpenter Creek has relatively gentle topography and forested land cover. It is not a significant source for sediment recruitment. In addition, the low stream gradient of the upper watershed has a relatively low transport capacity for mobilizing bedload sediment. As a result, the primary source of bedload sediment delivered to the project area is interpreted to occur in the lower reaches of the Carpenter Creek watershed where steep topography, erodible geology, channel incision, stormwater, and mass wasting potential are greater. In addition, these lower reaches have a higher sediment transport capacity and lower storage potential because of higher stream gradient and typically confined channel networks. Land use in the lower watershed may also influence sediment recruitment potential. Land uses that may influence sediment recruitment potential within the watershed are the active quarry, land clearing, and residential development.

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We noted areas where significant sediment source and stream recruitment potential had a higher probability of occurrence. These areas were identified based on slope, geologic composition, channel morphology, and land use (Figure 9). While it is likely that bedload sediment sources exist throughout the watershed, the identified areas are interpreted to have the greatest potential to deliver higher sediment volumes and rates that can affect stream management in the project reach.

Suspended Load Sediment

Fine-grained sediment sources that can create suspended sediment loads in Carpenter Creek are readily available throughout the watershed. These fine-grained sediments can be recruited and transported easily and are produced by the same physical processes that recruit bedload sediment. Fine-grained sediments are particularly sensitive to disturbance, grading, deforesting, and development activities.

4.3 Sediment Deposition

DEM analysis of the watershed revealed areas where topography created basin morphology which could enable deposition of sediment (Figure 10). For this analysis, we termed these topographic areas as a “sink.” We additionally considered areas with gradients of 4 percent or less as areas where deposition would be favored. The analysis revealed that a zone of potential sediment deposition exists in the upper watershed. This zone has the potential to store what is a likely significant volume of the bedload sediment that is delivered from the upper watershed into Carpenter Creek. The lower portion of the watershed is steeper and confined, where no sinks or low gradient sediment storage areas exist. The lower reach is therefore a transport reach.

In summary, bedload transported into the project reach can deposit in the Upper and Middle Segments, but instream storage capacity is low. Instream bedload sediment transport capacity in the Lower Segment is very low; therefore, bedload in the project reach is primarily stored in the Upper and Middle Segments. Floodplain storage in the Upper and Middle Segments is limited by natural and anthropogenic confinement, but the Middle Segment has more accessible floodplain area. Floodplain storage in the Lower Segment is virtually non-existent. The natural flow path(s) of Carpenter Creek would be towards the west where low gradient floodplain and sinks exist, but the current infrastructure and land use does not support this process.

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5 Conceptual Alternatives

5.1 Objectives

Alternatives were identified that are interpreted to provide some degree of increased benefit to address the drainage, habitat, and water quality goals of this project. The alternatives identification process considered the following side boards:

1. The existing levee infrastructure and public roadway infrastructure would be left in their existing configurations, with the exception of culvert/bridge sizing
2. project actions cannot increase flooding impacts on private properties without compensation or mitigation for increased impacts
3. Private property participation in any projects would be voluntary only
4. The selected project would result in either no change or a net benefit for all stakeholders

Alternatives identified could potentially achieve the following:

- Decrease sediment input into the system
- Alter in-stream deposition patterns by changing:
  - Channel slope
  - Bankfull width
  - Channel roughness
- Alter storage volume potential
- Modify infrastructure
  - Culverts and bridges
  - Levees
- Alter floodplain connectivity.

5.2 Identified Alternatives

1) No Action

If past managers were to cease managing sediment in Carpenter Creek – Hill Ditch, the channel would continue to lose capacity and would eventually fill in, resulting in increased overbank flooding and impacts to public infrastructure, private properties and businesses. The flooding could have indirect consequences that may have negative impacts to fish passage. It is expected that flooding would first impact residences east of Stackpole Road but would ultimately seek lowland routes towards the west that would direct water away from the existing channel alignment and into fields and agricultural drainage systems.

2) Stabilization of Lower Watershed Sediment Source Areas

The upper watershed area was not interpreted to be the primary source of bedload sediment. Instead, the primary source of bedload sediment impacting the project area is the lower watershed area. Therefore, we considered alternatives to stabilize sediment produced in the lower watershed area. We observed that bedload sediment recruitment from the lower watershed area was both localized from discrete point sources and chronic with widespread, non-point sources resulting from incision processes. Sediment delivery quantities and rates are likely variable with inputs from episodic mass wasting or hydrologic events. We concluded that it is not

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feasible to manage sediment inputs resulting from the larger natural processes such as incision and mass wasting. However, control of some of the localized point sources may be feasible, but often occurs on private property and may not be under County control.

For the areas where access was allowed, we considered the possibility of building logjam/boulder structures or stabilizing slopes, storing some bedload sediment, and slowing incision. Instream wood and logjams may naturally occur in Carpenter Creek. The concept of placing structures is to essentially form a low weir in the channel that allows mobilized bedload material to deposit and be stored on the upstream side. Although log-jam/boulder structures in Carpenter Creek can retain sediment in the channel, their function is temporary in nature. It is likely that the structures (man-made or natural) will fail eventually, and release the impounded sediment. Failure would be more likely to occur under high flow conditions (when forces exerted on the structure would be greatest), and the sediment that is released would have a high likelihood of being mobilized and moved down the system. Although it is not possible to predict, such failures might result in larger-scale destabilization of the streambed. Given the likely eventual failure of any of these structures, there could be legal implications and on-going maintenance obligations for the County. For this reason, this option would not likely be acceptable to the County.

3) Construction of a Sediment Basin and/or Managed Sediment Removal Area

The creek profile has a slight grade break and change in confinement in the **Upper Segment** of the project area where the Carpenter Creek alluvial fan encounters the modern Skagit River floodplain. The slope continues to decrease substantially in the **Middle Segments** and there are localized areas of confinement decrease and constrictions at bridges. Most of the flooding and levee overtopping occurs in this segment. The slope and confinement significantly decrease in the **Lower Segment** as the channel is confined between the levee and hills slope. Flow velocity and carrying capacity drops substantially. In a natural state, the Upper Segment is a location where sediment deposition would occur naturally (alluvial fan). Because of channelization, the deposition has been translated downgradient to the Middle Segment.

The reach of Carpenter Creek upstream of the Hickox Road bridge has been identified as potential spawning habitat whereas the project area has been observed as providing rearing habitat for salmon with limited, but occasional, spawning. Dredging operations occur most often in the Middle Segment. Given current site configurations, constraints, and management access, a basin sited in the Middle Segment is logical.

The basin or removal area would need to be sized based either on the available space and/or the proposed schedule of maintenance as a function of the sediment delivery rate. The basin will capture a greater volume of sediment than currently observed depositing in the project reach since the basin would reduce flow velocities and increase sedimentation efficiency, and therefore capture finer bedload sediment that would otherwise have transported through the project reach. On-going monitoring and adaptive management of the basin size, maintenance schedule, and outlet control(s) should be anticipated. Currently, DD3 removes sediment on an as-needed basis, which is often every year or every few years. The removal volumes are relatively small and on the order of a few hundred cubic yards. In 2018, approximately 730 cubic yards was removed.

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The sediment basin maintenance strategy can be considered to be of two strategies: 1) a "less-frequent but large disturbance" approach, and 2) a "more frequent but smaller disturbance" approach. The impacts of each have not been fully quantified, but the more frequent, smaller disturbance approach was recently favored by WDFW for other managed sediment basins in Skagit County (e.g., Coal Creek). A more frequent, but smaller sediment removal strategy may have slightly higher associated costs for the County (given the increased mobilization/demobilization costs of conducting annual removals), but this higher cost is likely minimal.

The feasibility of a sediment basin is subject to approval by WDFW, which may not be favored by the department. It is understood that sediment removal has negative impacts to salmon habitat; therefore, a comparative impact analysis may be needed to determine the least impact approach to instream sediment removals.

4) Infrastructure Improvements

Increasing the bridge-culvert crossings heights, widths, and increasing the freeboard of levees above the channel bed following create more storage volume in the project reach, reduce some conveyance issues, and reduce flooding risk to some properties and agricultural areas. It is anticipated, however, that the flooding of the adjacent properties east of Stackpole Road would increase in frequency and severity as cumulative sediment deposition occurs unless additional new flood infrastructures are included in the project.

5) Rerouting Carpenter Creek

Carpenter Creek in the project reach has been modified throughout the past century by straightening the channel. Increasing the sinuosity of Carpenter Creek would increase its length and could have some potential benefits. Increasing the channel length would increase the storage volume, but would also increase the depositional efficiency in the reach. These two factors would have some downstream benefits by reducing sediment arriving to the downstream reach. There may additionally be some potential increased habitat value. Channel maintenance would be encumbered by access challenges, resulting in impacts to flooding and land. Compensation for these impacts would need to be considered. Within the existing project reach, reroute options are fairly limited. Two conceptual areas are identified, but specifics would need to be evaluated once voluntary landowner involvement was determined.

6) Watershed Land Use Management

The upper watershed consists of forestry properties, active surface mining, and residential development. Forest practices are regulated by the Department of Natural Resources (DNR). Forestry harvests in the watershed appear to have peaked in the 1960's through 1980's. In recent years, the Timber Fish and Wildlife program has led to forest practice rules which are much more stringent than past rules and forest practices in areas with unstable slopes now require more scrutiny (Class IV Specials). This process enables the County and public to have the ability to provide comment to forest applications.

The active surface mine is regulated by DNR and under the National Pollution and Discharge Elimination System (NPDES) with regulatory oversight administered by Washington Department

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of Ecology (Ecology). In theory, the regulation protects off-site areas from surface water transport of sediment generated by the surface mining activities. We are unaware of any sediment deposition resulting from current mining practices. Historic surface mining was not subject to these regulations, therefore historical sedimentation rates may have been more impacted by surface mining practices.

Residential development on the hillslopes in the subject watershed began about 1990 and gradually built out over the following decades. The most recent “large” development in the watershed was a new road constructed in 2007 to service a residential long plat. It is anticipated that more build-out will occur over time, but that the 50-75% of build-out potential has already occurred. The stormwater management systems of these residential developments is in theory, managed to not increase flows and sedimentation. Field observations indicated that in practice there are impacts from stormwater. Improving stormwater systems in the upper watershed would be expected to reduce the sedimentation rate in the project area. No detailed assessment of how to implement a stormwater retrofit was undertaken.

7) Regular Maintenance Dredging (business as usual)

Regular maintenance dredging has been the method utilized for the better part of a century to manage this watercourse. It is affective at providing short-term capacity increases and reducing flooding impacts. In recent years, dredging has included the removal of fish from the project reach, which has reduced the impact to aquatic species. Managing agencies have requested that additional alternatives be considered that may further reduce impacts to the aquatic species and habitat.

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5.3 Comparative Analysis

To evaluate alternatives, we use a comparative analysis method. The method we use considers the following "values" as derived from the project goal:

- Flood benefit
- Habitat benefit
- Maintenance benefit
- Initial cost of project implementation
- 25-year running cost of project maintenance.

Relative scores between -3 to 3 are provided for each of the values. If an alternative has a negative impact, then a negative score will be assigned. If there are neither positive nor negative impacts, then a score of zero is used. Positive impacts receive positive scores. The range of impact scores for each value is subjective and based on the comparison of the other alternatives. For example, is one action more expensive or less expensive than another. Some values can be determined to have a higher priority or be "more important" in deciding a management alternative. For example, it may be determined that receiving flood benefit is more important than cost, or vice versa. To account for determining priorities, we include a "weight" factor. The weight factor can be increased or decreased by decision makers. The weight factor will be multiplied by the score assigned to the value. Once relative scores are obtained for each of the values, they are summed, and a total score is obtained. As a result, projects that have more positive impacts should receive higher scores than projects that have more negative impacts. The scores we have assigned for the values are provided in Table 3.

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Table 3: Comparative Analysis Assigned Values and Scores.

	Management Alternatives	Criteria	Flood Benefit	Habitat Benefit	Maintenance Benefit	Initial Cost	25-Year Cost	Total Score
		Range	-3 to 3	-3 to 3	-3 to 3	-3 to 0	-3 to 0	
		Weight	2	2	1	3	1	
1	No Action (assigned score)		-1	0	0	0	-2	
	Adjusted score (x weight)		-2	0	0	0	-2	**-4**
2	Stabilize Lower Watershed Sediment Source Areas		1	1	1	-2	-2	
	Adjusted score (x weight)		2	2	1	-6	-2	**-3**
3	Construct Sediment Basin/Sed. Removal Area		2	-1	1	-2	-1	
	Adjusted score (x weight)		4	-2	1	-6	-1	**-4**
4	Infrastructure Improvements		1	1	2	-3	-1	
	Adjusted score (x weight)		2	2	2	-9	-1	**-4**
5	Reroute Carpenter Creek		-1	2	2	-2	-1	
	Adjusted score (x weight)		-2	4	2	-6	-1	**-3**
6	Watershed Land Use Mgmt		0	1	1	-1	-1	
	Adjusted score (x weight)		0	2	1	-3	-1	**-1**
7	Business As Usual		2	-2	0	-1	-2	
	Adjusted score (x weight)		4	-4	0	-3	-2	**-5**

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6 Recommendations

6.1 Recommended Alternative

The recommended single alternative based on our assessment method is to manage watershed land use. However, we recognize that this project alone will not provide a management action that provides an immediate relief for the problems faced by the community. Therefore, it is our opinion that several alternatives be utilized in tandem. Our recommended approach is to adopt and implement the following management alternatives:

- Continue to utilize land use management strategies that address vegetative cover and stormwater management;
- Consider working directly with landowners in the Lower Watershed areas where sedimentation is determined to be a point source and stabilize these areas;
- Develop a re-route/sediment basin project in the Middle Segment of the project area to provide sediment capture and an alternative, lower impact method to remove sediment periodically.

A concept area is identifed for potential re-route/sediment basin location and configuration based on conditions that would favor deposition (Figure 11). Please note that this is a concept sketch only and does not imply landowner willingness or that detailed analysis and design has been performed. If this area becomes available, additional analysis could proceed to develop designs.

The outcome of this assessment provides a basic understanding the physical conditions to inform a range of potential management alternatives and identified a management alternative concept that preliminarily appears to have the highest potential to meet the stated management objectives. We recommend the next steps to advance the implementation of management actions:

1. Consider longer-term, comprehensive basin-wide management actions that address issues beyond the immediate project site
2. Assess the selected project for feasibility
   - More detailed evaluation of one or more of the selected alternatives
   - Additional landowner engagement
   - Development of the selected project design and engineer's cost estimate
3. Initiate the permitting process using 30% designs
   - Adapt designs following agency response and feedback
4. Finalize management plan and designs
5. Construction and monitoring
   - Perform baseline monitoring
   - Construction
   - Follow up monitoring.

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8 Closure

This report was prepared and submitted by:

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Earth and Environmental Sciences Manager – Principal

Statement of Limitations

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References

1) Lapen, T.J., Geologic Map of the Bellingham 1:100,000 Quadrangle, Washington. Washington State Department of Natural Resources, Division of Geology and Earth Resources Open File Report 2000-5, December 2000.

2) Natural Resources Conservation Service, Web Soil Survey, U.S. Department of Agriculture, http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx, 2017.

3) SCD (Skagit Conservation District). 2006. Characterization of the Fisher and Carpenter Creek Watershed of Skagit and Snohomish Counties, Washington.

4) SCD. 2008. Feasibility Study of Proposed Water Quality, Stream Flow and Habitat Improvement Activities in the Fisher and Carpenter Creek Watershed of Skagit and Snohomish Counties, Washington.

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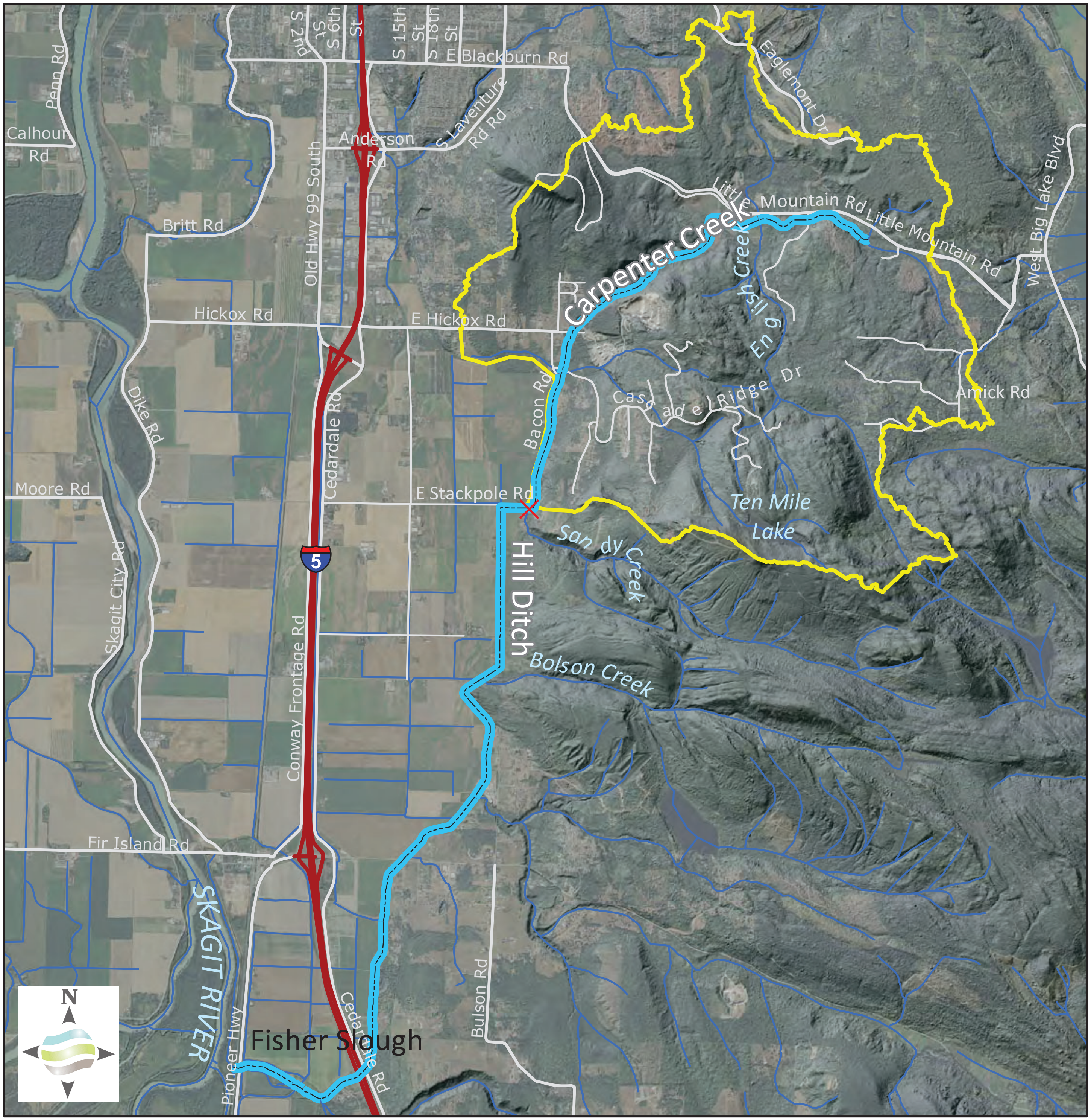

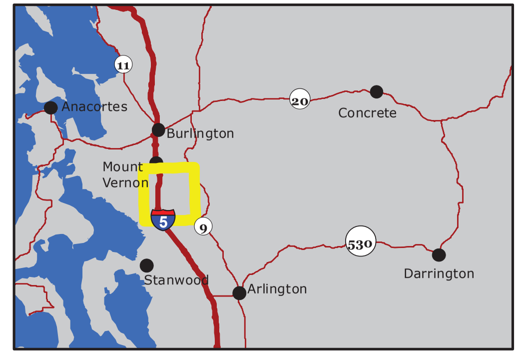

Data Credits:
WA DNR 2005, 2016
USDA NAIP 2015
USGS 2006

- Area Of Interest
- Caprepenter Creek - Hill Ditch
- Carpenter Creek Watershed
- Interstate 5
- Major Roads

Miles: 0, 0.35, 0.7, 1.05, 1.4

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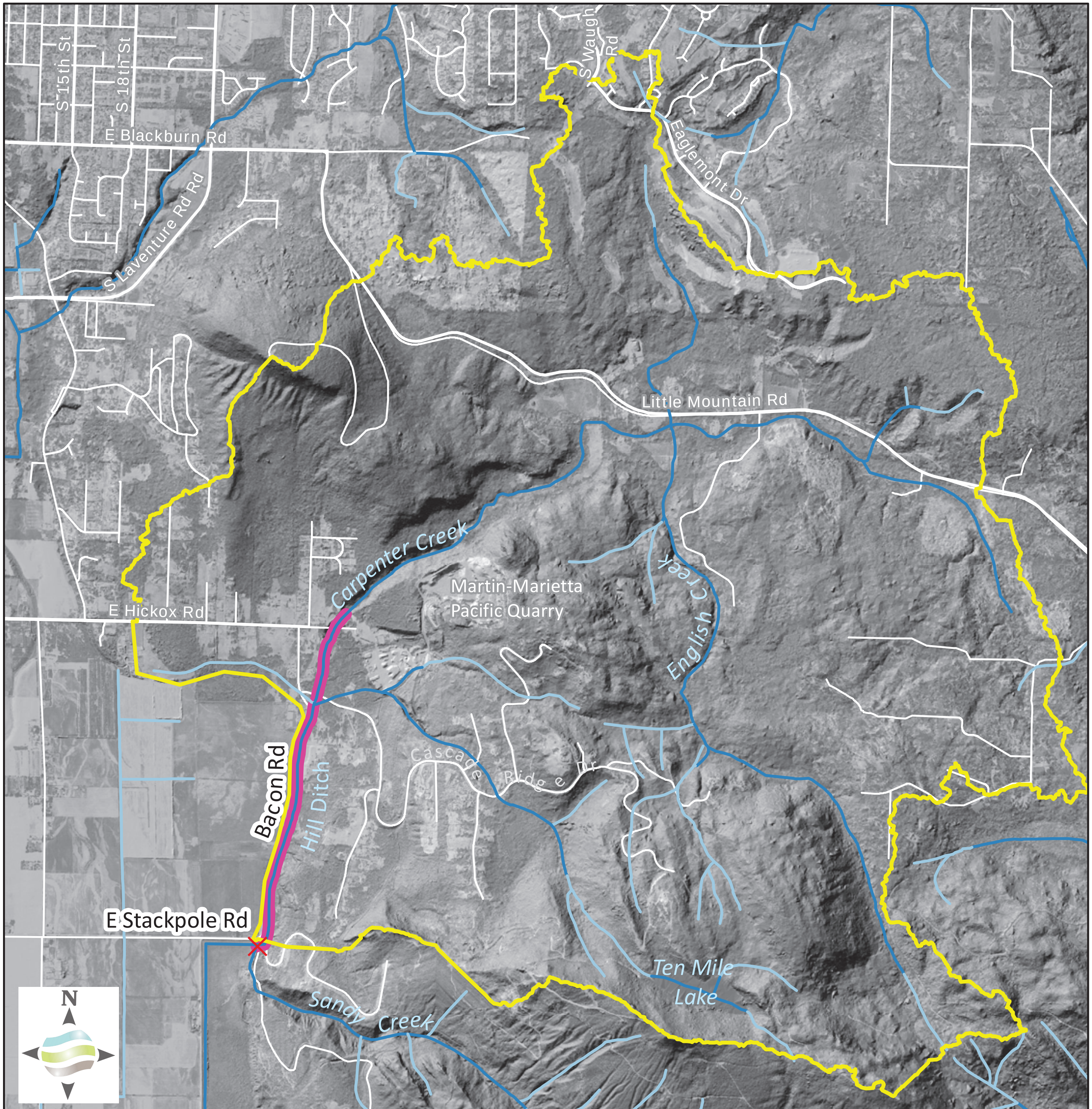
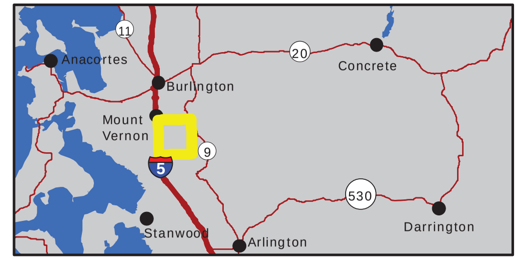
FIGURE 1

Hill Ditch Sediment Assessment
Site Vicinity Map

Date: 3/29/2019

Path: P:\Pse Project\2017177\ENVRMNT\GIS\Fig_1.mxd





Data Credits:
WA DNR 2005, 2016
USDA NAIP 2015
USGS 2006

Area Of Interest
Contributing Basin (Study Area)
Project Area

DNR Mapped Streams
Fishbearing
Non-Fishbearing

0 0.2 0.4 0.6 0.8 Miles

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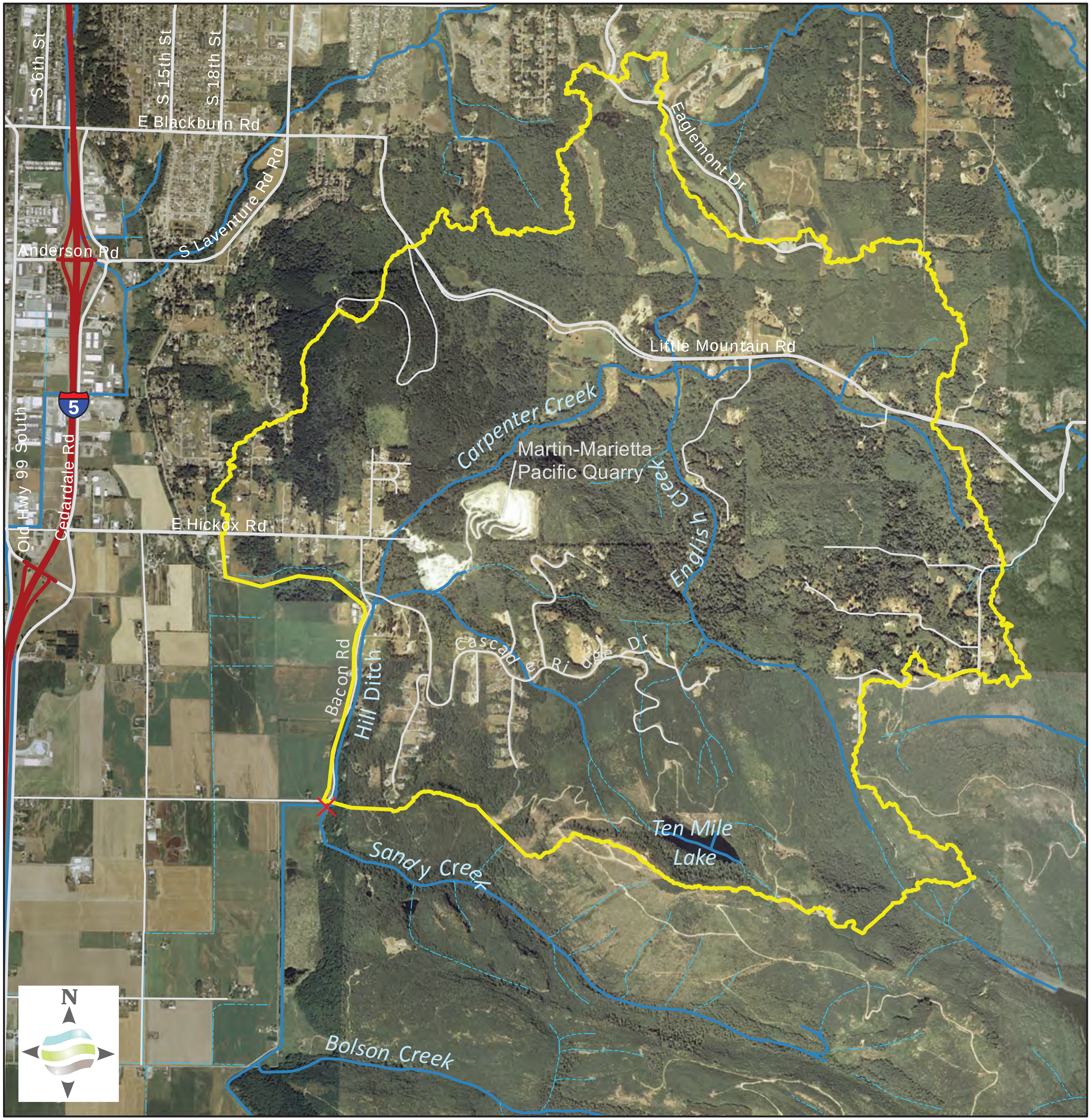
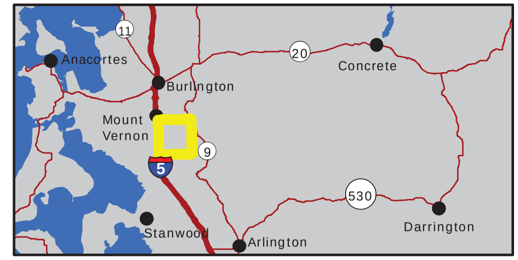
FIGURE 2

Hill Ditch Sediment Assessment
Project Reach

Date: 3/29/2019

Path: P:\Pse Project\2017177\ENVRMNT\GIS\Fig_2.mxd





Data Credits:
WA DNR 2005, 2016
USDA NAIP 2002

Area Of Interest
Contributing Basin
Roads

DNR Mapped Streams
Fishbearing
Non-Fishbearing

0 0.25 0.5 0.75 1 Miles

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FIGURE 3

Hill Ditch Sediment Assessment
2004 DOQ Imagery

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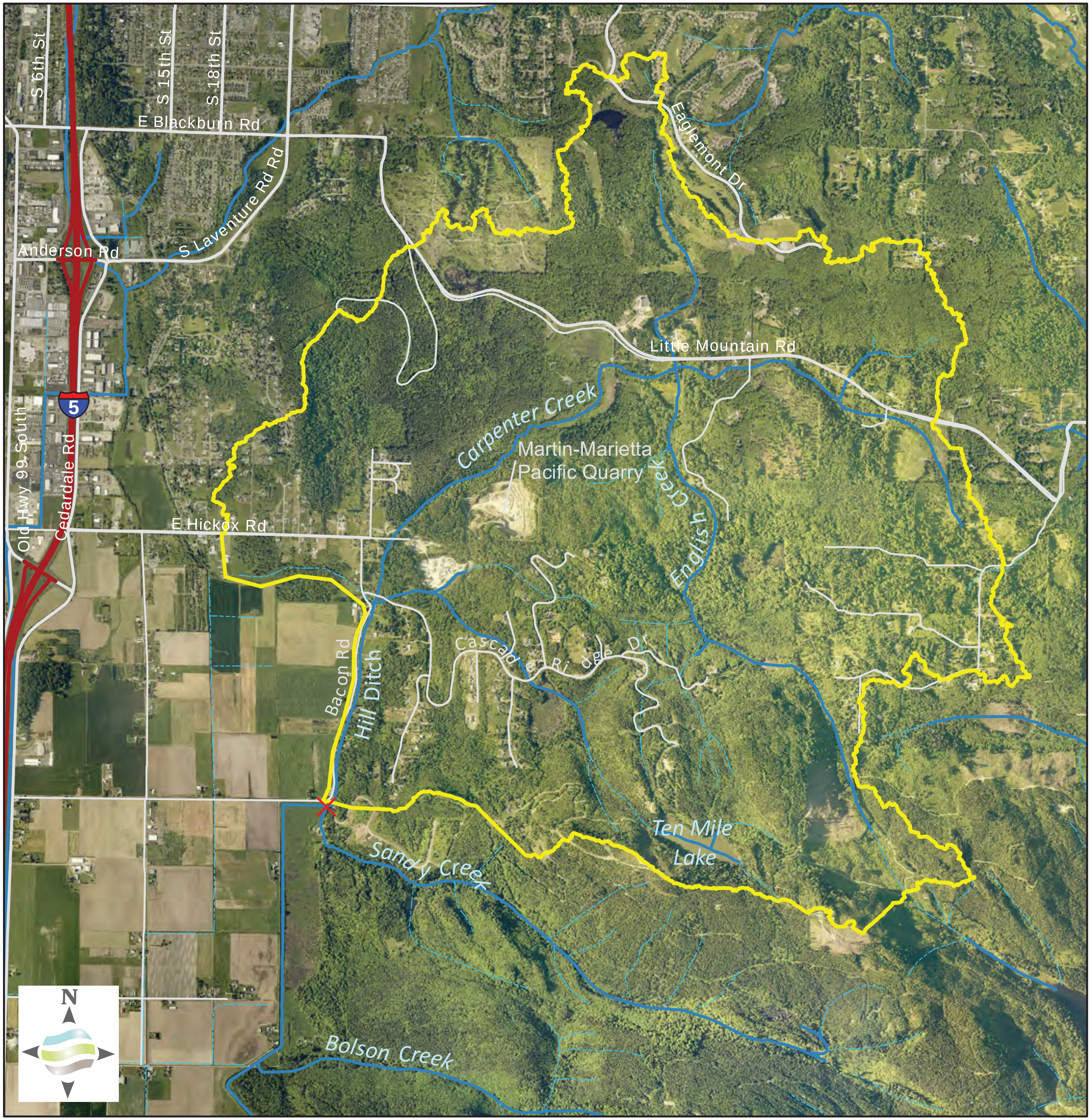

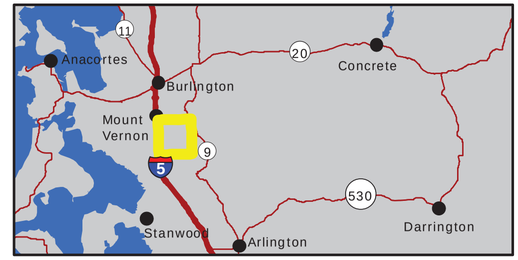

Data Credits:
WA DNR 2005, 2016
Pictometry International 2016

Area Of Interest
Contributing Basin
Roads

DNR Mapped Streams
Fishbearing
Non-Fishbearing

0 0.25 0.5 0.75 1 Miles

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FIGURE 4

Hill Ditch Sediment Assessment
2016 Aerial Imagery

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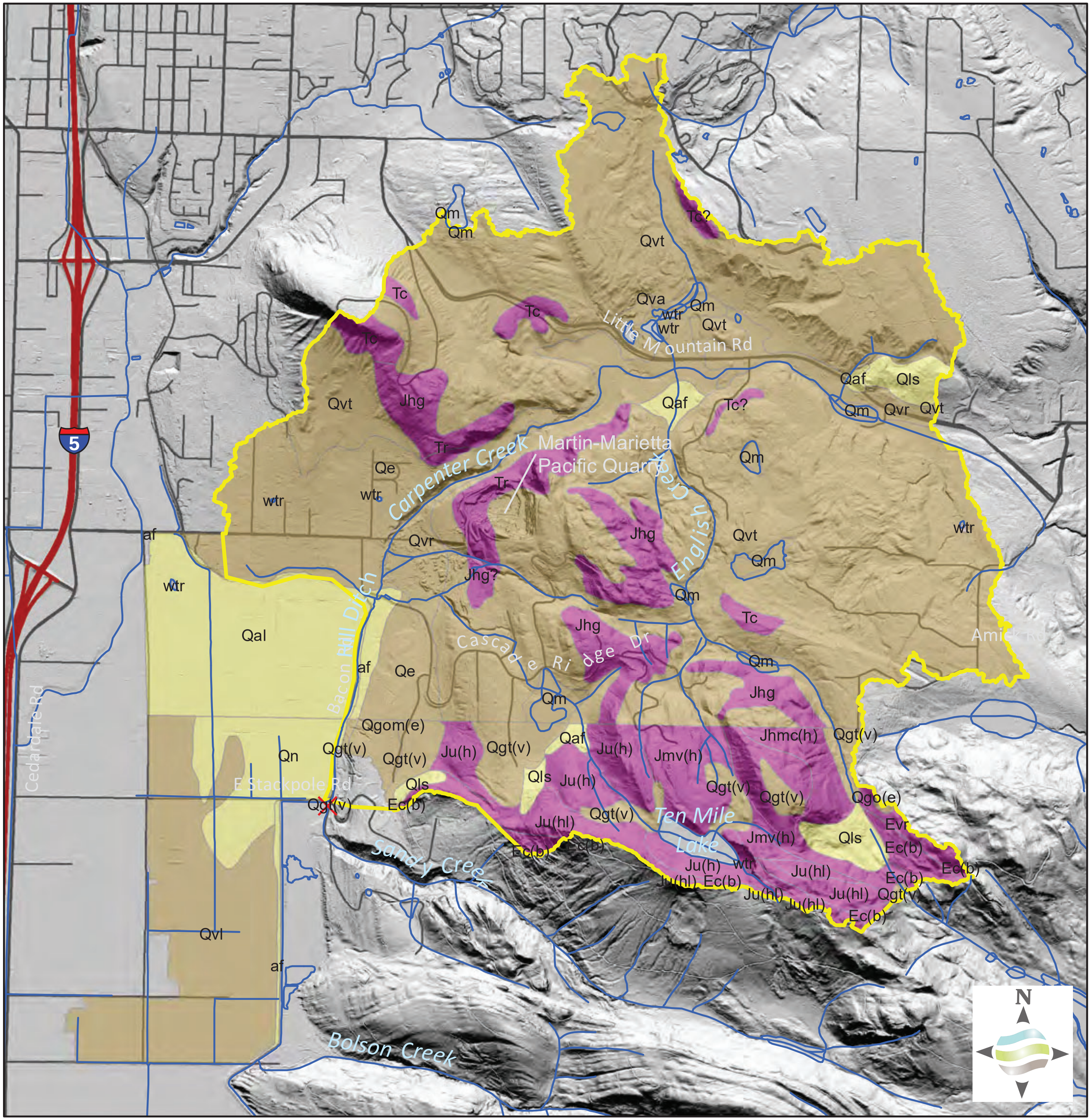

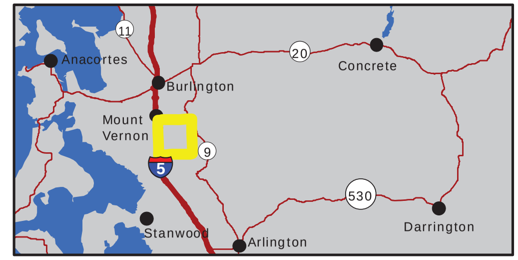

Data Credits:
WA DNR 2005, 2016
QSI, USGS 2017
WSDOT 2018

Area Of Interest
Mapped Streams (Skagit County Hydro-Arcs)
Contributing Basin
DNR Mapped Geology (1:24,000)
Bedrock Geology: Ec(b); Evr; Jhg; Jhg?; Jhmc(h); Jmv(h); Ju(h); Ju(hl); Tc; Tc?; Tr
Pleistocene Glacial Deposits: Qe; Qgo(e); Qgom(e); Qgt(v); Qm; Qva; Qvl; Qvr; Qvt
Holocene Sediments: Qal; Qaf; Qls; Qn; af
Interstate 5
Major Roads
Roads

0 0.25 0.5 1 Miles

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FIGURE 5

Hill Ditch Sediment Assessment
Geologic Conditions

Date: 3/29/2019

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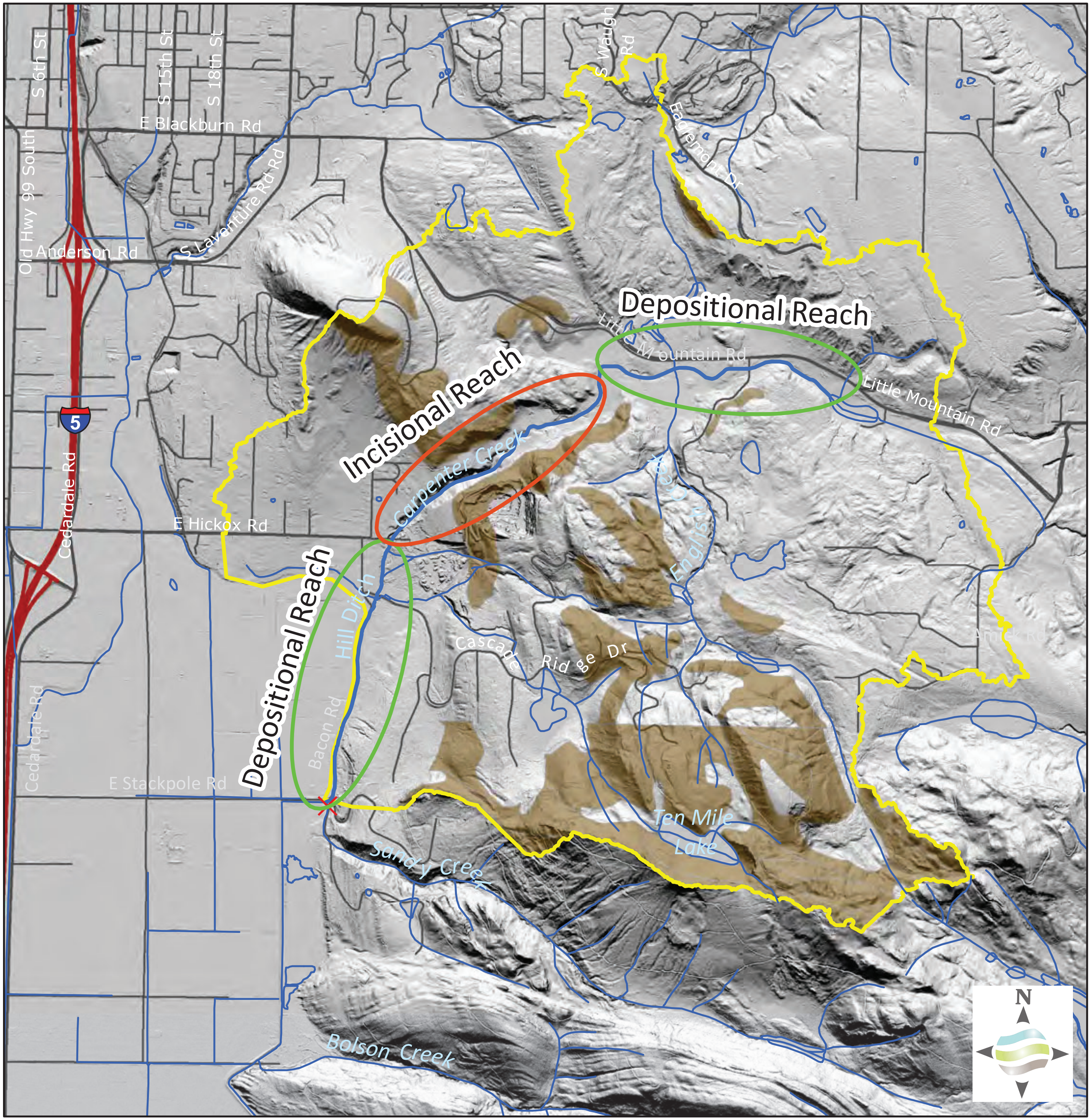

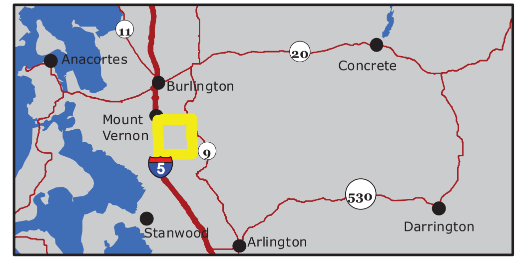

Data Credits:
WA DNR 2005, 2016
QSI, USGS 2017

Contributing Basin
Area Of Interest
Carpenter Creek
Skagit County Hydro-Arcs
DNR Mapped Geology (1:24,000)
Bedrock
Interstate 5
Roads

0 0.25 0.5 1 Miles

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FIGURE 6

Hill Ditch Sediment Assessment
Geomorphology

Date: 3/29/2019

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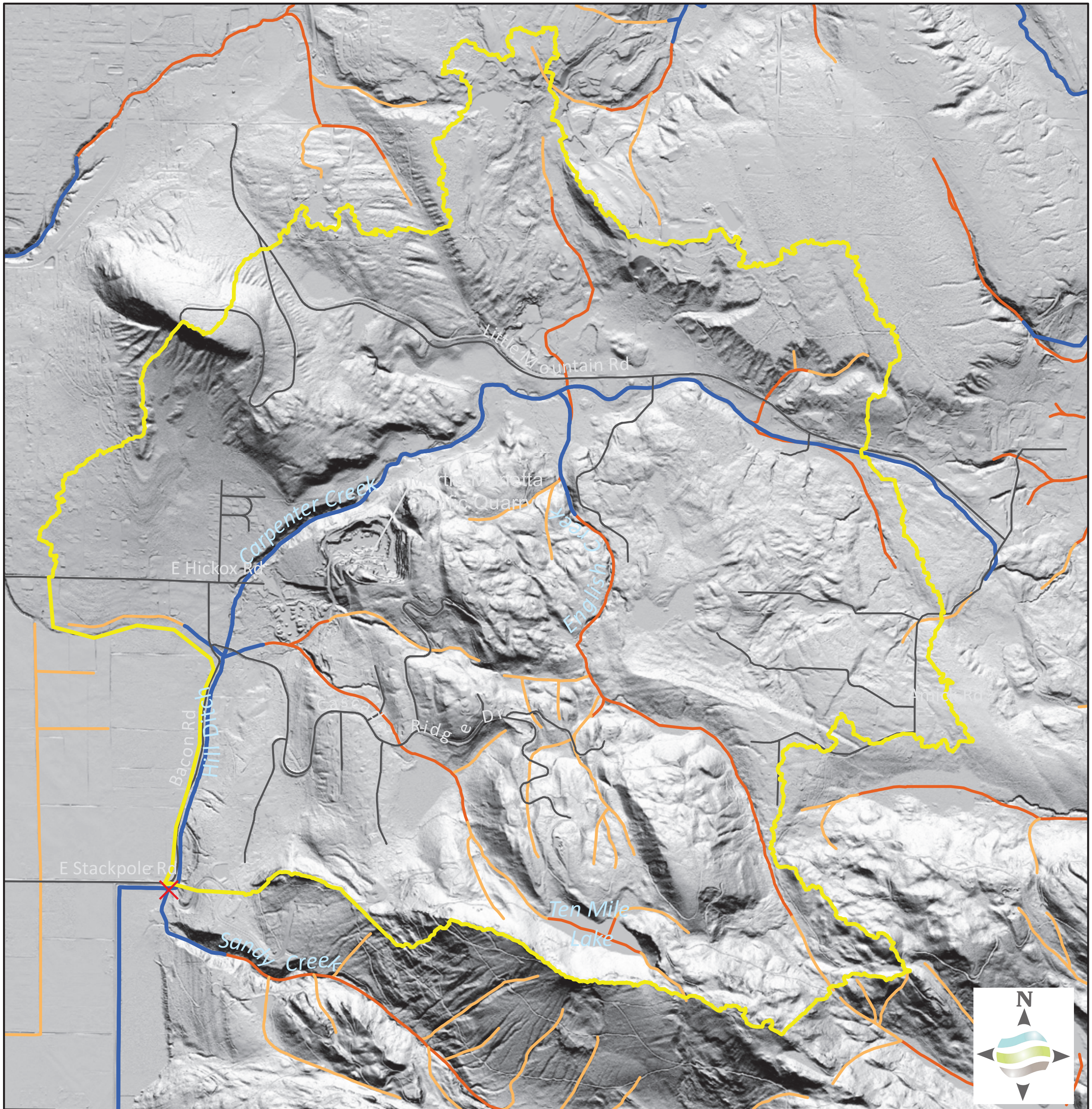

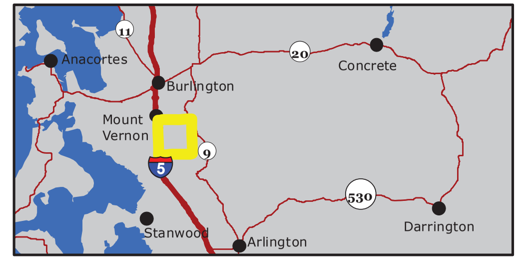

Data Credits:
WA DNR 2005, 2016
USDA NAIP 2017
QSI, USGS 2017
WDFW 2012

Area Of Interest
Contributing Basin
WDFW Fish Bearing Streams (2012)

DNR Mapped Streams (2005)
Fishbearing
Non-Fishbearing

Feet
0 1,000 2,000 3,000 4,000

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FIGURE 7

Hill Ditch Sediment Assessment
Documented Fish Use

Date: 3/29/2019

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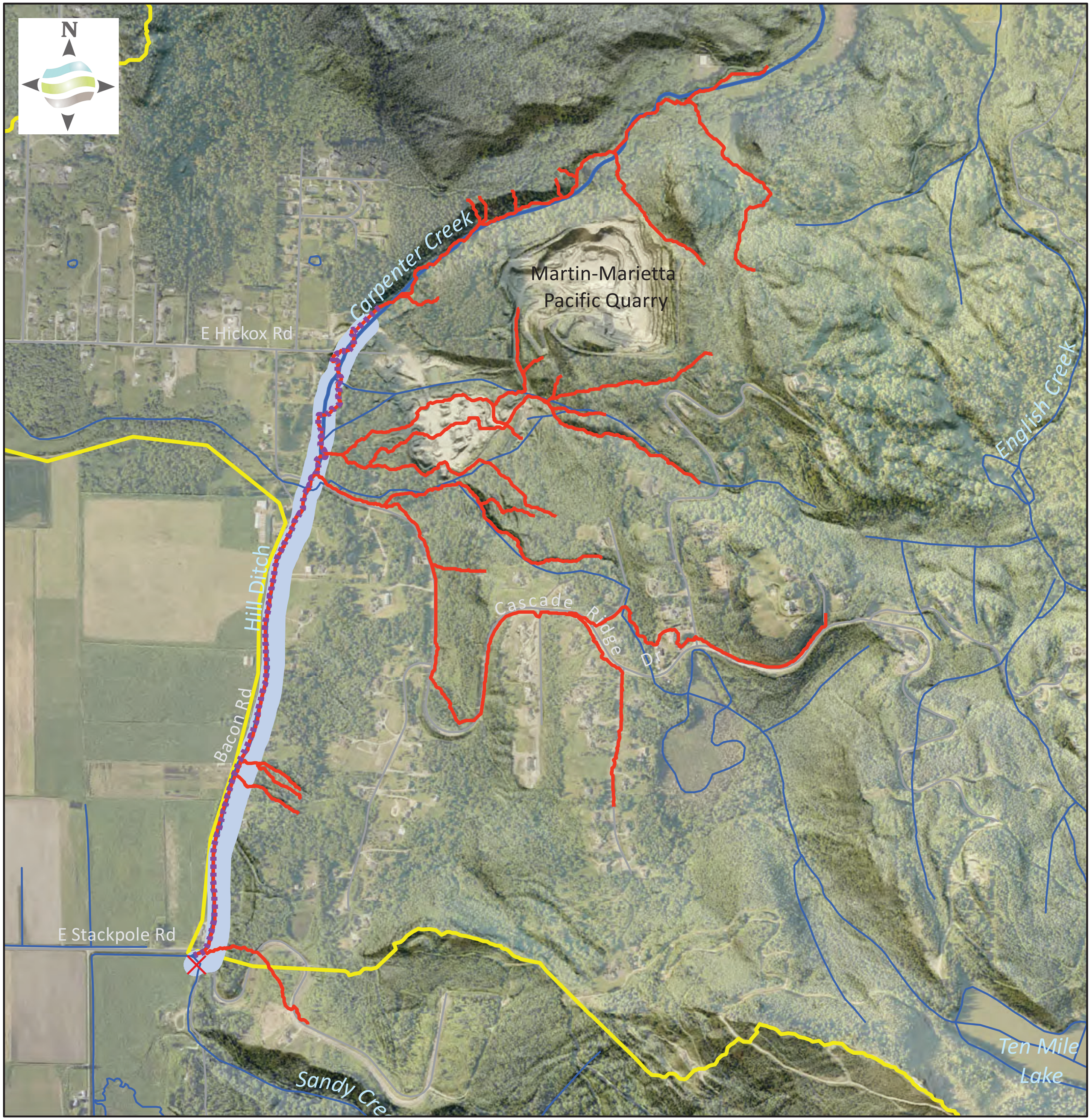

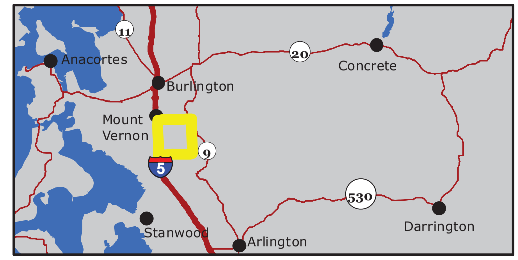

Data Credits:
WA DNR 2005, 2016
WDFW 2012
Skagit County 2017
QSI, USGS 2017

Project
Area Of Interest
Deposition and Management Issues
Primary Bedload Sediment Source and Transport
Mapped Streams (Skagit County Hydro-Arcs)
Carpenter Creek
Contributing Basin
Roads

0 550 1,100 2,200 Feet

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FIGURE 8

Hill Ditch Sediment Assessment
Primary Sediment Sources

Date: 3/29/2019

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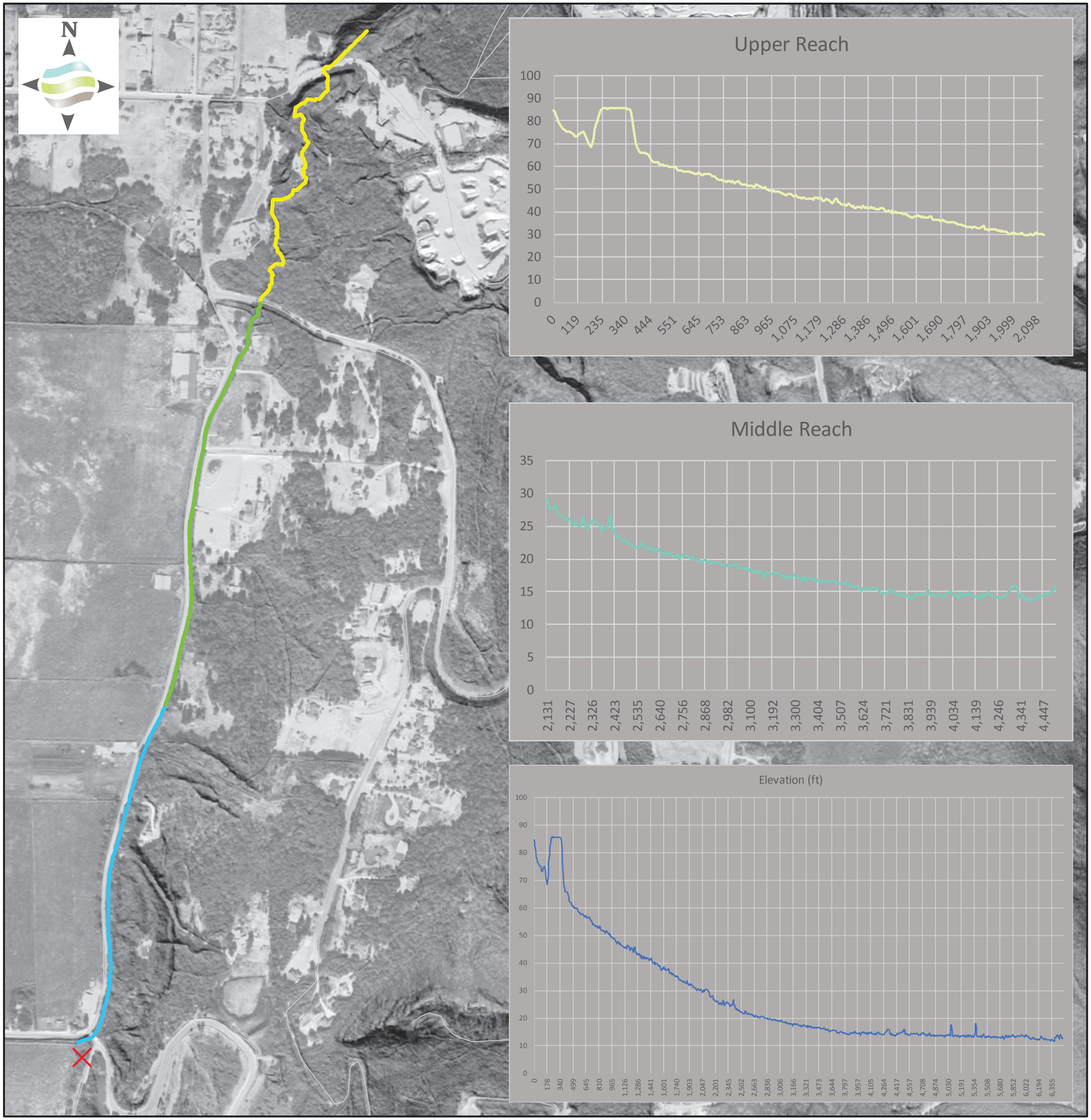

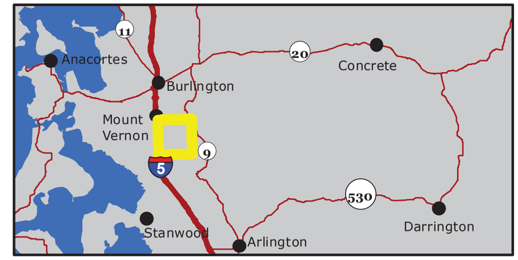

Data Credits:
QSI, USGS 2017
USDA NAIP 2017

Area Of Interest

Project Reach

Upper Segment

Middle Segment

Lower Segment

Feet

0 375 750 1,125 1,500

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FIGURE 9

Hill Ditch Sediment Assessment
Carpenter Creek Reach Profiles

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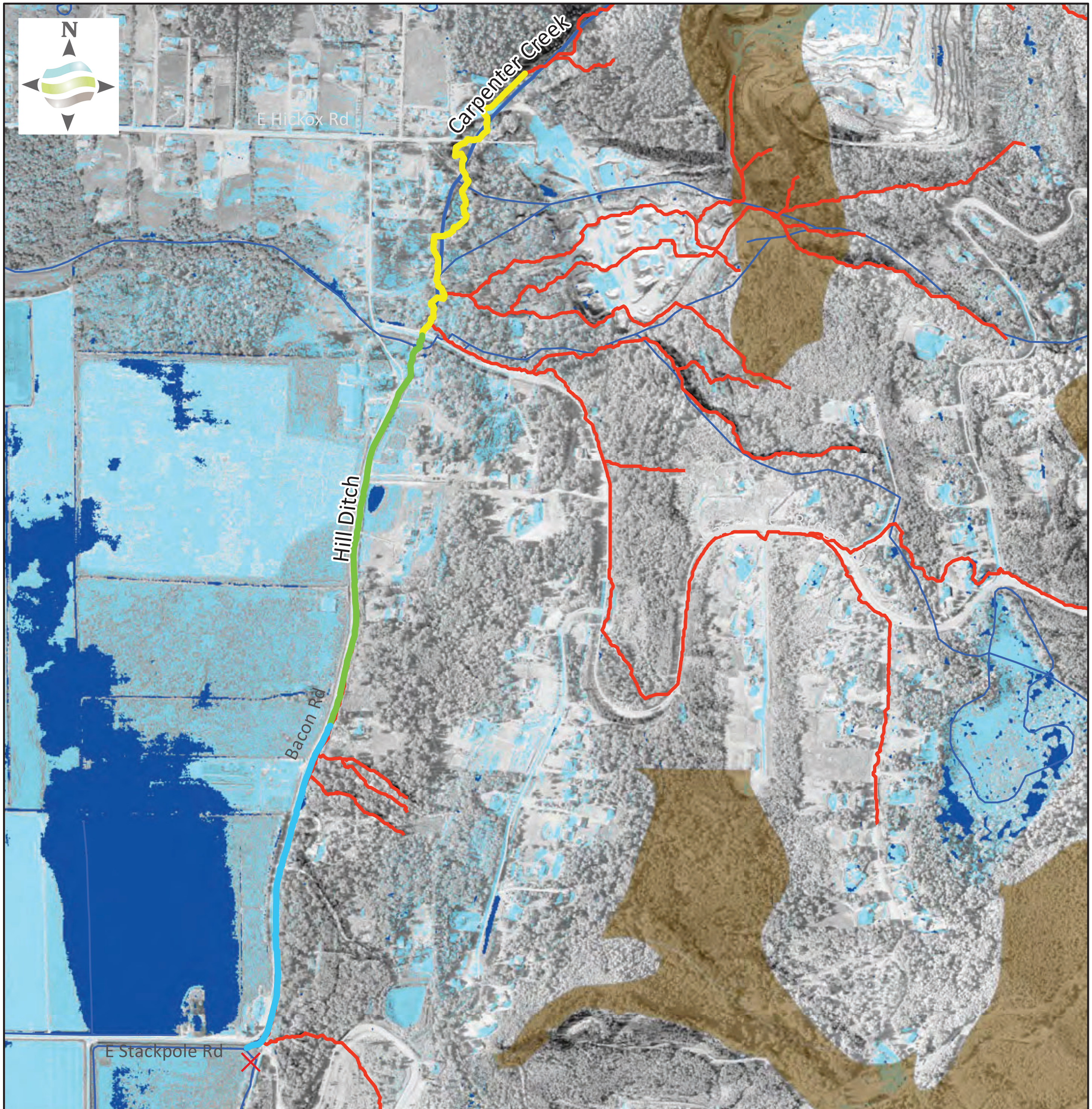

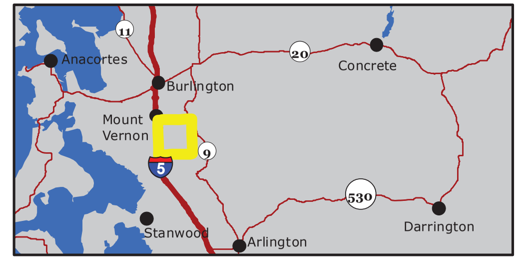

Data Credits:
WA DNR 2005, 2016
WDFW 2012
Skagit County 2017
QSI, USGS 2017

- Area Of Interest
- Upper Segment
- Middle Segment
- Lower Segment
- Primary Sediment Source and Transport
- Skagit County Hydro-Arcs
- Carpenter Creek

Topographic Sinks

- Basins and Sinks

Slope (% Grade)

- 0 - 4%
- > 4%

Miles: 0 0.05 0.1 0.2

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FIGURE 10

Hill Ditch Sediment Assessment
Slope and Sinks

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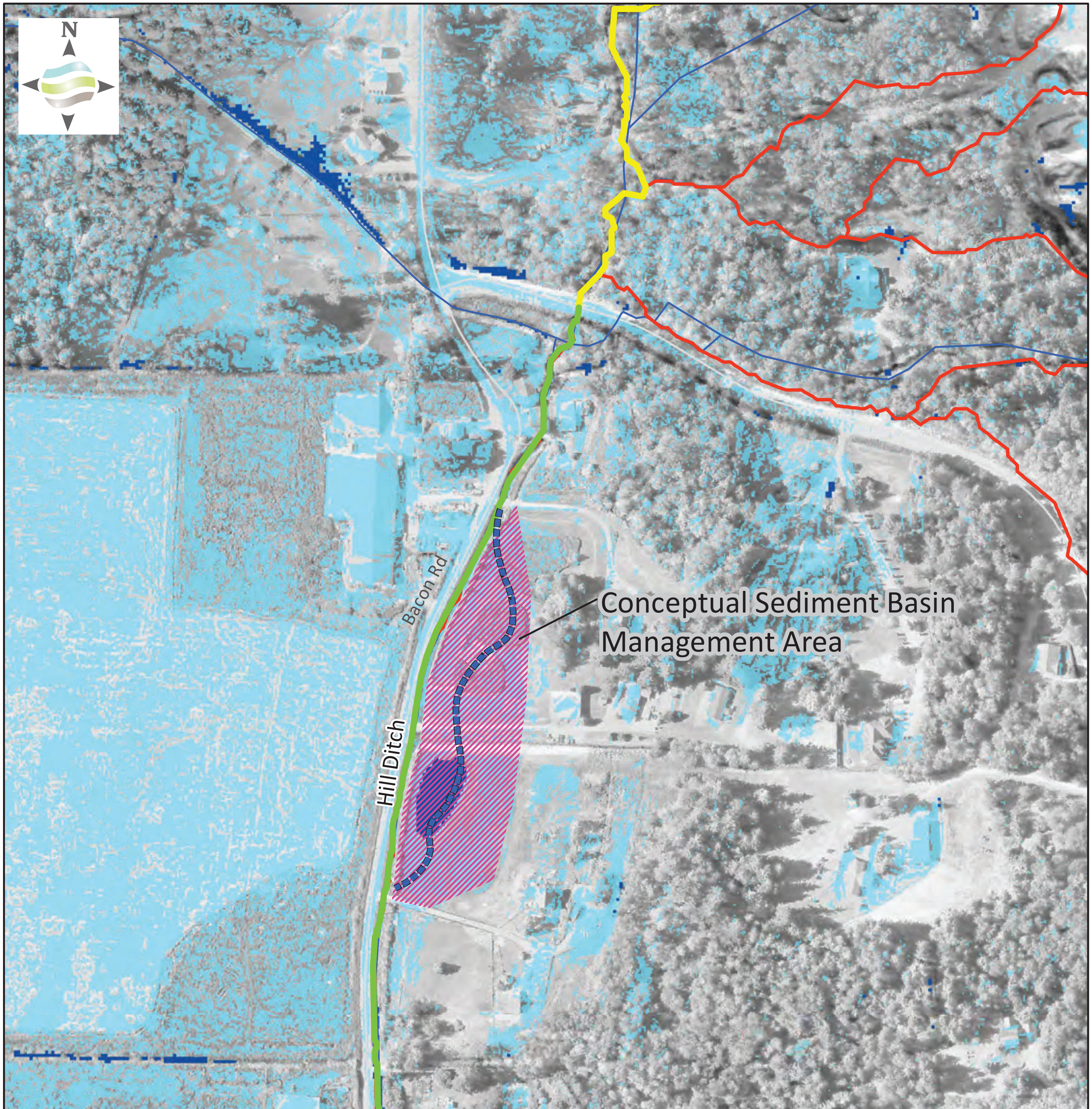

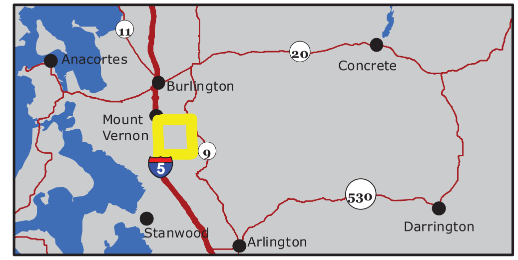

Data Credits:
WA DNR 2005, 2016
WDFW 2012
Skagit County 2017
QSI, USGS 2017

Area Of Interest
Upper Segment
Middle Segment
Lower Segment
Primary Sediment Source and Transport
Skagit County Hydro-Arcs

Topographic Sinks

Basins and Sinks

Slope (% Grade)

0 - 4%
> 4%

0 0.0225 0.045 0.09 Miles

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FIGURE 11

Hill Ditch Sediment Assessment
Conceptual Sediment
Management Area

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