HANSEN CREEK WATERSHED MANAGEMENT PLAN

Prepared by

Miller Consulting

With

Watershed Professionals Network

For

Skagit County Public Works Department
Surface Water Management

September 2002

HANSEN CREEK WATERSHED MANAGEMENT PLAN

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SUMMARY

The Hansen Creek Watershed Management Plan (Plan) is a concept plan. The Plan identifies the issues and problems associated with the Hansen Creek watershed and provides a range of possible solutions, each with associated costs and benefits. Specific details remain to be worked out during final design.

The Plan was initiated by Skagit County to determine a means to decrease flooding and improve fish habitat on Hansen Creek and its tributaries. The Plan stemmed from an agreement between Skagit County and the Washington Department of Fish and Wildlife to initiate a long-term management plan in exchange for a permit allowing a maintenance dredging of Hansen Creek for flood control in 1998. In 1999 Skagit County obtained a grant from the Governor's Salmon Recovery Office and in turn hired Miller Consulting and representatives from Watershed Professional Networks to complete the study.

The Problem

Flooding associated with Hansen Creek is mostly attributable to: 1) large amounts of sediment from the creek's headwaters filling in the creek channel caused by landslides stemming from both logging practices and naturally unstable bedrock, and 2) the channelization of a historic alluvial fan caused by past dredging practices. This combination causes sediment to deposit downstream of areas where it would naturally. Historically, the creek has been dredged for flood control; however, this has proven to be an ineffective long-term solution. Additionally, costs associated with dredging have increased yearly while permits for dredging activities have become harder to obtain. Long-term dredging north of Highway 20 through the wetlands on Northern State Recreation Area (NSRA) has resulted in the creek's thalweg (main channel) becoming raised above the level of the surrounding ground and contained within dredge spoils that act as small dikes, allowing little opportunity for surface water to drain back into the creek during flood events. From the wetland boundary north to the first terrace, dredging has caused downcutting through an alluvial fan separating the fan from the creek. In addition to the impacts listed above, dredging has had various negative impacts to fish habitat, such as destabilization of the streambed, removal of woody debris, hydro-modification, and overall simplification of habitat. Thus it was determined early in the study that gravel control within the system was key to the success of the project.

Historically, the Hansen Creek Watershed (Watershed) was utilized by large numbers of several salmon species, including Puget Sound Chinook, and Bull Trout, both currently listed as "threatened" under the Endangered Species Act. The Watershed still supports salmon runs; however the runs are greatly reduced from historic numbers. This is in part due to degraded fish habitat in Hansen creek and the associated tributaries. Habitat issues include: lack of woody debris and associated pools for refuge, lack of sufficient riparian cover to provide shade and forage material, increased sediment load that smothers eggs and alevin within the creek gravel, and a decreased floodplain wetland area.

Project Goals

By identifying the issues facing Hansen Creek as discussed above, the following project goals were established:

1. Correct current sediment deposition problems;
2. Reduce flooding on properties downstream of SR 20;
3. Enhance fish habitat within Hansen Creek and its tributaries; and
4. Balance this plan with the Northern State Recreation Area development objectives.

Each alternative stemming from these project goals was evaluated based on several criteria: a cost/benefit analysis of construction and maintenance costs, increase in habitat values, biological response to changes, ability to be self-sustaining/maintaining, political will, community support, and funding opportunities.

Study Process

Developing a plan for the Hansen Creek Watershed required the following tasks:

1. Individual reaches were designated within the watershed;
2. Reaches were identified by distinct geographic and/or physical boundaries (terraces, state highways, etc.);
3. Each reach was designated as an area to either provide sediment storage, flood protection, enhanced fish habitat, or a combination of any or all of the three;
4. Alternatives designed to achieve these goals were developed and assessed within each reach.

Many of the alternatives for improving fish habitat or decreasing flooding were mutually beneficial. The Plan was developed to balance passive and active recreation activities proposed for the Northern State Recreation Area with the project goals of reducing flooding and increasing habitat values.

Recommended Plan

Six reaches are located within the study area. A suite of alternatives have been developed for each reach representing possible solutions, with varying benefits and costs, meeting one or more of the project goals. Alternatives are discussed in detail in the main body of the report and in Appendix 1 – Alternatives Analysis. Figure S-1, located at the end of this summary, presents a graphic of the Recommended Plan.

Specific benefits of the Recommended Plan include: significant flood reduction between Highway 20 and Minkler Road, over 100 years of ultimate sediment storage, 112 acres of new or enhanced wetlands, 6,800 feet of new creek length, and almost 24,000 feet of enhanced creek length.

Once constructed and established over approximately a 20-year period, the Recommended Plan will require minimal maintenance, other than an initial "maintenance dredging" of the recommended alluvial fan approximately after 100 years and subsequently every 50 years thereafter. The following actions are recommended within each reach:

Reach 1: The goals for this reach are to provide sediment storage and enhance habitat values. At the northern section of Reach 1 it is recommended to replace the 16-foot culvert under Hansen Creek Road. This road and surrounding development is located on the upper alluvial fan. The culvert is a constriction to the alluvial fan and has caused downcutting in the creek upstream of the culvert. The Northwood Lane Bridge is recommended for replacement as well as the acquisition of property located along and around the historic channel through this area. Reach 1 recommendations on the Northern State Recreation Area (NSRA) include removal of various roads or road culverts, the existing sediment pond and upper NSRA bridge, relocation of a tributary into its historic channel and restoration of the floodplain, riparian areas and buffers. Reconnection of the creek to its floodplain will allow for natural processes to resume, additional sediment storage, increased side channel rearing areas for fish, and restoration of the riparian area.

Reach 2: The goals for this reach are to provide sediment storage and enhance habitat values. Recommendations include removal of the bridge at the south end of the reach, regrading bridge approaches, excavating select portions of adjacent creek bank, and restoration of riparian functions. Reconnection of the creek to its floodplain will allow for natural processes to resume, additional sediment storage, increased side channel rearing areas for fish, and restoration of the riparian area.

Reach 3: Restoration of a medium sized alluvial fan of approximately 80-acres is recommended in Reach 3. Literally the structural keystone of this Plan, the alluvial fan is designed to capture sediment in the area it historically occurred. Sediment deposited on the fan will reduce the size and amount of sediment transported and deposited downstream eliminating the progressively worsening flooding problem and associated maintenance dredging experienced south of Highway 20. Sediment deposition on the fan will also encourage deposition and habitat regeneration in the incised creek reaches upstream. Key elements considered in the sizing of the alluvial fan were level of flood protection provided to downstream property owners, sustainability and maintenance intervals and associated costs, area encompassed by the alluvial fan, basal diameter of the trees that develop on the fan over time, and their ability to be recruited as woody debris into the stream, and the ability to balance the needs at the Northern State Recreation Area for active ball fields and recreation facilities. See Figure S-2 at the end of this summary.

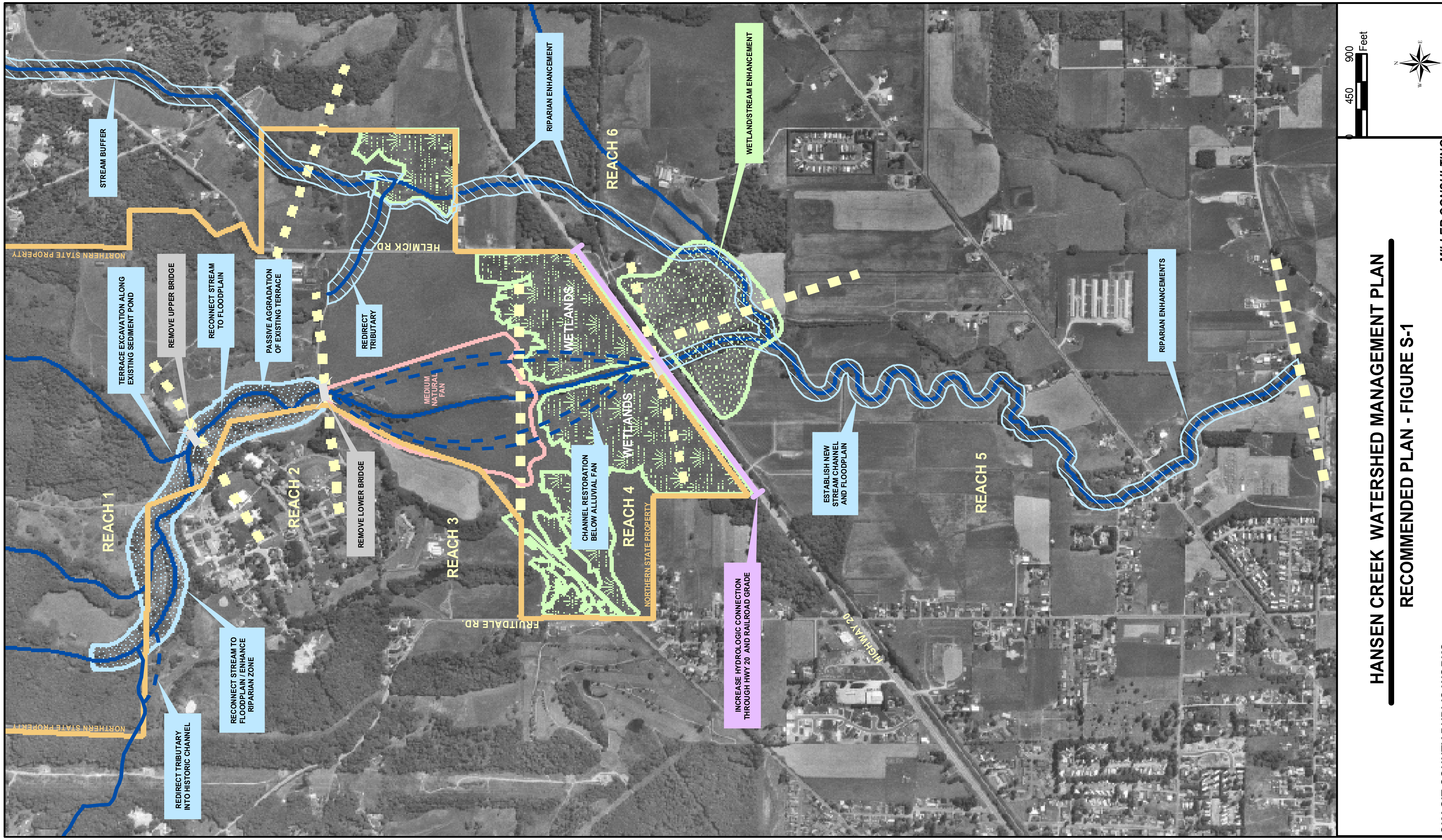
Reach 4: This wetlands area encompasses the southernmost portion of the NSRA between the alluvial fan and Highway 20 and was once part of a much greater historic wetlands complex. The goal for this reach is to enhance fish habitat. To do so involves reconnection of wetlands to the creek to provide rearing habitat for juvenile salmonids, reconnection of the historic alluvial fan to the wetlands complex to restore natural interactions between the alluvial fan and wetlands complex, improvement in the quality and diversity of wetlands, and reintroduction of native plant species typically found in this type of wetland. Most work associated with restoration of the floodplain wetlands will occur in the areas designated as wetlands or wetland buffers in the Northern State Recreational Area Wetlands Delineation.

Reach 5: This reach begins at Highway 20 and extends south to Minkler Road. The goals for this reach are to reduce flooding to private property owners and enhance fish habitat. A number of alternatives were developed focusing on three main areas: the crossing under Highway 20, re-connection of Hansen Creek's floodplain and associated wetlands, and creation of a more diverse creek channel.

Due to concerns raised by private property owners located within Reach 5, the Plan does not provide a preferred alternative for this reach. Rather, a suite of alternatives is presented, including both work within the existing stream corridor and potential relocation of Hansen Creek. In addition, a preferred alternative is not presented for the crossing at Highway 20, as it was determined that this area will require additional design consideration following discussions related to the crossing with the Washington State Department of Transportation and property owners adjacent to the highway.

Reach 6: Red Creek, a tributary to Hansen Creek, flows through the section of the NSRA located to the east of Helmick Road. Goals for this reach are to improve habitat and reduce flooding. The recommendation for Red Creek in the NSRA largely involves fencing the wetland boundary, riparian enhancements such as adding riparian plantings and creation of a larger floodplain area. South of the NSRA, recommended actions include placing conservation easements along the creek, buyout or lease of private properties for wetlands enhancement, planting of riparian buffers, removal or redesign of blocking culverts and removal of a flap-gate located at the confluence of Hansen and Red Creeks. The "Dairy Tributaries" are two small tributaries located immediately west of Helmick Road that drain out of the terrace onto the NSRA. These tributaries drain into a creek/roadside ditch that currently runs along the west side of Helmick Road and across into Red Creek via a road culvert. It should be noted that this creek/roadside ditch has been categorized by the Washington State Department of Fish and Wildlife as a type 3 stream and thus has 100' associated buffers. The recommended action is to reroute the tributaries under Helmick Road and connect them with Red Creek.

In total, the individual actions of the Recommended Plan utilize physical characteristics of each reach to reestablish processes disrupted decades ago when the historic alluvial fan was channelized, the downstream channel was straightened, and catastrophic landsliding in the upper watershed delivered excess sediment to the system. Simply put, the economy of this Plan is based upon restoring much of the creek system to its historical condition. Once restored, the creek system will heal and maintain itself resulting in reduced flooding and healthier fish and wildlife populations. It should also be noted that the Recommended Plan is compatible with the Northern State Recreation Area Conceptual Site Plan.


HANSEN CREEK WATERSHED MANAGEMENT PLAN
RECOMMENDED PLAN - FIGURE S-1
MILLER CONSULTING
SKAGIT COUNTY PUBLIC WORKS
APRIL 2002
0
450
900
Feet
STREAM BUFFER
TERRACE EXCAVATION ALONG EXISTING SEDIMENT POND
REMOVE UPPER BRIDGE
RECONNECT STREAM TO FLOODPLAIN
PASSIVE AGGRADATION OF EXISTING TERRACE
REDIRECT TRIBUTARY
REMOVE LOWER BRIDGE
RECONNECT STREAM TO FLOODPLAIN / ENHANCE RIPARIAN ZONE
REDIRECT TRIBUTARY INTO HISTORIC CHANNEL
RIPARIAN ENHANCEMENT
WETLAND/STREAM ENHANCEMENT
CHANNEL RESTORATION BELOW ALLUVIAL FAN
INCREASE HYDROLOGIC CONNECTION THROUGH HWY 20 AND RAILROAD GRADE
ESTABLISH NEW STREAM CHANNEL AND FLOODPLAIN
RIPARIAN ENHANCEMENTS
MEDIUM NATURAL FAN
WETLANDS
WETLANDS
REACH 1
REACH 2
REACH 3
REACH 4
REACH 5
REACH 6
HELMICK RD
FRUITDALE RD.
HIGHWAY 20
NORTHERN STATE PROPERTY
NORTHERN STATE PROPERTY
NORTHERN STATE PROPERTY

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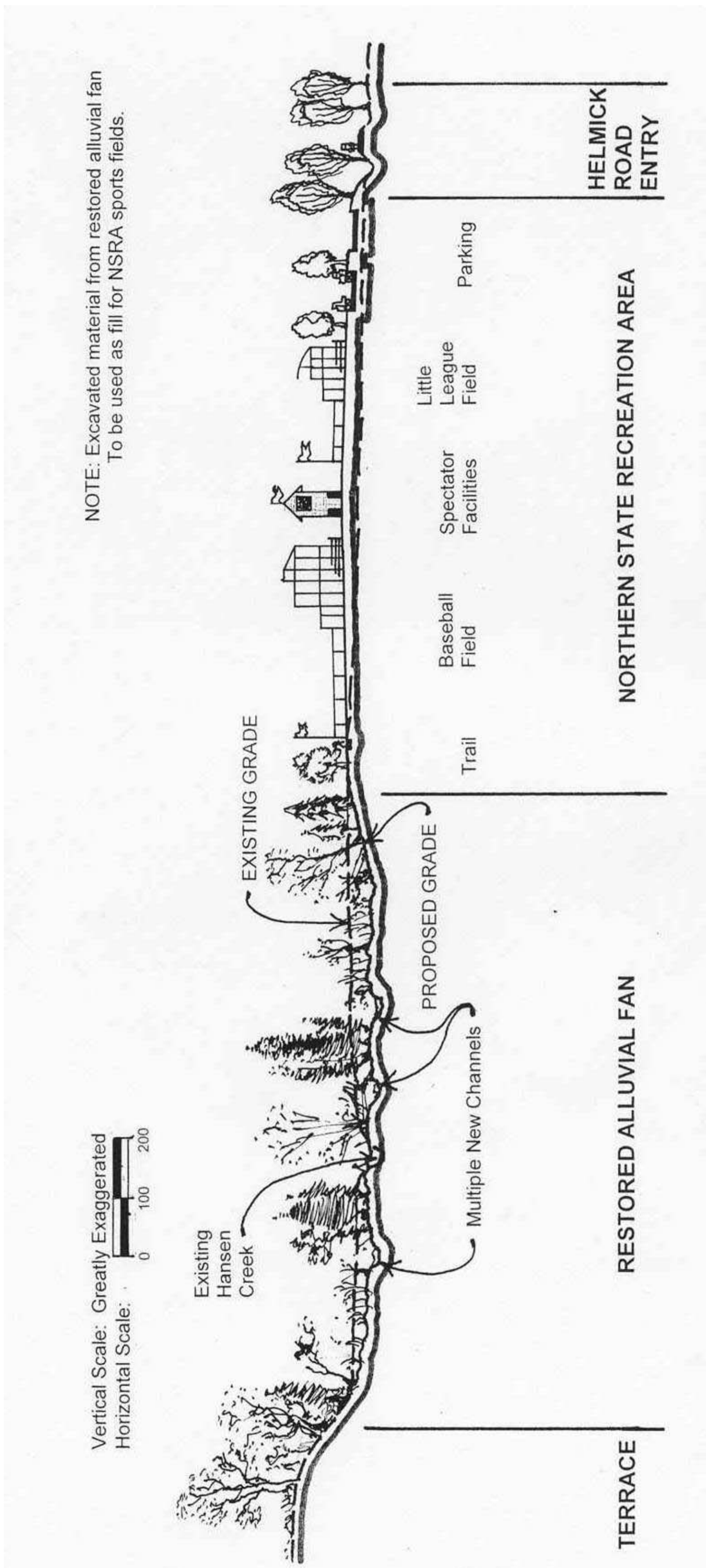

FIGURE S-2 – TYPICAL SECTION THROUGH RESTORED ALLUVIAL FAN AND NORTHERN STATE RECREATION AREA FACILITIES

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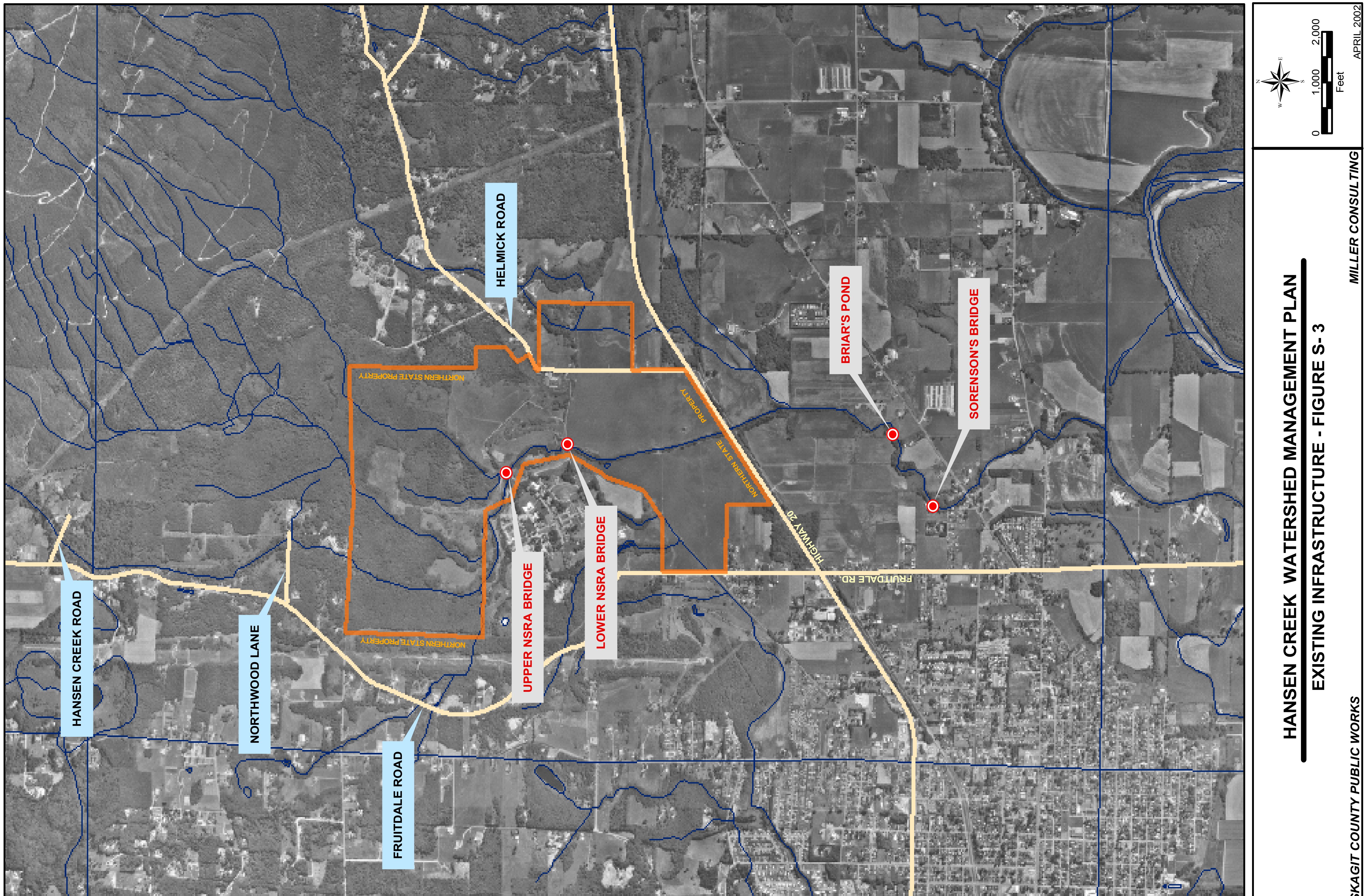
HELMICK ROAD
BRIAR'S POND
SORENSON'S BRIDGE
NORTHERN STATE PROPERTY
NORTHERN STATE PROPERTY
UPPER NSRA BRIDGE
LOWER NSRA BRIDGE
HIGHWAY 20
FRUITDALE RD
HANSEN CREEK ROAD
NORTHWOOD LANE
FRUITDALE ROAD
0
1,000
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APRIL 2002
HANSEN CREEK WATERSHED MANAGEMENT PLAN
EXISTING INFRASTRUCTURE - FIGURE S- 3
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SKAGIT COUNTY PUBLIC WORKS

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HANSEN CREEK WATERSHED MANAGEMENT PLAN

1.0 INTRODUCTION

1.1 Need and Background

The Hansen Creek Watershed Management Plan was developed to balance flood reduction measures with habitat restoration within the Hansen Creek Watershed. Historic flood control measures, mainly creek dredging and channel straightening, have had harmful effects on the habitat and associated fish populations of Hansen Creek. In addition, dredging has created sediment and flooding problems further downstream. Permits for maintenance activities have become difficult to obtain and in some cases, costs of mitigation have almost equaled costs of maintenance activities. In 1999, the Washington Department of Fish and Wildlife permitted a maintenance dredging of Hansen Creek with the condition that the county develop a long-term, cost-effective solution to address the fish habitat and flood concerns related to Hansen Creek.

A portion of Hansen Creek and several of its tributaries run through the Northern State property, operated as a state psychiatric hospital from 1910 to 1973. In 1991, Skagit County purchased 726 acres of the Northern State property for the purpose of establishing a public recreational facility, now known as the Northern State Recreation Area (NSRA). Historically, the Northern State Hospital modified the reach of the creek above the alluvial fan through armoring streambanks, rerouting tributaries, and adding culverts and bridges. Following the dredging and straightening of the creek through the alluvial fan, the lands along Hansen Creek below the terrace to Highway 20 were utilized for agricultural purposes. In later years, this land was allocated to cattle that grazed the grasslands and had unrestricted access to wetlands and the creek. A master plan has been developed for the NSRA that includes development of a ball field complex, multi-use event center, outdoor riding arena, trails, camping facilities, and an environmental education center. Therefore, one goal of the Plan is to balance flood reduction activities and habitat restoration with the development of outdoor recreation facilities at the NSRA.

Skagit County Surface Water Management applied for and received an early action grant from the Governor's Salmon Recovery Office to initiate the Hansen Creek Watershed Management Plan. Miller Consulting and Watershed Professionals Network (WPN) were hired to aid with group facilitation, complete a sediment transport study, develop and assess alternatives for restoration, recommend a preferred alternative, and draft a final report detailing the findings.

1.2 Purpose of the Plan

Historically, sediment was transported from Hansen Creek's headwaters and deposited on floodplains and alluvial fans. Since the beginning of the 20th century, the natural balance and processes of Hansen Creek and its watershed have been disrupted through human activity. The creek has responded to these disruptions by transporting sediment where it once deposited it, and depositing sediment where it once transported it. This change in sediment processing has resulted in a cycle of flood events not compatible with current land use patterns.

In short, the issues that need to be addressed and corrected are sediment instability, flooding and habitat destruction. The overall purpose of this Plan is therefore to correct current sediment problems, reduce flooding and increase habitat values. It is believed that the most practical, economical and long-term solution to these issues is a comprehensive restoration of the creek and the re-emergence of its natural processes. This approach will not only address the current sediment and flooding problems, but it will significantly restore, enhance, and increase the creek's in-stream and riparian habitat.

The Management Plan:

- Analyzes the existing condition of the creek and watershed,
- Determines the mechanisms leading to sediment transport and deposition, flooding and habitat destruction,
- Develops a list of conceptual design alternatives to address these issues,
- Analyzes the design alternatives to determine their effectiveness
- Compares and prioritizes the alternatives, and
- Recommends a preferred set of actions.

1.3 Level of Analysis and Design

Conceptual designs have been developed for a variety of possible alternatives. The analysis of each alternative was purposely limited in detail and depth, intended to provide an overview of options and assess their feasibility to determine which alternatives warrant further review. The recommended actions in this report will require more detailed analyses during final design. A list of "Considerations for Final Design and Implementation" (Section 7.0) is included at the end of this report to direct and help facilitate future efforts to implement the Plan.

1.4 Planning Process

The process for developing the management plan consisted of eight major tasks. (Figure 1.1 – Planning Process). The tasks were:

Task 1.0 Compile and Review Available Information

Existing information, including maps, air photos, past project information and reports, was gathered and reviewed. The information included historic and current land uses, fish use, geomorphic conditions, sediment and creek geomorphology, hydrologic conditions, and creek discharges for the watershed and Hansen and Red Creeks. Historic conditions, past projects and previous designs were reviewed.

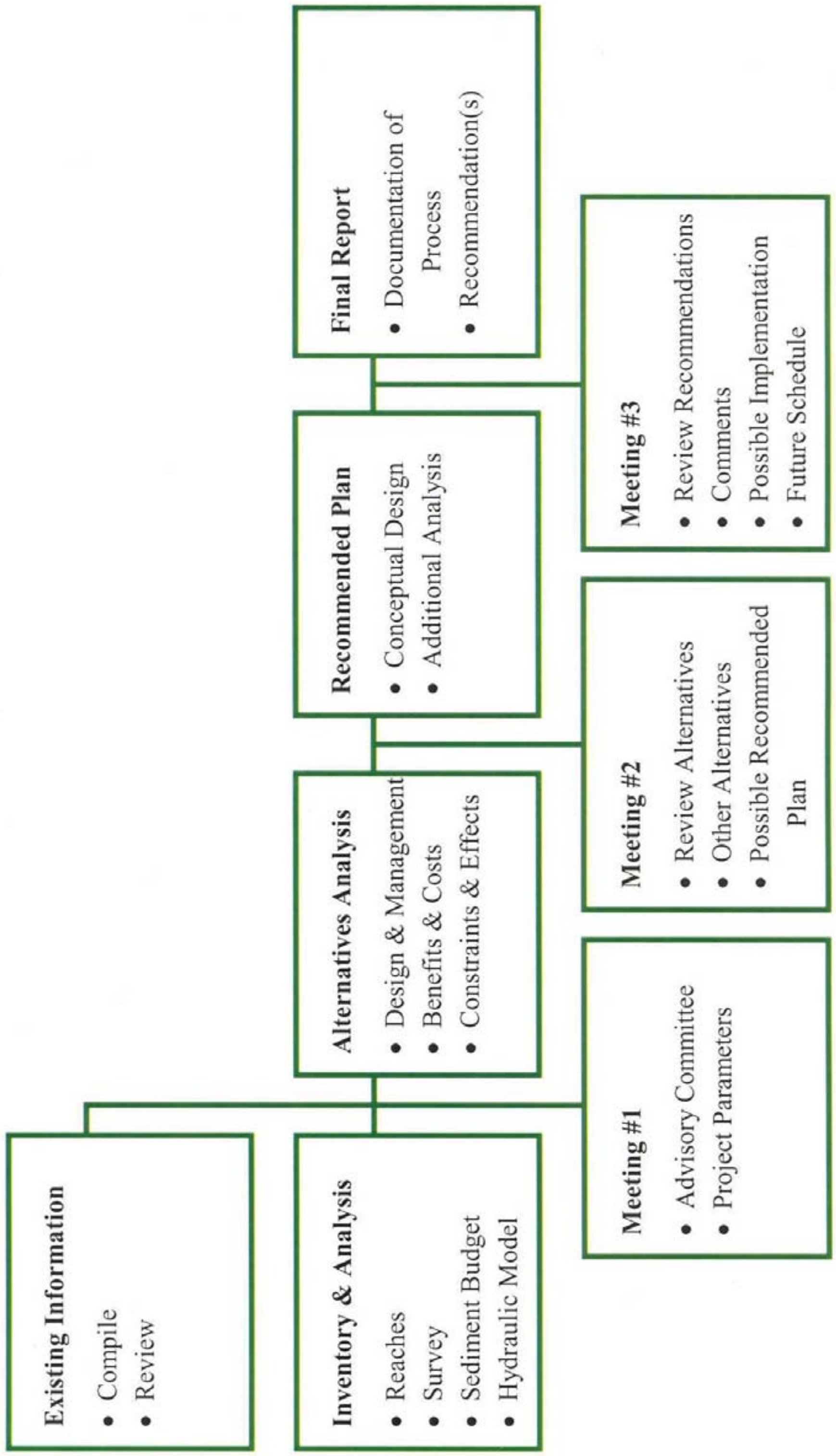
Task 2.0 Meeting 1 - Create Advisory Committee/ Refine Plan

An Advisory Committee was established to review tasks and products, provide historic prospective, give direction and advice, and support the planning process and

Figure 1.1

Hansen Creek Watershed Management Plan

Project Process



consultant team. The Committee was made up of local property owners (including the Hansen Creek Sub-flood Control Zone), representatives from local and state agencies, the Northern State Task Force, Crown Pacific, and Skagit River Tribes. At their first meeting, the Advisory Committee developed a list of desired results and reviewed a range of generic solutions that could address their issues.

Task 3.0 Inventory and Analysis of Data

Information was assembled on current and historic watershed characteristics, land use activities, and habitat conditions. For the purpose of this study, the creek was divided into six reaches, based upon topography and existing physical constraints in the system. Opportunities within each reach to maximize habitat values and fish use were developed. Topographic cross-sections were located and surveyed for each reach. Sediment samples were gathered along with measurements of the creek and creek channel, bridges, levees, and floodgates. A sediment budget was calculated including routing, gravel attrition, dredging volumes, and deposition rates. A hydraulic model of existing conditions was created to assess alternatives along the study reaches.

Task 4.0 Alternative Analysis

The Project Team developed a variety of alternatives to address this project's goals of sediment management, flood reduction, and habitat enhancement. The benefits, as they relate to these project goals, were quantified for each considered alternative. Construction quantities and cost estimates were also calculated for each alternative. A comparative analysis of each alternative was then performed to determine the relative cost effectiveness of the considered alternative.

Task 5.0 Meeting 2 - Review Alternatives

A second meeting was held with the Advisory Committee to present an understanding of historic, existing and future watershed, creek and habitat conditions. The agenda included discussion of past successful and failed Hansen Creek projects, potential design and management alternatives, associated opportunities for meeting the project goals, constraints to implementation, and analysis results. Discussions about the configuration of a recommended conceptual design provided direction to the Project Team.

Task 6.0 Recommended Plan

The Design Team developed a recommended alternative from information gathered from the second Advisory Committee Meeting, an alternative analysis, and the NRSA Planning Charette. A Draft Report, detailing process and results, was prepared and distributed for review and comment.

Task 7.0 Meeting 3 - Review Plan and Strategize Implementation.

A third meeting was held with the Advisory Committee to present the recommended plan and discuss implementation and scheduling. Comments on the Draft Report were received and reviewed.

Task 8.0 Final Report

This final Report, including maps, sketches, and supporting data, was completed to document the planning process, alternative analysis and recommended plan.

1.5 Report Format

This report is arranged into eight major sections. Following this Introduction, the subsequent sections discuss Site Location, History and Description of the landscape; Analysis Overview; Design Approach and Considerations; Alternative Analysis; the Recommended Plan; Considerations for Final Design; and Implementation; and References. Several appendices hold more detailed information on: Alternatives Analysis, Hydrology, Stream Hydraulics, Sediment Budget and Fluvial Morphology, Habitat Considerations, Construction Quantities and Costs, and Hansen Creek Watershed Potential: Historic Habitat and Vegetation Zones.

2.0 SITE LOCATION, HISTORY AND DESCRIPTION

2.1 Watershed Overview

The Hansen Creek watershed is located north and east of the City of Sedro Woolley, in Skagit County, Washington (Figure 2.1). The drainage area is approximately 11.8-mi^2, with approximately 7 miles of stream length accessible to anadromous fish and an additional 2.9 miles of accessible length in associated tributaries. Elevations within the watershed range from 40 feet above sea level at the confluence with the Skagit River to almost 4050 feet on Lyman Hill. Hansen Creek's watershed has three distinct geologic/geomorphic regions that are described below.

2.1.1 Upper Watershed – Current Conditions

The upper 1/3 of the Hansen Creek Watershed is dominated by moderate to steep slopes (20% to more than 70%) and is underlain by friable (unstable) phyllite, a weak metamorphic rock. This upper region is predominately forested and largely under private ownership (Crown Pacific) with some Washington State Department of Natural Resources (DNR) in holdings. Elevations in this region range from 400-ft to 4050-ft at the top of Lyman Hill. Stream channels have gradients ranging from about 8% to more than 20%, and are typically deeply incised with steep, unstable inner gorges (Beechie and Wyman, 1999).

Unstable bedrock throughout the upper watershed results in a naturally high rate of sediment production from landslides. About half the sediment delivered to streams since about 1940 originated from landslides occurring in undisturbed, mature forest. Road building and timber harvest in steep inner gorges have increased the amount of landslide activity. The worst period of landslide activity was in the 1940s and early 1950s, following initial clear-cut logging and partial burning of the watershed in the 1930s. Landslide activity was minimal in the 1960s and 1970s. Most of the more recent landslide activity occurred during the 1983 and 1990 winter storms. Boulders and large cobbles from landslides in this steep upper third of the watershed have

HANSEN CREEK WATERSHED MANAGEMENT PLAN

HANSEN CREEK WATERSHED BOUNDARIES - FIGURE 2.1

SKAGIT COUNTY PUBLIC WORKS *WATERSHED BOUNDARY* *MILLER CONSULTING*

0 500 1,000 Feet

OCT. 2001

deposited in a large alluvial fan at the base of the steep mountain front (Figure 2.2). This upper alluvial fan appears to be functioning fairly well: collecting larger sediments, and allowing smaller sediments to continue downstream.

The creek in this upper region of the watershed was not identified as an area suitable for improvements because it:

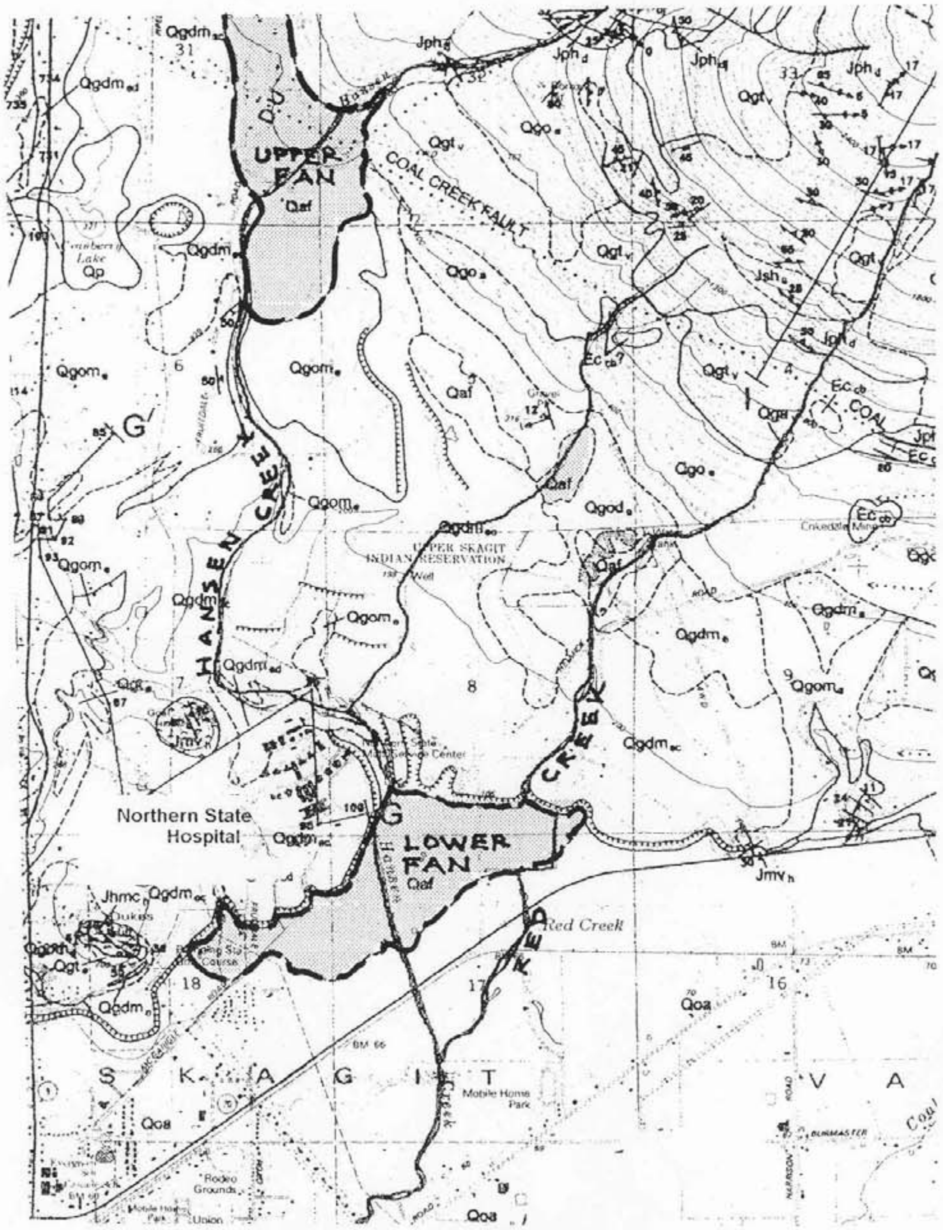
- Is largely under private ownership,
- Logging activities are no longer contributing excessive amounts of sediment into Hansen Creek. The forests and roads in this area are currently managed by applicable laws and practices,
- Has naturally high erosion rates,
- Has relatively limited fish spawning habitat, and
- Appears to be functioning adequately with respect to sediment deposition and transport.

2.1.2 Middle Watershed – Current Conditions

The middle 1/3 of the watershed is comprised of low terrace landforms underlain by glacial lake clays and outwash sands and gravels. This middle region is predominately forested and under private ownership except for Northern State property, under State and County ownership, and the Upper Skagit Indian Reservation located on Red Creek. Elevations in this area range from about 80-ft to 400-ft. Stream channel gradients are between 1.5% and 5%, and are accessible to anadromous fish.

Moderately sized sediments (sands, gravels, and small cobbles) from the upper 2/3rds of the watershed were historically deposited in an alluvial fan where the creek entered the Skagit River floodplain. This lower alluvial fan is located on the Northern State property (Figure 2.2). A straight, narrow channel through the lower fan was established prior to 1948, presumably to increase drainage of adjacent wetlands to make the meadow suitable for agriculture. This straightened, and hence steeper channel downcut through the alluvial fan and continues to downcut up to the northern bridge at Northern State. This modified channel efficiently transports sediment through the now inactive fan, depositing it in the flatter channel reaches downstream where it aggravates flooding.

A sediment pond was constructed upstream of the most northern bridge on the NSRA crossing Hansen Creek in an effort to capture sediment before it could cause flooding problems downstream. The pond was constructed by Skagit County in 1992 and has been dredged approximately every other year. Between dredgings, the pond has filled up and passed sediment downstream. During times when the pond has functioned to trap sediment, the relatively sediment free water exiting the pond has caused about 3-ft of channel degradation downstream. It is believed that this degradation scoured the footings of the two Northern State bridges over the creek and assisted in deepening the channel through the historic alluvial fan. It is likely that this degradation undercut the sediment pond's sheet piling enough to cause it to



Alluvial fans are shown in grey with the symbol Qaf.

Source: Geologic Map of the Sedro-Wooley North and Lyman 7.5-minute Quadrangles, Western Skagit County, Washington. Dragovich et al., 1999. Washington DNR, OFR 99-3.

SKAGIT COUNTY SURFACE WATER MANAGEMENT	HANSEN CREEK WATERSHED MANAGEMENT PLAN	N W E S
MILLER CONSULTING with WATERSHED PROFESSIONALS NETWORK	ALLUVIAL FANS Figure 2.2	

bend. Sediment eroding from the degrading channel and the sediment pond, as well as sediment passed through the pond when it was full, was conveyed downstream where it was redeposited in the creek bed and aggravated flooding. Thus, while the pond, when properly functioning, has been somewhat effective in trapping sediment, it has also caused downstream scour and sediment transport.

The creek and its tributaries in the middle region of the watershed upstream of the Northern State property were not identified as an area suitable for significant improvements because it:

- Appears to be functioning adequately with respect to sediment deposition and transport, and
- Currently contains the most productive fish-spawning habitat within the watershed.

Several alternatives are suggested north of the Northern State property. However, pursuit of these alternatives will require more detailed investigation.

The creek from the upstream Northern States property boundary downstream to the southern end of the historic alluvial fan was identified as an area suitable for significant improvements because:

- It is under state and/or county ownership,
- It has experienced moderate to severe degradation,
- It is both vertically and laterally unstable,
- Scour has occurred around the footings of both bridges within this reach.
- Historic floodplains have become vertically detached from the channel and subsequently exhibit diminished hydraulic (flood control) and habitat function,
- It has the physical potential to capture sediment if the historic alluvial fan is reactivated. This, in turn, will reduce the sediment transport downstream and the flooding it causes,
- It historically provided very productive fish habitat, and
- The reach between the two bridges has the potential to be restored to a productive fish spawning reach.

2.1.3 Lower Watershed – Current Conditions

The lower 1/3 of the watershed is primarily on the Skagit River floodplain and contains some areas of low terraces. Elevations range from about 40-ft to 80-ft. Only the main-stem of Hansen Creek and Red Creek traverse this region of the watershed. These channels have low gradients of less than 1.5% and historically meandered through a large wetland as mapped on an 1878 Ordinance Survey Map. Refer to Section 2.3 – Historic Watershed Conditions.

A floodgate at the mouth of Red Creek inhibits upstream fish passage. Aside from the northern portion of this lower watershed the land is in private ownership and land uses are primarily agricultural and residential. The sands and gravels transported through the now inactive alluvial fan are deposited in Hansen Creek between Highway 20 and Minkler Road. Sediment deposition in this area has aggravated flooding and subsequently been the catalyst for decades of channel straightening, dredging and levee construction. Downstream of Minkler Road, fine sands and silts are generally conveyed in suspension down into the Skagit River and cause no significant deposition or flooding concerns.

The portion of the lower watershed from the downstream end of the lower alluvial fan to Minkler Road was identified as an area suitable for improvements because it:

- Currently captures most of the sediment from upstream, causing severe flooding on private properties,
- Historically provided over 30% of anadromous fish production in the watershed, and currently fish habitat is deteriorated as a result of channel straightening, frequent sediment deposition and dredging,
- Has the potential to be enhanced in a manner that will significantly reduce flooding while reconnecting wetlands and increasing and enhancing fish spawning and rearing habitat, and
- It is destined to fill in with sediment, flood more frequently and severely, and experience extensive property damage if changes to the system are not made.

The creek downstream of Minkler Road was not identified as an area requiring significant improvements because sands and silts in this reach are generally conveyed in suspension to the Skagit River and cause no significant deposition or flooding concerns. This reach would benefit from habitat-enhancement projects including installation of riparian buffers

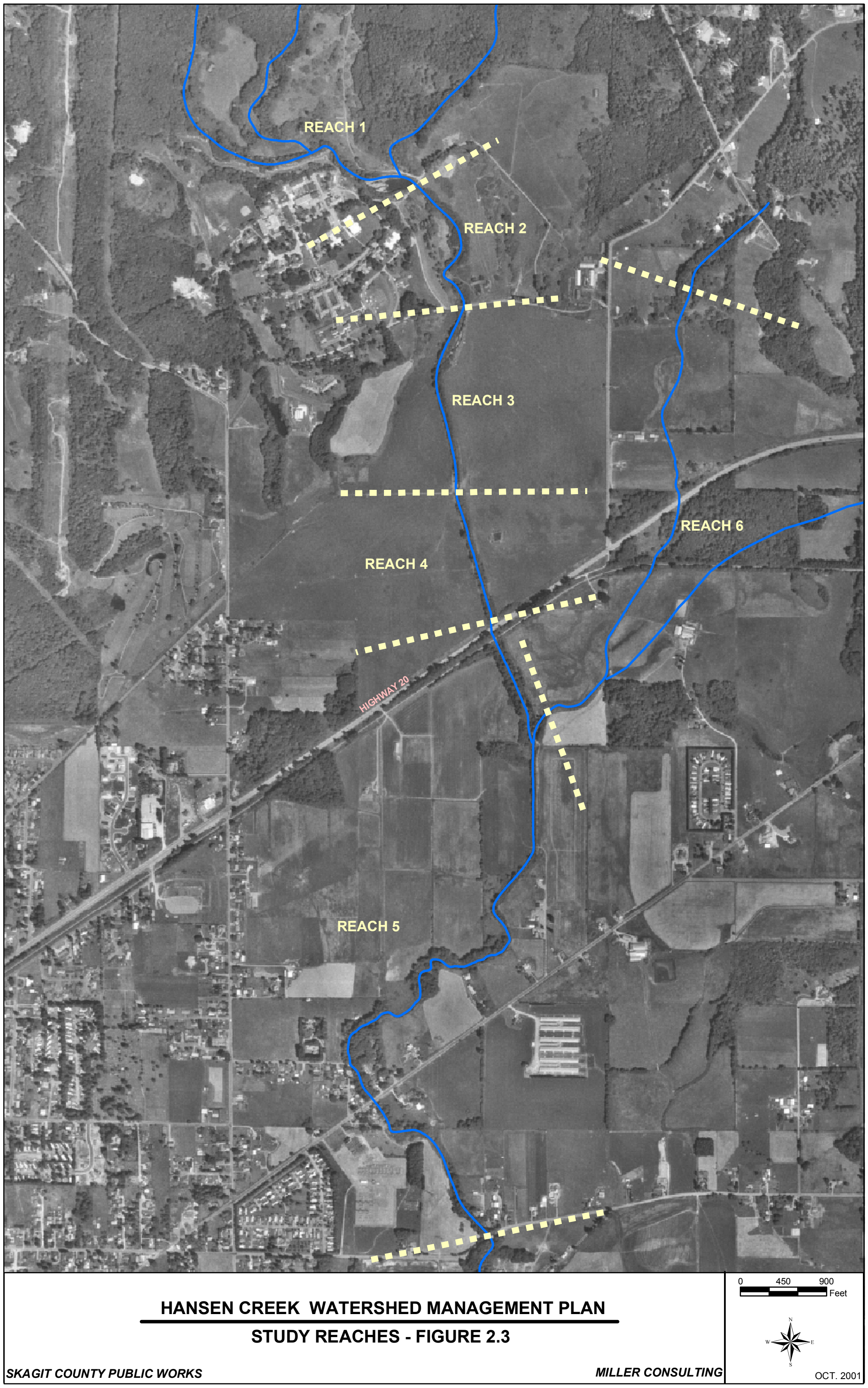
2.2 Study Area and Reach Identification

The project study area encompassed the entire Hansen Creek watershed, but most of the prescribed restoration activities are focused from the northern boundary of the NSRA south to the Minkler Road crossing and include alternatives for both Hansen and Red Creeks. Possible restoration activities on portions of the creek beyond these focused project limits are briefly discussed in Section 7.0 of this report.

The Hansen Creek Study Area encompasses six (6) different areas or reaches, each with its own set of distinctive traits and characteristics. Accordingly, different goals were determined and distinct solutions developed for each reach. These reaches are briefly described below and identified on Figure 2.3.

2.2.1 Reach 1: Upstream of Sediment Pond

Reach 1 is defined as Hansen Creek and its tributaries upstream of the existing sediment pond at the upper bridge on the Northern State property. The upper parts of this reach are relatively intact. Middle and lower parts of Hansen Creek in this reach have become incised through the installation of “LWD hardening” as part of attempted restoration projects, the use of a series of check dams, bank hardening via rip-rap and wood cribbing, and channel straightening. Riparian vegetation is



HANSEN CREEK WATERSHED MANAGEMENT PLAN

STUDY REACHES - FIGURE 2.3

limited; large trees that do exist are anchored in riprap and unlikely to recruit to the stream channel. The stream is also disconnected from its floodplain and from a deposition zone/small alluvial fan between the junctions with tributaries 04.0271 and 04.0272. Tributary 04.0272 has been redirected into a simplified channel leaving the historic channel disconnected from the creek system.

2.2.2 Reach 2: Between the Two Northern State Bridges

Reach 2 encompasses the length of creek between the upper and lower bridges on the NSRA. Historically, this reach consisted of a broad floodplain immediately upstream from the lower alluvial fan. The creek in this reach became incised when the downstream alluvial fan was channelized and subsequently downcut. Reach 2 is now vertically and laterally separated from its historic floodplain and effectively transports sediment. The channel elevation in this reach is directly influenced by the channel and alluvial fan downstream of the lower bridge. Minimal native riparian cover exists throughout this reach; however exotic invasive species are prevalent. Fish spawning has been documented in the fall/winter.

2.2.3 Reach 3: Historic Alluvial Fan

Reach 3 starts at the southern NSRA bridge and encompasses the historic alluvial fan below the river terrace. The fan was channelized through the Northern State property. (Figure 2.4 Cross-section). This reach now consists of a single hydromodified channel with dredge spoil dikes on either side of the channel. It lacks roughness elements and has minimal riparian vegetation. This reach became steeper after channelization, allowing water to be conveyed more rapidly, and subsequently the fan and upstream reaches were downcut (eroded).This incised reach no longer distributes floodwaters over a wide area (the alluvial fan). The alluvial fan historically absorbed and reduced the flood discharges realized downstream and captured sediment that now deposits in Reach 5. It can be surmised that this deeper incised reach no longer recharges the groundwater in the alluvial fan. As a result, the creek has a greater tendency to run low or dry-up during the summer months.

2.2.4 Reach 4: Toe of Historic Alluvial Fan to Highway 20

The incised channel through the historic fan in Reach 3 continues into Reach 4. Historic maps suggest that this reach was once part of a large wetland complex that may have had several defined channels that moved about over time. The reach experiences deposition of larger sediment (cobbles and gravel) and was historically dredged to maintain capacity. Dredge spoils have been piled along the creek banks creating levees and as a result, the channel bed is now higher than the surrounding floodplain. (Figure 2.5 Cross-section). In addition, the spoil piles/levees have separated the channel from its floodplain and adjacent wetlands. This separation significantly reduces Hansen Creek’s natural ability to detain and reduce flood discharges. Separation from the adjacent wetlands and ponds has also significantly reduced fish rearing habitat. Because of its straight alignment and dredge spoil levees; Reach 4 efficiently conveys smaller gravels and sands downstream to Reach


FIGURE 2.4
Typical Existing Reach #3 Cross-Section
(Station 128+80, Facing Downstream)
Original Creek (Aluvial Fan) Elevation
Elevation (ft)
Stations (ft)
Ground
1.5-Yr WSEL
10-Yr WSEL
50-Yr WSEL


FIGURE 2.5
Typical Existing Reach #4 Cross-Section
(Station 104+50, 800-ft U/S of Rte 20, Facing Downstream)
High Ground Points Are Levees From Dredging Spoils
Elevation (ft)
75
74
73
72
71
70
69
68
67
66
65
100
150
200
250
300
350
400
450
500
Stations (ft)
Ground
1.5-Yr WSEL
10-Yr WSEL
50-Yr WSEL

5 where they are deposited in the channel causing impacts to habitat and increased flooding.

2.2.5 Reach 5: From Highway 20 to Minkler Road

Reach 5 extends from the two bridge crossings (Highway 20 and the old railroad grade) south of Highway 20 to just below Sorenson's Bridge near Minkler Road. Segments of Reach 5 were straightened in the 1940's to increase the viability of surrounding agricultural lands. These dredging and hydromodification activities resulted in a simplified plane-bed channel with little riparian vegetation and a channel disconnected from its floodplain. Straightening caused the gradient to increase in Reach 5, but not enough to convey increased sediment loads resulting from landslide activity in the headwaters and downcutting of the alluvial fan through the NSRA. As mentioned, these actions increased sediment deposition resulting in flooding, subsequent dredging, levee creation, and habitat destruction (Figure 2.6 Cross-section). Anecdotal information from local property owners suggests that the creek dries up more frequently during summer months than it did historically.

2.2.6 Reach 6: Red Creek

Red Creek has been realigned and altered from its headwaters to its mouth at Hansen Creek. Once a productive anadromous fish bearing stream, Red Creek has been straightened and diked resulting in dramatically reduced habitat value. Flooding in Reach 5 of Hansen Creek causes waters in Red Creek to back up exacerbating flooding in agricultural lands near their confluence. A culvert with a flap-gate was installed at the mouth of Red Creek to prevent backwater from Hansen Creek entering Red Creek during flood events. This flap-gate is a barrier to anadromous fish passage and reduces fish passage into Red Creek. A tributary to Red Creek, dubbed the "Dairy Tributary" enters the floodplain below the historic dairy barns and then parallels Helmick Road in a ditch before entering the wetland north of Highway 20.

2.3 Historic Watershed Conditions

Ten "Historic Habitat and Vegetation Zones" were delineated in the Hansen Creek watershed. The watershed was evaluated from a historic perspective using current and archival data representing the presence, distribution, and location of key soil types, parent geology, landforms, and vegetation. This historic information assists in the development of and decisions regarding the project alternatives as existing and/or historic habitats within each zone can provide targets for restoration and provide guidance for watershed and land use management activities. See Appendix 7 – Historic Landscape Conditions for a complete discussion on the historic reconstruction method and results.

Vegetation and habitat relationships were grouped into the following landform zones: 1) Skagit River Floodplain, 2) Skagit River Terrace, 3) Terrace Wetlands, 4) Hansen Watershed Lower Alluvial Fan, 5) Adjacent Red and Brickyard Watershed Lower Alluvial Fans, 6) Middle Hansen Watershed Floodplain, Fans, and Terrace

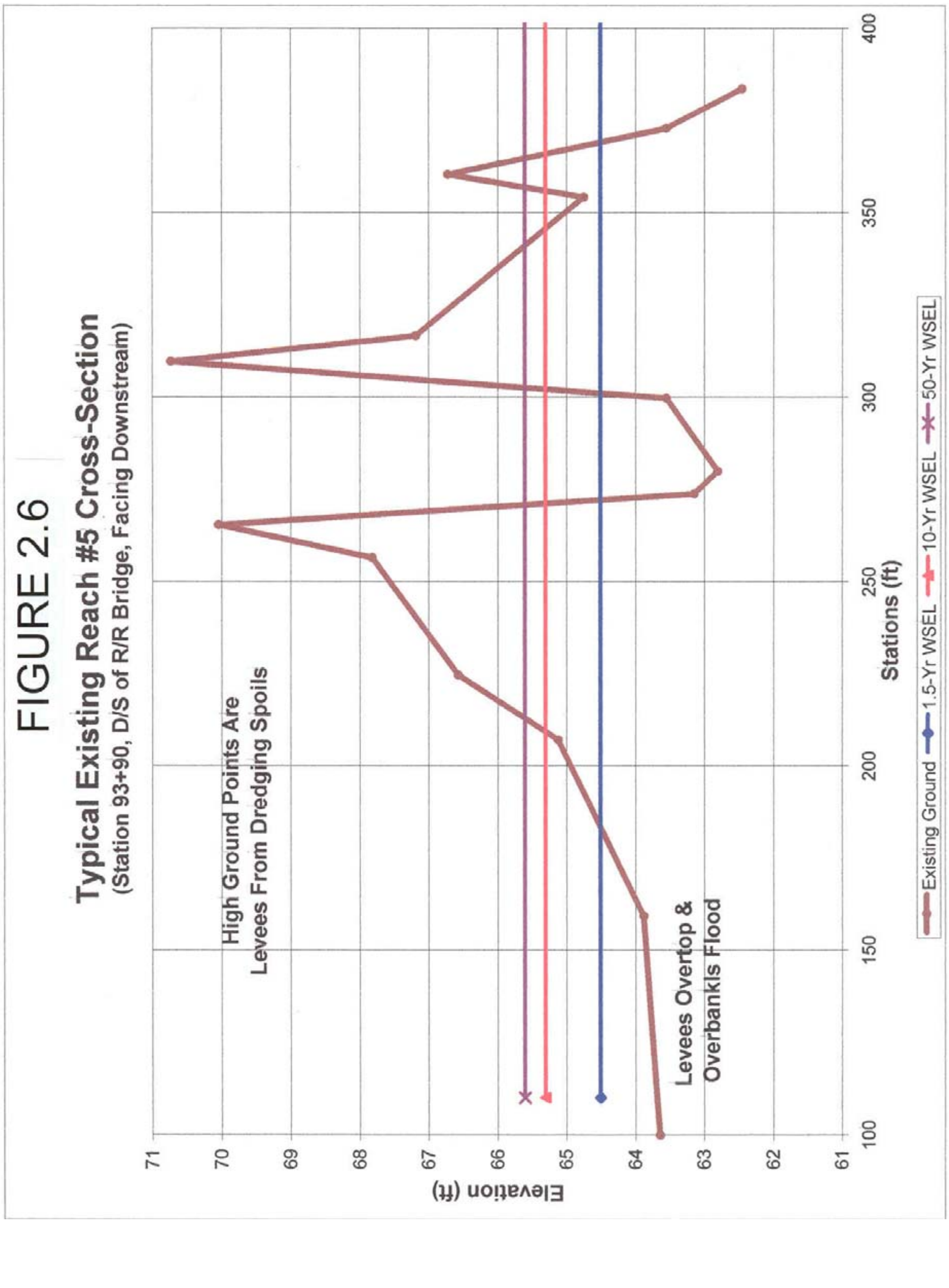


FIGURE 2.6
Typical Existing Reach #5 Cross-Section
(Station 93+90, D/S of R/R Bridge, Facing Downstream)
High Ground Points Are
Levees From Dredging Spoils
Levees Overtop &
Overbankls Flood
Elevation (ft)
71
70
69
68
67
66
65
64
63
62
61
100
150
200
250
300
350
400
Stations (ft)
Existing Ground
1.5-Yr WSEL
10-Yr WSEL
50-Yr WSEL

Escarpments, 7) Middle Hansen Watershed Glaciolacustrine Landforms, 8) Middle Hansen Watershed Slopes and Uplands, 9) Upper Hansen Creek Alluvial Fan, and 10) Upper Hansen Creek Watershed.

These zones are shown in Figure 2.7 and are described hereafter.

Skagit River Floodplain

The Skagit River Floodplain is an approximately 1,725-acre relatively flat landform located north of the Skagit River at approximately 40-60 feet elevation. This area is infrequently inundated during flood events. Based on this forest zone type and General Land Office (GLO) survey notes from the 1870's and 1880's, vegetation historically found in this area included Douglas fir, western hemlock, western red cedar, Sitka spruce, and red alder. Portions of the zone likely included upland forest with some large trees. Historic aquatic habitats in this zone were stream channels, sloughs, and wetlands. Stream channels would have been very low gradient, complex, pool riffle-type channels that were important anadromous fish habitat.

Skagit River Terrace

The Skagit River Terrace is an ancient river floodplain, abandoned as the river downcut through it. In total this is an approximately 1,380-acre relatively flat landform located downstream of the lower alluvial fan and wetland complex and includes all land between these zones and the Skagit River Floodplain at approximately 60-80 feet elevation. Historic vegetation associated with this area included Douglas fir, western hemlock, western red cedar, Sitka spruce, and red alder. Historic aquatic habitats in this zone were stream channels, sloughs, and wetlands. Stream channels would have been low gradient, complex, pool riffle-type channels that were productive and important anadromous fish habitat.

Terrace Wetlands

The Terrace Wetlands were an approximately 1,330-acre flat landform located in the lower watershed, downstream of the lowest alluvial fan including areas on the Skagit River Terrace Zone. Elevations in this area are approximately 60-80 feet. This area acted as a transition zone between the slopes and lowest alluvial fans of the tributary streams (Hansen and Red Creeks), and the Skagit River floodplain. The wetlands formed a highly productive habitat zone with varying vegetation and aquatic habitats. The wetland likely contracted and expanded over time within a given area depending on disturbance frequency, climactic variations, soil development in various vegetation zones, beaver activity, etc. The wetlands included extensive forested, shrub scrub ("crabapple swamp") and some emergent wetland areas. GLO survey notes also describe extensive "beaver swamp" and open water habitats in numerous places that were at least 2 to 3 feet deep. These habitats would have likely been accessible to anadromous fish. Stream channels would have been extremely low gradient, complex, pool riffle-type channels. Channels may have disappeared in extensive open water wetlands; however, based on the GLO notes, it appears that Hansen Creek maintained a clearly distinguishable channel approximately 30 feet wide.

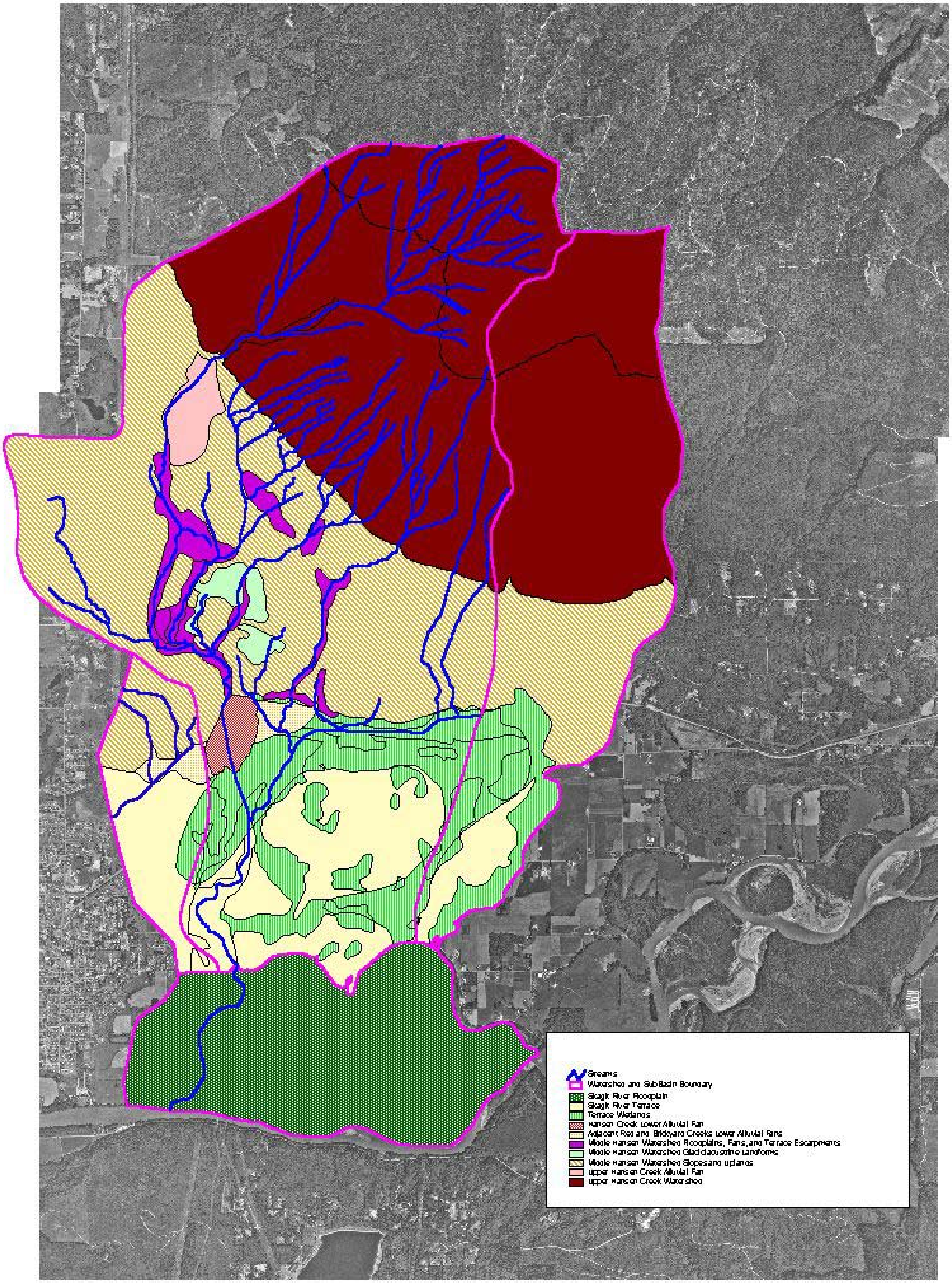


Figure 2.7: Historic Hansen Creek Watershed Habitat and Vegetation Zones

Hansen Creek Lower Alluvial Fan

The Hansen Creek Lower Alluvial Fan was a variable landform on a terrace above the Skagit River located at approximately 100 feet elevation. The fan served as a deposition zone for coarse to fine sediments transported from upslope areas by the creek. It was contiguous with a much larger alluvial fan extending to the east and west and influenced by several other streams including present-day Red and Brickyard Creeks. The area of this larger fan was approximately 200-acres in size, while the lower alluvial fan associated with Hansen Creek (shown in red in Figure 2.7) was estimated at almost 90-acres in size. This fan was likely low in gradient (less than 4%), with a substrate including fine to coarse alluvial deposits. Historic forest vegetation included Douglas fir, western hemlock, western red cedar and red alder. The fan likely included areas of forest cover bordered by wetland areas outside and down gradient of the fan. These forests would have provided valuable habitat functions including for large woody debris (LWD) recruitment for aquatic habitats on the fan as well as downstream. The lower alluvial fan likely contained multiple, low-gradient channels that would have persisted for extended periods of time, entrenched in the fan and anchored by LWD. Empirical information is presented in Appendix 7 – Historic Landscape Conditions.

Adjacent Red and Brickyard Creeks Lower Alluvial Fans

This fan area is associated with streams adjacent to Hansen Creek, including present-day Red and Brickyard Creeks and was approximately contiguous with the Lower Hansen Creek Alluvial Fan. Physical characteristics, vegetation, and aquatic habitats were very similar to those on the Hansen Creek Lower Alluvial Fan.

Middle Hansen Creek Floodplains, Fans, and Terrace Escarpments

The Middle Hansen Creek Floodplains, Fans, and Terrace Escarpments zone cover approximately 345-acres and are located in the middle of the watershed, ranging from approximately 100 feet in elevation at the top of the lower alluvial fan to over 300 feet in elevation at the base of the upper alluvial fan. This area includes the channels and floodplains of middle Hansen Creek, the lower reaches of several major tributaries, and adjacent steep terrace escarpments. Forest vegetation in this zone includes Douglas fir, western hemlock, western red cedar and red alder. Soils include silt loams on the Hansen Creek floodplain and on terrace escarpments, and gravelly/gravelly sandy loams on outwash terraces and alluvial fans. Aquatic habitats included low and moderate gradient, pool-riffle, forced pool-riffle and plane bed channels and some low gradient channel reaches with beaver pond complexes. These channels were important habitat for anadromous fish.

Middle Hansen Creek Glaciolacustrine Landforms

The Middle Hansen Creek Glaciolacustrine Landforms are scattered, wet, depressional areas, consisting of approximately 115-acres, adjacent to several tributary streams. These habitats are located in depressions formed by ancient glacial lakes and there are currently extensive wetlands in these areas. Forest vegetation in this zone includes Douglas fir, western hemlock, western red cedar and red alder. Historic aquatic habitats likely included low gradient channel reaches, wetlands, and associated beaver pond complexes. Channels, (particularly lower gradient reaches) and beaver pond complexes downstream of natural migration barriers were important anadromous fish habitat.

Upper Hansen Creek Alluvial Fan
The upper Hansen Creek alluvial fan was an approximately 128-acre variable landform located at the base of the steep mountain front at approximately 400 feet in elevation. The fan was contiguous with a much larger fan that received sediment from other streams outside and to the north of the Hansen Creek watershed. It was likely a high gradient fan that received deposits of coarser sediment than the Hansen Creek Lower Alluvial fan. The upper fan was a highly variable habitat zone with varying vegetation, substrate, and aquatic habitats, but with the potential for highly productive habitat areas. Current surface soil is mapped as sandy loam, but boulders, cobble, and gravel are abundant in fan deposits exposed in the banks of Hansen Creek (Perkins, personal communication). The fan area contained at least one, and perhaps multiple, low to steep gradient channels that were likely laterally unstable and where avulsion would be common.

Middle Hansen Creek Watershed Slopes and Uplands
This approximately 3,700-acre area extended from the lower alluvial fan and wetland up through forested slopes to an elevation of approximately 2500 feet. Historic forest vegetation included Douglas fir, western hemlock, western red cedar and red alder. There were (and are) some diverse aquatic habitats within this zone, including stream channels and beaver pond complexes with associated wetlands. Stream channels range from steep, confined channels in the upper reaches to low gradient, unconfined channels in the lowest reaches. Channels, (particularly lower gradient reaches) and beaver pond complexes downstream of natural migration barriers were important anadromous fish habitat.

Upper Hansen Creek Watershed
The Upper Hansen Creek Watershed is an approximately 4,900-acre forested, steep area extending from approximately 2500 feet to the upper limits of the watershed. This zone is underlain by weak phyllite bedrock covered by thin soils and is highly prone to mass wasting. Based on the forest zone type and GLO survey notes from the 1870's and 1880's, vegetation included Pacific silver fir, mountain hemlock, Douglas fir, western hemlock, western red cedar and red alder. Channels in this zone were typically steep (8 to over 20%) and confined to canyons with inner gorges with little or no floodplain. These channels provide limited fish habitat value, however they do act as a source of water, wood and sediment to downstream reaches.

2.4 Fish and Habitat Conditions

The dominant anadromous fish species in Hansen and Red Creeks are coho salmon and steelhead trout that occupy the creek and tributaries from the Skagit River to the base of Lyman Hill. Chinook, pink and chum salmon use is confined to the lower reaches of the creek in the Skagit River floodplain and historic alluvial fan area (Reaches 2, 3, 4, and 5). The lower watershed is also presumed forage habitat for native char such as Bull Trout. The historic number of fish produced in the Hansen Creek watershed was much higher than present. The change in fish numbers is due to a number of factors that have impacted habitat conditions over time. These are:

- Disappearance of much of a large wetland complex that encompassed portions of Reaches 4 and 5 of Hansen Creek and portions of Red Creek (Reach 6),
- Decrease in beaver activity and associated open water habitat,
- Lack of large woody debris in the creek that created complexity and pools,
- A high sediment supply that now impacts spawning areas,
- Lack of riparian vegetation along the creek due to agricultural practices, dredging and diking resulting in reduced shade, lack of large woody debris (LWD) recruitment, and increased predation,
- Past forestry practices including logging, and road construction and abandonment in the upper watershed that have increased sediment supply into the system.

Changes in habitat conditions are discussed in greater detail in the *Hansen Watershed Analysis, August 1994,* prepared by DNR, WDFW, Skagit System Cooperative and Crown Pacific.

2.5 Land Use Activities

Land use activities in the watershed have changed over time. Logging of the floodplain and river terraces began in the 1880's and over the years progressed up-slope. By the 1940's much of the basin had been harvested and agricultural activities dominated the floodplain and low terraces. Today, agriculture and rural residential uses dominate the watershed from the low terraces to the river and forestry activities are largely concentrated on Lyman Hill. The upper reaches of the Hansen Creek project area (Reaches 1 – 4), located north of Highway 20 and a portion of Reach 6 (Red Creek), are located on Northern State property and are therefore in public ownership. South of Highway 20 to the confluence with the Skagit River, lands adjacent to the creek in Reach 5 and Reach 6 are in private ownership.

The Hansen Creek Sub-Flood Control Zone was formed per Skagit County Resolution No. 9350, dated June 1, 1982. In conjunction with the creation of the Hansen Creek Sub-Flood Control Zone, a citizens' advisory committee for the Hansen Creek Sub-Flood zone was formed per Skagit County Resolution No. 9396 dated July 28th, 1982. The purpose of the zone is to protect life and property from damage resulting from flood and drainage water of the Hansen Creek Watershed. The zone encompasses approximately 7,500 acres and properties within the zone are assessed annually for continued operation and maintenance. Skagit County Public Works acts as the administrator for the sub-flood control zone and is also responsible for the consideration of any potential environmental impacts of proposed or recommended actions of the sub-zone. Actions taken by Skagit County within the sub-flood zone are coordinated with the citizen's advisory committee to address the specific needs of the sub-flood zone.

2.6 Regulatory Concerns

Implementation of the Hansen Creek Watershed Management Plan will be contingent on a number of approvals from a variety of Local, State, and Federal Agencies. Concerns related to wetland impacts, stream relocations, water quality and quantity, sediment transport, and other environmental impacts will have to be addressed and mitigated in order to receive the permits necessary to move the Plan to construction. It is anticipated that the permitting process for this project could take up to two years. Should permitting for this project be rolled into a suite of projects, including the Helmick Road Improvement Project and Northern State Recreation Area, the permitting process could take longer in order to appropriately address the additional environmental concerns stemming from those projects.

It is likely that the most time consuming element in permitting this project will be compliance with the Endangered Species Act due to the listed Chinook salmon and Bull Trout that utilize the Hansen Creek Watershed. Compliance with the Endangered Species Act is necessary as the project will likely contain elements that will involve a Federal Nexus stemming from federal grant monies that will ultimately help fund the project. Implementation of the Plan will likely require an Individual Permit from the US Army Corps of Engineers, as it will likely exceed the parameters of a Nationwide Permit. As part of the USACE's review process, the National Marine Fisheries Service and US Fish and Wildlife Service will be consulted to ensure that the project will not adversely impact the fisheries resource or associated critical habitat. A Biological Assessment (B.A.) will have to be prepared that details all of the impacts, both positive and negative, to the fisheries resources. NMFS and USFWS will then review the B.A. and issue a Biological Opinion (B.O.) that will state what effect the project will have on the fisheries resource.

Several Washington State Agencies will also be involved in the permitting process. The Washington Department of Ecology will review the project for both compliance with water quality standards and for wetland impacts. The Washington Department of Fish and Wildlife will review the project for compliance with the Washington State Hydraulic Code. The Department of Transportation will be involved in the process due to the connection with State Route 20. These agencies review will be triggered through the submittal of a Joint Aquatics Resource Project Application (JARPA) for the project.

Environmental review will also be required at the local county level. The Skagit County Critical Areas Ordinance is designed to protect the critical areas located within Skagit County. Review under the CAO will be triggered when permits are submitted for any earthwork and/or other construction related to the project. In addition, State Environmental Policy Act (SEPA) review will be required for the project. SEPA review will likely result in one of two possibilities: The project may be deemed to have a significant impact (DS) on the environment and will thus require an Environmental Impact Statement to be prepared addressing the impacts and mitigation necessary to offset those impacts or the project will not result in a significant environmental impact and the impacts of the project could be regulated through a series of mitigating measures (MDNS).

Implementation of the Hansen Creek Management Plan will likely occur simultaneously with implementation of planned improvements to Helmick Road and development of the Northern State Recreation Area. Due to the close proximity of the three projects, they will likely be permitted as a suite rather than on separate permitting tracks. As such, it is anticipated that impacts resulting from the NSRA and Helmick Road projects will be mitigated for by the various restoration activities undertaken as part of the Hansen Creek Management Plan.

2.7 Project Phasing

It is anticipated that the implementation of several elements of the Hansen Creek Management Plan will be conducted simultaneously with several other projects in the area. For example, the first phase of work should include the reactivation of the alluvial fan and the development of the sports fields for the Northern State Recreation Area. These elements are compatible and in some ways dependent. It is anticipated that the reactivation of the alluvial fan will create some material that could be used as a subbase for the ball fields proposed to the east of the alluvial fan. In addition, portions of the Helmick Road improvement project being conducted by Skagit County and the Upper Skagit Indian Tribe will take place within the watershed and on Northern State land. The rerouting of the Dairy Tributary under Helmick Road and pedestrian crossings of Helmick Road by recreation area users should be anticipated and addressed in the road project. Given the current schedule, this first phase of development could be completed over the next few years. Implementation of this first phase includes preliminary engineering, final design and construction for all elements. Implementation of additional phases of the Recreation Area and Hansen Creek restoration should also be coordinated and funding should be actively sought.

3.0 ANALYSIS OVERVIEW

3.1 General

The Hansen Creek Watershed Management Plan is the result of a collaborative effort carried out by the Project Team. Work completed by the Project Team is summarized below and, where appropriate, presented in detail in the Appendices.

3.2 Hydrology

At several locations on Hansen Creek, estimates of flood magnitudes were made using USGS regional regression equations and then verified by comparison with data from vicinity gages and previous records for Hansen Creek discharges. The 1.5-year discharges, assumed to reflect the creek's "bankfull discharge", were extrapolated from the discharges calculated from the regional regression equations. The discharges as well as the hydrologic parameters used in calculating the discharges are listed in Table 3.1 below. Details of the hydrologic analysis are found in Appendix 2 - Hydrology.

TABLE 3.1 Hansen Creek Discharges								
Location	Drainage Area (sq-mi)	Mean Annual Precip. (in)	Discharge Estimates (cfs)					
			1.5-Year	2-Year	10-Year	25-Year	50-Year	100-Year
Red Creek At Confluence W/ Hansen Creek	1.66	55	50	60	108	134	158	178
Red Creek (Diverted) At Helmick Road Crossing	0.79	55	25	31	57	71	83	94
Remainder Of Red Creek D/S Of Diversion	0.87	55	27	34	62	77	91	102
Hansen Creek, Upstream Of Route 20	7.56	55	183	225	403	497	584	655
Hansen Creek, Just D/S Of Red Creek Confluence	9.22	55	218	268	479	590	692	777
Hansen Creek, At Minkler Road	9.74	55	228	281	502	619	726	815

3.3 Field Survey

In January 2000, The Skagit County Public Works survey crew conducted cross-sectional surveys of the Hansen and Red Creek reaches at selected locations specified by the Project Team. Data from this effort and earlier surveys were used to calculate Hansen Creek's historic and anticipated sediment loads. The survey data was also used to develop a hydraulic model of Hansen and Red Creeks.

3.4 Hydraulics

Survey data was combined with data from previous field surveys and adjusted for compatibility. Data from these combined surveys was then used in conjunction with the U.S. Army Corps of Engineers Hydraulic Engineering Center's River Analysis System (HEC-RAS - Version 2.2) to create a simplistic hydraulic model of Hansen and Red Creeks.

The hydraulic model was created to understand how the creek functions under existing conditions. The creek's "behavior" was measured using a number of hydraulic characteristics, including water surface elevation, velocity, and shear stress. These hydraulic characteristics were used to estimate severity of flood conditions as well as the creek's ability to convey sediment. The existing condition model verified observed characteristics of the creek, including:

- Sediment transport in Reaches 1, 2 and 3
- Transport of smaller sediment in Reach 4
- Deposition of larger sediment in Reach 4
- Sediment deposition and frequent flooding in Reach 5

- Backwater effects on Red Creek related to the floodgate

In certain instances, the hydraulic model was adjusted to account for a variety of stream enhancement alternatives. In these instances, the model was used to analyze both hydraulic characteristics and sediment transport capacity. Alternatives were also developed using approximate stream dimensions and characteristics rather than adjusting the hydraulic model.

The Hydraulic Analysis Report in Appendix 3 discusses the processes, methods and assumptions used to perform this analysis.

3.5 Sediment Budget and Anticipated Deposition Rates

Records from the Soil Conservation Service and the Hansen Creek Sub-Flood Control Zone were used to estimate the sediment volume dredged from the creek both on Northern State property and further downstream. Recent and historic stream profiles were used to augment sediment volume calculations. Estimated volumes were divided by elapsed time to obtain average sediment deposition rates.

For the 57-year period 1942 to 1999, the long-term average rate of bedload sediment influx to the study area is approximately 28,000 cubic yards per decade. Bedload deposition rates are expected to vary from as low as 16,000 to over 40,000 cubic yards per decade. In addition, it is anticipated that 9,000 to 12,000 cubic yards of bedload deposition could occur in a single year stemming from moderate to large flood events. As much as 20,000 cubic yards of bedload could be deposited in a single year following widespread dam-break floods and debris flows such as occurred in the mid-1940s, however, the probability of such a large event is low.

As a long-term average rate of bedload sediment influx was estimated to be 28,000 cubic yards per decade, or 2,800 cubic yards per year. An average annual sediment load of 3,000 cubic yards accounting for both bed load and some suspended sediment was used to analyze sediment storage alternatives considered in this study. A more detailed discussion on Hansen Creek’s sediment budget and anticipated deposition rates is included in Appendix 4.

3.6 Habitat Analysis

An estimate of the historic change in juvenile coho production was conducted and factors limiting current production were determined to better understand changes in the watershed and associated fish habitat since European settlement (Beamer, unpublished data, 2000). This information also provides potential targets for habitat management and restoration strategies.

It is estimated that the historic numbers of juvenile coho in the Hansen Creek Watershed ranged from a low of 21,500 to a high of almost 81,000. These numbers do not include juvenile production input related to the historic wetlands associated with the Hansen Creek Watershed. Juvenile production numbers would likely be much higher if the input from the wetlands was considered. Current juvenile production is estimated at approximately 14,500, showing an overall decline from historic numbers of between 31 and 83%. Reaches of the creek with the highest potential productivity were the tributaries above the sediment pond on Northern State property, likely contributing over 30% of all fish to the creek system. The segment of the creek between Hoehn Road and the confluence of Red Creek (Reach 5) contributed 25% and from the base of the historic alluvial fan to the sediment pond (Reaches 1, 2, and 3) contributing 12%. Current fish numbers are significantly down in all reaches except for the tributaries above the sediment pond. Reaches 1, 2 and 3 have witnessed a decrease of between 94 and 98% and Reach 5 is down 85 to 96%. (Figure 3.1)

Factors currently limiting fish production in the watershed are:

- Natural barriers, falls and cascades, at the base of Lyman Hill
- Fish passage barriers such as the floodgate at the confluence of Red Creek and a dam on one of the tributaries
- The sediment pond control structure that may impede fish passage
- A lack of holding areas (pools over 3 feet deep), that provide refugia for adults
- Availability of stable spawning gravels
- Channelization of the creek and lack of riparian vegetation
- Lack of large woody debris and associated recruitment potential.

A more detailed presentation on Hansen Creek's potential salmon capability is included in Appendix 5. It should be noted that the fish numbers presented in this section and Appendix 5 do not account for the habitat value associated with the larger historic wetland complex that existed at this location.

3.7 Alternatives Analysis

The Project Team developed a variety of alternatives to address the project goals of sediment management, flood reduction and habitat enhancement. Benefits for each alternative, as related to the project goals, were quantified and in addition, construction quantities and cost estimates calculated for each alternative. A comparative analysis of the alternatives was performed using these costs and benefits to determine the relative cost effectiveness of each alternative considered. These criteria were used to objectively compare alternatives. A recommended design alternative was chosen following this comparative analysis and a presentation of alternatives was given to the Advisory Committee and other stakeholders (See Section 5.0 Alternative Analysis Summary for further discussion).

3.8 Cost Estimates

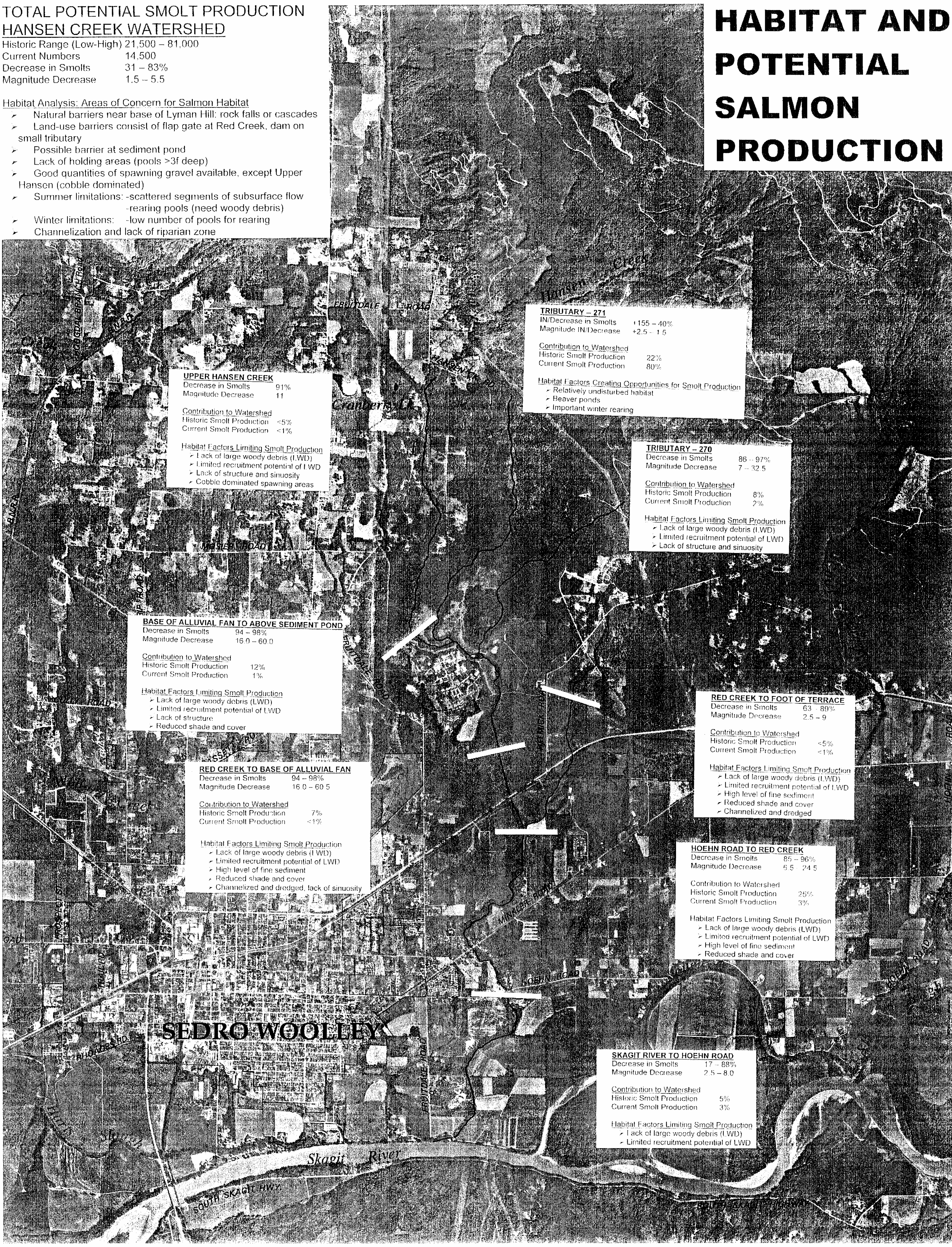
Cost estimates were calculated for each design alternative. Estimates were based on real estate values, construction quantities and unit costs, project design, permitting and management costs; and operations, maintenance, and monitoring costs. The Skagit County Public Works Department assisted in developing unit costs for the estimates. Operations, maintenance, and monitoring costs were converted to

HABITAT AND POTENTIAL SALMON PRODUCTION

TOTAL POTENTIAL SMOLT PRODUCTION
HANSEN CREEK WATERSHED

Historic Range (Low-High)	21,500 – 81,000
Current Numbers	14,500
Decrease in Smolts	31 – 83%
Magnitude Decrease	1.5 – 5.5

Habitat Analysis: Areas of Concern for Salmon Habitat
- Natural barriers near base of Lyman Hill: rock falls or cascades
- Land-use barriers consist of flap gate at Red Creek, dam on small tributary
- Possible barrier at sediment pond
- Lack of holding areas (pools >3f deep)
- Good quantities of spawning gravel available, except Upper Hansen (cobble dominated)
- Summer limitations: -scattered segments of subsurface flow -rearing pools (need woody debris)
- Winter limitations: -low number of pools for rearing
- Channelization and lack of riparian zone



Map by MILLER CONSULTING from information provided by SKAGIT SYSTEM COOPERATIVE

HANSEN CREEK WATERSHED

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"net present worth" values so that alternatives could be compared in "today's dollars". The present worth analysis was based on an assumed project life of 50 years and an interest rate of 5%.

It should again be emphasized that alternatives were developed at a planning level and are best suited to compare relative costs and benefits of the alternatives considered. Detailed analysis during project engineering and design will be required to fully understand benefits and costs. Graphs comparing the costs and cost effectiveness for the various alternatives are included in the Alternatives Analysis Summary of this report (Section 5.0).

Costs were also compared to the dredging frequency, or "Sediment Life Span", for the sediment capturing alternatives. The ratio of "Cost to Sediment Life Span" analyzes benefits realized from the sediment storage alternatives in terms of "dollars per year". This ratio helps determine those alternatives that provide the best cost/benefit ratio. Graphs comparing these ratios are included in the Alternatives Analysis Summary of this report. Similar analyses and bar charts were developed to show the cost per foot of creek enhancement and for each acre of wetland enhanced. These graphs are included in the Alternatives Analysis Summary of this report (Section 5.0).

4.0 DESIGN APPROACH AND CONSIDERATIONS

4.1 General Design Approach

Flooding and fish habitat issues associated with Hansen Creek are largely attributable to the disruption of the creek's natural balance of sediment transport and deposition. Reaches that historically collected sediment have been channelized, are now incised, continue to degrade, and efficiently convey sediment. Reaches that historically meandered in their floodplain and conveyed sediment have been straightened and now collect sediment deposits. As a result, flooding has increased and in-stream and riparian habitat has been degraded in an effort to reduce the impacts of flooding. The conceptual design alternatives considered in the Plan attempt to reestablish natural processes through employing the following two overriding design approaches.

- **Sediment Storage:** Allow sediment to deposit where it has historically in Reaches 1, 2 and 3, (thereby reducing the sediment transport downstream), and

- **Stream and Floodplain Restoration:** Allow the remaining smaller sediments and floodwaters to be conveyed through a more natural, self-maintaining creek channel and floodplain and riparian system through Reaches 4 and 5 and in Red Creek, Reach 6.

Where appropriately employed, these design approaches will provide increased sediment storage and effectively reduce flooding currently being experienced.

It is important to emphasize that these two design approaches must be employed together so that the creek once again functions as an integrated, continuous system. Stream restoration without upstream sediment collection would be fruitless since the restored channel would inevitably fill in with sediment. Sediment collection structures without downstream improvements would likely create downstream channel degradation and headcutting, thereby jeopardizing the stability of the downstream channel and habitat as well as the integrity of the upstream sediment collection structure. Furthermore, sediment collection structures without downstream improvements would not solve the existing flooding and habitat problems.

4.2 Sediment Storage (Reaches 1, 2 & 3)

4.2.1 Sediment Storage Methods

Sediment traps: deposition in still water

Sediment traps (or ponds) are the most common engineered method of capturing sediment. In the 1990's two sediment ponds were constructed on Hansen Creek and another sediment pond was constructed on neighboring Coal Creek. A pond is created through a combination of excavating below the streambed and constructing a dam at the outlet to raise the water level. Sediment is then deposited in the still water of the pond.

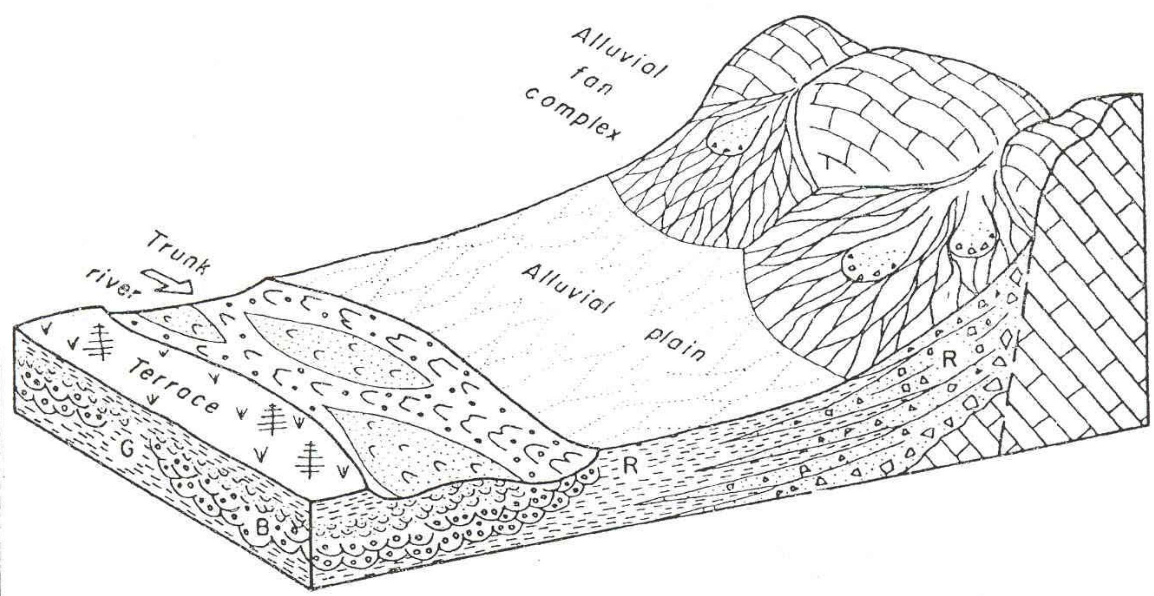
Sediment ponds have the following limitations:

- Bedload sediment (gravel, cobbles and coarse sand that roll and bounce along the streambed) drops out in a delta at the upstream end of the pond, regardless of pond size. It is the bedload sediment that causes channel filling and flooding problems in downstream reaches.
- Fine sediment drops out in the rest of the pond, reducing the volume available for bedload storage. Deposits in Hansen Creek and Coal Creek ponds are more than 50 percent fine sediment (John Abenroth, Skagit County Public Works, 2000). This means less than half the pond volume is available to trap the bedload sediment that is causing the downstream flooding problems.
- The sediment deposit has a flat surface until the pond has filled up, reducing the amount of sediment that can be trapped.
- Creek habitat is replaced by lake habitat for the length of the pond.
- The pond releases no bedload downstream. This causes the streambed downstream of the pond to erode, affecting habitat and producing more coarse sediment to drop out farther downstream. (Note: This is how Reach 2 became incised.)
- Deposition of bedload occurs at the upstream end of the pond and in the creek upstream of the pond, causing the bed to rise where it was not anticipated. This phenomenon can be observed at the Coal Creek sediment pond adjacent to the east edge of the Hansen Creek watershed.

The existing Hansen Creek sediment pond at the upper Northern State Bridge has required excavation every year or two since it was built in 1992. Assuming 40% of the pond volume is filled with bedload; the pond holds less than one average year of bedload sediment inflow and will require constant monitoring and maintenance.

Alluvial Fans: deposition in flowing water

Alluvial fans are nature's way of depositing and storing large amounts of sediment at locations where a stream's gradient suddenly decreases and a confined stream enters a wider valley (Figure 4.1, Diagram of Alluvial Fan). The sudden decline in gradient and flow depth reduces the amount of sediment the stream can carry, causing bedload sediment to deposit in relatively shallow, flowing water, while fine suspended sediment continues on downstream. Once the channel fills up with sediment, it shifts laterally and begins depositing sediment in a new location. Where floodplains are confined by terraces, similar to the historic Reach 2, the channel meanders and can become braided (possessing multiple channels). In locations were the lower gradient channel is completely unconfined, like in Reach 3, the sediment deposit becomes fan-shaped.



Source: Walker, R.G., 1984. Facies Models, Second Edition

SKAGIT COUNTY SURFACE WATER MANAGEMENT	HANSEN CREEK WATERSHED MANAGEMENT PLAN	N W E S
MILLER CONSULTING with WATERSHED PROFESSIONALS NETWORK	DIAGRAM OF ALLUVIAL FAN Figure 4.1	

Alluvial fans have the following advantages in situations where large amounts of sediment are anticipated:

- A large storage area is available
- Because the depositional surface is sloped, bedload drops out over a longer length of channel than in a pond
- As the channel moves laterally back and forth, it deposits bedload sediment across the full width of the floodplain
- Much less fine sediment is trapped, thereby maximizing storage volumes for larger sediments
- Some bedload sediment is released downstream, reducing channel incision
- The storage area retains creek-like characteristics , such as
  - Side channels
  - Forested floodplain
  - Potential for productive aquatic habitat

Sediment deposition in flowing water also occurs wherever a wide, flat floodplain exists upstream of a narrow constriction that backs up flow. These depositional zones are smaller in scale than an alluvial fan but can store significant amounts of sediment if channel migration is allowed to occur. Opportunities for this type of sediment storage exist in Reaches 1 and 2.

4.2.2 Reestablishing Alluvial Fan Deposition on Hansen Creek

The upper alluvial fan on Hansen Creek, at the foot of to the mountain front, is already functioning to a great extent. A series of historic aerial photos shows large deposits on that fan after each major landslide-producing storm event. The fan traps boulders and large cobbles as well as an unknown amount of smaller sediment, reducing the amount of bedload sediment that reaches lower Hansen Creek by at least 20 percent. However, post-flood dredging and the confinement of the channel to a single course by a bridge and culvert have resulted in somewhat less sediment storage than historically occurred. The relatively steep channel below the alluvial fan is still capable of carrying a large amount of sediment from the upper fan downstream to the project area near Highway 20.

A sediment storage project at the upper fan is not recommended for the following reasons:

- The fan is subject to direct impacts from large mass-wasting events such as debris flows and dam-break floods.
- The steep slopes and high velocities would lead to a high risk of failure for any structural solution during a large event.
- The land is mostly privately owned.
- Even if additional sediment were trapped in the upper fan, the creek would tend to replenish its sediment load by eroding stored sediment from the floodplain and channel between the upper and lower fans.

The lower alluvial fan (Reach 3) of Hansen Creek is presently inactive and the existing channel has incised through the fan due to past dredging and straightening. Because the creek is steep and flow cannot spread out, most sediment moves through the fan without being deposited. To reactivate the original fan, water must be allowed to expand laterally so it can deposit sediment as it moves back and forth across the floodplain. Reactivation of the lower fan is feasible because:

- It is not subject to the direct influence of mass wasting events.
- Shallow slopes and reduced stream velocities would lead to the reestablishment and balance of natural processes.
- The land is in public ownership.

4.3 Stream Restoration

4.3.1 Overview

Restoration actions in Reaches 1, 2 and 3 will increase sediment storage and decrease sediment deposition-related flooding. This will decrease the need for maintenance dredging in the downstream reaches. Moreover, some techniques used in the Plan to increase sediment storage will also improve habitat conditions (i.e., large woody debris placed or induced to recruit to the channel will store sediment and form pool habitat). Additional stream channel, wetland, and riparian habitat restoration will be required to restore habitat forming processes and improve the quality of habitat impacted by years of channel straightening and dredging, land use activities, and riparian encroachment.

A number of stream restoration alternatives are available for consideration. Alternatives range from the wholesale construction of new channels to less invasive techniques that provide aquatic habitat forming elements and provide for the future expression of habitat forming processes (e.g., utilizing existing trees to form in-channel large woody debris and planting riparian zones). It is likely that a combination of techniques will be used. Any alternative chosen should provide for sustainable, long-term habitat improvements through restoring the processes that create and maintain stream channel habitats.

4.3.2 Bankfull or Dominant Design Discharge

All channels in the study area are relatively low gradient, and would naturally include forced pool- riffle and pool-riffle reaches with some plane bed reaches. Some areas in Reaches 4, 5 and 6 may have possibly been surrounded by wetland, influenced by beavers, and had a less defined channel. Reach 3 historically flowed through an alluvial fan and would have variably consisted of a main channel and other subsidiary channels.

Aquatic habitats in the study area associated with Hansen Creek are currently degraded. Historic stream management on Hansen Creek within in the study area consisted of creating straighter, steeper, confined channels with little or no riparian vegetation. This approach has lead to unsustainable channel reaches, as sediment transport and deposition characteristics were neglected and aquatic and riparian habitat were simplified and degraded. Channels are typically maintained with levees and periodically dredged. Segments of Hansen Creek in Reach 1 and Reaches 3, 4 and 5 are examples of the results of this traditional design and management approach.

Unaltered natural streams typically have two different channels: the bankfull channel and the flood channel or floodplain. The bankfull channel conveys smaller discharges while the floodplain conveys larger discharges. Smaller discharges occur more frequently than larger discharges, therefore smaller discharges convey the majority of a stream's sediment over time. Accordingly, as smaller bankfull discharges convey the most sediment over time, they are the dominant channel-forming and channel-sustaining discharge. Research indicates that a channel's bankfull or dominant discharge generally has a recurrence interval ranging from 1.2 to 2 years. (Rosgen, 1996). For the purpose of this concept design, Hansen Creek's dominant discharge was assumed to have a recurrence frequency of 1.5 years. Additionally, historical evidence from GLO notes indicates that, at the time of settlement, Hansen Creek in the project area was approximately 8 meters wide. This dominant discharge and historic information can be used to size main channels in the alternatives development including wholesale construction of new meandering channels.

4.3.3 Dynamic Equilibrium

Natural rivers and streams are dynamic. Low gradient, unconfined channels are sinuous and form meanders. Meanders migrate both laterally and longitudinally through their floodplain. Bed elevations rise and fall in response to sediment loads and channel alterations. It is also recognized that certain streams are more stable than others. There may be less active meander migration or less active grade changes in these apparently stable streams. Such streams are said to be in "dynamic equilibrium". These streams have balanced the various forces, inputs and responses so that they are stable within their dynamic environment. It may be said that streams in dynamic equilibrium are "comfortable in their surroundings" and therefore do not attempt to depart from their relatively stable condition by displaying such characteristics as eroding cut-banks, degrading, aggrading, or avulsing.

This concept plan presents alternatives to restore Hansen Creek to a state of "dynamic equilibrium" where processes that create and maintain stream habitat conditions in this region are restored and maintained. Evidence suggests that some wholesale construction of new channels will need to be included along with the restoration of habitat-forming processes.

Channels and floodplains, including new meandering channels, were designed in accordance with the Rosgen Stream Classification Method (discussed below in 4.3.4). The Montgomery and Buffington classification system (also discussed below

4.3.4), developed for small streams west of the Cascade Mountains will also be used in the both design of new channels and in selecting techniques for habitat-forming process restoration. Final construction designs will be consistent with the kinds of stream habitats that would be present in the study area based on this classification system and will be accompanied by additional restoration project components designed to create and maintain appropriate habitat conditions at the project site.

4.3.4 Stream Morphology and Classification

In addition to being dependent on its watershed size and rainfall, a natural creek's size, shape, and habitat conditions are dependent on its valley, sediment composition, and routing and storage of water, wood and sediment through the system. Empirical relationships between these variables have been compiled and disseminated by Rosgen (1996) to classify rivers and streams. These classifications suggest the physical conditions in which a given stream will be "dynamically stable". This type of analysis facilitates the determination of appropriate stream characteristics such as meander pattern and amplitude, gradients, pool-riffle sequencing, belt widths, width/depth ratios and entrenchment ratios.

Data analysis empirically demonstrates the importance of gradient and the routing and storage of water, wood and sediment in shaping the morphology of these streams. Stream reaches can be categorized as response, transport or source in terms of sediment storage and transport (Montgomery and Buffington, 1993). The most productive salmon-producing stream segments are found in *response* reaches, with a low gradient range of 0-4%; this is the gradient range of Hansen Creek in the study area. Streams in western Washington within this gradient range almost universally can be classified as either pool-riffle (PR), forced pool-riffle (FPR), or plane-bed (PB) streams. Pool spacing, % of wood formed pools, and channel gradient collectively indicate channel type, with PR channels occurring at gradients of less than 3%, and FPR or PB channels occurring at 1 to 4%, depending on wood loading. FPR channels will have a pool spacing of less than 4 channel widths, while PB channels will have spacing >4. FPR channels will have >50% of pools formed by wood. PR channels typically have a pool spacing of 5 to 7 channel widths with no obstructions, or less if there are some obstructions that force pool development.

For salmonids the most productive channel types within these response reaches are PR and FPR. Moreover, when land use actions degrade streams, this typically means that FPR streams are converted to less productive PB streams. Currently, this is the case at Hansen Creek.

Riparian vegetation and land use activities play a key role in the function of response channel reaches. Riparian vegetation provides the LWD that creates productive FPR reaches. Without adequate riparian vegetation for LWD supply, FPR reaches eventually become less-productive PB reaches. This transition is sometimes hastened by stream cleaning (i.e., the deliberate removal of LWD) and hydromodification. Hydromodification results in increased channel gradient and decreased complexity. Other riparian problems can include reduced shading through vegetation removal and bank destabilization, fine sediment input and fecal material input via livestock access.

Additionally, the study area included a large historic wetland (adjacent to Reaches 4 and 5) and an alluvial fan (in Reach 3) that dramatically influenced channel morphology, function and habitat conditions. These classifications and the influence of the wetland and alluvial fan were considered in the development of restoration alternatives.

4.3.5 Conceptual Stream Restoration Activities by Reach

Stream restoration activities for each study reach should look to restore habitat-forming processes that allow the stream to "heal" itself. These include reconnecting the stream to its floodplain, improving sediment storage function in appropriate depositional areas, reactivating the historic alluvial fan, selectively removing dikes and spoils piles, encouraging LWD recruitment, providing future sources of LWD via riparian planting, providing for other riparian functions, and reconnecting wetlands. A combination of passive and long-term techniques with active, short-term restoration activities were considered. Potential active, short-term actions include excavating floodplain, fan and channel(s) as appropriate, placing roughness elements such as LWD in channel or on the floodplain where appropriate, and inducing LWD recruitment where LWD exists but recruitment is impaired due to hydromodification. Restoration activities will likely be conducted simultaneously with sediment work; however, much work will be phased to accommodate the results of sediment supply changes associated with previous restoration work (adaptive management).

Reach 1- The following activities should be accomplished simultaneously with sediment reduction work, (phasing will be determined during design): reconnecting the floodplain via dredging, increasing in-channel complexity through a combination of inducing recruitment of existing LWD and placing channel roughness elements, removing riprap and bank hardening (leaving some hard points), removing invasive vegetation, replanting the riparian zone, and reestablishing tributaries into their historic channels.

Reach 2- The following activities should be accomplished simultaneously with sediment reduction work (phasing will be determined during design): increasing channel complexity and floodplain connectivity via dredging and installation of channel roughness elements such as LWD or weirs, removing invasive riparian vegetation, replanting the riparian zone, and inducing existing LWD to recruit where appropriate.

Reach 3- The following activities should be accomplished simultaneously with alluvial fan reactivation work (This reach is one in which future adaptive management actions might be required): excavating the alluvial fan and adding floodplain roughness elements, excavating new channels on the fan based on historical channel locations and dimensions, plant excavated areas, remove dredge spoil berms to reconnect the stream and fan/floodplain. Associated actions include: removing exotic vegetation from the riparian zone and replanting with native species, encouraging conifer re-establishment, inducing larger existing trees to recruit to stream as LWD, and placement of other LWD elements to mimic pool spacing expected in natural system. Care must be taken to allow for channel migration while ensuring that the water eventually passes under SR20.

Reach 4- Restoration phasing in this reach will be determined by the size of fan developed in Reach 3 and any new work done to the Highway 20 crossing. Activities should include removing dredge spoil berms to reconnect stream and fan/floodplain, removing exotic vegetation from the riparian zone, and replanting with native species (particularly encouraging conifer re-establishment). Associated actions include inducing larger existing trees to recruit to the stream as LWD and placing other LWD elements to mimic pool spacing expected in natural system. Care must be taken to allow for channel migration while ensuring that water eventually passes under Highway 20.

Reach 5- Stream restoration activities must be conducted in close coordination or simultaneously with wetland restoration work. Activities include: relocating the channel, increasing sinuosity and channel length to decrease the gradient (based on classification of the channel and mimicking historical conditions as much as possible), constructing setback dikes as required, planting the riparian area (utilizing existing intact riparian vegetation as much as possible), and adding structure.

4.4 Land Use Concerns

4.4.1 Overview

Current and future land uses and property values adjacent to Hansen Creek weighed heavily in the development of this conceptual design. While a few alternatives require leasing, acquiring easements or purchase of property, care was taken to develop alternatives addressing the issues of sediment, flooding, and habitat while respecting and accommodating needs of adjacent property owners.

4.4.2 Northern State Property

Upstream of Highway 20, Reaches 1 – 4 and a portion of Red Creek exist on County owned property dedicated for public recreational use. The Northern State Recreation Area (NSRA) was purchased by the County from the State of Washington in 1991 for the purpose of providing outdoor recreation activities. In October 2001, a planning and design charette was convened resulting in the production of a conceptual site plan. The site plan locates active and passive recreation uses on portions of the 726-acre site and integrates these uses with actions proposed in this report for capturing sediment, reducing flooding and restoring habitat. The development scheme, as presented in the Northern State Recreational Area

Concept Plan includes a sports field complex, a Multi-Use Event Center, camping, an environmental education center, miles of trails, a day use area, and associated parking and other infrastructure.

Fully reverting the creek system back to its natural state might require, among other things, reactivating the whole historic alluvial fan. This alternative is incompatible with the NSRA Conceptual Site Plan because several of the uses (ball fields and parking) noted above were proposed where the historic alluvial fan was located. It was therefore important to balance the size of the alluvial fan with the proposed recreation facilities, per the conceptual site plan. This less than full size fan therefore may require periodic maintenance dredging. Dredging should be infrequent as to not preclude habitat and vegetation development on the fan. Sediment storage volumes and required dredging frequencies for the various alternative alluvial fan sizes are discussed in the Alternatives Analysis Summary (Section 5.0) and in Appendix 1. Though the proposed alluvial fan is smaller than what existed historically, it will still provide very significant natural function.

4.4.3 Private Property between Highway 20 and Minkler Road

Property along Hansen Creek between Highway 20 and Minkler Road (Reach 5) is privately owned. A large portion of this reach is actively farmed. The property adjacent to the lower half of this reach has a narrow riparian zone and is primarily developed with rural residential uses.

Adjacent landowner's livelihood depends, in part, on use of their property for agricultural activities. Therefore several less land intensive design alternatives were considered for Reach 5. Generally, less land intensive alternatives resulted in limited flood protection while more comprehensive alternatives resulted in substantial flood reduction.

4.4.4 Red Creek (Reach 6)

All of the property along Red Creek south of Highway 20 is privately owned. With the exception of the segment creek between Highway 20 and the old railroad alignment, this length of Red Creek has been straightened, is densely vegetated with reed canary grass, and managed for agricultural purposes.

The first 800-ft of Red Creek north of Highway 20 is also privately owned. This length of Red Creek has been straightened, is heavily grazed by livestock and contains little habitat suitable for anadromous fish.

The length of Red Creek immediately north of the private property is part of the NSRA. The creek in this area has a variable course through a relatively wide wetland and provides some fish habitat, but is currently grazed and impacted by cattle.

5.0 ALTERNATIVE ANALYSIS SUMMARY

5.1 Identification of Alternatives

A variety of possible design alternatives were considered within each of the project's six (6) reaches. A distinct number including a decimal point was assigned to each alternative. The number before the decimal point refers to the stream reach in which the alternative is located. The number after the decimal point refers to the distinct alternative in that reach. For example, "Alternative 2.3" refers to the third alternative in Reach 2.

5.2 Summary Tables and Graphs

The following figures and tables are included to facilitate a comprehensive review of the alternatives considered and analyzed. Sketches of individual alternatives and more detailed discussions of the alternatives are provided in Appendix 1.

- Table 5.1 -Comparison of Alternatives- summarizes the attributes analyzed for all the alternatives considered. Note: Figures 5.1-5.7 are based upon Table 5.1.

- Figure 5.1 -Cost Comparison of Alternatives- is a bar chart graphically comparing costs of each enhancement alternative.

- Figure 5.2 -Sediment Life Span- is a bar chart comparing the sediment life span of each alternative or the time between periodic "maintenance dredging", in the case of the alluvial fan alternatives in Reach 3. Longer life spans are generally considered "better". Note: not all alternatives are aimed at storing sediment. This chart only addresses the sediment storage alternatives in Reaches 1, 2 and 3.

- Figure 5.3 -Ratio of Cost versus Sediment Life Span- is a bar chart detailing ratios of an alternative's total cost divided by its sediment life span in terms of "Dollars per Year". Lower ratios are more economical. This chart only addresses the sediment storage alternatives in Reaches 1, 2 and 3.

- Figure 5.4 -Increased (or Enhanced) Wetland Area- is a bar chart detailing amounts of increased or enhanced wetland acreage for any given alternative. Note: not all alternatives are aimed at increasing or enhancing wetland acreage.

- Figure 5.5 -Ratio of Cost Versus Increased (or Enhanced) Wetland Area- is a bar chart comparing costs of increasing (or enhancing) a single acre of wetland for any given alternative. Lower ratios are more economical.

- Figure 5.6 -Enhanced Creek Length- is a bar chart detailing lengths of creek enhanced in any given alternative.

- Figure 5.7 -Ratio of Cost versus Enhanced Creek Length- is a bar chart detailing costs of enhancing a single foot of creek for any given alternative. Lower ratios are more economical.

Tables 5.2 – 5.7, summarize the attributes and costs of the various alternatives for each of the 6 project reaches**.**

TABLE 5.1

Comparison Of Alternatives

Alternative ID	Alternative Name	Total Cost	Total Cost	Sediment Life Span (Reaches 1-3)	Cost / Life Span (Reaches 1-3)	Increase In Wetland Area (Or Wetlands Enhanced)	Cost / Wetlands Enhanced	Increase In Creek Length	Creek Length Enhanced	Cost / Creek Length Enhanced
		($)	(Thousand $)	(Years)	($ / Year)	(Acres)	($ / Acre)	(Feet)	(Feet)	($ / Feet)
1.1	Replace Upper Hansen Creek Road Culvert w/ Bridge	$225,905	$226	0.0	0	0.0	$0	0	0	$0
1.2	Replace Northwood Lane Bridge. Secure Easements.	$239,897	$240	0.0	0	0.0	$0	0	0	$0
1.3	Terrace Excavation with Creek & Wetland Enhancements, Sub-Reach 1c.	$112,441	$112	4.0	27,852	2.5	$44,976	250	750	$150
1.4	Redirect Trib. #272 Back Into Historic Channel	$82,993	$83	0.0	0	3.0	$27,895	1,350	1,350	$61
1.5	Remove Upper NSH Bridge, Associated Roads & Culvert. Regrade.	$59,449	$59	1.1	55,273	1.0	$59,449	0	100	$594
1.6	LWD Placement & Passive Aggradation in Reach 1.	$48,109	$48	9.4	5,128	1.1	$45,557	0	1,150	$42
1.7	Terrace Excavation Along Existing Sediment Pond.	$253,933	$254	7.4	34,281	2.8	$92,178	0	600	$423
2.1	Remove Lower NSH Bridge & Regrade	$58,815	$59	0.0	0	0.0	$0	0	0	$0
2.2	Replace Lower NSH Bridge w/ Footbridge	$184,737	$185	0.0	0	0.0	$0	0	0	$0
2.3	LWD Placement and Passive Aggradation In Channel	$79,578	$80	12.6	6,319	9.0	$8,822	0	1,725	$46
2.4	Active Aggradation In Channel	$239,184	$239	6.7	35,797	9.0	$26,517	0	1,725	$139
2.5	Passive Aggradation on Excavated Terrace	$546,114	$546	22.5	24,304	9.0	$60,545	0	1,725	$317
3.1	Natural Alluvial Fan (Small)	$438,775	$439	68.2	6,429	10.0	$43,877	525	2,625	$167
3.2	Natural Alluvial Fan (Medium)	$555,664	$556	85.9	6,472	11.0	$50,515	525	2,625	$212
3.3	Natural Alluvial Fan (Large)	$744,265	$744	114.7	6,491	12.0	$62,022	525	2,625	$284
3.4	Engineered Alluvial Fan	$1,600,689	$1,601	50.4	31,749	0.0	$0	0	0	$0
4.1	Channel Restoration Downstream of Natural Alluvial Fan	$164,797	$165			5.0	$32,959	2,200	3,500	$47
4.2	Channel Restoration Downstream of Engineered Alluvial Fan	$116,966	$117			4.6	$25,475	1,150	3,450	$34
5.1	Culverts Through SR-20	$117,561	$118			0.0	$0	0	0	$0
5.2	Replace SR-20 Bridge with Longer Bridge	$12,539,875	$12,540			3.4	$3,641,580	225	225	$55,733
5.3	Reestablish Wetlands Downstream of SR-20	$212,528	$213			40.0	$5,317	0	0	$0
5.4	In-Stream Dredging	$234,113	$234			0.0	$0	0	0	$0
5.5	50-ft Floodplain Along Both Sides of Creek	$1,056,832	$1,057			9.2	$115,089	1,000	5,000	$211
5.6	Longer New Adjacent Channel	$702,621	$703			9.6	$73,190	1,100	5,100	$138
5.7	Shorter New Adjacent Channel	$506,976	$507			7.3	$69,449	1,300	4,200	$121
6.1	Redirect "Dairy Tributary" Under Helmick Road to Red Creek	$144,884	$145			4.1	$35,062	-400	1,350	$107
6.2	Redirect "Dairy Tributary" Along Prop. Improvements on Helmick Road	$137,014	$137			8.0	$17,052	875	2,625	$52
6.3	Fence Upper Red Creek On Public Property	$15,060	$15			18.5	$812	0	1,200	$13
6.4	Property Acquisition (or Easements) and Fence Upper Red Creek	$41,624	$42			22.5	$1,850	0	2,000	$21
6.5	Creek & Wetland Enhancements and Fencing along Upper Red Creek	$62,197	$62			18.5	$3,355	100	700	$89
6.6	Property Acquisition (or Easements), Enhancements and Fencing along Upper Red Creek	$141,322	$141			23.7	$5,962	500	1,850	$76
6.7	Property Acquisition (or Easements), Revegetation and Fencing Lower Red Creek	$109,139	$109			6.2	$17,608	0	2,700	$40
6.8	Property Acquisition and Restoration along Lower Red Creek	$238,611	$239			6.2	$38,496	1,300	4,000	$60

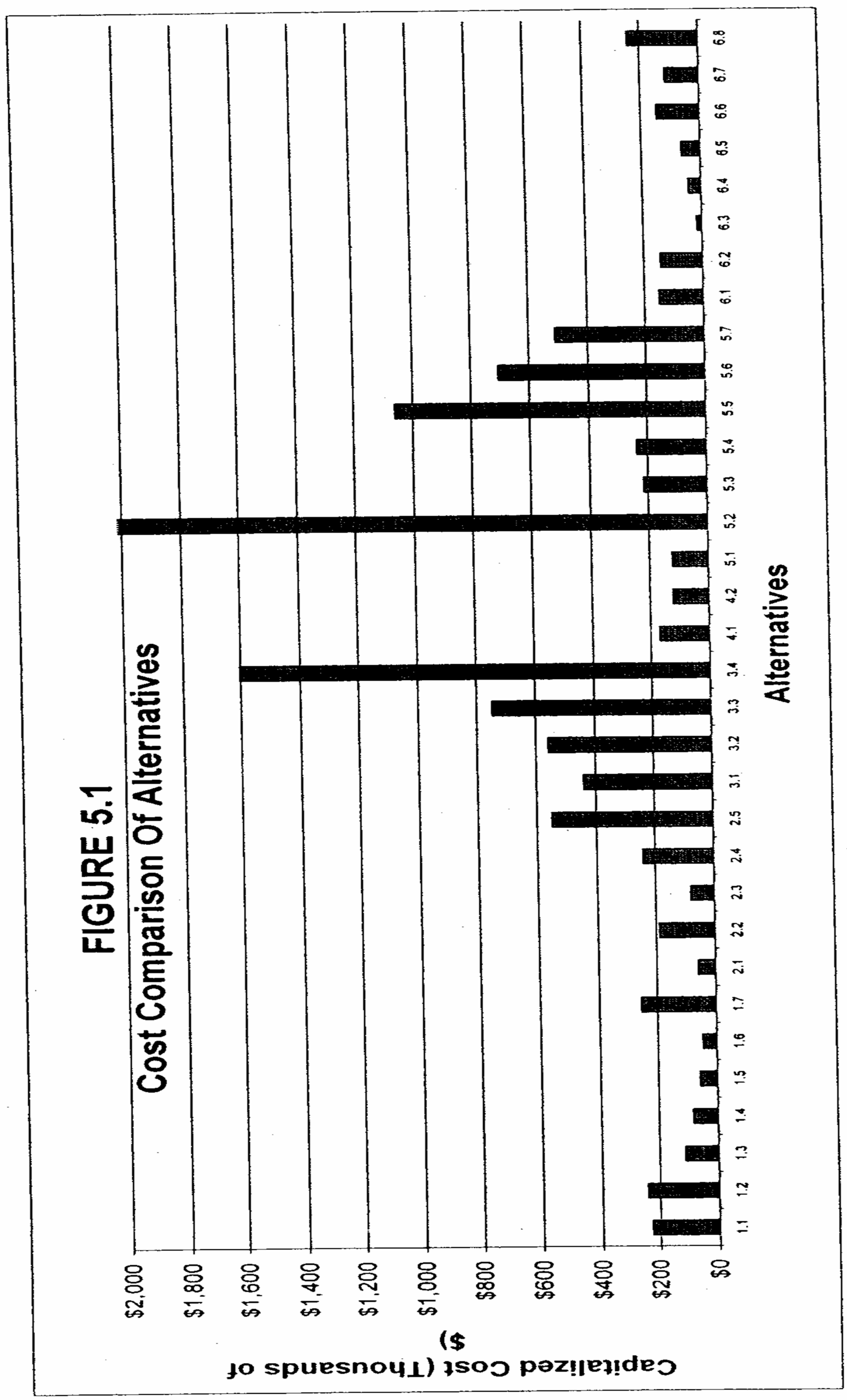


FIGURE 5.1
Cost Comparison Of Alternatives
Capitalized Cost (Thousands of $)
$2,000
$1,800
$1,600
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
2.1
2.2
2.3
2.4
2.5
3.1
3.2
3.3
3.4
4.1
4.2
5.1
5.2
5.3
5.4
5.5
5.6
5.7
6.1
6.2
6.3
6.4
6.5
6.6
6.7
6.8
Alternatives

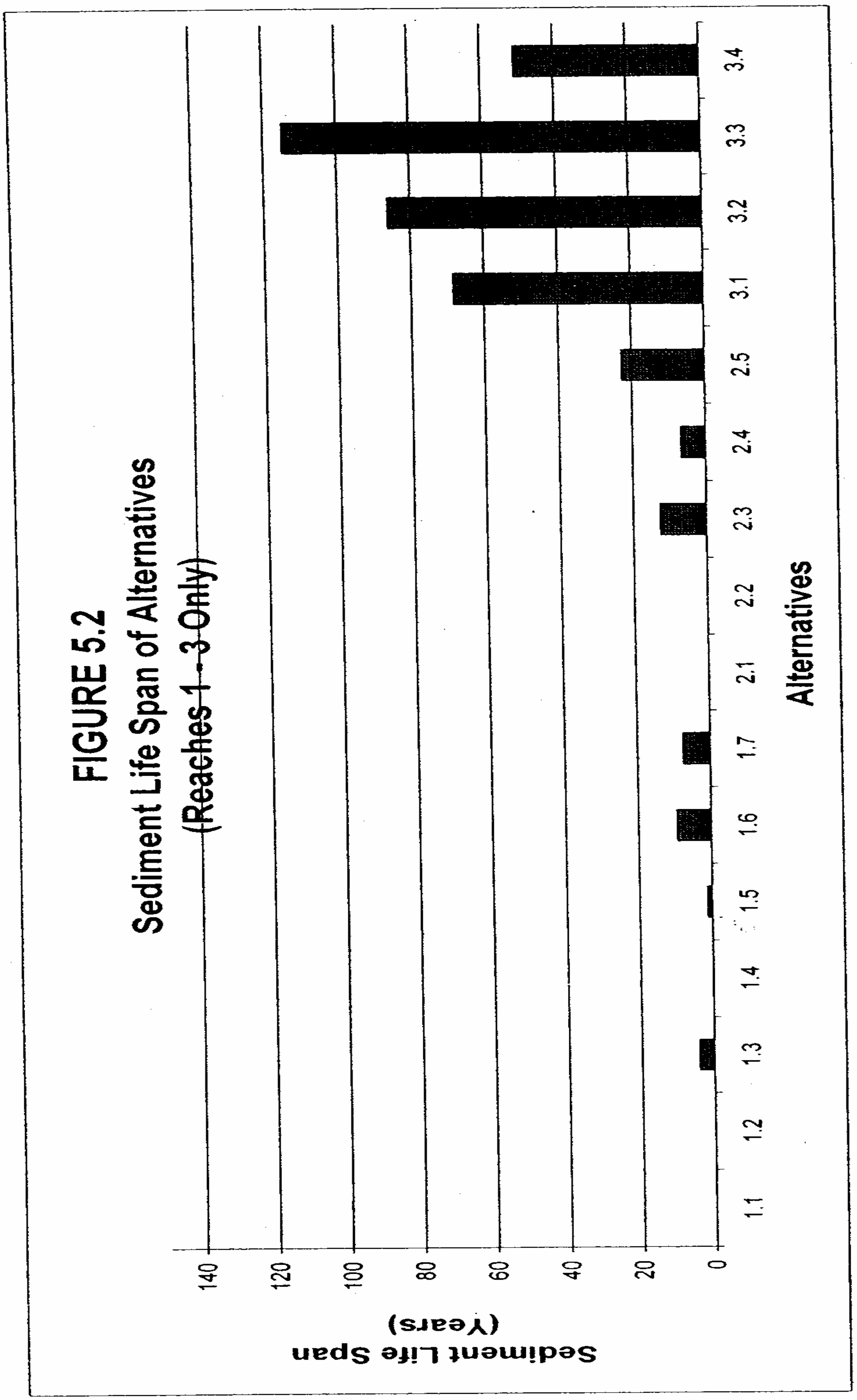


FIGURE 5.2
Sediment Life Span of Alternatives
(Reaches 1 - 3 Only)
Sediment Life Span
(Years)
0
20
40
60
80
100
120
140
1.1
1.2
1.3
1.4
1.5
1.6
1.7
2.1
2.2
2.3
2.4
2.5
3.1
3.2
3.3
3.4
Alternatives

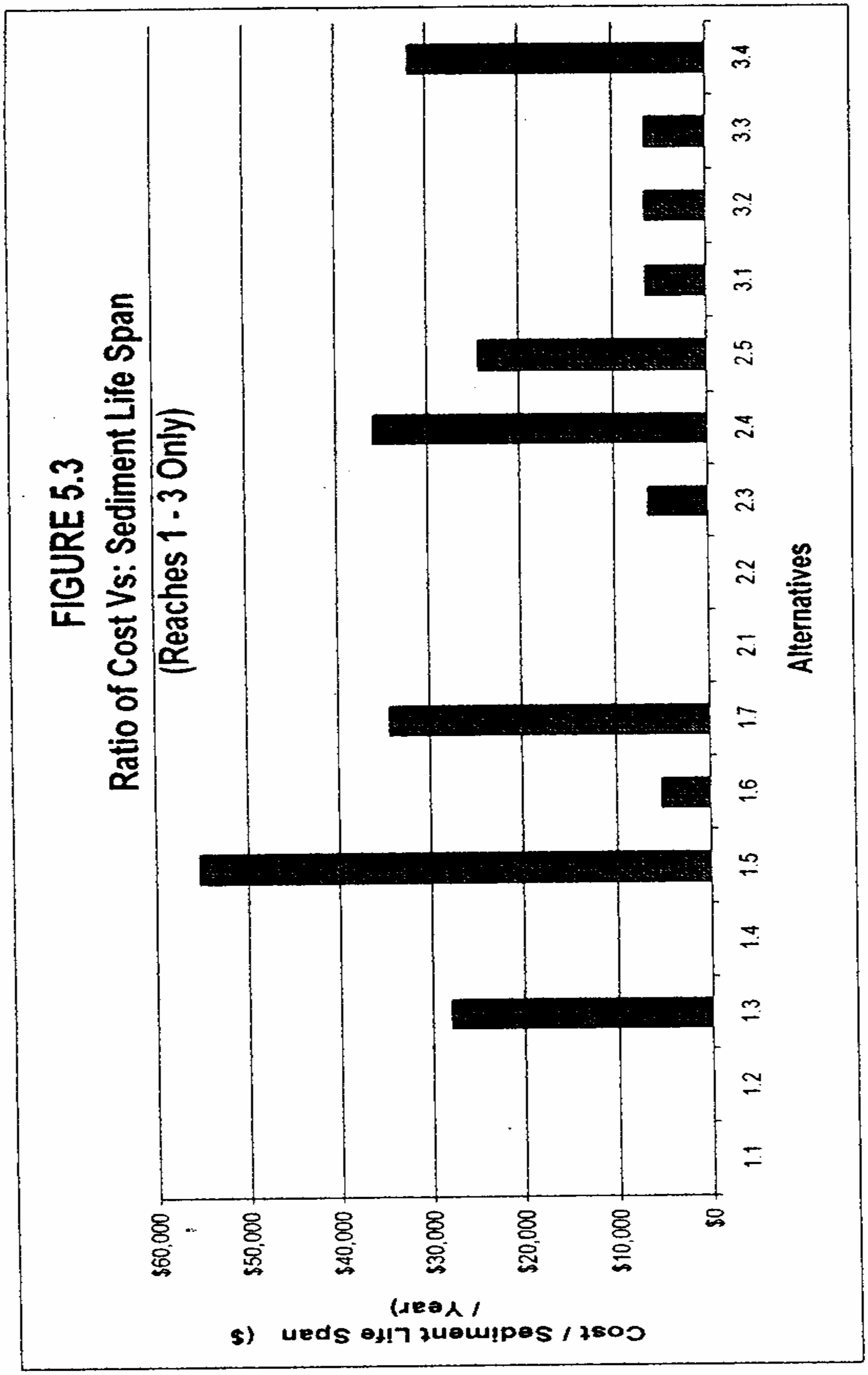


FIGURE 5.3
Ratio of Cost Vs: Sediment Life Span
(Reaches 1 - 3 Only)

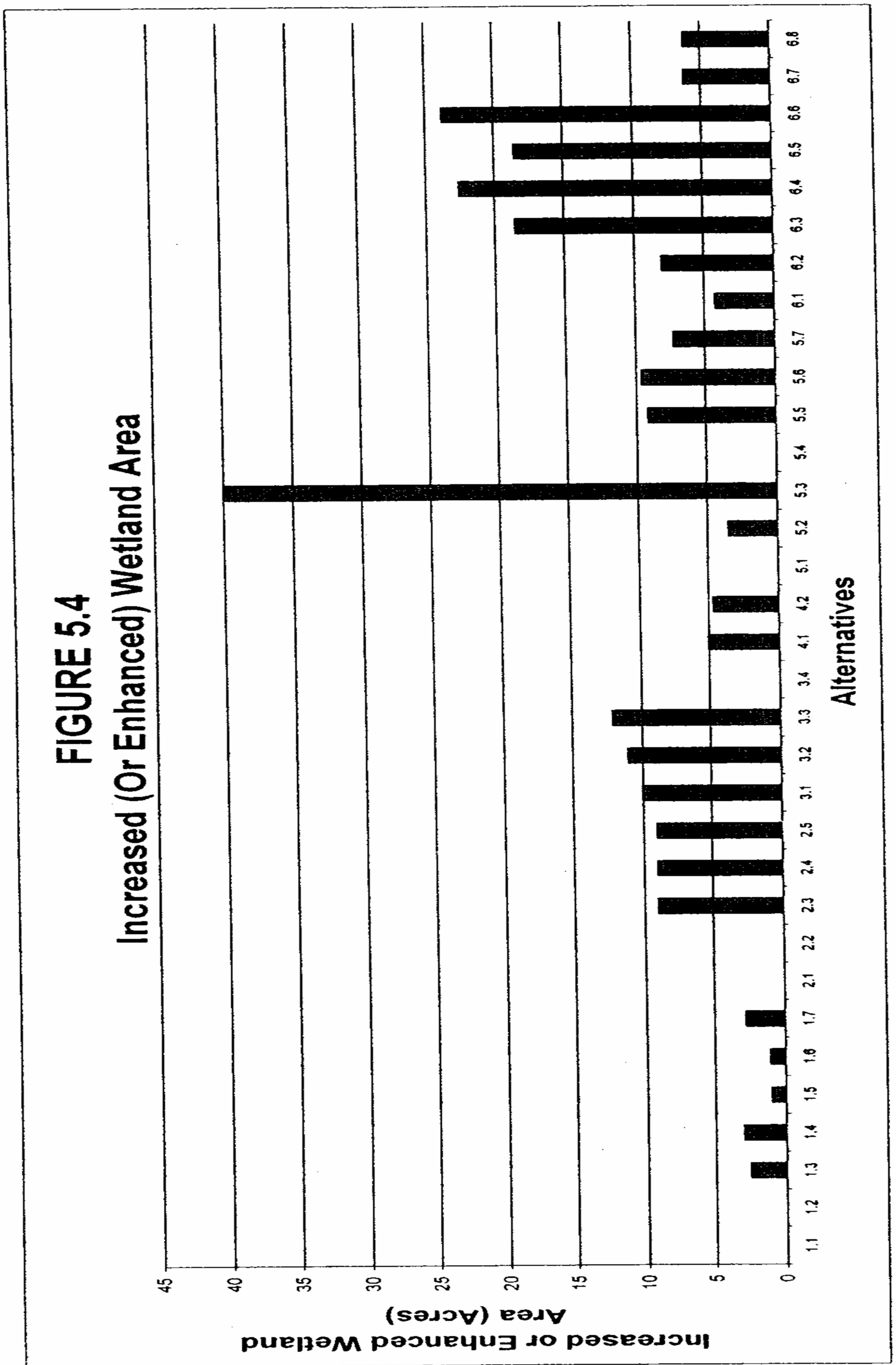


FIGURE 5.4
Increased (Or Enhanced) Wetland Area

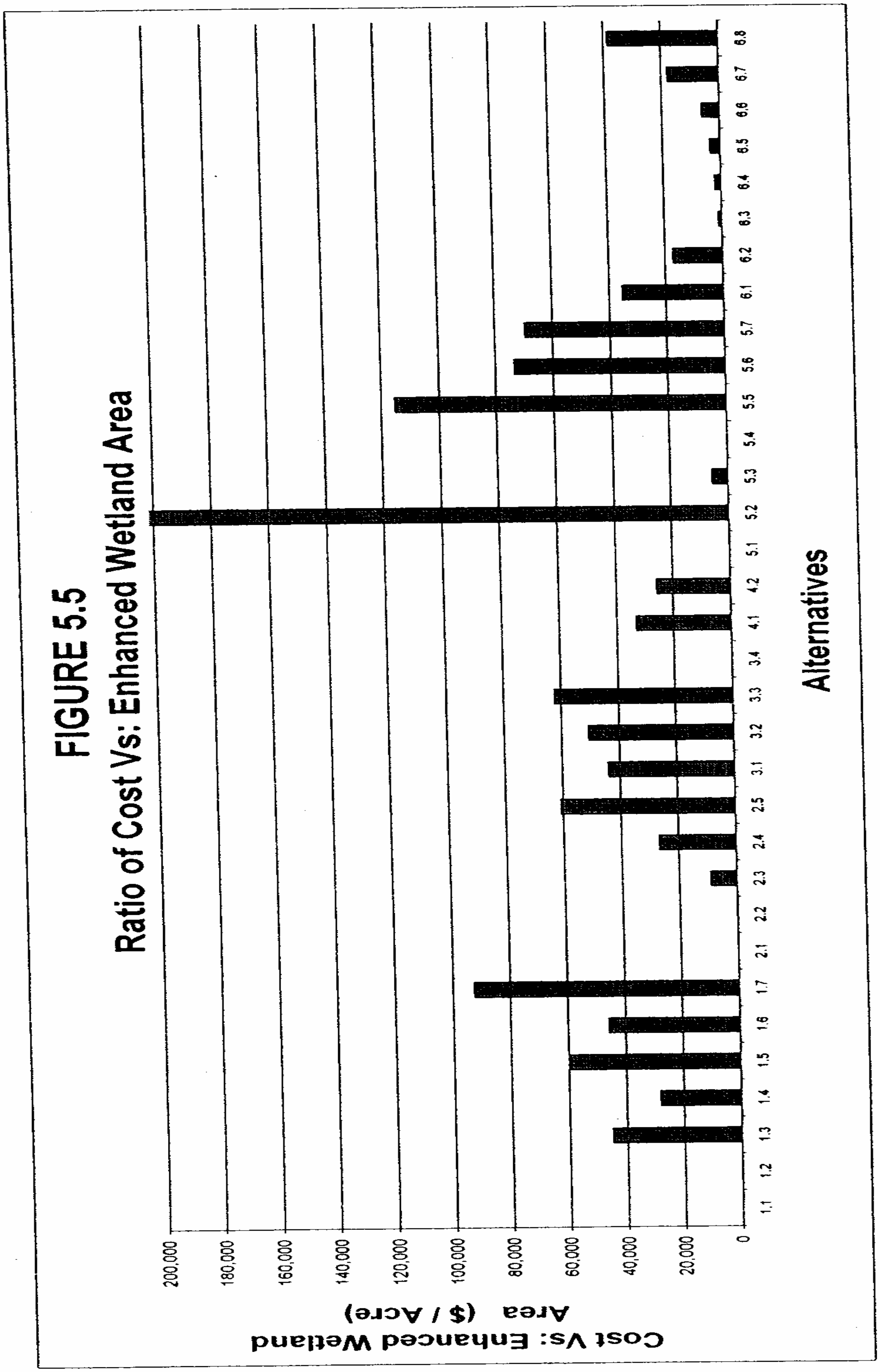


FIGURE 5.5
Ratio of Cost Vs: Enhanced Wetland Area
Cost Vs: Enhanced Wetland Area ($ / Acre)
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
2.1
2.2
2.3
2.4
2.5
3.1
3.2
3.3
3.4
4.1
4.2
5.1
5.2
5.3
5.4
5.5
5.6
5.7
6.1
6.2
6.3
6.4
6.5
6.6
6.7
6.8
Alternatives

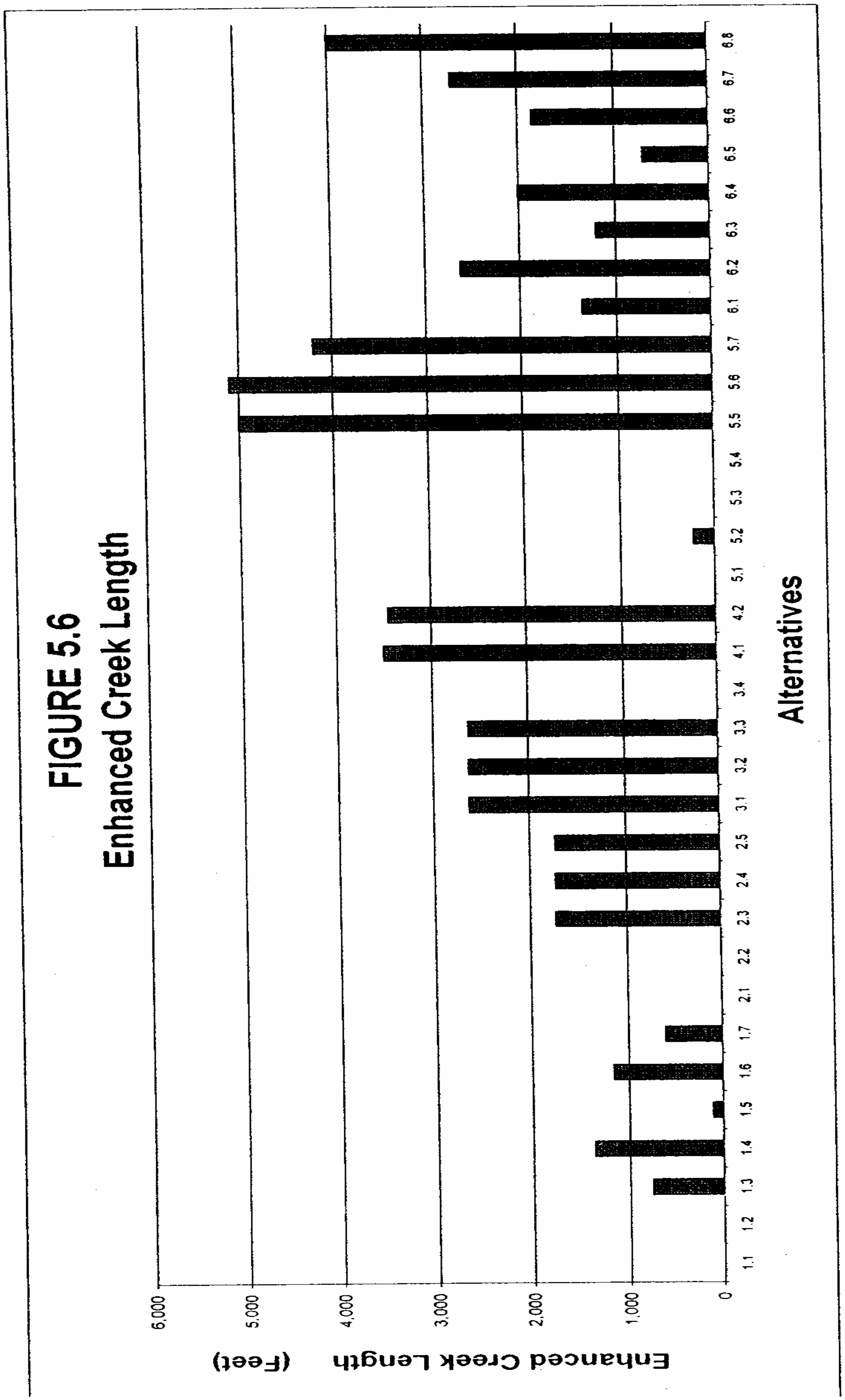


FIGURE 5.6
Enhanced Creek Length
Enhanced Creek Length (Feet)
6,000
5,000
4,000
3,000
2,000
1,000
0
1.1 1.2 1.3 1.4 1.5 1.6 1.7 2.1 2.2 2.3 2.4 2.5 3.1 3.2 3.3 3.4 4.1 4.2 5.1 5.2 5.3 5.4 5.5 5.6 5.7 6.1 6.2 6.3 6.4 6.5 6.6 6.7 6.8
Alternatives

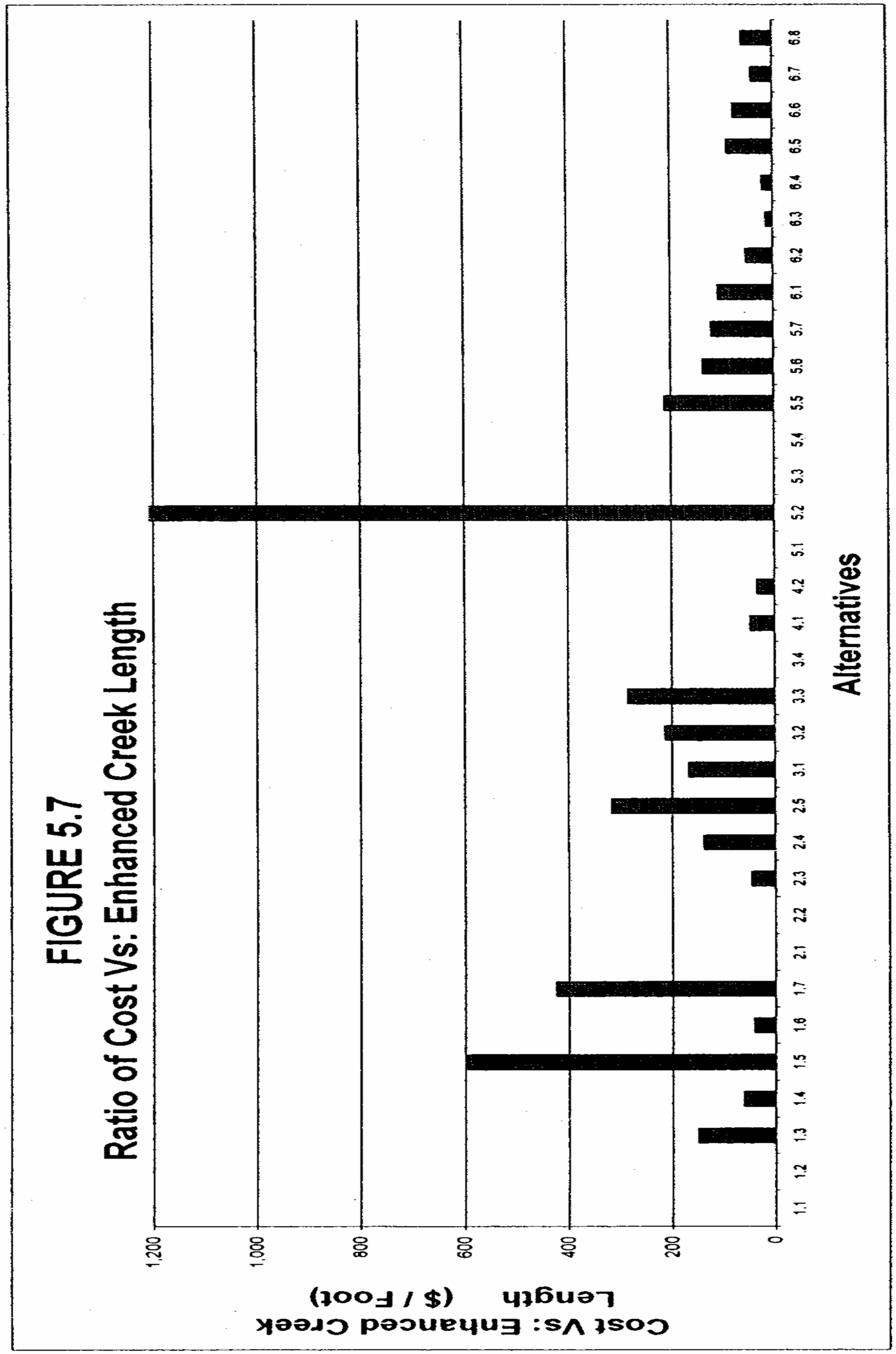


FIGURE 5.7
Ratio of Cost Vs: Enhanced Creek Length
Cost Vs: Enhanced Creek Length ($ / Foot)
1,200
1,000
800
600
400
200
0
1.1 1.2 1.3 1.4 1.5 1.6 1.7 2.1 2.2 2.3 2.4 2.5 3.1 3.2 3.3 3.4 4.1 4.2 5.1 5.2 5.3 5.4 5.5 5.6 5.7 6.1 6.2 6.3 6.4 6.5 6.6 6.7 6.8
Alternatives

Table 5.2

Reach 1 Alternatives

Item	Units	Alternative 1.1 Replace 16-ft Dia. Culvert On Hansen Creek Road w/ Bridge	Alternative 1.2 Replace Existing Northwood Lane Bridge. Secure Easements or Property.	Alternative 1.3 Terrace Excavation Along Sub-Reach 1c, Creek Enhancements (LWD)	Alternative 1.4 Redirect Trib. #272 Back Into Historic Channel	Alternative 1.5 Remove Upper NSH Bridge & Structure. Remove Trib. #270 Road & Culvert. Regrade Area.	Alternative 1.6 LWD Placement and Passive Aggradation in Sub-Reaches 1a and 1b.	Alternative 1.7 Terrace Excavation Along Existing Sediment Pond.
Project Costs								
Real Estate	$	$0	$5,625	$0	$0	$0	$0	$0
Construction	$	$156,600	$162,400	$77,946	$57,531	$41,211	$33,350	$176,029
Design, Permitting and Management	$	$40,716	$42,224	$20,266	$14,958	$10,715	$8,671	$45,768
Capitalized Operation, Maintenance & Monitoring	$	$28,589	$29,648	$14,230	$10,503	$7,523	$6,088	$32,136
Total Project Costs (Present Worth)	$	$225,905	$239,897	$112,441	$82,993	$59,449	$48,109	$253,933
Real Estate								
Footprint Area (On Public Property)	Acres	0.0	0.0	2.5	3.7	1.0	1.1	2.8
Footprint Area (On Private Property)	Acres	0.0	1.5	0.0	0.0	0.0	0.0	0.0
Wetlands (Floodplains Considered as Wetlands)								
Net Increase in Wetlands (Or Enhanced Wetlands)	Acres	0.0	0.0	2.5	3.0	1.0	1.1	2.8
% Of Historic Wetland Area (Existing Condition)	%	NA	NA	25.0%	4.2%	0.0%	0.0%	0.0%
% Of Historic Wetland Area (Proposed Condition)	%	NA	NA	45.8%	24.8%	8.3%	8.8%	23.0%
Creek Length								
Increase In Creek Length	LF	0.0	0.0	250.0	1350.0	0.0	0.0	0.0
Length of Creek Disturbed	LF	100.0	100.0	500.0	0.0	100.0	1150.0	600.0
Length of Creek Enhanced	LF	0.0	0.0	750.0	1350.0	100.0	1150.0	600.0
Sediment Control								
% Of Historic Alluvial Fan Area (Proposed)	%	NA	Makes historic channels in upper Alluvial Fan accessable.	NA	NA	NA	NA	NA
Volume Available for Future Sedimentation	CY	NA	NA	12111	NA	3227	28145	22222
Sediment Life Span (Years to Fill)	Years	NA	NA	4.0	NA	1.1	9.4	7.4
Total Cost to Sediment Life Span Ratio	$ / Year	NA	NA	$27,852	NA	$55,273	$5,128	$34,281
Flood Control								
Flood Detention Benefit	Subjective	Negligible	Negligible	Moderate	Minimal / Moderate	Minimal	Minimal	Minimal
Approx. Level of Protection (Reach 5 Only)	Years	NA	NA	NA	NA	NA	NA	NA

Table 5.3

Reach 2 Alternatives

Item	Units	Alternative 2.1 Remove Lower NSH Bridge & Regrade	Alternative 2.2 Replace Lower NSH Bridge w/ Footbridge	Alternative 2.3 LWD Placement and Passive Aggradation In Channel	Alternative 2.4 Active Aggradation In Channel	Alternative 2.5 Passive Aggradation on Excavated Terrace (100-ft Wide, 5-ft Deep)
Project Costs						
Real Estate	$	$0	$0	$0	$0	$0
Construction	$	$46,678	$116,000	$44,022	$132,315	$318,174
Design, Permitting and Management	$	$12,136	$47,560	$11,446	$34,402	$82,725
Capitalized Operation, Maintenance & Monitoring	$	$0	$21,177	$24,110	$72,466	$145,214
Total Project Costs (Present Worth)	$	$58,815	$184,737	$79,578	$239,184	$546,114
Real Estate						
Footprint Area (On Public Property)	Acres	2.0	0.0	1.2	1.2	5.1
Footprint Area (On Private Property)	Acres	0.0	0.0	0.0	0.0	0.0
Wetlands (Floodplains Considered as Wetlands)						
Net Increase in Wetlands (Or Enhanced Wetlands)	Acres	0.0	0.0	9.0	9.0	9.0
% Of Historic Wetland Area (Existing Condition)	%	NA	NA	18.0%	18.0%	18.0%
% Of Historic Wetland Area (Proposed Condition)	%	NA	NA	100.0%	100.0%	100.0%
Creek Length						
Increase In Creek Length	LF	0.0	0.0	0.0	0.0	0.0
Length of Creek Disturbed	LF	0.0	0.0	1725.0	1725.0	1725.0
Length of Creek Enhanced	LF	0.0	0.0	1725.0	1725.0	1725.0
Sediment Control						
% Of Historic Alluvial Fan Area (Proposed)	%	NA	NA	NA	NA	NA
7.0	CY	NA	NA	37780.0	20045.0	67409.6
Sediment Life Span (Years to Fill)	Years	NA	NA	12.6	6.7	22.5
Total Cost to Sediment Life Span Ratio	$ / Year	NA	NA	$6,319	$35,797	$24,304
Flood Control						
Flood Detention Benefit	Subjective	NA	NA	No Change	Reduces Storage, Negative Benefit	Moderate
Approx. Level of Protection (Reach 5 Only)	Years	NA	NA	NA	NA	NA

Table 5.4

Reach 3 Alternatives

Item	Units	Alternative 3.1	Alternative 3.2	Alternative 3.3	Alternative 3.4
		Natural Alluvial Fan (Small)	Natural Alluvial Fan (Medium)	Natural Alluvial Fan (Large)	Engineered Alluvial Fan
Project Costs					
Real Estate	$	$0	$0	$0	$0
Construction	$	$324,711	$411,213	$550,785	$816,464
Design, Permitting and Management	$	$84,425	$106,915	$143,204	$212,281
Capitalized Operation, Maintenance & Monitoring	$	$29,639	$37,535	$50,275	$571,945
Total Project Costs (Present Worth)	$	$438,775	$555,664	$744,265	$1,600,689
Real Estate					
Footprint Area (On Public Property)	Acres	33.5	42.0	56.0	13.9
Footprint Area (On Private Property)	Acres	0.0	0.0	0.0	0.0
Wetlands (Floodplains Considered as Wetlands)					
Net Increase in Wetlands (Or Enhanced Wetlands)	Acres	10.0	11.0	12.0	0.0
% Of Historic Wetland Area (Existing Condition)	%	0.0%	0.0%	0.0%	0.0%
% Of Historic Wetland Area (Proposed Condition)	%	0.0%	0.0%	0.0%	0.0%
Creek Length					
Increase In Creek Length	LF	525.0	525.0	525.0	0.0
Length of Creek Disturbed	LF	2100.0	2100.0	2100.0	1172.0
Length of Creek Enhanced	LF	2625.0	2625.0	2625.0	0.0
Sediment Control					
% Of Historic Alluvial Fan Area (Proposed)	%	33.5%	42.0%	56.0%	13.9%
Volume Available for Future Sedimentation	CY	204,749	257,583	343,980	151,250
Sediment Life Span (Years to Fill)	Years	68.2	85.9	114.7	50.4
Total Cost to Sediment Life Span Ratio	$ / Year	$6,429	$6,472	$6,491	$31,749
Flood Control					
Flood Detention Benefit	Subjective	Small	Moderate	Large	Very Small
Approx. Level of Protection (Reach 5 Only)	Years	NA	NA	NA	NA

Table 5.5

Reach 4 Alternatives

Item	Units	Alternative 4.1 Channel Restoration Downstream of Natural Alluvial Fan	Alternative 4.2 Channel Restoration Downstream of Engineered Alluvial Fan
Project Costs			
Real Estate	$	$0	$0
Construction	$	$121,956	$86,559
Design, Permitting and Management	$	$31,709	$22,505
Capitalized Operation, Maintenance & Monitoring	$	$11,132	$7,901
Total Project Costs (Present Worth)	$	$164,797	$116,966
Real Estate			
Footprint Area (On Public Property)	Acres	1.6	1.6
Footprint Area (On Private Property)	Acres	0.0	0.0
Wetlands (Floodplains Considered as Wetlands)			
Net Increase in Wetlands (Or Enhanced Wetlands)	Acres	5.0	4.6
% Of Historic Wetland Area (Existing Condition)	%	65.7%	65.7%
% Of Historic Wetland Area (Proposed Condition)	%	69.3%	69.0%
Creek Length			
Increase In Creek Length	LF	2200.0	1150.0
Length of Creek Disturbed	LF	1300.0	2300.0
Length of Creek Enhanced	LF	3500.0	3450.0
Sediment Control			
% Of Historic Alluvial Fan Area (Proposed)	%	NA	NA
Volume Available for Future Sedimentation	CY	NA	NA
Sediment Life Span (Years to Fill)	Years	NA	NA
Total Cost to Sediment Life Span Ratio	$ / Year	NA	NA
Flood Control			
Flood Detention Benefit	Subjective	Very Significant	Significant
Approx. Level of Protection (Reach 5 Only)	Years	NA	NA

Table 5.6

Reach 5 Alternatives

Item	Units	Alternative 5.1 Culverts Through SR-20	Alternative 5.2 Replace SR-20 Bridge with Longer Bridge	Alternative 5.3 Reestablish Wetlands Downstream of SR-20	Alternative 5.4 In-Stream Dredging	Alternative 5.5 50-ft Floodplain Along Both Sides of Creek	Alternative 5.6 Longer New Adjacent Channel	Alternative 5.7 Shorter New Adjacent Channel
Project Costs								
Real Estate	$	$0	$0	$149,879	$12,000	$48,209	$49,125	$37,875
Construction	$	$87,000	$9,280,000	$46,363	$164,372	$746,420	$500,518	$347,153
Design, Permitting and Management	$	$22,620	$2,412,800	$12,054	$42,737	$194,069	$130,135	$90,260
Capitalized Operation, Maintenance & Monitoring	$	$7,941	$847,075	$4,232	$15,004	$68,133	$22,844	$31,688
Total Project Costs (Present Worth)	$	$117,561	$12,539,875	$212,528	$234,113	$1,056,832	$702,621	$506,976
Real Estate								
Footprint Area (On Public Property)	Acres	0.0	3.4	0.0	0.0	0.0	0.0	0.0
Footprint Area (On Private Property)	Acres	0.0	0.0	40.0	3.2	12.9	13.1	10.1
Wetlands (Floodplains Considered as Wetlands)								
Net Increase in Wetlands (Or Enhanced Wetlands)	Acres	0.0	3.4	40.0	0.0	9.2	9.6	7.3
% Of Historic Wetland Area (Existing Condition)	%	NA	0.0%	0.0%	0.0%	0.3%	0.3%	0.3%
% Of Historic Wetland Area (Proposed Condition)	%	NA	0.9%	10.0%	0.0%	2.5%	2.7%	2.1%
Creek Length								
Increase In Creek Length	LF	0.0	225.0	0.0	0.0	1000.0	1100.0	1300.0
Length of Creek Disturbed	LF	0.0	0.0	0.0	4300.0	4000.0	4000.0	2900.0
Length of Creek Enhanced	LF	0.0	225.0	0.0	0.0	5000.0	5100.0	4200.0
Sediment Control								
% Of Historic Alluvial Fan Area (Proposed)	%	NA	NA	NA	NA	NA	NA	NA
Volume Available for Future Sedimentation	CY	NA	NA	NA	NA	NA	NA	NA
Sediment Life Span (Years to Fill)	Years	NA	NA	NA	NA	NA	NA	NA
Total Cost to Sediment Life Span Ratio	$ / Year	NA	NA	NA	NA	NA	NA	NA
Flood Control								
Flood Detention Benefit	Subjective	Negative Benefit (Reduces Detention)	Negative Benefit (Reduces Detention)	Moderate	Negligible	Minimal	Very Good	Moderate
Approx. Level of Protection (Reach 5 Only)	Years	Unknown	Unknown	< 20	< 5	< 10	> 100	10.0

Table 5.7

Reach 6 (Red Creek) Alternatives

Item	Units	Alternative 6.1 Redirect "Dairy Tributary" Under Helmick Road to Red Creek	Alternative 6.2 Redirect "Dairy Tributary" Along Prop. Improvements on Helmick Road	Alternative 6.3 Fence Upper Red Creek On Public Property	Alternative 6.4 Property Acquisition (or Easements) and Fence Upper Red Creek	Alternative 6.5 Creek & Wetland Enhancements and Fencing along Upper Red Creek	Alternative 6.6 Property Acquisition (or Easements), Enhancements and Fencing along Upper Red Creek	Alternative 6.7 Property Acquisition (or Easements), Revegetation and Fencing Lower Red Creek	Alternative 6.8 Property Acquisition and Restoration along Lower Red Creek
Project Costs									
Real Estate	$	$0	$0	$0	$14,850	$0	$19,370	$23,244	$23,244
Construction	$	$100,435	$101,395	$10,440	$18,560	$43,116	$90,250	$63,566	$159,380
Design, Permitting and Management	$	$26,113	$26,363	$2,714	$4,826	$11,210	$23,465	$16,527	$41,439
Capitalized Operation, Maintenance & Monitoring	$	$18,335	$9,255	$1,906	$3,388	$7,871	$8,238	$5,802	$14,548
Total Project Costs (Present Worth)	$	$144,884	$137,014	$15,060	$41,624	$62,197	$141,322	$109,139	$238,611
Real Estate									
Footprint Area (On Public Property)	Acres	4.1	8.0	18.5	18.5	18.5	18.5	0.0	0.0
Footprint Area (On Private Property)	Acres	0.0	0.0	0.0	4.0	0.0	5.2	6.2	6.2
Wetlands (Floodplains Considered as Wetlands)									
Net Increase in Wetlands (Or Enhanced Wetlands)	Acres	4.1	8.0	18.5	22.5	18.5	23.7	6.2	6.2
% Of Historic Wetland Area (Existing Condition)	%	0.5	0.5	0.5	0.5	0.5	0.5	0.2	0.2
% Of Historic Wetland Area (Proposed Condition)	%	0.6	0.6	0.8	0.9	0.8	0.9	0.3	0.3
Creek Length									
Increase In Creek Length	LF	-400.0	875.0	0.0	0.0	100.0	500.0	0.0	1300.0
Length of Creek Disturbed	LF	1750.0	1750.0	0.0	0.0	600.0	1350.0	0.0	2700.0
Length of Creek Enhanced	LF	1350.0	2625.0	1200.0	2000.0	700.0	1850.0	2700.0	4000.0
Sediment Control									
% Of Historic Alluvial Fan Area (Proposed)	%	NA	NA	NA	NA	NA	NA	NA	NA
Volume Available for Future Sedimentation	CY	NA	NA	NA	NA	NA	NA	NA	NA
Sediment Life Span (Years to Fill)	Years	NA	NA	NA	NA	NA	NA	NA	NA
Total Cost to Sediment Life Span Ratio	$ / Year	NA	NA	NA	NA	NA	NA	NA	NA
Flood Control									
Flood Detention Benefit	Subjective	Minimal	Minimal	Minimal	Minimal / Moderate	Minimal / Moderate	Moderate	Minimal	Good
Approx. Level of Protection (Reach 5 Only)	Years	NA	NA	NA	NA	NA	NA	NA	NA

5.3 Discussion of Alternatives

5.3.1 Overview

This section briefly summarizes the alternatives considered for each reach (see Figure 5.8). More detailed discussions regarding these alternatives are included in Appendix 1.

5.3.2 Reach 1 Alternatives

Alternative 1.1 Replace Upper Hansen Creek Road Culvert with Bridge
Alternative 1.1 involves replacing the existing 16-ft diameter metal culvert under Upper Hansen Creek Road with an appropriately sized bridge. The existing culvert is too small to convey all the creek's sediment and debris and will likely result in a total blockage and catastrophic failure of the road sometime in the future. Replacing the culvert will eliminate the risk of failure, but will likely reintroduce large amounts of sediment back into the stream system. This additional sediment will tend to shorten the life of the sediment storage alternatives considered further downstream.

This alternative does not directly address the project objectives and is not considered a part of this project. However, it is suggested that the County consider it as an independent project and determine how to address this potential problem.

Alternative 1.2 Replace Northwood Lane Bridge and Secure Flood Easements
Alternative 1.2 involves replacing the existing 30-ft, single-span bridge with a larger bridge to reduce bridge scour and sediment deposition upstream of the bridge. Securing flood easements on the property to the east would maintain historic creek channels available for possible future channel migration on the historic Upper Alluvial Fan.

It is **recommended** that flood easements along the historic creek channels be secured to maintain future creek access on the Upper Alluvial Fan. The replacement of the bridge does not directly address the project objectives and is therefore **not suggested** as part of this project. The bridge replacement does have value, however, and it is suggested that the County consider it as an independent project.

Alternative 1.3 Terrace Excavation with Creek and Wetland Enhancements
Alternative 1.3 involves the excavation of the creek terraces in order to reconnect the currently incised creek with its historic floodplains and Tributary #271.This alternative is **suggested** because it enhances both the in-stream and wetland habitat, captures sediment, helps in reducing downstream flooding, and has a high cost/benefit ratio. It is also **suggested** that this alternative be combined with Alternative 1.4.

Alternative 1.4 Redirect Tributary #272 Back into Historic Channel and Enhance Creek

Alternative 1.4 involves redirecting Tributary #272 back into its historic channel and enhancing the historic channel where appropriate.

This alternative is **suggested** since it creates more in-stream habitat, economically enhances both the in-stream and wetland habitat, helps in reducing downstream flooding, and has a high cost/benefit ratio. It is also **suggested** that this alternative be combined with Alternative 1.3.

Alternative 1.5 Remove Upper NSRA Bridge, Tributary #270 Culvert and Adjacent Road Regrade Area.

Alternative 1.5 involves the removal of the upper NSRA bridge and associated roadway approaches. This bridge is the dividing line between Reaches 1 and 2 and is currently substandard and dangerous. Removal of the bridge and its approaches will enable the creek to utilize its historic floodplain. This alternative also includes removal (but not replacement) of the road fill along the existing sediment pond and the culvert over Tributary #270. This road currently provides access to wells on the Northern State property. Elimination of this road fill would have to be coordinated with access to the wells.

This alternative is **suggested** since it eliminates the existing bridge hazard, creates better fish passage into Tributary #270 and provides continuity between Reaches 1 and 2 (in both the channel and floodplain).

Alternative 1.6 LWD Placement and Passive Aggradation

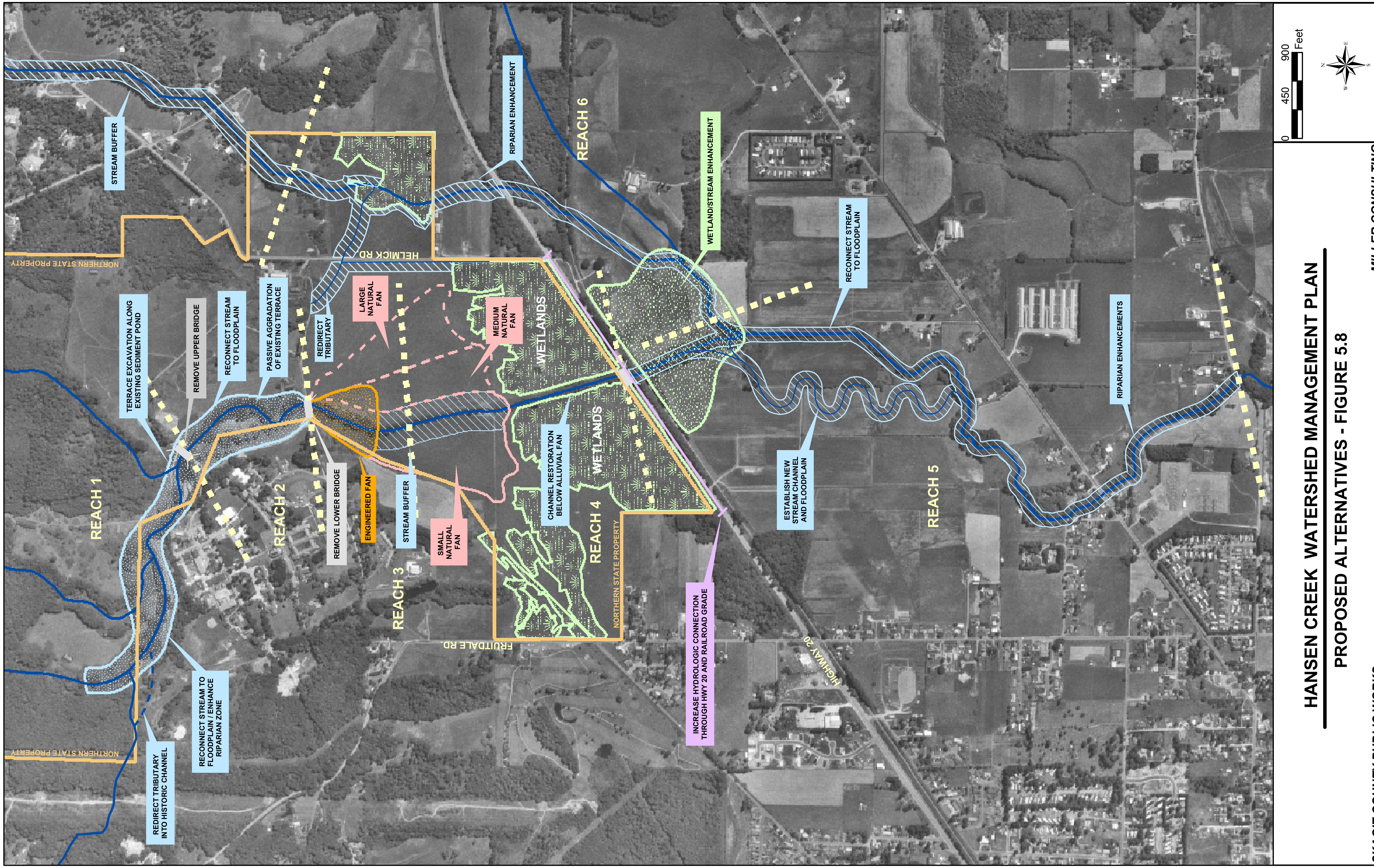
Alternative 1.6 involves periodic placement of Large Woody Debris (LWD) in the Main Stem of Hansen Creek to encourage sediment deposition and to enhance in-stream fish habitat. The LWD and deposition will be dependent upon sediment deposition in the downstream reaches, and will therefore need to occur periodically over a number of years. LWD placement will need to proceed upstream in a “step-wise” fashion.

This alternative is very cost effective in terms of habitat enhancement, and is **suggested** with other suggested Reach 1 alternatives. (Assumed to occur only in Sub-Reaches 1a and 1b.)

Alternative 1.7 Terrace Excavation Along Existing Sediment Pond

Alternative 1.7 considers the excavation of up to 5-ft from the terraces along the existing sediment pond. This excavation provides a wider floodplain enabling the creek to laterally migrate. This, in turn, encourages sediment deposition and habitat enhancement.

This alternative is **not suggested** as it is not cost effective in terms of sediment storage and habitat enhancement.


HANSEN CREEK WATERSHED MANAGEMENT PLAN
PROPOSED ALTERNATIVES - FIGURE 5.8
MILLER CONSULTING
SKAGIT COUNTY PUBLIC WORKS
OCT. 2001
0
450
900
Feet
STREAM BUFFER
RIPARIAN ENHANCEMENT
REACH 6
WETLAND/STREAM ENHANCEMENT
RECONNECT STREAM TO FLOODPLAIN
RIPARIAN ENHANCEMENTS
HELMICK RD
NORTHERN STATE PROPERTY
TERRACE EXCAVATION ALONG EXISTING SEDIMENT POND
REMOVE UPPER BRIDGE
RECONNECT STREAM TO FLOODPLAIN
PASSIVE AGGRADATION OF EXISTING TERRACE
REDIRECT TRIBUTARY
LARGE NATURAL FAN
MEDIUM NATURAL FAN
WETLANDS
CHANNEL RESTORATION BELOW ALLUVIAL FAN
WETLANDS
ESTABLISH NEW STREAM CHANNEL AND FLOODPLAIN
REACH 5
REACH 1
REACH 2
REMOVE LOWER BRIDGE
ENGINEERED FAN
STREAM BUFFER
SMALL NATURAL FAN
REACH 3
REACH 4
NORTHERN STATE PROPERTY
INCREASE HYDROLOGIC CONNECTION THROUGH HWY 20 AND RAILROAD GRADE
FRUITDALE RD
HIGHWAY 20
RECONNECT STREAM TO FLOODPLAIN / ENHANCE RIPARIAN ZONE
REDIRECT TRIBUTARY INTO HISTORIC CHANNEL
NORTHERN STATE PROPERTY

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5.3.3 Reach 2 Alternatives

Alternative 2.1 Remove Lower NSRA Bridge and Regrade Area
Alternative 2.1 involves the removal of the lower NSRA Bridge that is structurally unsound and hazardous. It also includes regrading the area in the vicinity of the existing bridge approaches.

This alternative is **suggested since** it eliminates the hazard associated with the existing bridge and provides a transitional area between Reach 2 and the apex of the suggested alluvial fan alternative immediately downstream.

Alternative 2.2 Replace Lower NSRA Bridge With Footbridge
Alternative 2.2 involves the construction of a new, long footbridge in the vicinity of the existing Lower NSRA Bridge (The removal of which is considered in Alternative 2.1).

This alternative does not directly address sediment control, habitat enhancement and/or flooding, and is therefore beyond the intended scope of this project. However, a bridge designed to allow pedestrian and light maintenance vehicle traffic over Hansen Creek will likely be necessary as part of the Northern State Recreation Area.

Alternative 2.3 LWD Placement and Passive Aggradation in Channel
Alternative 2.3 involves periodic placement of LWD in the incised Reach 2 after the downstream alluvial fan aggrades and begins to properly function (Dependent upon Alternative 3.2.).

This alternative is **suggested as** it is cost effective with respect to sediment storage, wetland enhancement and in-stream habitat enhancement.

Alternative 2.4 Active Aggradation in Channel
Alternative 2.4 involves placing sediment excavated from the downstream alluvial fan alternative(s) directly into the incised Reach 2. This would create more wetlands and better in-stream habitat immediately after construction and eliminate the need for periodic placement of LWD once the downstream alluvial fan becomes established.

This alternative is **not suggested as** it is dependent upon an alluvial fan alternative with a higher thalweg elevation. It is not considered a viable alternative as it would significantly reduce sediment storage potential in Reach 2. It is also inefficient with respect to sediment storage, wetland enhancement and in-stream habitat enhancement when compared to Alternative 2.3

Alternative 2.5 Passive Aggradation On Excavated Terrace
Alternative 2.5 involves excavating a recessed floodplain along Reach 2. Conceptually, the excavation would be approximately 5-ft deep and 50-ft wide on

each bank. Once the adjacent floodplain is excavated, the stream banks and channel would be restored. A recessed floodplain would enable the creek to access its floodplain, deposit sediment and meander more naturally immediately after construction. This alternative provides more sediment storage potential relative to the other Reach 2 alternatives.

This alternative is **not suggested in its entirety** because it requires complete removal of existing riparian vegetation along Reach 2. In addition, this alternative leaves the disturbed area vulnerable to large-scale erosion problems and is inefficient with respect to sediment storage, wetland enhancement and in-stream habitat restoration. There is some benefit to this type of alternative at specific locations within Reach 2, therefore it is **suggested that this alternative be considered along portions of Reach 2**, if determined to be appropriate in the design phase of this project.

5.3.4 Reach 3 Alternatives

Alternatives 3.1, 3.2 and 3.3 Natural Alluvial Fans

These 3 alluvial fan alternatives are similar with the exception of size. Respectively, Alternatives 3.1, 3.2 and 3.3 are the “Small”, “Medium” and “Large” versions of the “Natural Alluvial Fan” option.

The “Natural” alluvial fan alternatives are designed to replicate the functions of a natural alluvial fan without “external” or manmade controls. Over time, the whole fan area will aggrade (fill up with sediment). Aggradation will cause the elevation of the creek bed to rise on the fan as well as in the upstream reaches. This process will reverse the degradation (headcutting) experienced in the historic fan and upstream reaches for decades. The deposition of sediments on the fan will also eliminate conveyance of larger sediment downstream where it currently deposits in the creek and aggravates flooding in Reaches 4 and 5.

The County Parks Department plans to utilize the area east of the proposed alluvial fan location for ball fields and other recreational facilities as part of the NSRA development. The sediment excavated from the proposed fan could be distributed throughout the recreational area to increase the elevation of the recreational facilities. This “cut and fill” process increases the effective depth of the alluvial fan area while improving flood protection for the proposed recreation facilities. The effective depth (and therefore the associated “sediment life span”) of a natural alluvial fan increases as the size of the natural alluvial fan increases. It should be noted that, due to the large amount of land outside of existing critical areas and critical area buffers expected to be utilized for the footprint of the fan, the outside edge of the alluvial fan footprint will constitute the edge of any critical areas buffer and that no additional buffering will be required outside the footprint of the alluvial fan.

It is important to emphasize that if no recreational development were planned on the historic alluvial fan, the whole historic fan area could be utilized for the creation of a natural alluvial fan. Such a fan could be allowed to fill with sediment indefinitely without requiring maintenance dredging.

Periodic excavation of the proposed alluvial fan may be necessary since recreational development is planned in the vicinity of the historic fan, adjacent to the proposed alluvial fan. Without this “maintenance dredging”, the proposed recreational facilities might ultimately become inundated with sediment from the proposed alluvial fan.

The alluvial fan alternatives are essential to the overall Hansen Creek restoration plan. The fan is necessary to eliminate the conveyance and deposition of the larger sediments from the upper watershed to the downstream reaches that subsequently cause flooding on private property. Furthermore, a new alluvial fan will reverse downcutting that has occurred in the upstream reaches by depositing sediment on the fan itself as well as in the upstream reaches.

Alternative 3.2, the Medium Sized Natural Alluvial Fan, is suggested because it is the largest natural alluvial fan option compatible with the planned NSRA facilities. It has long-term sediment storage capacity, requires infrequent maintenance, and allows time for mature vegetation to reestablish on the fan thus increasing habitat values.

Alternative 3.4 Engineered Alluvial Fan

The engineered alluvial fan option is similar to the natural alluvial fan alternatives in that it will capture sediment, prevent sedimentation and flooding in downstream reaches and will reverse head cutting in upstream reaches. However, it would have minimal habitat value.

The engineered alluvial fan is contained by an earthen berm around its perimeter and controlled by in-stream structures at its upstream and downstream ends. Engineered structures would enable the engineered alluvial fan alternative to be substantially smaller than the natural alluvial fan alternatives.

In-stream control structures will require grade elevation controls or “stop-logs” for fish passage and to raise the channel elevation once the area upstream fills-up with sediment. These stop-logs will require frequent management. An in-stream control structure located downstream would localize the engineered fan’s discharge point as opposed to distributing the creek’s discharges over a wider area. The fan is relatively small and would require frequent maintenance dredging.

The County Parks Department will utilize the area to the east of (and perhaps to the south of) the engineered fan for ball fields and other recreational facilities. Where appropriate, sediment excavated from the proposed fan would be used as base fill for the proposed recreational developments. The major advantage of the engineered alluvial fan alternative is that it is significantly smaller than the natural alluvial fan alternatives, thereby leaving more land for NSRA facilities.

The engineered alluvial fan alternative is **not suggested** since it is significantly less cost effective (for both construction and maintenance), provides less base material for the proposed recreation facilities, and provides significantly less fish habitat benefits as compared to the natural alluvial fan alternatives.

5.3.5 Reach 4 Alternatives

Alternative 4.1 Channel Restoration Downstream of Natural Alluvial Fan

Alternative 4.1 involves creating several smaller tributary channels in the wetland immediately downstream of the suggested natural alluvial fan. The channels would be designed to approximate the historic channel types that existed downstream of the historic alluvial fan. Multiple smaller channels would be combined into a single channel prior to flowing beneath the Highway 20 Bridge should the present creek passage configuration remain. Channel banks would be restored and revegetated.

Existing levees along both sides of Hansen Creek upstream of the Highway 20 Bridge would be removed or breached at appropriate locations, preserving existing riparian vegetation. Breaching these levees increases the hydrologic connectivity between the creek and large wetland north of Highway 20. Connecting the creek and wetland will significantly detain floodwaters and reduce flood discharges experienced further downstream.

Alternative 4.1 is **suggested** as it increases and enhances in-stream and wetland habitat, significantly reduces downstream flooding, and is consistent with the suggested natural alluvial fan alternative. Furthermore, if this alternative is not reconstruct in conjunction with the alluvial fan alternative, the existing straight channel would degrade its bed in response to sediment trapping upstream, and the eroded sediment would move downstream possibly exacerbating flooding in Reach 5.

Alternative 4.2 Channel Restoration Downstream of Engineered Alluvial Fan

Like Alternative 4.1, Alternative 4.2 involves the removal and/or breaching of the existing levees along portions of both sides of Hansen Creek upstream of the Highway 20 Bridge. Breaching these levees would increase the hydrologic connectivity between the creek and large wetland north of Highway 20. Connecting the creek and wetland will significantly detain floodwaters and reduce flood discharges experienced further downstream.

Alternative 4.2 also involves creation of a single threaded main stem channel that approximates, as much as possible, an appropriate channel based on topography and geography. Multiple channels, similar to those considered in Alternative 4.1, are not necessary or appropriate in this situation since the engineered alluvial fan discharges from a single location rather than from a dispersed natural alluvial fan. Alternative 4.2 also includes restoration and revegetation of channel banks and the adjacent wetlands.

This alternative is **not suggested** because it creates wetland and channel types that are inconsistent with those that historically existed in this area. Additionally, this alternative is inconsistent with the suggested natural alluvial fan alternative.

5.3.6 Reach 5 Alternatives

Any activities proposed in Reach 5 require concurrence with private property owners located within that reach. A preferred alternative for Reach 5 has not been identified as, at the time of this report, there is not consensus amongst the landowners as to the best course of action. As such, a suite of possible alternatives is presented for Reach 5 that could be realized in the future once the plan elements proposed on the NSRA have been constructed.

For the purposes of developing a reference cost estimate for the preferred alternative detailed in this report, Alternative 5.6: *Create Longer New Adjacent Channel*, was used. This alternative best met the Plan goals of flood reduction, fish habitat enhancement, and sediment reduction.

Alternative 5.1 Additional Culverts Beneath Highway 20

Alternative 5.1 involves installation of additional culverts beneath Highway 20 and the old railroad grade to increase connectivity to the wetlands north of the highway and conveyance of water to the wetlands considered in Alternative 5.3. This alternative also includes extending the existing Highway 20 culvert beneath the old railroad grade. It is assumed that the new culverts could be jacked through the highway and railroad fill without any disruption to traffic.

Alternative 5.2 Replace Existing Highway 20 Bridge

Alternative 5.2 considers replacing the existing 45-ft long SR-20/Hansen Creek Bridge with a 2000-ft long bridge. The longer bridge would span a large portion of the historic wetland and provide greater continuity between the wetlands upstream and downstream of Highway 20. This alternative is dependent upon the recreation of the wetlands considered in Alternative 5.3.

Alternative 5.3 Reestablish Historic Wetlands Downstream of Highway 20

Alternative 5.3 would reestablish historic wetlands along both sides of Hansen Creek downstream of the existing Highway 20 bridge to the Red Creek confluence. Wetlands would be created on land that is, or recently was (within the last 80 years) classified as wetlands. While this alternative requires lease, easement or acquisition of a relatively large property, it is cost effective and beneficial with respect to overall habitat enhancement and flood control.

Alternative 5.4 In-Stream Dredging

Alternative 5.4 involves dredging the existing Hansen Creek channel from the Railroad Bridge to Sorensen's Bridge to a maximum of 2-ft below the existing channel. The existing channel alignment, bottom width, and bank vegetation would be maintained. In addition, levees and high banks on both banks would be maintained and/or improved. While moderate floodwaters would be contained within the levees, this alternative does not allow areas beyond the levees to drain causing ponding behind levees.

Alternative 5.5 Create 50-ft Floodplains Along Both Banks of Existing Creek

Alternative 5.5 involves excavating a 50-ft wide "recessed floodplain" along both banks of the existing creek from the Railroad Bridge down to Sorensen's Bridge and installing a 25-ft buffer beyond the excavated floodplain. This alternative maintains existing creek alignment and property boundaries, allows the creek to meander within the new recessed floodplain, enhances in-stream fish habitat through installation of LWD, and increases and enhances wetland and riparian habitat.

Alternative 5.5 requires replacement of 2 existing single span farm bridges. This alternative will be difficult to construct within the limits of existing creek alignment and has potential erosion and flooding problems both during construction and in the future. It does not improve stream-function (based on increased meanders, pools & riffles) and does not provide significant wetland and in-stream habitat enhancement. It provides little flood benefit (conveying an approximately 10-year flood discharge) and is relatively expensive.

Alternative 5.6 Create Longer New Adjacent Channel

Alternative 5.6 involves excavation of a new meandering channel and "recessed floodplain" adjacent to the existing Reach 5 channel from the Railroad Bridge south to Sorensen's Bridge. The new channel and floodplain will fully convey a 100-year discharge.

The new channel can be constructed off-line (away from) the existing creek, using the existing creek to convey water during construction. Once constructed, the new channel and floodplain could remain off-line for 2 to 3 years to allow vegetation to establish and the stream system to stabilize. This would limit flood hazards and erosion problems both during and immediately after construction.

Though this alternative has a relatively high overall cost, it is relatively cost effective with respect to in-stream and wetland habitat, and is very cost effective with respect to flood control.

Alternative 5.7 Create Shorter New Adjacent Channel

Alternative 5.7 involves excavation of a new meandering channel and "recessed floodplain" adjacent to the existing Reach 5 channel from the Railroad Bridge down to Brier's Pond. The new channel and floodplain will be revegetated, and enhanced with LWD. Unlike the similar Alternative 5.6 (Create Longer New Adjacent Channel), this alternative will only convey a 10-year discharge.

The new channel could be constructed off-line (away from the existing creek), and the existing creek used to convey water during construction. Once constructed, the new channel and floodplain could remain off-line for 2 to 3 years to allow vegetation to establish and the stream system to stabilize, limiting flood hazards and erosion problems both during and immediately after construction.

5.3.7 Reach 6 (Red Creek)

Similar to Reach 5, all activities proposed in Reach 6 and located on private land will require concurrence with private property owners located within that reach. A preferred alternative for activities proposed on private property within this reach has not been identified as, at the time of this report, there is not consensus amongst the landowners as to the best course of action. As such, a suite of possible alternatives is presented for the private property located within Reach 6 that could be realized in the future once the plan elements proposed on the NSRA have been constructed.

For the purposes of developing a reference cost estimate for the preferred alternative detailed in this report, Alternative 6.6: *Property Acquisition (Easements or Leases),Creek and Wetland Enhancements And Fencing Upper Red Creek* & Alternative 6.8: *Property Acquisition (Easements or Leases),Creek and Wetland Enhancements And Fencing Lower Red Creek* were used These alternatives best met the Plan goals of flood reduction, fish habitat enhancement, and sediment reduction.

For the purpose of the following discussion, Red Creek Reach is divided into two runs: Upper Run and Lower Run. The Upper Run is the length of Red Creek north of Highway 20 and the Lower Run is the length of creek south of Highway 20 to its confluence with Hansen Creek.

Unlike Hansen Creek, there appears to be too little sediment deposited in Red Creek below the Helmick Road crossing, likely reducing salmon spawning opportunities. Therefore, the following discussions focus on habitat restoration, rather than sediment control, in and around Red Creek. Replacement of the road culvert at the

Helmick Road crossing could result in sediment transport in the system not considered in this document.

Alternative 6.1 Redirect "Dairy Tributary" Easterly Under Helmick Road Into Red Creek

Alternative 6.1 involves redirecting the "Dairy Tributary" easterly beneath Helmick Road into Red Creek, establishing buffers along the redirected tributary, fencing along the buffer perimeter, and vegetating tributary banks and adjacent floodplain wetlands. While this alternative increases the amount of wetland and riparian habitat, it actually decreases overall stream length (the existing roadside ditch is longer than the proposed reach). While its length may be reduced in this alternative, stream habitat quality will be greatly enhanced.

This alternative is **suggested since** it accommodates both the proposed Helmick Road Widening/Improvement Project as well as the NSRA recreation development. Additionally, this alternative cost effectively enhances in-stream, wetland and riparian habitat.

Alternative 6.2 Redirect "Dairy Tributary" Along Proposed Helmick Road Improvements

Alternative 6.2 calls for the relocation of this tributary along the western side of Helmick Road to accommodate the proposed Helmick improvement project. Skagit County is currently proposing to widen and improve Helmick Road. In accordance with current environmental regulations, the relocation of this salmon-bearing stream would likely require mitigation including buffering of the proposed creek. The required buffer would likely consume a large portion of the property intended for recreational facilities. This alternative includes fencing along buffer perimeters and vegetation of the tributary banks and adjacent floodplain wetlands

This alternative is **not suggested as** it significantly reduces the amount of available property for recreational facilities and is not suggested in the NSRA Conceptual Site Plan. It also complicates, and adds expense to, the proposed Helmick Road Improvement project.

Alternative 6.3 Fencing Upper Red Creek On The County Owned Property

Alternative 6.3 calls for fencing the portion of Upper Red Creek that is currently owned by the County. Fencing would protect the creek and its associated wetland and riparian areas from grazing and public use. This protection would allow the creek to naturally regenerate itself and its associated vegetation. No physical improvements, other than fencing, are included in this alternative.

While very cost effective with respect to habitat enhancement, this alternative is **not suggested since** other Reach 6 alternatives were considered more comprehensive.

Alternative 6.4 Property Acquisition (Easements or Leases) And Fencing Upper Red Creek

Alternative 6.4 calls for acquisition, easement, or lease of private property between the NSRA and Highway 20. This alternative also calls for fencing the portion of Upper Red Creek on both public and private property.

Fencing would protect the creek and its associated wetland and riparian areas from grazing. This protection would allow the creek to naturally regenerate itself and its associated vegetation. No physical improvements, other than fencing, are included in this alternative.

Alternative 6.5 Creek and Wetland Enhancements And Fencing Upper Red Creek On The County Owned Property

Alternative 6.5 calls for fencing the portion of Upper Red Creek within the NSRA. Fencing would protect the creek and its associated wetland and riparian areas from grazing. This protection would allow the creek to naturally regenerate itself and its associated vegetation. This alternative also includes approximately 700-ft of stream enhancements (improved meander pattern, pools, riffles, plantings) and other wetland enhancements.

This alternative is **not suggested since** other Reach 6 alternatives were deemed more comprehensive.

Alternative 6.6 Property Acquisition (Easements or Leases), Creek and Wetland Enhancements And Fencing Upper Red Creek

Alternative 6.6 calls for the acquisition (or easements or leases) of the private property between the County owned property and Highway 20.

This alternative includes fencing the portion of Upper Red Creek on both the NSRA and private property and planting along approximately 1,850-ft of stream.

Alternative 6.7 Property Acquisition (Easements or Leases), Revegetation And Fencing Lower Red Creek

Alternative 6.7 calls for the acquisition (or easements or leases) of private property along Lower Red Creek extending 50-ft on both sides of the existing creek. The stream will be enhanced with LWD and the corridor fenced and revegetated with appropriate wetland and riparian plant species. The adjacent property owner could continue to graze adjacent lands.

Alternative 6.8 Property Acquisition (Easements or Leases), Creek and Wetland Enhancements And Fencing Lower Red Creek

Alternative 6.8 involves reestablishing Lower Red Creek with an appropriate size and meander pattern. It also calls for the acquisition (or easements or leases) of private property along Lower Red Creek. The stream will be enhanced with LWD and the area would be fenced and revegetated with appropriate wetland and riparian plant species. The existing floodgate at the mouth of Red Creek would be removed to provide better fish passage. The adjacent property owner would continue to graze the adjacent lands. Concerns have been raise by local property owners regarding potential flooding associated with removal of the existing floodgate. To mitigate such effects, it may be necessary to construct a small dike around the perimeter of the wetland complex to protect surrounding lands from flood damage.

6.0 RECOMMENDED PLAN

6.1 Overview

Individual alternatives were discussed in the previous section and those that best met the goals of the project were suggested. The suggested alternatives have been combined into a comprehensive and dynamic, system-wide Recommended Plan. The rationale behind the selection or rejection of each specific alternative has been discussed previously in Section 5.0. Appendix 1 – Alternatives Analysis provides greater detail for each individual alternative considered.

Table 6.1 summarizes the alternatives and their attributes chosen for the Recommended Plan. Table 6.2 summarizes various costs associated with the recommended alternatives chosen for the Recommended Plan. Figure 6.1 conceptually displays the overall Recommended Plan. Figures 6.2 - 6.6 are cross sections of the Recommended Plan elements within each Reach.

6.2 Discussion of Recommended Plan

The Recommended Plan for Hansen and Red Creeks balances the project goals of sediment control, flood reduction and habitat enhancement with economics, environmental regulations and land use concerns. This balance is achieved through a restoration plan that works within the geomorphic opportunities and land use constraints of the creek and watershed, minimizes construction and maintenance costs, and utilizes natural processes, where appropriate, to attain the desired results.

The Plan incorporates reestablishing the processes that were disrupted decades ago when the historic alluvial fan was channelized, the downstream channel was straightened, and catastrophic landsliding in the upper watershed delivered excess sediment to the system. Simply put, the economy of this Plan is based upon restoring much of the creek system to its historical condition. Once restored, the creek system will heal and naturally maintain itself. Once healed, the system will be

TABLE 6.1

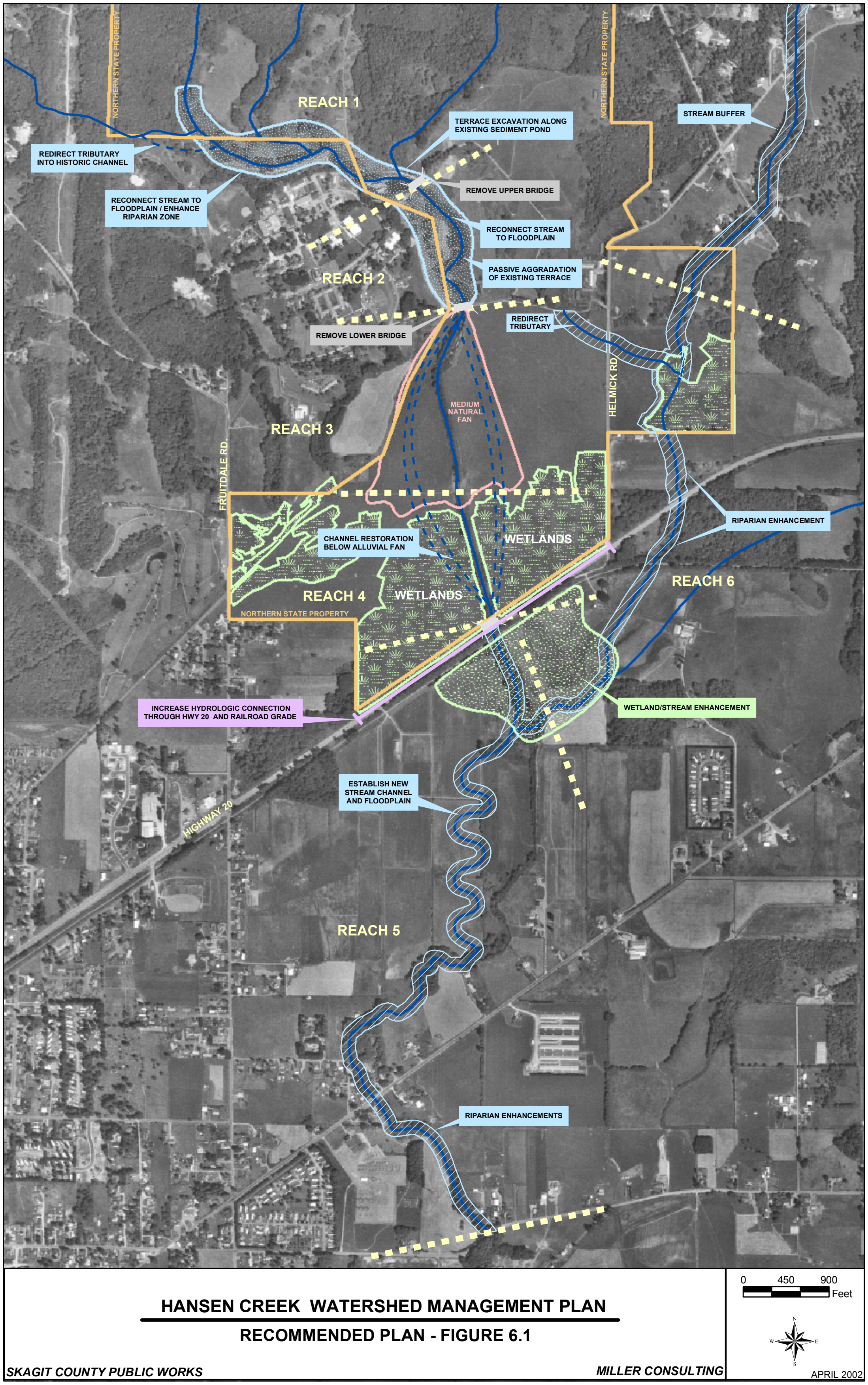
Recommended Alternatives

Alternative ID	Alternative Name	Comments & Adjustments	Total Cost	Sediment Life Span (Reaches 1-3)	Cost / Life Span (Reaches 1-3)	Increase in Wetland Area (Or Wetlands Enhanced)	Cost / Wetlands Enhanced	Increase in Creek Length	Creek Length Enhanced	Cost / Creek Length Enhanced
			($)	(Years)	($ / Year)	(Acres)	($ / Acre)	(Feet)	(Feet)	($ / Feet)
1.3	Terrace Excavation with Creek & Wetland Enhancements, Sub-Reach 1c.		$112,441	4.0	$27,852	2.5	$44,976	250	750	$150
1.4	Redirect Trib. #272 Back Into Historic Channel		$82,993	0.0	$0	3.0	$27,895	1350	1350	$61
1.5	Remove Upper NSH Bridge, Associated Roads & Culvert. Regrade.		$59,449	1.1	$55,273	1.0	$59,449	0	100	$594
1.6	LWD Placement & Passive Aggradation in Reach 1.		$48,109	9.4	$5,128	1.1	$45,557	0	1150	$42
2.1	Remove Lower NSH Bridge & Regrade		$58,815	0.0	$0	0.0	$0	0	0	$0
2.3	LWD Placement and Passive Aggradation In Channel		$79,578	12.6	$6,319	9.0	$8,822	0	1725	$46
2.5	Passive Aggradation on Excavated Terrace	Only in Select Locations. Reduced to 25%.	$136,528	5.6	$24,304	2.3	$15,136	0	431	$317
3.2	Natural Alluvial Fan (Medium)		$555,664	85.9	$6,472	11.0	$50,515	525	2625	$212
4.1	Channel Restoration Downstream of Natural Alluvial Fan		$164,797	0.0	$0	5.0	$32,959	2200	3500	$47
5.1	Culverts Through SR-20		$117,561	0.0	$0	0.0	$0	0	0	$0
5.3	Reestablish Wetlands Downstream of SR-20		$212,528	0.0	$0	40.0	$5,317	0	0	$0
5.6	Longer New Adjacent Channel		$702,621	0.0	$0	9.6	$73,190	1100	5100	$138
6.1	Redirect "Dairy Tributary" Under Helmick Road to Red Creek		$144,884	0.0	$0	4.1	$35,062	-400	1350	$107
6.6	Property Acquisition (or Easements), Enhancements and Fencing along Upper Red Creek	Reduced cost to account for fencing overlap.	$116,322	0.0	$0	23.7	$5,962	500	1850	$76
6.8	Property Acquisition and Restoration along Lower Red Creek	Reduced wetland area for overlap w/ 5.3.	$238,611	0.0	$0	0.0	$0	1300	4000	$60
	Recommended (Combined) Alternative		**$2,830,902**	**119**	**$9,561**	**112**	**$25,229**	**6,825**	**23,931**	**118**

TABLE 6.2

Summary Of Costs For Recommended Alternative

Alternative ID	Alternative Name	Real Estate Costs	Construction Costs	Design, Permitting and Management Costs	Capitalized Operations, Maintenance and Monitoring Costs	Total Cost
1.3	Terrace Excavation with Creek & Wetland Enhancements, Sub-Reach 1c.	$0	$77,946	$20,266	$14,230	$112,441
1.4	Redirect Trib. #272 Back Into Historic Channel	$0	$57,531	$14,958	$10,503	$82,993
1.5	Remove Upper NSH Bridge, Associated Roads & Culvert. Regrade.	$0	$41,211	$10,715	$7,523	$59,449
1.6	LWD Placement & Passive Aggradation in Reach 1.	$0	$33,350	$8,671	$6,088	$48,109
2.1	Remove Lower NSH Bridge & Regrade	$0	$46,678	$12,136	$0	$58,815
2.3	LWD Placement and Passive Aggradation In Channel	$0	$44,022	$11,446	$24,110	$79,578
2.5	Passive Aggradation on Excavated Terrace	$0	$79,544	$20,681	$36,304	$136,528
3.2	Natural Alluvial Fan (Medium)	$0	$411,213	$106,915	$37,535	$555,664
4.1	Channel Restoration Downstream of Natural Alluvial Fan	$0	$121,956	$31,709	$11,132	$164,797
5.1	Culverts Through SR-20	$0	$87,000	$22,620	$7,941	$117,561
5.3	Reestablish Wetlands Downstream of SR-20	$149,879	$46,363	$12,054	$4,232	$212,528
5.6	Longer New Adjacent Channel	$49,125	$500,518	$130,135	$22,844	$702,621
6.1	Redirect "Dairy Tributary" Under Helmick Road to Red Creek	$0	$100,435	$26,113	$18,335	$144,884
6.6	Property Acquisition (or Easements), Enhancements and Fencing along Upper Red Creek	$19,370	$65,250	$23,465	$8,238	$116,322
6.8	Property Acquisition and Restoration along Lower Red Creek	$23,244	$159,380	$41,439	$14,548	$238,611
	Recommended (Combined) Alternative	**$241,618**	**$1,872,397**	**$493,323**	**$223,564**	**$2,830,902**



HANSEN CREEK WATERSHED MANAGEMENT PLAN

RECOMMENDED PLAN - FIGURE 6.1

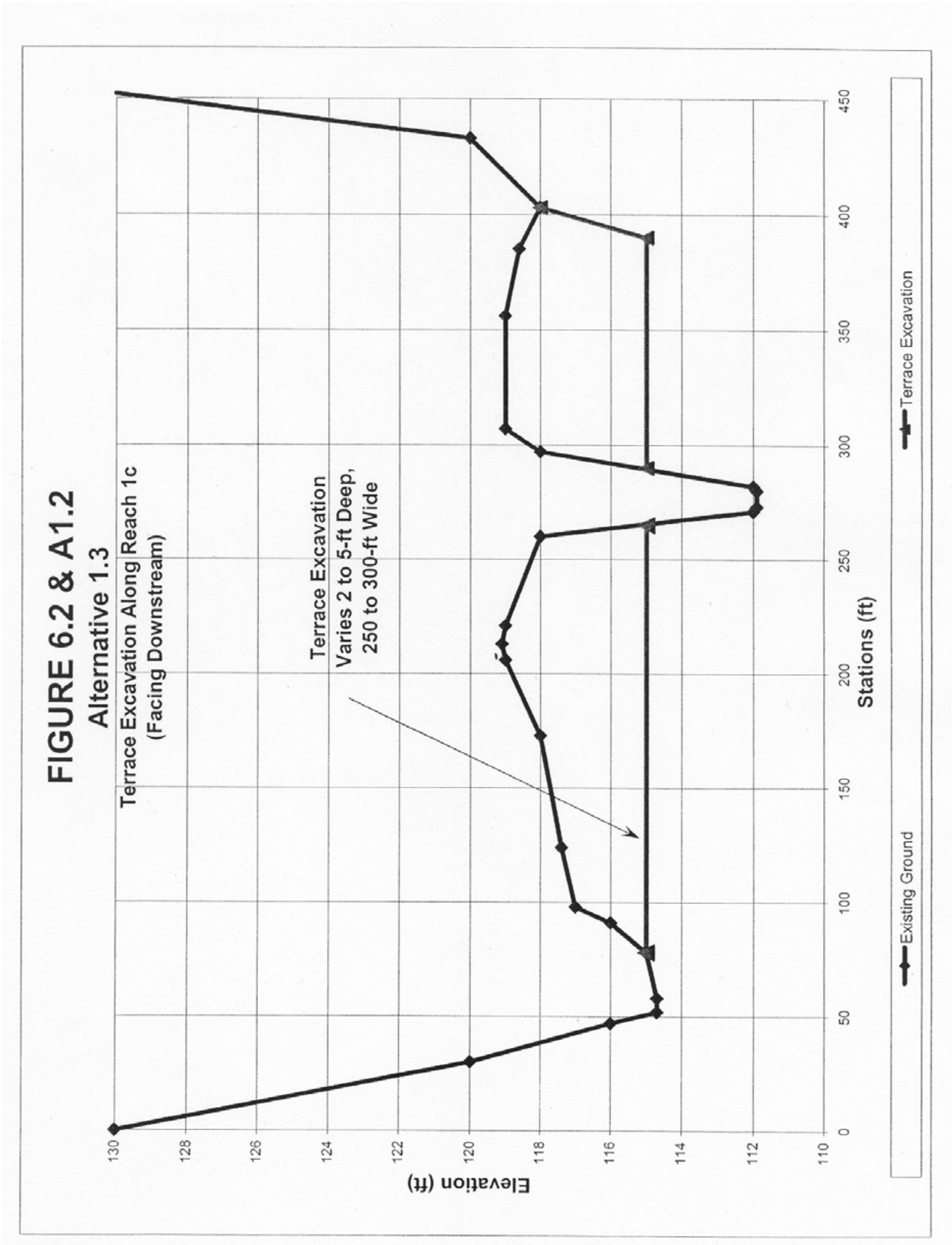


FIGURE 6.2 & A1.2
Alternative 1.3
Terrace Excavation Along Reach 1c
(Facing Downstream)
Terrace Excavation
Varies 2 to 5-ft Deep,
250 to 300-ft Wide
Elevation (ft)
130
128
126
124
122
120
118
116
114
112
110
Stations (ft)
0
50
100
150
200
250
300
350
400
450
Existing Ground
Terrace Excavation

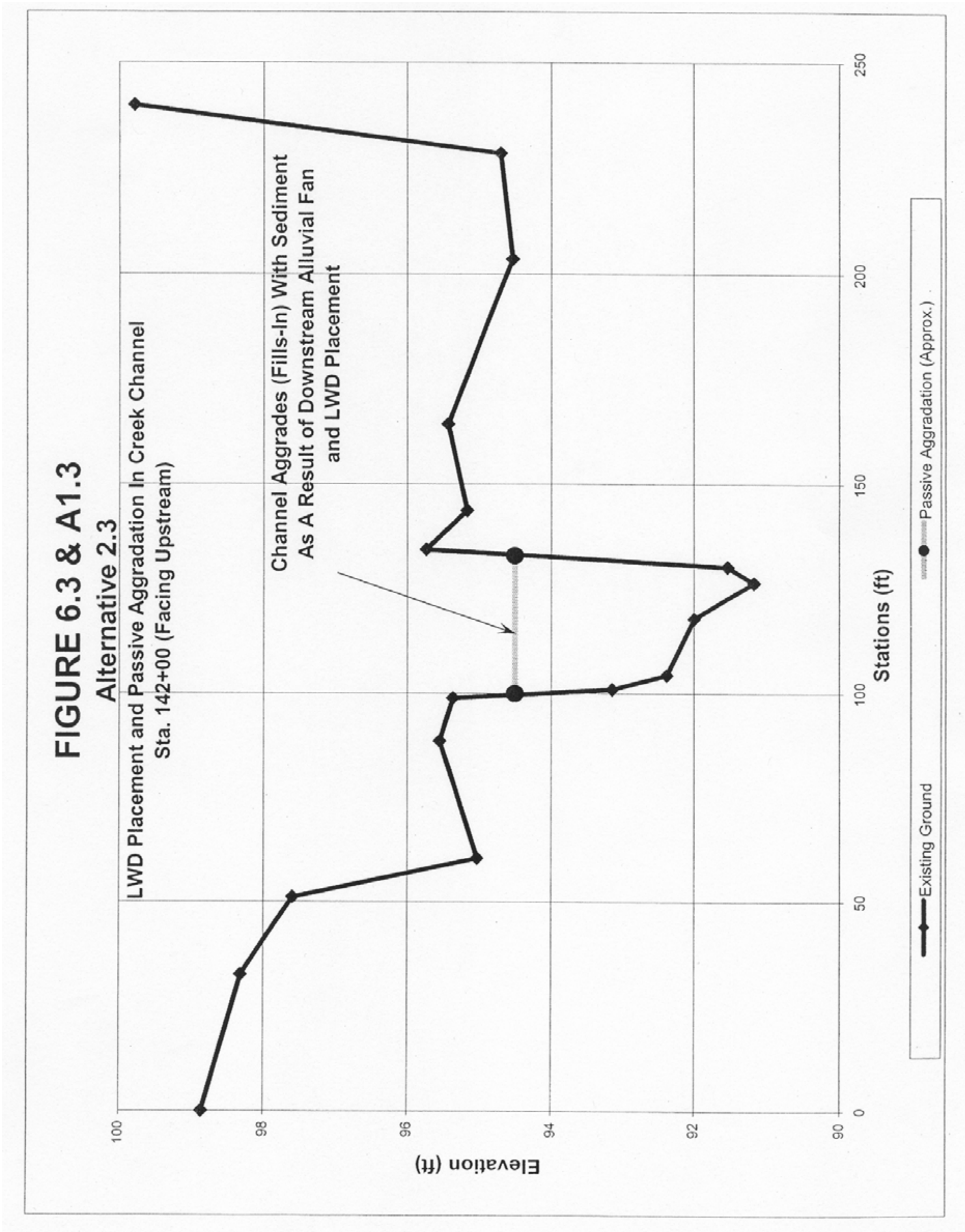


FIGURE 6.3 & A1.3
Alternative 2.3
LWD Placement and Passive Aggradation In Creek Channel
Sta. 142+00 (Facing Upstream)
Channel Aggrades (Fills-In) With Sediment
As A Result of Downstream Alluvial Fan
and LWD Placement
Elevation (ft)
100
98
96
94
92
90
0
50
100
150
200
250
Stations (ft)
Existing Ground
Passive Aggradation (Approx.)

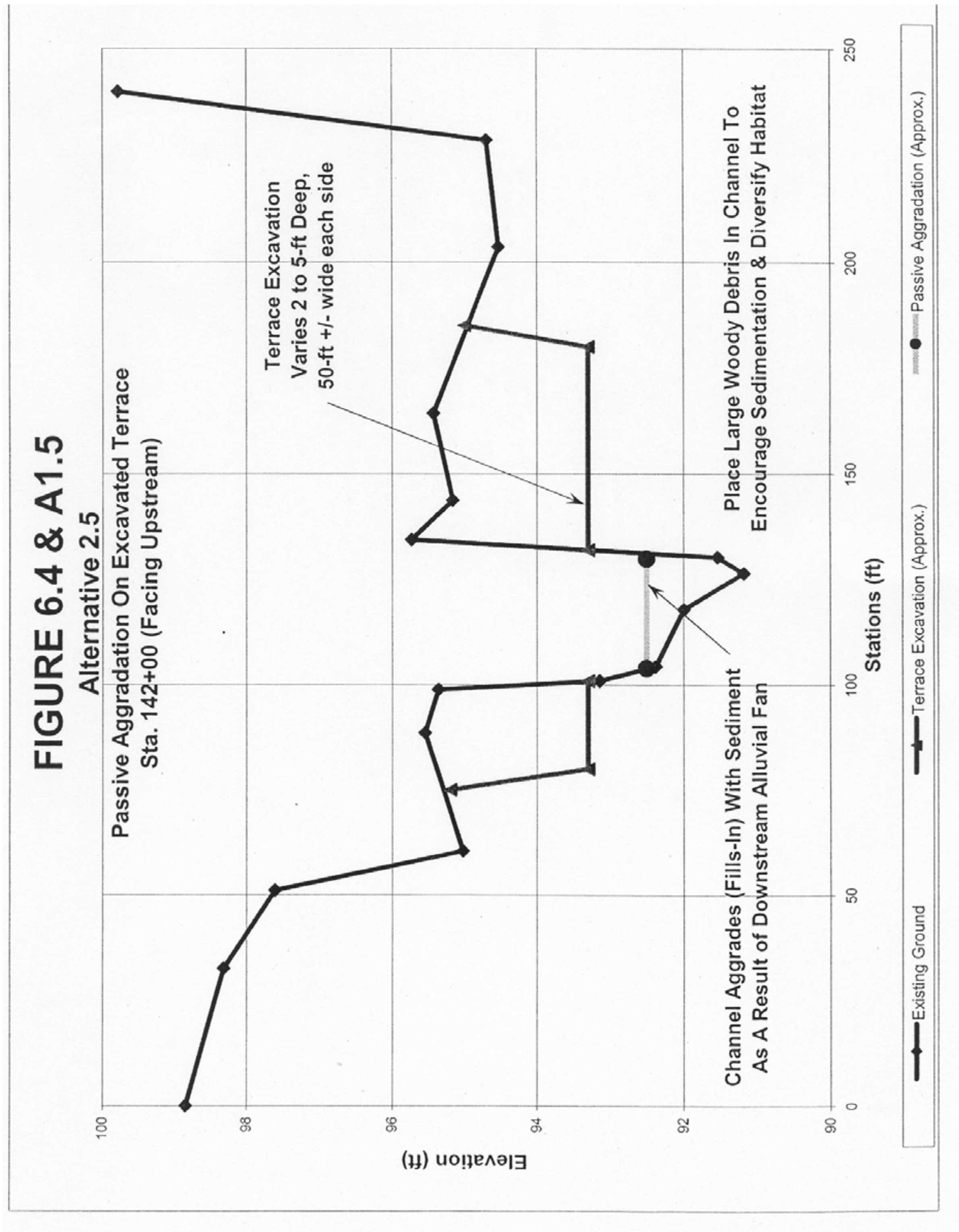


FIGURE 6.4 & A1.5
Alternative 2.5
Passive Aggradation On Excavated Terrace
Sta. 142+00 (Facing Upstream)
Terrace Excavation
Varies 2 to 5-ft Deep,
50-ft +/- wide each side
Place Large Woody Debris In Channel To
Encourage Sedimentation & Diversify Habitat
Channel Aggrades (Fills-In) With Sediment
As A Result of Downstream Alluvial Fan
Elevation (ft)
Stations (ft)
100
98
96
94
92
90
0
50
100
150
200
250
Existing Ground
Terrace Excavation (Approx.)
Passive Aggradation (Approx.)

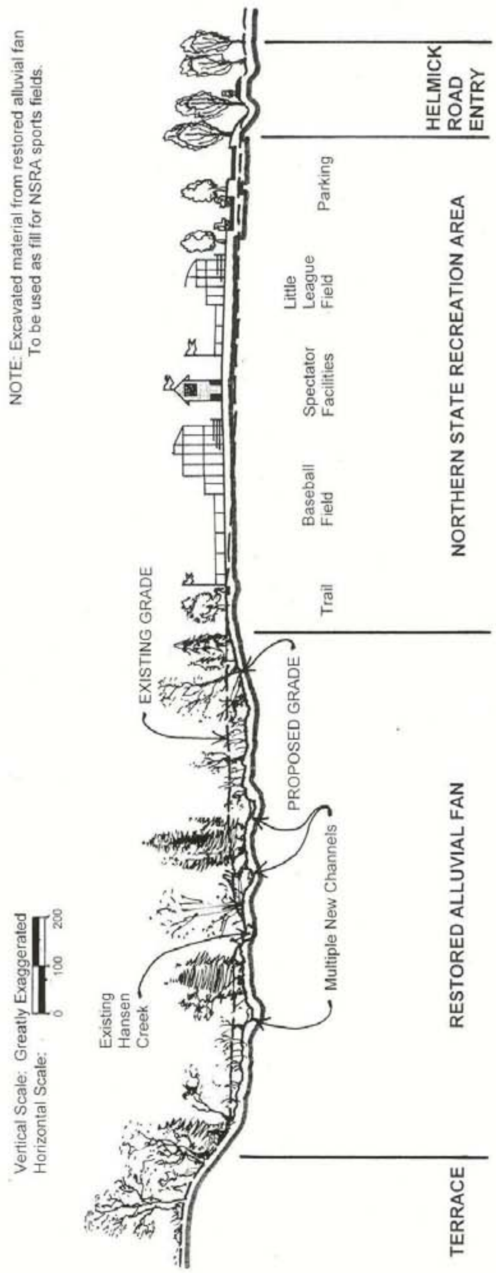


FIGURE 6.5 – TYPICAL SECTION THROUGH RESTORED ALLUVIAL FAN AND NORTHERN STATE RECREATION AREA FACILITIES

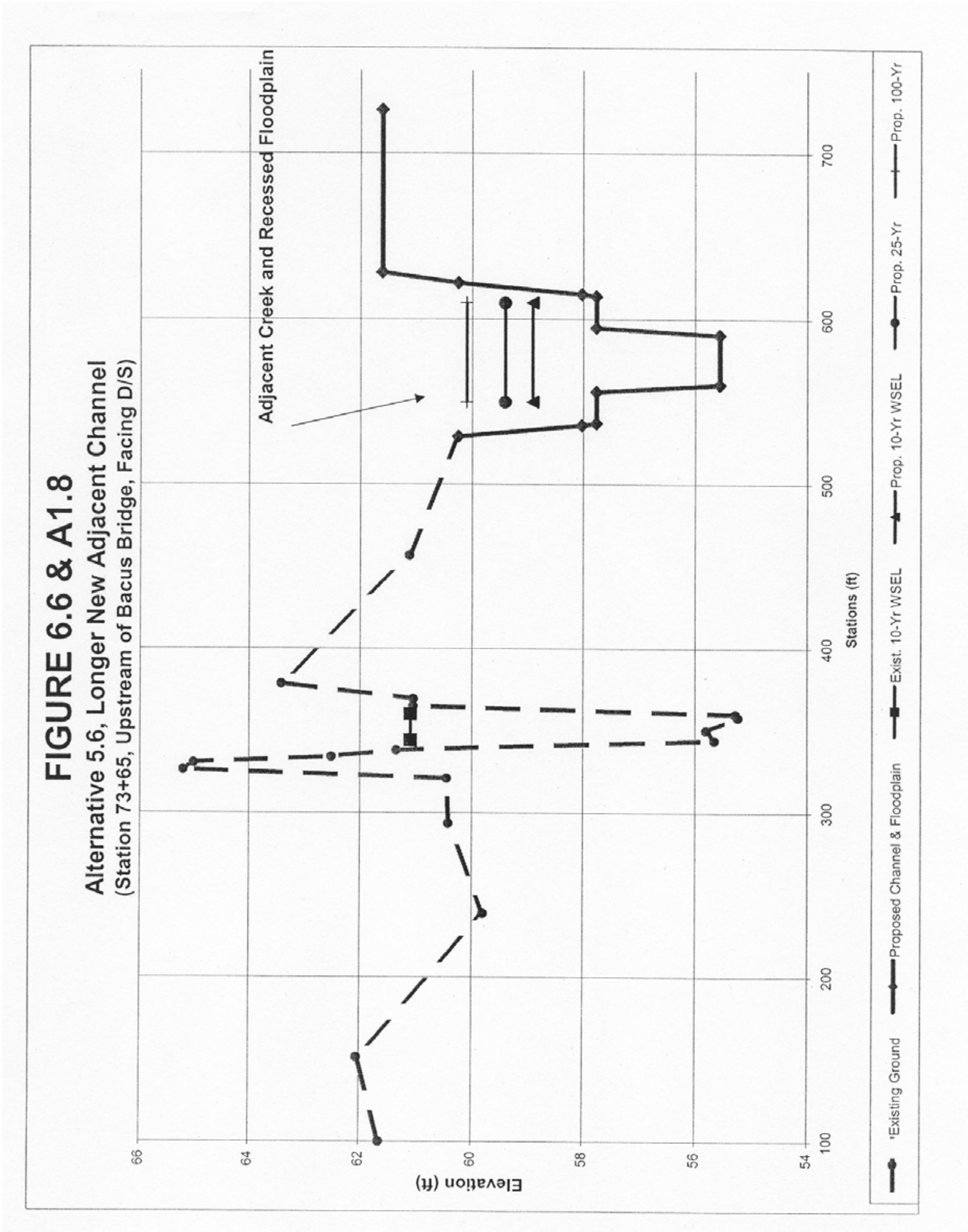


FIGURE 6.6 & A1.8
Alternative 5.6, Longer New Adjacent Channel
(Station 73+65, Upstream of Bacus Bridge, Facing D/S)
Adjacent Creek and Recessed Floodplain
Elevation (ft)
66
64
62
60
58
56
54
100
200
300
400
500
600
700
Stations (ft)
Existing Ground
Proposed Channel & Floodplain
Exist. 10-Yr WSEL
Prop. 10-Yr WSEL
Prop. 25-Yr
Prop. 100-Yr

able to support healthier fish and wildlife populations and store flood waters, in turn reducing damage resulting from flooding.

The recommended alluvial fan, literally the structural keystone of this Plan, is designed to capture sediment in the area it historically occurred. Allowing this re-emergence of natural processes will restore habitat types where Hansen Creek fish runs historically evolved. The recommended Plan:

- Mitigates past in-channel dredging (disturbed stream banks, straight plane-bed channel of all riffles, headcutting upstream and levees along the creek);
- Reverses present downcutting below Reach 1 that has separated Reach 2 channel from its floodplain;
- Restores the riparian zone, creating shade and allowing for eventual wood recruitment to the creek;
- Reestablishes channel migration processes within the meander belt that will form pools, undercut banks for cover, and in the long term, recruit LWD from adjacent riparian areas;
- Reconnects historic wetlands to the creek;
- Restores sinuosity to Hansen and Red Creeks
- Restores wetland associated with the creek floodplain south of Highway 20;
- Restores alluvial fan function at the historic alluvial fan location;
- Eliminates the Red Creek floodgate, providing fish access to a low-gradient channel with pools.
- Limits Critical Area buffers to the footprint of the alluvial fan in Reach 3.

During years with a high sediment load and/or moderate to large floods, bank erosion and deposition will occur in the fan and floodplain (Reaches 1 and 3). This will cause some local scouring and/or burial of salmon redds (as thalweg/pools migrate laterally) and filling of pools. It should be noted that many of these effects currently occur in Reach 1, lower Reach 2 and uppermost Reach 3, lower Reach 4, and Reach 5. The Plan eliminates these effects in Reaches 4 and 5, shifting them upstream to the geomorphologically and historically appropriate places.

In the alluvial fan, avulsions will sometimes occur where the channel switches to a new course. Some fish stranding could result during low water flows, as abandoned channels become dry or disconnected from the creek. This is a natural phenomenon that occurs on all unaltered alluvial fans throughout the region.

Cost estimates were calculated for each alternative. These estimates were based on real estate values, construction quantities and costs, design and management costs, and operations and maintenance costs. It should be emphasized that the alternatives were designed at a conceptual planning level and are best suited to compare the relative costs of the considered alternatives. A graph (Figure 5.1) and a table (Table 5.1) comparing the costs for all alternatives and are included in the Alternative Analysis Summary (Section 5.0) of this report.

The cost to implement the recommended plan is estimated to be $2.83 million. Costs per reach are:

- Reach 1 $ 303,000.
- Reach 2 $ 275,000.
- Reach 3 $ 556,000.
- Reach 4 $ 165,000.
- Reach 5 $1,032,000.
- Reach 6 $ 500,000.

As noted in Table 6.1, some of the specific benefits include: significant flood reduction between Highway 20 and Minkler Road, over 100 years of ultimate sediment capture, 112 acres of new or enhanced wetlands, 6,800 feet of new creek length, and almost 24,000 feet of enhanced creek length.

Once constructed and established over approximately a 20-year period, the Recommended Plan will require minimal maintenance, the exception being an initial “maintenance dredging” of the recommended alluvial fan after approximately 100 years and subsequent maintenance dredging approximately ever 50 years thereafter.

It should be understood that these time estimates are likely to vary depending upon the ultimate design and climactic conditions. Part of the operation and maintenance of the fan would be its excavation before full capacity is reached. Excavation would be performed under dry conditions, leaving the existing watered channels untouched while the remainder of the fan is excavated. The creek would naturally change to a new, lower channel the following winter. Maintenance dredging would probably occur more frequently in the future as Reaches 1 and 2 become stable and it is recommended that only a portion of the natural alluvial fan be dredged at any one time to maintain fish habitat and tree cover on the fan itself.

7.0 CONSIDERATIONS FOR FINAL DESIGN AND IMPLEMENTATION

The Hansen Creek Watershed Management Plan is a concept plan. It identifies the issues and problems associated with this watershed, and then provides a range of possible solutions, each with their associated costs and benefits. Specific details remain to be worked out during final design. The following list of items should be considered or addressed during final design.

7.1 Topographic Survey

The following survey items should be considered:

- Existing topographic data for the NSRA should be reviewed and updated as necessary.
- A detailed survey of the entire project site should be performed to augment the recent field survey. The survey should extend north and include all of the

Northern State Recreation Area and should be extended south to Minkler Road. The survey should include: frequent channel and valley cross-sections, stream profiles, and bridge cross-sections. Topographic data should extend far enough laterally to fully understand and/or model the overbank flow characteristics.

- Channel, floodplain, and flow limits should be surveyed downstream of Minkler Road well enough to understand and model hydraulic effects from downstream and the Skagit River.

7.2 Literature Search and Project Review

Activating an inactive alluvial fan has not (to our knowledge) been implemented before in western Washington. This likely has as much to do with the opportunity and amount of available land, as with technical constraints. Check-dams to raise base level in incised arroyos have been attempted throughout much of the arid west. We recommend undertaking a literature search and interviewing public works officials at other government agencies to identify relevant studies or projects that would provide design guidance.

7.3 Determination of Dominant Discharge

A regional hydrologic analysis should be performed in order to determine appropriate “bankfull” or “dominant” discharges and frequencies for the stream restoration aspects of this project.

7.4 Reference Reach Analysis

An analysis of local stable creeks should be performed in order to develop a better understanding of which types and aspects of creeks are locally stable. This analysis of bankfull dimensions and channel geometry could accompany the determination of the appropriate dominant discharges and frequencies.

7.5 Hydrologic and Hydraulic Modeling

The Concept Plan is based on distinct discharges, not hydrographs. Hydrographs will need to be developed and routed through recommended facilities in order to develop a full understanding of how the various facilities convey and detain water and sediment.

Future hydraulic models should also be calibrated. This may require a temporary stream gage in the project area. Additionally, the hydraulic relation between sediment deposition and the Minkler and Hoehn Road culverts needs to be understood.

7.6 Adaptive Management With Stream Restoration and Sediment Storage

The precise ways in which the channel will respond to decreased confinement, sediment deposition and stream and wetland restoration activities are not 100 percent predictable. The sequence of storms and associated sediment loads following construction is unknown. Furthermore, the channel can respond by adjusting many variables: gradient, width, lateral movement, number and size of channels, depth and sinuosity. Channel locations in Reaches 3 and 4 will likely shift over time. Deposition will occur in various locations in Reaches 1, 2 and 3.

A few quotes from Burchard Heede, a US Forest Service engineer with a great deal of experience in the design of grade control structures, seem appropriate:

"There is still insufficient knowledge to eliminate uncertainty from the design of dynamic equilibrium in streams. Empirical equations are available that must be tested and modified to fit the specific situation… Design plans must remain flexible…"

"at best, we may be able to foresee the trend of future stream development but not the magnitude of the stream's response"

Relocated/restored reaches of the creek will need to be maintained with an "adaptive management" style until the creek and floodplains become stable. Slight channel alterations and/or repairs will need to be made to respond to different situations. Large woody debris may need to be added more than once to Reaches 1, 2, and 3 as deposition occurs. Vegetation will need to be planted and maintained until well established. A monitoring, operations and maintenance plan should be developed with the final design.

7.7 Construction Phasing

The construction of the project should be phased in order to optimize the materials available for construction and provide maximum effectiveness. At a minimum, the primary sediment storage features of this design (alluvial fan construction) should be implemented before the downstream channels in Reaches 4 and 5 are constructed. Sediment storage projects in Reaches 2 and 1 should follow initial aggradation of the alluvial fan. Phasing will also need to address appropriate times for construction in water (fish windows). Depending on the phasing of channel improvements in the various reaches, a small sediment basin near Highway 20 may also be necessary as an interim measure.

7.8 Coordination with Northern State Recreation Area Development

There should be extensive coordination with implementation of this project and the development of recreation facilities at the Northern State Recreation Area. Coordination should start immediately – with the pursuit of funding and grants and continue through permitting, engineering and design and into construction. These projects should be treated as one integrated project by the county. In addition, the Counties Helmick Road Improvement Project should address issues relevant to both projects, such as relocation of the Dairy Tributary, park user safety at road crossings, the intersection of Helmick and Highway 20, wetland mitigation, etc.

7.9 Sediment Transport Continuity

The alluvial fan and adjacent wetland will greatly reduce the amount of sediment entering the channels in lower Reach 4. To prevent or minimize aggradation in

Reach 5, channels should ideally be designed so that sediment-transport capacity is relatively constant along the reach downstream of the alluvial fan to Minkler Road. This can be addressed during design by altering channel cross-section, sinuosity, roughness, and gradient.

Although the alluvial fan will trap large amounts of sediment, some bedload sediment and suspended sediment are expected to be released from the alluvial fan into Reach 4. Much of the suspended load will be deposited in the wetlands flanking the fan. An attempt can be made to estimate the sediment load continuing downstream; however it is likely to vary over time in response to the changes in gradient and braidedness as the channel shifts across the fan and aggrades. If the fan releases sediment into upper Reach 4 at a rate faster than the new channel can transport it, some aggradation could occur near the upstream end of the reach. The excess sediment would not significantly affect lower Reach 4 or Reach 5, as the new sinuous, low-gradient Reach 4 channel will transport sediment downstream at a much slower rate than the present channel.

If achieving sediment-transport continuity at the Reach 4-5 transition is not possible due to the final project components selected for Reach 5, a small off-channel sediment basin near Highway 20 would accommodate the anticipated sediment load that would be much lower than present due to the reduced gradient and confinement of Reach 4.

7.10 Lower Channel at Highway 20 Bridge and Reaches 4 and 5

Despite years of dredging, the existing channel at Highway 20 is about 5.5-ft higher than it was in 1948. The design of Reaches 4 and 5 may need to include provisions to lower both reaches near this bridge. While it appears desirable to lower Reaches 4 and 5, the ultimate elevations of these reaches need to factor in the connection to adjacent wetlands and the confluence with Red Creek.

7.11 Enhancements above Northern State

There are a number of recommended actions that occur in the northern end of the watershed that are not considered part of this project, but are significant to the health and safety of residents living in this area and to the health of habitat values. These are discussed in Section 5.0 and in Appendix 1 – Alternatives Analysis.

7.12 Stream Enhancements Below Project Area

This project focused on Hansen Creek down to a point about halfway between Highway 20 and Minkler Road as this is where the majority of sediment and flooding problems occur. This does not imply that the remaining reaches downstream could not be improved or enhanced.

The culverts at Hoehn and Minkler Roads, for example, are not as large as they could or should be, and each increases water elevations several feet during flood conditions. Each of these culverts should be enlarged when scheduled for replacement.

Additionally, past stream cleaning, channel straightening, and riparian clearing have left the channel largely devoid of the LWD and pools that provide important rearing habitat and flood refuge for salmonids.
These downstream reaches could benefit from additional in-stream and riparian habitat enhancements, particularly in the area downstream of Hoehn Road.

7.13 Disposal of Sediment

The recommended plan will result in large amounts of sediment excavation, initially during construction and eventually from maintenance dredging of the alluvial fan. This material could be used in several ways:

- Excavated material from the alluvial fan could be utilized in the construction of an alluvial fan levee to the west, if necessary.
- Most of the excavated sediment could be used as a subbase material during the development of facilities for the Northern State Recreation Area,
- A market for the excavated sediments could be developed in order to offset the cost of construction and dredging.

7.14 Vegetation Management

A vegetation management plan should be developed to establish a sustainable vegetative community made up of plants native and naturally adapted to the project area. The Plan should include establishing a vegetated riparian zone, noxious weed control, and monitoring protocols.

7.15 Potential Interim Actions

While this project is being planned and designed, the existing Northern State sediment pond could be operated and maintained to provide sediment storage. It may also be worthwhile to construct an off-line sediment trap south of Highway 20 prior to construction.

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