Geomorphic Assessment

Touchet River
Upstream of Dayton, Washington

for
City of Dayton

November 28, 2011

GeoEngineers
Earth Science + Technology

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File No. 10291-002-00

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GEOENGINEERS

Table of Contents

LIST OF TABLES

LIST OF CHARTS

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

APPENDICES

1.0 INTRODUCTION

The Touchet River Geomorphic Assessment Project is the product of a progressive community-wide collaboration to improve habitat for ESA listed steelhead and bull trout while simultaneously exploring ways to attenuate flood risk to the community. The framework of this project was developed so site-specific river/floodplain restoration opportunities are identified within the context of watershed processes. To support the established framework; GeoEngineers' multi-disciplinary team was retained to conduct a preliminary geomorphic assessment of the watershed upstream of the Highway 12 Bridge, prioritize potential restoration reaches throughout the watershed, and develop conceptual restoration solutions for an approximately 2 mile "Implementation Reach." Guidance for this work was further developed over the course of several meetings with the Columbia County Levee Round Table Group (LRTG) and the Snake River Salmon Recovery Board's Regional Technical Team (RTT), which are represented by local, state, and Federal government agencies as well as private landowners and non-profit organizations. This report serves as a foundation for future restoration planning and also provides conceptual restoration details for the top priority reach.

1.1. Background

1.1.1. Fish Habitat

The vision established in the Snake River Salmon Recovery plan (Recovery Plan) (Snake River Salmon Recover Board [SRSRB] 2006) is to "develop and maintain a healthy ecosystem that contributes to the rebuilding of key fish population by providing abundant, productive, and diverse populations of aquatic species that support the social, cultural, and economic well-being of the communities both within and outside the recovery region." It is understood that this vision is a long-term endeavor to develop an ecosystem that supports abundant and widely distributed salmonid populations. To achieve this condition there must be adequate and appropriate habitat for all freshwater salmonid life-stages and free access to that habitat.

The intent of this project, as it pertains to habitat restoration, is one of many individual projects that collectively will advance ecosystem restoration. Specifically, this project will increase aquatic habitat complexity by increasing Large Woody Debris (LWD) for resting and rearing, floodplain reconnectivity for juvenile refugia and groundwater recharge, encourage sediment deposition for spawning and invertebrate production, and expansion of the riparian corridor for stream shade and terrestrial wildlife. Together the expected results will address most of the limiting factors identified by SRSRB (2006) in a holistic context.

1.1.2. Flood Control

The City of Dayton, Washington is located within the historic floodplain of the Touchet River. Flood control for the City is provided by a system of federally authorized levees constructed in 1964-1965. Occasional non-federally authorized levees also are present in rural areas upstream of Dayton. In addition to flood control, portions of the federally authorized levees in Dayton also provide a park-like setting that includes a recreational trail; highly valued by the community. Trees and other riparian vegetation, growing on the levees, provide shade to reduce elevated summer river temperatures for fish species.

In recent years the levees have been damaged during flood events, which have required periodic repairs. A recent inspection report for the levees indicates much of the levee system is rated as "unacceptable" (Anderson Perry 2010). The report cites sediment accumulation in the floodway (near the Highway 12 Bridge), vegetation growth on the levees and channel degradation as contributors to reduced channel capacity and levee integrity issues. If not addressed, the unacceptable rating could result in "decertification" of the levees. Consequently, portions of the City could then be reclassified into the Federal Emergency Management Agency (FEMA) floodplain, which would require affected parties to obtain expensive flood insurance and limit future development.

This report and accompanying attachments summarize the methods and results of our preliminary geomorphic assessments and conceptual alternatives analysis. We emphasize that the intent of this report is to provide foundation information to assist with current and future efforts to improve fish habitat and reduce flood risk in the project area. Preliminary design, final design and construction of the preferred conceptual alternative developed in this study will be a beginning to achieving improved fish habitat and reduction of flood effects.

1.2. Project Area

The project area is shown with respect to surrounding features on the Vicinity Map, Figure 1. The area includes the North Fork Touchet, South Fork Touchet, Wolf Fork, and Robinson Fork. This area will be referred to as the "watershed." The watershed-scale assessment area begins upstream of the Highway 12 Bridge in the City of Dayton, Washington and encompasses:

- Main stem Touchet River from the highway 12 Bridge in Dayton, Washington to the confluence of the South and North Fork
- North Fork from the confluence with the South Fork to its headwaters at approximately river mile (RM) 22 (Refer to LiDAR Processing and GIS Data Development, Appendix C for discussion of the river mile convention used in this report)
- Wolf Fork from its confluence with the North Fork to its headwaters at approximately RM 16
- Robinson Fork from its confluence with the Wolf Fork to its headwaters at approximately RM 12
- South Fork from its confluence with the North Fork to its headwaters at approximately RM 17

The Implementation Reach-scale assessment (Implementation Reach) encompasses:

- A portion of the main stem Touchet River beginning at the North and South Forks confluence and terminating downstream approximately 2,200 feet, near the rivers' entrance into the channelized portion of the levee floodway
- The South Fork beginning at the confluence with the North Fork and terminating upstream approximately 2,000 feet, near a private driveway bridge crossing
- The North Fork beginning at the confluence with the South Fork and terminating upstream approximately 6,100 feet at the Boalsburg Bridge

1.3. Project Overview

1.3.1. Overview of Watershed and Implementation Reach Assessments

As discussed above, key issues considered for this assessment generally include enhancement of fish habitat and attenuating flood risk. During execution of our services, GeoEngineers worked closely with the LRTG and the RTT so both habitat enhancement and flood reduction issues were considered.

GeoEngineers started the project by researching and compiling existing information. We integrated the data into a Geographic Information System (GIS) database. Using GIS we conducted a preliminary assessment of overall geomorphic characteristics of the watershed. Based on geomorphic conditions, each of the forks was separated into individual geomorphic reaches. Based on the results of the watershed-scale assessment and weighted selection criteria provided by the workgroups, we developed a prioritization matrix to objectively select a preferred Implementation Reach that has desirable characteristics for flood reduction and fish habitat enhancement.

After the Implementation Reach was selected, a topographic survey was completed of the reach in order to construct a topographic map. We completed stream reconnaissance, streambed gravel sampling and reach-level analysis within the Implementation Reach including: geomorphic, hydrologic, hydraulic, sediment transport capacity and channel stability analysis. The results of these analyses, which are discussed in greater detail in this report, were used to evaluate the appropriateness of conceptual alternatives discussed in the next section.

1.3.2. Overview of Alternatives Development

Similar to the watershed evaluation, we collaborated with the City and local work groups to develop conceptual restoration alternatives. A sequential process was followed throughout the assessment so practical conceptual alternatives could be developed and compared against one another with the intent of selecting a preferred alternative.

In general, this process involves the identification of the preferred alternative based on specific goals and objectives defined by the LRTG and the RTT. The goals are relatively general and the objectives are more specific. Each objective was then assigned a numerical weighting by the LRTG and RTT based on its relative level of importance. Several conceptual alternatives were then developed using a combination of geomorphically appropriate enhancement treatments. A numerical rating system was used to facilitate the transparent selection of a preferred conceptual alternative. Because the more important objectives and the more effective alternatives were defined in terms of higher relative values or higher levels of effectiveness, the more desirable alternatives have higher benefit ratings. A benefit-to-cost ratio was then calculated to factor in the cost of implementing the alternatives. Using this process, the alternative with the highest benefit-to-cost ratio is the most desirable or “preferred alternative.” This assessment process and the results are discussed in greater detail.

1.3.3. Overview of Channel Migration Zone Evaluation

A channel migration zone (CMZ) or Migration Potential Area (MPA) is the area where a river channel is susceptible to movement from ongoing erosion and depositional processes. The direction of channel movement can be upstream, downstream or laterally. The degree of movement is variable and may occur as relatively slow continuous movement, over relatively long periods of time or relatively large movements over single storm events.

GeoEngineers conducted two levels of channel migration zone assessment for the Touchet River Project; qualitative and quantitative approaches. The qualitative approach was applied to channel areas upstream of the Implementation Reach and involved a broad-level assessment, which identified the maximum extent of potential future channel migration. The quantitative approach was applied to the Implementation Reach and involved detailed evaluation and delineation of high and moderate channel migration potential areas.

1.3.4. Report Organization

This report provides a summary of our watershed-scale and Implementation Reach assessment methodologies, the results of those assessments, evaluation of appropriate conceptual alternatives, and the identification of a preferred conceptual alternative. The following sections cover the overarching goals and objectives of the proposed project, which have been used to guide development of the most appropriate conceptual alternatives. The watershed and implementation reach-level conditions are then discussed in terms of processes that shaped the river and its ecosystem within the context of various ecological disciplines, including geology, hydrology, hydraulics, ecology, and geomorphology. The watershed and implementation reach-level assessments provide the basis upon which possible future enhancement alternatives may be developed. Next, the Implementation Reach prioritization evaluation is discussed followed by the conceptual alternatives development methodology. Following the body of the report are several supporting appendices, which are referenced throughout the report.

2.0 SCOPE OF SERVICES

GeoEngineers performed the following services in accordance with the "Agreement for Geomorphic Assessment on the Touchet River in Columbia County, Washington" between GeoEngineers and the City of Dayton, dated August 2, 2010 and amended on December 28, 2010. These services, briefly described below, have been completed and constitute the first of several necessary phases of this project. Subsequent phases, which are beyond the scope of this contract, include: funding acquisition, preliminary design, environmental permitting, final design, construction and post-construction monitoring.

2.1. Task 1 Project Kick-off, Compile and Review Existing Data

Prior to proceeding with the scope of services described below, GeoEngineers met with the City and the LRTG to conduct a project kick-off meeting, held on July 16, 2010. The meeting allowed a more detailed understanding of project goals, objectives and discussion of our approach to meet the goals and objectives. GeoEngineers prepared a letter to the City outlining project milestone dates and deliverables, submitted on September 21, 2010.

Following the kick-off meeting GeoEngineers obtained and processed Light Detection and Ranging (LiDAR) data, researched and obtained readily available topographic, geologic and soils maps and reports, pertinent GIS data layers and hydrologic data. These data were compiled into the GIS database, which was made available to interested stakeholders early on in the project through an on-line map service. Research and data acquisition resources used in our evaluation are included but were not limited to:

- City of Dayton and Columbia County
- Snake River Salmon Recovery Board (SRSRB)
- Washington State Department of Natural Resources (DNR)
- Washington State Department of Ecology (Ecology)
- U.S. Department of Agriculture Natural Resource Conservation Service (NRCS)
- U.S. Department of Agriculture Forest Services Administration (FSA)
- United States Geological Survey (USGS)
- United States Army Corps of Engineers (USACE)
- United States Bureau of Land Management (BLM)
- The GIS database is included as Appendix H of this report, delivered to the City via an external hard drive.

2.2. Task 2 Analyze Historic and Current Aerial Photos, and LiDAR

GeoEngineers obtained recent 2010 true-color orthophotography and LiDAR flown by Watershed Sciences, Inc. for a separate, earlier phase of the project. We also researched and obtained aerial photographs of the project area for the years 1964, 1996, and 1978. The aerial photographs were reviewed and selected photographs were georectified and incorporated into the project GIS database.

Additional aerial photography available on-line for the years 2005, 2006 and 2009 was also reviewed. Map information reviewed included General Land Office (GLO) maps dated 1874 and topographic maps from 1946, 1971 and 1983. The aerial photographs, topographic maps and LiDAR were used for the watershed and Implementation Reach assessments as described in the following sections.

In general, the 2010 orthophotography and LiDAR coverage was limited to an approximately 2,500-foot swath approximately centered on the respective watercourses. With the exception of the South Fork, LiDAR coverage did not extend to the upper reaches of the watershed. The coverage ended at approximately RM 14 on the North Fork, RM 6 on the Wolf Fork and RM 1.5 on the Robinson Fork.

2.3. Task 3 Preliminary Watershed-scale Geomorphic Assessment

Data developed during our watershed-scale assessment was used as a foundation for characterizing individual geomorphic reaches with the goal of selecting a preferred Implementation Reach. The watershed-scale assessment generally focused on:

- Channel type
- Floodplain and riparian extent

- Channel migration and relocation or avulsion
- Natural and anthropogenic disturbances
- Stream management activities such as dikes, revetments, dams, land use and infrastructure

This information was used in conjunction with a formal prioritization process to objectively select a preferred Implementation Reach for detailed assessment toward restoration concepts. This information also was used to delineate a general Channel Migration Zone (CMZ) for the upper portions of the watershed.

2.4. Task 4 Topographic Survey

A topographic survey was conducted by White Shield, Inc. within the selected Implementation Reach. The survey included acquiring 24 river cross sections at the locations shown in the Conceptual Design Drawings, Appendix G, Sheet 3.4. The cross sections extended to +3 feet above the edge of water. Select cross sections extended across portions of the floodplain. The survey was integrated with the LiDAR to construct a detailed hydraulic model of the Implementation Reach. Mapping units used were consistent with the 2010 LiDAR data collection survey control: Horizontal-UTM Zone 11 North NAD 1983/2007; Vertical-NAVD 1988; Units-Meters. All elevation data was re-projected into Washington State Plane South Coordinates NAD 1983. Vertical datum was transformed from NAVD 1988 meters to NAVD 1988 feet.

2.5. Task 5 Implementation Reach Stream Reconnaissance Assessment

A stream reconnaissance was performed within the Implementation Reach on November 10 through 12, 2010. Reconnaissance activities included, but were not limited to:

- Mapping and photo-documenting bank and terrace composition
- Documenting existing stream sediment, LWD, relic channels, irrigation diversion channels, significant areas of deposition and/or erosion
- Locating areas of past modifications including LWD and rock structures, “sugar dikes”
- Describing physical and geomorphic channel features and conditions

Using information gained from the preliminary watershed-scale assessment and our reconnaissance, we conducted a more detailed CMZ analysis for the selected Implementation Reach.

2.6. Task 6 Streambed Gravel Sampling

Twelve Wolman pebble counts were conducted at selected areas within the Implementation Reach during our reconnaissance and six bulk sediment samples from existing bars were collected for laboratory sieve analysis. We also photo-documented bank material and bar material throughout the Implementation Reach. The sediments were photographed at consistent scale to facilitate analysis. The photo log and respective photo locations are presented in Implementation Reach – Photo Log, Appendix A.

2.7. Task 7 Hydrologic Analysis

Hydrologic data was collected and analyzed on a watershed-scale to estimate river discharge values at selected return frequency intervals. The return frequency intervals analyzed ranged from the 2-year discharge up to the 100-year discharge. The hydrologic data was estimated for each geomorphic reach. A more detailed hydrologic analysis was completed for the Implementation Reach to increase the accuracy of the estimated discharge values used in the hydraulic model and alternatives analysis.

2.8. Task 8 Hydraulic Modeling

Using the Army Corps of Engineers Hydraulic Engineering Center – River Analysis System (HEC-RAS) version 4.1.0 computer model, we developed a limited hydraulic model of the river within the Implementation Reach. The model was built from a site specific survey and integrated with topographic data generated from the LiDAR survey. The physical topographic model was combined with hydrologic information and roughness values to represent the physical characteristics of the channel, banks and floodplain. This information was used to assess existing flood, habitat and geomorphic conditions within the Implementation Reach.

2.9. Task 9 Sediment Transport Capacity

The hydraulic model developed in Task 2.8 was used to analyze the ability of various flows to mobilize and transport sediment within the Implementation Reach. This model utilized streambed data and bulk samples collected from the project area (Task 6). Model results were used to develop conclusions regarding sediment transport capacity and to help confirm field derived characterizations regarding in-channel processes.

2.10. Task 10 Channel Stability Analysis

For the purposes of this project, 'channel stability' is considered in the context of dynamic equilibrium, and includes long term channel responses to recent and potential future changes in channel form and processes. The analysis was based largely on watershed and reach scale geomorphic characterizations, (including channel migration behavior), and the results of hydraulic and sediment transport capacity model runs within the Implementation Reach, which includes sediment transport capacity and bed mobilization thresholds.

2.11. Task 11 Develop Conceptual Alternatives

Four preliminary conceptual alternatives intended to satisfy the project goals and objectives were developed and presented to the SRSRB in December, 2010. The conceptual alternatives were modified based comments from the SRSRB and subsequently presented to the LRTG and RTT. The concepts were again revised based on further comments and presented to affected landowners for feedback during a meeting facilitated by the SRSRB at their office on February 10, 2011. The affected land owners were invited to the meeting by formal letter from the SRSRB. Comments received from the available landowners were incorporated into the concepts and an updated set provided to SRSRB in March, 2011. An objective alternatives analysis, discussed below, was completed on the preliminary concepts, which identified a preferred concept alternative.

3.0 PROJECT GOALS AND OBJECTIVES

The ultimate goals and objectives of this project are graphically depicted in Appendix G, Sheet 1.2 and discussed below.

3.1. Project Goals

The City of Dayton is a participating member in the Columbia County Comprehensive Flood Hazard Management Plan (CFHMP). The primary goal of this plan is to protect human life, health, and safety from flood events. The plan cites additional goals, which include reducing damage of repetitively flooded areas and identifying alternative solutions for flood control. Objectives cited in the CFHMP pertinent to this assessment include finding opportunities to incorporate fish enhancement projects that help mitigate flooding and using bio-engineering, purchase of property and setback levees to mitigate flood issues.

The overall goals of the City, LRTG and RTT are to increase, enhance and diversify aquatic, riparian and upland habitat in the watershed while simultaneously reducing the risk for flooding within the City and surrounding areas by addressing levee and sedimentation issues. Appropriate geomorphic design elements can be implemented to address both goals. For example, increasing floodplain connectivity increases off channel habitat for fish and increases potential flood water and sediment storage.

3.2. Project Objectives

To achieve the overall goals discussed above, seven specific objectives were identified and weighted by the LRTG and RTT. The first five objectives are primary objectives, which are used during the alternatives development process to facilitate the comparison of the enhancement alternatives. The secondary objectives are more general, cannot be as easily quantified and constitute general project guidelines and constraints. These objectives were defined, discussed and weighted by the RTT and LRTG during meetings with GeoEngineers on December 21, 2010 and January 10, 2011, respectively.

3.2.1. Objective 1: Increase Channel Complexity And Aquatic Habitat

An important objective for this project is to increase, enhance and diversify the aquatic habitat for the benefit of multiple fish species and all freshwater life stages of native fish species. Habitat should improve fish spawning, rearing, holding, and juvenile refugia. In general, these types of improvements include:

- Multiple habitat types in close proximity
- Primary pool habitat
- Substrate diversification
- Habitat structure and cover
- Side channel and low-velocity habitat

3.2.2. Objective 2: Increase/Enhance/Diversify Riparian Habitat

Healthy riparian habitat provides bed and bank stability, Large Woody Debris (LWD) recruitment, shade and also provides an environment for macroinvertebrates to thrive. In addition, healthy, diverse riparian and upland habitats, composed of native plant species, benefit the wider bird and wildlife communities that currently and/or historically inhabit or migrate through this river corridor. Therefore, a healthy riparian corridor benefits the entire ecosystem.

3.2.3. Objective 3: Enhance Geomorphic Stability

Geomorphic stability may be thought of as a channel in a state of dynamic equilibrium. As defined in Knighton, 1998, dynamic equilibrium is a state in which "small-scale adjustments are continually being made in order to maintain an approximate balance between processes and form" i.e. a channel that has sufficient area for channel forming processes to function and can exert energy in a productive beneficial manner. For example, rates of sediment deposition are balanced with rates of erosion. In the context of this project, a geomorphically stable channel is one that maintains a balance after properly functioning processes are established and is unrestricted to migrate within its high flow corridor (the floodplain area occupied during high flows).

3.2.4. Objective 4: Increase Floodplain Connectivity

Increasing floodplain connectivity, in itself, accomplishes several objectives including:

- Aquatic and riparian habitat
- Sediment and flood storage
- Hyporheic exchange

However, habitat improvements (objectives 1 and 2) could be realized, to a lesser extent, without increasing floodplain connectivity. Therefore, this objective specifically addresses the ecosystem benefits associated with reconnecting high flow, side channels and sloughs.

3.2.5. Objective 5: Increase Flood Storage Time And Volume

Increasing flood storage time and volume potentially attenuates downstream flood flows. As flood stage increases it opens up new areas to store flood water. This action detains flood waters, creates wetlands, promotes sediment deposition, and encourages groundwater recharge. Groundwater recharge helps support thriving riparian communities and base-flow cooling effects associated with hyporheic exchange.

3.2.6. Objective 6: Rapid Recovery Time

Recovery time is the time required for the disturbed areas to stabilize. This includes the time for new and/or disturbed vegetation to establish enough to provide sufficient erosion resistance. It also includes the time necessary for the bed and banks of the new channels to stabilize in terms of sediment transport, scour hole development, gravel bar development and bar and bank vegetation establishment. Recovery time can vary significantly between the proposed treatments and alternatives. For example; recovery time is relatively minimal for the small overflow/side channels proposed in the floodplains compared to the time necessary for a pilot channel to develop, expand, migrate and then stabilize itself over the course of many years. Longer recovery times generally involve more maintenance and greater risk of uncertainty and failure.

3.2.7. Objective 7: Design Practicality

Rather than specifically focusing on a specific design intent (for example, enhanced fish habitat), design practicality includes a number of items that are commonly considered as project constraints or limitations. In order to be successful, alternatives must address a wide range of design considerations, including:

- Accommodating physical, practical and regulatory concerns, such as:
  - Public safety
  - Zoning, easements, setbacks, flood zones
  - Property boundaries, landowner concerns
  - Neighboring landowner concerns
- Minimizing Project Complexity
  - Minimal disturbance to existing ground, habitat, vegetation and structures
  - Minimal landowner disturbance
  - Minimal construction schedule/seasons, phasing, river diversions
  - Minimal permitting concerns
  - Minimal maintenance

While project cost is directly proportional to some of these considerations, cost is not considered in this objective. Project costs are factored into the alternatives selection process by considering the benefit-to-cost ratio, which is discussed later in this report.

4.0 PRELIMINARY WATERSHED-SCALE ASSESSMENT

4.1. General

Our preliminary assessment included reviewing published maps and literature, aerial photographs and LiDAR to identify physical characteristics of the watershed. These characteristics included, but were not limited to topography, geology, regional and local channel gradients, channel dimensions, and the composition of riverbank and stream bed materials. This information was used to better understand geomorphic processes operating within the watershed. These watershed-scale characteristics are discussed in the following sections.

4.2. Basin Characteristics

The Touchet River originates on the north flanks of the Blue Mountains within the Umatilla National Forest. The overall basin is divided into five subbasins; the South Fork, Wolf Creek, Upper North Fork, Middle North Fork and Lower North Fork. These areas are shown on the Upper Touchet River Basin and Subbasins, Figure 2. The subbasins are drained by the South, Wolf North, and Robinson Forks, which flow northward before joining the main stem Touchet River south of the City of Dayton, Washington. The North Fork originates in the vicinity of the Bluewood Ski Area and the South Fork originates near Deadman Peak. The contributing drainage area to the main stem at the north/south fork confluence is approximately 163 square miles and includes the four forks described above and numerous smaller tributary streams. Runoff is primarily from snow melt and precipitation. However, significant flooding has occurred in the winter months from precipitation coupled with rapid snowmelt, rain-on-snow events.

4.3. Geology and Terrain

4.3.1. Geology

The upper Touchet River basin is situated near the boundary of the Columbia Basin and Blue Mountains physiographic provinces of southeastern Washington. Within the watershed, these provinces are characterized by river drainages that have incised deep canyons into the ancient flood basalt flows of the Columbia River Basalt Group (CRBG). The CRBG were formed by multiple, massive outpourings basalt lava flows which issued from fissures located near the Washington, Idaho and Oregon border during the Miocene (17.5 to 6 Million Years). Within the Touchet River watershed, the CRBG includes the Grand Ronde Basalt (Mvg) and the Wanapum Basalt (Mvw). During the Pleistocene, (1.8 million years to 11,000 years ago) the basalt was blanketed by large volumes of loess (wind-deposited fine sand, silt and clay) which resulted from erosion caused by continental ice sheets, located to the north.

The present terrain and surficial geology characterizing the watershed is the result of more recent geomorphic and geologic processes. These processes include faulting and erosion of the basalt and loess, deposition of alluvium (sediments deposited by modern rivers and streams) within the river canyons, the formation of modern soils and the influences of man. Surficial geology in the vicinity of the watershed is shown on Watershed-scale Geology, Figure 3.

An additional, but important process having an influence on the watershed is that of mass wasting. Review of the DNR 2008 GIS landslide layer relative, to mass-wasting in the assessment area, indicates three large landslide areas and numerous smaller landslide areas within the watershed. The first of the larger areas is located on the east canyon wall of the South Fork, offset from RM SF5 and SF6.5. This mapped landslide area is approximately 1 mile long, parallel to slope contour, and approximately 1,200 feet wide, perpendicular to slope contour. The second area is located on the Robinson Fork between RM RF2.75 and 3.5. The mapped area is approximately 1 mile long by 1 mile wide; the west half of the slide area is roughly bisected by the Robinson Fork. The third area is located east and along the ridgeline of the Robinson Fork slide. This mapped slide area measures approximately 1½ miles long by approximately 1,200 feet wide. These large landslides and the numerous smaller slides are generally mapped within the basalt unit. The locations of the landslides can be viewed on the GIS database, Appendix H.

4.3.2. Terrain

Terrain within the basin consists of a series of three prominent north-trending ridgelines that descend from the northwest flanks of the Blue Mountains from elevations on the order of 5,700 feet Mean Seal Level Datum (MSL). Robinette Mountain separates the South and Robinson Forks of the Touchet River, Newby Mountain separates the Robinson and Wolf Forks, and Chase Mountain separates the Wolf and North Forks. Each of these ridgelines is dissected by numerous steep, relatively short drainages that terminate at relatively prominent alluvial fans on the valley floors. Approximately 4 miles southeast of Dayton, the relatively narrow ridgelines give way to broad plateaus with elevations on the order of on the order of 2,000 feet. Valley floor Elevation at the downstream end of the project area, within the City of Dayton, is on the order of 1,700 feet.

4.4. Geomorphic Conditions

4.4.1. Valley and Channel Form

In the higher elevation portions of the watershed, the North Fork (RM 17.2 to 22), Wolf Fork (RM 10.9 to 16) and Robinson Fork (RM 6.3 to 11.4) are located in steep, narrow bedrock valleys. The valley widths are generally less than two channel widths and average floodplain widths are in the range of 40 to 150 feet valley wall to valley wall. In these upper reaches, the channels exhibit a generally straight planform.

In the middle to lower reaches of the North Fork (RM 0 to 17.2), Wolf Fork (0 to 10.9), Robinson Fork (RM 0 to 6.3) and the entire South Fork (RM 0 to 16.1) the valley sizes increase to widths in the range of 200 to 1,300 feet and the channels become moderately confined (valley width is greater than 2 channel widths and less than 4 channel widths) to unconfined. Average floodplain widths are in the range of 180 to 750 feet (North Fork), 108 to 600 feet (Wolf Fork), 220 to 500 feet (South Fork) and 200 to 280 feet on the Robinson Fork. In these reaches the channel planform generally consists of a single-thread moderately sinuous meander bend main stem channel. The main stem channel resides within a high flow corridor that includes one or more side channels, which cut through the forested floodplain. The main stem channel position in the valley is controlled to some degree by numerous alluvial fans located at the toe of the valley slopes. Refer to Appendix D for discussion of channel forming processes.

4.4.2. Sediment Production and Conveyance

Sediment in the watershed area is produced by several processes. In general, these include: 1) sediment delivery from the mountains, ridgelines and plateaus via the numerous tributary streams; 2) mass-wasting processes, including large and smaller landslides and debris flows, which may occur within the tributaries and/or along the valley walls during extended wet weather or intense precipitation events; 3) sediment stored in prehistoric and modern alluvial fans, located adjacent to the main stem floodplains; and 4) sediment stored on the modern alluvial floodplain. These processes and rates of sediment delivery are influenced by soil type, vegetation type and coverage, land use, climate and weathering/erosion rates. The quantities of sediment entering the channels are unknown at this time.

In the upper reaches of the watershed sediment supply is more limited. In these areas it appears sediment is transported relatively efficiently through the reach. This is due primarily to the narrow width and steeper gradient of the valleys and the associated higher stream velocities. After the sediment is conveyed through upper reaches it is deposited within the middle and lower reaches. Sediment conveyance though the middle and lower reaches is much less efficient. This is apparently due an increase in the availability of sediment volumes within the high flow corridor and floodplain, overall decrease in channel gradient, increase in valley and floodplain width and associated decrease in stream velocities. In these reaches the sediment deposited and stored in the high flow corridor and floodplain during low flow and is mobilized and transported during higher flow events. In addition, anthropogenic influences such as bridges can affect conveyance of sediment through a river system. Based on review of aerial photographs 1996 through 2011 and discussions with the LRTG and RTT workgroups significant sediment accumulation has been identified as a continuing problem in the levee system and immediately upstream of the Highway 12 Bridge.

4.5. Geomorphic Reach Divisions

The North, South, Wolf and Robinson Forks were divided into geomorphic reaches based on watershed-scale valley and channel characteristics observable from topographic maps, aerial photographs and LiDAR. We used the Channel Process Matrix, Ecology 2003, which relates channel confinement and gradient with typical channel bed morphology as a basis for estimating channel characteristics and delineating channel reaches.

Channel gradients were calculated for each of the forks using LiDAR and 10 meter digital elevation model (DEM), in areas where LiDAR was not available. Channel gradients for each of the tributary forks are summarized in Channel Gradient by River Mile, Table 1. Graphic representations of the stream profiles for each tributary fork are shown in Channel Gradient Profile, Figures 4 through 7. Details of our channel gradient calculations are presented in Appendix C.

Based on the above information, we divided the North Fork into 10 individual reaches, the South Fork into 6 reaches, the Wolf Fork into 8 reaches and the Robinson Fork into 5 reaches. The individual reaches are shown on Geomorphic Reaches, Figure 8. The reaches are labeled NF, SF, WF and RF for the North Fork, South Fork, Wolf Fork and Robinson Forks, respectively. Each reach begins at the tributary confluence at RM 0 and progresses upstream in ascending numerical order. Characteristics of the individual reaches are summarized in Preliminary Geomorphic Characteristics, Table 2.

4.6. Hydrology

The Touchet River watershed is approximately 163 square miles in area above the confluence with Patit Creek, Figure 2. This watershed as described before consists of predominately north flowing drainages with small, short and steep side tributaries draining water from the high ridgelines and plateaus down to the main tributaries in the valley bottoms. The watershed receives on average 30 inches of precipitation a year in the form of rain and snow, with the headwater areas receiving the majority of their precipitation in the form of snow. The watershed is comprised of approximately 45% forest, with the remaining land consisting of predominately agricultural fields.

Peak flows in this watershed are attributed predominately to rain on snow events with the annual hydrograph being controlled by snowmelt in the headwaters and peaking in April. There is limited historical flow data available throughout the watershed, but there were significant flood events of record in May 1906 (est. 6,000 cfs at Dayton), April 1931 (est. 6,000 cfs at Dayton), February 1949, December 1964 and February 1996. The discharges of the 1964 and 1996 floods are not known.

To estimate discharges efficiently, accurately and for a wide range of return frequencies regression equations were utilized. The United States Geological Survey (USGS) StreamStats Program utilizes the latest regression equations to estimate discharges throughout this region (USGS, 2010). The Touchet River is located within Region 9 of the Washington State's hydrologic regions (Knowles, 2001 and Sumioka, 1998). The regression equations for this region were developed from analyzing 36 historical gauge records on unregulated bodies of water with more than 10 years worth of data. Physical characteristics of the watershed were compared to discharge estimates to develop regression equations for each return interval. Within Region 9, the two most sensitive characteristics were average annual precipitation and basin area. Table 3, Region 9 Discharge Regression Equations, displays the regression equations used for selected return frequencies (Knowles, 2001 and Sumioka, 1998).

TABLE 3. REGION 9 DISCHARGE REGRESSION EQUATIONS

Discharge Equations		
$Q_{2\text{-YR}}$	=	$0.803*A^{0.672}*P^{1.16}$
$Q_{10\text{-YR}}$	=	$15.4*A^{0.597}*P^{0.662}$
$Q_{25\text{-YR}}$	=	$41.1*A^{0.570}*P^{0.508}$
$Q_{50\text{-YR}}$	=	$74.7*A^{0.553}*P^{0.420}$
$Q_{100\text{-YR}}$	=	$126*A^{0.538}*P^{0.344}$

Notes: Discharge (Q) is in cubic feet per second (cfs), Area (A) is in square miles (mi^2), and Precipitation (P) is in inches (in.).

Each geomorphic reach was analyzed within StreamStats to estimate peak flow discharges for the selected return intervals mentioned above. Table 4, Estimated Discharges Per Geomorphic Reach, displays the estimated discharges at selected return intervals for each geomorphic reach shown in Figure 8.

TABLE 4. ESTIMATED DISCHARGES PER GEOMORPHIC REACH.

Fork	Reach Number	Q (2-cfs)	Q (10-cfs)	Q (25-cfs)	Q (50-cfs)	Q (100-cfs)	Q (500-cfs)
Main stem	1	1250	3010	4150	5140	6200	9120
North Fork	1	963	2420	3390	4230	5140	7670
North Fork	2	955	2400	3350	4170	5080	7570
North Fork	3	923	2310	3220	4020	4880	7280
North Fork	4	638	1670	2370	2980	3650	5540
North Fork	5	571	1480	2100	2640	3240	4910
North Fork	6	540	1400	1980	2480	3050	4620
North Fork	7	403	1030	1460	1840	2250	3430
North Fork	8	365	935	1320	1670	2050	3130
North Fork	9	234	620	889	1130	1400	2170
North Fork	10	17	59.4	94.3	128	167	292
Wolf Fork	1	519	1370	1950	2470	3040	4640
Wolf Fork	2	518	1370	1950	2470	3040	4640
Wolf Fork	3	353	959	1380	1760	2180	3370

Fork	Reach Number	Q (2-cfs)	Q (10-cfs)	Q (25-cfs)	Q (50-cfs)	Q (100-cfs)	Q (500-cfs)
Wolf Fork	4	350	949	1370	1740	2150	3330
Wolf Fork	5	347	942	1360	1730	2140	3310
Wolf Fork	6	341	923	1330	1690	2090	3240
Wolf Fork	7	170	470	684	877	1090	1730
Wolf Fork	8	62.4	187	282	369	469	769
South Fork	1	570	1460	2060	2590	3170	4800
South Fork	2	552	1400	1970	2470	3020	4550
South Fork	3	550	1390	1960	2450	3000	4520
South Fork	4	530	1330	1860	2330	2850	4300
South Fork	5	458	1130	1580	1970	2410	3620
South Fork	6	343	848	1190	1490	1820	2770
Robinson Fork	1	264	755	1110	1420	1780	2800
Robinson Fork	2	262	752	1100	1420	1770	2790
Robinson Fork	3	245	701	1030	1320	1660	2610
Robinson Fork	4	160	464	686	887	1110	1780
Robinson Fork	5	79.2	236	354	462	585	953

4.7. Land Use

Following exploration by Lewis and Clark in 1806, the area of Dayton was first settled by pioneers in 1859. Early land use was cattle grazing, however because of the fertile soil and climate grazing soon gave way to dry land grain farming. A post office was finally established in the City of Dayton in 1872 (City of Dayton, 2010). Over the years, general land use in the watershed area has evolved to include: commercial and residential development; widely spaced rural and recreational residences; large-scale agricultural consisting of dry land and irrigated farming, cattle grazing and timber harvest; and public and private road and bridge infrastructure. Modern commercial and residential land uses are concentrated near and within the City of Dayton. Upstream of Dayton the population decreases significantly turning to rural residences, which typically are located adjacent to the river in the bottom of the canyons. Dry land, wheat farming is typically located on the upper plateau and ridgelines surrounding the river valleys. Irrigated and some dry land farming and cattle grazing are the primary agricultural land uses of the river floodplains in the valley bottoms. The extreme upper reaches of the watershed are located within the Umatilla National Forest, which primary land use includes recreation, forest management and some timber harvest.

4.7.1. Levee System

As discussed in the Background section of this report, flood control for the City of Dayton is provided by a system of federally authorized levees. The approximate locations of the federally authorized levees relative to this geomorphic assessment project are shown in Figure 8. Levee embankment deficiencies recommended for correction in Anderson–Perry, 2010 included vegetation removal, removal and management of levee encroachments, stabilization and replacement of displaced riprap and removal of sediment from riprap.

Occasional non-federally authorized levees, locally referred to as “sugar dikes” or “push up dikes” also are present in rural areas throughout the watershed. The sugar dikes typically consist of relatively low berms composed of floodplain gravel “pushed up” along the main stem channels. In many areas the river has been channelized by construction of the levees disconnecting significant portions of the floodplain.

In their Walla Wall River Watershed Study Reconnaissance Report, (USACE 1997) identified the following flood and wildlife-related concerns and opportunities for the City of Dayton and Upper Touchet Basin above Dayton. These problems/opportunities are consistent with the goals and objectives of this geomorphic assessment project.

City of Dayton Concerns:

- Failure of existing non-federal levee system to provide adequate protection against high-water events.
- Failure of the stream channel to provide adequate continuous habitat for fish.
- Failure of the floodplain to provide adequate continuous nesting opportunities for neotropical migrating birds.
- Lack of the floodplain to serve as a buffer for flood control.
- Development within the floodplain
- Flooding of Dayton sewage treatment plant

City of Dayton Opportunities:

- Increase wildlife habitat along the Touchet River
- Increase native fish habitat and allow for expansion of salmonid species in the Touchet River
- Develop open park lands along the Touchet River
- Provide increased recreational opportunities along the waterfront
- Maintain flood control facilities better and reduce future flooding
- Reduce or limit development in the floodplain

Upper Touchet Basin above Dayton Concerns:

- Land management practices impacting riparian zone and stream channel morphology
- Development in floodplain
- Flood damages
- Upper Touchet Basin above Dayton Opportunities
- Increase wildlife and native fish habitation along the upper Touchet River

- Allow for expansion of salmon species in the area
- Reduce future flood damages and/or reduce development in floodplain.

The USACE report discussed several flood reduction alternatives, which generally are located downstream of Dayton, with the exception of a headwater storage alternative on the South Fork approximately 10 miles upstream of Dayton. This alternative involves building a dam with the purpose of storing water from high winter flows and allowing releases later in the year to augment in-stream flows.

4.8. Habitat

The Touchet River Watershed, upstream from Patit Creek, is designated as a priority restoration and protection reach in the Recovery Plan (SRSRB 2006) and Walla Walla Subbasin Plan (Walla Walla Watershed Planning Unit and Walla Walla Basin Watershed Council 2004). This designation is based largely on Major Spawning Aggregations of ESA listed Mid-Columbia ESU steelhead (*Oncorhynchus mykiss*) as defined by the Interior Columbia Basin Technical Recovery Team (ICTRT 2004) and SRSRB (2006). In addition to steelhead, this reach also contains other key species such as ESA listed bull trout (*Salvelinus confulentus*), interior redband rainbow trout (*O.mykiss*), Chinook salmon (*O. tshawytscha*), and a diverse terrestrial wildlife community.

4.9. Channel Migration Potential Evaluation (watershed-scale)

4.9.1. Qualitative Approach

Our approach to delineating the probable extent of channel migration on the upper reaches of the North, South, Wolf and Robinson Forks is based in part on the assumption that, in the absence of channel constraints, the future character of migration will be similar to the past, given similar water and sediment discharge conditions. Based on our geomorphic evaluations described below, we applied a maximum zone of future migration based on the past and current behavior of channel in terms of migration. Our approach included the following:

- Evaluation of watershed-scale geomorphic conditions discussed in Section 4.4 and summarized in Table 2.
- Review and evaluation of limited time-series aerial photographs georectified into a GIS database (channel lines and other floodplain characteristics were not digitized into GIS for this qualitative level of evaluation).
- Evaluation of channel and floodplain characteristics observable in the 2010 LiDAR GIS hillshade data, where available. We focused on the location of relict channel traces and on modern active and abandoned channels traces.
- Delineation of a maximum migration boundary.

4.9.1.1. CMZ EXCLUSION AREAS AND ANTHROPOGENIC INFLUENCES

As discussed previously, the upper reaches of the North, Wolf and Robinson Forks are confined in steep, narrow valleys. Channels in these valleys generally are straight and tend not to migrate, mostly because of resistant bank materials. Therefore, CMZ's were not delineated for these upper reach areas.

Human activities that affect potential channel migration in the watershed include levees, revetments, road embankments, and bridge crossings among others. Although some infrastructure, such as bridges, can be observed by aerial photography and LiDAR, several other features, such as small dikes and revetments cannot be readily discerned at this broad-level of evaluation. Therefore, these features were not considered barriers to channel migration.

4.9.2. Maximum Migration Potential Area Boundary Delineation

Based on the above approach, we applied maximum migration boundary lines on either side of the channel indicating the area of maximum channel migration. Within the middle and lower portions of the watershed and the entire South Fork, the valleys become wider. With the exception of areas severely modified by farming, visual evidence of past and present channel features are located sporadically across the valley floor. The evidence includes the presence of relict channels at various locations on the flood plain, and areas where the main stem rivers appeared to be actively eroding the toes of alluvial fans. Based on the locations, and abundance, of these features, the maximum zone of migration was set to encompass the entire width of the valley floor. In cases where the CMZ boundary intersected an alluvial fan, a portion of the alluvial fan (approximately two channel widths) was included within the maximum migration zone to accommodate future erosion. In areas where the alluvial fan appeared to be deflecting the main stem channel we assumed the toe of the alluvial fan to be the edge of the boundary. The boundaries for the North, South, Wolf and Robinson Forks are shown on Figures 9a, 9b and 9c.

4.9.3. CTUIR GIS CMZ Layer

The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) prepared a CMZ GIS shapefile for the Upper Touchet River Watershed and provided the information to GeoEngineers for inclusion in the project GIS Database, Appendix H. We reviewed the CMZ shapefile data; however, we did not receive a report discussing the methodology and results. Based on our review of the shapefile, it appears the CTUIR CMZ boundaries are similar to those delineated by GeoEngineers, in that the boundaries are placed at the edge of the valley walls. In some instances the CTUIR and GeoEngineers boundaries differ. It appears that most of the differences are due to the CTUIR treatment of structures that may resist erosion. As discussed above, for the purposes of our evaluation, GeoEngineers did not consider such features as boundaries to migration.

4.10. Implementation Reach Prioritization

As discussed previously, the project goals are to increase and enhance fish habitat and reduce flood risk for Dayton and the surrounding community. To focus these goals, a formal process was undertaken to objectively select an approximately 2 mile-long Implementation Reach for detailed assessment and development of conceptual restoration alternatives. To accomplish this, GeoEngineers worked closely with the LRTG and RTT to develop selection criteria important to the local stakeholders to meet the project goals and objectives. Once the criteria were selected, numerical values of importance for each of the criteria were agreed upon and assigned by the two groups. This relative value was applied to each of the geomorphic reaches. The sum of the values resulted in a total score prioritization of the geomorphic reaches for each tributary fork. The higher values were considered a higher priority for meeting the project goals. It was also noted that selection of a preferred Implementation Reach need not be isolated to a specific geomorphic reach, but may cross into different reaches. Prioritization Criteria are discussed in the following sections and summarized, with their respective relative values, in Tables 5 through 8 for the North, South, Wolf and Robinson Forks, respectively. These tables are located behind the table tab at the back of this report.

4.10.1. Prioritization Criteria

4.10.1.1. GEOMORPHIC REACH LENGTH

The longer the reach length the higher the potential for restoration project opportunities. In general, longer reaches are able to accommodate larger and more diverse habitats as well as accommodate larger flood volumes. Likewise, longer geomorphic reaches have a higher relative value than shorter reaches.

4.10.1.2. CRITICAL INFRASTRUCTURE WITHIN 200 FEET OF THE ACTIVE CHANNEL

For the purposes of this evaluation, we considered critical infrastructure to include: private residences and public infrastructure, such as bridges and roadways, within 200 feet of the active channel. We assumed the fewer number of critical infrastructures near the active channel represented lower potential project complexity and associated project cost.

4.10.1.3. RATIO OF 100-YEAR FLOODPLAIN TO REACH LENGTH

A larger available floodplain area increases the potential for floodplain connectivity, increased habitat and increased flood storage. Therefore, with respect to this analysis, larger floodplain areas were assigned higher relative values than smaller areas.

4.10.1.4. CHANNEL CONFINEMENT

Confined channels indicate lower potential for habitat enhancement and lower flood storage benefits. Consequently, confined reaches (valley width less than 2 channel widths) were assigned the lowest relative value and unconfined channels (valley width greater than 4 channel widths) were assigned the highest.

In the extreme upper reaches of the North, Wolf and Robinson Forks, the steep channel gradient and high channel confinement suggest that little to no benefit may be recognized toward the project goals. On this basis, Reach 10 (North Fork), Reach 8 (Wolf Fork) and Reach 5 (Robinson Fork) were not considered further as potential implementation reaches.

4.10.1.5. FUTURE CHANNEL RESPONSE (CHANNEL MIGRATION)

At the watershed scale, reaches that have the highest potential for favorable channel responses will typically contain wider floodplain areas, lower gradients, a sufficient sediment supply, the ability to store or retain sediment and floodplain/channel connectivity. These areas also provide increased ecosystem-level function by refreshing and creating new habitat.

Evaluation of future channel response is based on channel changes observed in aerial photographs from 1964, 1978, 1996, 2006, 2010 and LiDAR 2010. Relative values increase with increased historic channel movement.

4.10.1.6. REGIONAL TECHNICAL TEAM (RTT) OPINION

Review and support of an Implementation Reach by local RTT increase potential that the selected reach addresses the project goals and objectives. Individuals in the RTT have unique perspectives and experience that need to be considered as part of a prioritization analysis. Therefore, Relative Value increases with the level of RTT agreement.

The results of the prioritization indicate the lower reaches of the assessment area present greater potential opportunities and benefit for restoration projects. The LRTG and RTT agreed that an Implementation Reach which included portions of the North Fork, South Fork and main stem would provide the greatest benefit as this would encompass sediment and discharge from the entire watershed. The results of the prioritization process are presented in Tables 5 through 8. The finally selected Implementation Reach is shown in Implementation Reach, Relative Surface Model, Figure 10 and Sheet 3.5 in Appendix G.

4.11. Conclusions of Preliminary Watershed-scale Assessment

Based on our watershed-scale assessment we conclude the following:

- No single source or sources of large scale sediment production were observed during our assessment. Primary sediment inputs appear to be relatively uniform across the watershed. Although sediment is generated from the mass-wasting processes noted in the Sediment Production and Conveyance Section 4.4.2, the large landslides mapped in the watershed are older slides mapped within the basalt unit, and thus are not significant contributors of sediment. The smaller landslides appear to occur within the soils or loess overlying the basalt, and are not considered significant contributors of sediment, unless they are located immediately adjacent to a drainage course.
- Excluding anthropogenic influences, it is our opinion that given the right conditions the channel is capable of migrating across the entire valley floors of the middle to lower reaches of the North, South, Wolf and Robinson Forks. More detailed, reach-scale CMZ analysis of specific areas of interest might refine the maximum migration boundary in such areas.
- Since the late 1800's the watershed has been developed as a result of agriculture, logging and infrastructure. Federally authorized levees, public and private dikes and revetments, and county roads and bridges have caused constriction and channelizing of the main stem and tributary forks. Further influencing channel behavior.
- The effects of bridges, such as the Highway 12 Bridge may likely contribute to sediment conveyance problems. However, site specific hydraulic and sediment transport capacity analysis is necessary to define the specific bridges effects on sedimentation.
- Based on the results of our Implementation Reach prioritization process, the selected Reach is located between RM TR 54.5, RM NF 1.1 and RM SF .04.

5.0 IMPLEMENTATION REACH ASSESSMENT

5.1. General

In addition to watershed-scale processes, discussed above, we evaluated and characterized geomorphic processes in the Implementation Reach. Principal Implementation Reach processes include flow dynamics, sediment supply and delivery, sediment transport capacity, and erosion and deposition within the channel. These characteristics are discussed in the following sections.

5.2. Stream Reconnaissance

GeoEngineers conducted a stream reconnaissance of the Implementation Reach. Our reconnaissance included detailed mapping of geology, geomorphology, and channel characteristics. Stream conditions documented included the presence of large woody debris, grade controls and bank stabilization structures. Streambed sediments were analyzed using Wolman pebble counts, bulk sample collection from gravel bars for laboratory testing, and a scaled photo log of gravel bar sediment. These data were used in the sediment transport capacity analysis and channel designs to promote a geomorphically stable channel. The adjacent floodplain areas were evaluated for relict channels, side channels, limits of the high flow corridor, and other areas with potential reconnection to the main stem channel. Federally authorized and non-authorized levees were documented and evaluated for setback potential. The reconnaissance provided necessary background information to develop conceptual alternatives that meet the project goals and objectives. The location and photographs of river features documented during our reconnaissance are presented in Appendix A.

5.2.1. Geology/Soils

5.2.1.1. SITE GEOLOGY

Bedrock within the Implementation Reach consists of the Frenchman Springs (Map Unit Mv[(wfs]) and Grande Ronde basalt (Map Unit Mv[gN2]) of the CRBG. The rock consists of black to gray, weathered to competent fine-grained basalt. Basalt is exposed along the right bank of the North Fork between approximately RM NF 0.1 and RM NF 0.2. Over the majority of the valley bottom, the basalt is overlain by recent alluvium deposited by the Touchet River. The alluvium consists of a mixture of silt, sand, gravel, cobbles and boulders. Lower and higher terraces are present southwest of the main stem and South Fork confluence. The height of the lower terrace surface varies from 6 to 8 feet above the floodplain and the higher terrace surface varies from of 12 to 18 feet above the floodplain. The higher surface includes a 1 to 2-foot-thick developed soil horizon, over 1 to 4 feet of loess overlying the alluvium, composed of erodible silty gravel and cobbles with sand. On the ridge slopes, adjacent to the river valley, the basalt is blanketed with loess. Geologic units mapped in the vicinity of the Implementation Reach are presented on Implementation Reach Geology Map and Sediment Sample Locations, Figure 11.

5.2.1.2. SITE SOILS

Soil units within the Implementation Reach are mapped by United States Department of Agriculture Natural Resource Conservation Service (NRCS) as: Riverwash (Map unit Rn); Patit Creek silt loam, 0 to 3 percent slopes (Map Unit PkA); Patit Creek gravelly silt loam, 0 to 3 percent slopes (Map Unit PIA); Patit Creek cobbly silt loam, 0 to 3 percent slopes (Map Unit PoA); Hermiston silt loam, 0 to 3 percent slopes (Map Unit HmA) and Athena silt loam, 8 to 25 percent slopes (Map Unit AtD).

The Rn unit is described as consisting of unsorted sand and gravel and is primarily mapped in the active river floodplain as show on the Implementation Reach Soils Map, Figure 12.

The Patit Creek Soil Series (PkA, PIA and PoA) consists of deep, well-drained soils formed in recent alluvium on bottomlands along streams at an elevation of 1,200 to 2,800 feet. The soils formed in alluvium derived mainly from loess, mixed with basaltic material. In general, the PIA and PoA units are mapped adjacent to the active floodplain. The PkA unit is mapped on the lower terrace surfaces.

The Hermiston series consists of deep, well-drained soils that formed in silty alluvium on stream bottoms and on terraces. The soil formed in alluvium from silty loess and ash. The HmA unit is mapped on the higher terraces surface southwest of the North and South Forks confluence.

The Athena series consists of deep and very deep well-drained soils that formed in loess mixed with volcanic ash on canyon sides, hills and plateaus. The AtD unit is mapped on the east canyon hillside above the North Fork Touchet River and generally upslope of North Touchet Road.

In general, the description of geologic and soil units within the Implementation Reach is consistent with our field observations.

5.2.2. Geomorphology

In general the geomorphic character of the Touchet River, within the Implementation Reach, can be summarized as moderately sinuous, single-thread, partially confined channel with low gradient, and limited geomorphic complexity and variability. The Implementation Reach was divided into five segments based on their dominant characteristics. Specific geomorphic parameters are outlined in Table 9, Existing Geomorphic Parameters, for the North Fork Touchet, South Fork Touchet and main stem Touchet River.

The North Fork Touchet River, from Baileysburg Bridge downstream to the South Fork Touchet Road Bridge, is a minimally entrenched channel with an accessible floodplain. The main channel resides within a high flow corridor that includes smaller side channels within the floodplain. Some of these channels have been disconnected from the main stem by small discontinuous push-up dikes. This reach is predominately a transport reach with stream bed material sizes in the range of coarse gravels to small cobbles.

The North Fork Touchet River, downstream of the South Fork Touchet River Road Bridge to approximately 300 feet upstream of its confluence with the South Fork Touchet River, is a moderately entrenched channel with limited floodplain connection. Confinement has caused some incision within this reach, reducing floodplain and side channel connectivity as well as creating a slightly armored channel bed. Several channel improvement measures are been constructed within this reach presumably to reduce bank and streambed erosion. These measures include rootwads placed in the channel banks and rock-boulder weirs placed downstream of the bridge.

The South Fork Touchet River, from the upstream end of the Implementation Reach downstream to approximately 300 feet above the confluence with the North Fork Touchet River, is a minimally entrenched channel with an accessible floodplain. This reach is a transport reach with bed material sizes in the range of coarse gravels to small cobbles. Small, discontinuous private revetments are located along channel banks to control bank recession into agricultural fields.

All three channels within 300 feet of the confluence of the North Fork Touchet and South Fork Touchet are influenced by the cumulative effects of each channel's flow and sediment discharge. The sediment regime is generally depositional, as evidenced by the presence of small bars. The main stem channel is confined along the right bank by a federally authorized levee that disconnects the river from a portion of the historic floodplain. The channel planform maintains a single-thread configuration but there is an increase in the number of side channels, predominantly along the toe of the levee, where helical flow against the levee has scoured out small channels parallel to the levee. The stream bed material sizes range from coarse gravels to small cobbles.

From 300 feet downstream of the confluence to the downstream end of the Implementation Reach, the main stem of the Touchet River is confined along the entire right bank by the federally authorized levee. The channel is single-thread with multiple high flow and side channels located within the riparian zone along the left side of the flood corridor. The channel becomes confined by the right bank levee and low and high terraces discussed in the Site Geology, Section 5.2.1.1. Severe bank erosion is occurring where the existing channel is eroding into the terraces. The right bank confinement has led to minimal incision and created a transport dominated reach.

TABLE 9. EXISTING GEOMORPHIC PARAMETERS

Parameter	North Fork Touchet	South Fork Touchet	Main stem Touchet
Bankfull Width (ft)	60	58	63
Bankfull Depth (ft)	3.2	2.9	3.5
Width Depth Ratio (ft)	18.6	19.7	18.0
Flood Prone Width	103/225	220	195
Flood Prone Depth	6.4	5.8	7.0
Entrenchment Ratio (ft/ft)	1.7/3.8	3.8	3.1
Sinuosity (ft/ft)	1.19	1.15	1.08
Slope (ft/ft)	0.0106	0.0110	0.0086
D_{50} (material)	Gravel/Cobble	Gravel	Gravel
Rosgen Stream Type	B3-B4/C3-C4	C4	C4

5.3. Streambed Gravel Sampling/Analysis

Two streambed sampling methods were utilized to aid in the estimation of bed material for channel classification, habitat type, and potential sediment transport analyses through the Implementation Reach. Bulk samples were obtained on the downstream third of the depositional bars, to better understand potential sizes of bed load material. Wolman pebble counts were conducted through the active stream channel (within bankfull elevations) to estimate the distribution and size of surface streambed materials. Comparing a bulk sample to a Wolman sample should also show the potential development of a surface armoring layer. Photographs of streambed sediments were taken on gravel bars where Wolman pebble counts or bulk samples of the bed were not obtained to augment the sediment size data.

5.3.1. Streambed Bulk Sediment Sample Analysis

Six bulk samples were obtained from various locations throughout the Implementation Reach. The majority of these samples were obtained in or adjacent to the ordinary high channel. One sample was obtained from the surface of the floodplain along the South Fork Touchet to evaluate the amount of finer-sized soil particles in the alluvium. The six samples were analyzed in the laboratory to determine site specific gradations. These data, along with the pebble counts, were used to estimate representative gradations for the respective channels through the Implementation Reach. The results of the laboratory gain-size analysis are presented in Appendix B, Figures B-1 through

B-3. Grain sizes, in inches, at specific gradation points are shown in, Bulk Sediment Sample Gradation Summary, Table 10.

TABLE 10. BULK SEDIMENT SAMPLE GRADATION SUMMARY

Sample	River	Location[1]	D15[2]	D35[2]	D50[2]	D85[2]	D95[2]
BS-1	S. Fork	0.25	0.011	0.023	0.04	1.7	2.4
BS-2	S. Fork	0.1	0.75	1.1	1.3	1.9	2.5
BS-3	N. Fork	0.85	0.28	1.2	1.7	4.0	4.1
BS-4	N. Fork	0.85	0.26	1.1	1.5	3.6	4.1
BS-5	N. Fork	0.53	0.67	1.3	1.6	4.0	4.1
BS-6	Main	0.9	0.22	1.0	1.3	2.4	3.5

Notes:

1. Location refers to the river distance in miles from the mouth of each fork.
2. Diameter size is in inches.

The samples from the channel and floodplain were used to verify and help calibrate the existing conditions hydraulic model, by looking at model shear stress and flow velocities and relating these to existing sediment sizes being retained in the channel. The gradations also were used as direct input into the sediment module within HEC-RAS to complete a sediment analysis within the Implementation Reach. Please refer to the Hydraulic Model and Sediment Transport Capacity Analysis sections of this report for further discussion.

5.3.2. Wolman Pebble Count

Twelve pebble counts were conducted within the Implementation Reach in general accordance with the Wolman Pebble Count Procedure (Wolman 1954) on November 10 through 12, 2010. Three of the counts were conducted on the South Fork, two on the Main Stem downstream of the North and South Forks confluence and seven on the North Fork. The approximate locations of the pebble counts are shown in Figure 11.

The pebble count data was summarized to estimate the approximate particle sizes of each sample. The estimated particle sizes, in inches, at various gradation points are shown in the Wolman Pebble Count Summary, Table 10. The results of the pebble counts indicate that, on average, the North Fork Touchet has a D^{50} of approximately 2.9 inches, the South Fork a D^{50} of approximately 2.3 inches and the Main Touchet a D^{50} of approximately 2.75 inches. The results of the Wolman pebble counts are graphically presented in Appendix B, Figures B-4 through B-15.

TABLE 11. WOLMAN PEBBLE COUNT SUMMARY

Sample	River	Location[1]	D15[2]	D35[2]	D50[2]	D85[2]	D95[2]
1	Main Stem	0.6	1.4	2.4	3.3	5.5	7.1
2	Main Stem	0. 8	1.2	1.9	2.3	4.6	7.3
3	N. Fork	0.1	1.6	2.5	3.2	5.5	7.3
4	N. Fork	0.2	1.2	1.9	2.6	4.7	7.9
5	N. Fork	0.3	1.5	2.4	3.3	6.1	8.8

Sample	River	Location[1]	D15[2]	D35[2]	D50[2]	D85[2]	D95[2]
6	N. Fork	0.5	1.5	2.2	2.7	4.6	6.4
7	N. Fork	0.6	1.3	2.1	2.8	4.8	6.6
8	N. Fork	0.9	1.5	2.7	3.3	6.1	7.9
9	N. Fork	1.1	1.3	2.0	2.7	6.6	10.3
10	S. Fork	0.2	1.1	1.8	2.2	4.2	5.8
11	S. Fork	0.3	1.1	2.0	2.5	4.2	6.4
12	S. Fork	0.8	1.1	1.6	2.2	4.4	6.4

Notes:

1. Location refers to the river distance in miles from the mouth of each fork.
2. Diameter size is in inches.

5.4. Hydrologic Analysis

A hydrologic analysis was completed for the Implementation Reach to increase the level of precision in estimated annual peak, monthly average, and average daily exceedance flows. For the purposes of our analysis, we divided watershed in to the following sub-basins: 1) North Fork, which included the Wolf and Robinson Forks; South Fork; and main stem. Flows were estimated from three specific points located on the North and South Forks immediately upstream of their confluence and the main stem Touchet immediately upstream of Patit Creek.

Three historic USGS gauges along the Touchet River were used in this analysis. The USGS Gauge 14017500 located at Touchet, Washington was used. This gauge has a historic record of 1941-1955. USGS Gauge 14017000, located just downstream of Bolles, Washington, was used and this historic record extends from 1925-1989. The only historic gauge within the project watershed was USGS Gauge 14016500 located on the North Fork Touchet River, just upstream of the South Fork Touchet Road. This historic gauge has a record from 1941-1968. The Washington Department of Ecology (DOE) is currently operating a stream gauge on the North Fork Touchet River at the South Fork Touchet Road Bridge over the North Fork. This DOE gauge (Gauge DOE-32E050) has a record from 2003-2010.

5.4.1. Peak Flows

To estimate annual instantaneous peak flows for the Implementation Reach, GeoEngineers utilized four methods for initial comparison. The first method was to complete a regression analysis on the historical gauge (USGS Gauge 14016500) within the Implementation Reach. This gauge was statistically analyzed using a Log-Pearson Type III (LP3) Distribution to estimate flood recurrence intervals and discharges. This gauge was evaluated with its original historical record. It was also evaluated with an artificially extended record using the downstream USGS gauges. Finally, it was analyzed with its historical gauge data along with the historic data from the DOE gauge. The USGS StreamStats program was also utilized for the fourth and final method as well as to validate our assumptions used in the watershed-scale assessment.

All three of these historical records were statistically analyzed using the USGS PeakFQ program to estimate flow discharges at various exceedance probabilities or flood return intervals (USGS, 2009). The USGS PeakFQ program utilizes the Log Pearson Type III statistical distribution as described in Bulletin 17B from the USGS to estimate the discharges at selected exceedance probabilities (USGS, 1982).

Comparing these four flood frequency distributions it became evident that StreamStats was consistently larger than the other three methods while the two artificially extended records resulted in smaller discharges but all fell within the 95% confidence intervals of each other. The flood frequency distribution from the original historic record from 1941-1968 was ultimately used to develop relationships for the North Fork Touchet at the confluence, the South Fork Touchet at the confluence and the main stem Touchet above Patit Creek up to the confluence of the North and South Fork.

Flood flow frequencies for these three locations were then estimated using three different methods. The USGS StreamStats program was used to estimate discharges. Based on the report by Knowles and Sumiok (2001), there was a regression equation used to estimate discharges at ungaged sites near gauged sites on the same stream. The limiting factor for this equation is that the ungaged site has to be within 50 and 150 percent of the drainage area of the gauged site (Knowles and Sumiok 2001). Table 12, Watershed Sub-Basin Areas, shows that extrapolating discharges for the South Fork and main stem pushes the envelope of the effective limits of this regression equation.

TABLE 12. WATERSHED SUB-BASIN AREAS

Site Location	Basin Area (mi^2)	% Area of USGS Site
USGS Gauge 14016500	107	100%
North Fork Touchet	115	107%
South Fork Touchet	43.6	41%
Main stem Touchet	163	152%

A third method to estimate the flood flow frequencies at these locations consisted of developing a regression equation between the estimated discharges from the USGS StreamStats program and the discharges from the LP3 distribution, ultimately used at the North Fork gauging site. The USGS StreamStats discharges were used since the StreamStats program is easily reproducible and is a consistent method valid at all three locations. This regression equation was then applied to each site's USGS StreamStats flows to adjust them to better represent the historic gauge data from the North Fork Touchet Gauge. Again when comparing the three methods of estimating the flood frequency discharges, StreamStats was the most conservative while the area regression equation was the least conservative. The regression equation developed from the historic data and StreamStats was ultimately used in our analysis because it was slightly more conservative than the regression equation recommended by Knowles and Sumiok (2001). A summary of all of these methods can be found in Appendix E. Table 13, Discharge Summary Table, displays the flood frequency return intervals and discharges utilized for each reach within the Implementation Reach based on the StreamStats method.

TABLE 13. DISCHARGE SUMMARY TABLE (DISCHARGES IN CFS)

Flow Reach	Flood Frequency (Years)						
	1.5	2	5	10	25	50	100
Main stem Touchet	900	1118	1940	2654	3724	4679	5766
North Fork Touchet	700	882	1570	2113	2981	3762	4640
South Fork Touchet	450	564	945	1292	1801	2263	2781

Note: 1. The main stem Touchet discharges do not represent the sum of the North and South Forks because flood events in each fork statistically do not occur simultaneously.

The peak discharges for selected return intervals were also compared to the discharges used in the original the Federal Emergency Management Agency's (FEMA) Flood Insurance Study for Columbia County, Washington and Incorporated Areas, date July 19, 2000. These discharges are compared in Table 14, Flood Discharge Comparison, below. FEMA flows were usually slightly higher than those estimated in the regression analysis especially for the main stem Touchet. In subsequent phases an analysis should be conducted to determine the probability of a significant flood occurring on both the South Fork and North Fork at the same time, therefore, increasing the potential peak discharges in the main stem.

TABLE 14. FLOOD DISCHARGE COMPARISON (CFS).

Method	Return Interval (Years)	North Fork Touchet	South Fork Touchet	Main stem Touchet
FEMA	10	2570	1390	3270
GeoEngineers	10	2113	1292	2654
FEMA	50	4200	2290	5380
GeoEngineers	50	3762	2263	4679
FEMA	100	5030	2750	6470
GeoEngineers	100	4640	2781	5766
FEMA	500	7360	4040	9520
GeoEngineers	500	7256	4308	8973

5.4.2. Average Monthly Flows

Average monthly flows were obtained at the USGS historic gauging sites for the period of record along with the historic data from the DOE gauge. The DOE gauge's record was modified to account for the difference in area between the North Fork gauge and the DOE gauge. These data were used to estimate average monthly discharge values for the downstream end of the three separate channels, within the Implementation Reach, using the regression equation recommended by Knowles and Sumiok (2001). The monthly discharges for each reach can be seen in Table 15, Average Monthly Discharges. It should be noted that since average monthly flows occur simultaneously we assumed the combination of the North Fork and South Fork discharges would accumulate to the discharge in the main stem Touchet for each month as opposed to applying the regression equation to the main stem during instantaneous peak flows that could be independent of each other.

TABLE 15. AVERAGE MONTHLY DISCHARGES (CFS).

Month	North Fork Touchet	South Fork Touchet	Main stem Touchet
October	52	29	81
November	82	47	129
December	137	77	215
January	147	83	230
February	184	104	287
March	196	111	307
April	234	132	366
May	201	113	315
June	111	63	174
July	55	31	86
August	45	25	70
September	45	25	70

5.4.3. Average Daily Exceedance Flows

Average daily flows were analyzed for the historic record on the North Fork Touchet. The area regression equation was applied to these flows to estimate average daily flows for the South Fork and North Fork Touchet. Like the average monthly flows, the average daily flows from the South and North Fork's were totaled to approximate the average daily discharge in the main stem. The average daily flow hydrograph for each reach can be seen in Appendix E.

A probability of exceedance of average day discharges was analyzed to estimate low-flow discharges for fish passage. Low-flow passage is usually estimated as the five percent flow or flow that is exceeded 95 percent of the time. The 95 percent exceedance low-flows were 44, 25, and 68 for the North Fork, South Fork and main stem Touchet, respectively.

Estimated historic daily low-flows for the given historic data record (1941-1968 and 2003-2010) for each reach was also analyzed. The extreme low-flow discharge measured for one day at the historic gauge site (USGS Gauge 14016500) was 20 cfs recorded on January 20, 1960 and was used to estimate extreme low-flows for each reach. The historic low daily average discharge for each reach is 21, 12, and 33 for the North Fork, South Fork and main stem Touchet, respectively.

5.5. Hydraulic Model

5.5.1. Hydraulic Computer Model

GeoEngineers applied the US Army Corps of Engineers (USACE) Hydrologic Engineering Center – River Analysis System (HEC-RAS) Version 4.1.0 to estimate water surface elevations and to delineate flood extents through the project area for various discharges, including the 100-year base flood (USACE, 2010). HEC-RAS modeling software is the industry standard one-dimensional model for most flood analyses and is commonly used to delineate regulatory floodplains, floodways, and estimate base flood elevations. This hydraulic model was also utilized to run a sediment transport model to estimate sediment transport capacity within the Implementation Reach.

5.5.2. Historic Hydraulic Computer Model

FEMA had historically completed a detailed hydraulic model through the Implementation Reach. A data request was submitted to FEMA and this historic model was obtained. This model was originally created in HEC-2. The HEC-2 input files were converted over to HEC-RAS input files and the model was run in HEC-RAS. This model is necessary background data with any request that will be submitted to FEMA. Ultimately this model will be used during the design process and resubmitted to FEMA with the Conditional Letter of Map Revision (CLOMR) application prior to construction and ultimately the Letter of Map Revision (LOMR) application after construction.

5.5.3. Hydraulic Model Development

5.5.3.1. CROSS SECTIONS

Cross sections were developed for the implementation area by using LiDAR flown by Watershed Sciences, Inc. along with surveyed bathymetry within the channels, surveyed by White Shield, Inc. November 20 through 24, 2010. These sections were located across the Implementation Reaches channel and floodplain, approximately perpendicular to the anticipated direction of flow. The cross sections used in the hydraulic model are displayed on Sheet 3.4 of Appendix G.

The approximate bridge geometries were included in the development of the model to account for any potential backwater effects or overtopping effects from the three bridges located within the Implementation Reach. Bridge widths were measured during the bathymetric survey, as was deck height, and pier locations and dimensions.

Levees and ineffective flow areas were placed in accordance with FEMA certified levees, field observations, and professional judgment. This included the two levees along the right bank, one short levee immediately upstream of the South Fork Touchet Road Bridge, over the North Fork Touchet River, and the other levee downstream along the right bank adjacent to the North Fork Touchet all the way downstream to the end of the Implementation Reach. Channel and floodplain roughness values were approximated with a Manning's n-value and were based off of standard hydraulic reference manuals, field exploration, photos and engineering experience.

5.5.3.2. ANALYZED DISCHARGES

The steady state model was run for a varied range of discharges including the 1.5-, 2-, 5-, 10-, 25-, 50-, and 100-year peak discharges. The base flood extents were modeled using the 100-year peak discharge values obtained in this study as opposed to those currently approved by FEMA.

The quazi-steady state flows used in the sediment transport module of HEC-RAS were based off of the 2-year discharge values. These discharges were applied to an actual hydrograph from the North Fork Touchet River stream gauging site currently maintained by the Washington Department of Ecology. The hydrograph was approximately 30 days long and consisted of average daily flows. This hydrograph was normalized and scaled for each respective fork of the Implementation Reach. This was the only hydrograph and discharges analyzed in the sediment transport module.

5.5.3.3. BOUNDARY CONDITIONS

The boundary condition used for the starting water surface at the downstream extent of the analyzed river reach for the steady state analysis was normal depth. A normal depth starting water surface boundary condition requires the input of the average gradient of the channel bottom for the entire modeled reach. The project reach gradient used for this boundary condition was 0.7 percent. Originally the estimated FEMA base flood elevation at the downstream end of the hydraulic model was used as a starting boundary condition for the 100-year base flood, but starting water surface elevations defaulted to critical depth, so normal depth was used for its conservative elevation estimate.

Discharge hydrographs were used as input boundary conditions for the North fork and South fork reaches during the sediment transport module run. As in the steady state module, normal depth was used for the downstream boundary condition of the main stem Touchet River. Sediment boundary conditions also had to be estimated at the upstream and downstream cross sections of the hydraulic model. Since no existing sediment data was available we assumed that the upstream and downstream most cross sections would simply transport all material through them, allowing neither deposition nor scour.

All models were run in a subcritical flow regime. Subcritical flow regimes are developed by a downstream control and propagate upstream. In this manner water surface elevations are calculated from the downstream project limits upstream. Subcritical flows produce greater flow depths than supercritical flow regimes and are more conservative in relation to flood elevations and extents.

5.5.4. Hydraulic Model Results

Steady state model results were obtained for the 1.5-, 2-, 5-, 25-, 50-, and 100-year recurrence interval discharges. These results contain certain hydraulic characteristics used to describe what is occurring at each individual cross section. These parameters include flow depth, velocity, shear, and stream power. Parameters obtained during the more frequently occurring flood intervals (1.5- and 2-year), which tend to be the channel forming flows, will be used in future channel design.

Water surface elevations were also obtained for the array of channel discharges run through the hydraulic model. The computed elevation to which floodwater is anticipated to rise during the 100-year base flood is known as Base Flood Elevations (BFEs). The BFEs for both the FEMA floodplain and the existing conditions floodplain are illustrated in Table 16, Base Flood Elevations. FEMA BFEs were originally recorded in the National Geographic Vertical Datum of 1929 (NGVD 29) and were adjusted to the North American Vertical Datum of 1988 (NAVD 88) to match the results of our model. An average conversion factor of +3.182 was used to convert from the NGVD 29 datum to the NAVD 88 datum. These elevations will be used in validating flood extents, estimating available levee freeboard, and in future levee designs.

TABLE 16. BASE FLOOD ELEVATIONS

River Reach	FEMA Cross Section	FEMA (ft)	Existing (ft)	Difference (ft)
Touchet	AH	1657.1	1658.6	1.5
	AI	1663.5	1662.7	-0.8
	AJ	1669.9	1669.7	-0.2
	AK	1673.8	1674.0	0.2
North Fork	A	1680.8	1681.5	0.7
	B	1690.1	1691.0	0.9
	C	1702.3	1700.7	-1.6
	D	1706.8	1707.1	0.3
	E	1712.0	1712.1	0.1
	F	1721.2	1722.78	1.6
	G	1729.3	1730.2	0.9
South Fork	A	1680.7	1681.5	0.8
	B	1690.8	1690.9	0.1

Flood extents were estimated based upon water surface elevations at each cross section. Extents were analyzed for the 1.5-, 2-, 5-, 25-, 50- and 100-year flood conditions. A relative flood surface model of the detailed flood study was created to show approximate inundation depths and potential high-flow channels. This relative surface model can be seen on Figure 10. The 100-year base flood extents can be seen on Sheet 3.4 in Appendix G. The other inundation extents are available within the GIS database developed as part of this project. We assumed the federally authorized levees were in a functioning order and able to withhold the floods.

5.6. Sediment Transport Capacity Analysis

Discharges for several recurrence interval flows were routed through the hydraulic model to analyze potential sediment transport and transport capacity along with an actual 1.5-year hydrograph. The selected flows include the 1.5 and 2 year storm discharges (considered bank full in different parts of the reach), as well as the 10, 25, 50, 100 and 500 year storm flows. The Meyer-Peter Müller bedload transport equation was used in the sediment transport element of the HEC-RAS model. The model output included channel velocities and total boundary shear stress (T) for the selected discharges and at various time steps throughout the hydrograph. Model output was used in the sediment transport element of the HEC-RAS model to estimate the ability of the selected flows to 1) maintain the transportation of various grain sizes comprising the bedload; and 2) mobilize and entrain sediment comprising the streambed.

The results of the transport capacity model runs for the North Fork and South Fork channels are provided in Sediment Transport Capacity Results, Table 17, located behind the Tables Index Tab. The results are given for each HEC-RAS cross section, and for each selected recurrence interval. The cross section locations are shown in Appendix G, sheet 3.4.

Results for the North Fork channel indicate that channel velocities and boundary shear stresses generated by flows at most cross sections upstream of cross section (XS) 3350 (bridge crossing) are sufficient to maintain the transport of bedload, but incapable of eroding the stream. Results indicate only marginal capacity of flows to mobilize the stream bed (sporadically) from the 1.5 to the 100 year storm discharges. Downstream of XC 3350 model results indicate marginal to full mobilization and transport takes place during events equal to or greater than the 2 to 5 year event (bankfull condition). These results indicate the North Fork is primarily a transport reach. This was validated through the 2-year hydrograph.

Results for the South Fork channel indicate that channel velocities and boundary shear stresses generated by flows at all cross sections upstream of XS 2780 are not sufficient of maintaining bedload transport, and incapable of mobilizing sediment from the bed. This could be likely caused by the hydraulic controls of the private bridge crossing the South Fork at this location. Downstream from XS 2780, model results indicate marginal to full mobilization of the bed between at about bankfull conditions, and fully maintained transport of bedload through the reach to the confluence. These results indicate that the area above the XS 2780 functions largely as a zone of deposition, and the area downstream of the bridge is largely erosional. These results are consistent with the 2-year hydrograph results which show deposition upstream of the bridge and erosion downstream of the bridge.

Results for the Touchet main stem indicate that channel velocities and boundary shear stresses generated by flows at cross section XS 2071 are incapable of mobilizing the bed, and insufficient to maintain transport of sediment sizes greater than small gravel. Modeled transport conditions downstream of XS 2071 indicate the bed is marginally mobilized at the 1.5 and 2 year flows, and fully mobilized at 10 year and greater flows. These results suggest this area is a primarily a depositional zone, which is consistent with field observations indicating that sediment deposition is possibly aggrading the channel floor. Modeled conditions upstream of XS 2071 indicate the bed is predominately stable during the 1.5- to 2-year and material is falling out of transport creating a depositional zone. However, during the 10- to 100-year discharges the bed material is mobilized and transported downstream of the Implementation Reach. This deposition occurring near the confluence with a moderately stable bed near the downstream end of the Implementation Reach was also verified throughout the 2-year hydrograph.

5.7. Channel Migration Potential Evaluation

5.7.1. Implementation Reach Approach

Our approach to delineating the probable extent of channel migration within the Implementation Reach expanded on the results of our qualitative watershed-scale evaluation, by adding a quantitative component. Our quantitative approach included the following evaluations and assumptions:

- Evaluation of the watershed-scale geomorphic conditions discussed in Section 4.4 and summarized in Table 2 relative to the Implementation Reach.
- Review of georectified aerial photographs developed into the GIS database. A high flow corridor was digitized for the years 1964, 1978, 1996, 2006 and 2010. The high flow corridor for each year included the modern channel, flood plain, modern and historic abandoned and

relict channels. The high flow corridor traces were overlaid in GIS to develop the Historic Channel Migration Zone (HMZ).

- Using GIS, the maximum observed lateral channel movement was measured at several points over the aerial photo record and calculated as an average. The distances of movement via reoccupation of older channels were not considered in the measurements.
- Federally authorized publically maintained levees were considered barriers to migration.
- High, moderate and disconnected migration potential areas were delineated.

5.7.2. Channel Migration Potential Area Delineation

Three areas were delineated for the Implementation Reach channel migration potential evaluation. These included: 1) a high migration potential area (MPA); 2) a moderate MPA; and 3) a disconnected migration area (DMA). The Implementation Reach MPAs are presented on Figures 13a and 13b.

5.7.2.1. HIGH MIGRATION POTENTIAL AREA

The high MPA was defined as the HMZ. This area is considered the area with the highest potential for channel migration during a single storm event based on evidence of past channel occupation and relatively erosive alluvial soils.

5.7.2.2. MODERATE MIGRATION POTENTIAL AREA

Review of the time-series aerial photographs did not reveal significant steady migration of the main stem channel outside the high flow corridor. Rather, migration appears characterized by episodic movement of the main stem channel into previously abandoned channels or relatively rapid lateral migration within the highflow corridor. For this reason, calculating an average rate of migration was not deemed appropriate. As an alternative approach to defining the moderate MPA, we took the average maximum migration of 59 feet and applied a factor of 1.5. The result is a 90 foot-wide buffer, which was applied to the outside on each side of the high MPA. This area represents the moderate MPA.

5.7.2.3. DISCONNECTED MIGRATION AREAS

We assumed that the USACE levees (right bank levee in Dayton and the “Star” levee upstream of Dayton) will be maintained as erosion resistant flood control structures. For the purposes of this evaluation, these levees were considered as a barrier to channel migration. However, the areas behind the levees suggest past channel occupancy. Therefore, these areas were delineated as Disconnected Migration Area (DMAs).

5.7.3. CTUIR GIS CMZ Layer

We reviewed the CTUIR CMZ shapefile data relative to the Implementation Reach. As discussed above, GeoEngineers’ boundaries in the Implementation Reach were refined to include high and moderate MPAs and DMAs. The CTUIR did not make these boundary distinctions. As discussed in Section 4.9.3, it appears that the CTUIR data refines the migration zone based on the presence of structures that may resist erosion. GeoEngineers did not consider such features as boundaries to migration.

5.8. Channel Stability Analysis

The results of the reach scale geomorphic characterization, hydraulic and sediment transport capacity modeling and channel migration potential analyses were evaluated together to assess the general stability of the channel within the Implementation Reach. The lack of significant dynamic movement of most sections of the North and South Fork channels, and the prevalence of sediment transport through both channels suggests these channels are not in dynamic equilibrium. The dis-equilibrium and lack of dynamic behavior is due largely to channel confinement, which in turn has resulted in streambed erosion and channel incision.

The mainstem Touchet also appears to be out of equilibrium. In this area, the disequilibrium is the result of sediment deposition in the form of long-lived bars, resulting in aggradation of the channel floor. In unconfined rivers, the typical 'stable' channel response to aggradation is channel widening, and/or channel migration. However, the main stem Touchet channel in this reach is tightly confined by revetted levees that have effectively prevented bank erosion and channel migration. Consequently, the aggrading bars have had the effect of displacing the conveyance capacity of the channel and promoting more frequent episodes of flooding.

Alternative measures proposed for the Implementation Reach will improve the connectivity between the river channels and portions of the floodplain, thus enlarging the high flow corridor. This action alone will help restore some of the dynamic channel behavior previously lost to channel confinement. The introduction of in-channel structures will also recover dynamic behavior by diverting flow and creating small areas of deposition, which are important to achieving channel stability and balancing the volume of sediment entering and exiting the reach.

5.9. Conclusions of Implementation Reach Assessment

Based on our Implementation Reach assessment we conclude the following:

- Relevant processes in the Implementation Reach primarily include: lateral and vertical scour (bank erosion and downcutting) with localized depositional areas and overall transport of sediment through the reach.
- Active erosion into floodplain alluvium and historic terraces at the confluence of the North and South Forks and at the downstream end of the Implementation Reach, respectively, is a likely source of sediment into the levee floodway downstream of the Implementation Reach.
- Human activities associated with agriculture and rural development have resulted in the following limiting factors for habitat and flood reduction:
    - Channel confinement
    - Disconnected floodplain and side channels
    - Streambed and stream bank degradation
    - Reduction of LWD
- Primary Potential benefits from restoration within the Implementation Reach will be:
    - Reconnecting side channels with portions of the floodplain
    - Improve habitat

  - Increase riparian density and width
  - Increase channel complexity and habitat diversity by adding structure (LWD etc.)
  - Increase low-velocity habitat areas for juvenile rearing
  - Increase hyporheic exchange for increased base-flow and cooler water at low-flow
  - Increase and improve cover and migration corridors for fish and terrestrial wildlife
- Improve flood storage capacity

6.0 CONCEPTUAL ALTERNATIVES DEVELOPMENT

6.1. Overview of Alternatives Development

GeoEngineers prepared this alternatives development in collaboration with the City, LRTG and RTT. The following sequential process was followed throughout this assessment so practical enhancement alternatives could be developed and compared against one another with the intent of selecting a preferred conceptual alternative.

This process involves the identification of the project in terms of its goals and objectives. The project goals are relatively general and the project objectives are more specific. Each project objective was assigned a numerical weighting by the LRTG and RTT based on its relative level of importance. Note, the goals, objectives and numerical weighting of this alternatives assessment are similar but not the same as the goals and objectives for the watershed reach prioritization process, described previous.

Lists of geomorphically appropriate enhancement treatments, which focus on achieving the specific project objectives, were then developed. These treatments range from physical, on-the-ground improvements, to more passive land management practices. Project constraints, which constitute the practical limitations of the project, were also identified during this early stage of the project. These alternatives were only developed to a conceptual level of detail using similar assumptions and cost estimates to facilitate a reasonable side-by-side comparison. The alternative ultimately selected will require a more rigorous design effort.

The numerical rating system was then used to objectively identify a preferred enhancement alternative. A numerical rating of each alternative was calculated for each objective by multiplying the objective's level of importance by the alternative's level of effectiveness in achieving the objective. A benefit rating for each alternative was then calculated by summing the alternative's rating for each objective. Because the more important objectives and the more effective alternatives were defined in terms of higher value, the alternative with the highest rating provides the greatest benefit, relative to the other alternatives.

The costs of implementing each of the alternatives were estimated then factored into the assessment. To account for costs, we divided the benefit rating, for each alternative, by its cost to establish a benefit-to-cost ratio (Because the benefit units are different from dollars, we also multiplied the ratio by 20,000 to obtain a ratio that was just less than 1.0). This technique normalizes the benefits with the costs. The alternative with the highest benefit-to-cost ratio is therefore the most desirable or preferred alternative as defined by the overriding project objectives and input from the stakeholders. These analyses were performed using a proprietary workbook, a copy of which is included in Appendix F. The specifics of these analyses and the results thereof are discussed below.

6.2. Selection Criteria

The project objectives, discussed in Section 3.2, are also the selection criteria used to develop and compare the enhancement alternatives. These criteria were collectively identified and numerically weighted by GeoEngineers, City of Dayton, RTT and LRTG. The weights, which range from 1 to 5, were based upon the relative level of importance of each objective as defined by the project area stakeholders. The weights, relative to their level of importance to the stakeholders, are listed in Table 18. The associated weights of each selection criteria are listed in Table 19 and discussed in greater detail below.

TABLE 18. RELATIVE LEVEL OF IMPORTANCE WEIGHTING

Weight	Level of Importance
1	Lowest Level of Importance
2	Low Level of Importance
3	Moderate Level of Importance
4	High Level of Importance
5	Highest Level of Importance

TABLE 19. WEIGHTED SELECTION CRITERIA

Selection Criteria (Project Objectives)	Weighted Level of Importance
Increase Channel Complexity and Aquatic Habitat	5.0
Increase/Enhance/Diversify Riparian Habitat	3.5
Geomorphic Stability	4.0
Increase Floodplain Connectivity	5.0
Increase Storage Time and Volume	4.0
Rapid Recovery Time	2.0
Design Practicality	2.0

6.3. Levels of Effectiveness

The level of effectiveness is a quantifiable ranking that numerically defines how an alternative will address each of the selection criteria. Defining effectiveness numerically allows it to be included as a multiplier in the alternative prioritization matrix. Table 20, below shows the various levels of effectiveness considered.

TABLE 20. LEVELS OF EFFECTIVENESS

Level of Effectiveness	Effectiveness
1	Ineffective
2	Minimally Effective
3	Moderately Effective
4	Effective
5	Very Effective

6.4. Conceptual Alternatives

6.4.1. Overview of all Alternatives

A total of five enhancement alternatives, including the "no action" alternative, were developed for this project. The enhancement alternatives were developed utilizing the proposed geomorphic parameters and a combination of the enhancement treatments discussed above. Because the proposed parameters and treatments were developed from our assessment of the historic and existing conditions, they are intended to be appropriate in terms of the site's geomorphology, hydrology, hydraulics and habitat. And, because the treatments stem from the objectives, which in turn stem from the single overarching project goal, the resulting enhancement alternatives target the project's project goal as well.

The specific locations of the proposed treatments, in each alternative, are based upon floodplain topography, channel bathymetry, vegetated cover, and historic channel locations as observed during field reconnaissance. In locating proposed channel realignments and/or side-channels, we also took into consideration landowner concerns, land use practices and location of infrastructure. Existing floodplain features were utilized in the conceptual designs, wherever possible, to reduce construction costs. Basic geomorphic, engineering, and biological considerations were also taken into account, when developing feasible alternatives, in order to increase constructability, longevity, and biological benefit.

The enhancement alternatives considered are discussed below. In general, the alternatives increase in complexity, disturbance, habitat benefit and cost in the order in which they are presented. Table 21, Comparison of Conceptual Alternatives, which follows these discussions, summarizes how effective each alternative is at achieving each objective. This table is similar to the workbook, included in Appendix F, which was used to compare the alternatives numerically.

6.4.1.1. ALTERNATIVE 1 –

The Sheet 4 series of drawings in Appendix G depict the general concept of Alternative 1. Generally, Alternative 1 is the least invasive of the four "action" alternatives. The general intent of Alternative 1 is to increase channel complexity by utilizing existing landscape features such as; low areas/potential historic channels "sugar" dike removal, and main channel sculpting to allow the channel and floodplain to develop with the least amount of earthwork and structure placement. Removal of the small "sugar" dikes will allow the channel to access more of its floodplain to create more wetted usable area as discharges increase. Existing main channels will be sculpted to accentuate viable pools and riffles, define a channel thalweg and to create more complex habitat structure through the Implementation Reach. All of the proposed LWD structures in Alternative 1 are intended to increase habitat diversity but some also serve the purpose of encouraging the channel to meander to increase floodplain connection and future LWD recruitment. Areas of minimal and degraded riparian habitat will be planted with dense native riparian vegetation and will have partially and fully buried logs and brush located throughout to increase floodplain roughness. Increased floodplain roughness will promote sediment deposition on the floodplain, protect agricultural fields and/or residential buildings, and create a more complete and complex riparian buffer zone Once established this riparian corridor will provide shade, bank stability, and ultimately a future source of LWD recruitment.

6.4.1.2. ALTERNATIVE 2 –

The Sheet 5 series of drawings, located in Appendix G, depict the general concept of Alternative 2, which has the same proposed design intent as Alternative 1, with slightly more in-stream and off-channel excavation. Alternative 2 proposes to set back a portion of the federally authorized levee system near the confluence to allow access to more floodplain habitat, increase the riparian buffer, and encourage more deposition within this reach. Additionally, Alternative 2 includes increasing the radius of curvature at two locations on the main channel of the North Fork Touchet that currently exhibit cut banks and high erosion potential. This should attenuate approach velocities, bend scour potential, bank erosion rates and protect the North Fork Touchet River Road Right-of-Way.

The goals for Alternative 2 are the same as Alternative 1 but will be achieved more rapidly than with Alternative 1. The more rapid achievement of the goals will require more earthwork and structure placement and, therefore have a higher associated cost. In areas where the channel will be slightly relocated, the steep eroding banks will be protected by the addition of a terraced LWD and soil structure in the abandoned channel and will be backfilled with the material removed from the excavation. This will create pool habitat and in-stream cover along the outside of the meander bends for fish and will provide greater bank stability in these areas of concern. The levee setback will create more floodplain conveyance, promote more deposition at the confluence and provide a riparian buffer adjacent to the new levee. Again a dense riparian vegetation plan is proposed to create a viable riparian corridor and to increase floodplain roughness to help attenuate and store flood waters.

6.4.1.3. ALTERNATIVE 3 –

As shown on the Sheet 6 series of drawings, Alternative 3 builds upon the complexity of Alternatives 1 and 2 through the addition of more main-stem channel relocations. The intent for Alternative 3 is the same as Alternatives 1 and 2, but creates a more geomorphically appropriate sinuosity, removal of “sugar” levees, the setback of certified levees, and an increase in side channels and high flow channels throughout the Implementation Reach. Alternative 3 anticipates the locations where channel migration and side channel development will be of the most benefit and incorporates them into the design for immediate construction. This includes the setback of a longer length of levee along the main Touchet River, upstream to the confluence. A tight meander pattern, at the very downstream end, is intended to encourage floodplain overtopping and a more prominent backwater condition at smaller discharges to promote deposition of material before entering the confined section of river immediately downstream of the project boundary. Channel relocations in the North Fork and South Fork are proposed to increase sinuosity, floodplain access and disperse energy, and to encourage channel diversity. High flow channels were added through or adjacent to off channel ponds to increase flood storage and on-site detention. Again LWD, dense riparian buffers, side channel creation, and channel sculpting as described in Alternatives 1 and 2 will be incorporated into the overall design to create a naturally functioning, geomorphically stable channel.

6.4.1.4. ALTERNATIVE 4 –

Alternative 4 (Sheet 7 series of Appendix G) was developed after an initial review of alternatives by a member of the RTT. To create Alternative 4, Alternative 3 was slightly modified to incorporate some aspects of Alternatives 1 and 2 along with a few slight alterations based on landowner concerns. Alterations included the removal of the high flood channel into the off channel pond and the slight modification of the location of a new meander to avoid a property corner. A more natural meander wave length was designed along the main Touchet River with an increase in high flow channels to attenuate flood conditions. Alternative 4 also included the addition of backwater side channels to increase juvenile rearing habitat throughout the main channel, while promoting hyporheic exchange into these areas. It should be noted that the location of every conceptual design element has been scrutinized for geomorphic and biologic continuity within the given constraints known at the time.

6.4.1.5. ALTERNATIVE 5 –

Alternative 5 proposes no action. If no action is taken at the site, fish spawning and rearing habitat and increased floodplain connection will likely improve very little over time. Reaches adjacent to federally authorized levees will have to meet new compliance regulations and will likely be cleared of existing vegetation reducing shade, riparian vegetation and potential LWD recruitment. In areas without levees that have erosion into some of the existing high banks will become more prominent as the river naturally increase sinuosity and meanders through the floodplain. Natural recruitment of native riparian vegetation and subsequent in-stream LWD will likely improve without taking any action but the process will occur very slowly assuming degrading activities don't continue. It is unclear how long this natural enhancement process would take but it is reasonable to assume it would take upwards of 100 years or more to achieve the same benefits the previous alternatives would provide within 2-10 years. Left alone it could also become worse as invasive species could colonize more rapidly, bank erosion could increase depending on land use practices, riparian buffers could shrink, and existing or new hardened confined levees could keep the river and its habitat in its current, less-than-optimal condition.

TABLE 21. COMPARISON OF CONCEPTUAL ALTERNATIVES

Objective	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Increase, Channel Complexity and Aquatic Habitat	2 Minimally Effective	3 Moderately Effective	4 Effective	5 Very Effective	1 Ineffective
Increase/Enhance/ Diversify Riparian Habitat	2 Minimally Effective	3 Minimally Effective	4.5 Effective to Very Effective	4.5 Effective to Very Effective	1 Ineffective
Geomorphic Stability	3 Effective	4 Effective	4 Effective	5 Very Effective	3 Moderately Effective

Objective	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Increase Floodplain Connectivity	2 Minimally Effective	3 Minimally Effective	5 Very Effective	5 Very Effective	1 Ineffective
Increase Storage Time and Volume	2 Minimally Effective	3 Moderately Effective	5 Very Effective	5 Very Effective	1 Ineffective
Rapid Recovery Time	3 Moderately Effective	3 Moderately Effective	4 Effective	4 Effective	1 Ineffective
Design Practicality	4 Effective	4 Effective	2 Minimally Effective	2 Minimally Effective	5 Very Effective

6.5. Construction Quantities and Cost Estimates

Approximate construction quantities and cost estimates were calculated for each enhancement alternative considered. These costs were developed using a single list of standard unit costs based upon GeoEngineers' recent project design/construction experience, inquiries to local construction contractors, suppliers and/or agencies, R.S. Means Heavy Construction Cost Data, and other appropriate sources. In addition to unit costs for specific construction quantities, our unit cost basis includes costs and variables to account for inflation, project location adjustment factors, mobilization, incidentals and contingencies. Design and permitting fees have not been included in the construction cost estimates. While these cost estimates are very approximate, they are all based on the same unit costs and therefore provide a sound basis to compare the relative alternatives against one another. The workbook in Appendix F summarizes the construction quantities and costs, which are also presented in Table 22 below.

TABLE 22. COST ESTIMATES FOR EACH ALTERNATIVE

Alternative	Cost
Alternative 1	$1,950,000
Alternative 2	$2,309,000
Alternative 3	$2,984,000
Alternative 4	$3,139,000
Alternative 5	NA

6.6. Benefit-to-Cost Analysis

As noted above, a numerical rating system was used to identify a preferred enhancement alternative. A numerical rating of each alternative was calculated for each objective by multiplying the objective's level of importance by the alternative's level of effectiveness in achieving the objective. A total benefit for each alternative was then calculated by summing the alternative's rating for each objective. Because the more important objectives and the more effective alternatives were defined in terms of higher value, the alternative with the highest rating provides the greatest benefit.

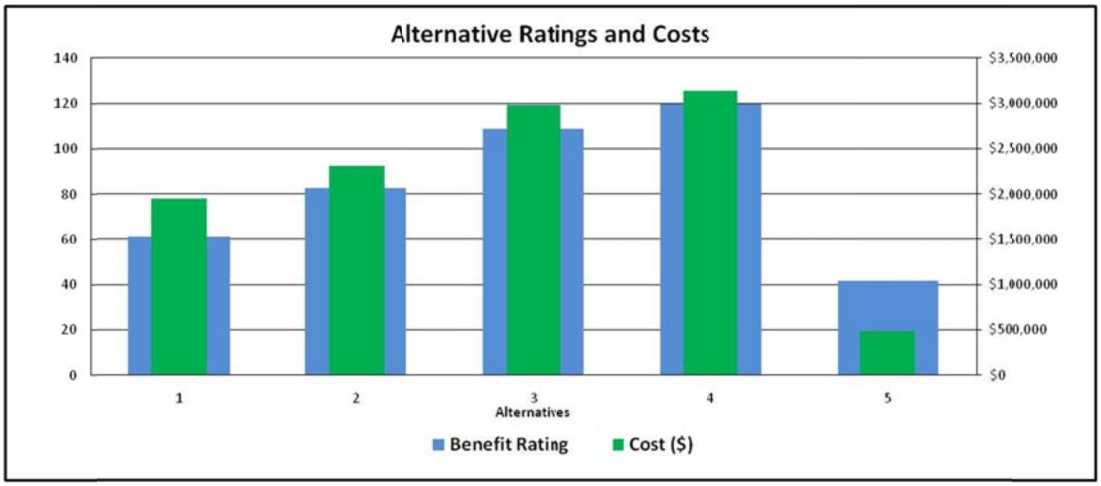
The costs of implementing the alternatives were then factored into the assessment. To account for costs, we divided the benefit rating for each alternative by its cost to establish a benefit-to-cost ratio. Because the benefit units are different from dollars, we multiplied the ratio by 20,000 to obtain a ratio that was just less than 1.0. This technique normalizes the benefits with the costs.

The alternative with the highest benefit-to-cost ratio is therefore the more desirable or preferred alternative as defined by the overriding project goals and input from the stakeholders. This analysis was performed using a workbook, which is included in Appendix F. Table 23 summarizes the numerical results of this benefit-to-cost analysis. The resulting benefits and cost for each alternative are graphically expressed in Chart 1. The benefit-to-cost ratio is expressed in Chart 2. Because it has the highest benefit-to-cost ratio, Alternative 4 is the preferred alternative as defined by the overriding project goals and input from the stakeholders.

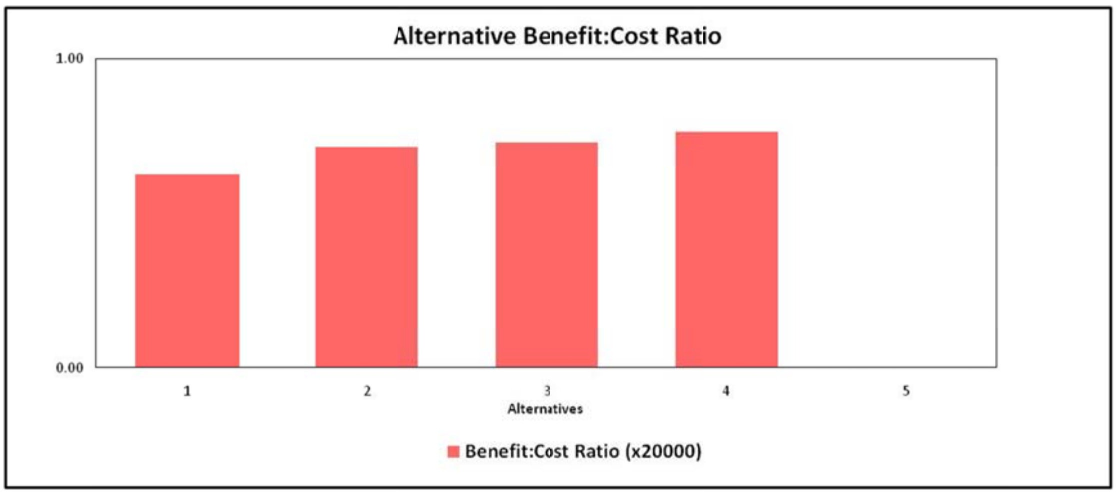
TABLE 23. ALTERNATIVE BENEFITS, COSTS AND BENEFIT: COST RATIOS

Alternative	Description	Benefit Rating	Cost ($)	Benefit: Cost Ratio (x20,000)
1	Side channel and high flow channel creation (minimal excavation)	61	1,950,000	0.63
2	Side channel and high flow channel creation with levee setback and main stem alterations that increases complexity	83	2,309,000	0.71
3	Side channel and high flow channel creation with larger levee setback and main stem channel relocation that increases complexity	109	2,984,000	0.73
4	Side channel and high flow channel creation with larger levee setback and main stem channel relocation that increases complexity and protects some existing floodplain features	120	3,139,000	0.76
5	No Action	42	NA	NA

6.7. Chart 1. Alternative Ratings and Costs



6.8. Chart 2. Alternative Benefit : Cost Ratio



6.9. Conclusions of Alternatives Development

Based on the process described in this report, input from the stakeholders and discussions with LRTG and RTT, the enhancement alternative that provides the greatest benefit for its associated cost should be selected as the preferred alternative. Accordingly, Conceptual Alternative 4 is considered the preferred alternative because it has the highest benefit to cost ratio. This alternative attempts to satisfy the project goals by the following:

- Creates new and reconnects existing side channels and floodplain areas
- Enhances channel sinuosity to encourage sediment deposition (potentially reduce sediment entering the levee floodway) and create more diverse and complex in-stream habitat for juvenile and adult native salmonids
- Enhances the riparian corridor to provide shade and future LWD recruitment

- Encourages geomorphic stability
- Increases flood storage capacity to help attenuate flood elevations
- Has a relatively rapid recovery time due to the magnitude of work being completed

7.0 LIMITATIONS

We have prepared this report for the City of Dayton and their authorized agents and regulatory agencies for the Touchet River Geomorphic Assessment. The watershed-scale project area begins upstream of the City of Dayton, Washington and continues upstream to the headwaters. The "Implementation Reach" encompasses areas of the main stem, North Fork and South Fork Touchet River and the associated floodplain areas immediately upstream of Dayton.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in the field of stream and river habitat enhancement, stabilization and enhancement design engineering in this area at the time this report was prepared. The conclusions, recommendations, and opinions presented in this report are based on our professional knowledge, judgment and experience. No warranty or other conditions, expressed or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table and/or figure), if provided, and any attachments should be considered a copy of the original document. The original document is stored by GeoEngineers, Inc. and will serve as the official document of record.

Please refer to the appendix titled "Report Limitations and Guidelines for Use" for additional information pertaining to the use of this report.

8.0 REFERENCES

Anderson - Perry & Associates, Inc., 2010, Periodic Inspection Report, Dayton – Right Bank Levee, Prepared for the United States Army Corps of Engineers, Walla Walla District.

Anderson – Perry & Associates, Inc. 2010, Periodic Inspection Report, Dayton – Left Bank Levee, Prepared for the United States Army Corps of Engineers, Walla Walla District.

City of Dayton, http://www.daytonwa.com

Columbia County Comprehensive Flood hazard Management Plan, 2002

Federal Emergency Management Agency (FEMA), 2000, Flood Insurance Study, Columbia County, Washington and Incorporated Areas, Revised July 19, 2000.

Knighton, D. 1998, Fluvial Forms and Processes, A New Perspective.

Knowles, S.M. and Sumiok, S.S., 2001, "The National Flood-Frequency Program – Methods for Estimating Flood Magnitude and Frequency in Washington," U.S. Geological Survey Fact Sheet FS-016-01, 4p.

Rapp, C.F. and Abbe, T.B., 2003, A Framework for Delineating channel Migration Zones. Washington State Department of Ecology and Washington State Department of Transportation. Ecology Publication #03-06-027

Schuster, J.E., Gulick, C.W., Reidel, S.P., Fecht, K.R. and Zurenko, S. 1997, Geologic Map of Washington - Southeast Quadrant, 1 to 100,000 Scale. Washington Division of Geology and Earth Resources, Geologic Map GM-45

Sumioka, S.S., Kresh, D.L., Kasnick K.D., 1998, "Magnitude and Frequency of Floods in Washington," United States Geological Survey Water Resource Investigation Report 97-4277, 91p.

United States Army Corps of Engineers, Hydraulic Engineering Center – River Analysis System (HEC-RAS). Version 4.0.0, March, 2008.

United States Army Corps of Engineers (USACE), Hydraulic Engineering Center – River Analysis System (HEC-RAS), Version 4.1.0, January 2010.

United States Geological Survey (USGS), 2010, StreamStats Program, http://water.usgs.gov/osw/streamstats/Washington.html

United States Geological Survey (USGS), 2009, PEAKFQ – Flood Frequency Analysis, Version 5.2.0, 2009.

United States Geological Survey (USGS), 1982, "Guidelines for Determining Flood-Flow Frequency: Bulletin 17B of the Hydrology Subcommittee." Interagency Advisory Committee on Water Data. Reston, VA.

Wolman, M.G. 1954. A method of sampling coarse river-bed material. Transactions of American Geophysical Union 35.

TABLES

Table 1

Channel Gradients by Rivermile

Touchet River

Upstream of Dayton, Washington

River Fork	Rivermile Segment	Elevation Downstream (feet)	Elevation Upstream (feet)	Difference (Downstream - Upsteam)	Segment Length (feet)	Gradient (Percent)
North Fork Touchet River	NF 1	1671	1732	62	5280	1.2
	NF 2	1732	1794	61	5280	1.2
	NF 3	1794	1852	59	5280	1.1
	NF 4	1852	1913	61	5280	1.2
	NF 5	1913	2001	88	5280	1.7
	NF 6	2001	2090	89	5280	1.7
	NF 7	2090	2183	94	5280	1.8
	NF 8	2183	2280	96	5280	1.8
	NF 9	2280	2388	108	5280	2.1
	NF 10	2388	2506	118	5280	2.2
	NF 11	2506	2619	113	5280	2.1
	NF 12	2619	2741	122	5280	2.3
	NF 13	2741	2892	151	5280	2.9
	NF 14	2892	3055	163	5280	3.1
	NF 15	3055	3214	159	5280	3.0
	NF 15	3214	3405	192	5280	3.6
	NF 17	3405	3601	196	5280	3.7
	NF 18	3601	3845	244	5280	4.6
	NF 19	3845	4093	248	5280	4.7
	NF 20	4093	4312	218	5280	4.1
	NF 21	4312	4745	433	5280	8.2
	NF 22	4745	5249	504	3173	15.9
Robinson Creek	RF 1	2140	2258	118	5280	2.2
	RF 1	2562	2735	173	5280	3.3
	RF 2	2258	2401	142	5280	2.7
	RF 3	2401	2562	161	5280	3.1
	RF 5	2735	2889	154	5280	2.9
	RF 6	2889	3081	192	5280	3.6
	RF 7	3081	3320	239	5280	4.5
	RF 8	3320	3622	302	5280	5.7
	RF 9	3622	4051	429	5280	8.1
	RF 10	4051	4537	486	5280	9.2
	RF 11	4537	5021	483	5280	9.2
	RF 12	5021	5301	280	2126	13.2
South Fork Touchet River	SF 1	1671	1732	61	5280	1.2
	SF 2	1732	1789	57	5280	1.1
	SF 3	1789	1854	66	5280	1.2
	SF 4	1854	1926	71	5280	1.3
	SF 5	1926	1990	64	5280	1.2
	SF 6	1990	2060	70	5280	1.3
	SF 7	2060	2124	64	5280	1.2
	SF 8	2124	2208	85	5280	1.6
	SF 9	2208	2282	74	5280	1.4
	SF 10	2282	2364	82	5280	1.6
	SF 11	2364	2449	85	5280	1.6
	SF 12	2449	2540	91	5280	1.7
	SF 13	2540	2641	101	5280	1.9
	SF 14	2641	2739	97	5280	1.8
	SF 15	2739	2847	109	5280	2.1
	SF 16	2847	2963	115	5280	2.2
	SF 17	2963	2983	20	812	2.5

River Fork	Rivermile Segment	Elevation Downstream (feet)	Elevation Upstream (feet)	Difference (Downstream - Upsteam)	Segment Length (feet)	Gradient (Percent)
Touchet River	TR 54	1580	1629	49	5862	0.8
	TR 55	1629	1671	42	4938	0.8
Wolf Creek	WF 1	1904	1987	83	5280	1.6
	WF 2	1987	2063	76	5280	1.4
	WF 3	2063	2156	93	5280	1.8
	WF 4	2156	2286	130	5280	2.5
	WF 5	2286	2378	92	5280	1.7
	WF 6	2378	2499	121	5280	2.3
	WF 7	2499	2633	134	5280	2.5
	WF 8	2633	2789	156	5280	3.0
	WF 9	2789	2961	172	5280	3.3
	WF 10	2961	3166	205	5280	3.9
	WF 11	3166	3419	253	5280	4.8
	WF 12	3419	3689	270	5280	5.1
	WF 13	3689	4028	339	5280	6.4
	WF 14	4028	4397	368	5280	7.0
	WF 15	4397	4857	461	5280	8.7
	WF 16	4857	5518	660	5280	12.5

http://projects/sites/1029100200/Draft/REPORT DOCUMENTS/Draft Report Tables/[Stream Gradient Tables-Charts Table 1.xlsx]Table

Note:
Gradients calculated from LiDAR along National Hydrography Data Set for repsective river fork. Refer to Appendix C for additional detail.

Table 2

Preliminary Geomorphic Characteristics

Touchet River

Upstream of Dayton, Wasington

Watercourse	Reach Number	Rivermile	Approximate Reach Length (miles)	Gradient Range[1] (percent)	Degree of Natural Channel Confinement[2]	Approximate Valley Width[3, 6, 7] (feet)	Average Floodplain Width[3] (feet)	Approximate Channel Width[3] (feet)	Sediment Transport Regime[4]	Channel Planform
Main stem	54	54 to 55	1.9	0.8 to 1	Unconfined	2,200	200	50	Response[5]	Single thread Straight
North Fork	1	0 to 1	1	1.2	Unconfined	1300	500	50 to 70	Response[5]	Single-thread meander
North Fork	2	1 to 3.3	2.3	1.2	Unconfined	1300	750	50 to 70	Response[5]	Single-thread straight
North Fork	3	3.3 to 3.9	0.6	1.2	Unconfined	700	600	50t o 70	Response	Straight single-thread with multi-channel HFC
North Fork	4	3.9 to 5	1.1	1.2	Unconfined	500 to 1000	550	50	Response	Single-thread straight
North Fork	5	5 to 8	3	1.7 to 1.8	Unconfined	500	550	30	Response	Single-thread meander with multichannel HFC
North Fork	6	8 to 12	4	2 to 2.3	Unconfined	500	350	30	Response	Single-thread meander with multichannel HFC
North Fork	7	12 to 14.2	2.2	3	Unconfined	200	180	30	Response	Single-thread meander with multichannel HFC
North Fork	8	14.2 to 17.2	3	3 to 4	Moderatley Confined	VW<4CW	150	<20	Response	Straight single-thread with multi channel HFC
North Fork	9	17.2 to 21	3.8	4 to 8	Confined	VW<2CW	150	<20	Transport	Straight -Step Pool
North Fork	10	21 to 21.6	0.6	8 to 16	Confined	VW<2CW	150	<20	Transport	Straight -Cascade
Wolf Fork	1	0 to 0.3	0.3	1.6	Unconfined	1,000	350	50	Response	Single-thread meander with multichannel HFC
Wolf Fork	2	0.3 to 2.9	2.6	1.6 to 1.8	Unconfined	800	600	60	Response	Single-thread meander with multichannel HFC
Wolf Fork	3	2.9 to 3.7	0.8	1.8 to 2	Unconfined	500	180	40	Response	Single-thread meander with multichannel HFC
Wolf Fork	4	3.7 to 4	0.3	1.8 to 2.4	Unconfined	300 to 400	220	40	Response	Straight
Wolf Fork	5	4 to 5	1	1.7 to 2.5	Unconfined	270	190	50	Response	Straight to minor meander with multi channel HFC
Wolf Fork	6	5 to 10.9	5.9	1.7 to 4	Unconfined	260	180	20	Response	Straight to minor meander with bedrock controlled bends
Wolf Fork	7	10.9 to 14.5	3.6	4 to 8	Confined	VW<2CW	40	<20	Transport	Straight -Step Pool
Wolf Fork	8	14.5 to 16	1.5	8 to 12.5	Confined	VW<2CW	40	<20	Transport	Straight - Cascade
South Fork	1	0 to 2.9	2.9	1.2	unconfined	1,800	400	40 to 70	Response[5]	Single-thread meander with multichannel HFC
South Fork	2	2.9 to 3.7	0.8	1.2	unconfined	1,200	500	40 to 70	Response	Single-thread meander with multichannel HFC
South Fork	3	3.7 to 6.7	3	1.3	unconfined	500 to 600	280	50 to 60	Response	Single-thread meander with multichannel HFC
South Fork	4	6.7 to 11.2	4.5	1.2 to 1.6	unconfined	650	200	40	Response	Single-thread meander with multichannel HFC
South Fork	5	11.2 to 15.2	4	1.6 to 2	unconfined	300 to 500	220	30 to 50	Response	Single-thread meander with multichannel HFC
South Fork	6	15.2 to 16.1	0.9	2 to 2.5	unconfined	200 to 300	220	15 to 20	Response	Single-thread meander with multichannel HFC
Robinson Fork	1	0 to 0.3	0.3	2	unconfined	800	280	60 to 70	Response	Single-thread Straight with multi-channel HFC
Robinson Fork	2	0.3 to 2.2	1.9	2 to 3	unconfined	200	200	20	Response	Single-thread Straight with multi-channel HFC
Robinson Fork	3	2.2 to 6.3	4.1	2.5 to 4	unconfined	200 to 300	200	20	Response	Single-thread Straight with HFC
Robinson Fork	4	6.3 to 9	2.7	4 to 8	confined	VW<2CW	40	<20	Transport	Straight-step pool
Robinson Fork	5	9 to 11.4	2.4	8 to 13	confined	VW<2CW	40	<20	Transport	Straight-cascade

Watercourse	Reach Number	Stream Type Rosgen (1996) Broad Level Classification	Infrastructure/Development	Alluvial, Colluvial or Bedrock Controlled	Estimated Bank Material (Based on NRCS Soil Mapping)	General Geomorphic Stability[8]
Main stem	54	C	Federal Levee, State bridge/roads	Alluvial	Sa, gr, cob	Stable
North Fork	1	C	Federal Levee, County bridge/roads	Alluvial	Sa, gr, cob	Unstable
North Fork	2	C	County roads/bridge, private bridge, residences	Alluvial	Sa, gr, cob	Moderately Stable
North Fork	3	C	Residence	Alluvial	Sa, gr, cob	Moderately Stable
North Fork	4	C	County Bridge	Alluvial	Gr to cob silt loam	Moderately Stable
North Fork	5	C	County roads, residences	Alluvial	Gr to cob silt loam	Moderately Stable
North Fork	6	C	County roads/bridge, residences, Huckleberry Mountain Reservoir	Alluvial	Gr to cob silt loam	Moderately Stable
North Fork	7	B	County roads, residences	Bedrock and alluvial	Sa, gr, cob	Moderately Stable
North Fork	8	B	County roads/bridge	Bedrock	Not mapped	Stable
North Fork	9	A	County and USFS road/bridge	Bedrock	Not mapped	Stable
North Fork	10	A	N/A	Bedrock	Not mapped	Stable
Wolf Fork	1	C	N/A	Alluvial	Gr to cob silt loam	Unstable
Wolf Fork	2	C	Private bridges and residences	Alluvial	Gr to cob silt loam	Unstable
Wolf Fork	3	C	County roads/bridge	Alluvial	Gr to cob silt loam	Unstable
Wolf Fork	4	C	Residence	Alluvial	Gr to cob silt loam	Moderately Stable
Wolf Fork	5	B-C	County roads/bridge	Alluvial	Gr to cob silt loam	Unstable
Wolf Fork	6	A	County roads/bridge	Bedrock	Gr to cob and very rocky silt loam	Moderately Stable
Wolf Fork	7	A	N/A	Bedrock	Not mapped	Moderately Stable
Wolf Fork	8	A	N/A	Bedrock	Not mapped	Stable
South Fork	1	C	County roads/bridges, Private bridge	Alluvial	Sa, gr, cob	Unstable
South Fork	2	C	County roads/bridge	Alluvial	Sa, gr, cob	Moderately Stable
South Fork	3	C	County roads, residences	Alluvial	Gr to cob silt loam	Moderately Stable
South Fork	4	C	County roads/bridge, private bridge	Alluvial	Gr to cob silt loam	Stable
South Fork	5	C	N/A	Alluvial	Gr to cob and v rocky silt loam	Stable
South Fork	6	B	N/A	Alluvial	Very rocky silt loam	Stable
Robinson Fork	1	B	Private bridge, residences	Alluvial	Gr to cob silt loam	Unstable
Robinson Fork	2	B	County roads/bridges	Alluvial	Gr to cob silt loam	Unstable
Robinson Fork	3	B	N/A	Alluvial and Bedrock	Silt loam and very rocky silt loam	Moderately Stable
Robinson Fork	4	A	N/A	Bedrock	Silt loam and extremly rocky silt loam	Stable
Robinson Fork	5	A	N/A	Bedrock	Not mapped	Stable

Notes:

[1]Calculated from LiDAR along National Hydrograpy River Centerline.

[2]Channel valley confinement. Condition of anthropogenic features such as levees and roadways are unknown at this level of assessment. Therefore, such features were not considered as confinement barriers.

[3]Measurements of topographic and river features in this summary table were taken from LiDAR or aerial photogrpahs using ArcMap. Measurements should be considered approximate.

[4]Based on channel gradient, confinement and planform in accordance with Washington State Department of Ecology 2003 Channel Process Matrix.

[5]Revised to transport reach by GeoEngineers Implementation Reach-scale analysis. Refer to Sediment Transport Capacity Analysis.

[6]VW = Valley Width

[7]CW = Channel Width

[8]General Geomorphic Stability based on observations of channel movement (1996, 2006, 2010 aerial photography and LiDAR)

-Stable = no evidence of past channel movement

-Moderately Stable = minor to moderate evidence of past channel movement

-Unstable = significant evidence of past channel movment

TABLE 5
NORTH FORK TOUCHET RIVER
GEOMORPHIC REACH PRIORITIZATION
Upstream of Dayton, Washington

Selection Criteria	Description	Relative Value of Selection Criteria			Assigned Value of Selection Criteria								
		1	2	3	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9
1	Geomorphic Reach length	<0.5	0.5 to 1	>1	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0
2	Critical infrastructure within 200 feet active channel	>6	3 to 6	<3	3.0	2.0	3.0	3.0	2.0	1.0	2.0	2.0	2.0
3	Ratio of 100 year floodplain to reach length (Flood reduction potential)	<.03	.03 to .06	>.06	3.0	2.0	1.0	3.0	2.0	1.0	1.0	1.0	1.0
4	Channel confinement	Confined (VW < 2CW)	Moderately confined (2CW< VW < 4CW)	Unconfined (VW >4 CW)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	1.0
5	Future Channel Response (Channel migration)	No evidence of past channel movement	Minor to moderate past channel movement	Significant past channel movement	3.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0	1.0
6	Regional Technical Team Opinion	<80 Percent Vote	>80 Percent Vote	Unanimous	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total Score					18.0	13.0	12.0	15.0	13.0	11.0	12.0	10.0	9.0

Note 1: Reach 10 was removed from consideration because of a combination of steep gradient and channel confinement

Note 2: Selection Criteria Rationale

Reach Length: The number of potential restoration areas is likey greater in longer reaches.

Critical infrastructure : Fewer structures reduces overall project complexity and cost (considers all strucures within 200 feet of active channel)

Ratio of 100 year floodplain to reach length: Higher values indicate greater potential for floodplain connectivity and flood reduction

Channel valley confinement: Confined channels indicate lower flood storage benefits

Future channel response (Channel migration): At the watershed scale, reaches that have the highest potential for favorable channel responses will typically contain wider floodplain areas, lower gradients, sufficient sediment supply, ability to store or retian sediment, and floodplain/channel connectivity.

Regional Technical Team: Results of Independent Review

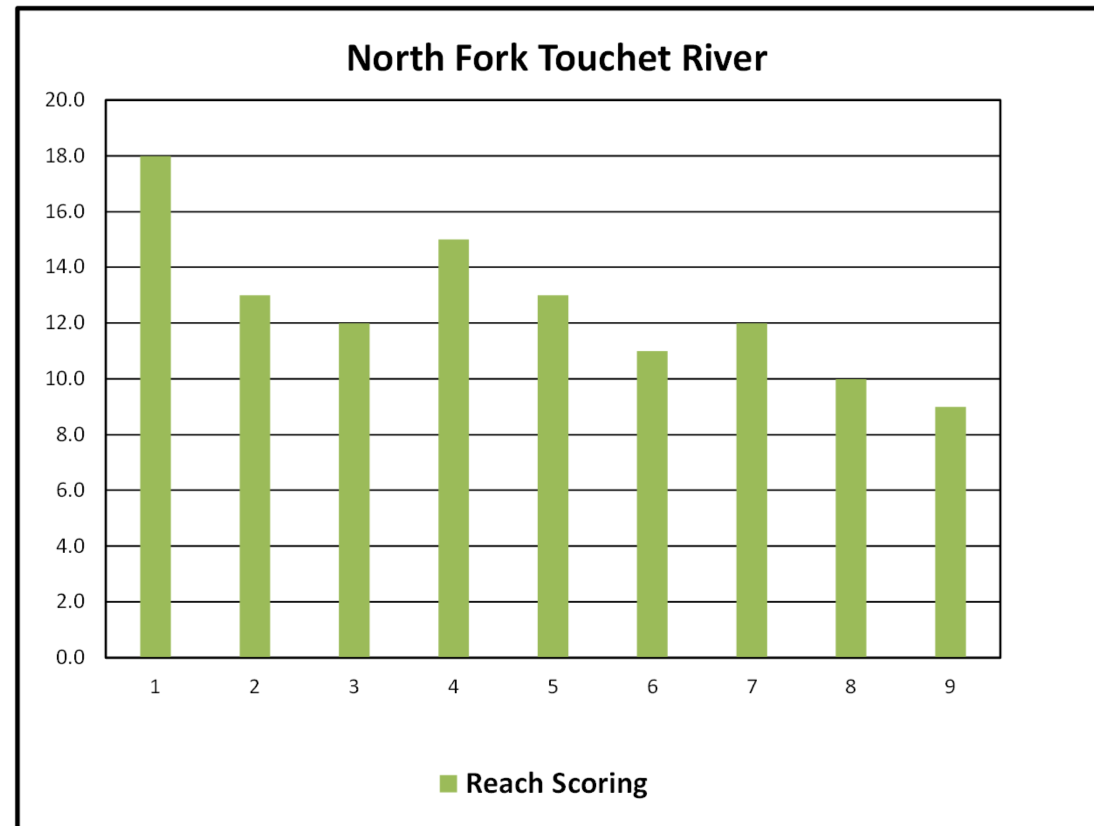


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TABLE 6

SOUTH FORK TOUCHET RIVER GEOMORPHIC REACH PRIORITIZATION

Upstream of Dayton, Washington

Selection Criteria	Description	Relative Value of Selection Criteria			Assigned Value of Selection Criteria					
		1	2	3	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
1	Geomorphic Reach length	<0.5	0.5 to 1	>1	3.0	2.0	3.0	3.0	3.0	2.0
2	Critical infrastructure within 200 feet active channel	>6	3 to 6	<3	3.0	3.0	1.0	3.0	3.0	3.0
3	Ratio of 100 year floodplain to reach length (Flood reduction potential)	<.03	.03 to .06	>.06	2.0	3.0	1.0	1.0	1.0	1.0
4	Channel confinement	Confined (VW < 2CW)	Moderately confined (2CW< VW < 4CW)	Unconfined (VW >4 CW)	3.0	3.0	3.0	3.0	3.0	3.0
5	Future Channel Response (Channel migration)	No evidence of past channel movement	Minor to moderate past channel movement	Significant past channel movement	3.0	2.0	2.0	1.0	1.0	1.0
6	Regional Technical Team Opinion	<80 Percent Vote	>80 Percent Vote	Unanimous	3.0	1.0	1.0	1.0	1.0	1.0
Total Score					17.0	14.0	11.0	12.0	12.0	11.0

Note 1: Selection Criteria Rationale

Reach Length: The number of potential restoration areas is likey greater in longer reaches.

Critical infrastructure : Fewer structures reduces overall project complexity and cost (considers all strucures within 200 feet of active channel)

Ratio of 100 year floodplain to reach length: Higher values indicate greater potential for floodplain connectivity and flood reduction

Channel valley confinement: Confined channels indicate lower flood storage benefits

Future channel response (Channel migration): At the watershed scale, reaches that have the highest potential for favorable channel responses will typically contain wider floodplain areas, lower gradients, sufficient sediment supply, ability to store or retian sediment, and floodplain/channel connectiveity.

Regional Technical Team: Results of Independent Review

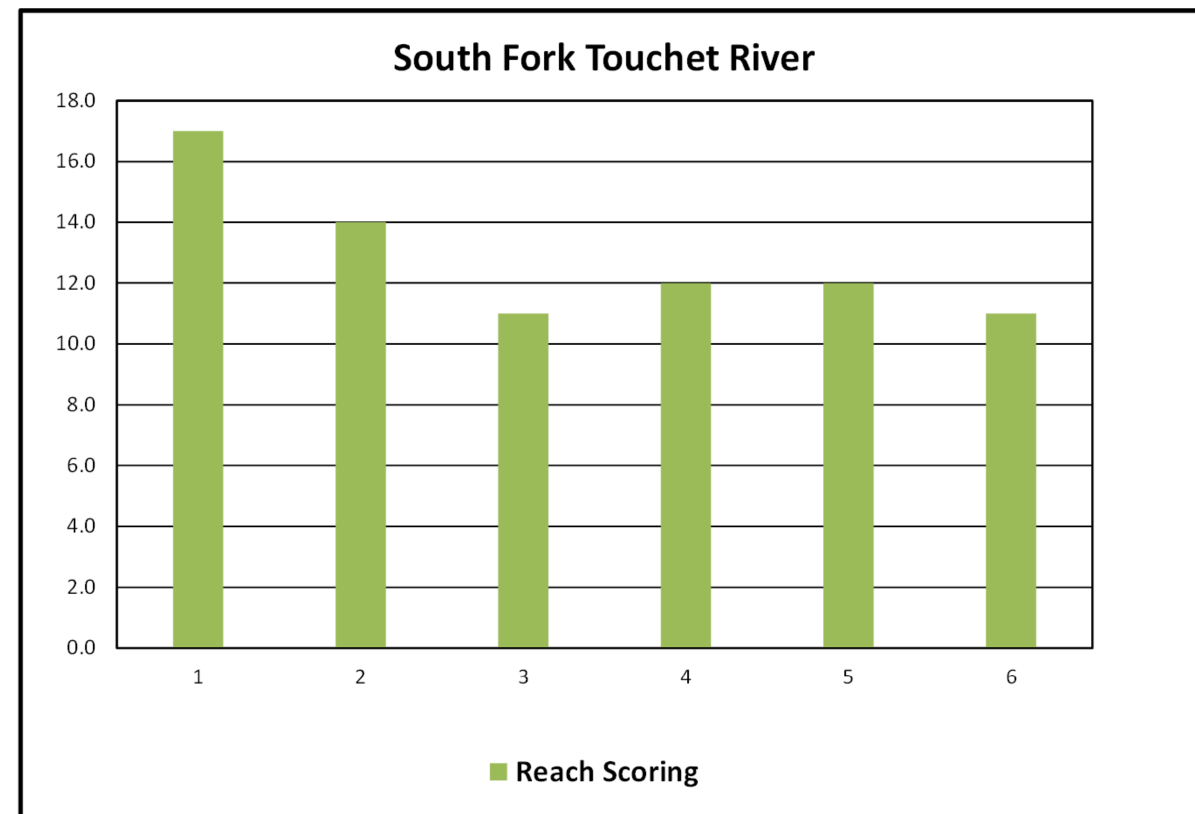

TABLE 7
WOLF FORK TOUCHET RIVER GEOMORPHIC REACH PRIORITIZATION
Upstream of Dayton, Washington

Selection Criteria	Description	Relative Value of Selection Criteria			Assigned Value of Selection Criteria						
		1	2	3	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
1	Geomorphic Reach length	<0.5	0.5 to 1	>1	3.0	3.0	2.0	3.0	3.0	3.0	3.0
2	Critical infrastructure within 200 feet active channel	>6	3 to 6	<3	3.0	2.0	3.0	3.0	2.0	1.0	2.0
3	Ratio of 100 year floodplain to reach length (Flood reduction potential)	<.03	.03 to .06	>.06	3.0	2.0	1.0	3.0	2.0	1.0	1.0
4	Channel confinement	Confined (VW < 2CW)	Moderately confined (2CW< VW < 4CW)	Unconfined (VW >4 CW)	3.0	3.0	3.0	3.0	3.0	3.0	3.0
5	Future Channel Response (Channel migration)	No evidence of past channel movement	Minor to moderate past channel movement	Significant past channel movement	3.0	3.0	3.0	2.0	3.0	2.0	2.0
6	Regional Technical Team Opinion	<80 Percent Vote	>80 Percent Vote	Unanimous	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total Score					16.0	14.0	13.0	15.0	14.0	11.0	12.0

Note 1: Reach 8 was removed from consideration because of a combination of steep gradient and channel confinement

Note 2: Selection Criteria Rationale

Reach Length: The number of potential restoration areas is likey greater in longer reaches.

Critical infrastructure : Fewer structures reduces overall project complexity and cost (considers all strucures within 200 feet of active channel)

Ratio of 100 year floodplain to reach length: Higher values indicate greater potential for floodplain connectivity and flood reduction

Channel valley confinement: Confined channels indicate lower flood storage benefits

Future channel response (Channel migration): At the watershed scale, reaches that have the highest potential for favorable channel responses will typically contain wider floodplain areas, lower gradients, sufficient sediment supply, ability to store or retian sediment, and floodplain/channel connectivity.

Regional Technical Team: Results of Independent Review

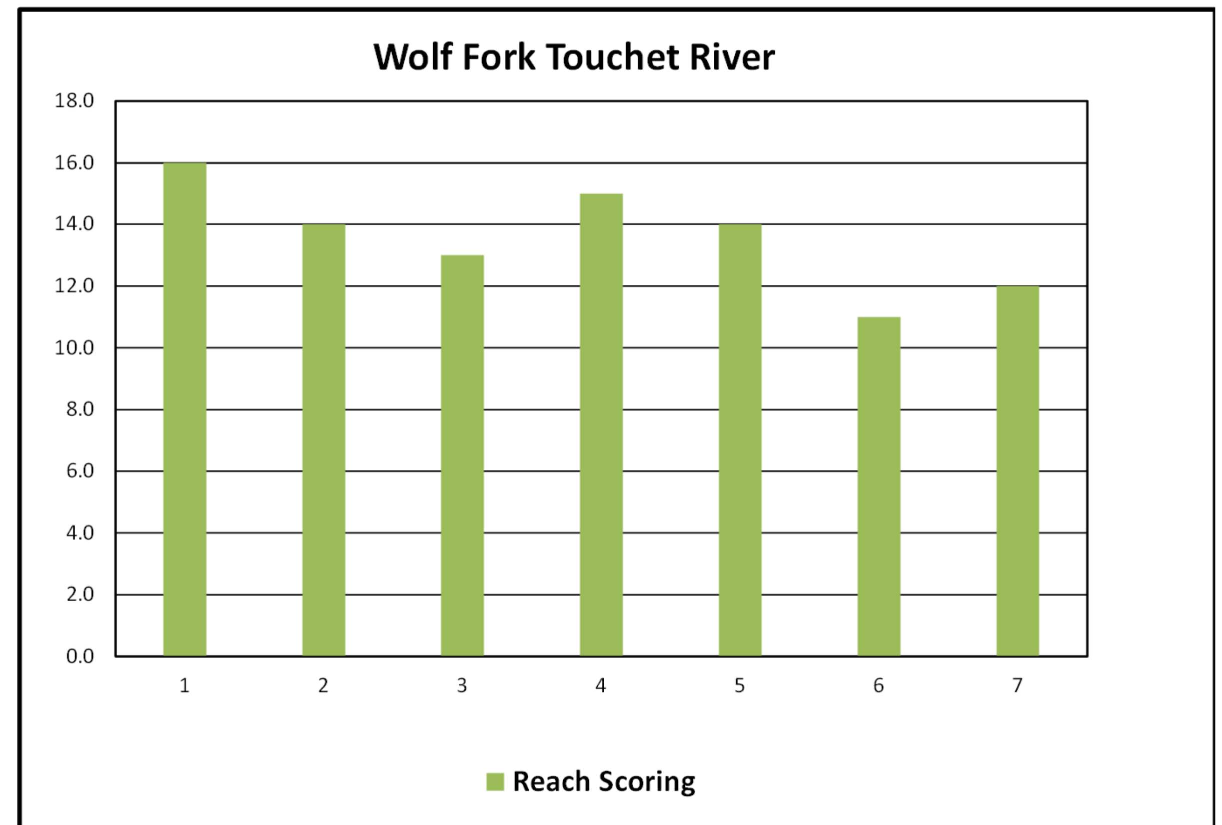

TABLE 8

ROBINSON FORK TOUCHET RIVER GEOMORPHIC REACH PRIORITIZATION

Upstream of Dayton, Washington

Selection Criteria	Description	Relative Value of Selection Criteria			Assigned Value of Selection Criteria			
		1	2	3	Reach 1	Reach 2	Reach 3	Reach 4
1	Geomorphic Reach length	<0.5	0.5 to 1	>1	1.0	3.0	2.0	3.0
2	Critical infrastructure within 200 feet active channel	>6	3 to 6	<3	2.0	2.0	3.0	3.0
3	Ratio of 100 year floodplain to reach length (Flood reduction potential)	<.03	.03 to .06	>.06	3.0	1.0	1.0	1.0
4	Channel confinement	Confined (VW < 2CW)	Moderately confined (2CW< VW < 4CW)	Unconfined (VW >4 CW)	3.0	3.0	3.0	1.0
5	Future Channel Response (Channel migration)	No evidence of past channel movement	Minor to moderate past channel movement	Significant past channel movement	3.0	3.0	2.0	1.0
6	Regional Technical Team Opinion	<80 Percent Vote	>80 Percent Vote	Unanimous	1.0	1.0	1.0	1.0
Total Score					13.0	13.0	12.0	10.0

Note 1: Reach 5 was removed from consideration because of a combination of steep gradient and channel confinement

Note 2: Selection Criteria Rationale

Reach Length: The number of potential restoration areas is likey greater in longer reaches

Critical infrastructure : Fewer structures reduces overall project complexity and cost (considers all strucures within 200 feet of active channel)

Ratio of 100 year floodplain to reach length: Higher values indicate greater potential for floodplain connectivity and flood reduction

Channel valley confinement: Confined channels indicate lower flood storage benefits

Future channel response (Channel migration): At the watershed scale, reaches that have the highest potential for favorable channel responses will typically contain wider floodplain areas, lower gradients, sufficient sediment supply, ability to store or retian sediment, and floodplain/channel connectiveity.

Regional Technical Team: Results of Independent Review

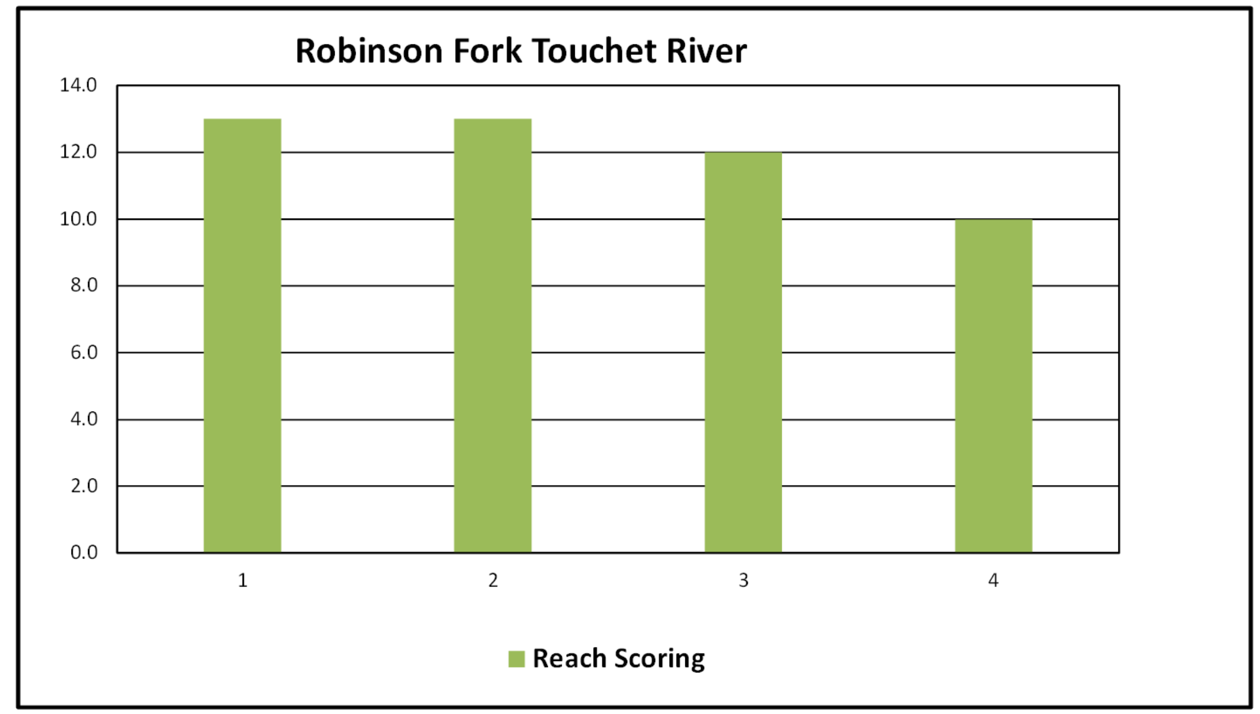

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Table 17

Touchet River Sediment Transport Capacity Results - North Fork

Touchet River

Upstream of Dayton, Washington

Cross Section Number	Recurrence Interval	Discharge (cfs)	Velocity (ft/s)	Shear (lb/ft^2)	Critical Velocity (ft/s)	Critical Shear (lb/ft^2)	Bed Mobile[1]	Maximum D50 in Transport[2] (mm)
7088.101	1.5	700	7.02	1.31	8.60	2.11	NO	46
7088.101	2	882	7.85	1.58	8.76	2.11	MAYBE	61
7088.101	5	2113	10.89	2.58	9.51	2.11	YES	128
7088.101	25	2981	12.19	3.01	9.84	2.11	YES	162
7088.101	50	3762	13.20	3.38	10.07	2.11	YES	192
7088.101	100	4640	14.24	3.78	10.27	2.11	YES	227
7088.101	500	7256	11.75	2.16	11.22	2.11	YES	98
7015.755	1.5	700	5.15	0.73	8.45	2.11	NO	30
7015.755	2	882	5.55	0.81	8.63	2.11	NO	30
7015.755	5	2113	6.84	1.03	9.47	2.11	NO	32
7015.755	25	2981	7.60	1.19	9.78	2.11	NO	40
7015.755	50	3762	8.59	1.49	9.92	2.11	NO	55
7015.755	100	4640	9.04	1.59	10.11	2.11	MAYBE	61
7015.755	500	7256	7.87	1.00	11.10	2.11	NO	30
6993.965		Bridge						
6976.085	1.5	700	4.72	0.60	8.51	2.11	NO	22
6976.085	2	882	4.97	0.64	8.72	2.11	NO	24
6976.085	5	2113	6.10	0.80	9.55	2.11	NO	30
6976.085	25	2981	6.92	0.98	9.83	2.11	NO	30
6976.085	50	3762	8.24	1.37	9.90	2.11	NO	49
6976.085	100	4640	9.68	1.87	9.95	2.11	MAYBE	78
6976.085	500	7256	12.78	3.14	10.15	2.11	YES	170
6879.815	1.5	700	6.64	1.20	8.47	2.11	NO	41
6879.815	2	882	7.38	1.43	8.64	2.11	NO	53
6879.815	5	2113	10.31	2.35	9.41	2.11	YES	112
6879.815	25	2981	11.17	2.56	9.77	2.11	YES	127
6879.815	50	3762	10.73	2.22	10.09	2.11	YES	102
6879.815	100	4640	11.40	2.43	10.25	2.11	YES	117
6879.815	500	7256	13.17	3.04	10.58	2.11	YES	164
6406.934	1.5	700	6.32	1.09	8.47	2.11	NO	35
6406.934	2	882	6.80	1.20	8.69	2.11	NO	41
6406.934	5	2113	8.15	1.48	9.38	2.11	NO	56
6406.934	25	2981	8.76	1.63	9.60	2.11	MAYBE	65
6406.934	50	3762	9.33	1.80	9.73	2.11	MAYBE	75
6406.934	100	4640	9.24	1.72	9.85	2.11	MAYBE	70
6406.934	500	7256	10.92	2.32	10.04	2.11	YES	110
5900.132	1.5	700	7.15	1.36	8.57	2.11	NO	49
5900.132	2	882	7.94	1.62	8.75	2.11	MAYBE	64
5900.132	5	2113	8.29	1.48	9.55	2.11	NO	56
5900.132	25	2981	9.19	1.75	9.74	2.11	MAYBE	72
5900.132	50	3762	9.68	1.89	9.87	2.11	MAYBE	80
5900.132	100	4640	10.70	2.27	9.95	2.11	YES	106
5900.132	500	7256	10.72	2.17	10.19	2.11	YES	99

Cross Section Number	Recurrence Interval	Discharge (cfs)	Velocity (ft/s)	Shear (lb/ft^2)	Critical Velocity (ft/s)	Critical Shear (lb/ft^2)	Bed Mobile[1]	Maximum D50 in Transport[2] (mm)
5402.716	1.5	700	8.32	1.84	8.61	2.11	MAYBE	77
5402.716	2	882	8.92	2.01	8.81	2.11	YES	88
5402.716	5	2113	8.73	1.60	9.68	2.11	MAYBE	63
5402.716	25	2981	9.96	2.01	9.83	2.11	YES	89
5402.716	50	3762	10.93	2.38	9.93	2.11	YES	114
5402.716	100	4640	11.96	2.79	10.02	2.11	YES	145
5402.716	500	7256	12.51	2.90	10.28	2.11	YES	153
5066.368	1.5	700	5.75	0.93	8.37	2.11	NO	31
5066.368	2	882	6.47	1.13	8.53	2.11	NO	37
5066.368	5	2113	8.85	1.76	9.34	2.11	MAYBE	72
5066.368	25	2981	10.22	2.21	9.64	2.11	YES	101
5066.368	50	3762	11.43	2.65	9.83	2.11	YES	134
5066.368	100	4640	12.49	3.06	10.00	2.11	YES	166
5066.368	500	7256	11.59	2.34	10.61	2.11	YES	111
4492.401	1.5	700	6.58	1.17	7.98	1.51	NO	39
4492.401	2	882	6.93	1.23	8.20	1.51	MAYBE	42
4492.401	5	2113	10.01	2.23	8.80	1.51	YES	103
4492.401	25	2981	11.38	2.73	9.05	1.51	YES	139
4492.401	50	3762	12.13	2.96	9.26	1.51	YES	158
4492.401	100	4640	9.94	1.83	9.66	1.51	YES	77
4492.401	500	7256	11.52	2.36	9.86	1.51	YES	112
3860.439	1.5	700	6.36	1.22	7.56	1.51	MAYBE	42
3860.439	2	882	7.36	1.59	7.68	1.51	YES	62
3860.439	5	2113	9.70	2.26	8.47	1.51	YES	105
3860.439	25	2981	10.87	2.63	8.79	1.51	YES	132
3860.439	50	3762	11.59	2.84	9.04	1.51	YES	148
3860.439	100	4640	12.13	2.95	9.27	1.51	YES	157
3860.439	500	7256	13.56	3.34	9.74	1.51	YES	189
3439.957	1.5	700	6.61	1.29	7.56	1.46	MAYBE	45
3439.957	2	882	6.71	1.25	7.81	1.46	MAYBE	43
3439.957	5	2113	8.07	1.46	8.71	1.46	YES	53
3439.957	25	2981	7.73	1.19	9.26	1.46	MAYBE	39
3439.957	50	3762	8.14	1.26	9.53	1.46	MAYBE	42
3439.957	100	4640	8.57	1.33	9.77	1.46	MAYBE	45
3439.957	500	7256	9.72	1.56	10.26	1.46	YES	57
3375.069	1.5	700	4.64	0.57	7.97	1.46	NO	19
3375.069	2	882	4.89	0.60	8.15	1.46	NO	21
3375.069	5	2113	6.34	0.87	8.83	1.46	NO	30
3375.069	25	2981	6.15	0.75	9.25	1.46	NO	25
3375.069	50	3762	6.46	0.79	9.45	1.46	NO	27
3375.069	100	4640	6.74	0.83	9.61	1.46	NO	29
3375.069	500	7256	7.30	0.91	9.94	1.46	NO	30
3350		Bridge						
3327.648	1.5	700	5.53	0.82	7.90	1.46	NO	30
3327.648	2	882	6.00	0.93	8.06	1.46	NO	30
3327.648	5	2113	9.04	1.88	8.55	1.46	YES	79
3327.648	25	2981	10.12	2.23	8.80	1.46	YES	102
3327.648	50	3762	11.55	2.83	8.91	1.46	YES	146

Cross Section Number	Recurrence Interval	Discharge (cfs)	Velocity (ft/s)	Shear (lb/ft^2)	Critical Velocity (ft/s)	Critical Shear (lb/ft^2)	Bed Mobile[1]	Maximum D50 in Transport[2] (mm)
3327.648	100	4640	12.47	3.20	9.05	1.46	YES	175
3327.648	500	7256	13.99	3.75	9.40	1.46	YES	222
3235.069	1.5	700	7.59	1.65	7.66	1.46	YES	65
3235.069	2	882	7.90	1.74	7.77	1.46	YES	71
3235.069	5	2113	9.34	2.09	8.39	1.46	YES	93
3235.069	25	2981	10.78	2.64	8.62	1.46	YES	132
3235.069	50	3762	11.51	2.89	8.81	1.46	YES	150
3235.069	100	4640	12.20	3.13	8.97	1.46	YES	169
3235.069	500	7256	13.89	3.69	9.41	1.46	YES	216
2805.561	1.5	700	6.45	1.05	8.77	1.93	NO	32
2805.561	2	882	7.10	1.23	8.89	1.93	NO	41
2805.561	5	2113	10.53	2.46	9.35	1.93	YES	116
2805.561	25	2981	10.82	2.42	9.69	1.93	YES	113
2805.561	50	3762	11.21	2.49	9.90	1.93	YES	118
2805.561	100	4640	12.21	2.88	10.04	1.93	YES	146
2805.561	500	7256	11.20	2.23	10.46	1.93	YES	100
2054.835	1.5	700	8.11	1.78	7.76	1.42	YES	73
2054.835	2	882	8.48	1.86	7.93	1.42	YES	78
2054.835	5	2113	10.11	2.20	8.71	1.42	YES	100
2054.835	25	2981	11.40	2.64	8.96	1.42	YES	132
2054.835	50	3762	12.37	2.99	9.14	1.42	YES	159
2054.835	100	4640	13.35	3.37	9.30	1.42	YES	190
2054.835	500	7256	15.90	4.44	9.64	1.42	YES	288
1528.123	1.5	700	6.51	1.18	8.15	1.69	NO	40
1528.123	2	882	6.96	1.30	8.34	1.69	NO	45
1528.123	5	2113	9.02	1.86	9.03	1.69	YES	78
1528.123	25	2981	9.82	2.07	9.32	1.69	YES	91
1528.123	50	3762	10.19	2.14	9.52	1.69	YES	96
1528.123	100	4640	10.52	2.20	9.71	1.69	YES	99
1528.123	500	7256	11.07	2.24	10.12	1.69	YES	102
1000	1.5	700	7.90	1.60	8.60	1.69	MAYBE	61
1000	2	882	8.65	1.86	8.74	1.69	YES	76
1000	5	2113	12.16	3.23	9.34	1.69	YES	173
1000	25	2981	13.75	3.90	9.61	1.69	YES	229
1000	50	3762	14.90	4.40	9.80	1.69	YES	275
1000	100	4640	16.00	4.88	9.99	1.69	YES	321
1000	500	7256	17.57	5.37	10.46	1.69	YES	370

Notes:

[1]Capability to mobilize streambed

[2]D50 of sediment in transport

Table 17

Touchet River Sediment Transport Capacity Results - South Fork

Touchet River

Upstream of Dayton, Washington

Cross Section Number	Recurrence Interval	Discharge (cfs)	Velocity (ft/s)	Shear (lb/ft^2)	Critical Velocity (ft/s)	Critical Shear (lb/ft^2)	Bed Mobile[1]	Maximum D50 in Transport[2] (mm)
2891.291	1.5	450	3.48	0.34	7.56	1.39	NO	8
2891.291	2	564	3.62	0.35	7.77	1.39	NO	8
2891.291	5	1292	4.36	0.42	8.55	1.39	NO	8
2891.291	25	1801	4.73	0.46	8.85	1.39	NO	9
2891.291	50	2263	4.94	0.48	9.06	1.39	NO	9
2891.291	100	2781	5.18	0.51	9.25	1.39	NO	10
2891.291	500	4308	5.59	0.54	9.71	1.39	NO	9
2817.991	1.5	450	2.61	0.18	7.83	1.39	NO	2
2817.991	2	564	2.80	0.20	8.00	1.39	NO	3
2817.991	5	1292	3.67	0.30	8.59	1.39	NO	4
2817.991	25	1801	4.08	0.34	8.83	1.39	NO	5
2817.991	50	2263	4.38	0.38	9.05	1.39	NO	6
2817.991	100	2781	4.67	0.41	9.24	1.39	NO	6
2817.991	500	4308	5.39	0.51	9.64	1.39	NO	8
2780.617		Bridge						
2734.557	1.5	450	6.46	1.32	7.11	1.39	MAYBE	47
2734.557	2	564	6.95	1.47	7.25	1.39	YES	56
2734.557	5	1292	8.62	1.90	7.93	1.39	YES	81
2734.557	25	1801	9.51	2.15	8.22	1.39	YES	98
2734.557	50	2263	10.26	2.39	8.41	1.39	YES	114
2734.557	100	2781	10.82	2.54	8.61	1.39	YES	125
2734.557	500	4308	13.24	3.56	8.91	1.39	YES	207
2088.319	1.5	450	4.78	0.68	6.97	1.29	NO	30
2088.319	2	564	5.00	0.72	7.06	1.29	NO	30
2088.319	5	1292	6.02	0.95	7.41	1.29	NO	30
2088.319	25	1801	6.70	1.12	7.60	1.29	MAYBE	36
2088.319	50	2263	7.07	1.20	7.74	1.29	MAYBE	40
2088.319	100	2781	7.56	1.33	7.86	1.29	YES	47
2088.319	500	4308	8.29	1.48	8.19	1.29	YES	55
1692.379	1.5	450	6.97	1.48	6.87	1.29	YES	55
1692.379	2	564	7.39	1.58	7.03	1.29	YES	62
1692.379	5	1292	8.82	1.89	7.69	1.29	YES	80
1692.379	25	1801	9.35	1.99	7.94	1.29	YES	87
1692.379	50	2263	9.88	2.14	8.09	1.29	YES	97
1692.379	100	2781	10.23	2.22	8.23	1.29	YES	102
1692.379	500	4308	12.05	2.92	8.45	1.29	YES	154
1000	1.5	450	5.93	1.01	7.19	1.31	NO	31
1000	2	564	6.53	1.17	7.34	1.31	MAYBE	39
1000	5	1292	9.25	2.04	7.88	1.31	YES	89
1000	25	1801	10.27	2.36	8.14	1.31	YES	111
1000	50	2263	10.48	2.32	8.37	1.31	YES	108
1000	100	2781	11.24	2.58	8.51	1.31	YES	127
1000	500	4308	10.04	1.88	8.92	1.31	YES	79

Notes:

[1]Capability to mobilize streambed

[2]D50 of sediment in transport

Table 17

Touchet River Sediment Transport Capacity Results - Touchet

Touchet River

Upstream of Dayton, Washington

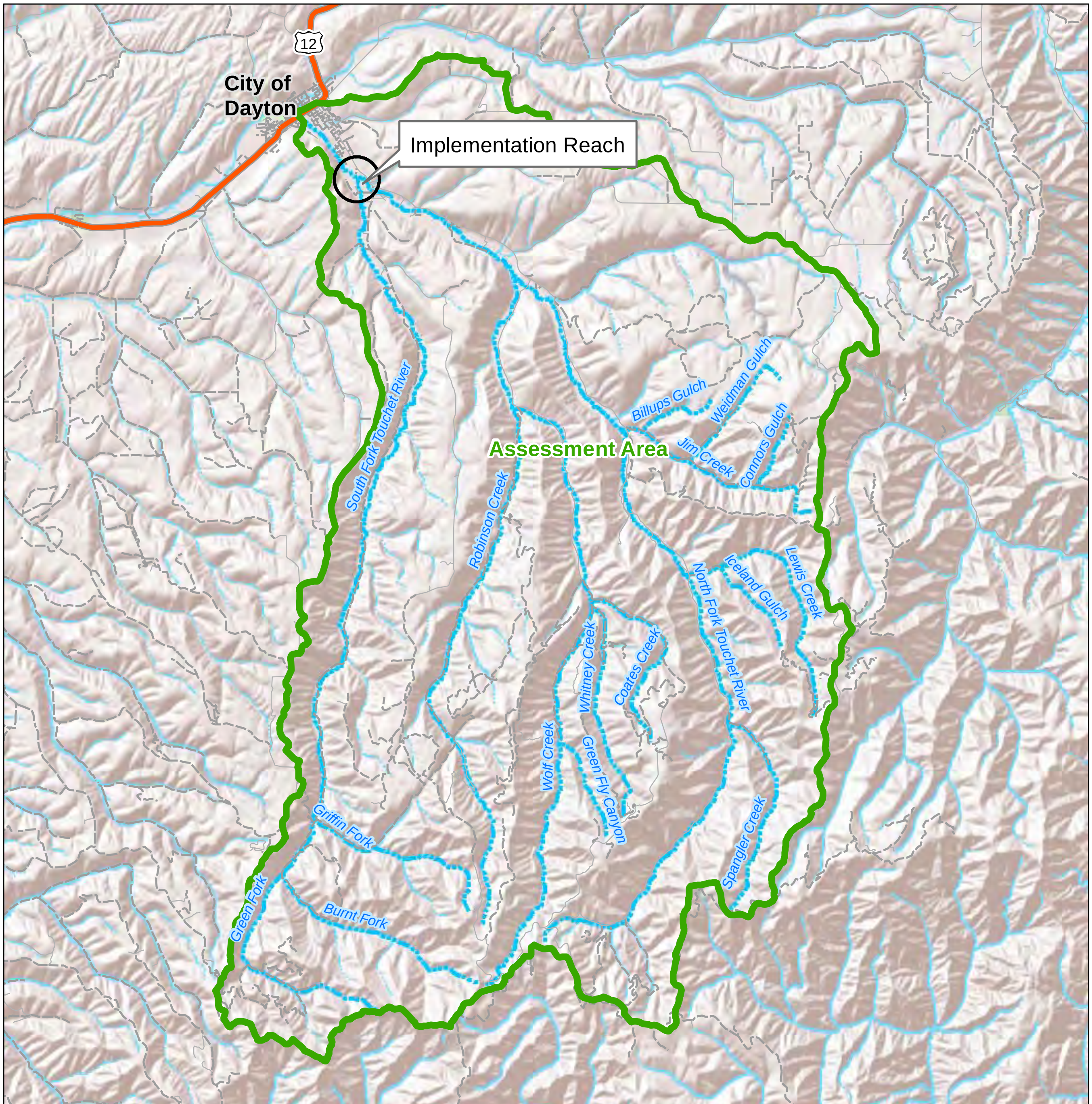
Cross Section Number	Recurrence Interval	Discharge (cfs)	Velocity (ft/s)	Shear (lb/ft^2)	Critical Velocity (ft/s)	Critical Shear (lb/ft^2)	Bed Mobile[1]	Maximum D50 in Transport[2] (mm)
3339.405	1.5	900	6.42	1.19	7.27	1.46	MAYBE	14
3339.405	2	1118	6.94	1.34	7.42	1.46	MAYBE	16
3339.405	5	2654	8.75	1.77	8.15	1.46	YES	30
3339.405	25	3724	9.91	2.13	8.41	1.46	YES	95
3339.405	50	4679	10.89	2.48	8.58	1.46	YES	119
3339.405	100	5766	11.99	2.90	8.73	1.46	YES	151
3339.405	500	8973	13.50	3.34	9.16	1.46	YES	186
2823.203	1.5	900	6.14	0.99	7.61	1.46	NO	23
2823.203	2	1118	6.49	1.07	7.76	1.46	NO	27
2823.203	5	2654	8.62	1.71	8.17	1.46	YES	68
2823.203	25	3724	9.52	2.03	8.28	1.46	YES	88
2823.203	50	4679	10.44	2.36	8.41	1.46	YES	111
2823.203	100	5766	11.25	2.65	8.55	1.46	YES	132
2823.203	500	8973	13.01	3.29	8.88	1.46	YES	183
2071.517	1.5	900	7.38	1.52	7.40	1.46	YES	30
2071.517	2	1118	8.06	1.76	7.50	1.46	YES	30
2071.517	5	2654	8.95	2.00	7.82	1.46	YES	87
2071.517	25	3724	9.73	2.18	8.13	1.46	YES	99
2071.517	50	4679	10.20	2.27	8.36	1.46	YES	105
2071.517	100	5766	10.71	2.38	8.58	1.46	YES	113
2071.517	500	8973	10.49	2.03	9.10	1.46	YES	89
1351.858	1.5	900	5.91	0.90	8.68	1.74	NO	30
1351.858	2	1118	6.21	0.95	8.88	1.74	NO	30
1351.858	5	2654	8.26	1.41	9.68	1.74	MAYBE	52
1351.858	25	3724	9.33	1.69	10.01	1.74	MAYBE	67
1351.858	50	4679	10.12	1.90	10.23	1.74	YES	81
1351.858	100	5766	10.89	2.12	10.43	1.74	YES	95
1351.858	500	8973	12.63	2.61	10.89	1.74	YES	130
1000	1.5	900	7.56	1.36	9.06	1.74	MAYBE	48
1000	2	1118	8.22	1.54	9.26	1.74	MAYBE	58
1000	5	2654	11.03	2.39	9.96	1.74	YES	113
1000	25	3724	12.32	2.82	10.24	1.74	YES	145
1000	50	4679	13.28	3.16	10.44	1.74	YES	171
1000	100	5766	14.23	3.51	10.62	1.74	YES	200
1000	500	8973	16.52	4.39	11.02	1.74	YES	280

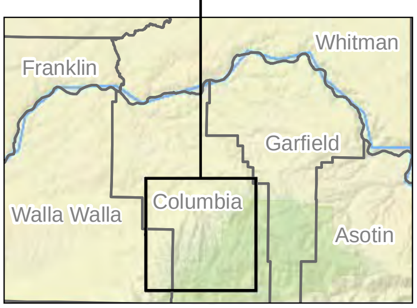
Notes:

[1]Capability to mobilize streambed

[2]D50 of sediment in transport

FIGURES





N
W E
S

3 0 3
Miles

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
Data Sources: ESRI Data & Maps, Street Maps 2008.
Projection: NAD 1983, UTM Zone 11 North.

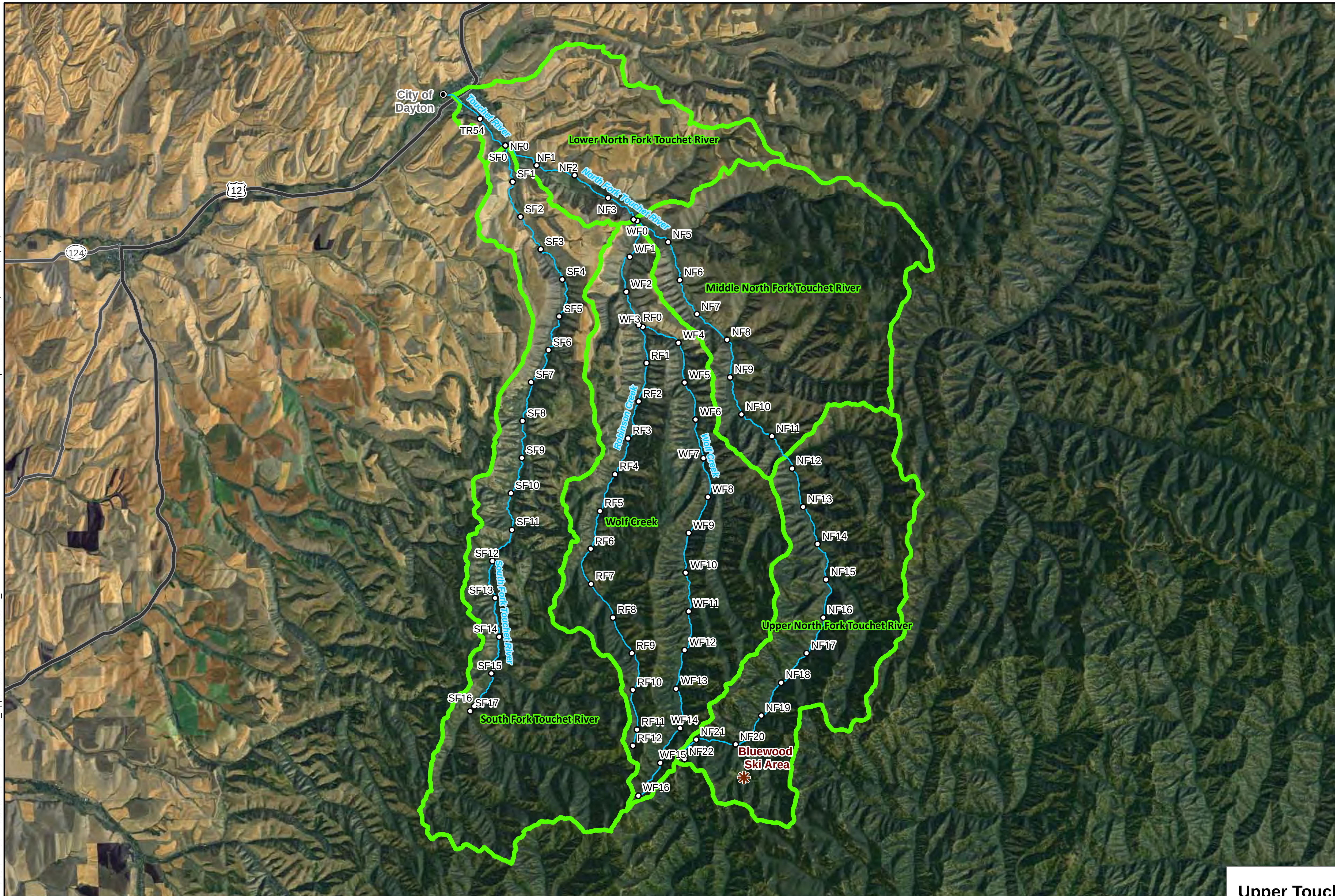
Vicinity Map

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure 1

Office: PORT Path: P:\10\1029100200\GIS\MXD\1029100200_VM_F1.mxd Map Revised: 3/31/2011 CRC,EL, CRC



Bluewood Ski Area

River Mile

Watercourses

Watershed Boundary (Level 6 WRIA)

N W E S

2 0 2

Miles

Map Revised:March 31, 2011 CRC, EL, CRC

Path: P:\10\1029100200\GIS\00\GIS\MXD\1029100200_UpperTouchetBasinSubbasins_F2.mxd

OfficeLocation: PORT

Reference: WRIA Watershed boundary from Washington DNR. Watercourses from Pacific Northwest Hydrography.
Aerial imagery (I-cubed) from ESRI ArcGIS Online.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

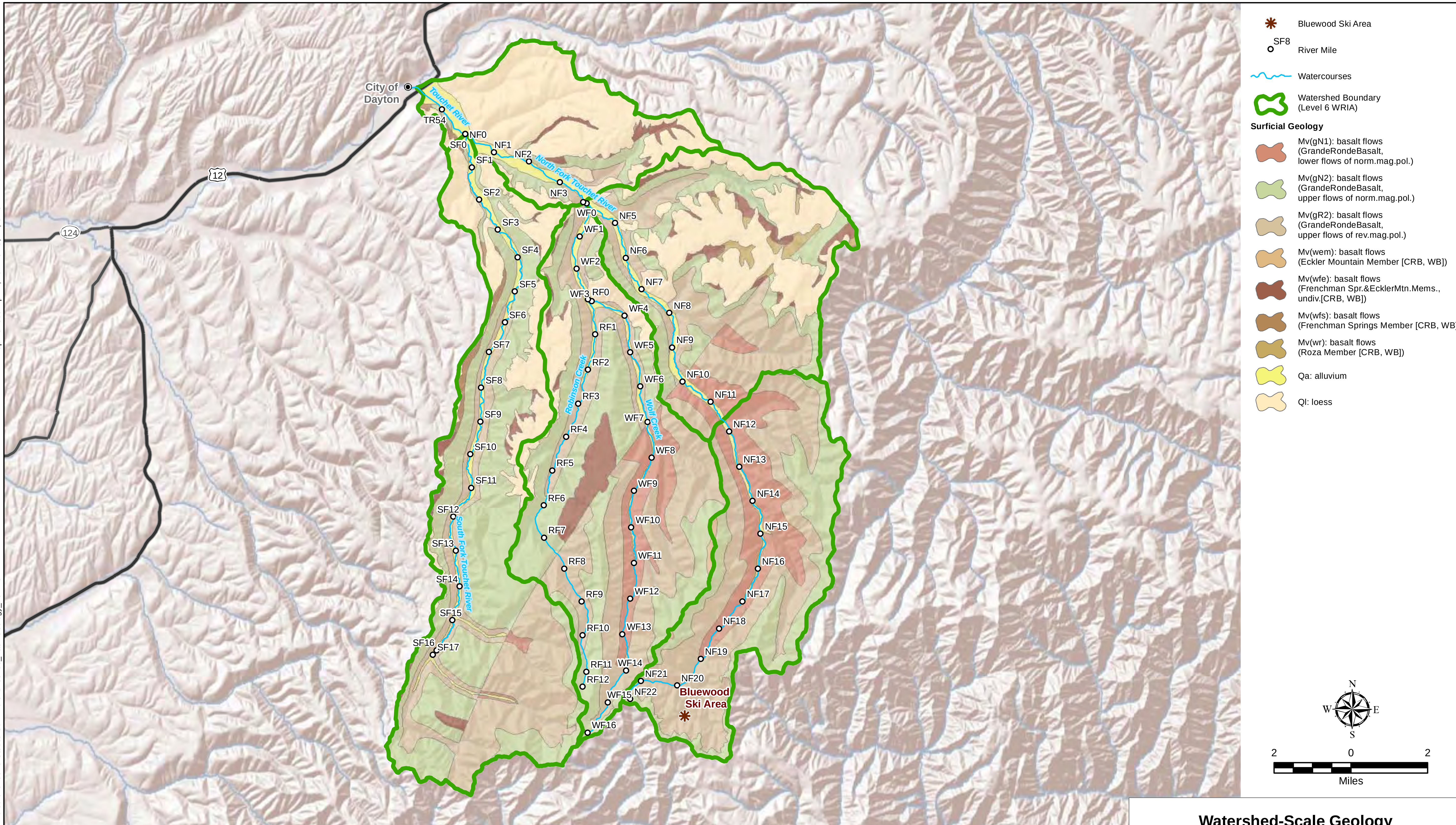
Upper Touchet River Basin and Subbasins

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure 2

Map Revised: April 1, 2011 CRC, EL, CRC
Path: P:\10\1029100200\GIS\MXD\1029100200_BasinGeology_F3.mxd
OfficeLocation: PORT



Reference: WRIA Watershed boundary and surficial geology from Washington DNR. Watercourses from Pacific Northwest Hydrography.
Shaded relief from ESRI ArcGIS Online.

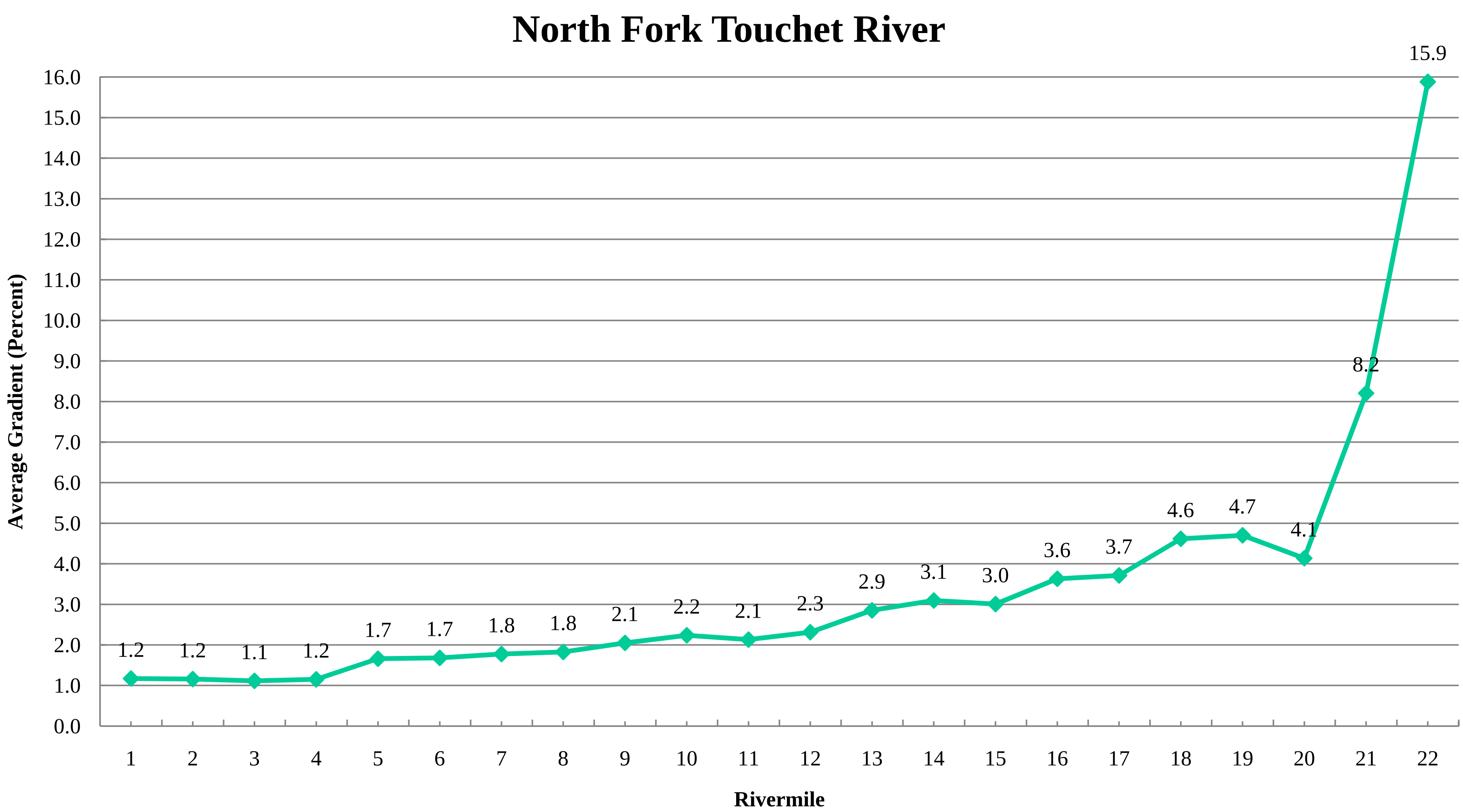
Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Watershed-Scale Geology

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure 3

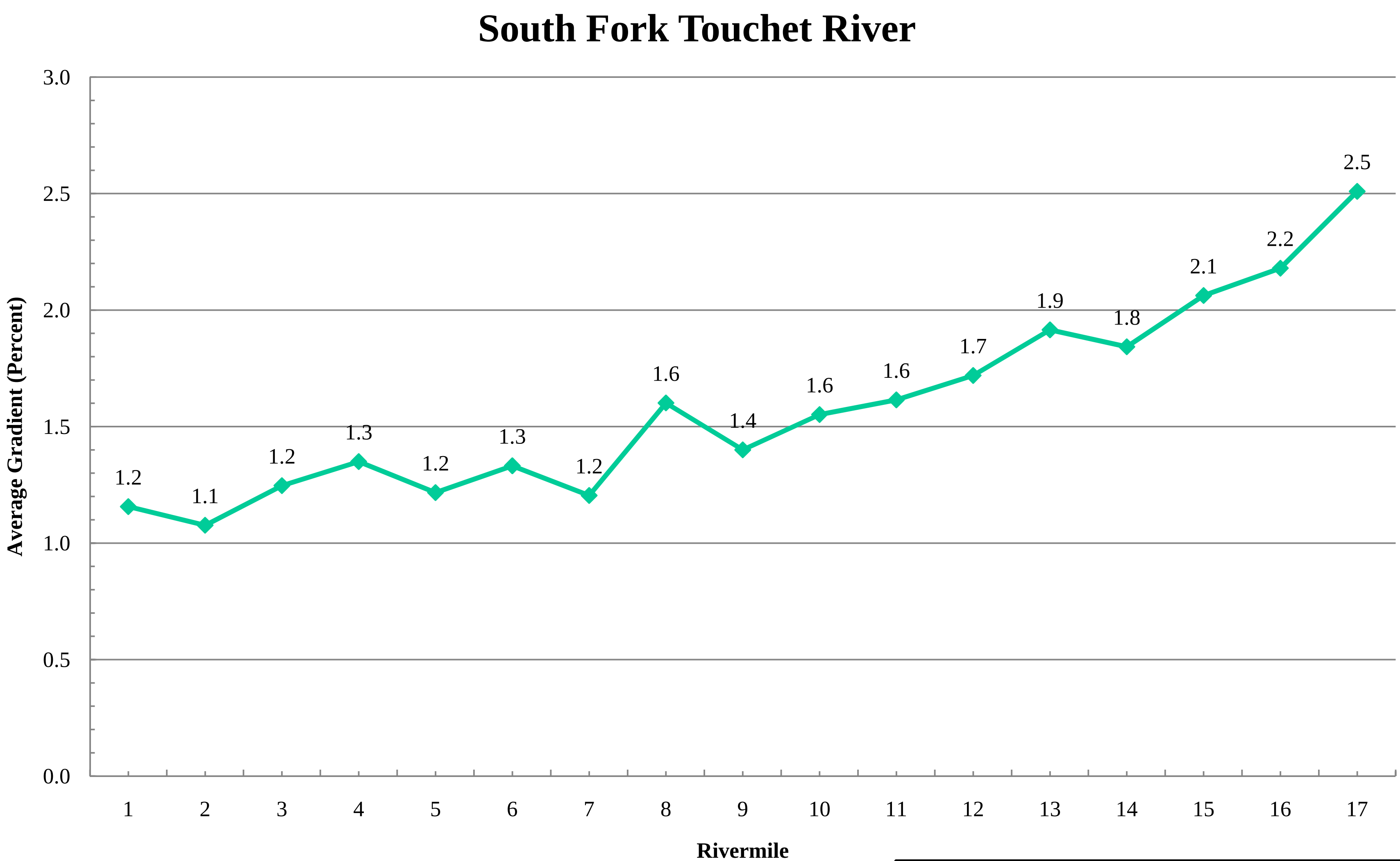


Channel Gradient
North Fork

Touchet River Geomorphic Assessment
Columbia County, Washington

GEOENGINEERS

Figure 4



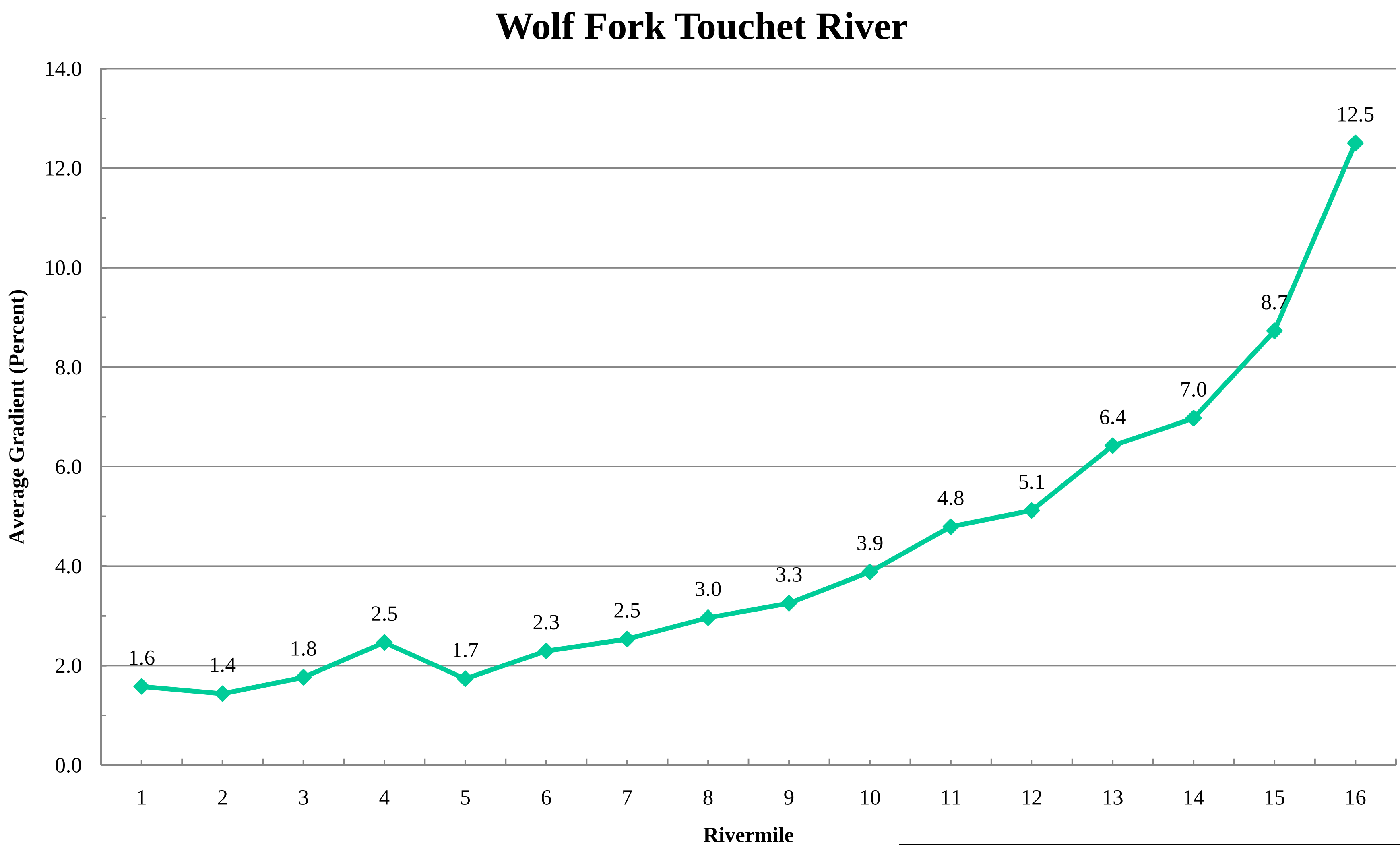
Channel Gradient
South Fork

Touchet River Geomorphic Assessment
Columbia County, Washington

GEOENGINEERS

Figure 5

SP\1029100200\Report Documents\Figures 4 through 7   CJE 02/07/11

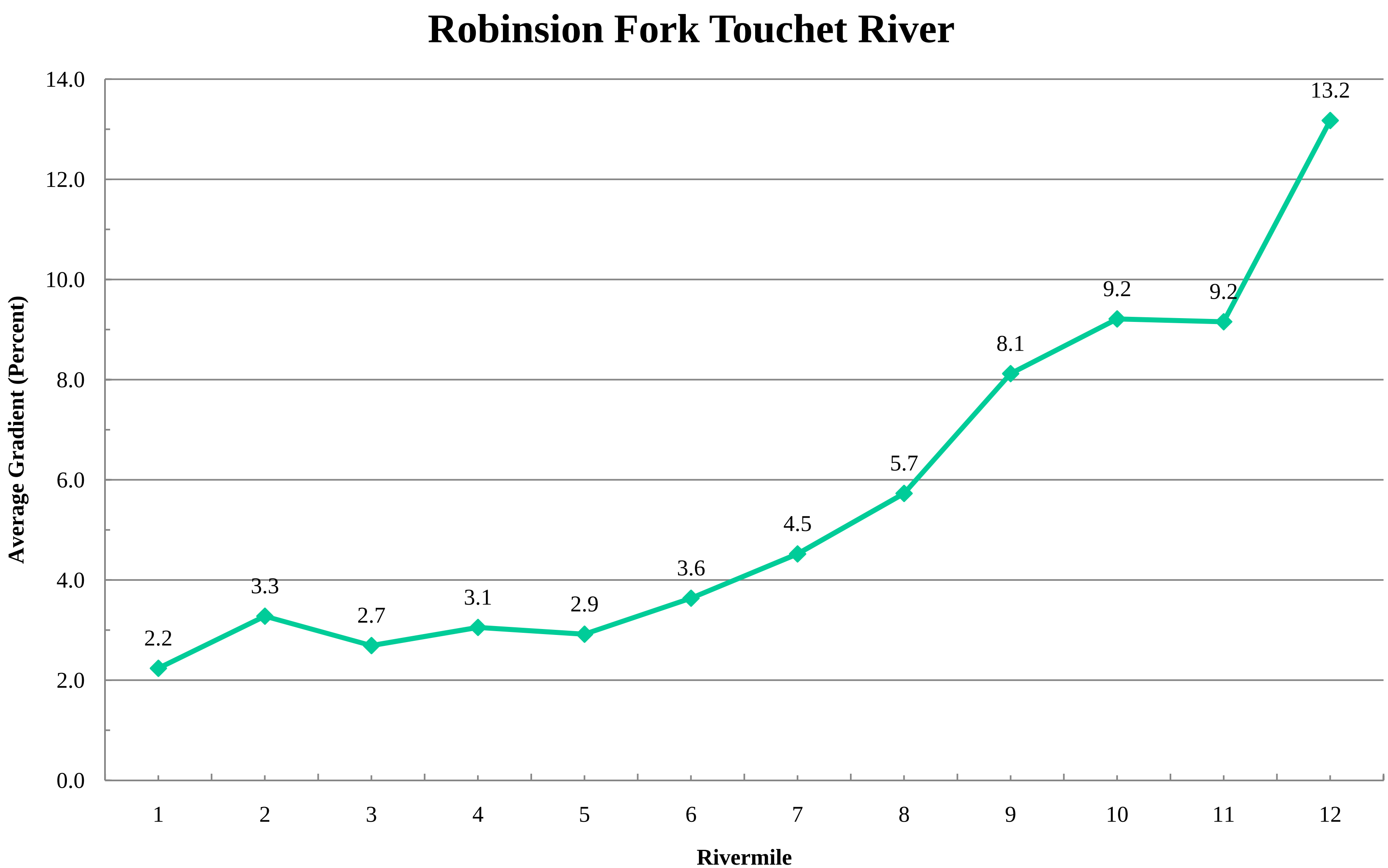


Channel Gradient
Wolf Fork

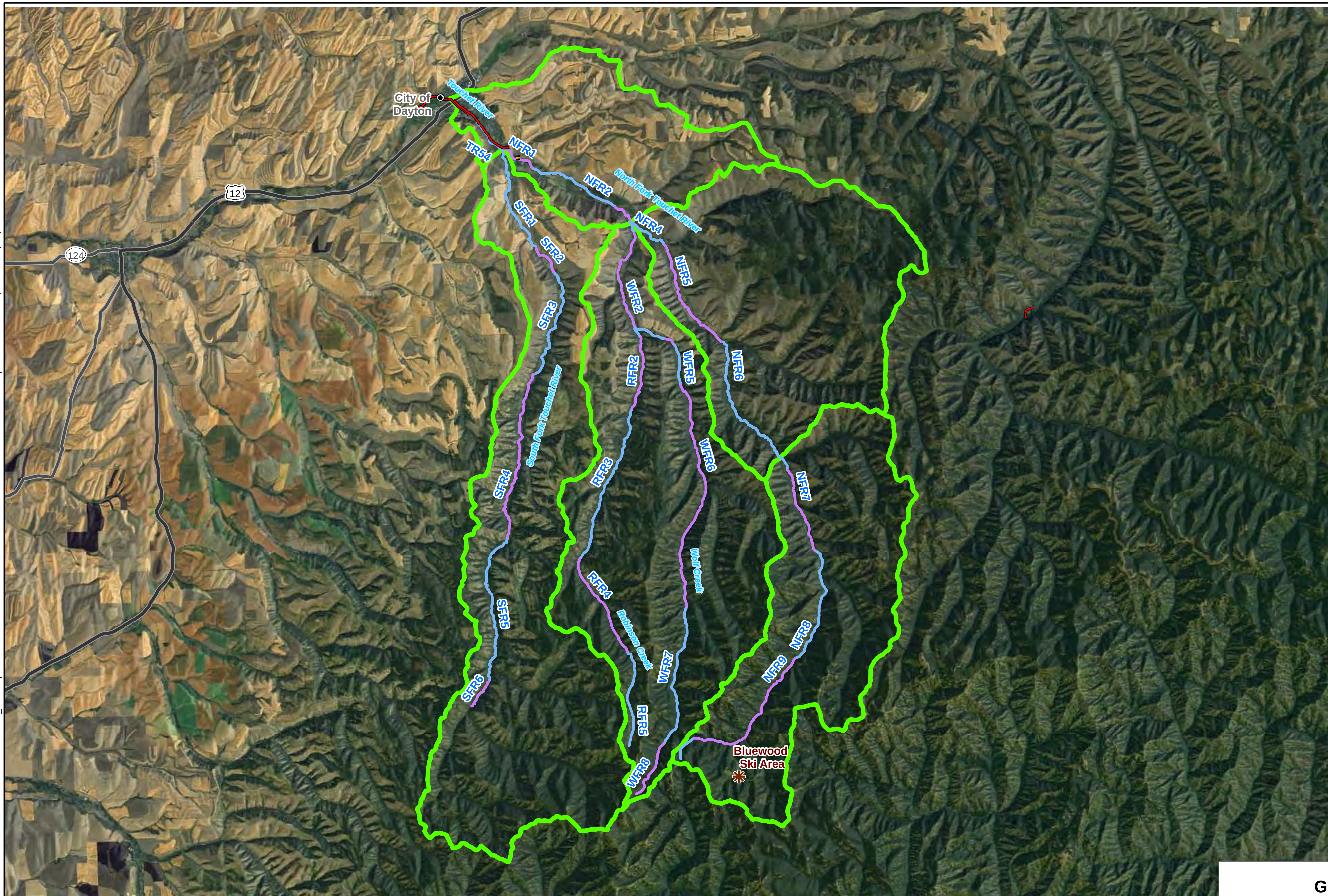
Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure 6



Channel Gradient Robinson Fork	
Touchet River Geomorphic Assessment Columbia County, Washington	
GeoEngineers	**Figure 7**



Bluewood Ski Area
Star Levee
USACE Levee
Geomorphic Reaches
TR54
NFR1
Watershed Boundary (Level 6 WRIA)

N
W E
S

2 0 2
Miles

Geomorphic Reaches

Touchet River Geomorphic Assessment
Columbia County, Washington

GEOENGINEERS

Figure 8

Reference: WRIA Watershed boundary from Washington DNR. Watercourses from Pacific Northwest Hydrography.
Aerial imagery (I-cubed) from ESRI ArcGIS Online.

Notes:
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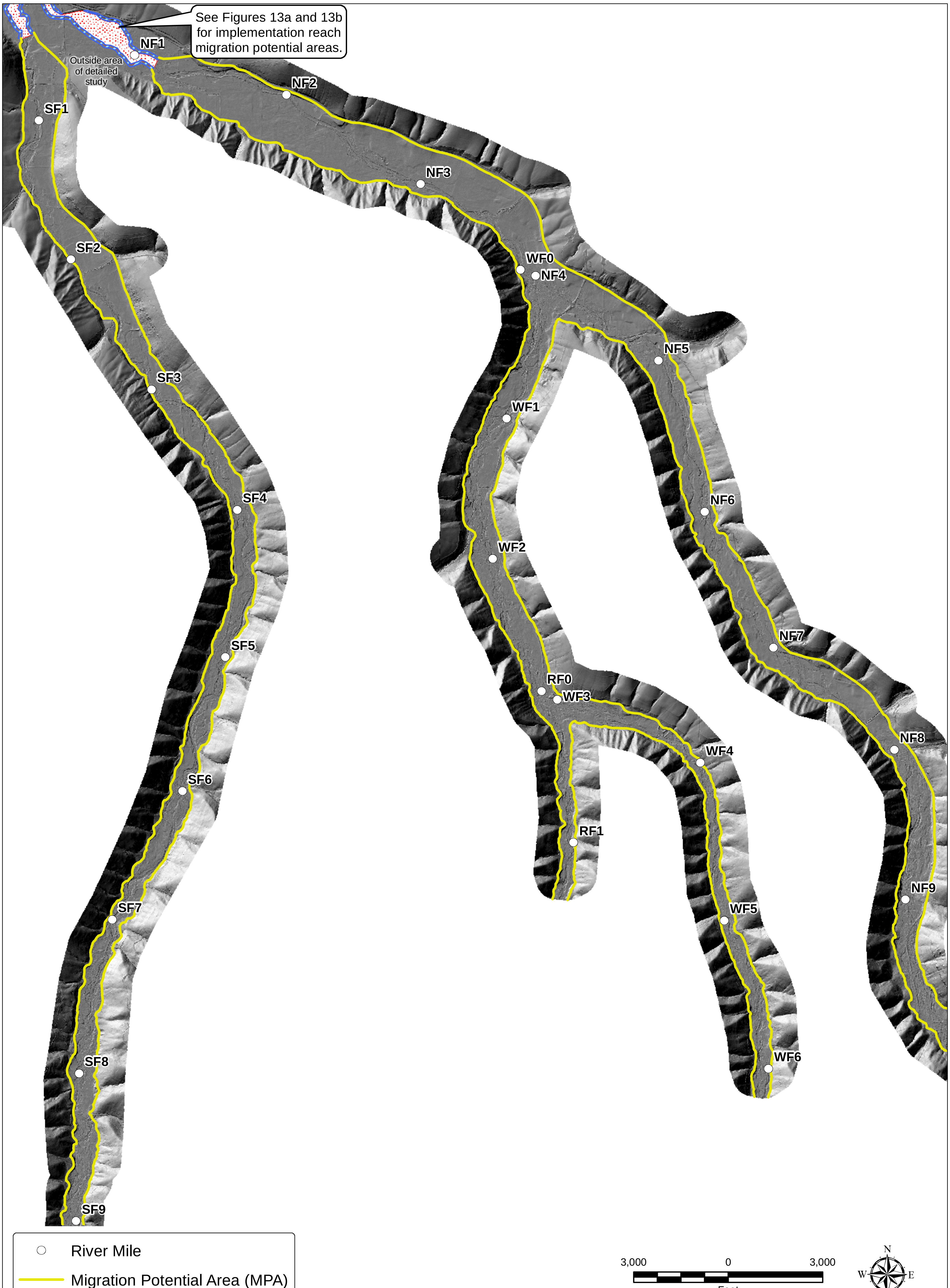
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Map Revised: March 31, 2011 CRC, EL, CRC
Path: P:\10\1029100\2GIS\00\GIS\MXD\1029100200_GeomorphReaches.mxd
OfficeLocation: PORT



River Mile

Migration Potential Area (MPA)

NF: North Fork Touchet River
RF: Robinson Fork
SF: South Fork Touchet River
WF: Wolf Fork

Reference: 2010 LiDAR obtained from Watershed Sciences, Inc.

Notes:
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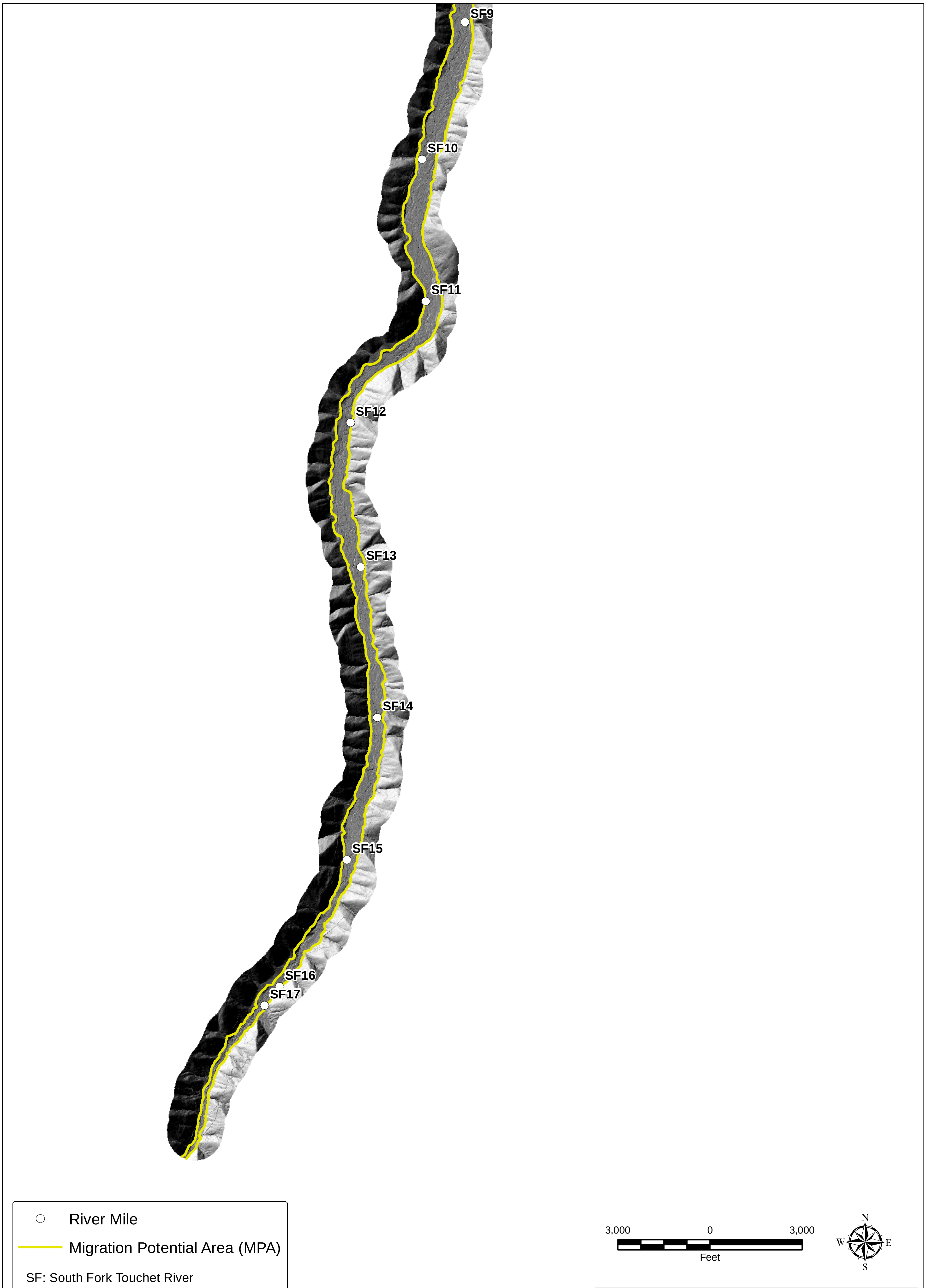
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Channel Migration Potential Area for North Fork, South Fork, Wolf Fork and Robinson Fork

Touchet River Geomorphic Assessment
Columbia County, Washington

GEOENGINEERS

Figure 9a



Channel Migration Potential Area for South Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure 9b

Reference: 2010 LiDAR obtained from Watershed Sciences, Inc.

Notes:
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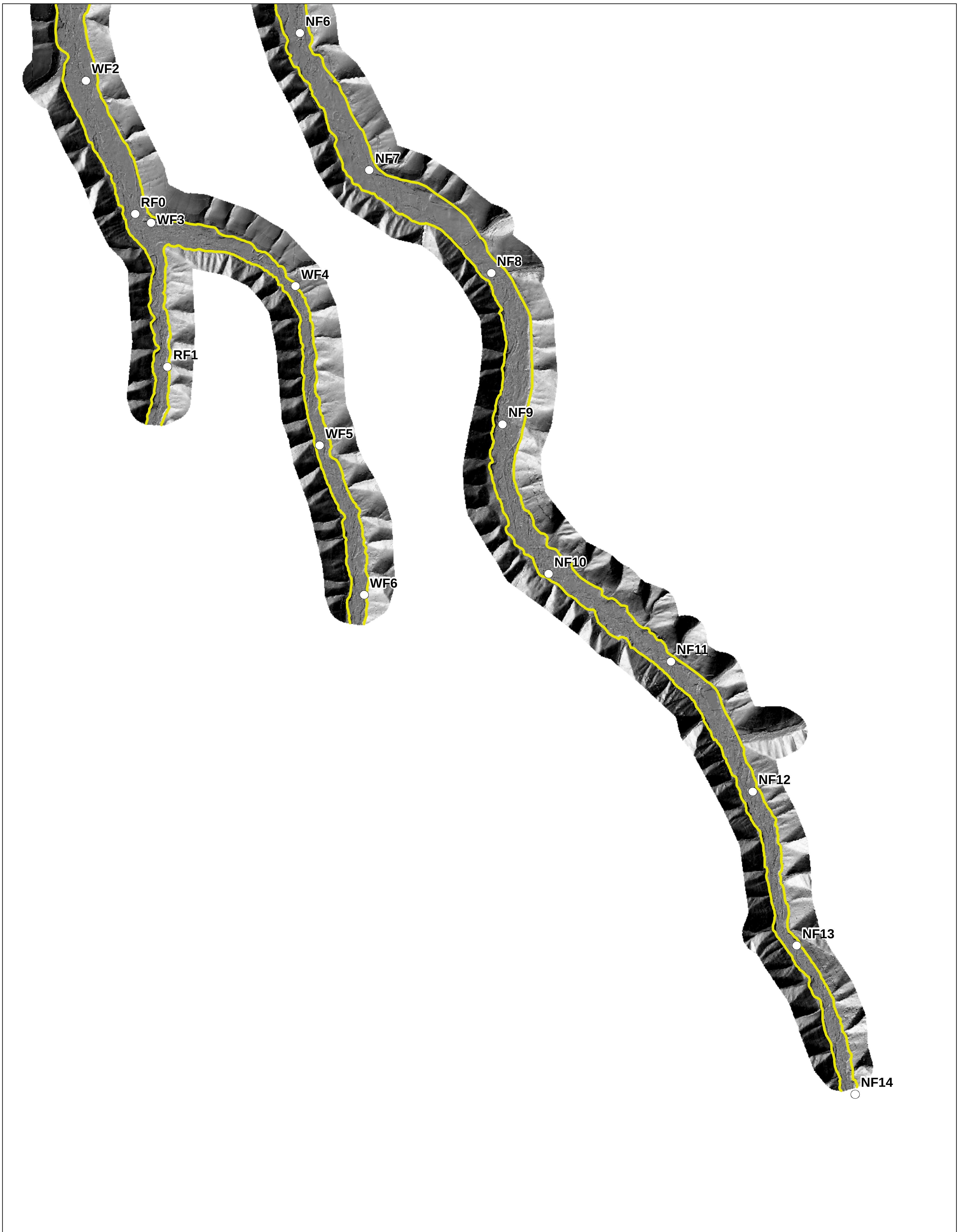
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Office: PORT Path: P:\10\1029100200GIS\GIS\1029100200_F9c.mxd

Map Revised: March 31, 2011



River Mile

Migration Potential Area (MPA)

NF: North Fork Touchet River
RF: Robinson Fork
WF: Wolf Fork

3,000 0 3,000

Feet

N W E S

Channel Migration Potential Area for North Fork, Wolf Fork and Robinson Fork

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure 9c

Reference: 2010 LiDAR obtained from Watershed Sciences, Inc.

Notes:
1. The locations of all features shown are approximate.
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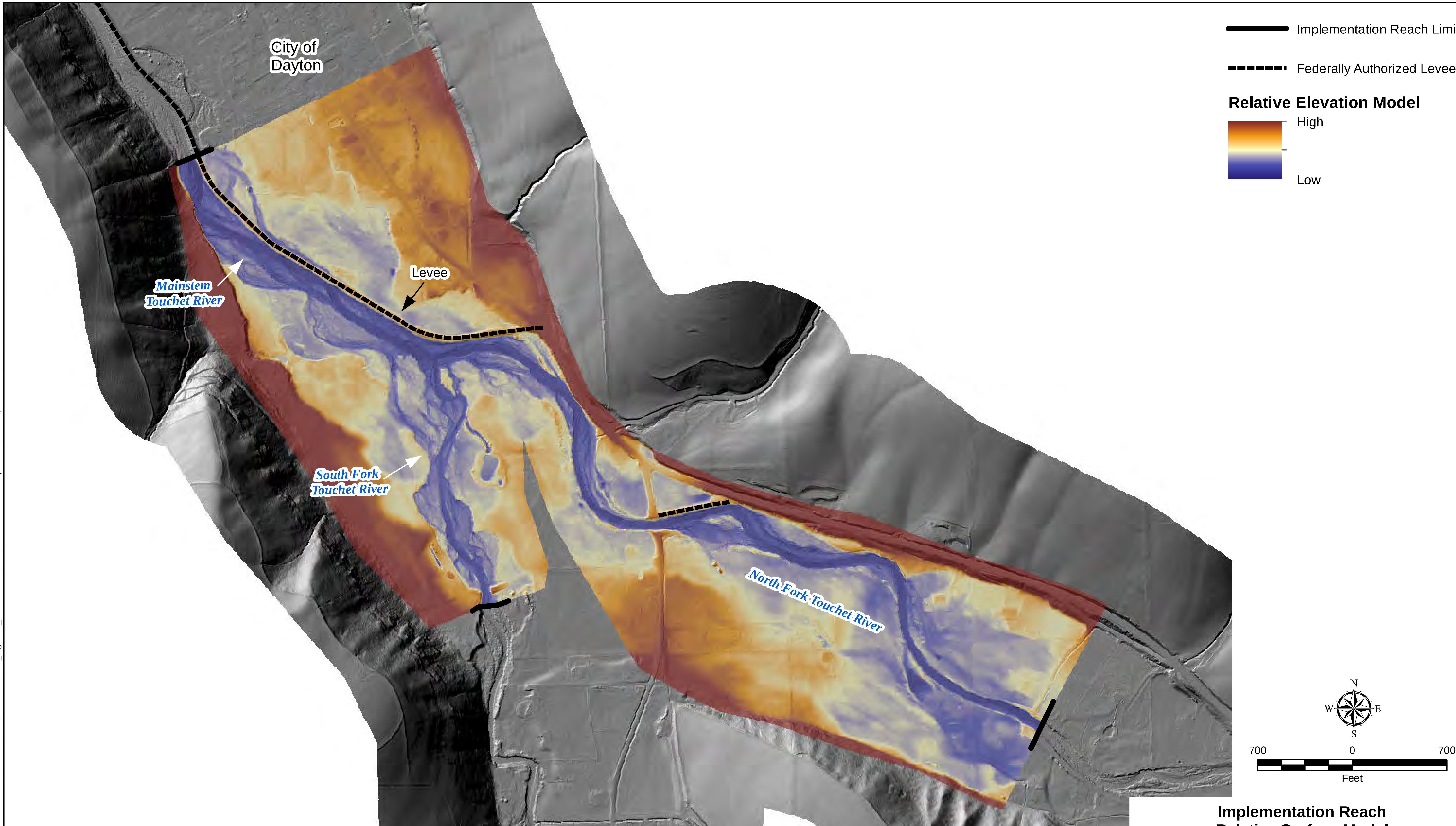

Reference:
LiDAR data collected by Watershed Sciences, Inc, July 2010. Relative Elevation Model derived from LiDAR data.
Levee location from US Army Corps of Engineers (USACE)

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Implementation Reach
Relative Surface Model

Touchet River Geomorphic Assessment
Columbia County, Washington

GEOENGINEERS

Figure 10

Office Location: PORT Path:W:\Portland\0\0291002\00\GIS\1029100200_Figure10_RelativeElevationModel.mxd Map Revised: April 1, 2011 BKB:EL:CRC

Map Revised: April 08, 2011 EL:CRC

OfficeLocation: PORT Path: P:\10\1029100\2GIS\00\GIS\MXD\1029100200_Figure11_ProjectReachGeology.mxd

Reference: Streets from ESRI Online Data Resources. I-cubed imagery from ESRI Data Online. Surficial Geology from Washington Department of Natiral Resources.

Notes:
1. The locations of all features shown are approximate.
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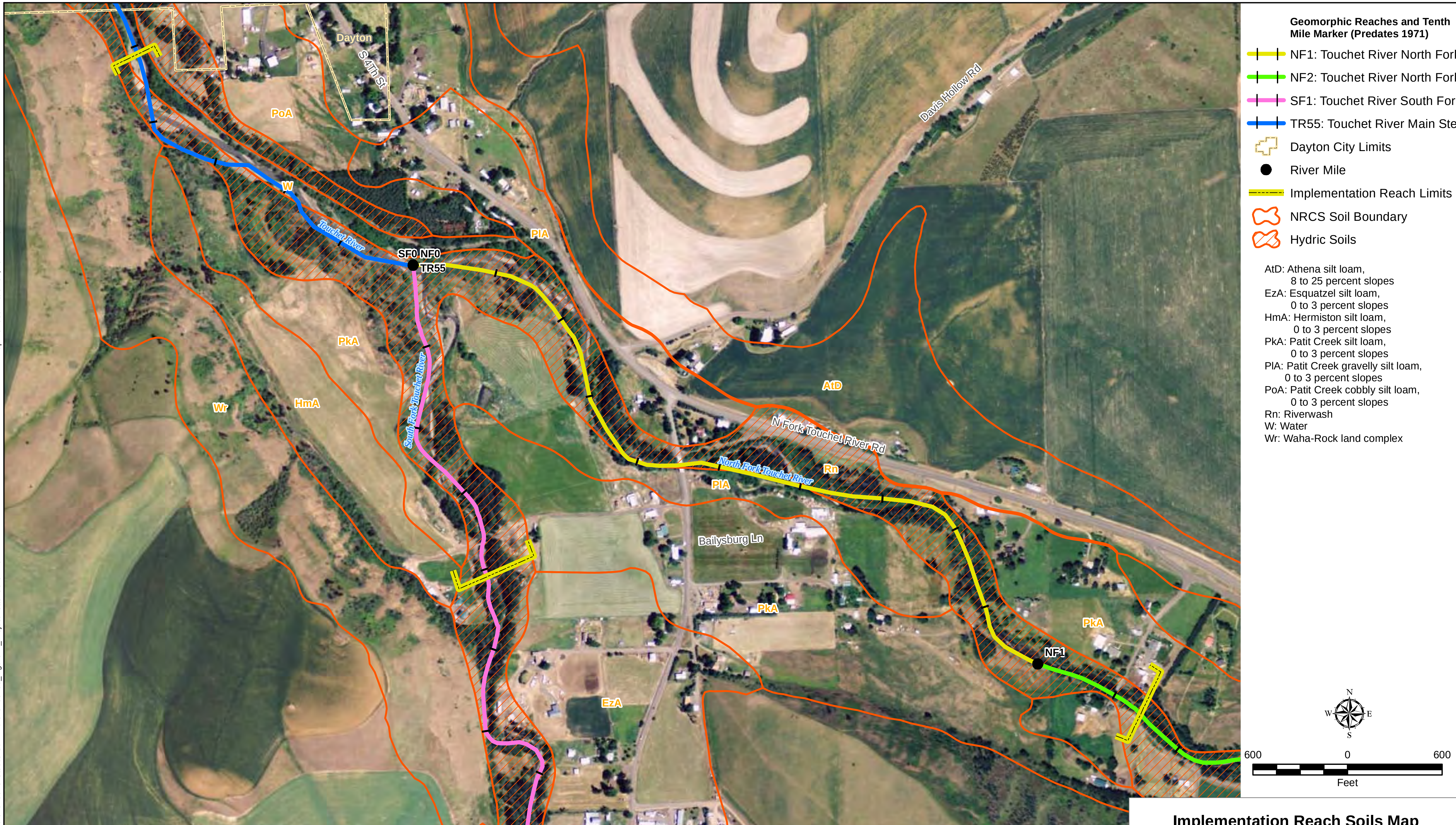
Implementation Reach Geology Map and Sediment Sample Locations

Touchet River Geomorphic Assessment
Columbia County, Washington

GEOENGINEERS

Figure 11



Map Revised: March 31, 2011 EL:CRC

OfficeLocation: PORT Path: P:\1\1029100\2\GIS\00\GIS\MXD\1029100200_Figure12_ProjectReachSoils.mxd

Reference: Streets from ESRI Online Data Resources. I-cubed imagery from ESRI Data Online. Soils data from Natural Resources Conservation Service (United States), NRCS.

Notes:
1. The locations of all features shown are approximate.
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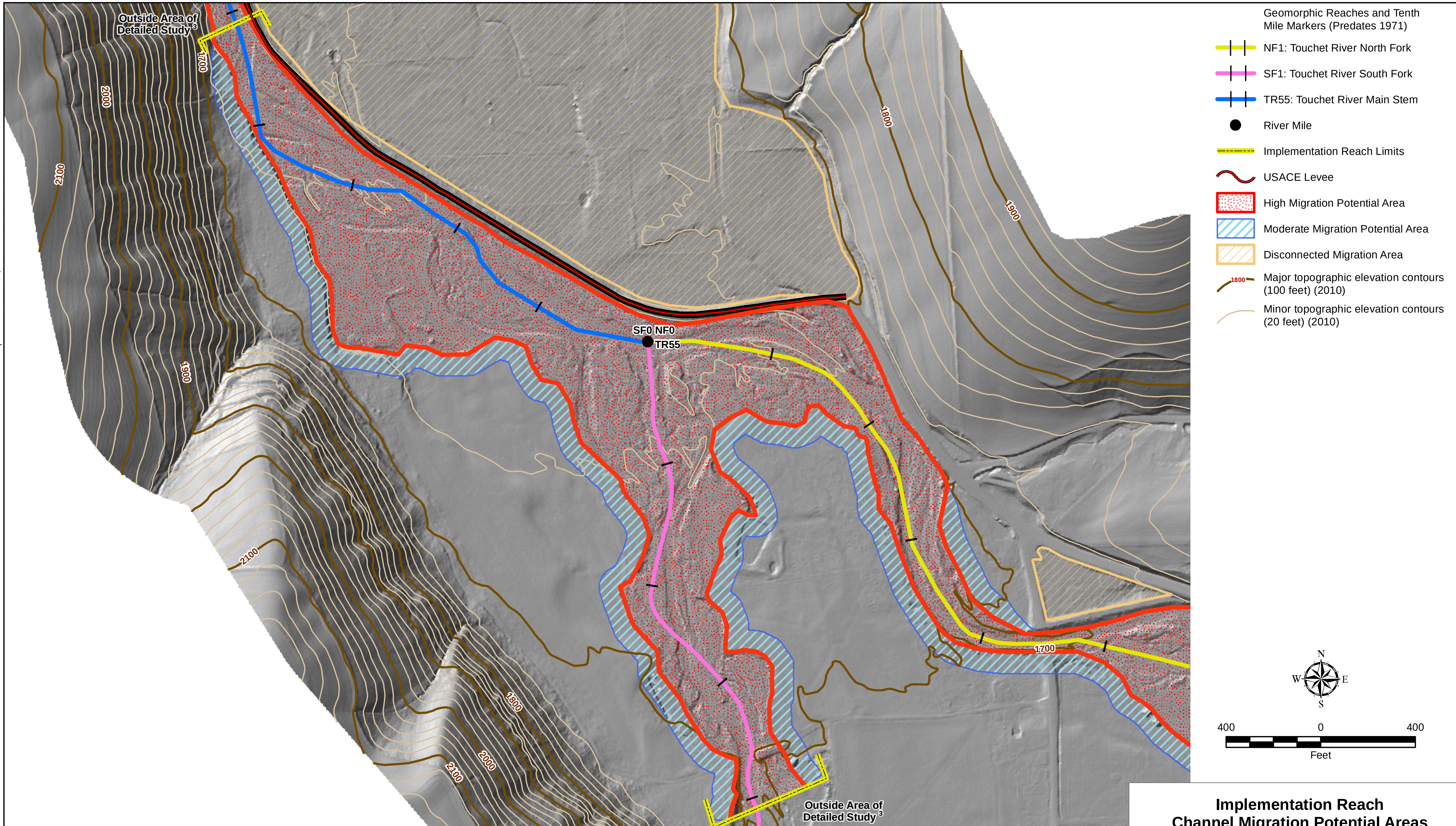
Implementation Reach Soils Map

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure 12



Map Revised: March 31, 2011 BKB:CRC:EL:CRC

Path:W:\Portland\10\1029100200\GIS\1029100200_Figure13a_ChanMigrationPot.mxd

OfficeLocation: PORT

Reference: Hillshade and contours derived from 2010 LiDAR data.
Channel locations from National Hydrography Dataset

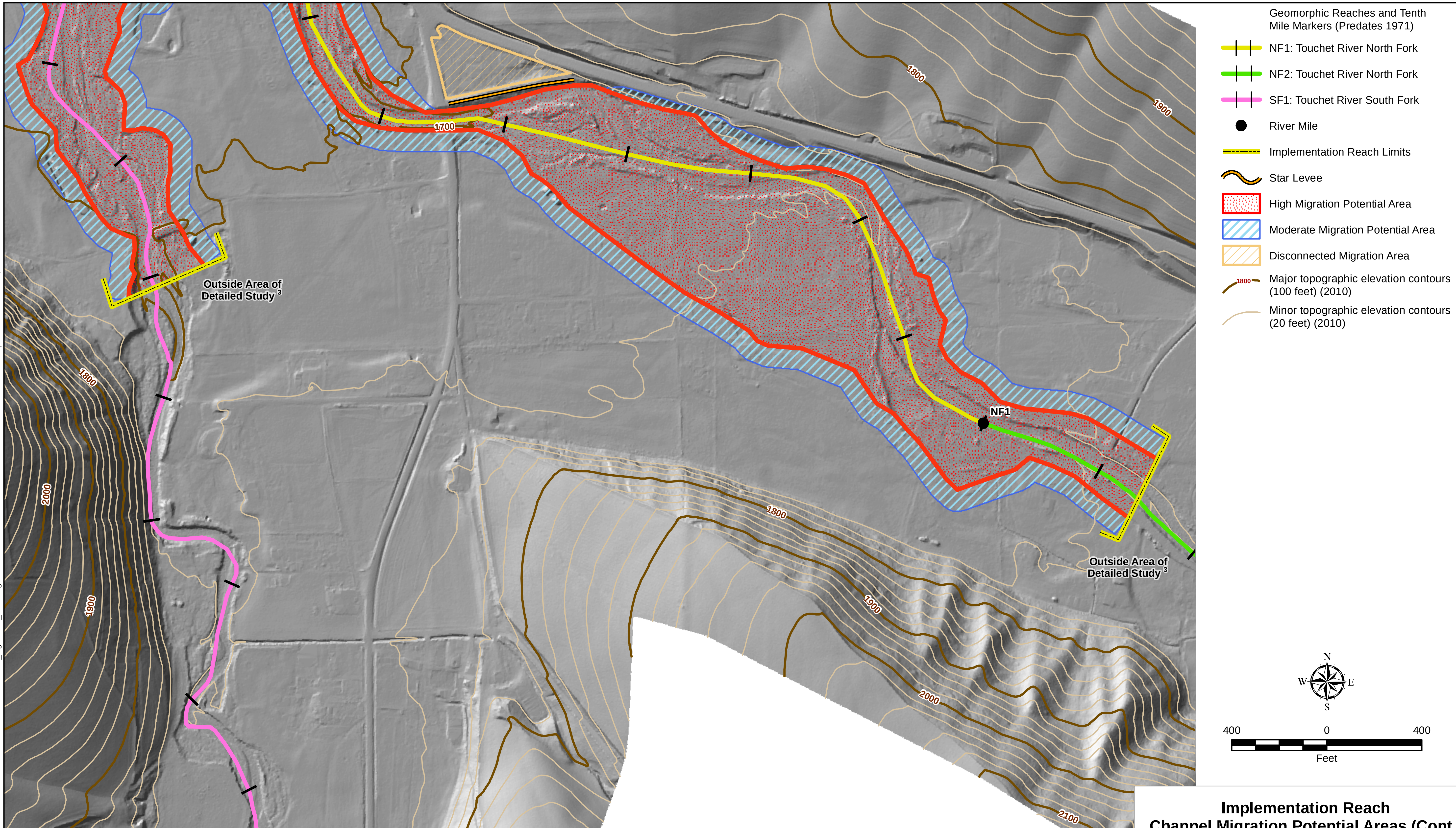
Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. See figure 9 for migration potential areas outside area of detailed study.

Implementation Reach Channel Migration Potential Areas

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure 13a



Map Revised: March 31, 2011 BKB:CRC:EL:CRC

Path:W:\Portland\0\0291002\00\GIS\1029100200_Figure13b_ChanMigrationPot.mxd

OfficeLocation: PORT

Reference: Hillshade and contours derived from 2010 LiDAR data.
Channel locations from National Hydrography Dataset.

Notes:
1. The locations of all features shown are approximate.
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3. See figure 9 for migration potential areas outside area of detailed study.

Implementation Reach Channel Migration Potential Areas (Cont.)

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure 13b

APPENDICES

Appendix A
Implementation Reach Photo Log

Map Revised: April 8, 2011

OfficeLocation: PORT Path: P:\10\1029100200\GIS\MXD\1029100200_ExistingRiverineStructures.mxd

Reference: Street labels from ESRI Online Data Resources. Parcel layer from Columbia County, Washington GIS department.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Photograph Locations

Touchet River Geomorphic Assessment
Columbia County, Washington

GEOENGINEERS

Figure A-1

Map Revised: April 8, 2011

OfficeLocation: PORT Path: P:\10\1029100200\GIS\MXD\1029100200_ExistingRiverineStructures.mxd

Reference: Street labels from ESRI Online Data Resources. Parcel layer from Columbia County, Washington GIS department.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Photograph Locations

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure A-2

Reference: Street labels from ESRI Online Data Resources. Parcel layer from Columbia County, Washington GIS department.

Notes:
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Photograph Locations

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure A-3

Map Revised: April 8, 2011

OfficeLocation: PORT Path: P:\10\1029100200\GIS\00\GIS\MXD\1029100200_ExistingRiverineStructures.mxd

Map Revised: April 8, 2011

OfficeLocation: PORT Path: P:\10\1029100200\GIS\00\GIS\MXD\1029100200_ExistingRiverineStructures.mxd

Reference: Street labels from ESRI Online Data Resources. Parcel layer from Columbia County, Washington GIS department.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Photograph Locations

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure A-4

Map Revised: April 8, 2011

Reference: Street labels from ESRI Online Data Resources. Parcel layer from Columbia County, Washington GIS department.

Notes:
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Photograph Locations

Touchet River Geomorphic Assessment
Columbia County, Washington

GEOENGINEERS

Figure A-5

OfficeLocation: PORT Path: P:\10\1029100200\GIS\00\GIS\MXD\1029100200_ExistingRiverineStructures.mxd

Photo 1. Right bank riprap protection, large basalt columns

Photo 2. Upstream north fork bridge,
looking upstream with one pier near left bank

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure A-6**

Photo 3. 24 inch drainage culvert along the right bank immediately downstream of bridge

Photo 4. Cottonwood sweeper perpendicular to flow along left bank immediately downstream of bridge

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GEOENGINEERS

Figure A-7

SharePoint\10291-002-00\Working\Report Documents\Touchet River Appendix A Figures.ppt JJF:mlh 12/16/10

Photo 5. Rock barb along the left bank

Photo 6. Channel spanning U-weir

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure A-8

Photo 7. Channel spanning sweepers perpendicular to flow along both banks

Photo 8. Concrete stair access along the right bank

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure A-9**

SharePoint\10291-002-00\Working\Report Documents\Touchet River Appendix A Figures.ppt JJF:mlh 12/16/10

Photo 9. Cut bank and piping along roots along the left bank

Photo 10. Broken concrete riprap end dumped along the right bank

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Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GEOENGINEERS | **Figure A-10**

Photo 11A. Apex bar jams located at the head of the mid channel bar near the right bank

Photo 11B. Apex bar jams located at the head of the mid channel bar near the right bank

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure A-11**

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Photo 12. Erosion and actively cutting bank along the right bank at hardened bend

Photo 13. Rootwads (3) located along the left bank

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | Figure A-12

SharePoint\10291-002-00\Working\Report Documents\Touchet River Appendix A Figures.ppt JJF:mlh 12/16/10

Photo 14. Rock barb along the left bank with some rock migration downstream

Photo 15. Rootwads (8) with toe logs located along the left bank

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure A-13

SharePoint\10291-002-00\Working\Report Documents\Touchet River Appendix A Figures.ppt JJF:mlh 12/16/10

Photo 16. Riprap bank protection along the left bank, very localized

Photo 17. Irrigation diversion to pond along the left bank

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure A-14**

Photo 18. Large woody debris along the left bank and two apex bar jams located on the mid channel bar

Photo 19. Rock and concrete riprap located along the right bank

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure A-15**

Photo 20. Drainage culvert entering the floodplain on the left bank upstream of the South Touchet Road bridge

Photo 21. South Touchet Road bridge with abutment riprap on both banks

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Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-16

Photo 22. Rock barb on left bank

Photo 23. Rock J-hook on the left bank, minimum flows are directed to the far right side of the channel

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-17

Photo 24A. Rock U-weir across the channel

Photo 24B. Rock U-weir across the channel

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Site Photographs

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Columbia County, Washington

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Figure A-18

Photo 25. Concrete and metal revetment along the left bank

Photo 26. Rootwads (6) with toe logs and rock ballast along the left bank

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure A-19**

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Photo 27. Distressed rootwads (6) with toe logs and rock ballast along the left bank

Photo 28. Short span of rock armoring along the left bank between LWD

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Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-20

Photo 29A. Rootwads (5) with toe logs and rock ballast along the left bank

Photo 29B. Rootwads (5) with toe logs and rock ballast along the left bank

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Site Photographs

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Columbia County, Washington

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Figure A-21

Photo 30. Automobile debris along the right bank (Only 1 car visible)

Photo 31. Rock barb along the left bank with large left side scour hole

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Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-22

Photo 32. Short stretch of random boulders placed in channel

Photo 33. Point of diversion along the left bank

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure A-23**

Photo 34. Weathered basalt along the right bank adjacent to the Touchet River Road

Photo 35. Right bank point of diversion
(goes to a canal gate and crosses under the levee)

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GEOENGINEERS | **Figure A-24**

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Photo 36. Left bank downstream sweepers (3)

Photo 37. Small apex jams (2) along the left bank

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Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-25

Photo 38. Small longitudinal log along the right bank near the head of a gravel bar

Photo 39. Alder rootwads along the right bank below a right bank bar

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-26

Photo 40. Small alder apex jam along the right bank

Photo 41. Small LWD elevated barb and channel log along the left bank

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-27

Photo 42. Eroding gravel deposits along the left bank

Photo 43. USACE's repaired section of levee along the right bank

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure A-28

Photo 44. High cut bank along the left bank of the channel near downstream end of implementation reach

Photo 45. Eroding right bank immediately downstream of picture 42

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Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-29

Photo 46. View upstream of private bridge along the South Fork Touchet near upstream project boundary

Photo 47. Small alder apex jam along the right bank

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-30

Photo 48. Small alder apex jam along the right bank

Photo 49. Overbank racking members and debris blocking along the right bank

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Site Photographs

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Columbia County, Washington

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Figure A-31

Photo 50. Channel spanning logs and racking members along the left bank

Photo 51. Concrete revetment along the left bank floodplain

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Site Photographs	
Touchet River Geomorphic Assessment Columbia County, Washington	
GeoEngineers	**Figure A-32**

Photo 52. Abandoned farm equipment located in the left overbank riparian corridor

Photo 53. Small wood apex jam along the left bank

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-33

Photo 54. Channel spanning log with minor racking members on the left bank side

Photo 55. Racking members at entrance to left bank overflow side channel

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Site Photographs	
Touchet River Geomorphic Assessment Columbia County, Washington	
GeoEngineers	Figure A-34

Photo 56. High cut bank along the right bank

Photo 57. Downstream view of right cut bank being actively eroded

Site Photographs

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Columbia County, Washington

GeoEngineers	Figure A-35

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Photo 58. Small wood accumulation along the right bank

Photo 59. Left bank floodplain and levee toe

Site Photographs

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GeoEngineers | **Figure A-36**

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Photo 60. Left bank reentrant high flow channel

Photo 61. Left bank reentrant high flow channel

Site Photographs

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Columbia County, Washington

GEOENGINEERS | **Figure A-37**

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Photo 62. Left bank gravel deposits

Photo 63. Numerous car bodies in high flow channel

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | Figure A-38

Photo 64. Numerous car bodies in high flow channel

Photo 65. Historic erosional bank of terrace

Site Photographs

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Columbia County, Washington

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Figure A-39

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Photo 64. High cut bank along the left bank of the channel near downstream end of implementation reach

Photo 65. Low area in field, possible historic high flow channel

Site Photographs

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Columbia County, Washington

GeoEngineers | **Figure A-40**

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Photo 66. Second photo of high cut bank along the right bank (photo 56)

Site Photographs

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-41

GB-1a and 1b: Gravel bar located along the left bank upstream of a bend to the right

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure A-42**

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GB-2: Gravel bar located along the right bank immediately upstream of a hardened bend to the left

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Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-43

GB-3a and 3b: Mid-channel gravel bar located immediately downstream of the hardened bend to the left and adjacent to an eroding right bank

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure A-44**

GB-4a and 4b: Vegetated gravel bar located along the left bank located downstream of hardened bend to left

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-45

GB-5a and 5b: Gravel bar located along the left bank downstream of left bank LWD protection.

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure A-46**

GB-6a and 6b: Mid-channel gravel bar along the right side of the channel, some LWD is present

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure A-47**

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GB-7a and 7b: Gravel bar along the left bank located on the inside of a sharp bend to the left, heavily vegetated with grass

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

GEOENGINEERS

Figure A-48

GB-8a and 8b: Gravel bar located along the right bank downstream of hard bend to left and upstream of bridge

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-49

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GB-9: Small gravel bar along the left bank located immediately upstream of the South Touchet Road bridge crossing

GB-10: Gravel bar along the right bank located immediately upstream of bend to the left and bedrock contact point on right bank

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-50

GB-11: Gravel bar along the right bank located downstream of bedrock contact point with diversion along far right side

GB-12: Mid-channel bar located toward the right edge of the channel, heavily vegetated with grass

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-51

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GB-13: Small mid-channel bar located toward the right edge of the channel, minor wood accumulation

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Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

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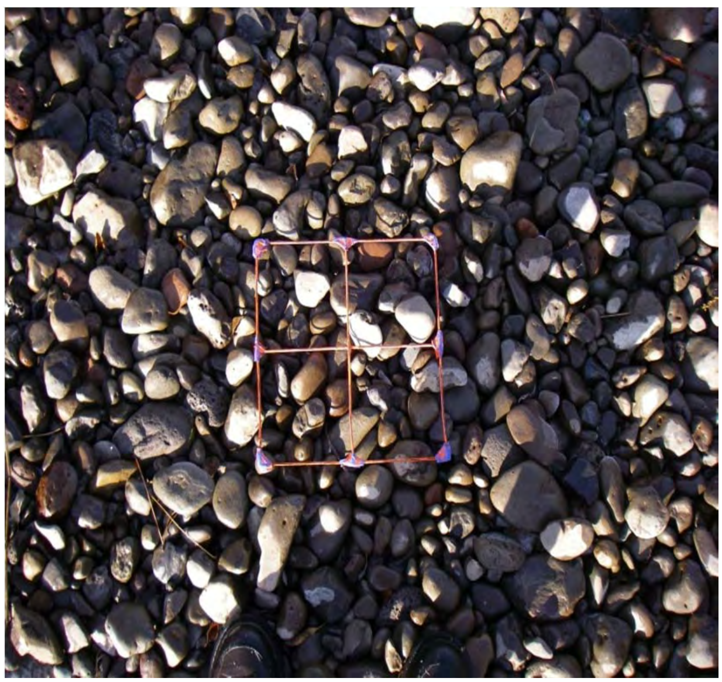
Figure A-52



GB-14a and 14b: Gravel bar along the left bank located immediately downstream of the North Fork and South Fork confluence

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-53

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GB-15a and 15b: Gravel bar along the right bank immediately downstream of the North Fork and South Fork confluence

Gravel Bar Inventory Photos

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Columbia County, Washington

GeoEngineers | Figure A-54

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GB-16a and 16b: Large gravel bar located along the right bank upstream of levee repair

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure A-55**

GB-17a and 17b: Small mid-channel bar located along the right edge of channel downstream of levee repair

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-56

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GB-18: Large vegetated gravel bar along the left bank upstream of sharp bend to right

GB-19: Gravel bar along the left bank on inside of bend downstream of private bridge

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

GEOENGINEERS | **Figure A-57**

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GB-20: Gravel bar along the right bank upstream of some wood debris blocking floodplain

GB-21: Bar located along the left bank upstream of the confluence, channel has occupied a historic channel at the right in the last 20 years

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure A-58

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GB-22: Another picture of bar located along the left bank upstream of the North Fork and South Fork confluence.

Gravel Bar Inventory Photos

Touchet River Geomorphic Assessment
Columbia County, Washington

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Appendix B
Laboratory Sieve Analyses and Pebble Counts

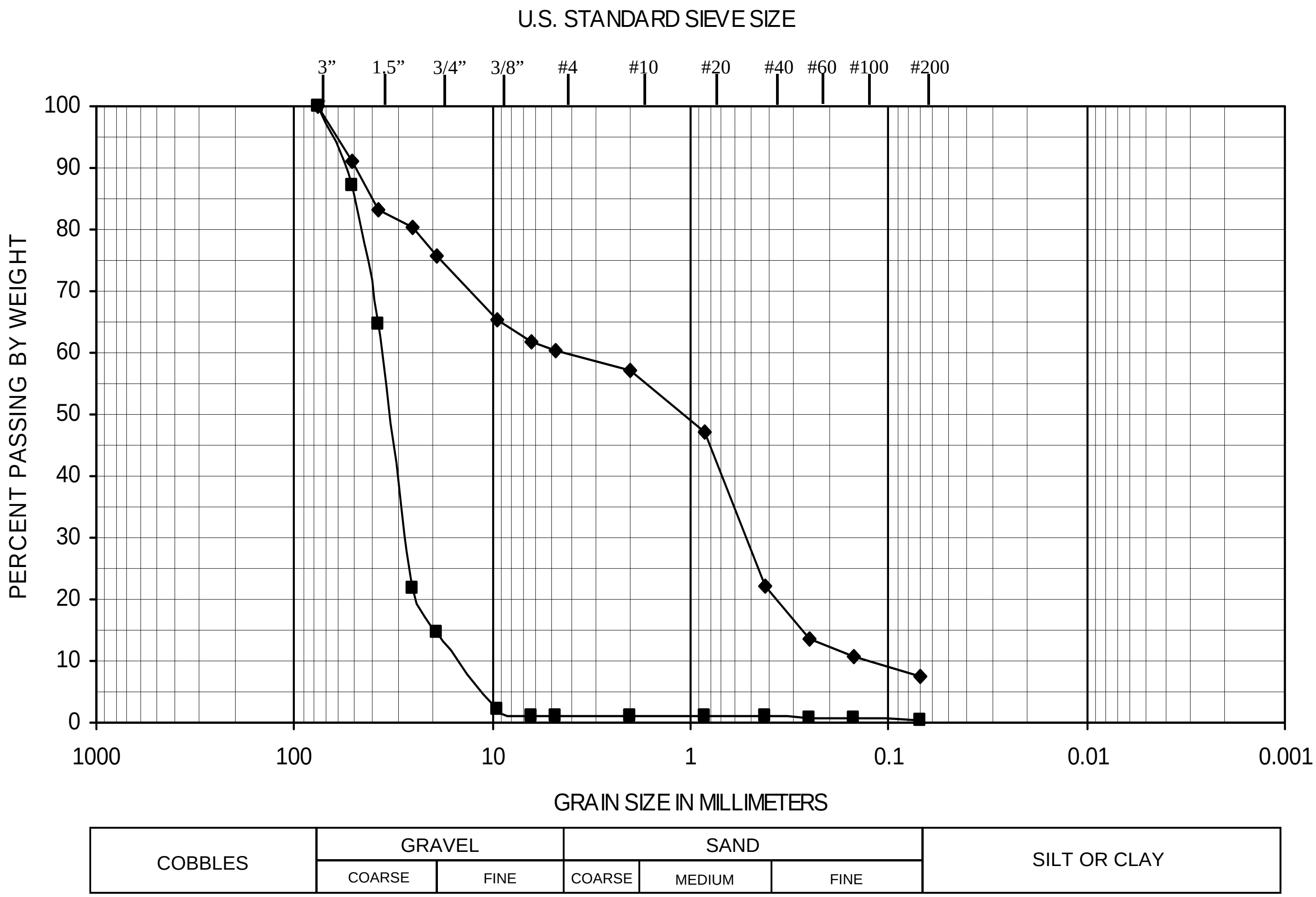
APPENDIX B
LABORATORY SIEVE ANALYSIS AND PEBBLE COUNTS

Laboratory Sieve Analysis

Bulk sediment samples were obtained from the streambed and in-channel sediment bars (inundated during bank-full flow) at the six locations shown in Figure 11. The samples were returned to our soils laboratory in Spokane, Washington for testing. Laboratory gradation tests were conducted on the six samples in general accordance with the ASTM International (ASTM C-136) testing procedure. Results of the gradation tests are presented in Figure B-1 through B-3.

Wolman Pebble Count

Twelve pebble counts were conducted within the Implementation Reach in general accordance with the Wolman Pebble Count Procedure on November 10 through 12, 2010. The locations of the pebble counts were recorded in the field using of a Trimble handheld GPS and are shown in Figure 11. The pebble count data was summarized in the office to estimate the approximate particle sizes of each sample. The results of the pebble count data are presented in Figures B-4 through B-9.



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	BS-1 S-1 surface sample	NA	Dark brown silty fine to coarse subrounded gravel with sand (medium) (SM/GM)
■	BS-2 S-2 surface sample	NA	Dark brown fine to coarse subrounded gravel (medium) (GP) (pea gravel)

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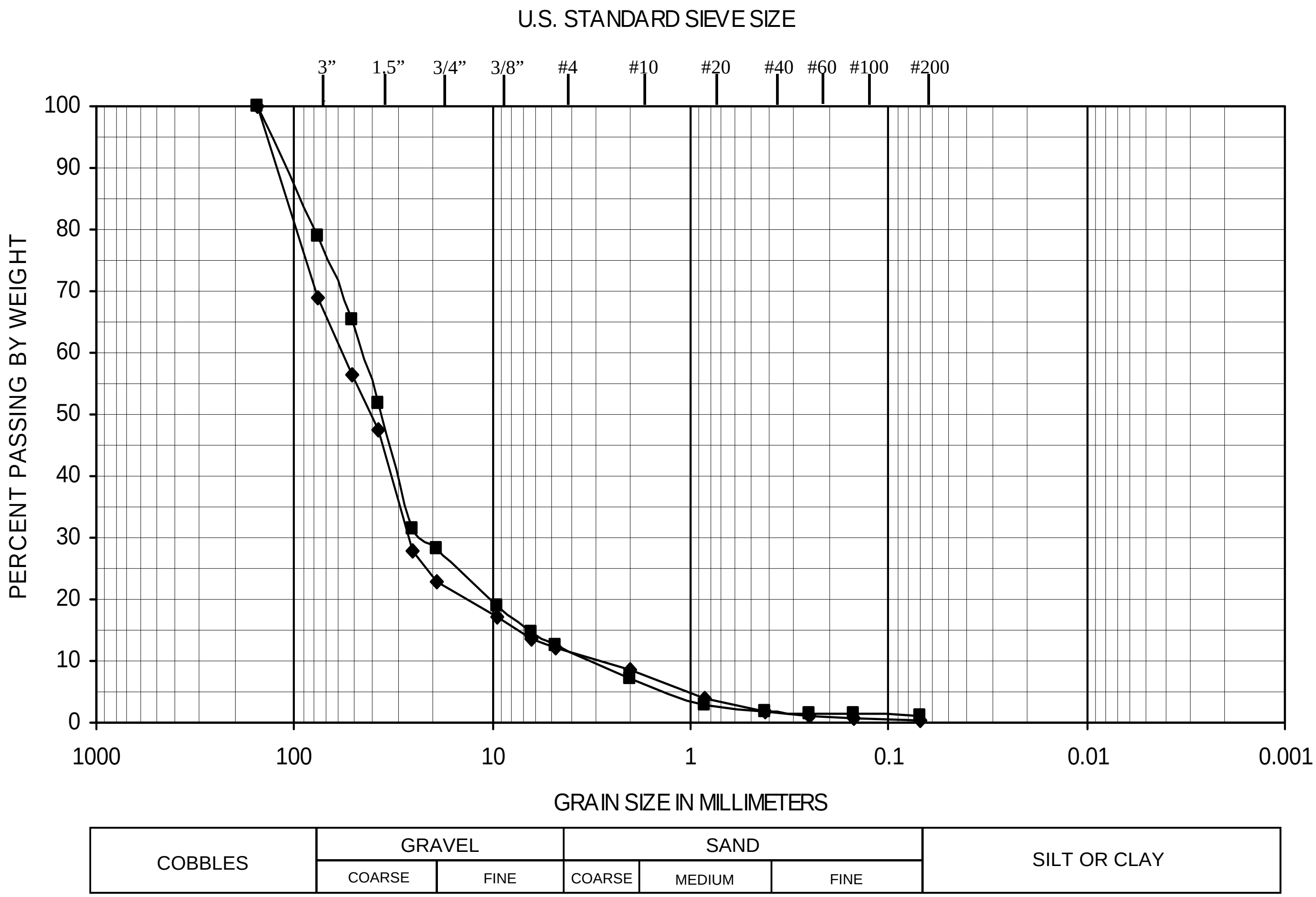
Sieve Analysis Results

City of Dayton Touchet River
Dayton, Washington

GEOENGINEERS

Figure B-1



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	BS-3 S-3 surface sample	NA	Dark brown fine to coarse subrounded gravel with sand and trace silt (medium) (GP)
■	BS-4 S-4 surface sample	NA	Black to dark brown fine to coarse subrounded gravel with sand and trace silt (wet) (GP)

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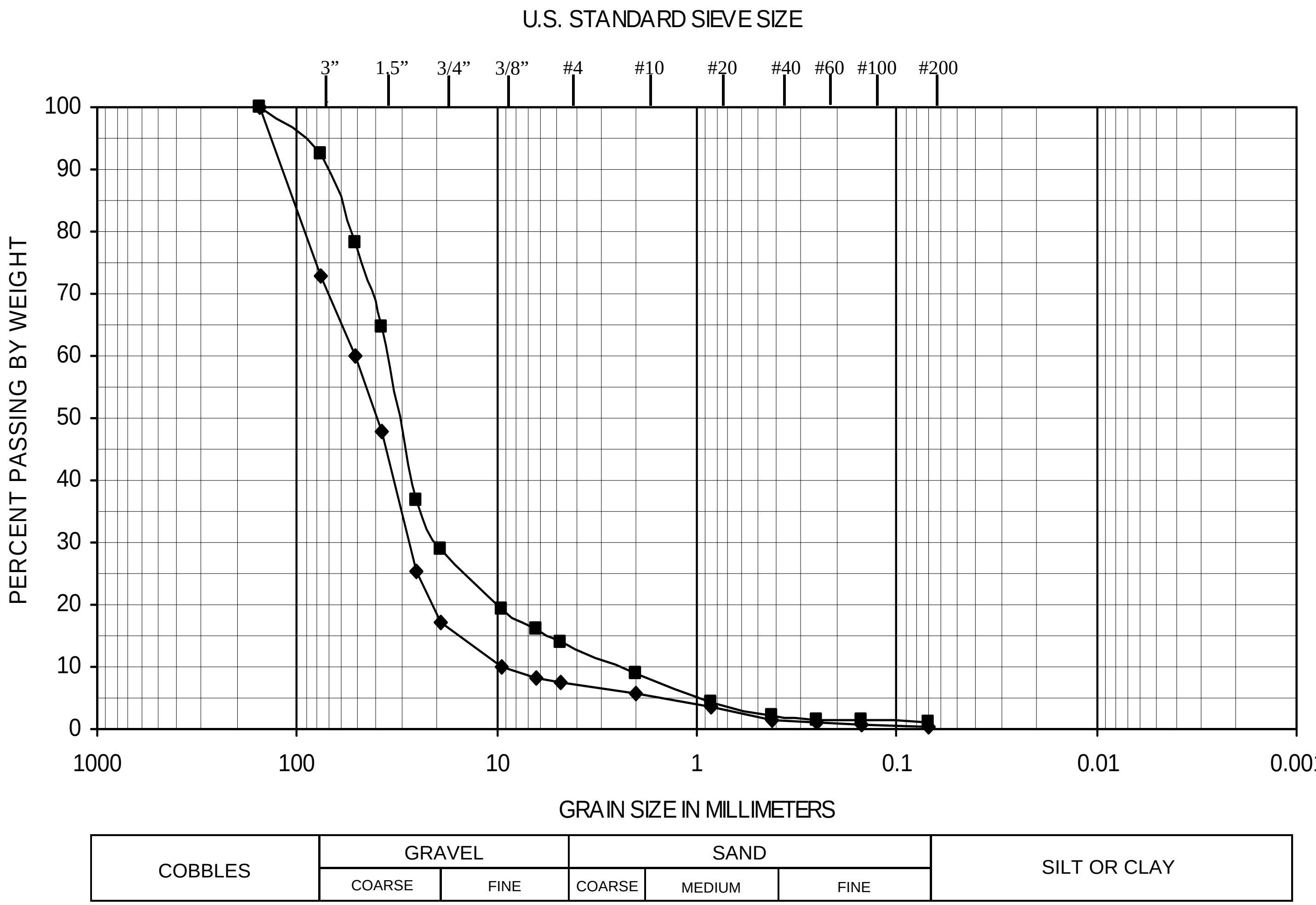
Sieve Analysis Results

City of Dayton Touchet River
Dayton, Washington

GeoEngineers

Figure B-2



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	BS-5 S-1 surface sample	NA	Coarse gravel with trace sand
■	BS-6 S-1 surface sample	NA	Fine to coarse gravel with trace sand and trace silt

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Sieve Analysis Results

City of Dayton Touchet River
Dayton, Washington

GEOENGINEERS

Figure B-3

Pebble Count Worksheet

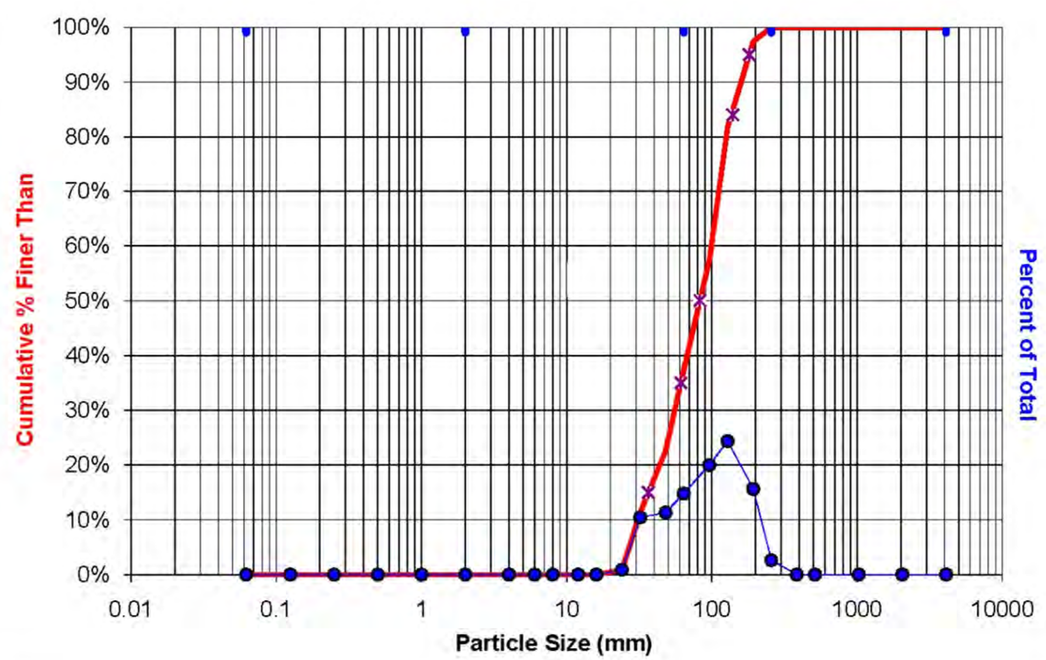
Particle Size (mm)	% finer than	Total Count
<0.062	0%	0
0.062 - 0.125	0%	0
0.125 - 0.25	0%	0
0.25 - 0.5	0%	0
0.5 - 1.0	0%	0
1 - 2	0%	0
2 - 4	0%	0
4 - 6	0%	0
6 - 8	0%	0
8 - 12	0%	0
12 - 16	0%	0
16 - 24	1%	1
24 - 32	11%	12
32 - 48	23%	13
48 - 64	37%	17
64 - 96	57%	23
96 - 128	82%	28
128 - 192	97%	18
192 - 256	100%	3
256 - 384	100%	0
384 - 512	100%	0
512 - 1024	100%	0
1024 - 2048	100%	0
2048 - 4096	100%	0

COMMENTS: Sample W-1: Downstream Limits of Implementation Reach

STREAM NAME: Touchet River
DATE: 11/10/2010
USGS # :
CREW: JJF, JL
Reach: N. Fork Touchet River - Riffle Reach

Particle Size Distribution (mm)

D15	D35	D50	D85	D95
36.5	61.1	82.6	139.3	180.5



Wolman Pebble Count
Sample W-1

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure B-4

Pebble Count Worksheet

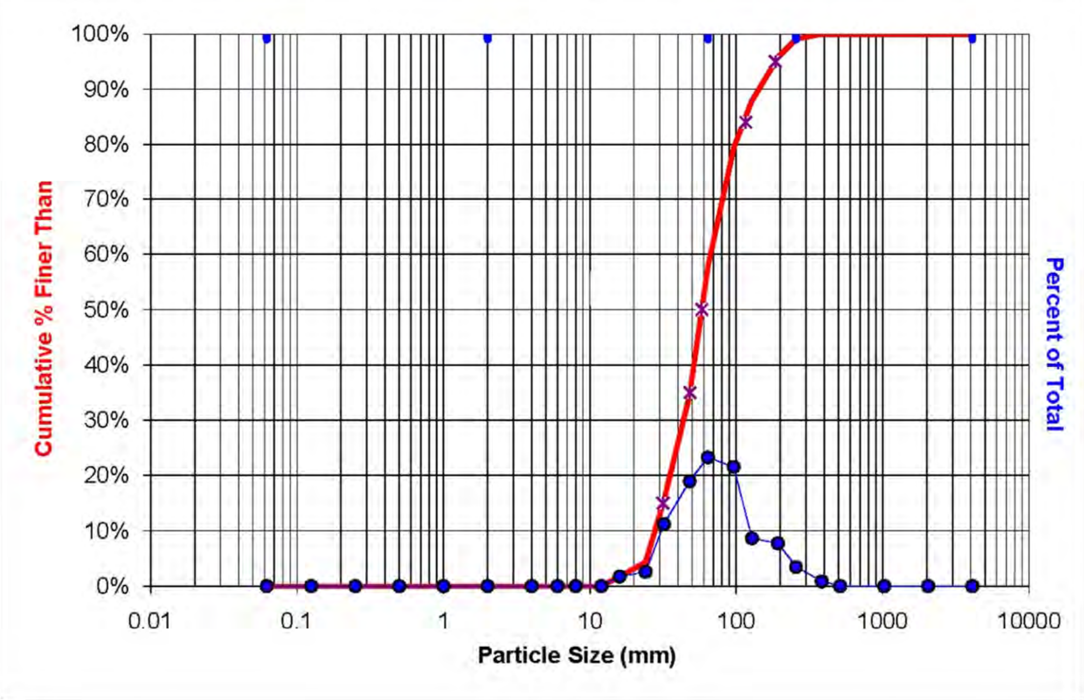
Particle Size (mm)	% finer than	Total Count
<0.062	0%	0
0.062 - 0.125	0%	0
0.125 - 0.25	0%	0
0.25 - 0.5	0%	0
0.5 - 1.0	0%	0
1 - 2	0%	0
2 - 4	0%	0
4 - 6	0%	0
6 - 8	0%	0
8 - 12	0%	0
12 - 16	2%	2
16 - 24	4%	3
24 - 32	16%	13
32 - 48	34%	22
48 - 64	58%	27
64 - 96	79%	25
96 - 128	88%	10
128 - 192	96%	9
192 - 256	99%	4
256 - 384	100%	1
384 - 512	100%	0
512 - 1024	100%	0
1024 - 2048	100%	0
2048 - 4096	100%	0

COMMENTS: Sample W-2: Touchet River Downstream of Confluence

STREAM NAME: Touchet River
USGS # :
Reach: Touchet River Downstream of Confluence

DATE: 11/10/2010
CREW: JJF, JL

Particle Size Distribution (mm)	D15	D35	D50	D85	D95
	31.6	48.3	58.1	116.1	185.2



Wolman Pebble Count
Sample W-2

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure B-5

Pebble Count Worksheet

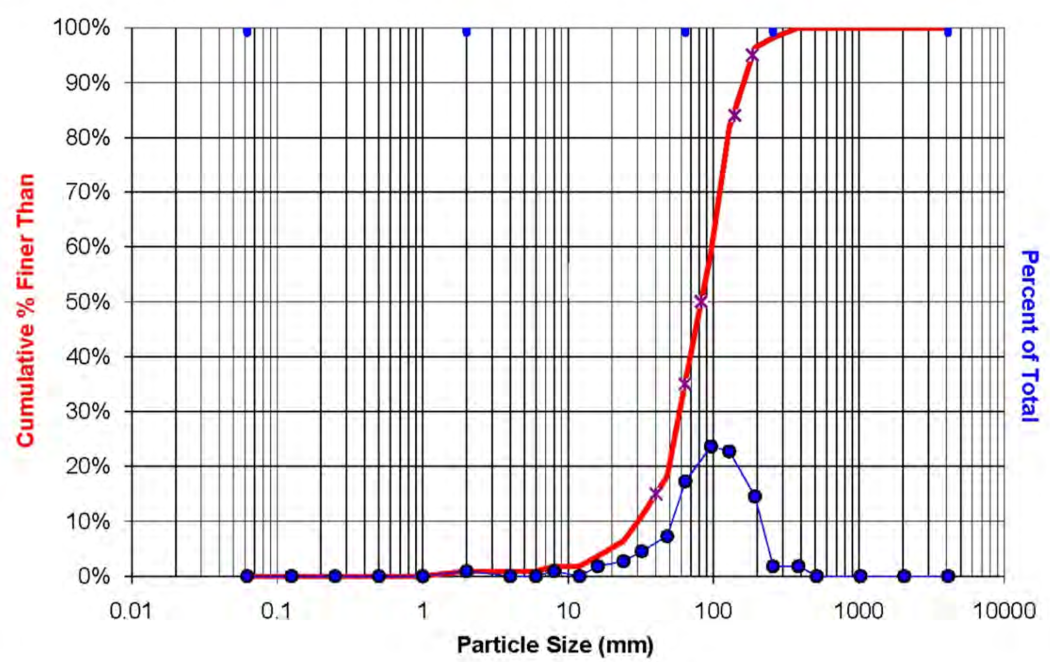
Particle Size (mm)	% finer than	Total Count
<0.062	0%	0
0.062 - 0.125	0%	0
0.125 - 0.25	0%	0
0.25 - 0.5	0%	0
0.5 - 1.0	0%	0
1 - 2	1%	1
2 - 4	1%	0
4 - 6	1%	0
6 - 8	2%	1
8 - 12	2%	0
12 - 16	4%	2
16 - 24	6%	3
24 - 32	11%	5
32 - 48	18%	8
48 - 64	35%	19
64 - 96	59%	26
96 - 128	82%	25
128 - 192	96%	16
192 - 256	98%	2
256 - 384	100%	2
384 - 512	100%	0
512 - 1024	100%	0
1024 - 2048	100%	0
2048 - 4096	100%	0

COMMENTS: Sample W-3: 225' Upstream of Confluence on North Fork

STREAM NAME: North Fork Touchet
USGS # :
Reach: 225' US Confluence N. Fork Touchet

DATE: 11/10/2010
CREW: JJF, JL

Particle Size Distribution (mm)	D15	D35	D50	D85	D95
	40.2	63.5	82.1	139.9	184.8



Wolman Pebble Count
Sample W-3

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure B-6

Pebble Count Worksheet

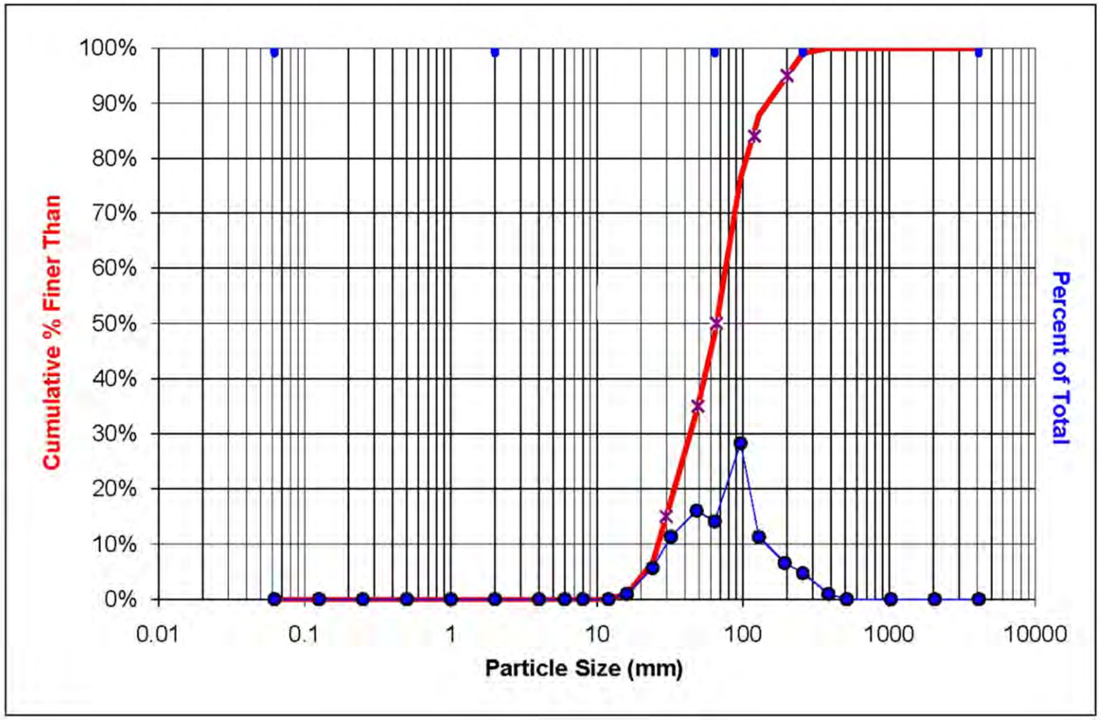
Particle Size (mm)	% finer than	Total Count
<0.062	0%	0
0.062 - 0.125	0%	0
0.125 - 0.25	0%	0
0.25 - 0.5	0%	0
0.5 - 1.0	0%	0
1 - 2	0%	0
2 - 4	0%	0
4 - 6	0%	0
6 - 8	0%	0
8 - 12	0%	0
12 - 16	1%	1
16 - 24	7%	6
24 - 32	18%	12
32 - 48	34%	17
48 - 64	48%	15
64 - 96	76%	30
96 - 128	88%	12
128 - 192	94%	7
192 - 256	99%	5
256 - 384	100%	1
384 - 512	100%	0
512 - 1024	100%	0
1024 - 2048	100%	0
2048 - 4096	100%	0

COMMENTS: Sample W-4: Upstream of bedrock contact point on North Fork Touchet

STREAM NAME: Touchet River
USGS # :
Reach: US levee/diversion US/bedrock

DATE: 11/10/2010
CREW: JJF, JL

Particle Size Distribution (mm)	D15	D35	D50	D85	D95
	29.7	49.0	65.8	119.4	199.9



Wolman Pebble Count
Sample W-4

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure B-7

Pebble Count Worksheet

Particle Size (mm)	% finer than	Total Count
<0.062	0%	0
0.062 - 0.125	0%	0
0.125 - 0.25	0%	0
0.25 - 0.5	0%	0
0.5 - 1.0	0%	0
1 - 2	0%	0
2 - 4	0%	0
4 - 6	0%	0
6 - 8	0%	0
8 - 12	0%	0
12 - 16	2%	2
16 - 24	4%	3
24 - 32	8%	4
32 - 48	25%	20
48 - 64	36%	14
64 - 96	58%	25
96 - 128	78%	24
128 - 192	92%	17
192 - 256	97%	6
256 - 384	99%	2
384 - 512	100%	1
512 - 1024	100%	0
1024 - 2048	100%	0
2048 - 4096	100%	0

COMMENTS: Sample W-5: Downstream of South Fork Touchet Rd. on North Fork Touchet

STREAM NAME: North Fork Touchet River

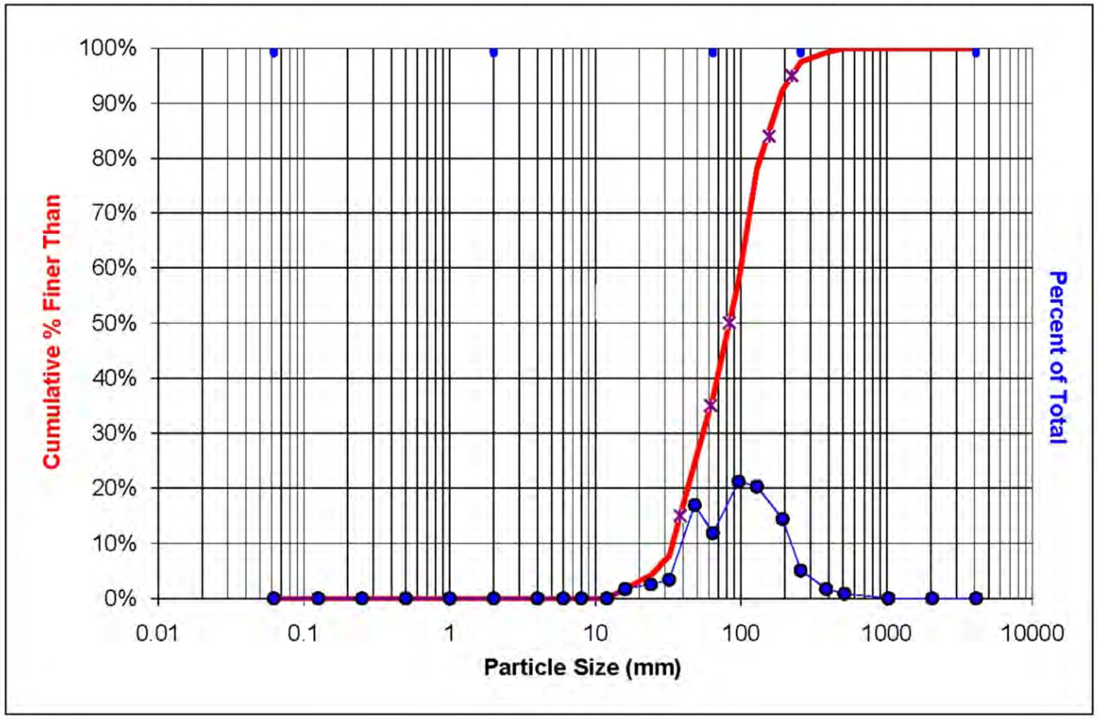
DATE: 11/10/2010

USGS # :

CREW: JJF, JL

Reach: N. Fork 200' DS of structures US of RW RB

Particle Size Distribution (mm)	**D15**	**D35**	**D50**	**D85**	**D95**
	38.2	**61.8**	**83.0**	**156.0**	**222.8**



Wolman Pebble Count
Sample W-5

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure B-8

Pebble Count Worksheet

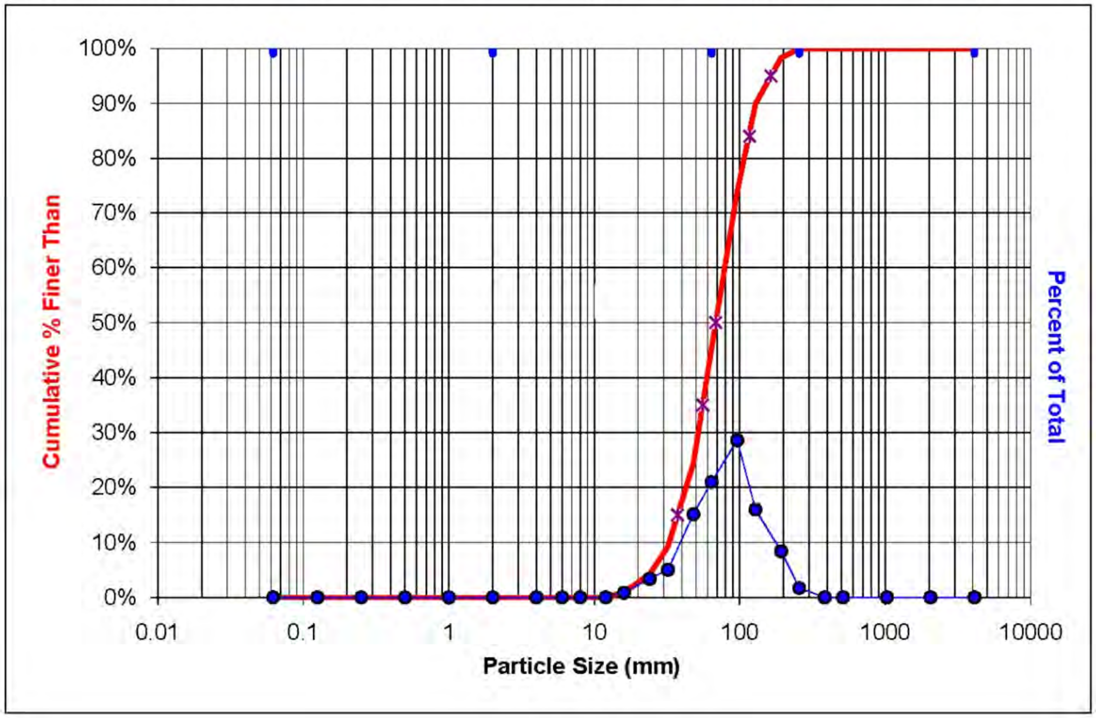
Particle Size (mm)	% finer than	Total Count
<0.062	0%	0
0.062 - 0.125	0%	0
0.125 - 0.25	0%	0
0.25 - 0.5	0%	0
0.5 - 1.0	0%	0
1 - 2	0%	0
2 - 4	0%	0
4 - 6	0%	0
6 - 8	0%	0
8 - 12	0%	0
12 - 16	1%	1
16 - 24	4%	4
24 - 32	9%	6
32 - 48	24%	18
48 - 64	45%	25
64 - 96	74%	34
96 - 128	90%	19
128 - 192	98%	10
192 - 256	100%	2
256 - 384	100%	0
384 - 512	100%	0
512 - 1024	100%	0
1024 - 2048	100%	0
2048 - 4096	100%	0

COMMENTS: Sample W-6: 200' US of S. Fork Touchet Rd. on the North Fork Touchet

STREAM NAME: North Fork Touchet River
USGS # :
Reach: 200' US of Bridge N. Fork

DATE: 11/10/2010
CREW: JJF, JL

Particle Size Distribution (mm)	D15	D35	D50	D85	D95
	37.3	55.5	68.3	117.1	163.6



Wolman Pebble Count
Sample W-6

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure B-9

Pebble Count Worksheet

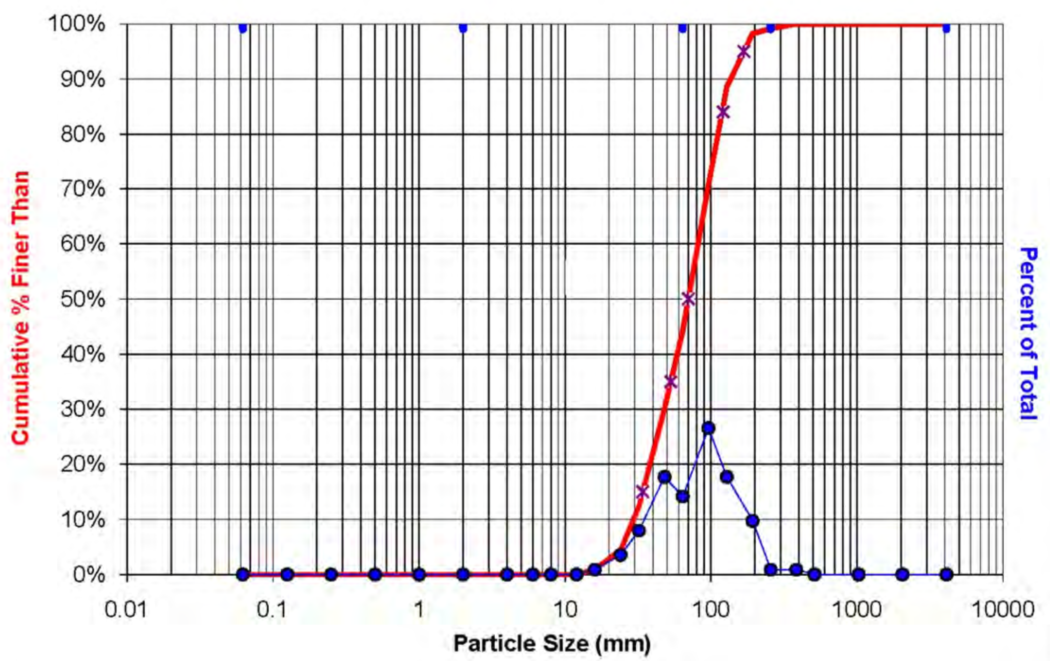
Particle Size (mm)	% finer than	Total Count
<0.062	0%	0
0.062 - 0.125	0%	0
0.125 - 0.25	0%	0
0.25 - 0.5	0%	0
0.5 - 1.0	0%	0
1 - 2	0%	0
2 - 4	0%	0
4 - 6	0%	0
6 - 8	0%	0
8 - 12	0%	0
12 - 16	1%	1
16 - 24	4%	4
24 - 32	12%	9
32 - 48	30%	20
48 - 64	44%	16
64 - 96	71%	30
96 - 128	88%	20
128 - 192	98%	11
192 - 256	99%	1
256 - 384	100%	1
384 - 512	100%	0
512 - 1024	100%	0
1024 - 2048	100%	0
2048 - 4096	100%	0

COMMENTS: Sample W-7

STREAM NAME: North Fork Touchet River
USGS # :
Reach: US of bend left and 1st levee on right Bank

DATE: 11/10/2010
CREW: JJF, JL

Particle Size Distribution (mm)	D15	D35	D50	D85	D95
	34.0	53.0	69.9	120.9	167.8



Wolman Pebble Count
Sample W-7

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure B-10**

Pebble Count Worksheet

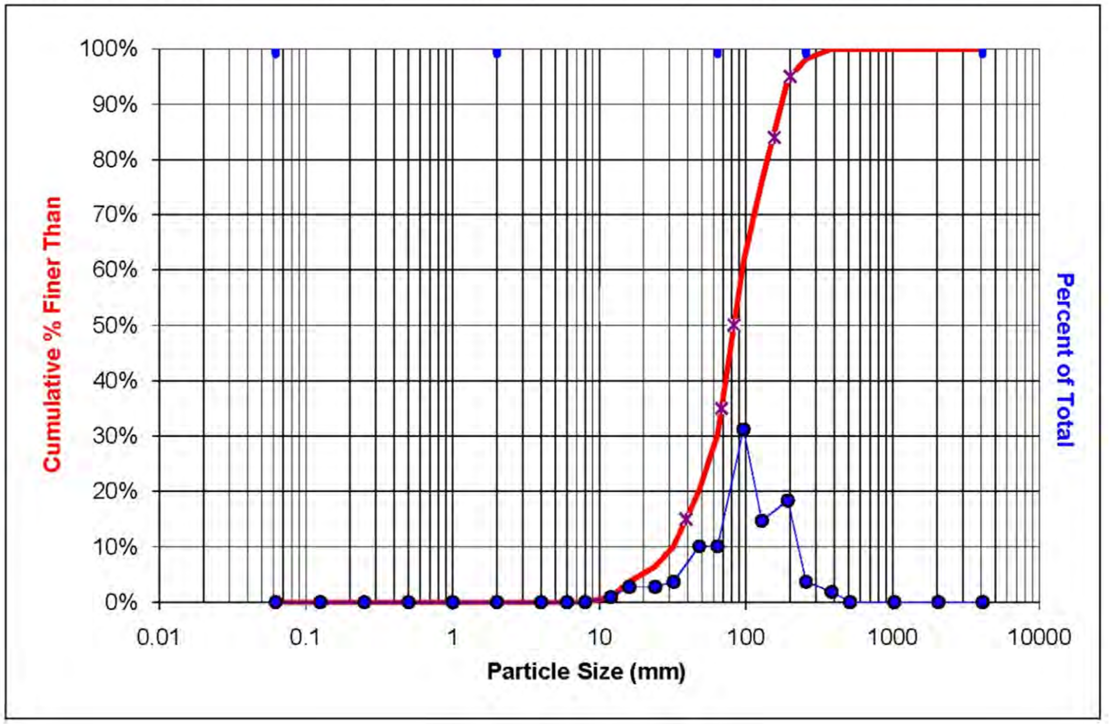
Particle Size (mm)	% finer than	Total Count
<0.062	0%	0
0.062 - 0.125	0%	0
0.125 - 0.25	0%	0
0.25 - 0.5	0%	0
0.5 - 1.0	0%	0
1 - 2	0%	0
2 - 4	0%	0
4 - 6	0%	0
6 - 8	0%	0
8 - 12	1%	1
12 - 16	4%	3
16 - 24	6%	3
24 - 32	10%	4
32 - 48	20%	11
48 - 64	30%	11
64 - 96	61%	34
96 - 128	76%	16
128 - 192	94%	20
192 - 256	98%	4
256 - 384	100%	2
384 - 512	100%	0
512 - 1024	100%	0
1024 - 2048	100%	0
2048 - 4096	100%	0

COMMENTS: Sample W-8: Near bank erosion on left bank North Fork Touchet

STREAM NAME: North Fork Touchet River
USGS # :
Reach: US of BS-3 and BS-4 N. Fork Touchet

DATE: 11/10/2010
CREW: JJF, JL

Particle Size Distribution (mm)	D15	D35	D50	D85	D95
	39.0	68.1	82.7	155.7	199.7



Wolman Pebble Count
Sample W-8

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure B-11

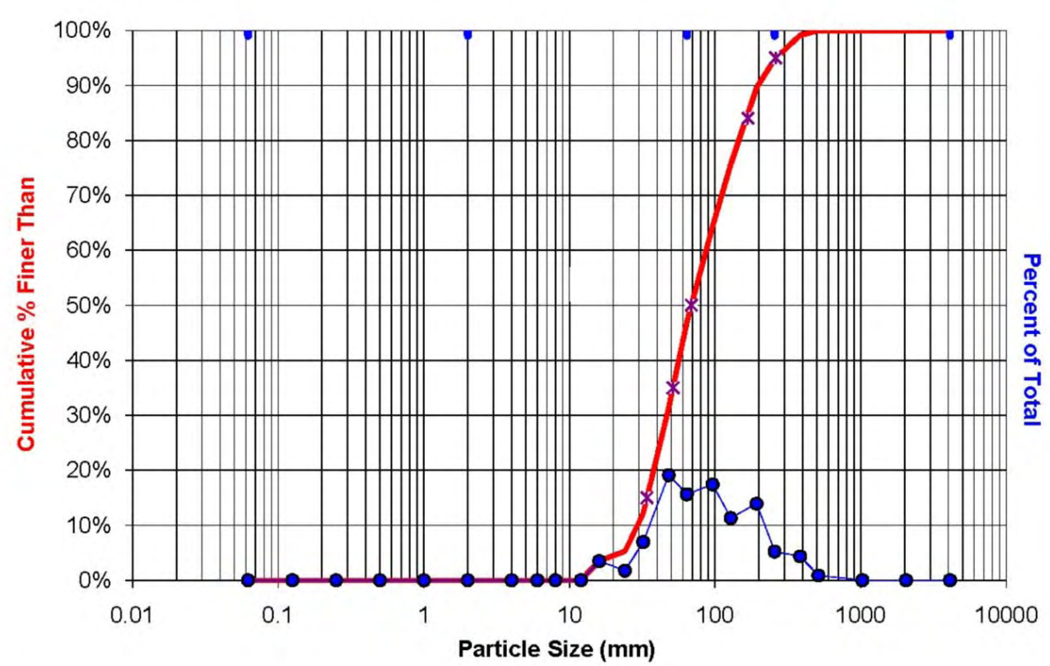
Pebble Count Worksheet

Particle Size (mm)	% finer than	Total Count
<0.062	0%	0
0.062 - 0.125	0%	0
0.125 - 0.25	0%	0
0.25 - 0.5	0%	0
0.5 - 1.0	0%	0
1 - 2	0%	0
2 - 4	0%	0
4 - 6	0%	0
6 - 8	0%	0
8 - 12	0%	0
12 - 16	3%	4
16 - 24	5%	2
24 - 32	12%	8
32 - 48	31%	22
48 - 64	47%	18
64 - 96	64%	20
96 - 128	76%	13
128 - 192	90%	16
192 - 256	95%	6
256 - 384	99%	5
384 - 512	100%	1
512 - 1024	100%	0
1024 - 2048	100%	0
2048 - 4096	100%	0

COMMENTS: Sample W-9: 200' DS of US Bridge

STREAM NAME: North Fork Touchet River
DATE: 11/10/2010
USGS # :
CREW: JJF, JL
Reach: N. Fork Touchet River - Riffle Reach

Particle Size Distribution (mm)	D15	D35	D50	D85	D95
	34.0	51.4	68.7	168.1	261.2



Wolman Pebble Count
Sample W-9

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure B-12

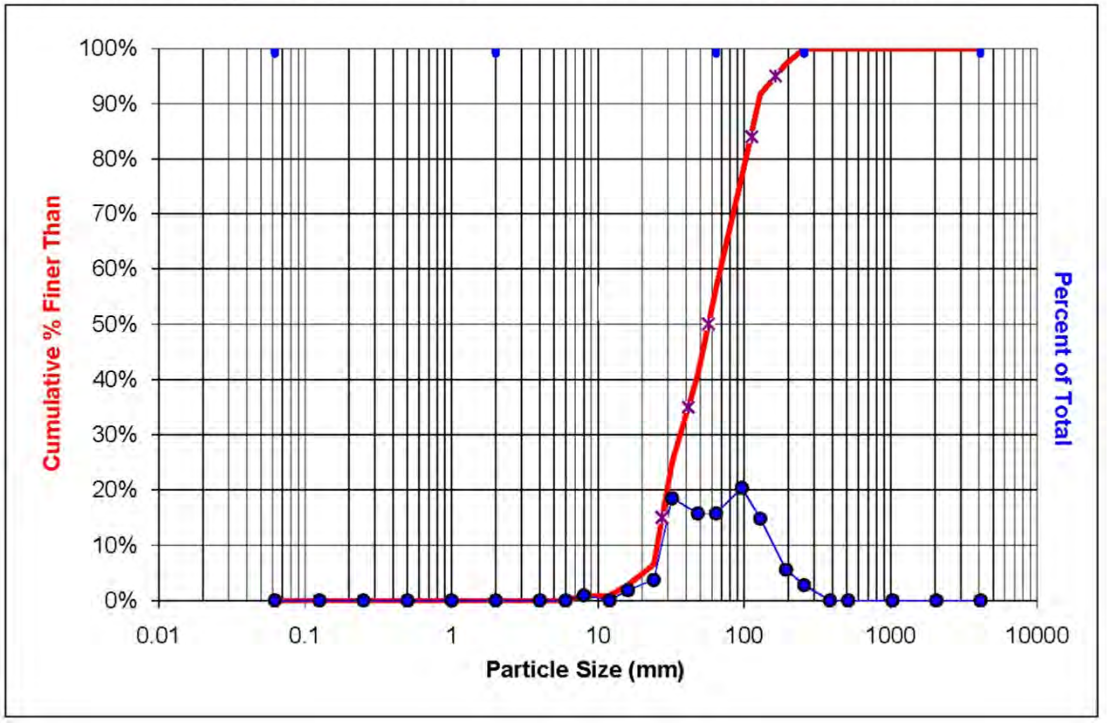
Pebble Count Worksheet

Particle Size (mm)	% finer than	Total Count
<0.062	0%	0
0.062 - 0.125	0%	0
0.125 - 0.25	0%	0
0.25 - 0.5	0%	0
0.5 - 1.0	0%	0
1 - 2	0%	0
2 - 4	0%	0
4 - 6	0%	0
6 - 8	1%	1
8 - 12	1%	0
12 - 16	3%	2
16 - 24	6%	4
24 - 32	25%	20
32 - 48	41%	17
48 - 64	56%	17
64 - 96	77%	22
96 - 128	92%	16
128 - 192	97%	6
192 - 256	100%	3
256 - 384	100%	0
384 - 512	100%	0
512 - 1024	100%	0
1024 - 2048	100%	0
2048 - 4096	100%	0

COMMENTS: Sample W-10: Upstream of Confluence on South Fork

STREAM NAME: South Fork Touchet River
DATE: 11/10/2010
USGS # :
CREW: JJF, JL
Reach: S. Fork US of Confluence

Particle Size Distribution (mm)	D15	D35	D50	D85	D95
	27.4	41.4	56.9	112.5	163.3



Wolman Pebble Count
Sample W-10

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure B-13

Pebble Count Worksheet

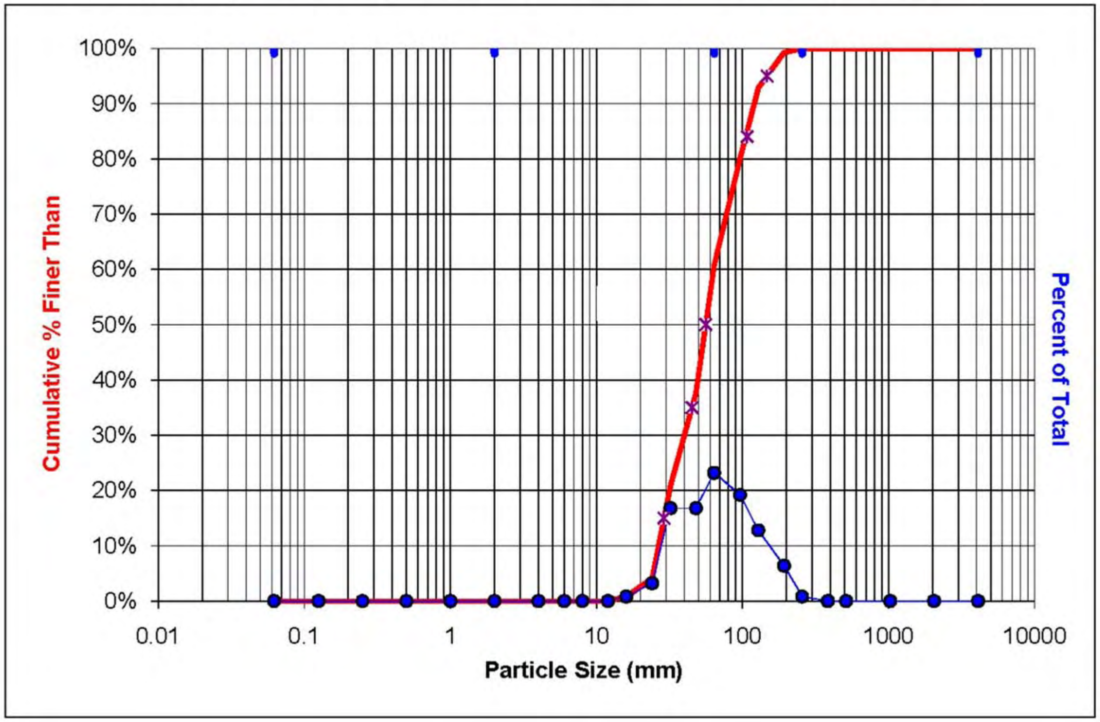
Particle Size (mm)	% finer than	Total Count
<0.062	0%	0
0.062 - 0.125	0%	0
0.125 - 0.25	0%	0
0.25 - 0.5	0%	0
0.5 - 1.0	0%	0
1 - 2	0%	0
2 - 4	0%	0
4 - 6	0%	0
6 - 8	0%	0
8 - 12	0%	0
12 - 16	1%	1
16 - 24	4%	4
24 - 32	21%	21
32 - 48	38%	21
48 - 64	61%	29
64 - 96	80%	24
96 - 128	93%	16
128 - 192	99%	8
192 - 256	100%	1
256 - 384	100%	0
384 - 512	100%	0
512 - 1024	100%	0
1024 - 2048	100%	0
2048 - 4096	100%	0

COMMENTS: Sample W-11: South Fork Touchet Typical Riffle

STREAM NAME: South Fork Touchet Riffle
USGS # :
Reach: South Fork Touchet Riffle

DATE: 11/10/2010
CREW: JJF, JL

Particle Size Distribution (mm)	D15	D35	D50	D85	D95
	29.0	45.1	56.0	107.4	147.1



Wolman Pebble Count
Sample W-11

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure B-14

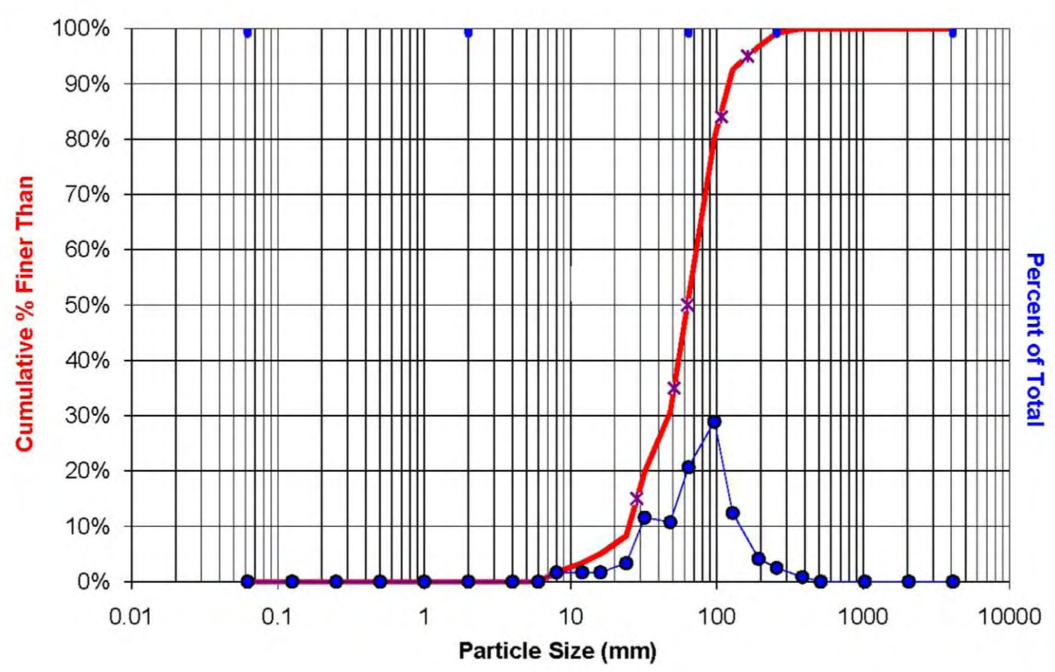
Pebble Count Worksheet

Particle Size (mm)	% finer than	Total Count
<0.062	0%	0
0.062 - 0.125	0%	0
0.125 - 0.25	0%	0
0.25 - 0.5	0%	0
0.5 - 1.0	0%	0
1 - 2	0%	0
2 - 4	0%	0
4 - 6	0%	0
6 - 8	2%	2
8 - 12	3%	2
12 - 16	5%	2
16 - 24	8%	4
24 - 32	20%	14
32 - 48	31%	13
48 - 64	51%	25
64 - 96	80%	35
96 - 128	93%	15
128 - 192	97%	5
192 - 256	99%	3
256 - 384	100%	1
384 - 512	100%	0
512 - 1024	100%	0
1024 - 2048	100%	0
2048 - 4096	100%	0

COMMENTS: Sample W-12: 500' Downstream of Project Boundary South Fork Touchet

STREAM NAME: South Fork Touchet River
DATE: 11/10/2010
USGS # :
CREW: JJF, JL
Reach: SF - 500' DS of Bridge

Particle Size Distribution (mm)	D15	D35	D50	D85	D95
	28.4	51.0	62.9	107.4	162.6



Wolman Pebble Count
Sample W-12

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure B-15

APPENDIX C
LiDAR Processing and GIS Data Development

APPENDIX C
LIDAR PROCESSING AND GIS DATA DEVELOPMENT

LiDAR Processing

A bare earth multi-point GIS feature class was generated from the All Return LAS LiDAR files using ArcGIS "LAS to Multipoint" tool. The multi-point data and LiDAR extent polygon dataset were imported into a file geodatabase. A terrain was created using the multi-point and extent data within the file geodatabase. The terrain was then converted to a digital elevation model (DEM) and a hillshade (shaded relief model) was generated from the DEM.

River Mile Convention

USGS river mile designations for the main stem Touchet River near the City of Dayton at RM 54 located north of Dayton Washington. To assist with descriptive locations relative to this report, each of the tributaries were divided into one mile-long segments (river miles) labeled as follows: main stem (TR), North Fork (NF), South Fork (SF), Wolf Fork (WF) and Robinson Fork (RF). For the main stem/North Fork RM TR54 = NF0. Each of the tributary forks begins at its' respective confluence (river mile "0") and progresses in ascending value upstream i.e. NF2, NF3 etc.

Gradient Calculations

Watershed-scale streambed channel gradients were calculated for the North, South, Wolf and Robinson Forks. The channel gradients were calculated beginning upstream from the USGS RM 53, located north of State Route (SR) 12 bridge in Dayton, Washington. Pertinent river location data was extracted from the USGS National Hydrography Dataset for the main stem and the North, South, Wolf and Robinson Fork tributaries. Points were identified for the upstream and downstream ends of each river mile segment and the point elevations calculated using the LiDAR or, where LiDAR was not available, a USGS 10 meter digital elevation model (DEM). The upstream and downstream elevations for each segment were entered into a Microsoft Excel workbook to calculate the segment gradients, which are summarized in Table 1 and shown graphically in Figures 4 through 7.

GIS Data Development

GIS data layers were obtained from several different data sources including Columbia County, SRSRB, DNR, Ecology, NRCS, FSA, USGS, USACE, BLM and ESRI. These GIS data layers were re-projected to a common coordinate system and added to the GIS.

Three types of GIS data were developed for the project: 1) digital rectified aerial photographs; 2) digitized channels and other features from aerial photographs; 3) LiDAR data, flown in March/April 2010 by Watershed Sciences for the City of Dayton and Confederated Tribes of the Umatilla Indian Reservation; and 4) GPS data obtained during the November stream reconnaissance. The GIS data development and analysis were completed using ESRI's ArcGIS version 10 software.

The aerial photographs were scanned and rectified to the 2010 orthophotography. Due to inherent distortions when rectifying older photographs to current orthophotography, our target Route Mean Square (RMS) error of all the control points was equal to or less than 20 feet. In some cases, only a portion of the photograph was rectified. Some aerial photographs were highly distorted. In these cases, the photograph was rectified with the lowest RMS error possible.

The development of GIS data included digitizing and attributing points, lines and polygons with critical information from scanned aerial photographs. Digitizing was completed at a scale of approximately 1:12,000 (or 1 inch = 1000 feet). Channel information was digitized into a GIS shape files, also referred to as GIS layers: for the historical channel migration zone (HMZ) and migration Potential Areas (MPAs).

Appendix D
Channel Forming Processes

APPENDIX D
CHANNEL FORMING PROCESSES

Channel Migration

In natural drainage systems, stream channels entering lower gradient reaches are seldom straight, except over short distances. Lower gradients usually encourage deposition of a portion of the sediment load in transport, which causes small to large changes in the flow patterns, often resulting in erosion along the outside bank of channel curves and bends. In a state of dynamic equilibrium, erosion and deposition occur simultaneously, and at more or less similar rates. As the outside bank erodes it recedes, further changing the course of the flow. Simultaneously, sediment deposition occurs along the inside bank of the bend. A result of this process is the lateral movement, or migration, of the channel across the flood plain.

The extent to which channels can migrate is highly dependent on the materials comprising the channel floor and banks. These materials may be grouped into three categories: bedrock, semi-controlled, and alluvial channels. Channels formed in bedrock, which is essentially erosion resistant, are defined as stable over time and do not change their position appreciably unless weaker (less resistant) bedrock sections are subject to erosion. Semi-controlled channels commonly have local controls that resist channel movement, such as bedrock outcrops. Channel sections without local erosion controls are more prone to erosion and migration. Alluvial channel banks and streambeds are composed of sediment previously transported and deposited by the stream. These deposits are usually highly prone to erosion and allow for higher rates of migration.

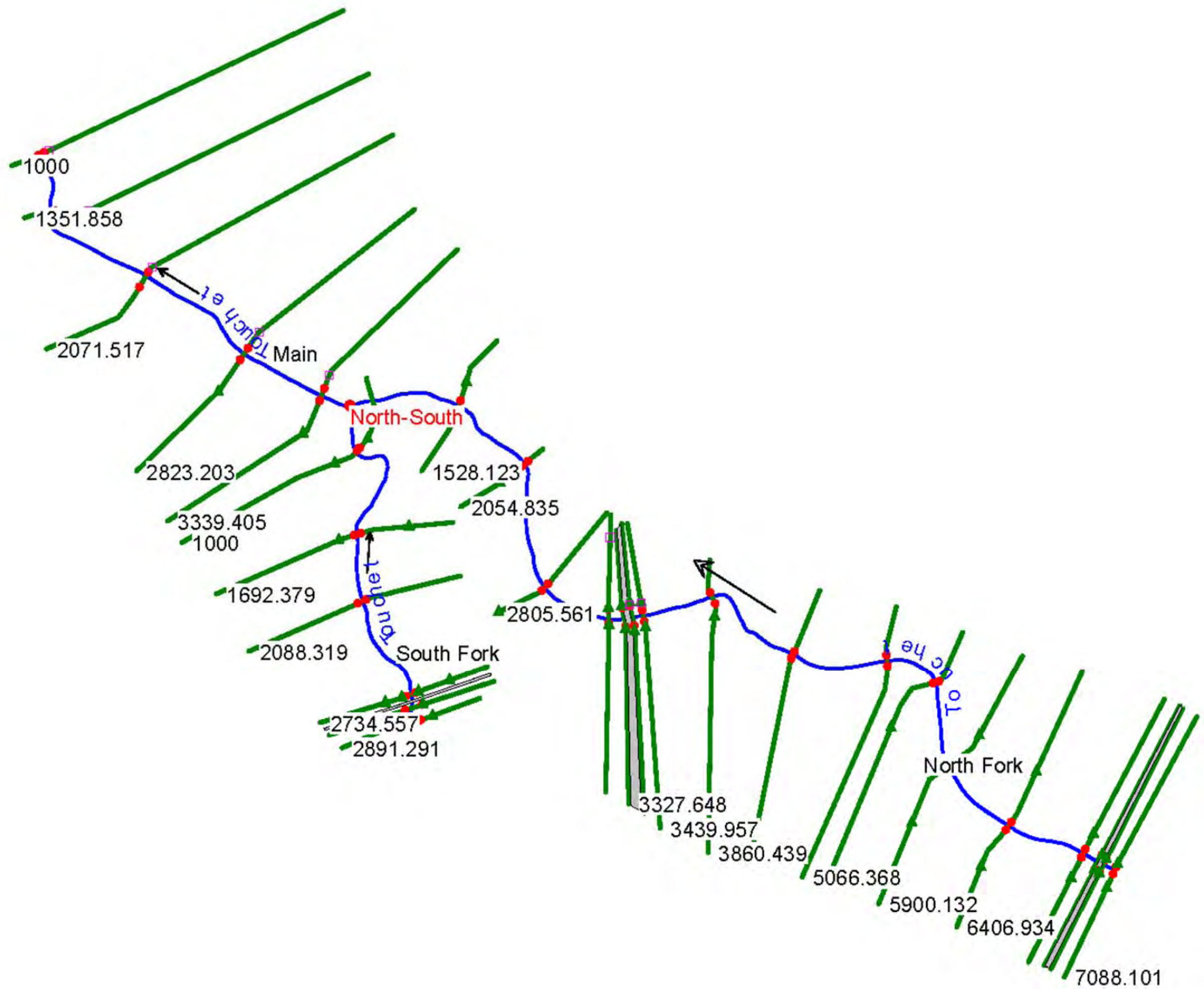
Types of Channel Migration

Two principle types of migration that occur most commonly in the Touchet River watershed include: meander bend migration of the main stem, low flow channel and avulsion.

Meander bend migration involves erosion of the outside bank of the river bend coupled with concurrent deposition of sediment along the inside bank of the bend. This process results in the lateral movement of the channel, while maintaining consistent channel shape and width. However, the area of most pronounced migration usually occurs where flow converges against the outer bank near the downstream end of a bend, resulting in both lateral and downstream migration of the bend.

Avulsion is the abrupt movement of an active channel to a new location in the river corridor. This process usually occurs in response to sudden deposition and infilling of the active channel by sediment or debris, causing the stream to erode a new channel or reoccupy a formerly abandoned channel. In the Touchet watershed, avulsion is most likely in reaches with multiple side channels, where the active channel may abruptly abandon its location for a pre-existing side channel within the high flow corridor or temporarily occupy a side channel during the event.

APPENDIX E
Hydraulic Model Excerpts

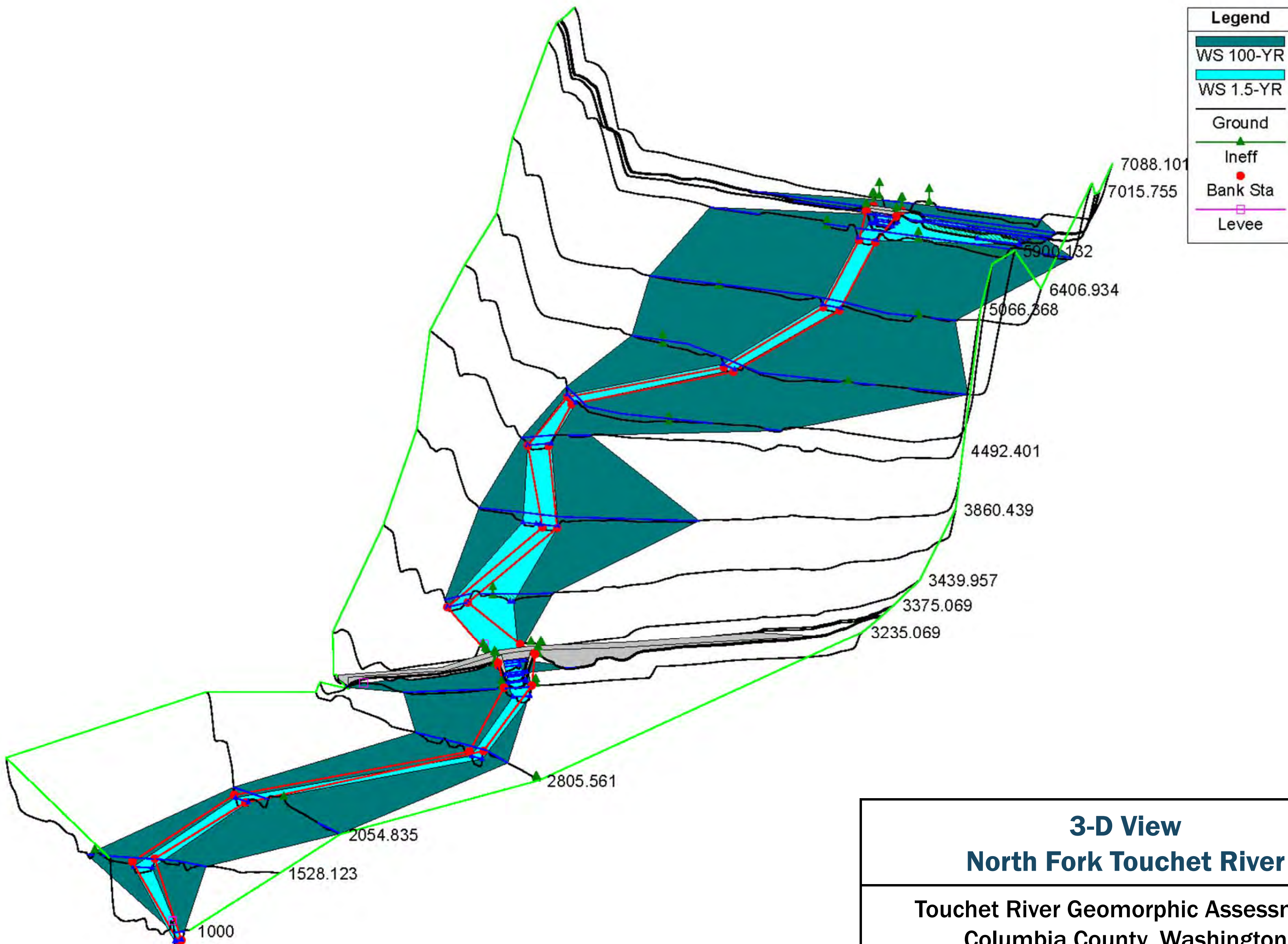


Plan View

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure E-1**

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0



Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

3-D View
North Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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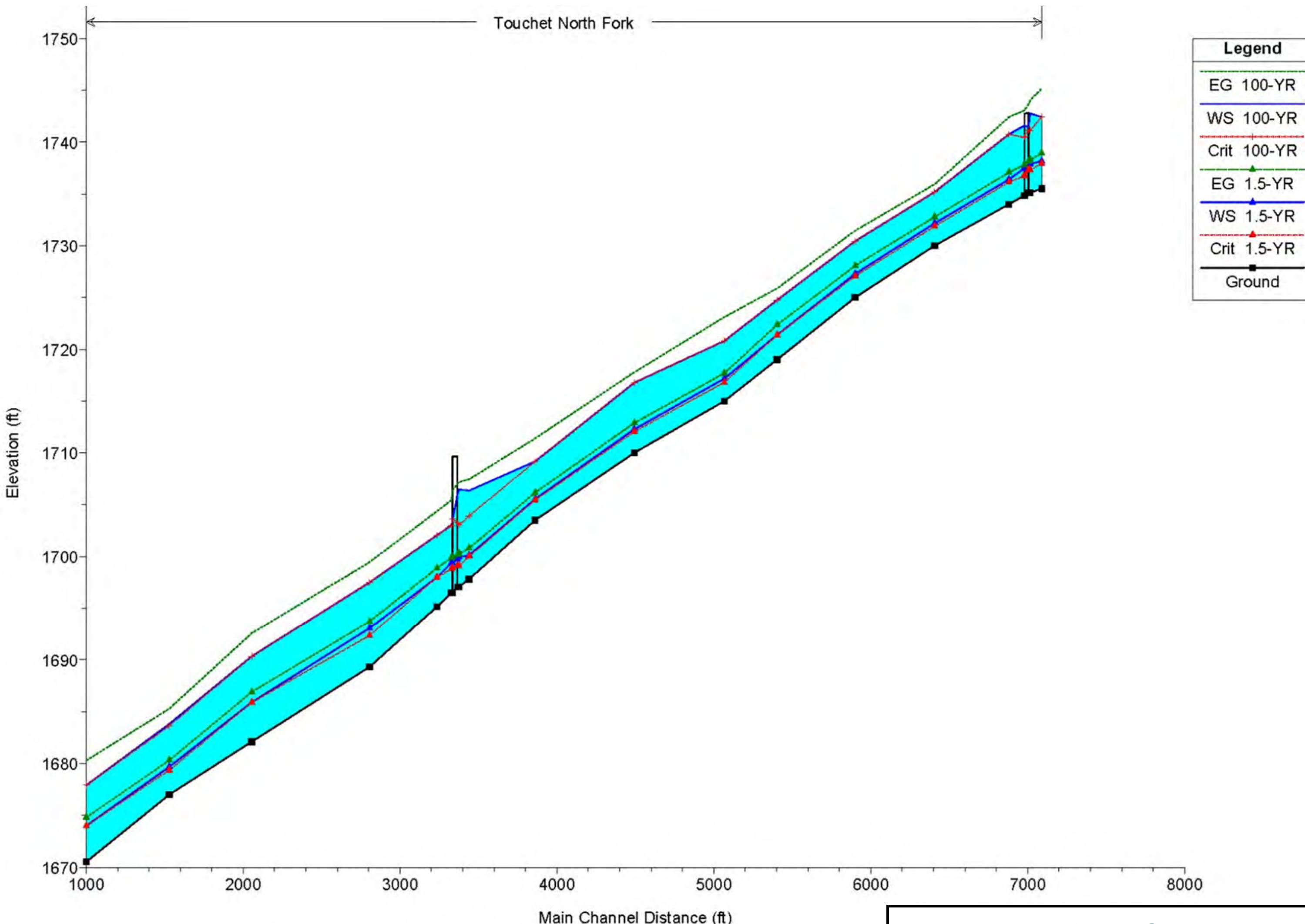
Figure E-2



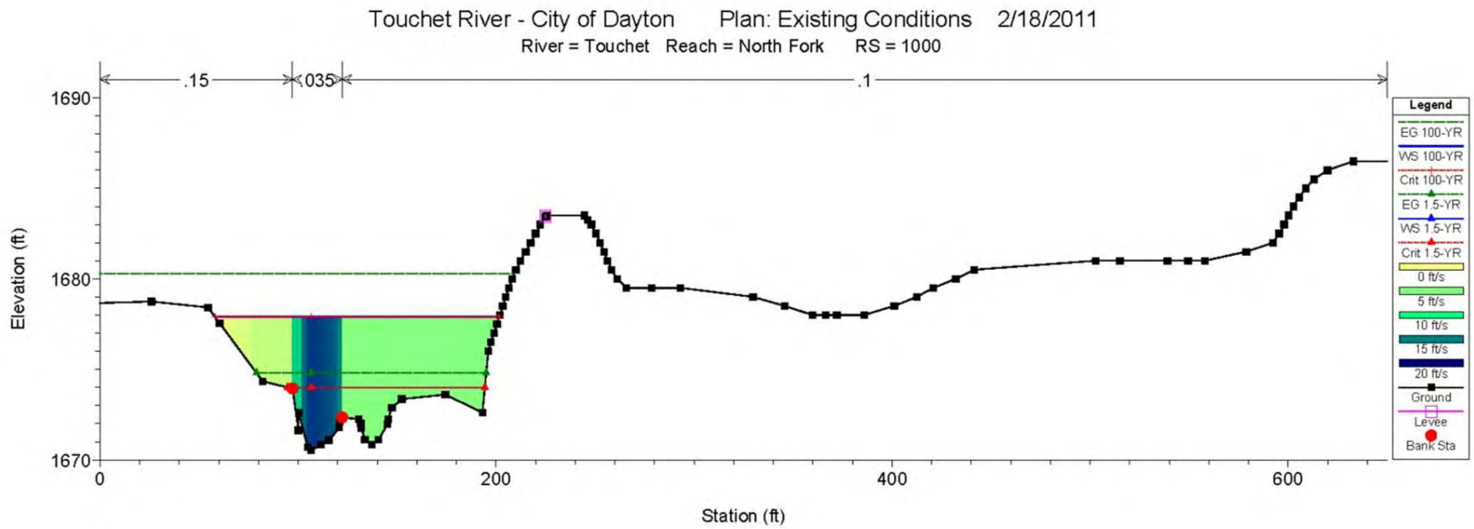
Profile View
North Fork Touchet River

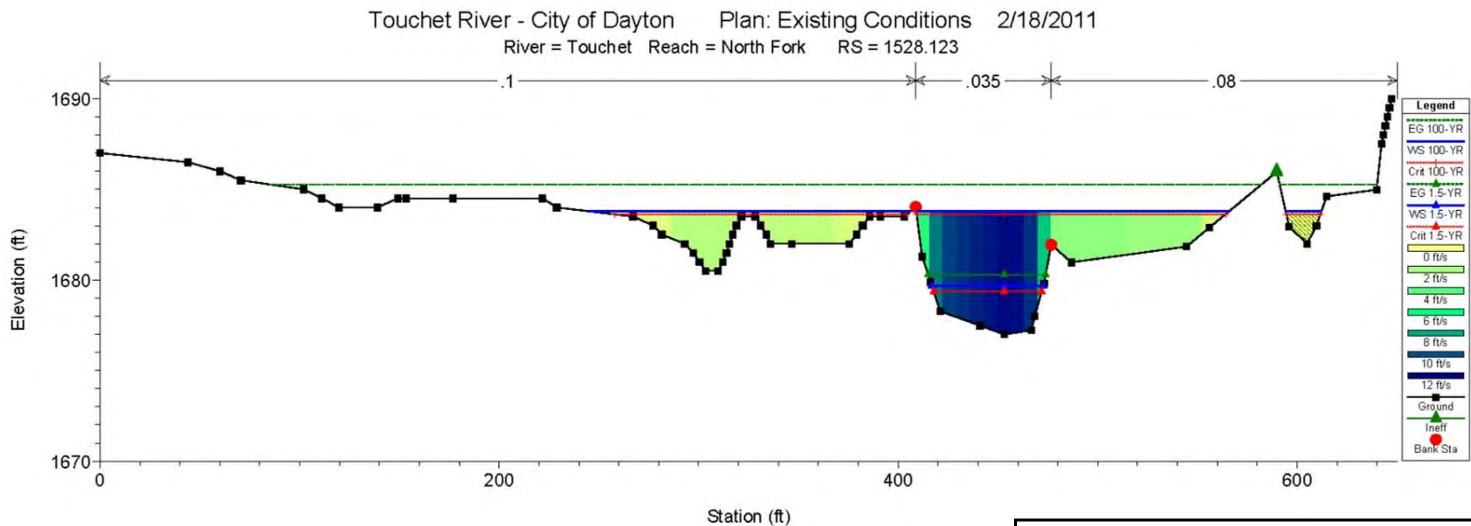
Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure E-3

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0





Cross Sections
North Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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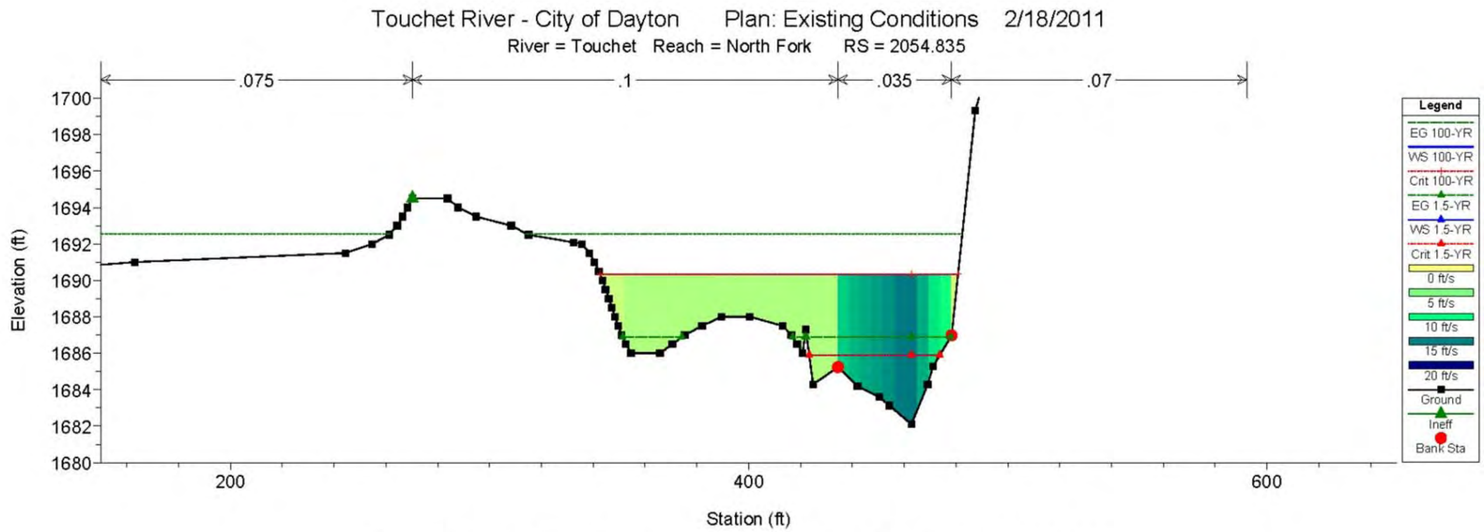
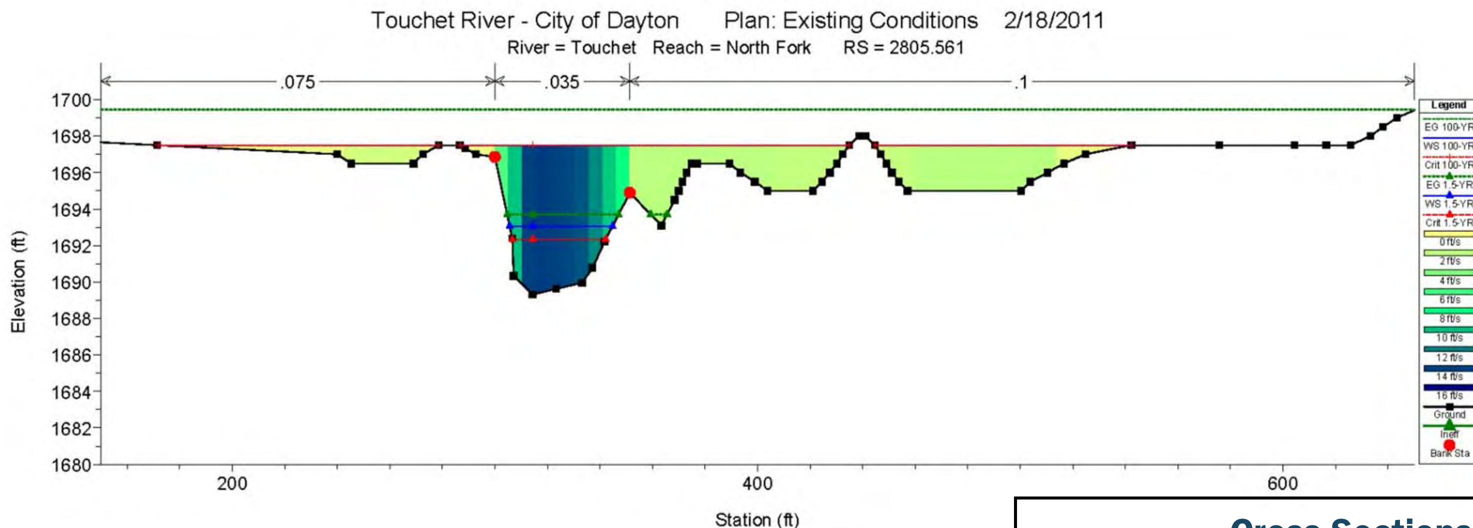
Figure E-4

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0





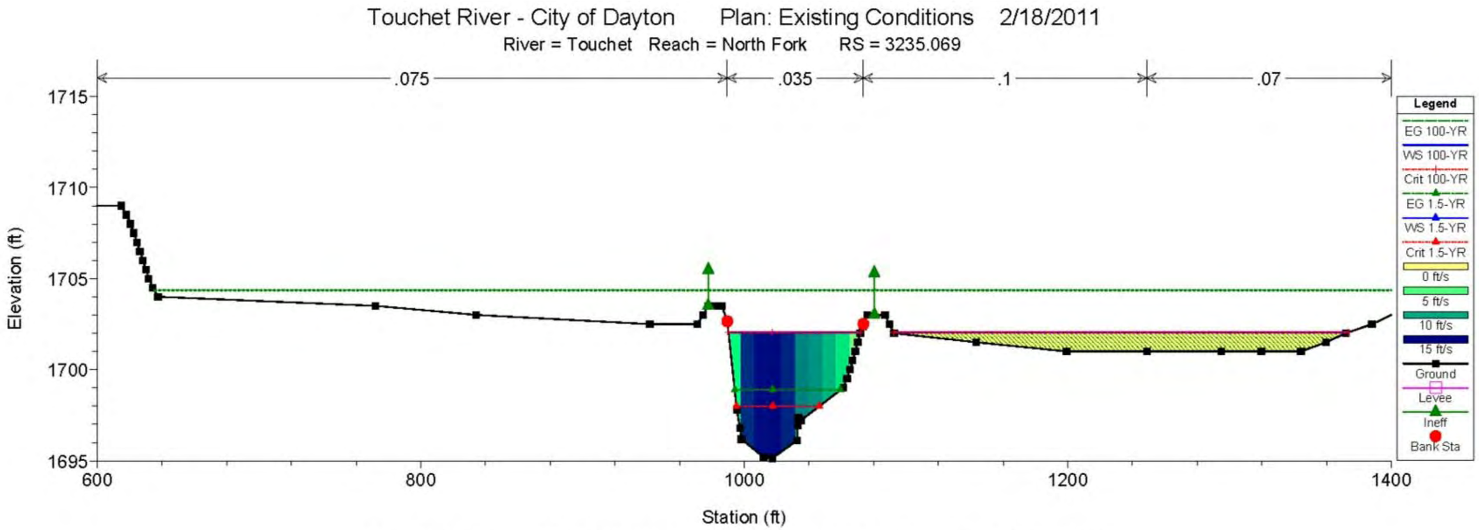
Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

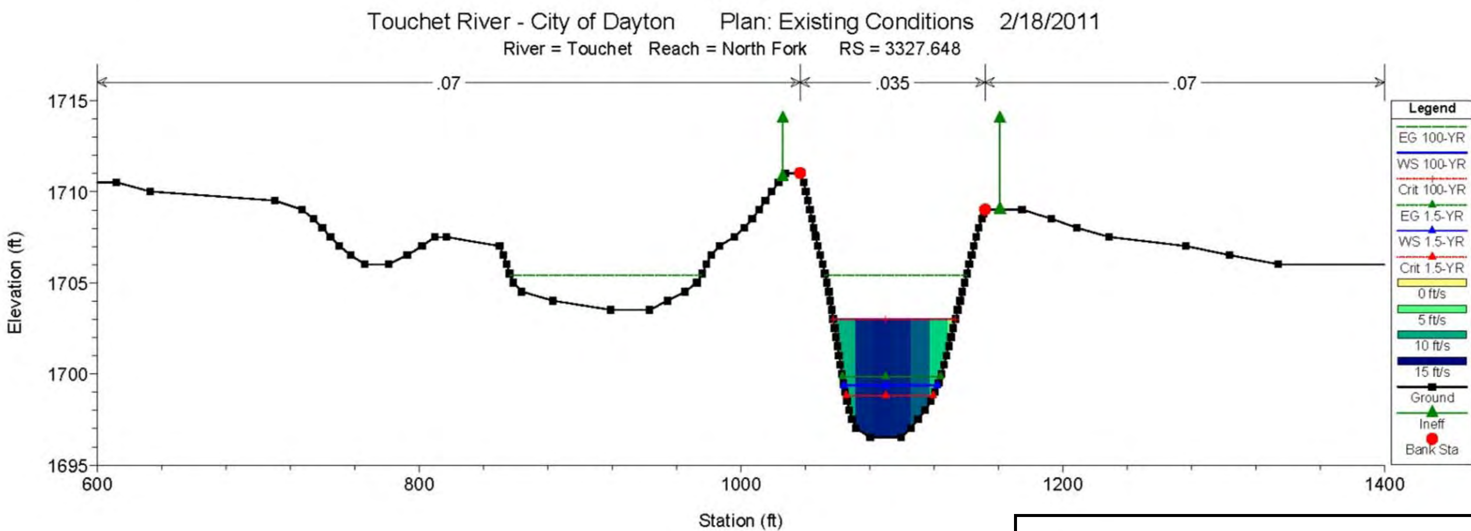
Cross Sections
North Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure E-5





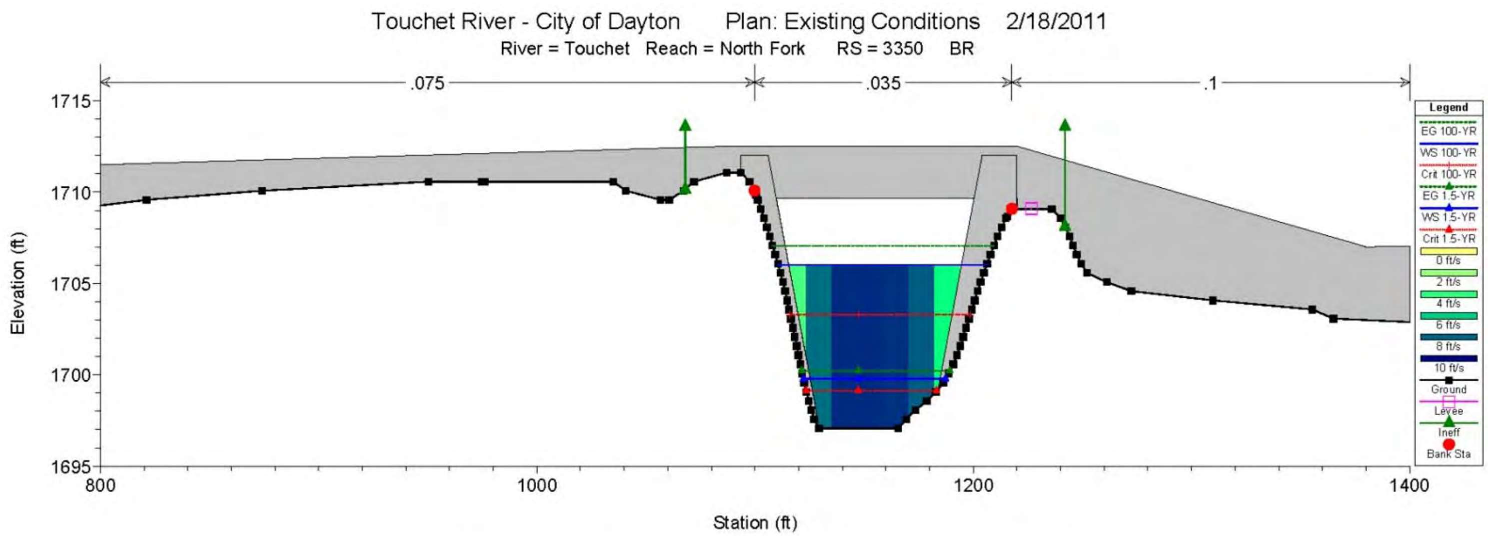
Cross Sections
North Fork Touchet River

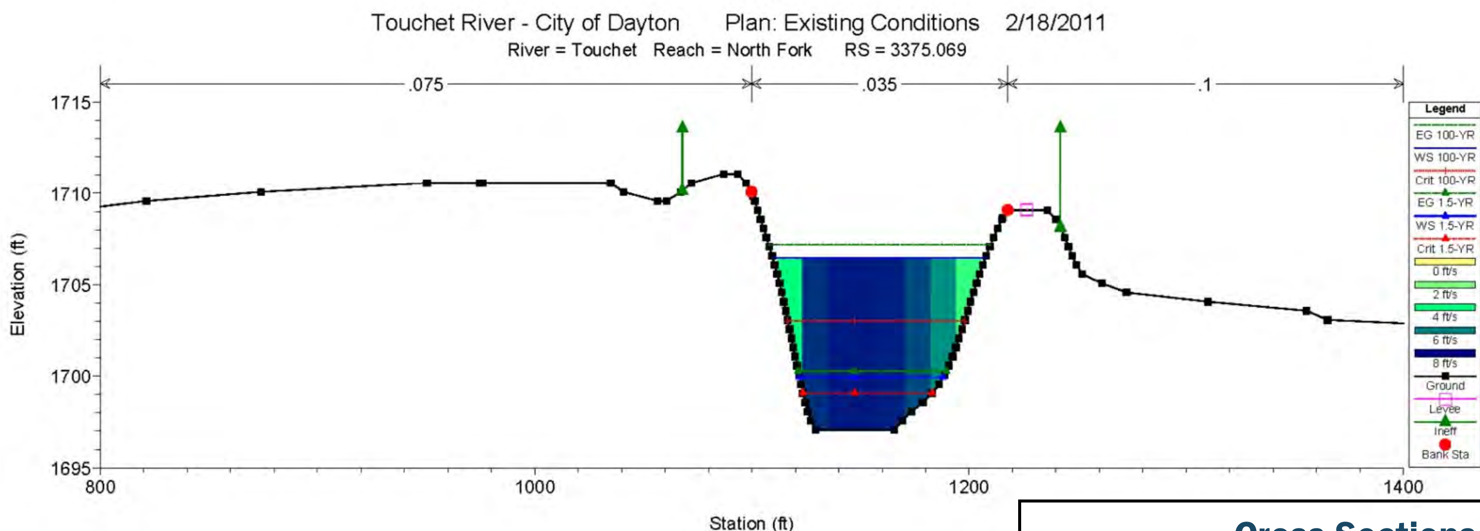
Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure E-6

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0





Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

Cross Sections
North Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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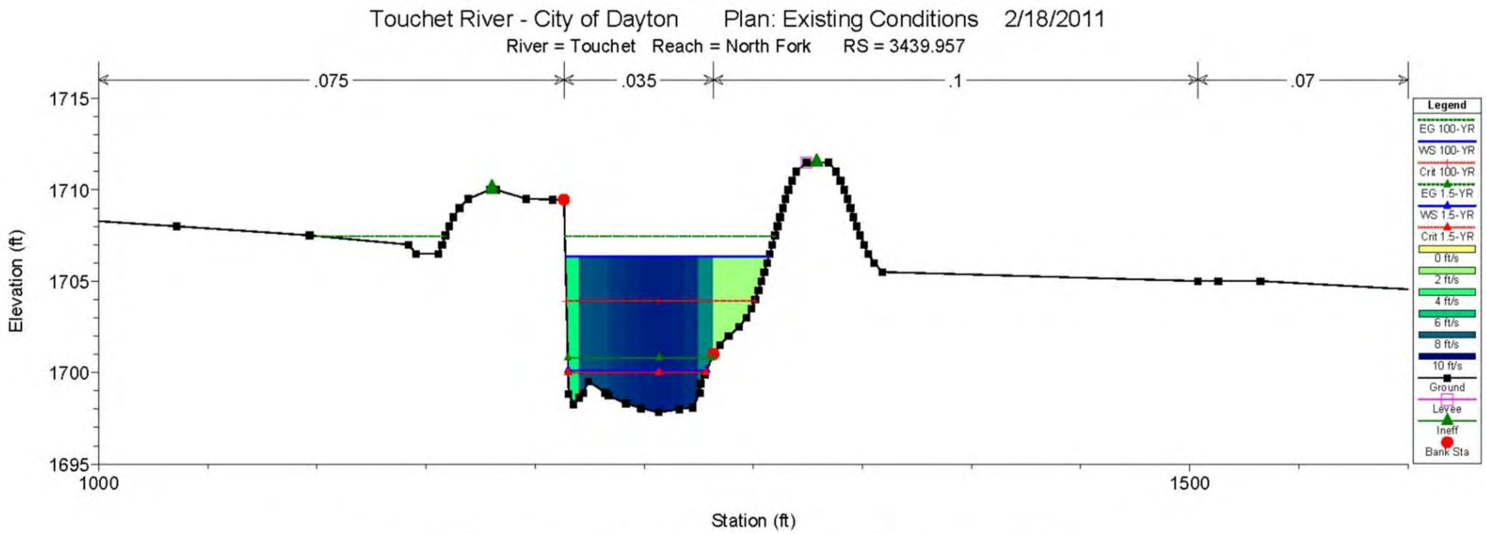
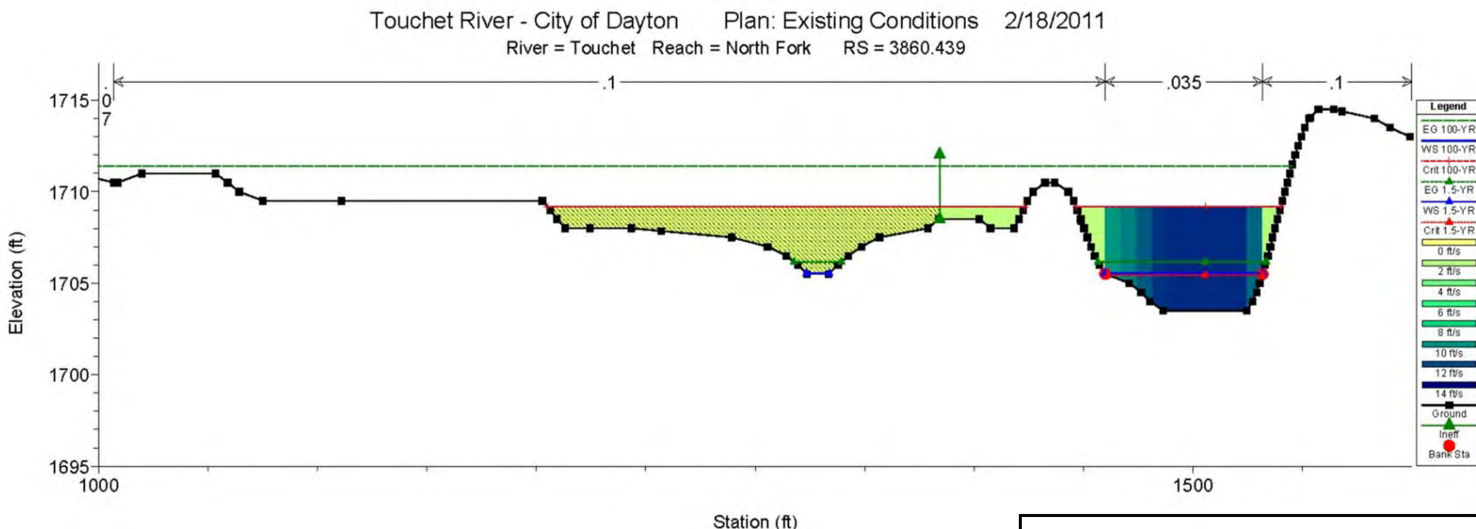
Figure E-7





Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

Cross Sections North Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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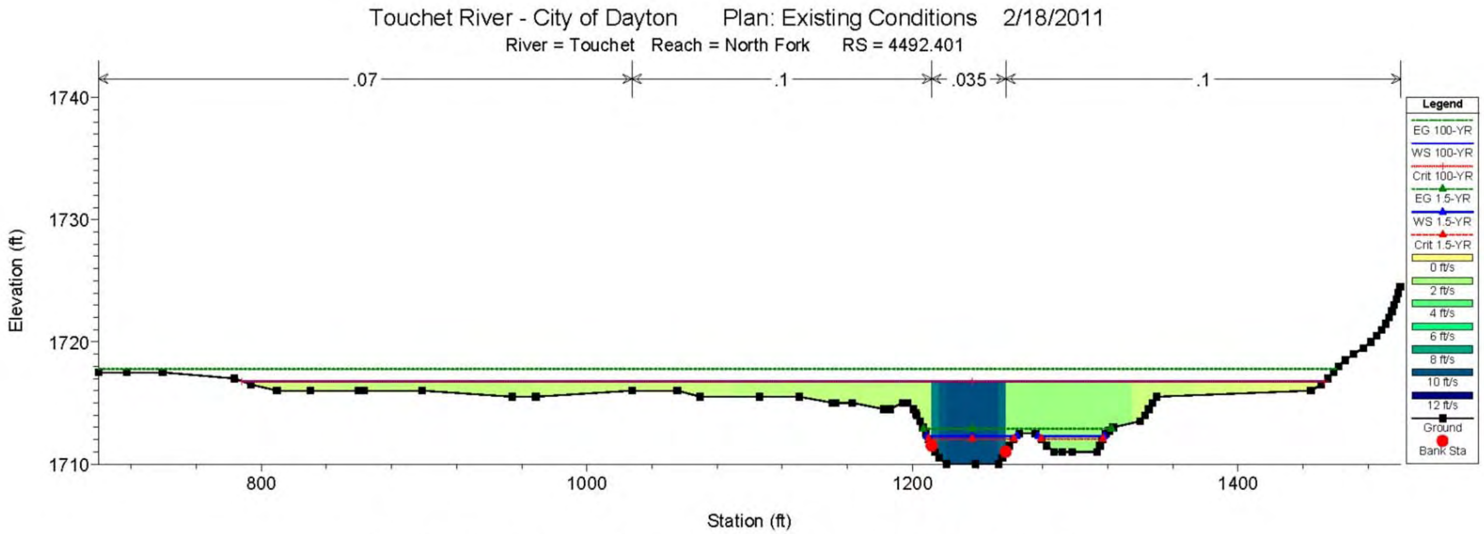
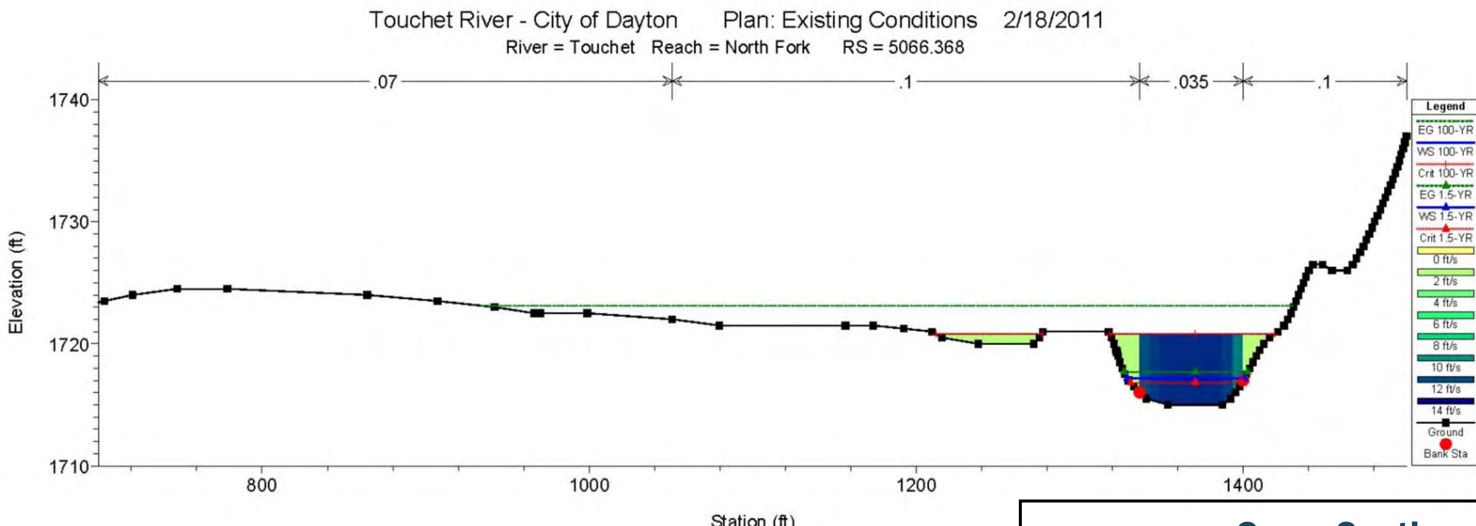
Figure E-8





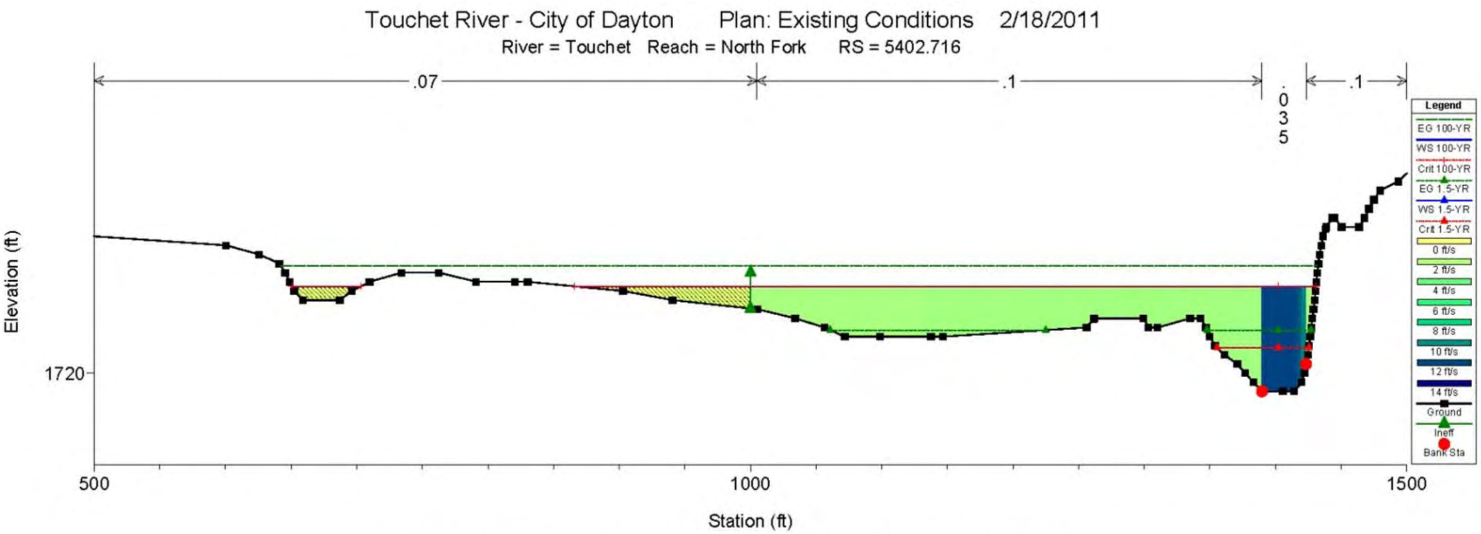
Cross Sections
North Fork Touchet River

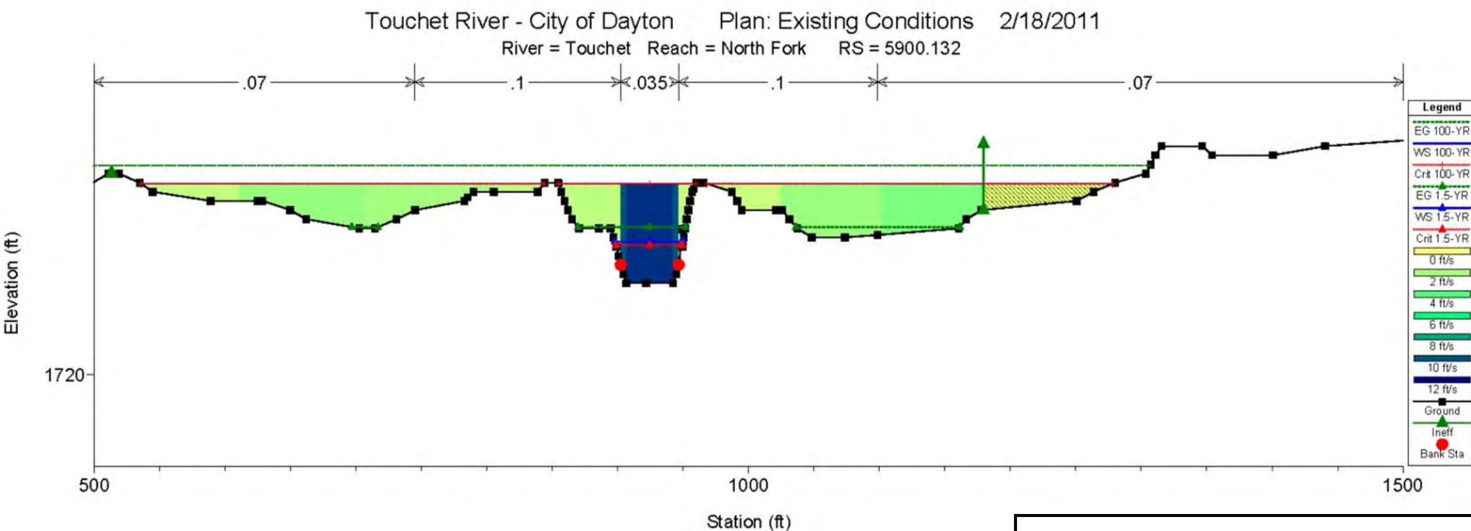
Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure E-9

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0





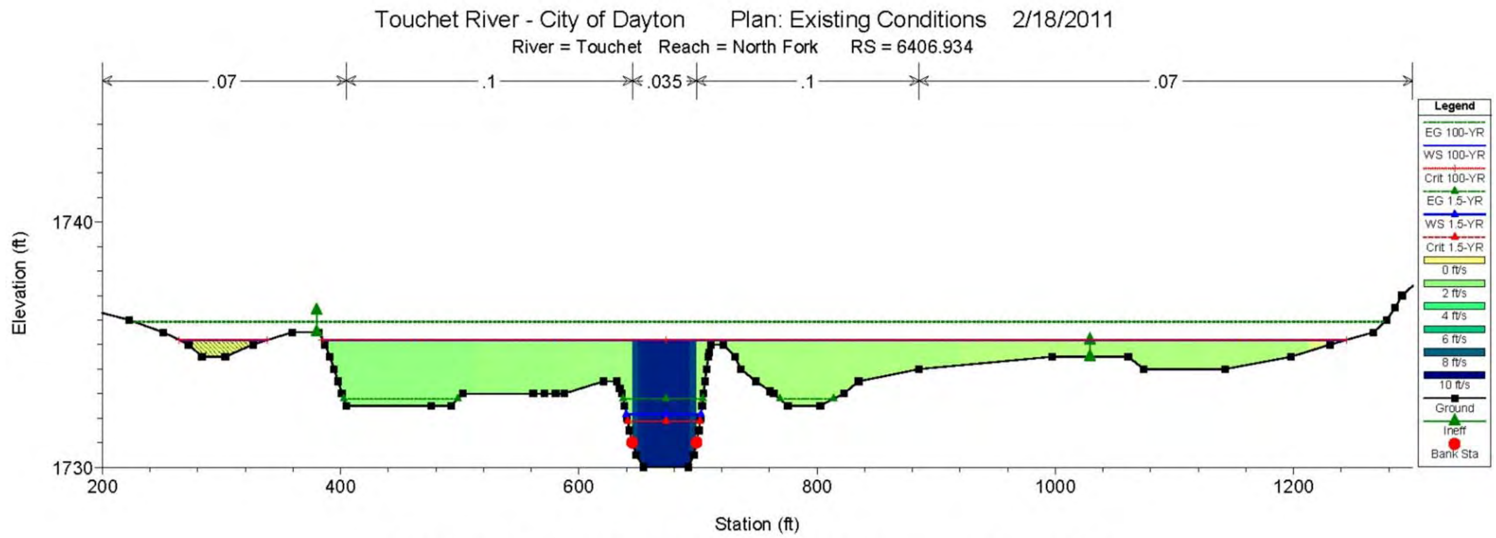
Cross Sections
North Fork Touchet River

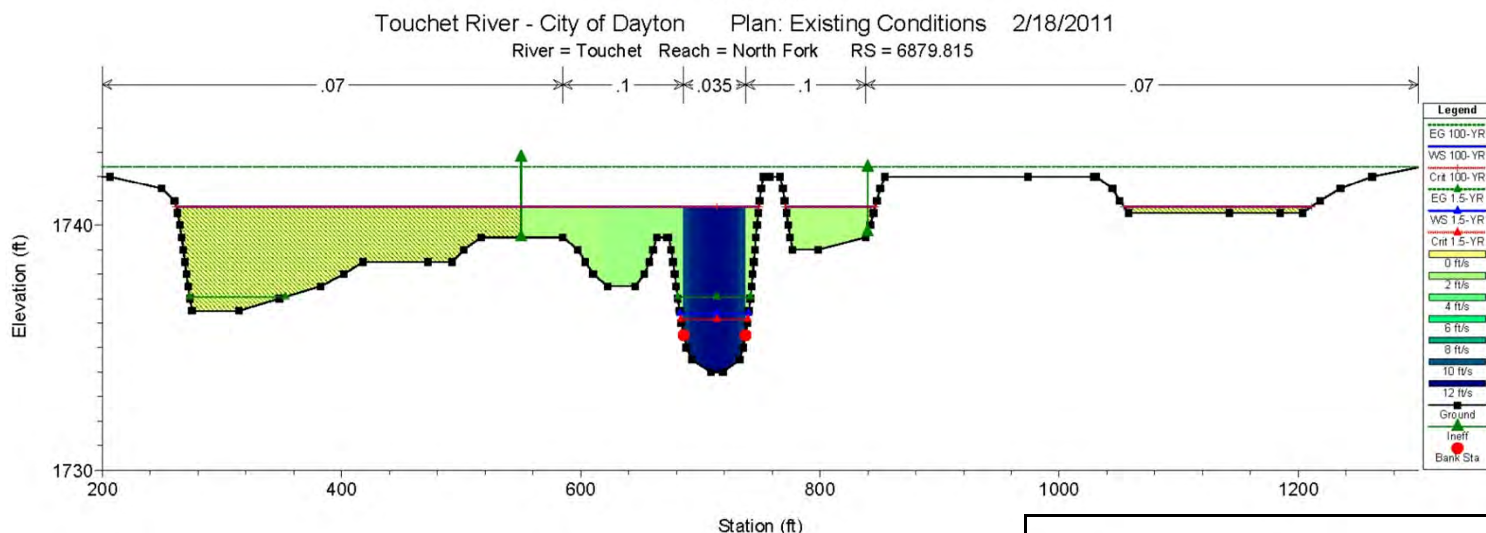
Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure E-10

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0





Cross Sections
North Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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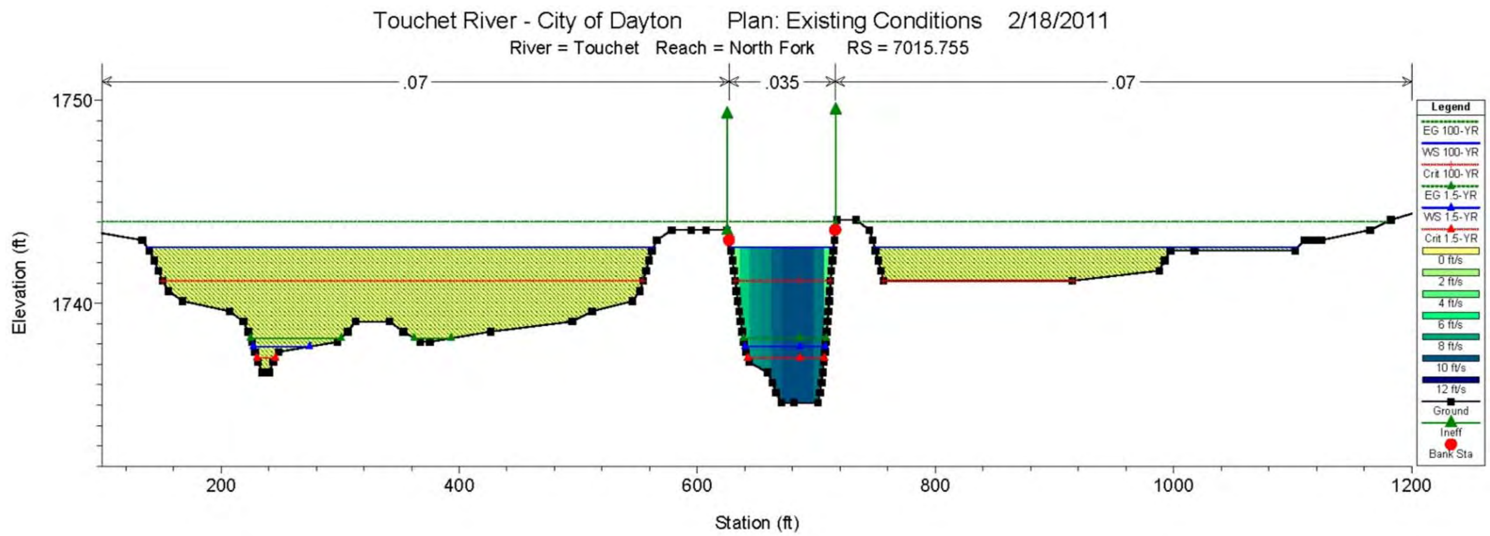
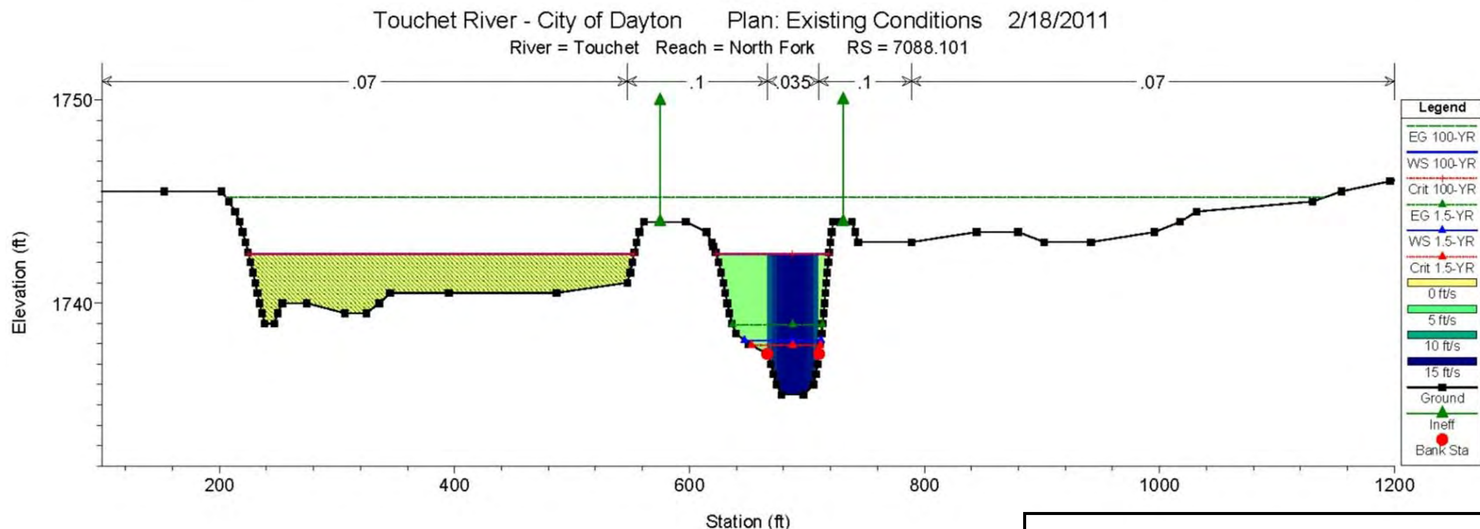
Figure E-11

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

http://projects/sites/1029100200/Final/Forms/AllItems.aspx JDL:mlh 03/15/11





Cross Sections
North Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure E-12**

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

HEC-RAS Plan: Existing River: Touchet Reach: North Fork

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Power Chan
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/ft s)
North Fork	7088.101	100-YR	4640.00	1735.50	1742.42	1742.42	1745.20	0.009408	14.24	461.78	424.47	0.98	3.78	53.77
North Fork	7088.101	1.5-YR	700.00	1735.50	1738.17	1737.93	1738.93	0.009428	7.02	106.33	65.01	0.83	1.31	9.18
North Fork	7088.101	2-YR	882.00	1735.50	1738.43	1738.29	1739.38	0.010158	7.85	124.46	71.43	0.87	1.58	12.37
North Fork	7088.101	5-YR	2113.00	1735.50	1740.02	1740.00	1741.74	0.010186	10.89	248.15	185.12	0.95	2.58	28.08
North Fork	7088.101	25-YR	2981.00	1735.50	1740.95	1740.95	1743.05	0.009703	12.19	327.53	397.64	0.96	3.01	36.75
North Fork	7088.101	50-YR	3762.00	1735.50	1741.68	1741.68	1744.11	0.009480	13.20	393.16	413.92	0.97	3.38	44.55
North Fork	7088.101	500-YR	7256.00	1735.50	1746.96	1745.22	1748.67	0.003158	11.75	1089.73	1199.86	0.62	2.16	25.32
North Fork	7015.755	100-YR	4640.00	1735.11	1742.75	1741.12	1744.02	0.004456	9.04	513.06	867.10	0.65	1.59	14.34
North Fork	7015.755	1.5-YR	700.00	1735.11	1737.87	1737.32	1738.28	0.005913	5.15	135.80	114.65	0.64	0.73	3.78
North Fork	7015.755	2-YR	882.00	1735.11	1738.21	1737.59	1738.69	0.005752	5.55	158.96	164.67	0.65	0.81	4.51
North Fork	7015.755	5-YR	2113.00	1735.11	1740.25	1739.02	1740.98	0.004236	6.84	308.70	459.97	0.60	1.03	7.06
North Fork	7015.755	25-YR	2981.00	1735.11	1741.31	1739.82	1742.21	0.004069	7.60	392.39	675.77	0.61	1.19	9.07
North Fork	7015.755	50-YR	3762.00	1735.11	1741.87	1740.46	1743.01	0.004667	8.59	437.94	733.00	0.66	1.49	12.76
North Fork	7015.755	500-YR	7256.00	1735.11	1747.32	1742.87	1748.28	0.001614	7.87	927.85	1451.28	0.43	1.00	7.86
North Fork	6993.965		Bridge											
North Fork	6976.085	100-YR	4640.00	1734.83	1741.59	1740.46	1743.04	0.005707	9.68	479.53	527.57	0.74	1.87	18.07
North Fork	6976.085	1.5-YR	700.00	1734.83	1737.45	1736.75	1737.80	0.004649	4.72	148.45	205.64	0.57	0.60	2.85
North Fork	6976.085	2-YR	882.00	1734.83	1737.86	1737.02	1738.24	0.004247	4.97	177.42	264.40	0.56	0.64	3.17
North Fork	6976.085	5-YR	2113.00	1734.83	1740.03	1738.42	1740.61	0.003123	6.10	346.28	464.36	0.52	0.80	4.91
North Fork	6976.085	25-YR	2981.00	1734.83	1741.04	1739.19	1741.78	0.003222	6.92	431.03	497.41	0.55	0.98	6.76
North Fork	6976.085	50-YR	3762.00	1734.83	1741.33	1739.82	1742.38	0.004330	8.24	456.57	511.28	0.64	1.37	11.28
North Fork	6976.085	500-YR	7256.00	1734.83	1742.55	1742.18	1745.09	0.008550	12.78	567.75	1035.16	0.92	3.14	40.09
North Fork	6879.815	100-YR	4640.00	1734.00	1740.76	1740.76	1742.41	0.006102	11.40	768.33	819.36	0.79	2.43	27.70
North Fork	6879.815	1.5-YR	700.00	1734.00	1736.39	1736.15	1737.07	0.009517	6.64	107.83	57.32	0.82	1.20	7.99
North Fork	6879.815	2-YR	882.00	1734.00	1736.66	1736.45	1737.50	0.010008	7.38	123.22	109.17	0.86	1.43	10.57
North Fork	6879.815	5-YR	2113.00	1734.00	1738.20	1738.20	1739.81	0.009835	10.31	245.69	252.21	0.93	2.35	24.26
North Fork	6879.815	25-YR	2981.00	1734.00	1739.17	1739.17	1740.98	0.008548	11.17	372.38	415.32	0.90	2.56	28.58
North Fork	6879.815	50-YR	3762.00	1734.00	1740.19	1740.19	1741.74	0.006109	10.73	618.42	630.63	0.78	2.22	23.79
North Fork	6879.815	500-YR	7256.00	1734.00	1742.11	1742.11	1744.10	0.006306	13.17	1137.88	1300.75	0.83	3.04	40.07
North Fork	6406.934	100-YR	4640.00	1730.00	1735.19	1735.19	1735.93	0.005469	9.24	1504.77	933.75	0.72	1.72	15.92
North Fork	6406.934	1.5-YR	700.00	1730.00	1732.17	1731.87	1732.78	0.008600	6.32	115.35	62.74	0.78	1.09	6.90
North Fork	6406.934	2-YR	882.00	1730.00	1732.51	1732.17	1733.22	0.008095	6.80	137.89	181.19	0.78	1.20	8.15
North Fork	6406.934	5-YR	2113.00	1730.00	1733.91	1733.91	1734.73	0.006274	8.15	586.68	450.25	0.74	1.48	12.05
North Fork	6406.934	25-YR	2981.00	1730.00	1734.46	1734.46	1735.29	0.006054	8.76	865.22	705.01	0.74	1.63	14.31
North Fork	6406.934	50-YR	3762.00	1730.00	1734.82	1734.82	1735.68	0.006164	9.33	1087.26	857.45	0.76	1.80	16.80
North Fork	6406.934	500-YR	7256.00	1730.00	1735.78	1735.78	1736.68	0.006584	10.92	2028.16	1038.41	0.81	2.32	25.31
North Fork	5900.132	100-YR	4640.00	1725.00	1730.44	1730.44	1731.45	0.006832	10.70	1187.24	967.52	0.82	2.27	24.31
North Fork	5900.132	1.5-YR	700.00	1725.00	1727.28	1727.07	1728.07	0.010010	7.15	101.51	51.37	0.85	1.36	9.76
North Fork	5900.132	2-YR	882.00	1725.00	1727.57	1727.41	1728.54	0.010484	7.94	118.86	93.06	0.89	1.62	12.83
North Fork	5900.132	5-YR	2113.00	1725.00	1729.29	1729.29	1730.08	0.005677	8.29	574.97	450.46	0.71	1.48	12.27

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

HEC-RAS Output Table
North Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure E-13

HEC-RAS Plan: Existing River: Touchet Reach: North Fork (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Power Chan
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/ft s)
North Fork	5900.132	25-YR	2981.00	1725.00	1729.80	1729.80	1730.66	0.005978	9.19	814.71	709.71	0.75	1.75	16.08
North Fork	5900.132	50-YR	3762.00	1725.00	1730.20	1730.20	1731.07	0.005952	9.68	1036.12	878.79	0.75	1.89	18.27
North Fork	5900.132	500-YR	7256.00	1725.00	1731.29	1731.29	1732.06	0.005635	10.72	2208.22	1202.14	0.76	2.17	23.24
North Fork	5402.716	100-YR	4640.00	1719.00	1724.75	1724.75	1725.88	0.008007	11.96	1169.84	617.00	0.89	2.79	33.39
North Fork	5402.716	1.5-YR	700.00	1719.00	1721.39	1721.39	1722.36	0.013143	8.32	115.16	69.87	0.98	1.84	15.28
North Fork	5402.716	2-YR	882.00	1719.00	1721.73	1721.73	1722.83	0.012471	8.92	140.09	73.96	0.98	2.01	17.92
North Fork	5402.716	5-YR	2113.00	1719.00	1723.68	1723.68	1724.44	0.005659	8.73	708.69	447.41	0.72	1.60	13.93
North Fork	5402.716	25-YR	2981.00	1719.00	1724.12	1724.12	1725.00	0.006513	9.96	897.08	529.90	0.79	2.01	20.06
North Fork	5402.716	50-YR	3762.00	1719.00	1724.44	1724.44	1725.44	0.007219	10.93	1036.75	565.15	0.84	2.38	26.00
North Fork	5402.716	500-YR	7256.00	1719.00	1725.67	1725.67	1726.66	0.007152	12.51	1942.11	788.08	0.86	2.90	36.31
North Fork	5066.368	100-YR	4640.00	1715.00	1720.81	1720.81	1723.11	0.008863	12.49	477.23	165.60	0.93	3.06	38.19
North Fork	5066.368	1.5-YR	700.00	1715.00	1717.17	1716.81	1717.68	0.007801	5.75	125.72	71.67	0.73	0.93	5.32
North Fork	5066.368	2-YR	882.00	1715.00	1717.40	1717.08	1718.04	0.008514	6.47	142.00	73.57	0.78	1.13	7.30
North Fork	5066.368	5-YR	2113.00	1715.00	1718.93	1718.50	1720.12	0.007723	8.85	263.34	84.10	0.81	1.76	15.60
North Fork	5066.368	25-YR	2981.00	1715.00	1719.71	1719.31	1721.28	0.007977	10.22	330.51	89.42	0.85	2.21	22.55
North Fork	5066.368	50-YR	3762.00	1715.00	1720.25	1719.98	1722.20	0.008561	11.43	389.73	140.66	0.90	2.65	30.33
North Fork	5066.368	500-YR	7256.00	1715.00	1723.17	1723.17	1724.84	0.004754	11.59	1338.74	529.94	0.73	2.34	27.08
North Fork	4492.401	100-YR	4640.00	1710.00	1716.78	1716.78	1717.78	0.004460	9.94	1320.71	665.27	0.68	1.83	18.19
North Fork	4492.401	1.5-YR	700.00	1710.00	1712.28	1712.05	1712.89	0.008948	6.58	144.32	95.87	0.80	1.17	7.71
North Fork	4492.401	2-YR	882.00	1710.00	1712.66	1712.35	1713.33	0.007958	6.93	183.70	112.58	0.77	1.23	8.52
North Fork	4492.401	5-YR	2113.00	1710.00	1713.96	1713.89	1715.24	0.009483	10.01	348.63	139.82	0.91	2.23	22.31
North Fork	4492.401	25-YR	2981.00	1710.00	1714.66	1714.66	1716.26	0.009782	11.38	450.42	159.03	0.95	2.73	31.04
North Fork	4492.401	50-YR	3762.00	1710.00	1715.31	1715.31	1717.07	0.009267	12.13	571.60	210.83	0.94	2.96	35.86
North Fork	4492.401	500-YR	7256.00	1710.00	1717.64	1717.64	1718.79	0.005084	11.52	1924.43	763.63	0.74	2.36	27.17
North Fork	3860.439	100-YR	4640.00	1703.50	1709.18	1709.18	1711.40	0.009201	12.13	446.65	311.65	0.94	2.95	35.81
North Fork	3860.439	1.5-YR	700.00	1703.50	1705.54	1705.44	1706.17	0.012820	6.36	110.06	82.76	0.91	1.22	7.75
North Fork	3860.439	2-YR	882.00	1703.50	1705.68	1705.68	1706.52	0.015319	7.36	119.96	86.18	1.00	1.59	11.67
North Fork	3860.439	5-YR	2113.00	1703.50	1707.02	1707.02	1708.48	0.012097	9.70	224.83	125.95	0.99	2.26	21.95
North Fork	3860.439	25-YR	2981.00	1703.50	1707.78	1707.78	1709.60	0.011235	10.87	288.95	192.53	0.99	2.63	28.62
North Fork	3860.439	50-YR	3762.00	1703.50	1708.45	1708.45	1710.50	0.010284	11.59	353.83	280.57	0.97	2.84	32.87
North Fork	3860.439	500-YR	7256.00	1703.50	1710.97	1710.97	1713.64	0.007741	13.56	707.25	518.96	0.91	3.34	45.35
North Fork	3439.957	100-YR	4640.00	1697.82	1706.35	1703.93	1707.46	0.003050	8.57	607.90	93.29	0.54	1.33	11.41
North Fork	3439.957	1.5-YR	700.00	1697.82	1700.12	1700.01	1700.80	0.012672	6.61	105.95	63.41	0.90	1.29	8.50
North Fork	3439.957	2-YR	882.00	1697.82	1700.52	1700.29	1701.22	0.010193	6.71	131.46	64.97	0.83	1.25	8.36
North Fork	3439.957	5-YR	2113.00	1697.82	1702.46	1701.72	1703.47	0.006356	8.07	268.48	78.52	0.72	1.46	11.78
North Fork	3439.957	25-YR	2981.00	1697.82	1704.22	1702.55	1705.13	0.003668	7.73	415.33	87.22	0.57	1.19	9.23
North Fork	3439.957	50-YR	3762.00	1697.82	1705.28	1703.22	1706.28	0.003295	8.14	509.17	90.37	0.56	1.26	10.23
North Fork	3439.957	500-YR	7256.00	1697.82	1709.07	1705.71	1710.47	0.002745	9.72	871.49	371.05	0.53	1.56	15.20
North Fork	3375.069	100-YR	4640.00	1697.07	1706.48	1703.02	1707.18	0.001965	6.74	688.52	98.11	0.45	0.83	5.60
North Fork	3375.069	1.5-YR	700.00	1697.07	1699.94	1699.09	1700.28	0.004036	4.64	150.94	66.17	0.54	0.57	2.63

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

HEC-RAS Output Table
North Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure E-14

HEC-RAS Plan: Existing River: Touchet Reach: North Fork (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Power Chan
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/ft s)
North Fork	3375.069	2-YR	882.00	1697.07	1700.38	1699.37	1700.75	0.003732	4.89	180.54	68.89	0.53	0.60	2.94
North Fork	3375.069	5-YR	2113.00	1697.07	1702.44	1700.88	1703.07	0.003357	6.34	333.49	78.86	0.54	0.87	5.49
North Fork	3375.069	25-YR	2981.00	1697.07	1704.27	1701.70	1704.86	0.002207	6.15	484.91	86.97	0.46	0.75	4.58
North Fork	3375.069	50-YR	3762.00	1697.07	1705.36	1702.34	1706.01	0.002068	6.46	582.64	92.19	0.45	0.79	5.10
North Fork	3375.069	500-YR	7256.00	1697.07	1709.33	1704.75	1710.16	0.001767	7.30	1002.66	752.73	0.44	0.91	6.66
North Fork	3350		Bridge											
North Fork	3327.648	100-YR	4640.00	1696.52	1703.01	1703.00	1705.43	0.010774	12.47	371.95	79.85	0.99	3.20	39.96
North Fork	3327.648	1.5-YR	700.00	1696.52	1699.38	1698.80	1699.86	0.006102	5.53	126.66	58.27	0.66	0.82	4.53
North Fork	3327.648	2-YR	882.00	1696.52	1699.72	1699.10	1700.28	0.006198	6.00	146.92	60.30	0.68	0.93	5.59
North Fork	3327.648	5-YR	2113.00	1696.52	1701.08	1700.69	1702.35	0.008827	9.04	233.77	67.25	0.85	1.88	16.99
North Fork	3327.648	25-YR	2981.00	1696.52	1701.96	1701.58	1703.55	0.008834	10.12	294.50	71.24	0.88	2.23	22.55
North Fork	3327.648	50-YR	3762.00	1696.52	1702.39	1702.28	1704.46	0.010450	11.55	325.69	73.16	0.96	2.83	32.72
North Fork	3327.648	500-YR	7256.00	1696.52	1704.84	1704.84	1707.88	0.010136	13.99	518.62	210.49	1.00	3.75	52.43
North Fork	3235.069	100-YR	4640.00	1695.14	1702.05	1702.05	1704.36	0.011203	12.20	380.23	362.79	1.00	3.13	38.20
North Fork	3235.069	1.5-YR	700.00	1695.14	1697.99	1697.99	1698.89	0.015095	7.59	92.25	51.27	1.00	1.65	12.55
North Fork	3235.069	2-YR	882.00	1695.14	1698.35	1698.35	1699.32	0.014602	7.90	111.64	56.98	0.99	1.74	13.76
North Fork	3235.069	5-YR	2113.00	1695.14	1700.06	1699.91	1701.41	0.011124	9.34	226.33	72.98	0.93	2.09	19.52
North Fork	3235.069	25-YR	2981.00	1695.14	1700.73	1700.73	1702.54	0.012025	10.78	276.59	75.97	1.00	2.64	28.50
North Fork	3235.069	50-YR	3762.00	1695.14	1701.38	1701.38	1703.44	0.011562	11.51	326.87	278.11	1.00	2.89	33.26
North Fork	3235.069	500-YR	7256.00	1695.14	1703.73	1703.73	1706.72	0.009942	13.89	531.13	700.09	0.98	3.69	51.28
North Fork	2805.561	100-YR	4640.00	1689.31	1697.50	1697.50	1699.46	0.007938	12.21	711.33	352.38	0.86	2.88	35.13
North Fork	2805.561	1.5-YR	700.00	1689.31	1693.06	1692.34	1693.71	0.006430	6.46	108.42	39.21	0.68	1.05	6.77
North Fork	2805.561	2-YR	882.00	1689.31	1693.45	1692.76	1694.23	0.006948	7.10	124.81	44.87	0.72	1.23	8.76
North Fork	2805.561	5-YR	2113.00	1689.31	1695.08	1694.97	1696.77	0.010339	10.53	222.27	130.32	0.92	2.46	25.87
North Fork	2805.561	25-YR	2981.00	1689.31	1696.23	1696.23	1697.92	0.008197	10.82	397.27	173.16	0.85	2.42	26.16
North Fork	2805.561	50-YR	3762.00	1689.31	1697.01	1697.01	1698.73	0.007445	11.21	564.46	252.50	0.82	2.49	27.87
North Fork	2805.561	500-YR	7256.00	1689.31	1699.23	1699.23	1700.49	0.004805	11.20	1744.39	647.09	0.70	2.23	24.94
North Fork	2054.835	100-YR	4640.00	1682.10	1690.34	1690.34	1692.57	0.008768	13.35	589.43	243.86	0.94	3.37	45.00
North Fork	2054.835	1.5-YR	700.00	1682.10	1685.90	1685.90	1686.89	0.013699	8.11	95.81	50.41	0.98	1.78	14.46
North Fork	2054.835	2-YR	882.00	1682.10	1686.30	1686.30	1687.37	0.012541	8.48	120.52	69.25	0.96	1.86	15.80
North Fork	2054.835	5-YR	2113.00	1682.10	1688.31	1688.31	1689.73	0.008455	10.11	315.51	131.61	0.86	2.20	22.26
North Fork	2054.835	25-YR	2981.00	1682.10	1689.09	1689.09	1690.82	0.008571	11.40	420.34	134.10	0.89	2.64	30.15
North Fork	2054.835	50-YR	3762.00	1682.10	1689.72	1689.72	1691.68	0.008637	12.37	504.45	163.60	0.92	2.99	37.02
North Fork	2054.835	500-YR	7256.00	1682.10	1691.88	1691.88	1694.89	0.009280	15.90	807.21	397.68	1.00	4.44	70.57
North Fork	1528.123	100-YR	4640.00	1676.99	1683.80	1683.62	1685.26	0.006629	10.52	751.91	336.89	0.79	2.20	23.14
North Fork	1528.123	1.5-YR	700.00	1676.99	1679.68	1679.37	1680.30	0.009064	6.32	110.78	55.93	0.79	1.11	6.99
North Fork	1528.123	2-YR	882.00	1676.99	1680.01	1679.67	1680.73	0.008904	6.81	129.55	57.60	0.80	1.23	8.38
North Fork	1528.123	5-YR	2113.00	1676.99	1681.65	1681.38	1682.90	0.008575	9.02	262.96	135.59	0.84	1.86	16.79
North Fork	1528.123	25-YR	2981.00	1676.99	1682.48	1682.46	1683.89	0.007952	9.82	414.66	227.82	0.83	2.07	20.35
North Fork	1528.123	50-YR	3762.00	1676.99	1683.13	1683.05	1684.57	0.007238	10.19	565.82	261.05	0.81	2.14	21.82

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

HEC-RAS Output Table
North Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure E-15

HEC-RAS Plan: Existing River: Touchet Reach: North Fork (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Power Chan
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/ft s)
North Fork	1528.123	500-YR	7256.00	1676.99	1685.36	1685.10	1686.78	0.005284	11.07	1418.90	553.22	0.73	2.24	24.81
North Fork	1000	100-YR	4640.00	1670.52	1677.90	1677.90	1680.29	0.013097	16.00	645.38	143.74	1.11	4.88	78.12
North Fork	1000	1.5-YR	700.00	1670.52	1674.00	1674.00	1674.80	0.011648	8.18	155.37	99.62	0.89	1.73	14.19
North Fork	1000	2-YR	882.00	1670.52	1674.28	1674.28	1675.20	0.011969	8.89	185.54	110.68	0.92	1.98	17.60
North Fork	1000	5-YR	2113.00	1670.52	1675.74	1675.74	1677.25	0.012975	12.16	357.42	123.27	1.03	3.23	39.31
North Fork	1000	25-YR	2981.00	1670.52	1676.56	1676.56	1678.41	0.013180	13.75	460.78	130.64	1.07	3.90	53.61
North Fork	1000	50-YR	3762.00	1670.52	1677.22	1677.22	1679.34	0.013180	14.90	549.43	137.14	1.09	4.40	65.56
North Fork	1000	500-YR	7256.00	1670.52	1680.00	1680.00	1682.70	0.010891	17.57	1043.78	215.11	1.06	5.37	94.41

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

HEC-RAS Output Table
North Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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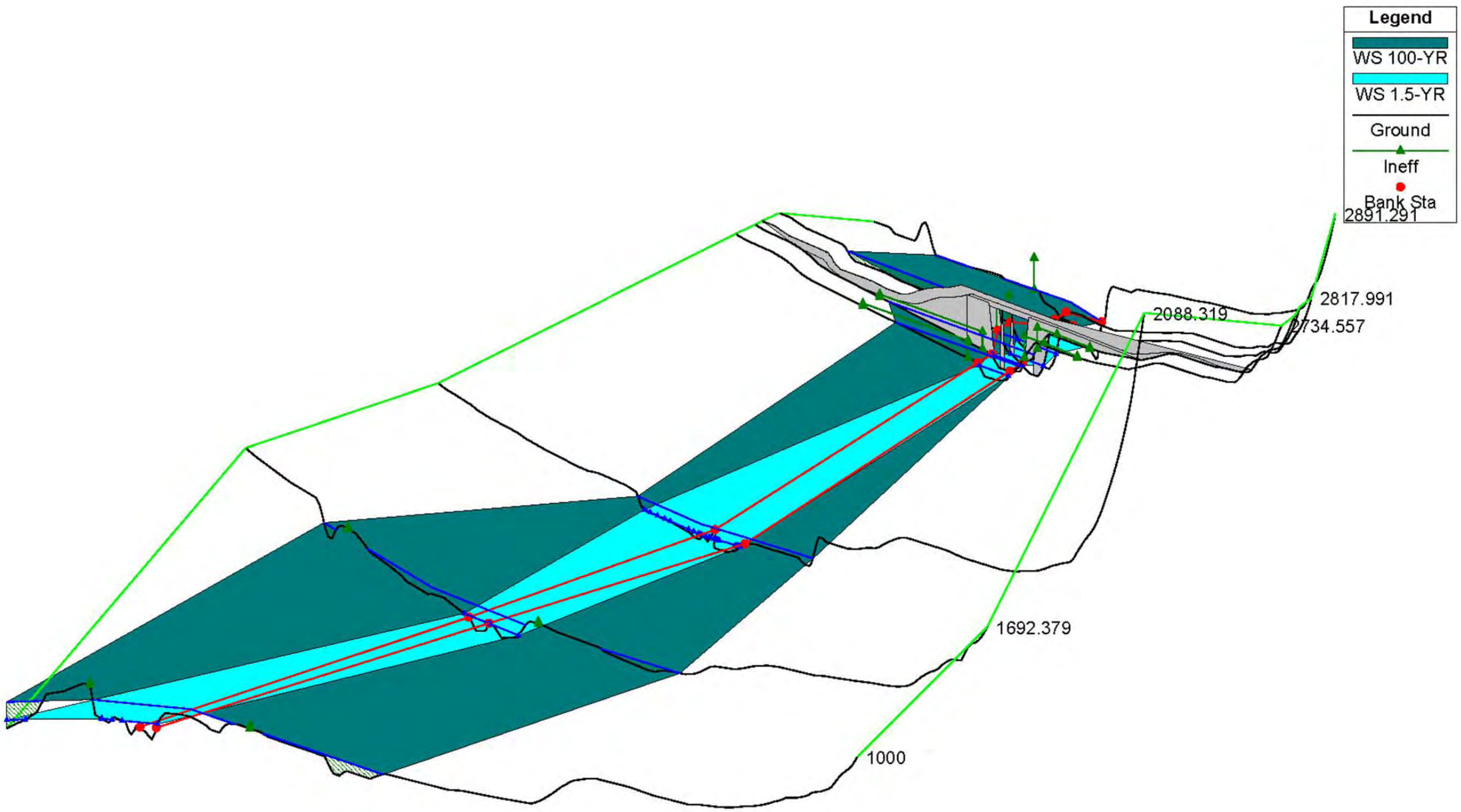
Figure E-16



Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

3-D View
South Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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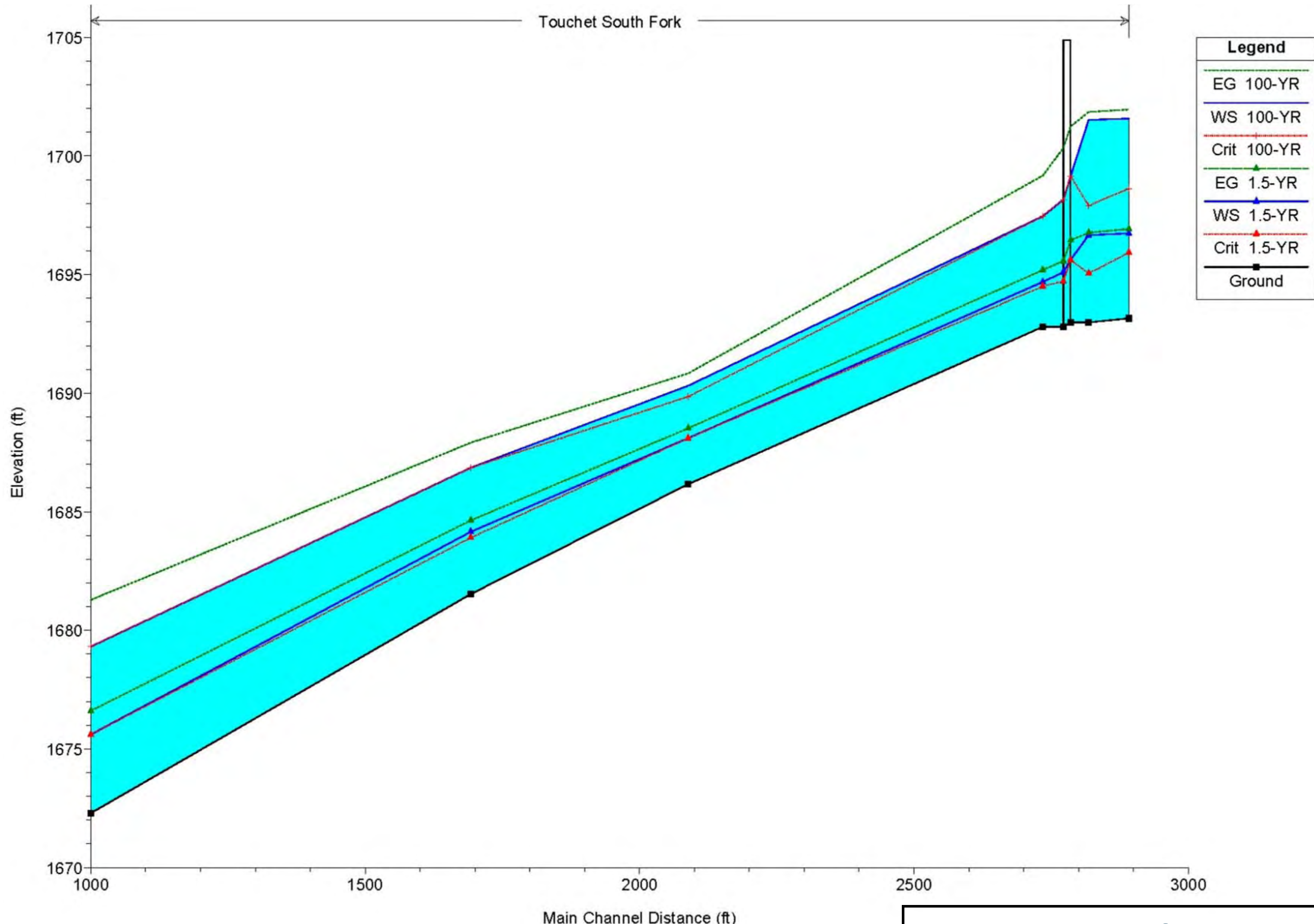

Profile View
South Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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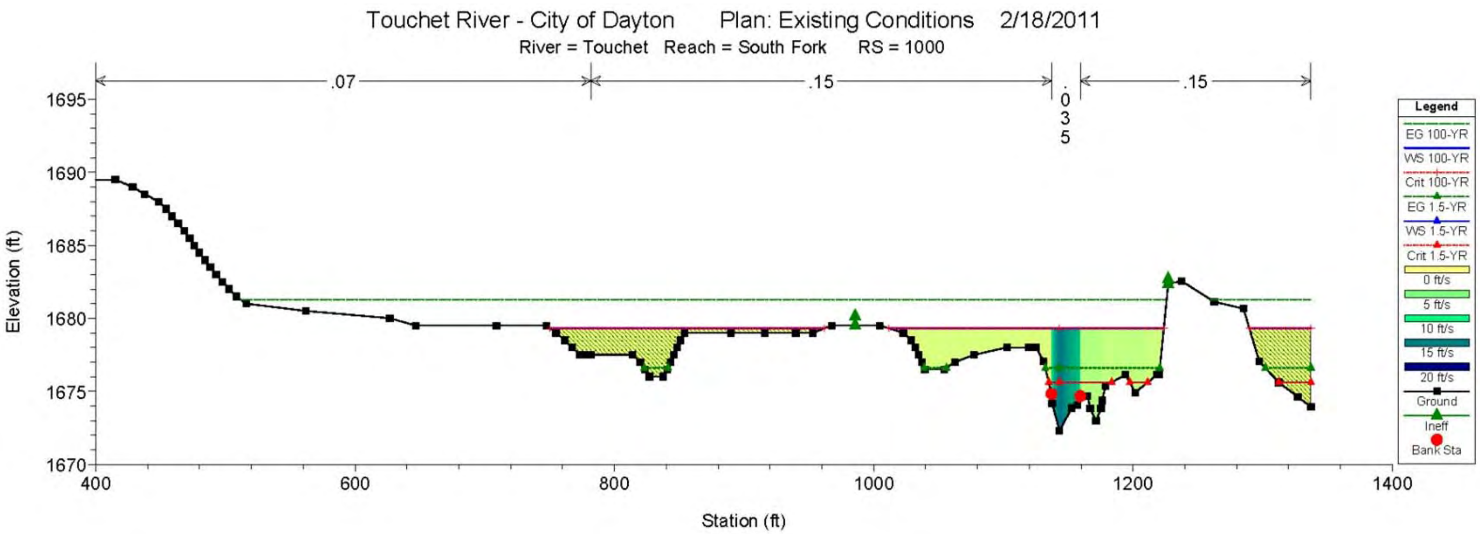
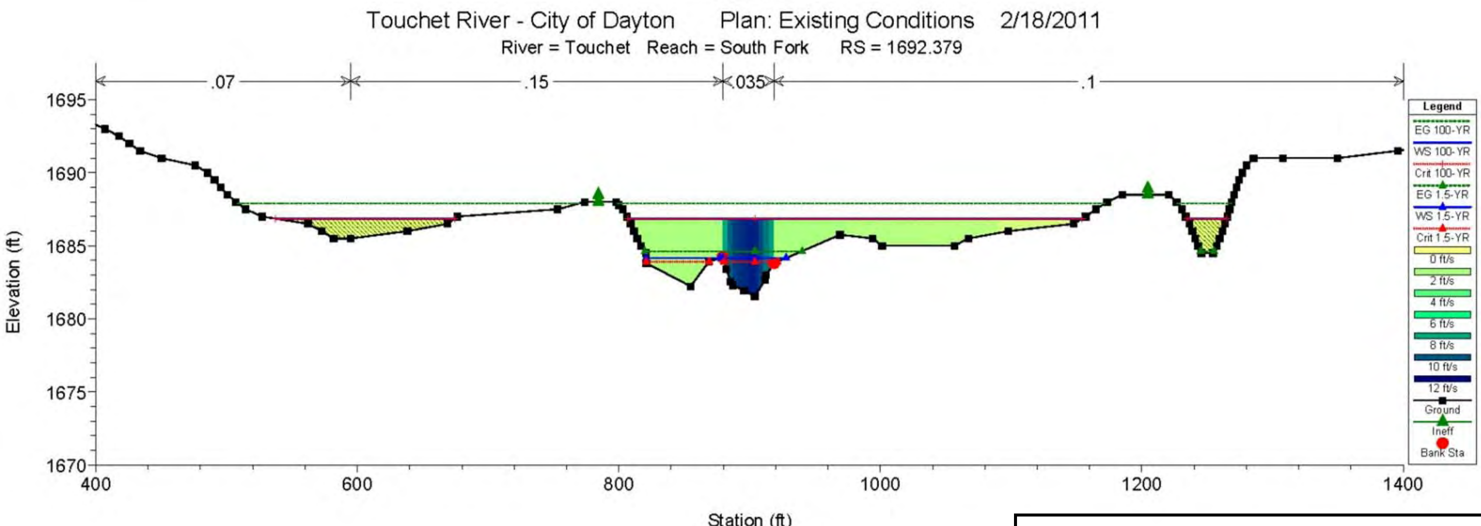
Figure E-18

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0



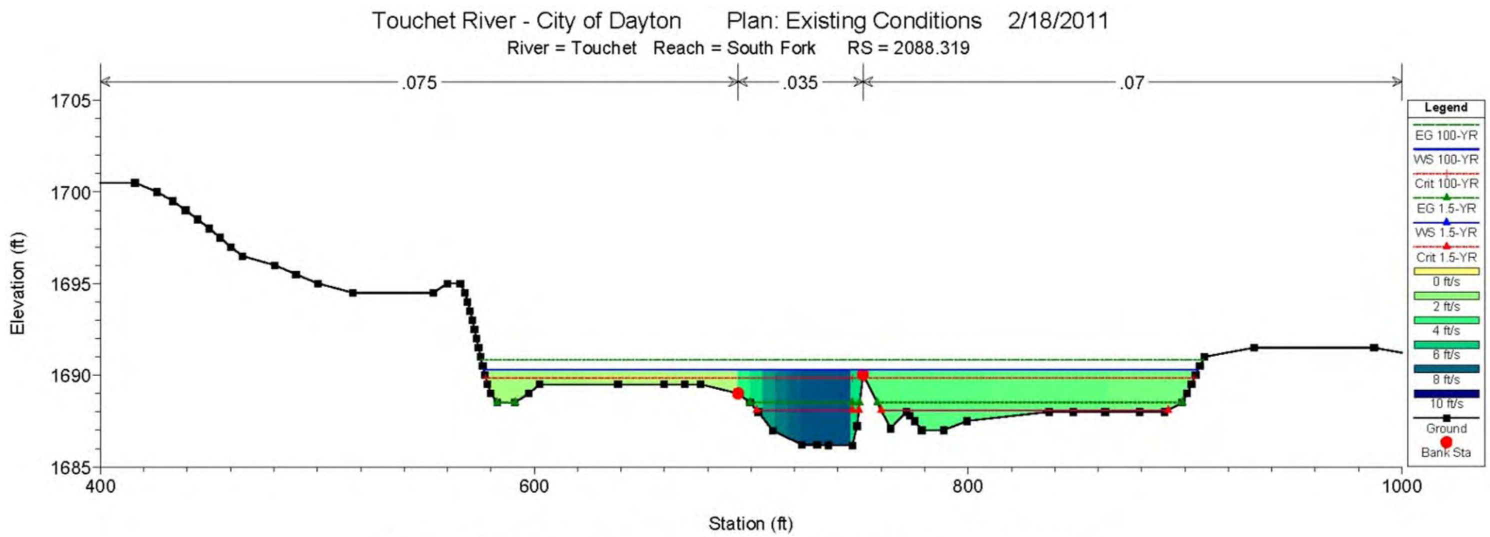


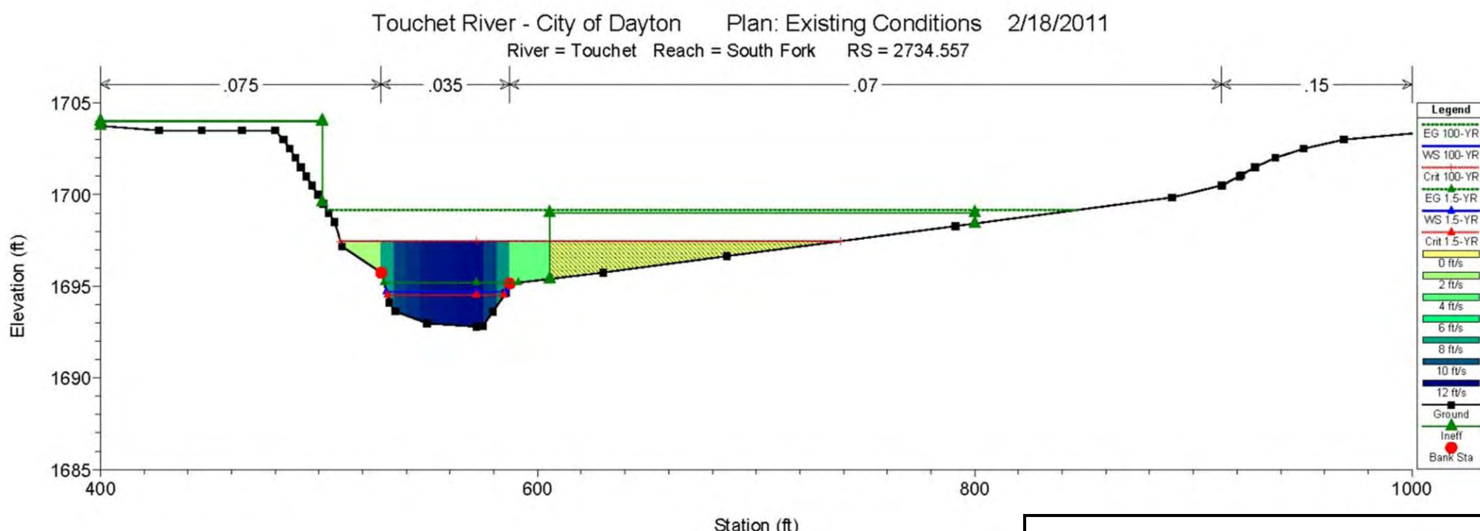
Cross Sections
South Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure E-19**

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0



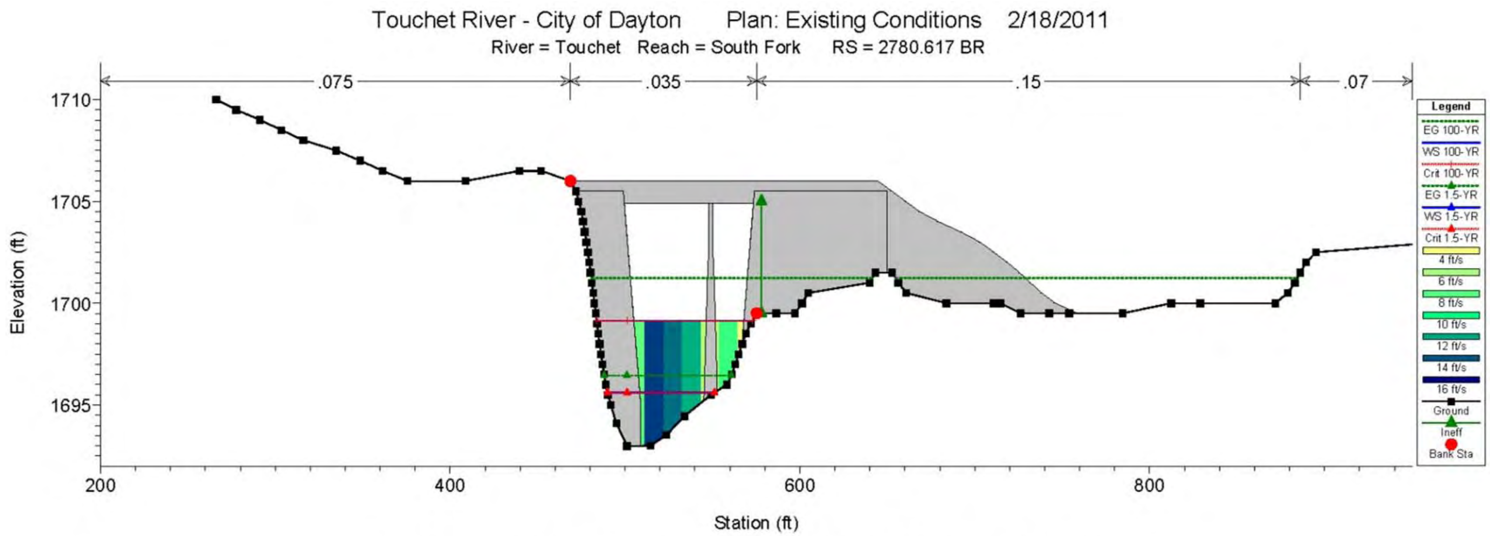


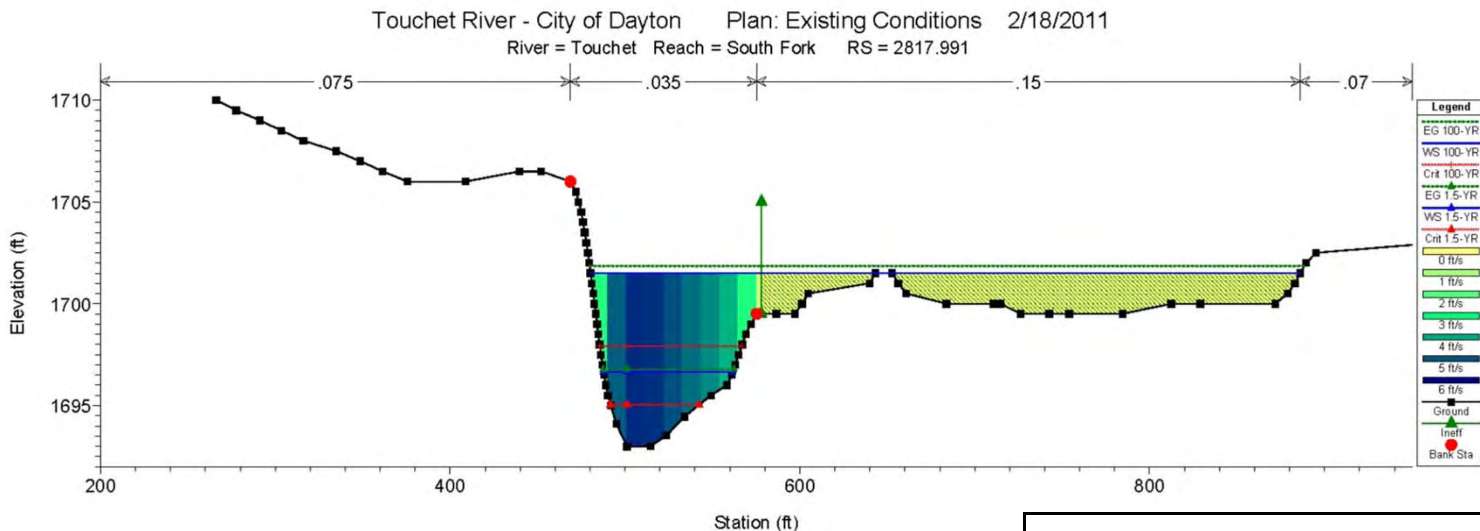
Cross Sections
South Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers | **Figure E-20**

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0





Cross Sections
South Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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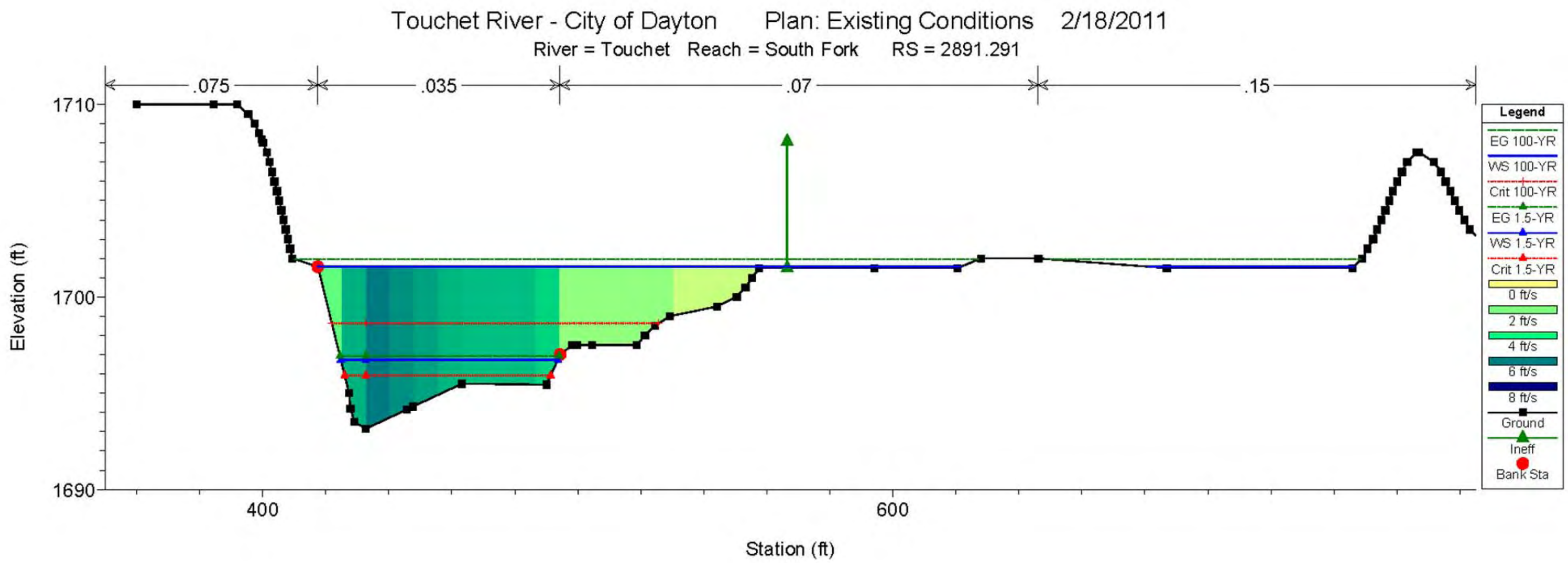
Figure E-21

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0



Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

Cross Sections
South Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure E-22

HEC-RAS Plan: Existing River: Touchet Reach: South Fork

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Power Chan
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/ft s)
South Fork	2891.291	100-YR	2781.00	1693.15	1701.57	1698.63	1701.95	0.001350	5.18	670.66	269.57	0.36	0.51	2.64
South Fork	2891.291	1.5-YR	450.00	1693.15	1696.73	1695.92	1696.92	0.002992	3.48	129.22	68.87	0.45	0.34	1.19
South Fork	2891.291	2-YR	564.00	1693.15	1697.11	1696.11	1697.32	0.002601	3.62	155.64	71.03	0.43	0.35	1.27
South Fork	2891.291	5-YR	1292.00	1693.15	1698.94	1697.10	1699.23	0.001768	4.36	328.83	107.25	0.39	0.42	1.83
South Fork	2891.291	25-YR	1801.00	1693.15	1699.93	1697.71	1700.26	0.001588	4.73	447.45	129.63	0.38	0.46	2.19
South Fork	2891.291	50-YR	2263.00	1693.15	1700.74	1698.17	1701.09	0.001443	4.94	555.32	135.52	0.37	0.48	2.38
South Fork	2891.291	500-YR	4308.00	1693.15	1703.72	1699.87	1704.14	0.001063	5.59	1007.79	394.57	0.34	0.54	3.01
South Fork	2817.991	100-YR	2781.00	1692.98	1701.51	1697.90	1701.85	0.001085	4.67	600.43	405.97	0.33	0.41	1.93
South Fork	2817.991	1.5-YR	450.00	1692.98	1696.66	1695.04	1696.76	0.001245	2.61	172.23	74.04	0.30	0.18	0.47
South Fork	2817.991	2-YR	564.00	1692.98	1697.04	1695.29	1697.17	0.001211	2.80	201.40	76.29	0.30	0.20	0.55
South Fork	2817.991	5-YR	1292.00	1692.98	1698.89	1696.42	1699.10	0.001193	3.67	351.95	87.22	0.32	0.30	1.08
South Fork	2817.991	25-YR	1801.00	1692.98	1699.88	1696.97	1700.14	0.001182	4.08	442.74	205.73	0.33	0.34	1.40
South Fork	2817.991	50-YR	2263.00	1692.98	1700.69	1697.43	1700.98	0.001127	4.38	520.02	357.77	0.33	0.38	1.66
South Fork	2817.991	500-YR	4308.00	1692.98	1703.61	1699.09	1704.06	0.001035	5.39	808.33	507.75	0.33	0.51	2.73
South Fork	2780.617		Bridge											
South Fork	2734.557	100-YR	2781.00	1692.79	1697.46	1697.46	1699.17	0.010058	10.82	298.81	228.95	0.94	2.54	27.51
South Fork	2734.557	1.5-YR	450.00	1692.79	1694.69	1694.50	1695.19	0.011007	5.67	79.31	54.82	0.83	0.99	5.61
South Fork	2734.557	2-YR	564.00	1692.79	1694.83	1694.72	1695.48	0.012802	6.46	87.35	55.66	0.91	1.25	8.04
South Fork	2734.557	5-YR	1292.00	1692.79	1695.88	1695.88	1697.02	0.012254	8.62	158.99	111.90	0.96	1.90	16.40
South Fork	2734.557	25-YR	1801.00	1692.79	1696.48	1696.48	1697.84	0.011188	9.51	208.76	157.37	0.95	2.15	20.47
South Fork	2734.557	50-YR	2263.00	1692.79	1696.94	1696.94	1698.50	0.010829	10.26	249.81	192.31	0.96	2.39	24.52
South Fork	2734.557	500-YR	4308.00	1692.79	1698.40	1698.40	1700.90	0.011440	13.24	389.97	291.26	1.04	3.56	47.10
South Fork	2088.319	100-YR	2781.00	1686.16	1690.31	1689.85	1690.83	0.006525	7.56	679.69	329.48	0.73	1.33	10.06
South Fork	2088.319	1.5-YR	450.00	1686.16	1688.10	1688.10	1688.52	0.009668	5.49	121.40	179.59	0.78	0.91	5.01
South Fork	2088.319	2-YR	564.00	1686.16	1688.32	1688.25	1688.71	0.008523	5.50	162.06	186.00	0.75	0.89	4.87
South Fork	2088.319	5-YR	1292.00	1686.16	1689.27	1688.94	1689.65	0.006617	6.02	360.51	234.15	0.69	0.95	5.73
South Fork	2088.319	25-YR	1801.00	1686.16	1689.68	1689.25	1690.13	0.006692	6.70	474.24	323.81	0.71	1.12	7.51
South Fork	2088.319	50-YR	2263.00	1686.16	1690.01	1689.49	1690.49	0.006456	7.07	582.74	327.62	0.71	1.20	8.50
South Fork	2088.319	500-YR	4308.00	1686.16	1691.23	1690.48	1691.82	0.005673	8.29	999.32	408.05	0.71	1.48	12.26
South Fork	1692.379	100-YR	2781.00	1681.53	1686.86	1686.86	1687.91	0.008157	10.23	736.15	514.74	0.86	2.22	22.69
South Fork	1692.379	1.5-YR	450.00	1681.53	1684.16	1683.91	1684.63	0.009522	5.90	124.03	104.74	0.79	1.01	5.95
South Fork	1692.379	2-YR	564.00	1681.53	1684.32	1684.16	1684.92	0.010716	6.63	142.42	111.54	0.85	1.24	8.23
South Fork	1692.379	5-YR	1292.00	1681.53	1685.39	1685.39	1686.35	0.010395	8.82	302.93	231.95	0.91	1.89	16.63
South Fork	1692.379	25-YR	1801.00	1681.53	1686.01	1686.01	1687.02	0.009046	9.35	462.18	377.65	0.87	1.99	18.62
South Fork	1692.379	50-YR	2263.00	1681.53	1686.44	1686.44	1687.49	0.008695	9.88	592.89	460.35	0.87	2.14	21.14
South Fork	1692.379	500-YR	4308.00	1681.53	1687.62	1687.62	1688.95	0.009150	12.05	1009.07	648.58	0.93	2.92	35.21
South Fork	1000	100-YR	2781.00	1672.29	1679.31	1679.31	1681.28	0.010605	13.86	607.06	471.54	1.01	3.74	51.84
South Fork	1000	1.5-YR	450.00	1672.29	1675.61	1675.61	1676.61	0.015020	8.46	83.63	87.16	1.02	1.95	16.47
South Fork	1000	2-YR	564.00	1672.29	1676.03	1676.03	1677.07	0.012547	8.71	113.72	120.28	0.96	1.94	16.93
South Fork	1000	5-YR	1292.00	1672.29	1677.64	1677.64	1678.98	0.009700	10.60	291.60	261.74	0.91	2.44	25.90
South Fork	1000	25-YR	1801.00	1672.29	1678.52	1678.52	1679.90	0.008400	11.20	448.06	328.81	0.88	2.56	28.70
South Fork	1000	50-YR	2263.00	1672.29	1679.00	1679.00	1680.57	0.008870	12.23	542.96	445.07	0.91	2.96	36.21

HEC-RAS Output Table
South Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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Figure E-23

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

HEC-RAS Plan: Existing River: Touchet Reach: South Fork (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Power Chan
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/ft s)
South Fork	1000	500-YR	4308.00	1672.29	1680.66	1680.66	1681.66	0.005900	11.87	1628.29	730.18	0.78	2.56	30.39

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

HEC-RAS Output Table
South Fork Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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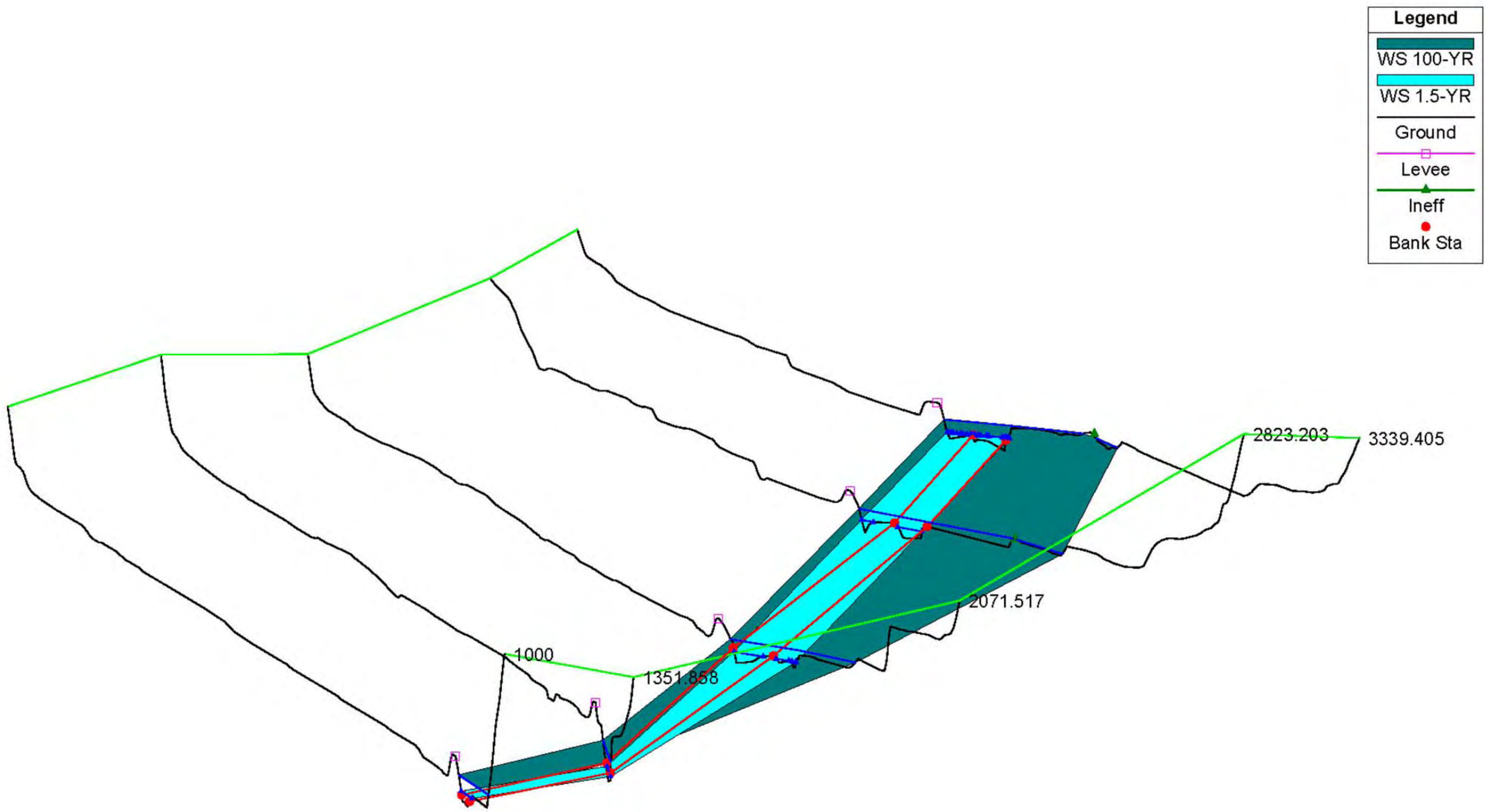
Figure E-24



Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

3-D View
Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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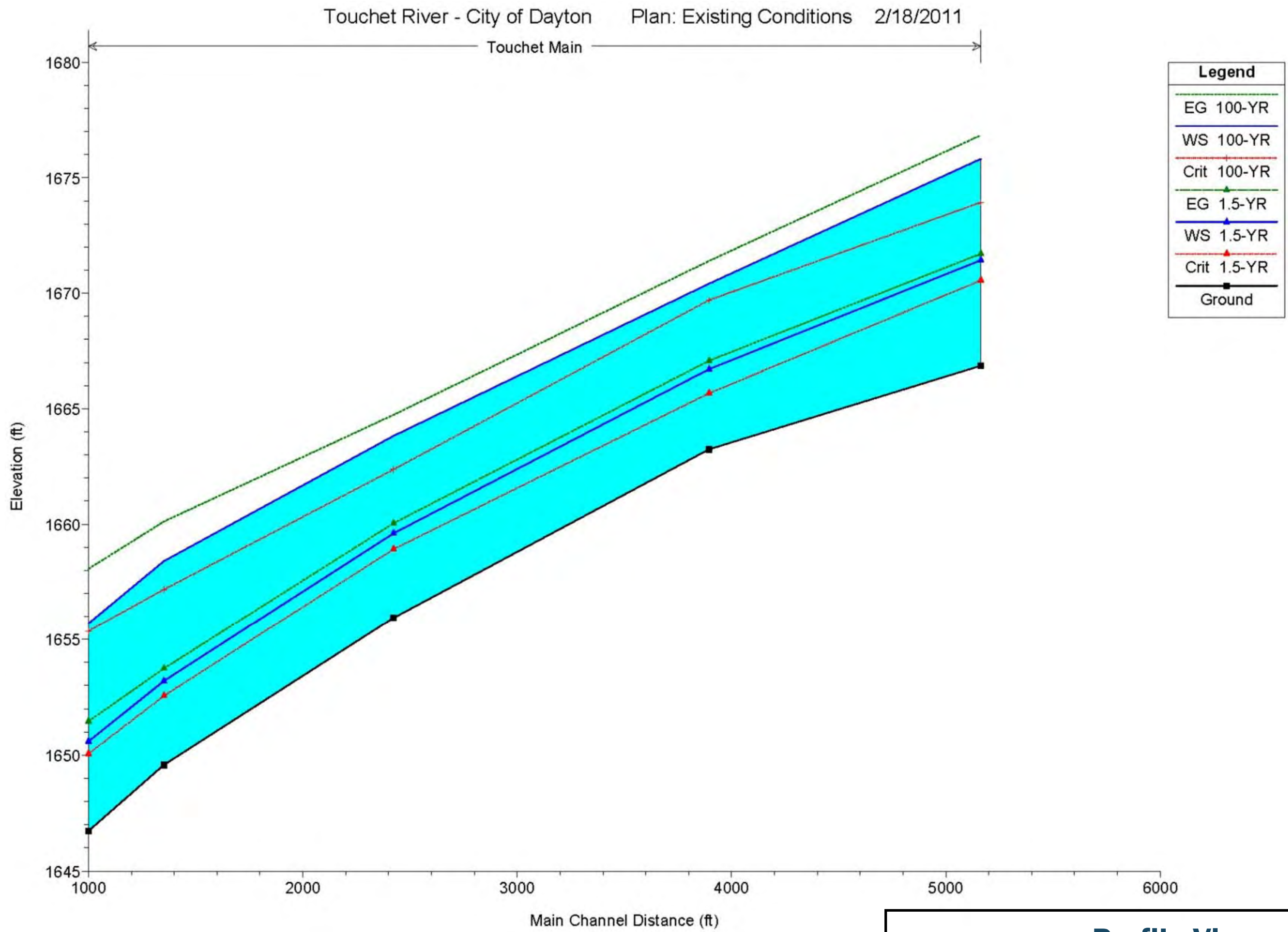
Figure E-25



Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

Profile View
Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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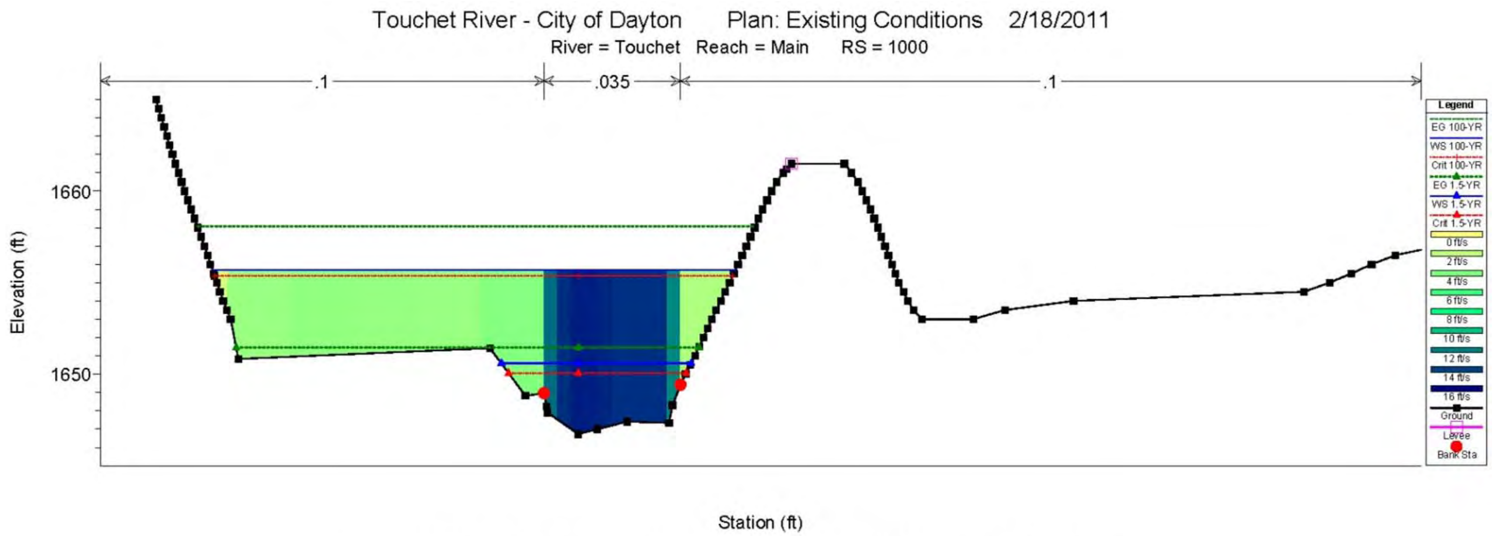
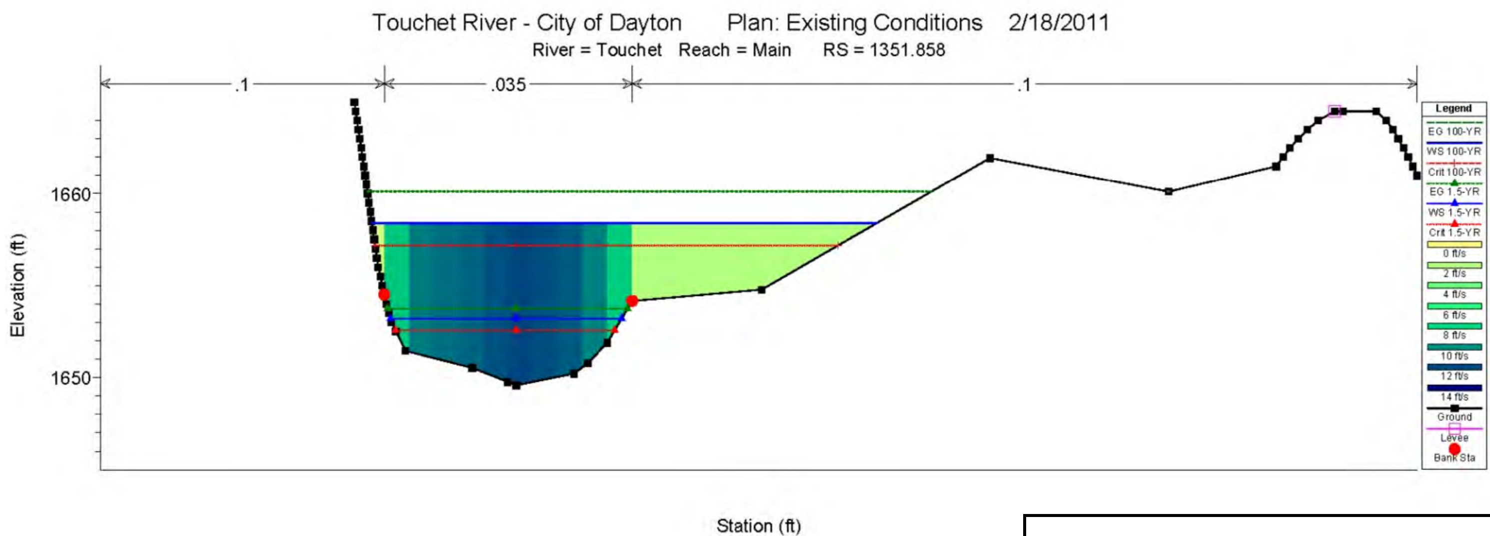
Figure E-26





Cross Sections
Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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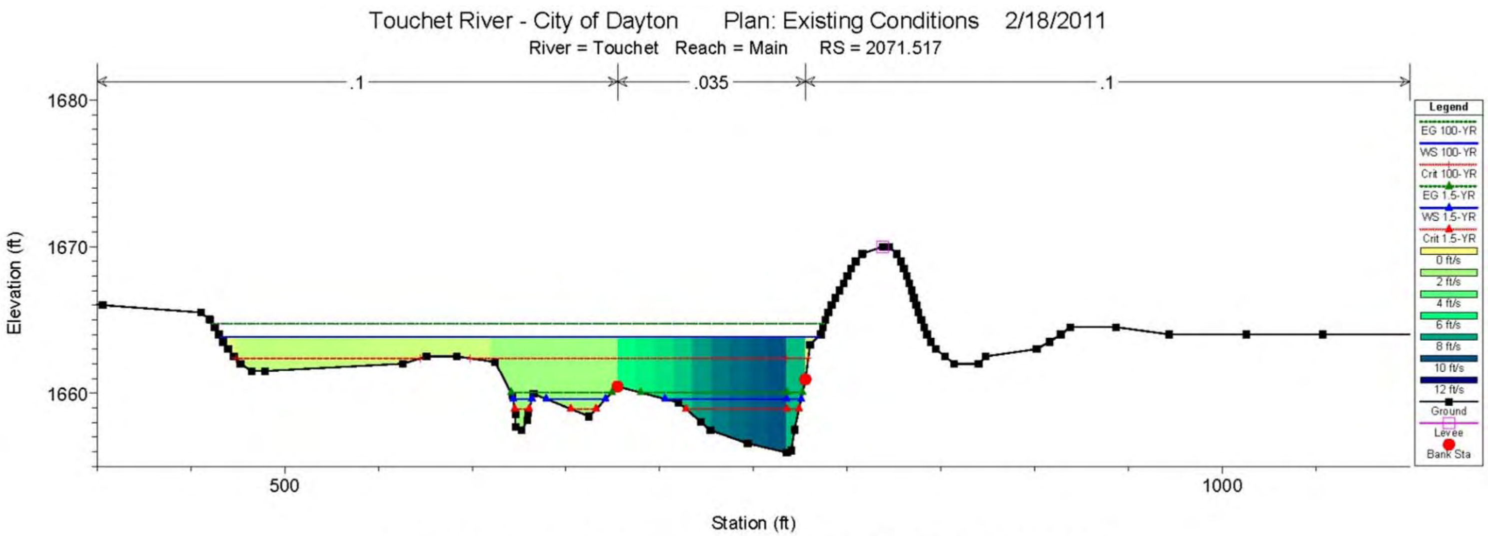
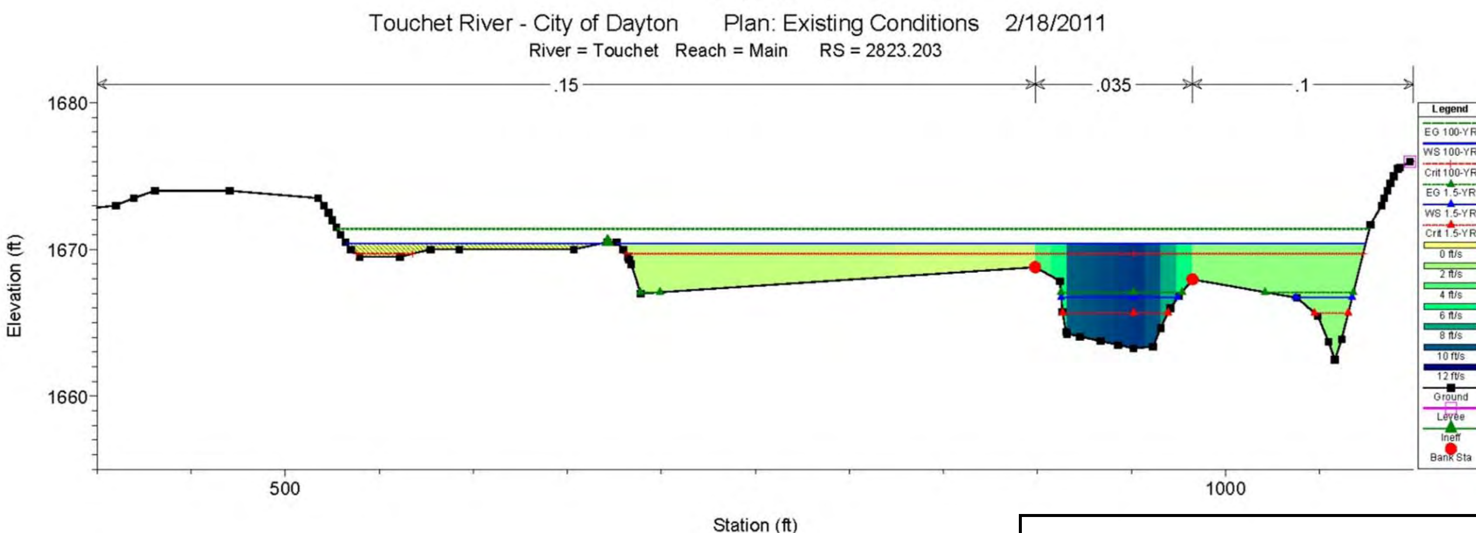
Figure E-27

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0





Cross Sections
Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

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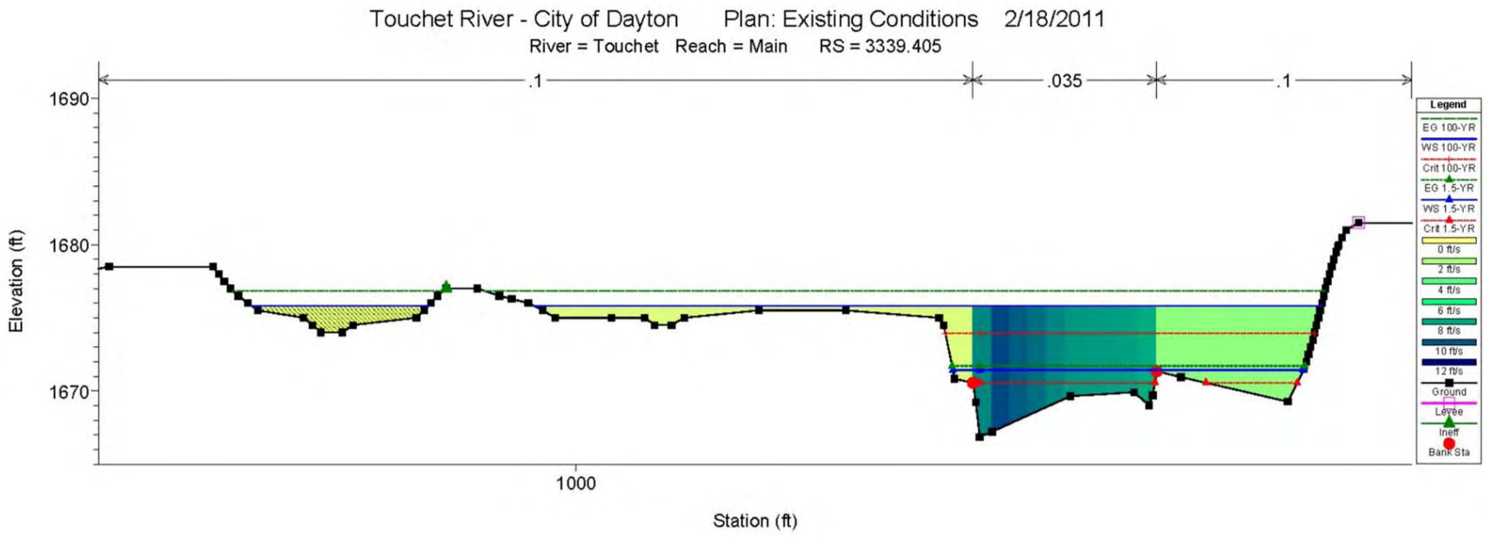
Figure E-28

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0



Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

Cross Sections
Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure E-29

HEC-RAS Plan: Existing River: Touchet Reach: Main

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Power Chan
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/ft s)
Main	3339.405	100-YR	5766.00	1666.86	1675.81	1673.94	1676.84	0.003562	8.93	1043.93	404.11	0.60	1.47	13.13
Main	3339.405	1.5-YR	900.00	1666.86	1671.43	1670.56	1671.71	0.003354	4.38	264.75	146.87	0.49	0.50	2.19
Main	3339.405	2-YR	1118.00	1666.86	1671.77	1670.81	1672.08	0.003224	4.69	315.34	148.05	0.49	0.55	2.56
Main	3339.405	5-YR	2654.00	1666.86	1673.57	1672.14	1674.12	0.003065	6.36	587.31	153.59	0.52	0.85	5.42
Main	3339.405	25-YR	3724.00	1666.86	1674.43	1672.81	1675.15	0.003304	7.40	719.68	171.78	0.56	1.09	8.05
Main	3339.405	50-YR	4679.00	1666.86	1675.11	1673.35	1675.99	0.003482	8.21	839.29	281.59	0.58	1.29	10.58
Main	3339.405	500-YR	8973.00	1666.86	1677.32	1675.96	1678.54	0.003612	10.26	1767.08	460.82	0.63	1.82	18.65
Main	2823.203	100-YR	5766.00	1663.24	1670.41	1669.70	1671.40	0.005291	9.30	1340.29	533.50	0.71	1.73	16.04
Main	2823.203	1.5-YR	900.00	1663.24	1666.71	1665.67	1667.08	0.003984	5.06	216.47	92.01	0.55	0.64	3.26
Main	2823.203	2-YR	1118.00	1663.24	1667.15	1665.99	1667.57	0.003945	5.40	263.28	133.86	0.55	0.71	3.84
Main	2823.203	5-YR	2654.00	1663.24	1668.85	1668.12	1669.45	0.004519	6.83	729.56	387.30	0.62	1.04	7.14
Main	2823.203	25-YR	3724.00	1663.24	1669.50	1668.83	1670.22	0.004675	7.72	981.45	412.14	0.64	1.27	9.77
Main	2823.203	50-YR	4679.00	1663.24	1669.98	1669.27	1670.82	0.004857	8.43	1171.38	435.61	0.67	1.46	12.28
Main	2823.203	500-YR	8973.00	1663.24	1671.57	1670.87	1672.86	0.005735	11.02	2038.67	549.87	0.76	2.27	25.05
Main	2071.517	100-YR	5766.00	1655.93	1663.82	1662.37	1664.74	0.003920	8.39	1131.65	318.71	0.62	1.37	11.51
Main	2071.517	1.5-YR	900.00	1655.93	1659.60	1658.92	1660.04	0.005842	5.42	192.84	114.48	0.64	0.79	4.28
Main	2071.517	2-YR	1118.00	1655.93	1659.97	1659.23	1660.44	0.006112	5.62	239.54	137.26	0.66	0.84	4.73
Main	2071.517	5-YR	2654.00	1655.93	1661.54	1660.76	1662.23	0.005375	6.98	486.43	177.20	0.67	1.13	7.88
Main	2071.517	25-YR	3724.00	1655.93	1662.40	1661.40	1663.22	0.004856	7.71	691.17	281.58	0.66	1.28	9.83
Main	2071.517	50-YR	4679.00	1655.93	1663.10	1661.98	1664.00	0.004443	8.16	903.81	310.68	0.64	1.36	11.07
Main	2071.517	500-YR	8973.00	1655.93	1665.81	1664.01	1666.80	0.003040	9.02	1787.98	368.15	0.57	1.44	12.95
Main	1351.858	100-YR	5766.00	1649.58	1658.39	1657.17	1660.11	0.004639	10.89	689.99	134.24	0.70	2.12	23.07
Main	1351.858	1.5-YR	900.00	1649.58	1653.20	1652.56	1653.74	0.005886	5.91	152.29	61.49	0.66	0.90	5.31
Main	1351.858	2-YR	1118.00	1649.58	1653.64	1652.88	1654.24	0.005438	6.21	180.03	63.40	0.65	0.95	5.89
Main	1351.858	5-YR	2654.00	1649.58	1655.71	1654.67	1656.75	0.004830	8.26	362.21	109.48	0.67	1.41	11.66
Main	1351.858	25-YR	3724.00	1649.58	1656.74	1655.67	1658.04	0.004754	9.33	480.24	119.09	0.68	1.69	15.76
Main	1351.858	50-YR	4679.00	1649.58	1657.55	1656.40	1659.06	0.004700	10.12	580.05	126.53	0.69	1.90	19.27
Main	1351.858	500-YR	8973.00	1649.58	1660.58	1659.10	1662.81	0.004431	12.63	1010.30	176.26	0.72	2.61	33.02
Main	1000	100-YR	5766.00	1646.73	1655.69	1655.36	1658.07	0.007005	14.23	751.33	138.66	0.87	3.51	49.91
Main	1000	1.5-YR	900.00	1646.73	1650.59	1650.06	1651.46	0.007009	7.56	132.01	50.39	0.74	1.36	10.26
Main	1000	2-YR	1118.00	1646.73	1651.02	1650.49	1652.04	0.007001	8.22	156.44	74.96	0.76	1.54	12.63
Main	1000	5-YR	2654.00	1646.73	1653.05	1652.92	1654.67	0.007002	11.03	399.14	127.75	0.82	2.39	26.37
Main	1000	25-YR	3724.00	1646.73	1654.07	1653.86	1655.97	0.007002	12.32	531.92	132.17	0.84	2.82	34.75
Main	1000	50-YR	4679.00	1646.73	1654.87	1654.61	1657.00	0.007006	13.28	638.58	135.39	0.86	3.16	41.96
Main	1000	500-YR	8973.00	1646.73	1657.78	1657.29	1660.79	0.007003	16.52	1049.18	146.69	0.90	4.39	72.47

Reference: Model output obtained from HEC-RAS Hydraulic Model v 4.1.0

HEC-RAS Output Table
Touchet River

Touchet River Geomorphic Assessment
Columbia County, Washington

GeoEngineers

Figure E-30

APPENDIX F
Alternative Assessment Workbook

1: Alternatives Analysis Workbook

Project:	Touchet River Geomorphic Assessment	**Site:**	Touchet, N.F. Touchet, S.F. Touchet
Project Number:	10291-002-00	**Analyst:**	Jeff Fealko
Watercourse:	Touchet River	**Latest Revision:**	1/6/2011

Workbook Description

- This workbook is:
- proprietary to GeoEngineers, Inc.,
- contains spreadsheets that facilitate the analysis and/or design of this project,
- lists the general project and workbook information that is consistent throughout the workbook,
- lists the titles of the spreadsheets contained in this workbook, and
- is intended for use with ENGLISH UNITS.

Filename: *http://projects/sites/1029100200/Draft/REPORT DOCUMENTS/[Touchet_Alternatives_Assessment_Workbook 1-10-11.xlsx]Intro*

Sheet Titles:

1: Alternatives Analysis Workbook
2: Selection and Refinement Criteria
3: Alternatives Considered
4: Rating of Alternatives
5: Unit Cost Sheet
6: Alternative 1 Cost Estimate
7: Alternative 2 Cost Estimate
8: Alternative 3 Cost Estimate
9: Alternative 4 Cost Estimate
10: Alternative 5 Cost Estimate
11: Summary Charts

2: Selection and Refinement Criteria

Project: Touchet River Geomorphic Assessment
Site: Touchet, N.F. Touchet, S.F. Touchet
Project Number: 10291-002-00
Analyst: Jeff Fealko
Watercourse: Touchet River
Latest Revision: 1/6/2011

- This spreadsheet lists selection criteria identified by GeoEngineers and the City of Dayton (including input from the Columbia County Levee Round Table Group and local Snake River Salmon Recoovery Board Regional Technical Team.
- Each of the selection criteria has been assigned a value based on its relative level of importance in achieving the overall project objectives as determined by GeoEngineers and the respectively. (decimals and/or similar values may be used if deemed necessary.)
- Subsequent spreadsheets in this workbook enable the user to rate each possible design alternative in terms of its level of effectiveness in addressing or achieving the refinement and selection criteria.

Relative Value of Selection Refinement Criteria
1 = Lowest Level of Importance
2 = Low Level of Importance
3 = Moderate Importance
4 = High Level of Importance
5 = Highest Level of Importance

Selection Criteria	Description	Relative Value (Avg) of Criteria Based on Level of Importance Identified by LRTG and RTT
SC1:	Obj. 1: Increase channel complexity and aquatic habitat	5.0
SC2:	Obj. 2: Increase/enhance/diversify riparian habitat	3.5
SC3:	Obj. 3: Geomorphic stability	4.0
SC4:	Obj. 4: Increase floodplain connectivity	5.0
SC5:	Obj. 5: Increase storage time and volume	4.0
SC6:	Obj. 6: Rapid Recovery Time	2.0
SC7:	Obj. 7: Design Practicality	2.0

3: Alternatives Considered

Project: Touchet River Geomorphic Assessment
Site: Touchet, N.F. Touchet, S.F. Touchet
Project Number: 10291-002-00
Analyst: Jeff Fealko
Watercourse: Touchet River
Latest Revision: 1/6/2011

- This spreadsheet lists the design alternatives considered to acheive the stated project objectives.
- The Design Alternatives were developed from suitable restoration options as determined by GeoEngineers.
- "No Action" alternative was added to the suitable alternatives.
- Subsequent spreadsheets in this workbook enable the user to rate each possible Design Alternative in terms of its level of effectiveness in addressing or achieving the selection and refinement criteria.

Alternative	Description
1	Side-Channel Creation - No Levee Setback
2	Side-Channel Creation - Small Levee Setback
3	Side-Channel and Channel Realignment - Levee Setback #1
4	Side-Channel and Channel Realignment - Levee Setback #2
5	No Action

4: Rating of Alternatives

Project: Touchet River Geomorphic Assessment
Project Number: 10291-002-00
Watercourse: Touchet River

Site: Touchet, N.F. Touchet, S.F. Touchet
Analyst: Jeff Fealko
Latest Revision: 1/6/2011

- This spreadsheet enables the user to rate how effective each possible design alternative is at achieving the stated selection criteria.
- The Rating for each alternative is calculated below by multiplying the relative value of each criterion by the alternative's relative effectiveness at acheiving the stated criterion. (Decimals and/or similar values may be used for relative effectivness if necessary.)
- The overall effectiveness of an alternative is based upon its final rating. Higher ratings are better.

Relative Effectiveness (score)
1 = Ineffective
2 = Minimally Effective
3 = Moderately Effective
4 = Effective
5 = Very Effective

Selection Criteria	Description	Relative Value of Criterian (weight)	Alternative 1		Alternative 2		Alternative 3		Alternative 4		Alternative 5		
			Side-Channel Creation - No Levee Setback		Side-Channel Creation - Small Levee Setback		Side-Channel and Channel Realignment - Levee Setback #1		Side-Channel and Channel Realignment - Levee Setback #2		No Action		
			Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Max Possible
SC1:	**Obj. 1: Increase channel complexity and aquatic habitat**	5	2	10	3	15	4	20	5	25	1	5	**25**
SC2:	**Obj. 2: Increase/enhance/diversify riparian habitat**	3.5	2	7	3	10.5	4.5	15.75	4.5	15.75	1	3.5	**17.5**
SC3:	**Obj. 3: Geomorphic stability**	4	3	12	4	16	4	16	5	20	3	12	**20**
SC4:	**Obj. 4: Increase floodplain connectivity**	5	2	10	3	15	5	25	5	25	1	5	**25**
SC5:	**Obj. 5: Increase storage time and volume**	4	2	8	3	12	5	20	5	20	1	4	**20**
SC6:	**Obj. 6: Rapid Recovery Time**	2	3	6	3	6	4	8	4	8	1	2	**10**
SC7:	**Obj. 7: Design Practicality**	2	4	8	4	8	2	4	3	6	5	10	**10**
Final Benefit Rating				**61.0**		**82.5**		**108.8**		**119.8**		**41.5**	127.5

5: Unit Cost Sheet

Project: Touchet River Geomorphic Assessment **Analyst:** Jeff Fealko

Project Number: 10291-002-00 **Latest Revision:** 1/6/2011

- This spreadsheet calculates the costs associated with site preparation. Unit costs include materials, labor, equipment, overhead and contractor profit.
- Reference used for "unit costs" include:
  (1) R.S. Means Heavy Construction Cost Data Manual, 2004 (Means)
  (2) Engineering Experience & Recent Similar Projects
  (3) Contractor or Supplier
- Inflation adjustment is a rough estimate using the Consumer Price Index average between 1999 and 2004.
- Additional adjustments are based on engineering judgement, experience and site-specific degree of difficulty.
- Blank rows are provided at the bottom for additional items. Add new items & unit costs on this sheet, if necessary. These will be used to calculate costs on subsequent sheets.
- General mark-up percentages are also provided at the bottom.

0	= Adjustment for inflation from to 2004 to 2012 (Construction) (%)
-3.4	= Location Factor (Clarkston/Richland) (%) (Adjustment from national average)
0	= Additional Location Factor (Remote) (%)

Item #	Item Description	Ref. ID	Ref. #	Page #	Units	Unit Cost ($)	Inflation & Location Adjustments (%)	Additional Adjustments (%)	Adjusted Unit Price ($)
1	Temporary Stream Diversion	1, 2			LS	20,000.00	0	0	20,000.00
2	Side Channel Excavation (excavator and 22 CY dump w/ 1,000-ft off-road haul)	1	31-23-16.42-0200 31-23-23.20-5000	219 243	CY	6.54	0.1	20	7.86
3	High Flow Channel Excavation (excavator and 22 CY dump w/ 1,000-ft off-road haul)	1	31-23-16.42-0200 31-23-23.20-5000	219 243	CY	6.54	0.1	0	6.55
4	Main Channel Sculpting (excavation and placement of excavated material in old channel and/or bar)	1	31-23-16.13-6080	214	CY	6.15	0.1	0	6.16
5	Main Channel Creation (excavation and placement of excavated material in abandoned channel and/or bar)	1	31-23-16.13-6080	214	CY	6.54	0.1	40	9.16
6	Channel Grading	1	31-22-16.10-1020	211	Acre	5,330.00	0.1	150	13,330.33
7	Floodplain/Wetland Grading (including terrace grading/shaping)	1	31-22-16.10-1020	211	Acre	5,330.00	0.1	100	10,665.33
8	Levee Removal (excavator and 20 CY dump w/ 2-mile haul)	1	31-23-16.42-0200 31-23-23.20-4020	219 239	CY	6.15	0.1	0	6.16
9	Levee Construction	1	31-23-16.42-0200 31-23-23.20-4020	219 239	CY	7.25	0.1	50	10.87
10	Large Woody Debris (acquisition, delivery, installation)	2,3			Each	1,200.00	0	0	1,200.00
11	Rock Structures (acquisition, delivery, installation)	2,3			CY	50.00	0	0	50.00
12	Riparian Vegetation (live staking and selective planting)	2			Acre	3,000.00	0	0	3,000.00
13	BMPs (jute mat, silt fence, hay bales, etc.)	2			Mile	20,000.00	0	0	20,000.00
14	Riparian Vegetation (full planting)	2			Acre	10,000.00	0	0	10,000.00
15	Levee (vegetation and debris clearing and placement of rock and riprap material)	2,3			LF	100.00	0	0	100.00
101	Mobilization (as % of Construction Sub-Total)							2	
102	Construction Observation (per alternative)							n/a	
103	Incidentals not included in items above (as % of Construction Sub-Total)							10	
104	Contingency (as % of Construction Sub-Total)							15	
105	Design (suitable for design build)							n/a	
106	Permitting							n/a	

6: Alternative 1 Cost Estimate

Project: Touchet River Geomorphic Assessment　　**Analyst:** Jeff Fealko

Project No: 10291-002-00　　**Latest Revision:** 1/6/2011

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost Sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost Sheet.

Item #	Item Description	Units	Adjusted Unit Cost ($)	No. of Units	Cost per Item ($)
1	Temporary Stream Diversion	LS	20,000.00	3.0	60,000
2	Side Channel Excavation (excavator and 22 CY dump w/ 1,000-ft off-road haul)	CY	7.86	12,233.0	96,136
3	High Flow Channel Excavation (excavator and 22 CY dump w/ 1,000-ft off-road haul)	CY	6.55	5,327.0	34,892
4	Main Channel Sculpting (excavation and placement of excavated material in old channel and/or bar)	CY	6.16	5,528.0	34,031
5	Main Channel Creation (excavation and placement of excavated material in abandoned channel and/or bar)	CY	9.16	0.0	0
6	Channel Grading	Acre	13,330.33	6.9	91,979
7	Floodplain/Wetland Grading (including terrace grading/shaping)	Acre	10,665.33	10.4	110,919
8	Levee Removal (excavator and 20 CY dump w/ 2-mile haul)	CY	6.16	0.0	0
9	Levee Construction	CY	10.87	0.0	0
10	Large Woody Debris (acquisition, delivery, installation)	Each	1,200.00	397.0	476,400
11	Rock Structures (acquisition, delivery, installation)	CY	50.00	332.0	16,600
12	Riparian Vegetation (live staking and selective planting)	Acre	3,000.00	16.2	48,600
13	BMPs (jute mat, silt fence, hay bales, etc.)	Mile	20,000.00	4.4	88,000
14	Riparian Vegetation (full planting)	Acre	10,000.00	6.5	65,000
15	Levee (vegetation and debris clearing and placement of rock and riprap material)	LF	100.00	3,375.0	337,500
	Constrution Sub-Total				**1,460,058**
101	Mobilization (as % of Construction Sub-Total)			n/a	25,000
102	Construction Observation (per alternative)			n/a	40,000
103	Incidentals not included in items above (as % of Construction Sub-Total)			10.0%	146,006
104	Contingency (as % of Construction Sub-Total)			15.0%	219,009
105	Design (suitable for design build)			n/a	60,000
106	Permitting			n/a	n/a
	Final Construction Cost				**1,950,072**

7: Alternative 2 Cost Estimate

Project: Touchet River Geomorphic Assessment
Analyst: Jeff Fealko
Project No: 10291-002-00
Latest Revision: 1/6/2011

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost Sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost Sheet.

Item #	Item Description	Units	Adjusted Unit Cost ($)	No. of Units	Cost per Item ($)
1	Temporary Stream Diversion	LS	20,000.00	5.0	100,000
2	Side Channel Excavation (excavator and 22 CY dump w/ 1,000-ft off-road haul)	CY	7.86	7,227.0	56,795
3	High Flow Channel Excavation (excavator and 22 CY dump w/ 1,000-ft off-road haul)	CY	6.55	11,840.0	77,553
4	Main Channel Sculpting (excavation and placement of excavated material in old channel and/or bar)	CY	6.16	5,528.0	34,031
5	Main Channel Creation (excavation and placement of excavated material in abandoned channel and/or bar)	CY	9.16	5,557.0	50,916
6	Channel Grading	Acre	13,330.33	7.8	103,977
7	Floodplain/Wetland Grading (including terrace grading/shaping)	Acre	10,665.33	12.0	127,984
8	Levee Removal (excavator and 20 CY dump w/ 2-mile haul)	CY	6.16	17,778.0	109,444
9	Levee Construction	CY	10.87	16,474.0	179,151
10	Large Woody Debris (acquisition, delivery, installation)	Each	1,200.00	404.0	484,800
11	Rock Structures (acquisition, delivery, installation)	CY	50.00	380.0	19,000
12	Riparian Vegetation (live staking and selective planting)	Acre	3,000.00	15.8	47,400
13	BMPs (jute mat, silt fence, hay bales, etc.)	Mile	20,000.00	4.4	88,000
14	Riparian Vegetation (full planting)	Acre	10,000.00	6.3	63,000
15	Levee (vegetation and debris clearing and placement of rock and riprap material)	LF	100.00	1,875.0	187,500
	Constrution Sub-Total				**1,729,550**
101	Mobilization (as % of Construction Sub-Total)			n/a	25,000
102	Construction Observation (per alternative)			n/a	52,000
103	Incidentals not included in items above (as % of Construction Sub-Total)			10.0%	172,955
104	Contingency (as % of Construction Sub-Total)			15.0%	259,433
105	Design (suitable for design build)			n/a	70,000
106	Permitting			n/a	n/a
	Final Construction Cost				**2,308,938**

8: Alternative 3 Cost Estimate

Project: Touchet River Geomorphic Assessment **Analyst:** Jeff Fealko
Project No: 10291-002-00 **Latest Revision:** 1/6/2011

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost Sheet.
- The unit costs are based upon those listed and calculated on the Unit Cost Sheet.

Item #	Item Description	Units	Adjusted Unit Cost ($)	No. of Units	Cost per Item ($)
1	Temporary Stream Diversion	LS	20,000.00	6.0	120,000
2	Side Channel Excavation (excavator and 22 CY dump w/ 1,000-ft off-road haul)	CY	7.86	13,271.0	104,293
3	High Flow Channel Excavation (excavator and 22 CY dump w/ 1,000-ft off-road haul)	CY	6.55	7,097.0	46,486
4	Main Channel Sculpting (excavation and placement of excavated material in old channel and/or bar)	CY	6.16	4,739.0	29,174
5	Main Channel Creation (excavation and placement of excavated material in abandoned channel and/or bar)	CY	9.16	38,240.0	350,376
6	Channel Grading	Acre	13,330.33	5.9	78,649
7	Floodplain/Wetland Grading (including terrace grading/shaping)	Acre	10,665.33	12.4	132,250
8	Levee Removal (excavator and 20 CY dump w/ 2-mile haul)	CY	6.16	30,317.0	186,636
9	Levee Construction	CY	10.87	28,492.0	309,843
10	Large Woody Debris (acquisition, delivery, installation)	Each	1,200.00	508.0	609,600
11	Rock Structures (acquisition, delivery, installation)	CY	50.00	409.0	20,450
12	Riparian Vegetation (live staking and selective planting)	Acre	3,000.00	12.0	36,000
13	BMPs (jute mat, silt fence, hay bales, etc.)	Mile	20,000.00	4.4	88,000
14	Riparian Vegetation (full planting)	Acre	10,000.00	4.8	48,000
15	Levee (vegetation and debris clearing and placement of rock and riprap material)	LF	100.00	817.0	81,700
	Constrution Sub-Total				**2,241,457**
101	Mobilization (as % of Construction Sub-Total)			n/a	25,000
102	Construction Observation (per alternative)			n/a	67,000
103	Incidentals not included in items above (as % of Construction Sub-Total)			10.0%	224,146
104	Contingency (as % of Construction Sub-Total)			15.0%	336,219
105	Design (suitable for design build)			n/a	90,000
106	Permitting			n/a	n/a
	Final Construction Cost				**2,983,821**

9: Alternative 4 Cost Estimate

Project: Touchet River Geomorphic Assessment **Analyst:** Jeff Fealko
Project No: 10291-002-00 **Latest Revision:** 1/6/2011

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost Sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost Sheet.

Item #	Item Description	Units	Adjusted Unit Cost ($)	No. of Units	Cost per Item ($)
1	Temporary Stream Diversion	LS	20,000.00	6.0	120,000
2	Side Channel Excavation (excavator and 22 CY dump w/ 1,000-ft off-road haul)	CY	7.86	13,103.0	102,973
3	High Flow Channel Excavation (excavator and 22 CY dump w/ 1,000-ft off-road haul)	CY	6.55	6,632.0	43,440
4	Main Channel Sculpting (excavation and placement of excavated material in old channel and/or bar)	CY	6.16	4,528.0	27,875
5	Main Channel Creation (excavation and placement of excavated material in abandoned channel and/or bar)	CY	9.16	46,401.0	425,151
6	Channel Grading	Acre	13,330.33	5.6	74,650
7	Floodplain/Wetland Grading (including terrace grading/shaping)	Acre	10,665.33	11.9	126,917
8	Levee Removal (excavator and 20 CY dump w/ 2-mile haul)	CY	6.16	30,317.0	186,636
9	Levee Construction	CY	10.87	28,492.0	309,843
10	Large Woody Debris (acquisition, delivery, installation)	Each	1,200.00	539.0	646,800
11	Rock Structures (acquisition, delivery, installation)	CY	50.00	403.0	20,150
12	Riparian Vegetation (live staking and selective planting)	Acre	3,000.00	15.1	45,300
13	BMPs (jute mat, silt fence, hay bales, etc.)	Mile	20,000.00	4.4	88,000
14	Riparian Vegetation (full planting)	Acre	10,000.00	6.0	60,000
15	Levee (vegetation and debris clearing and placement of rock and riprap material)	LF	100.00	817.0	81,700
	Constrution Sub-Total				**2,359,436**
101	Mobilization (as % of Construction Sub-Total)			n/a	25,000
102	Construction Observation (per alternative)			n/a	74,000
103	Incidentals not included in items above (as % of Construction Sub-Total)			10.0%	235,944
104	Contingency (as % of Construction Sub-Total)			15.0%	353,915
105	Design (suitable for design build)			n/a	90,000
106	Permitting			n/a	n/a
	Final Construction Cost				**3,138,294**

10: Alternative 5 Cost Estimate

Project: Touchet River Geomorphic Assessment **Analyst:** Jeff Fealko

Project No: 10291-002-00 **Latest Revision:** 1/6/2011

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost Sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost Sheet.

Item #	Item Description	Units	Adjusted Unit Cost ($)	No. of Units	Cost per Item ($)
1	Temporary Stream Diversion	LS	20,000.00	0.0	0
2	Side Channel Excavation (excavator and 22 CY dump w/ 1,000-ft off-road haul)	CY	7.86	0.0	0
3	High Flow Channel Excavation (excavator and 22 CY dump w/ 1,000-ft off-road haul)	CY	6.55	0.0	0
4	Main Channel Sculpting (excavation and placement of excavated material in old channel and/or bar)	CY	6.16	0.0	0
5	Main Channel Creation (excavation and placement of excavated material in abandoned channel and/or bar)	CY	9.16	0.0	0
6	Channel Grading	Acre	13,330.33	0.0	0
7	Floodplain/Wetland Grading (including terrace grading/shaping)	Acre	10,665.33	0.0	0
8	Levee Removal (excavator and 20 CY dump w/ 2-mile haul)	CY	6.16	0.0	0
9	Levee Construction	CY	10.87	0.0	0
10	Large Woody Debris (acquisition, delivery, installation)	Each	1,200.00	0.0	0
11	Rock Structures (acquisition, delivery, installation)	CY	50.00	0.0	0
12	Riparian Vegetation (live staking and selective planting)	Acre	3,000.00	0.0	0
13	BMPs (jute mat, silt fence, hay bales, etc.)	Mile	20,000.00	0.0	0
14	Riparian Vegetation (full planting)	Acre	10,000.00	0.0	0
15	Levee (vegetation and debris clearing and placement of rock and riprap material)	LF	100.00	3,375.0	337,500
	Constrution Sub-Total				**337,500**
101	Mobilization (as % of Construction Sub-Total)			n/a	20,000
102	Construction Observation (per alternative)			n/a	22,000
103	Incidentals not included in items above (as % of Construction Sub-Total)			10.0%	33,750
104	Contingency (as % of Construction Sub-Total)			15.0%	50,625
105	Design (suitable for design build)			n/a	20,000
106	Permitting			n/a	n/a
	Final Construction Cost				**483,875**

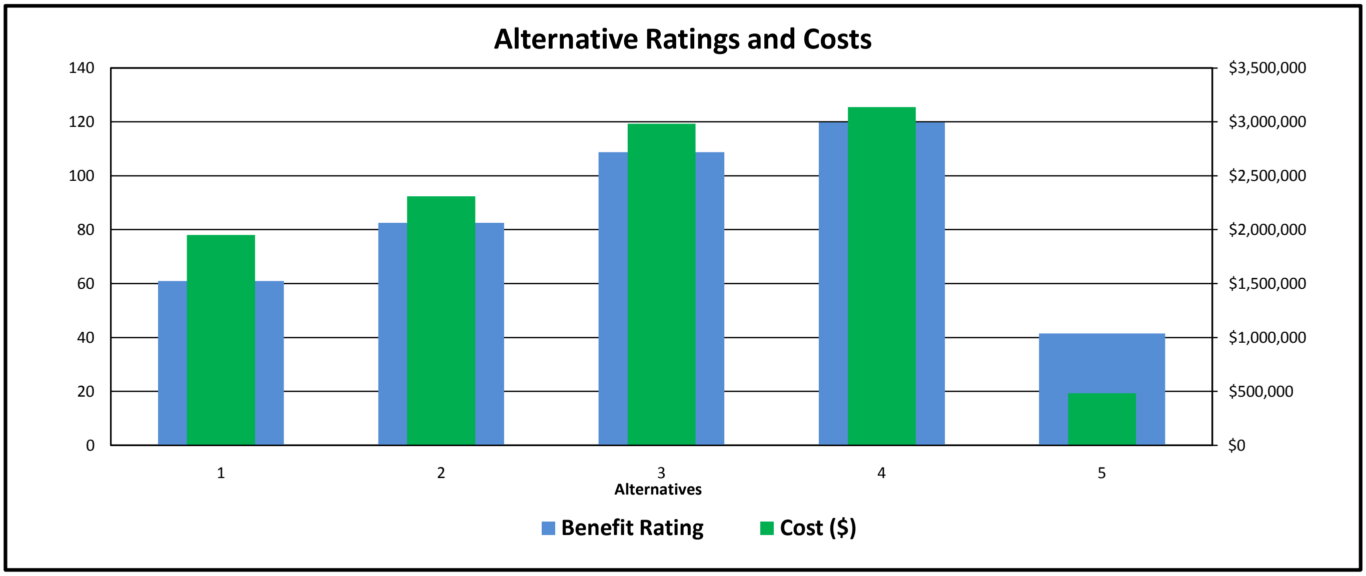
11: Summary Charts

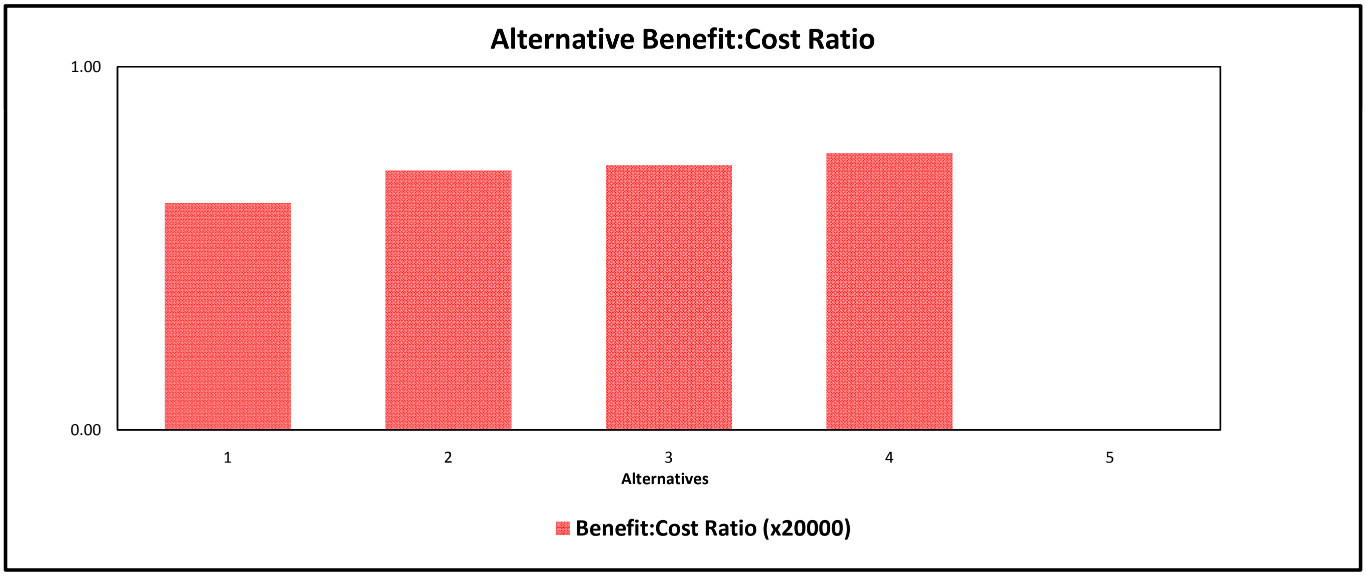
Project: Touchet River Geomorphic Assessment
Project Number: 10291-002-00
Watercourse: Touchet River

Site: Touchet, N.F. Touchet, S.F. Touch
Analyst: Jeff Fealko
Latest Revision: 1/6/2011

Spreadsheet Description:

- This spreadsheet charts the relative ratings and cost of each Alternative considered. The ratings are based upon the relative value of the criterion based on the level of importance.



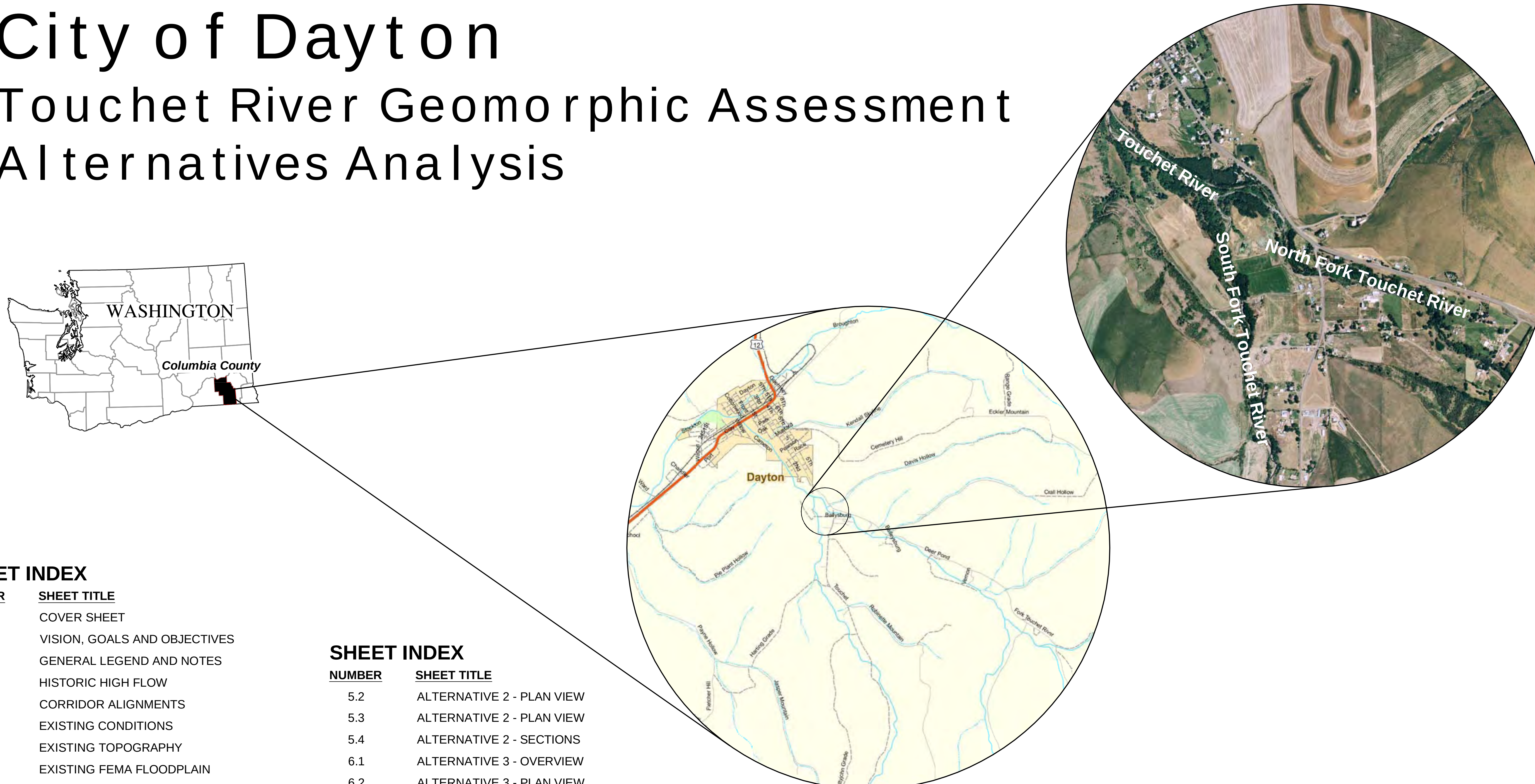


Alternative	Description	Benefit Rating	Cost ($)	Benefit:Cost Ratio (x20000)
1	Side-Channel Creation - No Levee Setback	61	1,950,072	0.63
2	Side-Channel Creation - Small Levee Setback	83	2,308,938	0.71
3	Side-Channel and Channel Realignment - Levee Setback #1	109	2,983,821	0.73
4	Side-Channel and Channel Realignment - Levee Setback #2	120	3,138,294	0.76
5	No Action	42	483,875	n/a

APPENDIX G
Conceptual Design Drawings

City of Dayton

Touchet River Geomorphic Assessment Alternatives Analysis



SHEET INDEX

SHEET INDEX

PROJECT MANAGER

GeoEngineers, Inc.
Jodie Lamb, LEG, LG
523 E. Second Ave.
Spokane, WA 99202
PH: 509.363.3125
FAX: 509.36.3126

Project Location:
Project is located approximately 2 miles southeast of Main Street in downtown Dayton, Washington and encompasses approximately 1.2 miles of the North Fork Touchet River, 0.4 miles of the South Fork Touchet River and 0.4 miles of the Touchet River.

Reference: Washington state map provided by the US Census Bureau. Vicinity map obtained from ESRI. Aerial image obtained from NAIP.

Revision No:	Date:	Description:	Initials:	
		FOR CONCEPTUAL USE ONLY		Designed: JJF
				Drawn: JLH
				Checked: MKH
				Date: 03/11/11
				Project No: 10291-002-00

Touchet River
Columbia County, WA

City of Dayton, Washington

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Spokane, WA 99202

Cover Sheet

Touchet River Alternatives Analysis

Sheet **1.1**

JJF : JJF

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Vision → *Goals* → *Objectives*

Vision

Increase, enhance and diversify aquatic riparian and upland habitat in the upper Touchet River watershed for juvenile and adult anadromous salmonids while simultaneously reducing the risk for flooding within the City of Dayton and surrounding areas by addressing levee and sediment issues.

Increase and Enhance Habitat

Increase Channel Complexity and Aquatic Habitat
- Multiple Habitats Close Together
- Primary Pool Habitat
- Substrate Diversification
- Instream Habitat Structure
- Side Channel/Off Channel Habitat
- Floodplain Connectivity

Increase Floodplain Function
- Increase Floodplain Connectivity
- Increase Floodplain Storage Time and Volume

Increase, Enhance Diversify Riparian Habitat
- Diverse Vegetation (Cover, Temperature, Recruitment, Macroinvertebrates)
- Bio-Engineering (Native Plants. Channel, Floodplain and Habitat Stability)

Geomorphic Stability
- Reduces Erosion, Sedimentation, Property Loss
- Self-Sustaining, Self-Maintaining
- Minimize Maintenance
- Cost Effective

Benefits to Other Species (Water fowl, Song Birds, Upland Species)

Treatment Options

In-Stream Habitat Structures
- Woody Habitat Structures
- Roughened Channels, Boulder Structures

Floodplain Connectivity
- Layback Steep Existing Slopes
- Levee Removal and/or Setback
- Levee Maintenance
- Floodplain Benching
- High Flow Flood Channels
- Floodplain Excavation
- Revetment Removal and/or Setback

Side Channel / Off Channel Habitat
- Create Side Channels
- Meander Creation (Side Channel, Main Channel)
- Wetlands
- Backwater Habitat

Preserve, Enhance and Minimize Disturbance to High-Value Resources

Vegetation Plan
- Bank Stabilization
- Floodplain Roughness

Design Practicality

Accommodate Physical, Practical and Regulatory Site Constraints

Minimize Project Complexity

Rapid Recovery Time

Practical Design Considerations

- Public Safety
- Flood Management (USACE, FEMA)
- Geomorphic Stability (Minimizes Avulsions, Erosion, Sedimentation, Habitat Destruction)
- Zoning, Easements, Setbacks, Floodplains, Zones
- Levees and Levee Maintenance
- Property Boundaries
- Landowner Desires
- Neighboring Properties
- Bridges, Utilities, Water Rights
- Grades, Access, Views
- Permits, Schedule, Budget, Maintenance, Constructability
- Economics

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				Project No: 10291-002-00

Touchet River
Columbia County, WA

City of Dayton, Washington

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Vision, Goals and Objectives

Touchet River Alternatives Analysis

Sheet **1.2**

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JJF : JJF

LEGEND

- EXISTING MAIN CHANNEL
- PROPOSED MAIN CHANNEL
- PROPOSED SIDE CHANNEL
- PROPOSED HIGH FLOW CHANNEL
- PROPOSED LEVEE
- EXISTING LEVEE
- PROPOSED FLOODPLAIN ROUGHNESS
- PROPOSED HABITAT STRUCTURE
- EXISTING MAJOR CONTOUR
- EXISTING MINOR CONTOUR
- PROPERTY LINE
- BOULDER CLUSTER
- FEMA FLOODPLAIN
- ZONE X FLOODPLAIN
- FEMA CROSS SECTIONS
- FEMA FLOODWAY

DRAWING REFERENCE DATA:

1. PARCEL DATA IS FROM THE COLUMBIA COUNTY, WASHINGTON GIS DEPARTMENT.
2. LIDAR (TOPOGRAPHY) WAS FLOWN BY WATERSHED SCIENCES, INC. BETWEEN MARCH 31, 2010 AND APRIL 14, 2010.
3. AERIAL PHOTOGRAPHY WAS FLOWN BY WATERSHED SCIENCES, INC. BETWEEN MARCH 31, 2010 AND APRIL 14, 2010.
4. FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA) FLOODPLAIN MAPS AND INFORMATION WAS OBTAINED FROM THE FEMA FLOOD INSURANCE RATE MAP (FIRM) 53013C0154B EFFECTIVE MAY 4, 1988 AND THE FLOOD INSURANCE STUDY (FIS) FOR COLUMBIA COUNTY, WASHINGTON AND INCORPORATED AREAS REVISED JULY 19, 2000.
5. HORIZONTAL DATUM IS NORTH AMERICAN DATUM 1983, WASHINGTON STATE PLANE COORDINATES, SOUTH, FEET.
6. VERTICAL DATUM IS NORTH AMERICAN VERTICAL DATUM (NAVD) OF 1988, US FEET.
7. FEMA BASE FLOOD ELEVATIONS SHOWN ON SHEET 3.3 ARE CURRENTLY SHOWN IN THE NATIONAL GEODETIC VERTICAL DATUM (NGVD) OF 1929, FEET.

JJF : JLH

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				Project No: 10291-002-00

Touchet River
Columbia County, WA

City of Dayton, Washington

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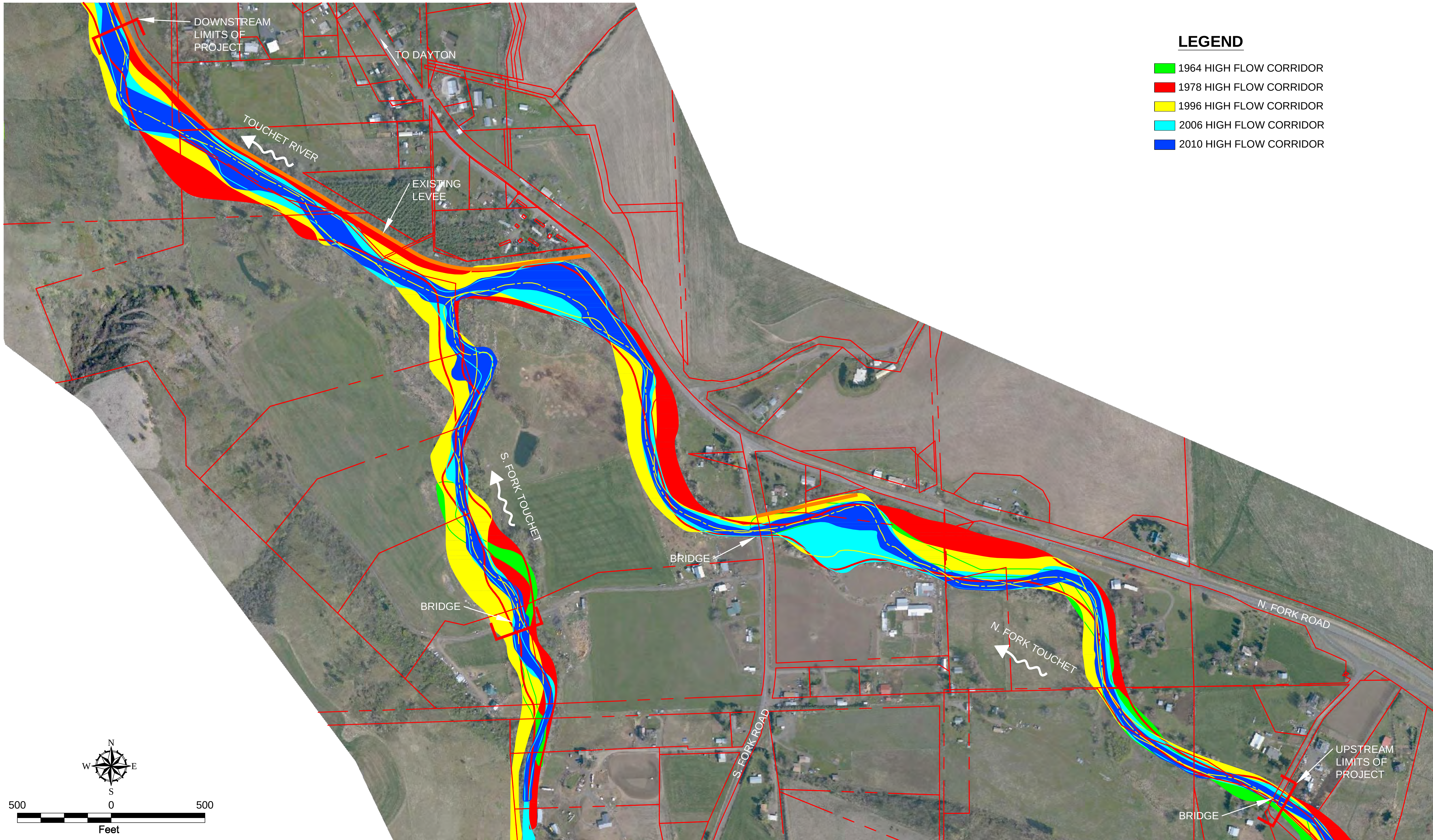
General Legend and Notes

Touchet River Alternatives Analysis

Sheet **1.3**



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Touchet River
Columbia County, WA

City of Dayton, Washington

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Historic Channel Alignments

Touchet River Alternatives Analysis

Sheet
2.1

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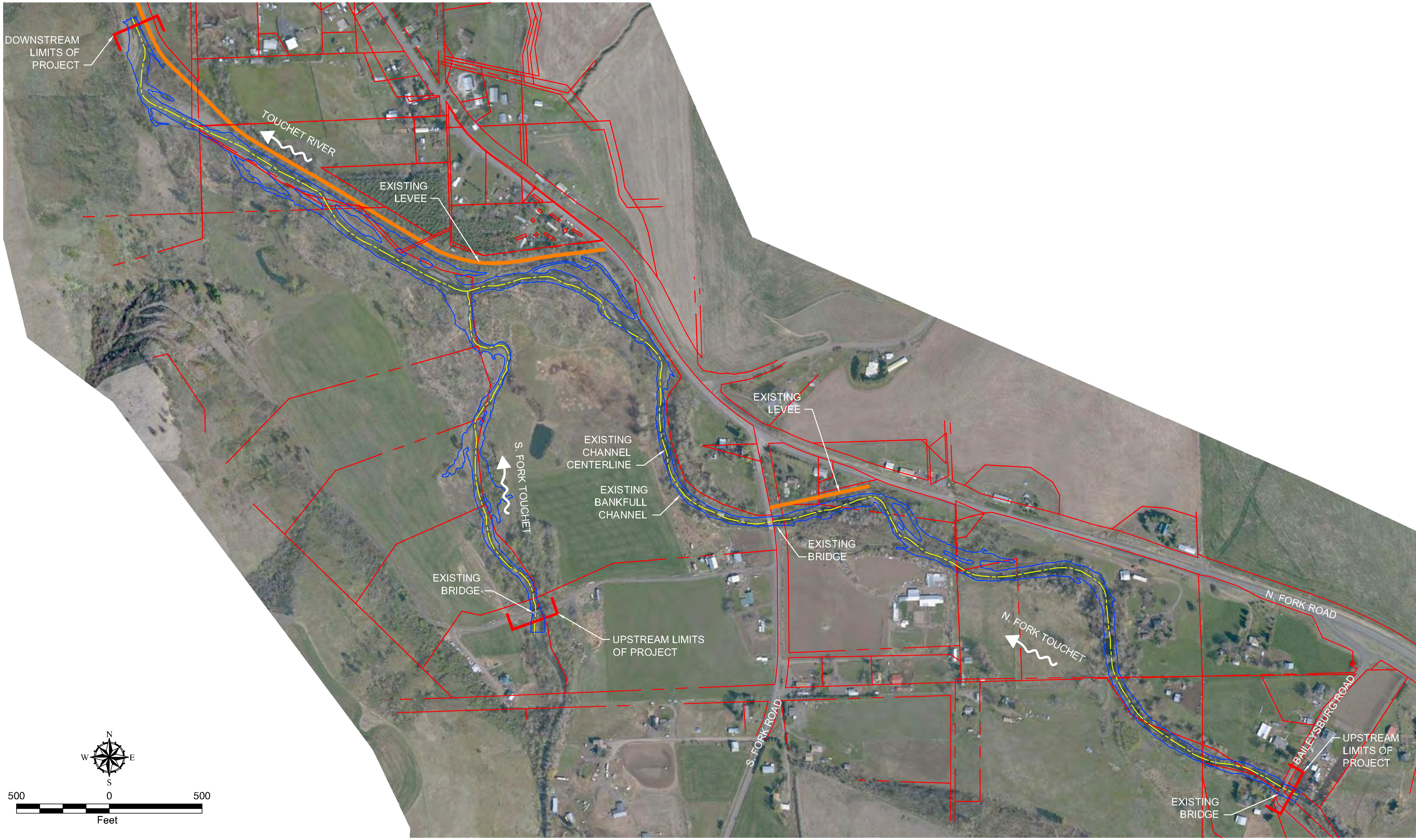

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				Project No: 10291-002-00

Touchet River
Columbia County, WA

City of Dayton, Washington

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Existing Conditions

Touchet River Alternatives Analysis

Sheet
3.1

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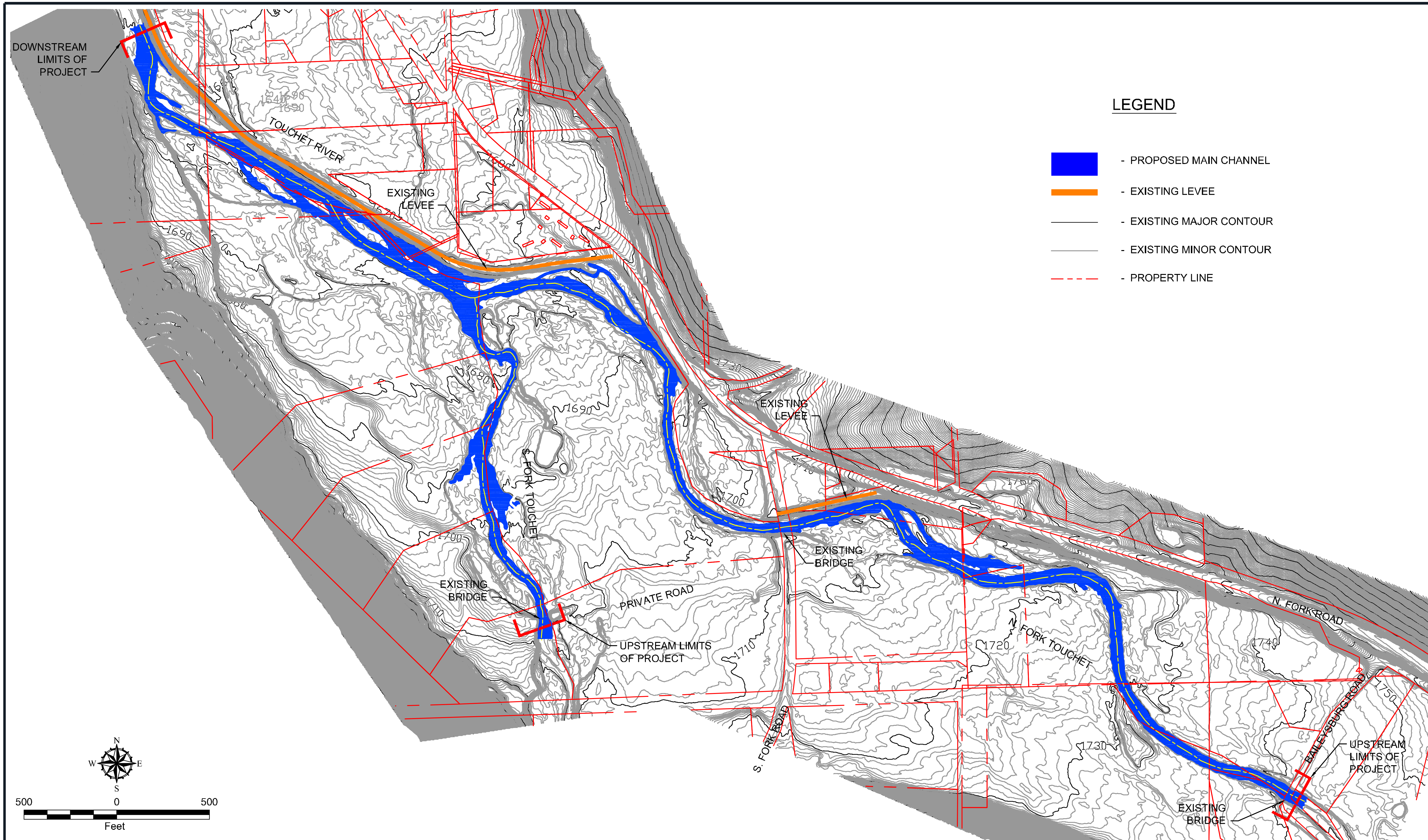

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Project No: 10291-002-00

Touchet River
Columbia County, WA

City of Dayton, Washington

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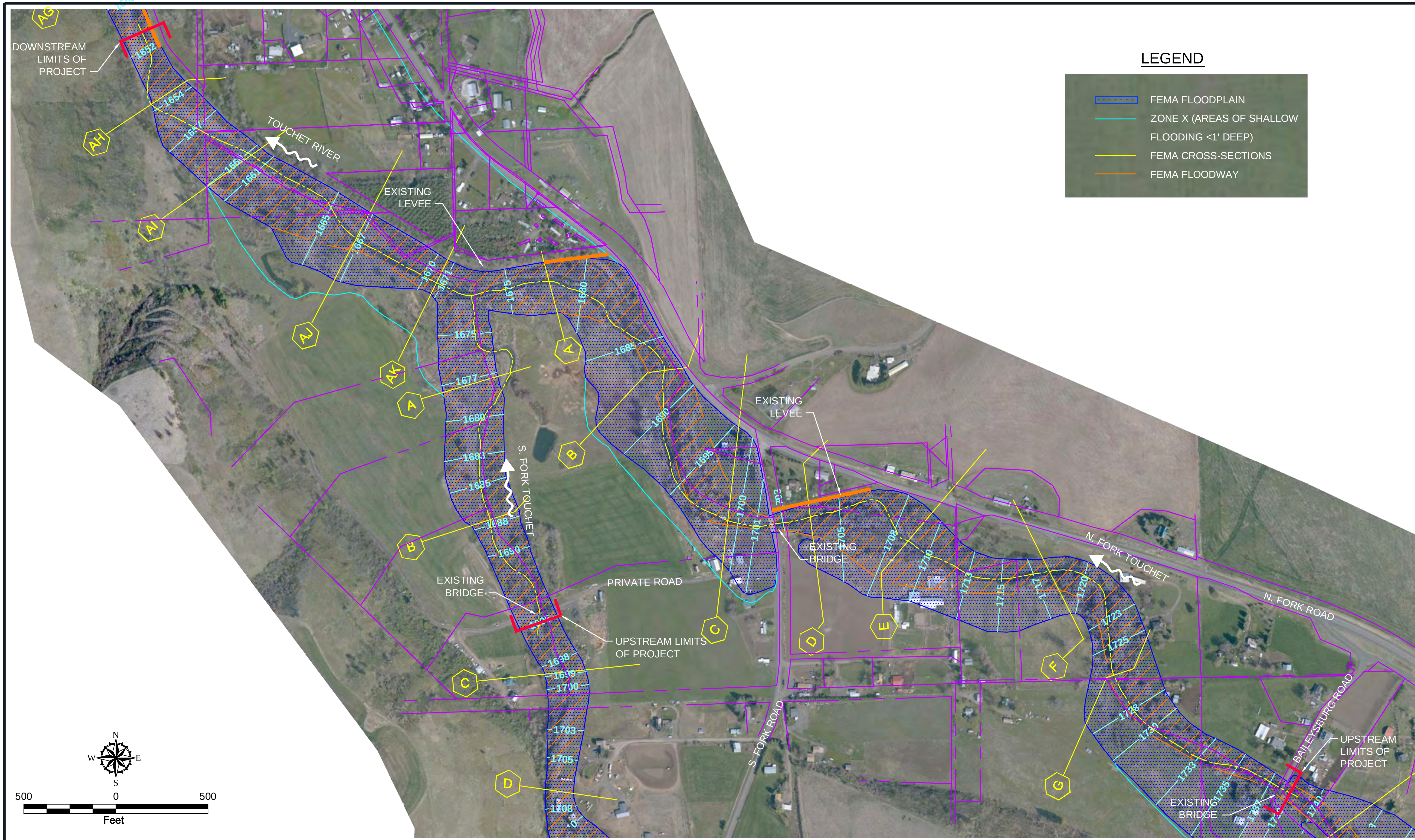
Existing Topography

Touchet River Alternatives Analysis

Sheet
3.2



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				Checked: MKH
				Date: 11/23/11
				Project No: 10291-002-00

Touchet River
Columbia County, WA

City of Dayton, Washington

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Existing FEMA Floodplain

Touchet River Alternatives Analysis

Sheet
3.3

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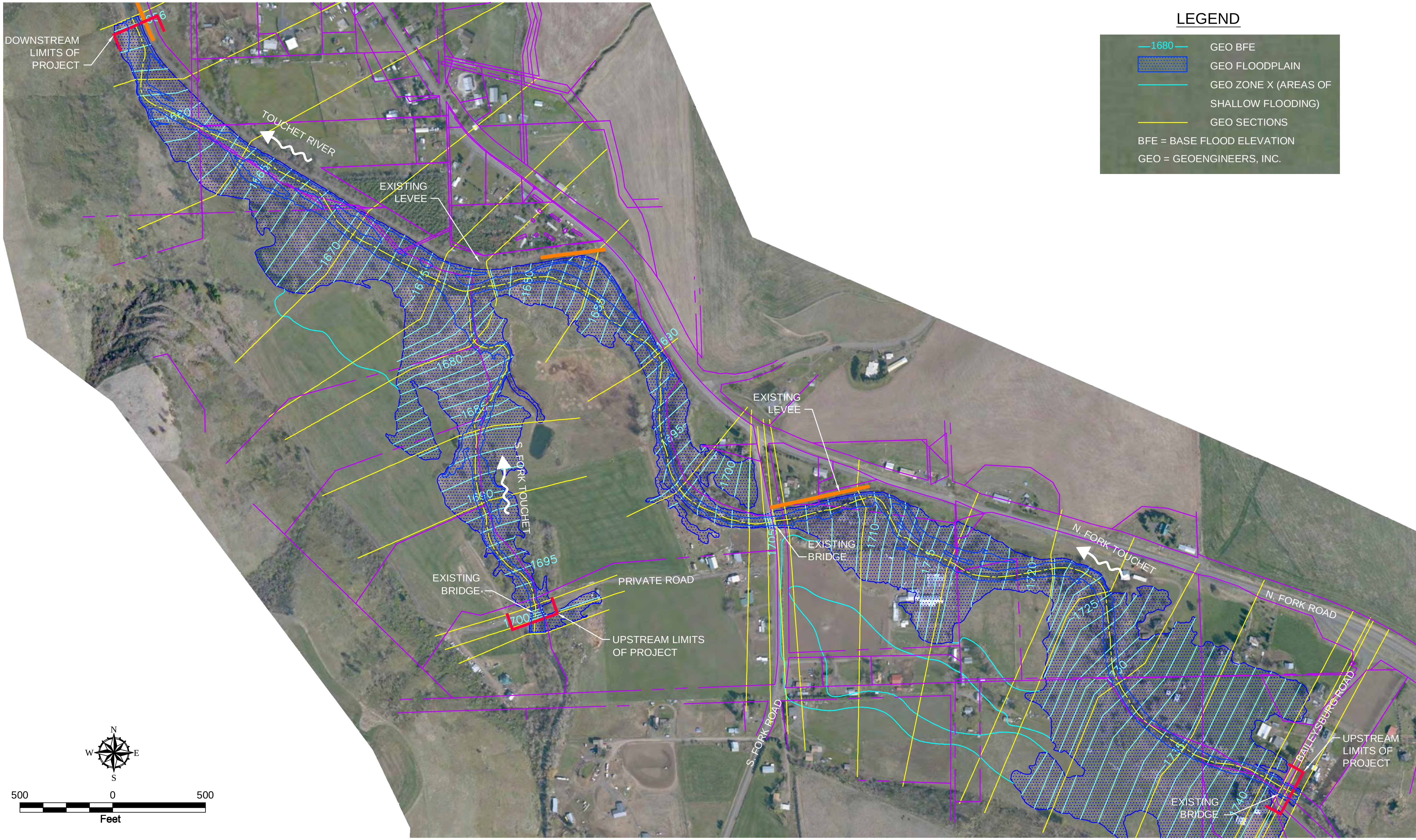

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Touchet River
Columbia County, WA

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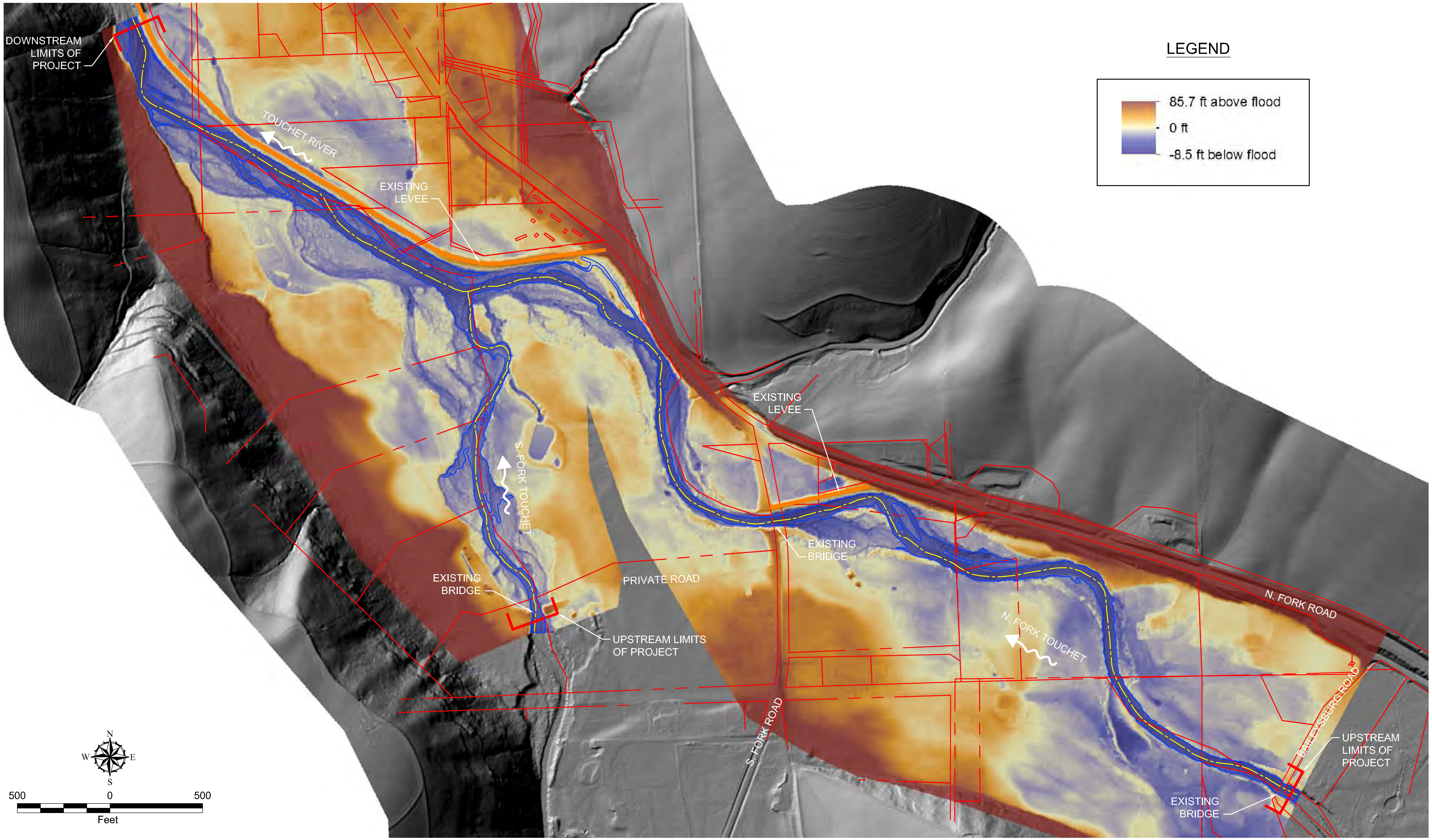
Existing GeoEngineers Floodplain

Touchet River Alternatives Analysis

Sheet **3.4**



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Touchet River
Columbia County, WA

City of Dayton, Washington

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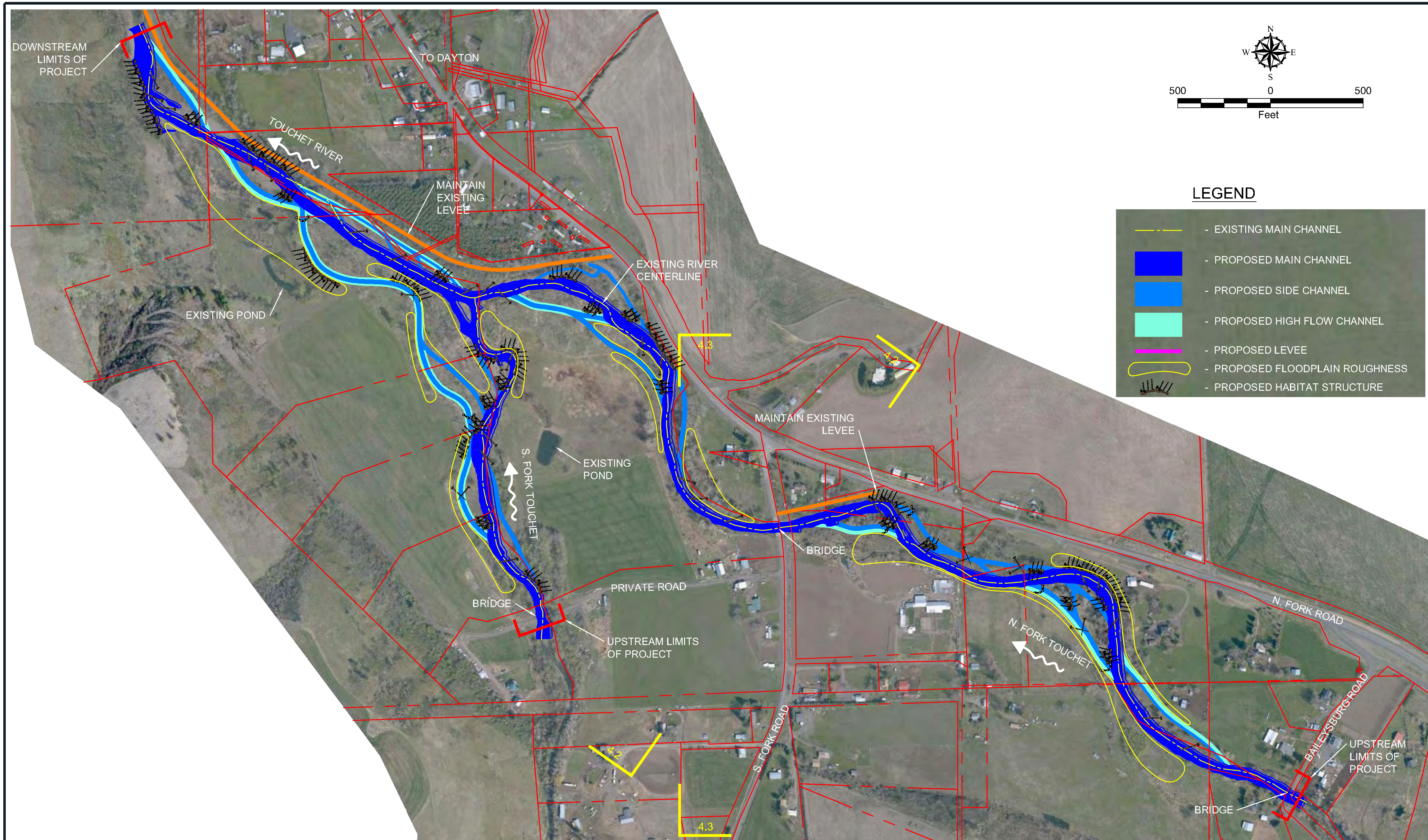
Relative Surface Model

Touchet River Alternatives Analysis

Sheet
3.5



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FOR CONCEPTUAL USE ONLY				Designed: JJF	Touchet River Columbia County, WA City of Dayton, Washington	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	**Alternative 1 - Overview** Touchet River Alternatives Analysis	**Sheet** **4.1**
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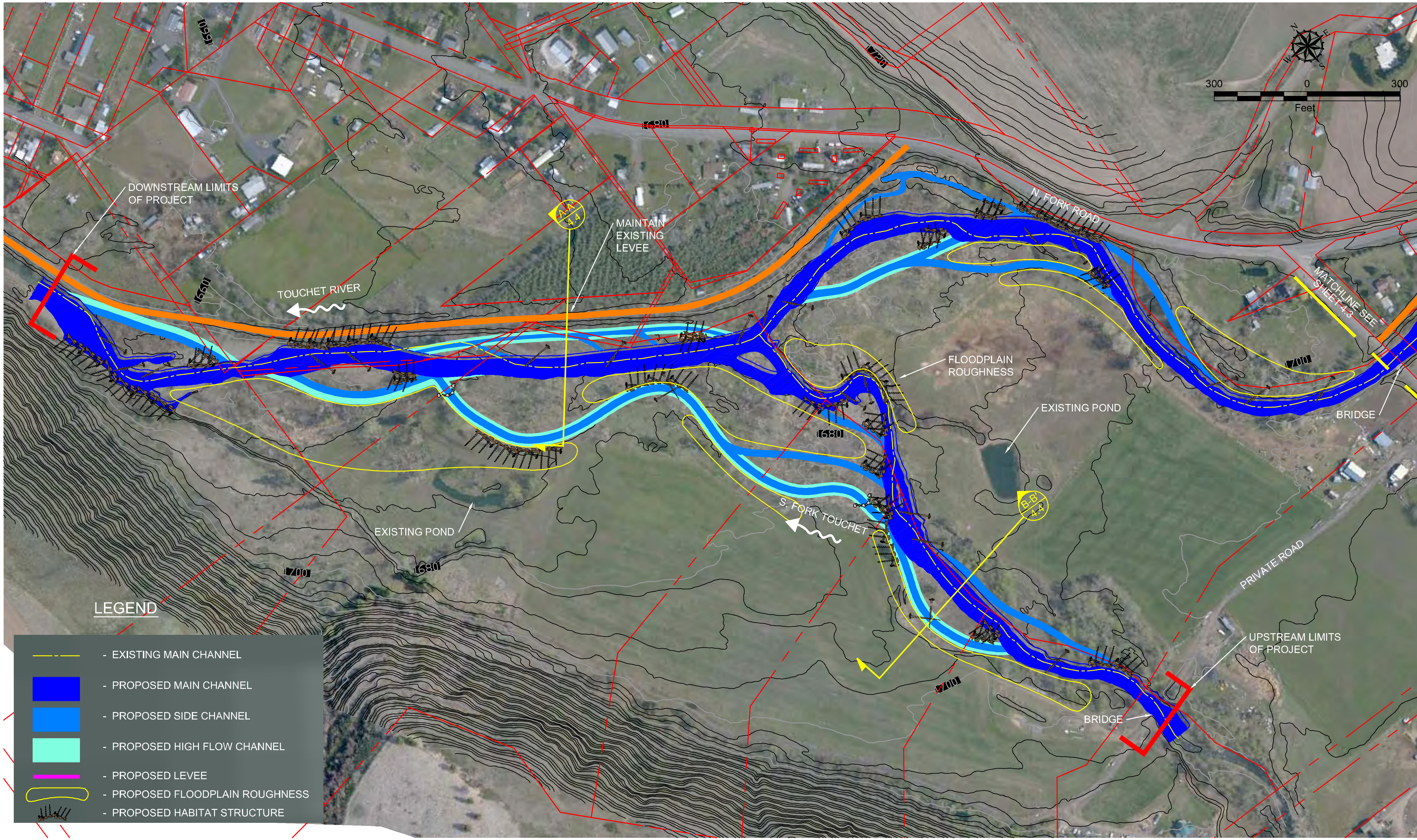
				Checked: MKH				
				Date: 03/11/11				
				Project No: 10291-002-00				



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				Project No: 10291-002-00

Touchet River
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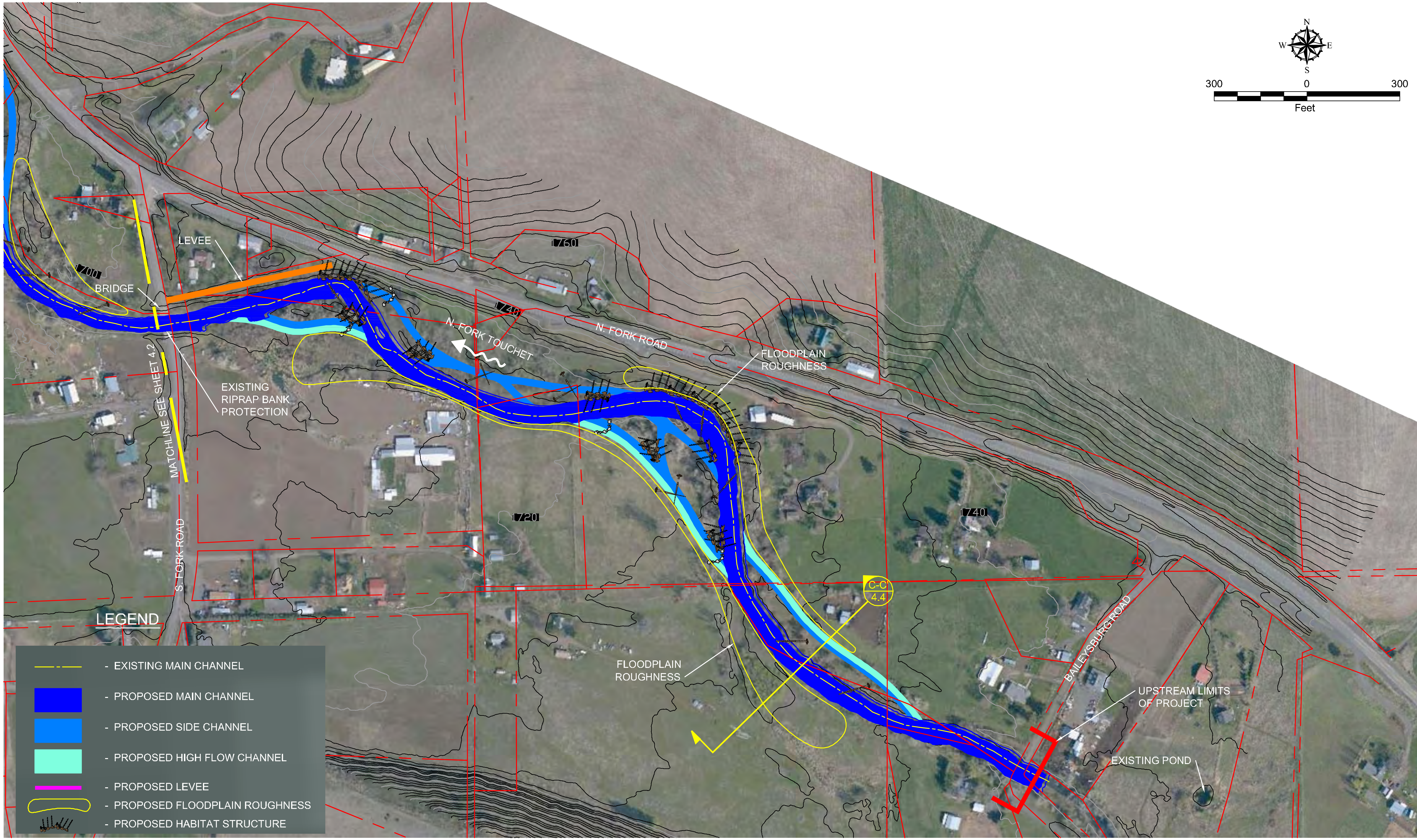
Alternative 1 - Plan View

Touchet River Alternatives Analysis

Sheet
4.2



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Touchet River
Columbia County, WA

City of Dayton, Washington

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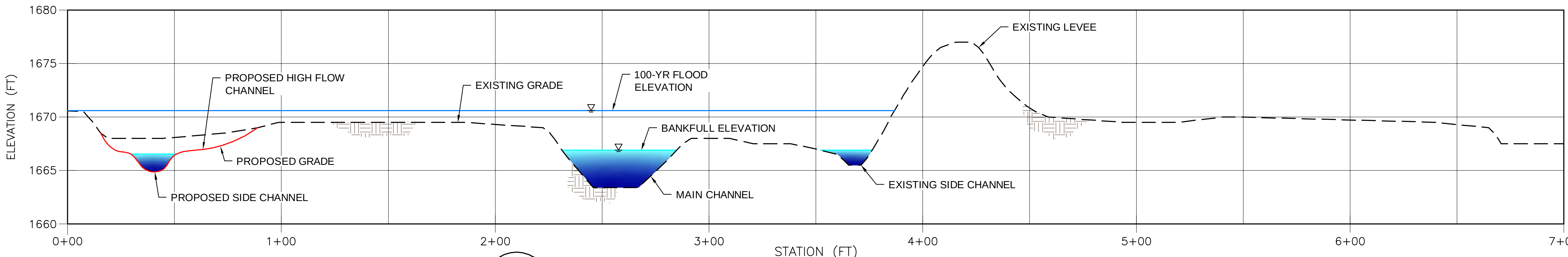
Alternative 1 - Plan View

Touchet River Alternatives Analysis

Sheet
4.3



A–A'
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CROSS SECTION A–A'

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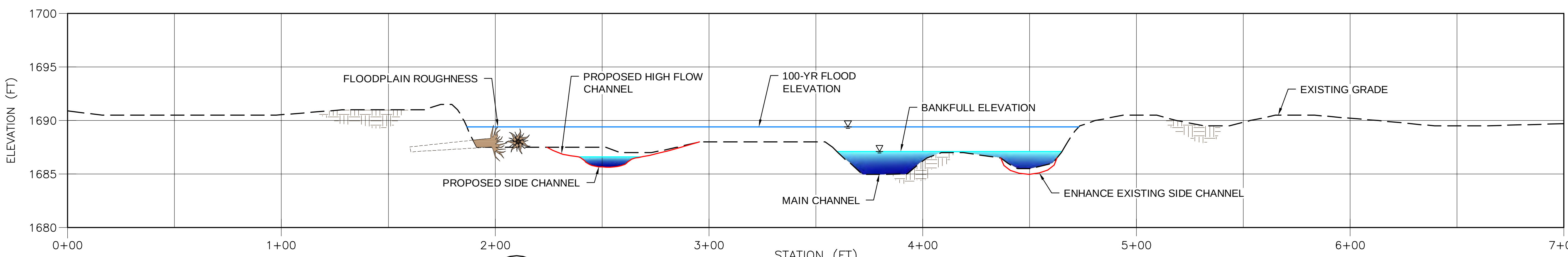

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CROSS SECTION B–B'

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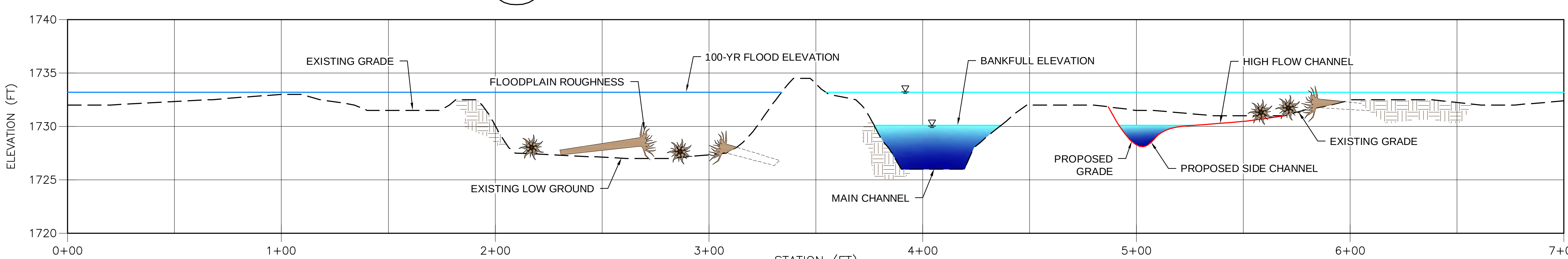

C–C'
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CROSS SECTION C–C'

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Touchet River
Columbia County, WA

City of Dayton, Washington

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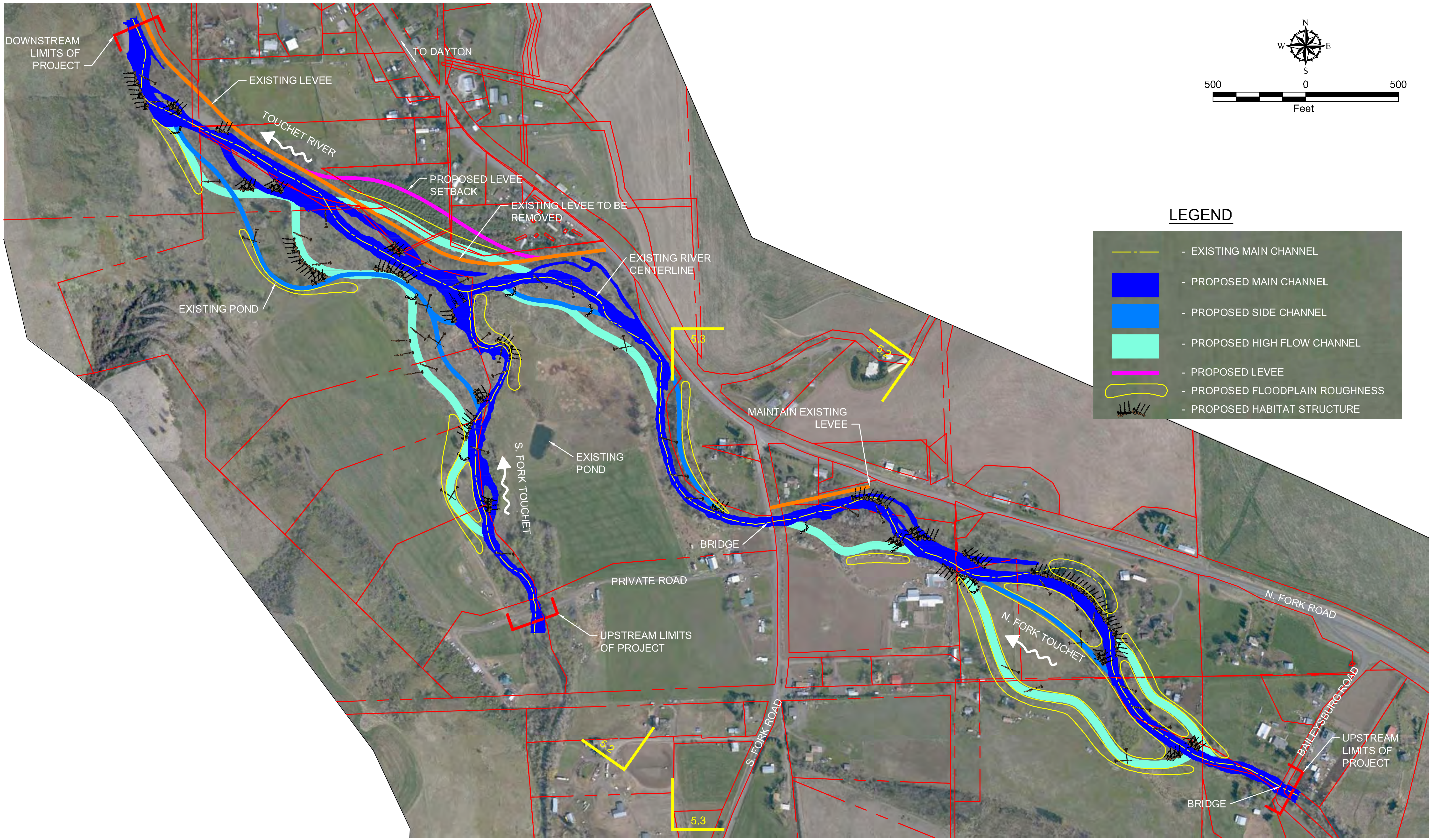
Alternative 1 - Sections

Touchet River Alternatives Analysis

Sheet
4.4



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				Project No: 10291-002-00

Touchet River
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Alternative 2 - Overview

Touchet River Alternatives Analysis

Sheet
5.1

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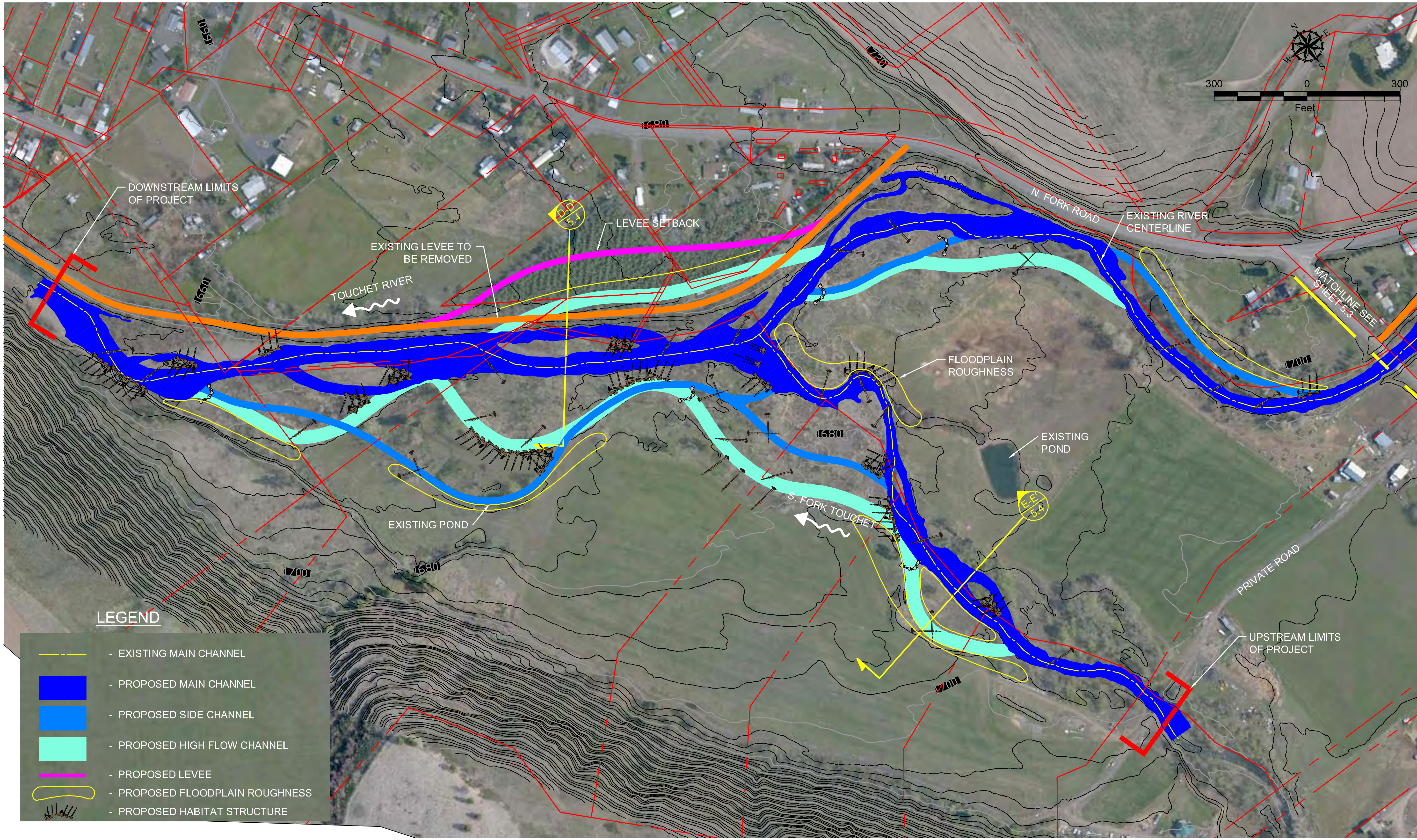

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				Project No: 10291-002-00

Touchet River
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City of Dayton, Washington

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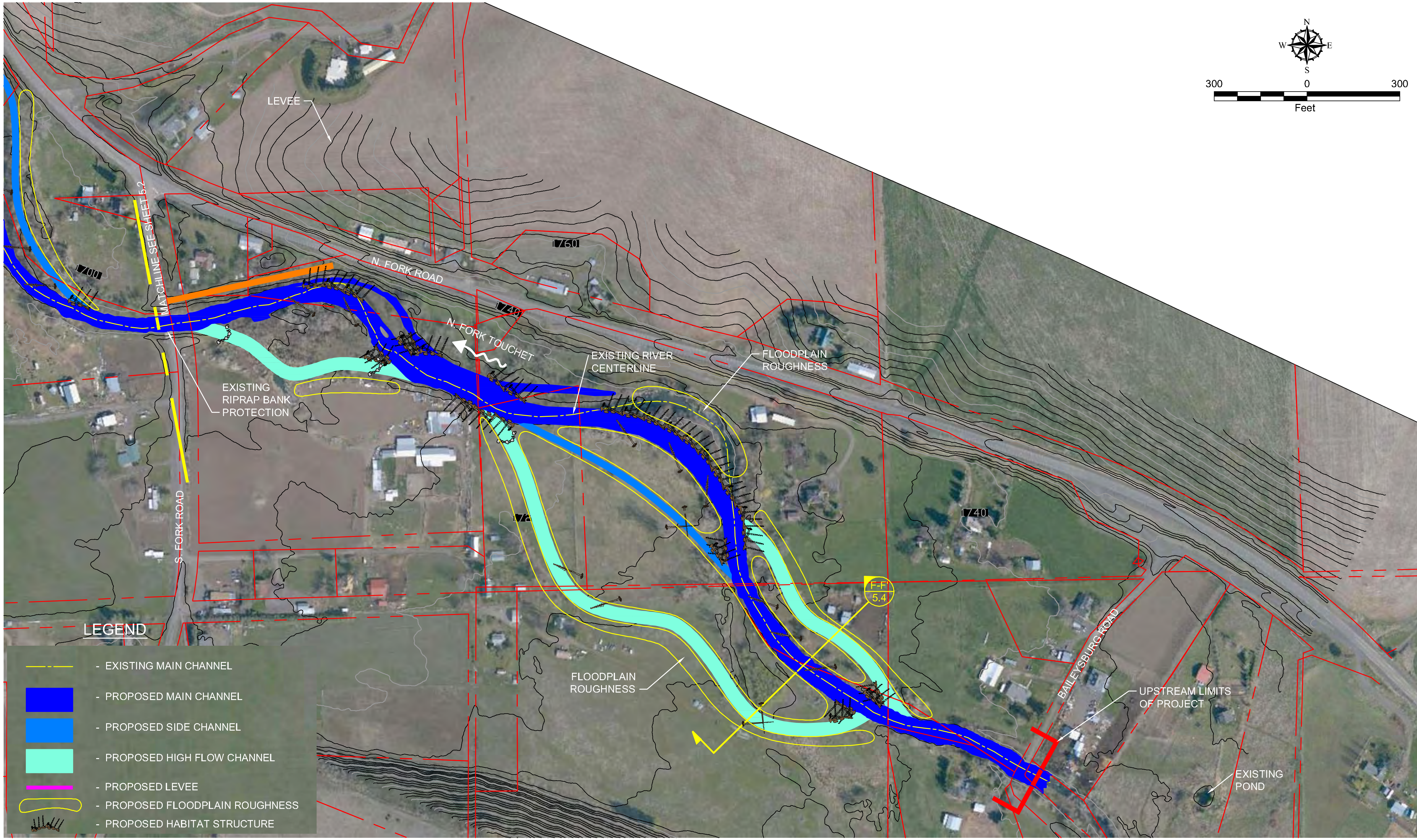
Alternative 2 - Plan View

Touchet River Alternatives Analysis

Sheet
5.2



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				Date: 03/11/11
				Project No: 10291-002-00

Touchet River
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City of Dayton, Washington

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Alternative 2 - Plan View

Touchet River Alternatives Analysis

Sheet
5.3

JJF : JJF

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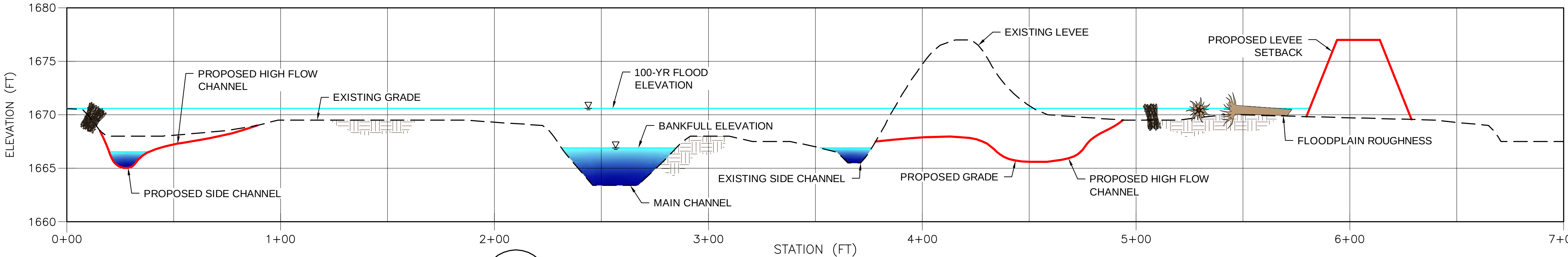

D–D' 5.2

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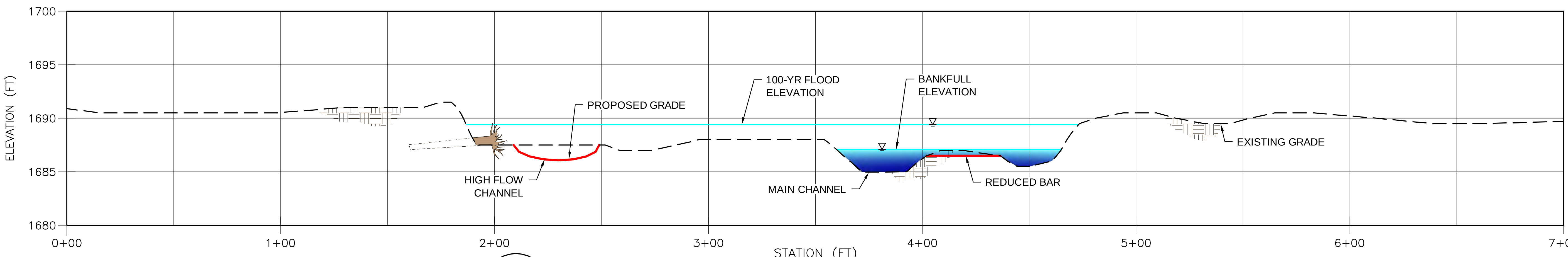

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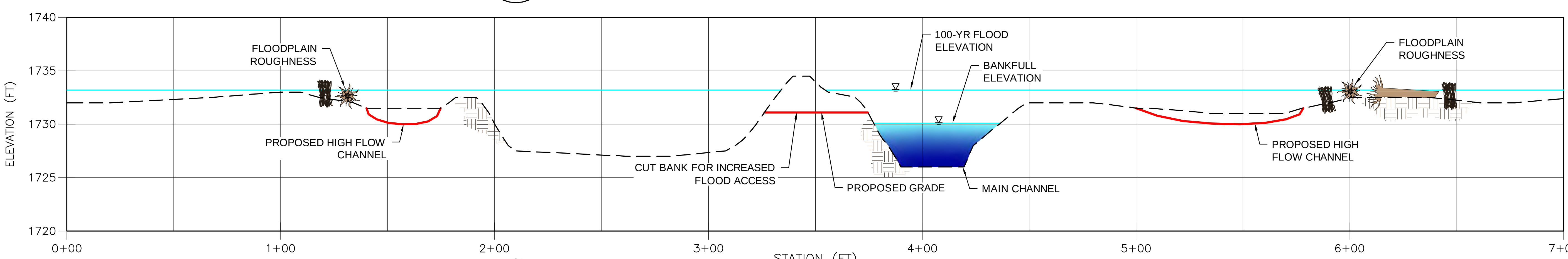

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Drawn: JJF, JLH
Checked: MKH
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Project No: 10291-002-00

Touchet River
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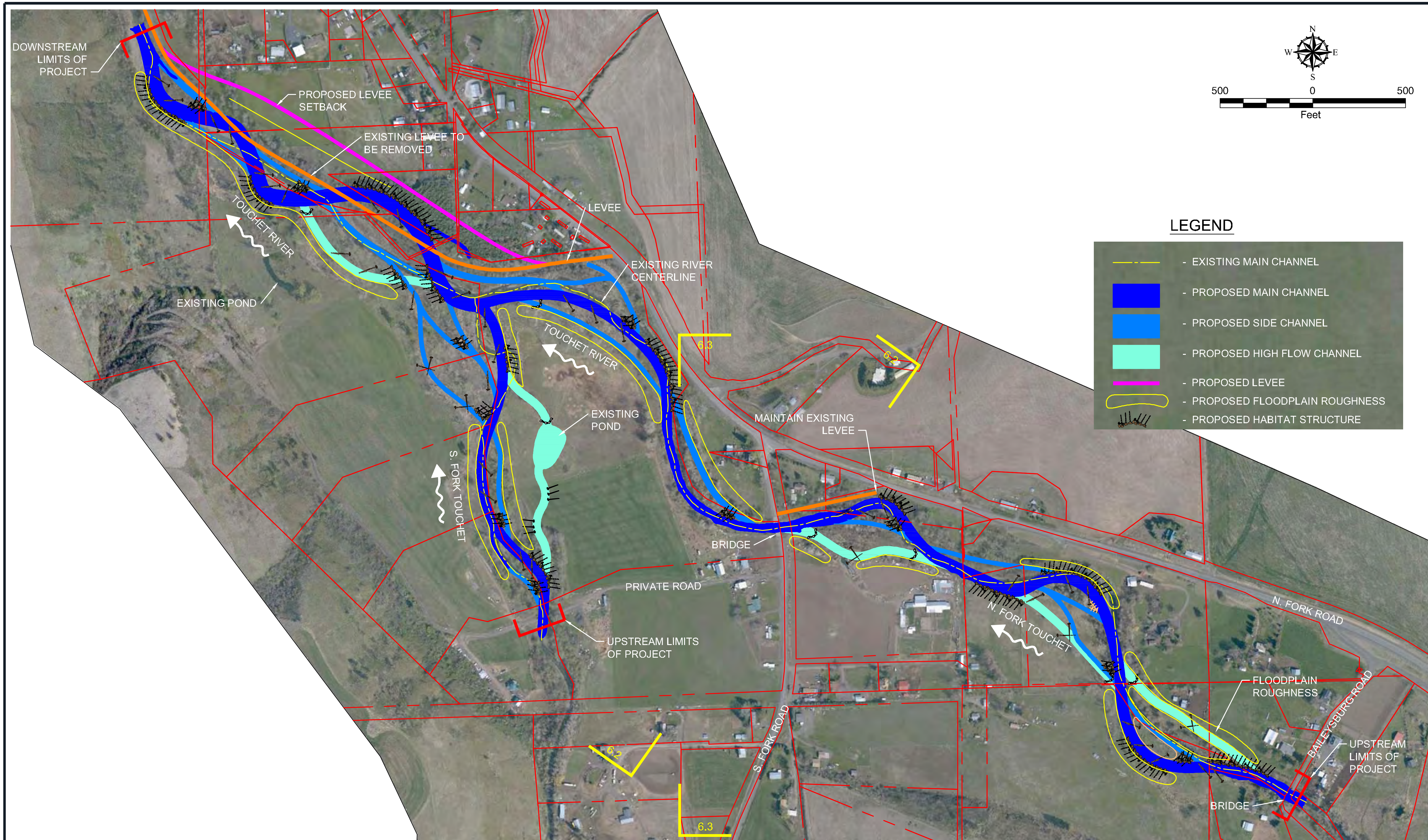
Alternative 2 - Sections

Touchet River Alternatives Analysis

Sheet
5.4



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		FOR CONCEPTUAL USE ONLY		Designed: JJF	Touchet River Columbia County, WA City of Dayton, Washington	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	**Alternative 3 - Overview** Touchet River Alternatives Analysis	**Sheet** **6.1**
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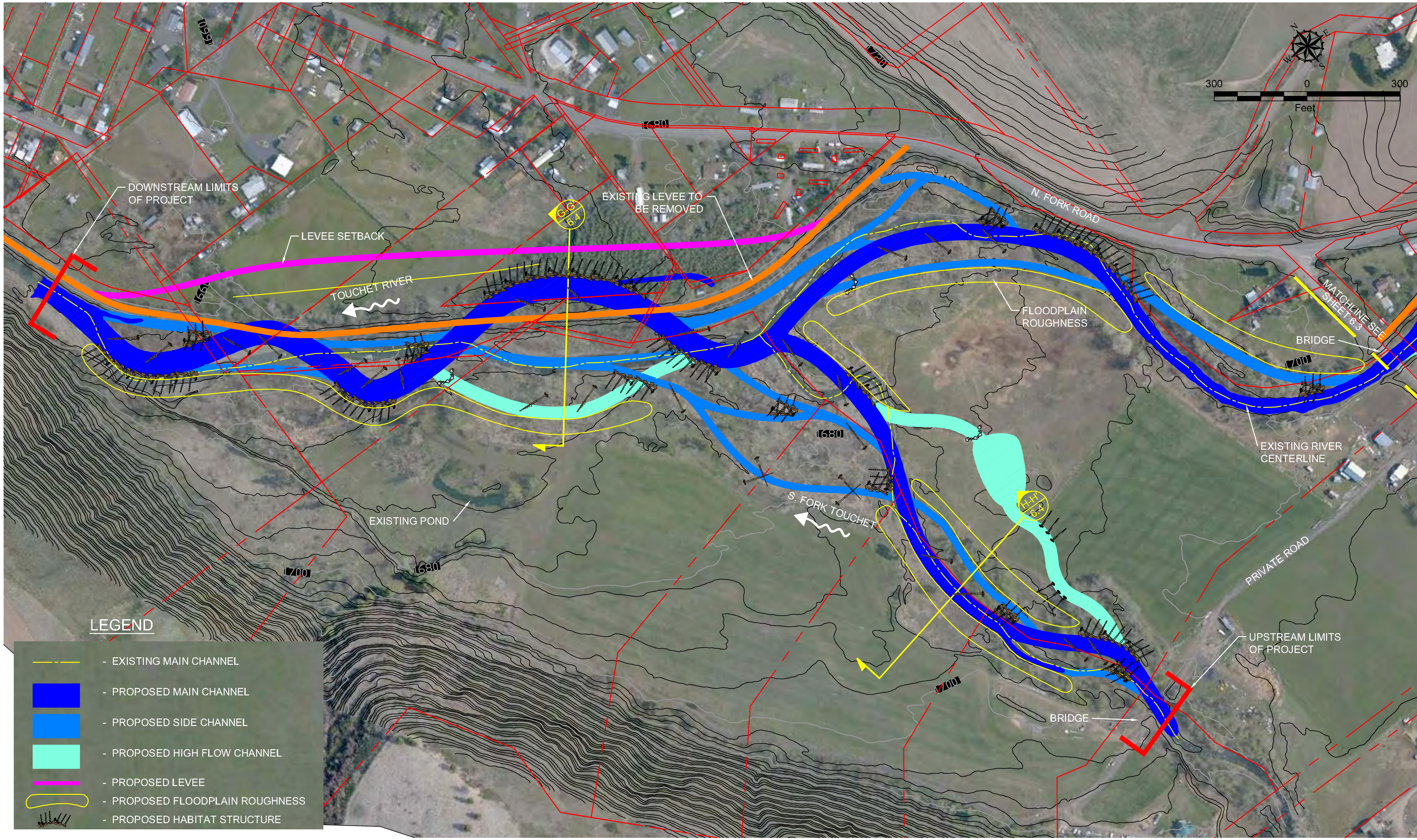
				Checked: MKH				
				Date: 03/11/11				
				Project No: 10291-002-00				



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				Checked: MKH
				Date: 03/11/11
				Project No: 10291-002-00

Touchet River
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City of Dayton, Washington

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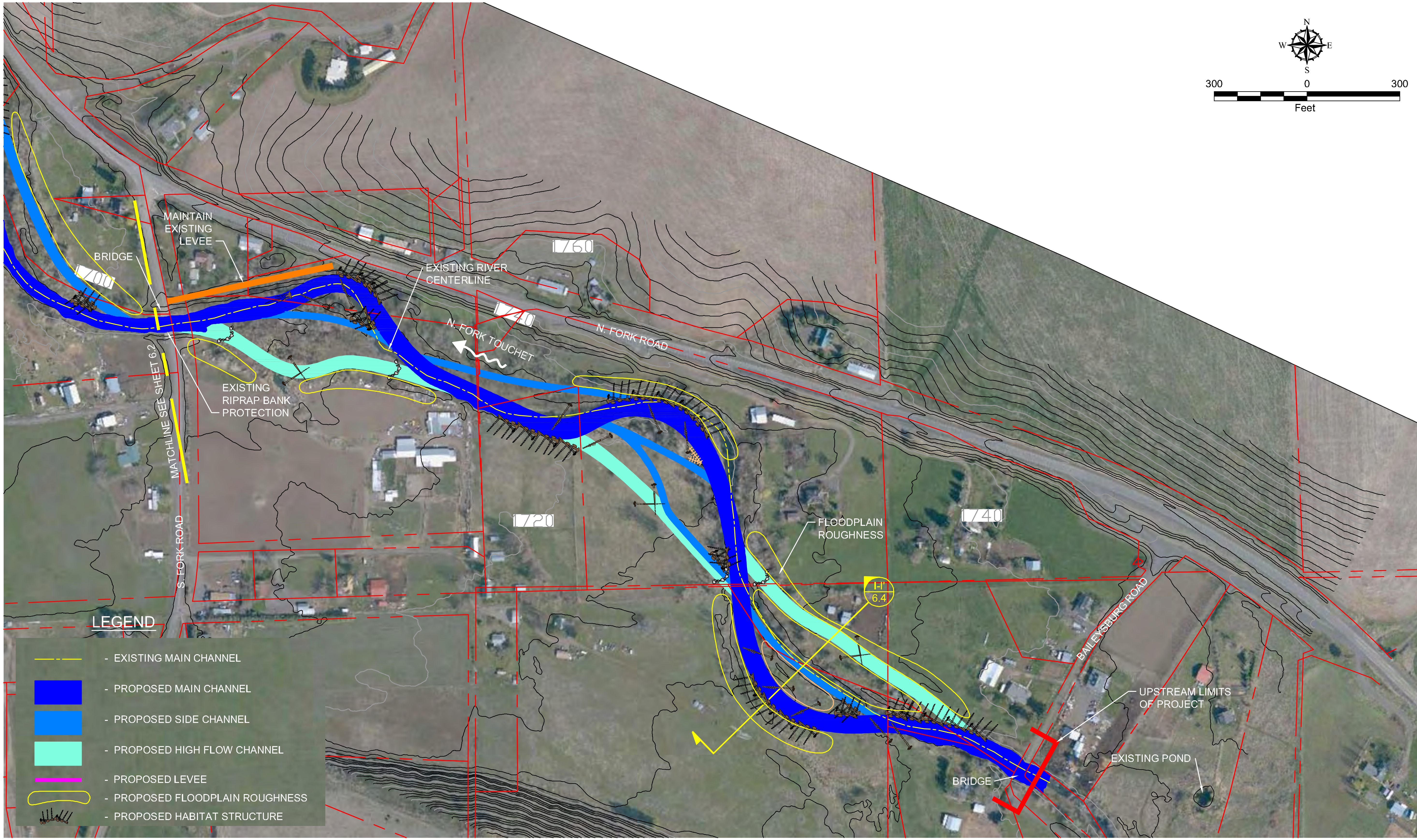
Alternative 3 - Plan View

Touchet River Alternatives Analysis

Sheet
6.2



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				Project No: 10291-002-00

Touchet River
Columbia County, WA

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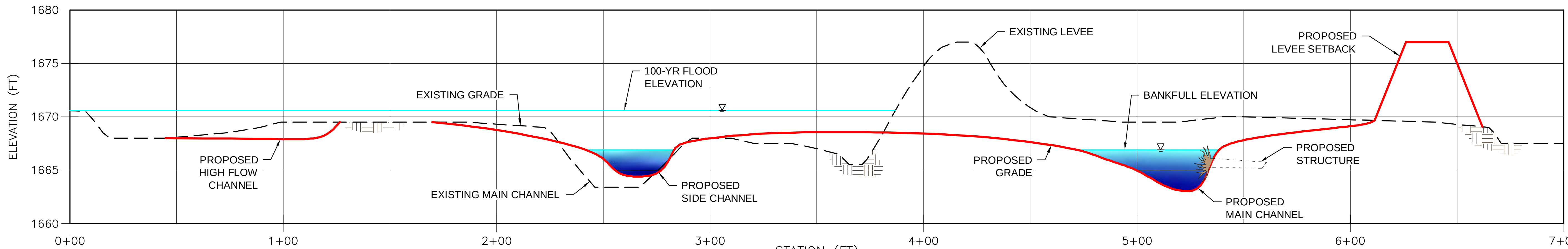
Alternative 3 - Plan View

Touchet River Alternatives Analysis

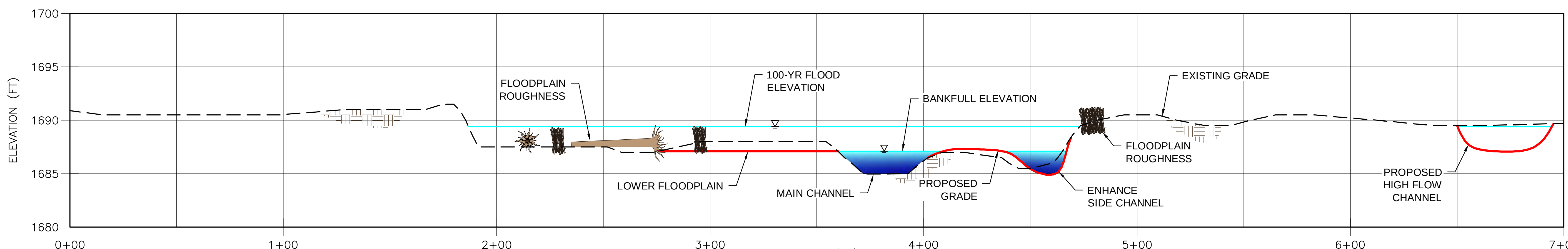
Sheet
6.3



G–G'
6.2

CROSS SECTION G–G'

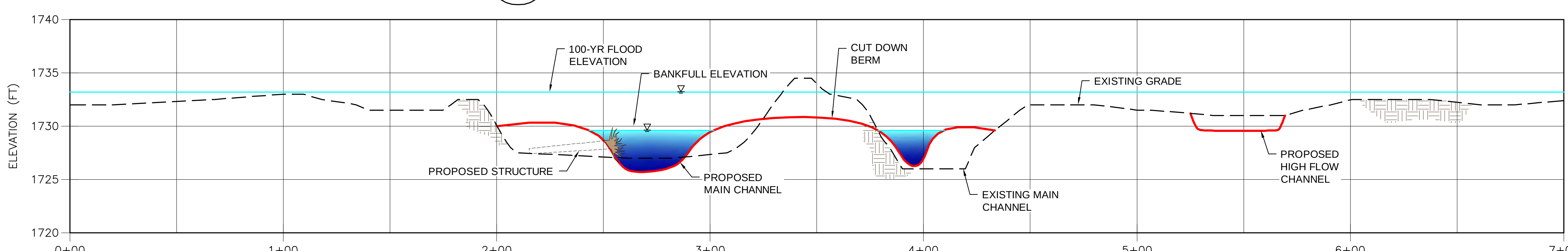
SCALE: 1" = 50' HORIZONTAL, 1" = 10' VERTICAL



H–H'
6.2

CROSS SECTION H–H'

SCALE: 1" = 50' HORIZONTAL, 1" = 10' VERTICAL



I–I'
6.3

CROSS SECTION I–I'

SCALE: 1" = 50' HORIZONTAL, 1" = 10' VERTICAL

JJF : JJF

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Touchet River
Columbia County, WA

City of Dayton, Washington

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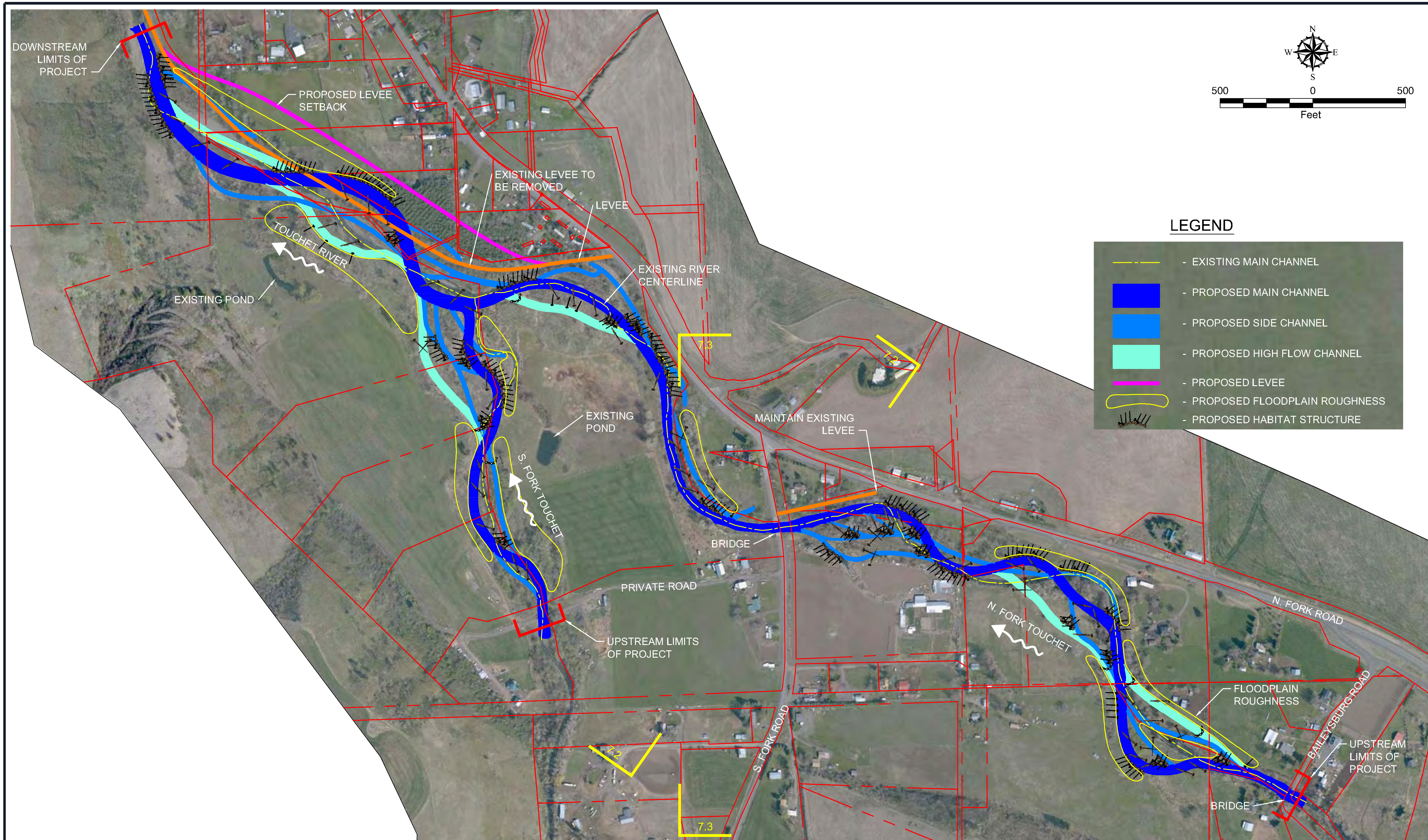
Alternative 3 - Sections

Touchet River Alternatives Analysis

Sheet
6.4



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				Project No: 10291-002-00

Touchet River
Columbia County, WA

City of Dayton, Washington

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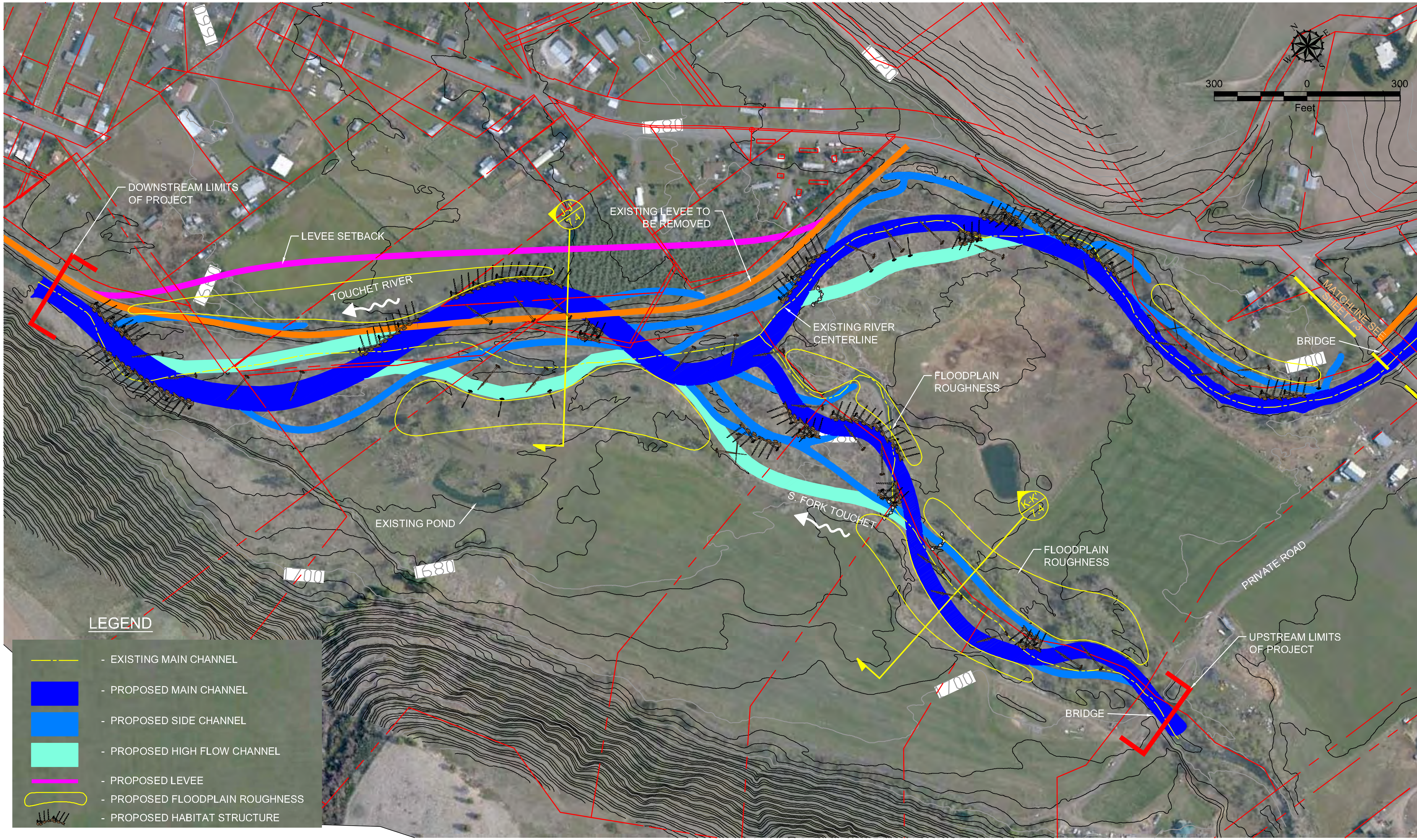
Alternative 4 - Overview

Touchet River Alternatives Analysis

Sheet
7.1



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				Project No: 10291-002-00

Touchet River
Columbia County, WA

City of Dayton, Washington

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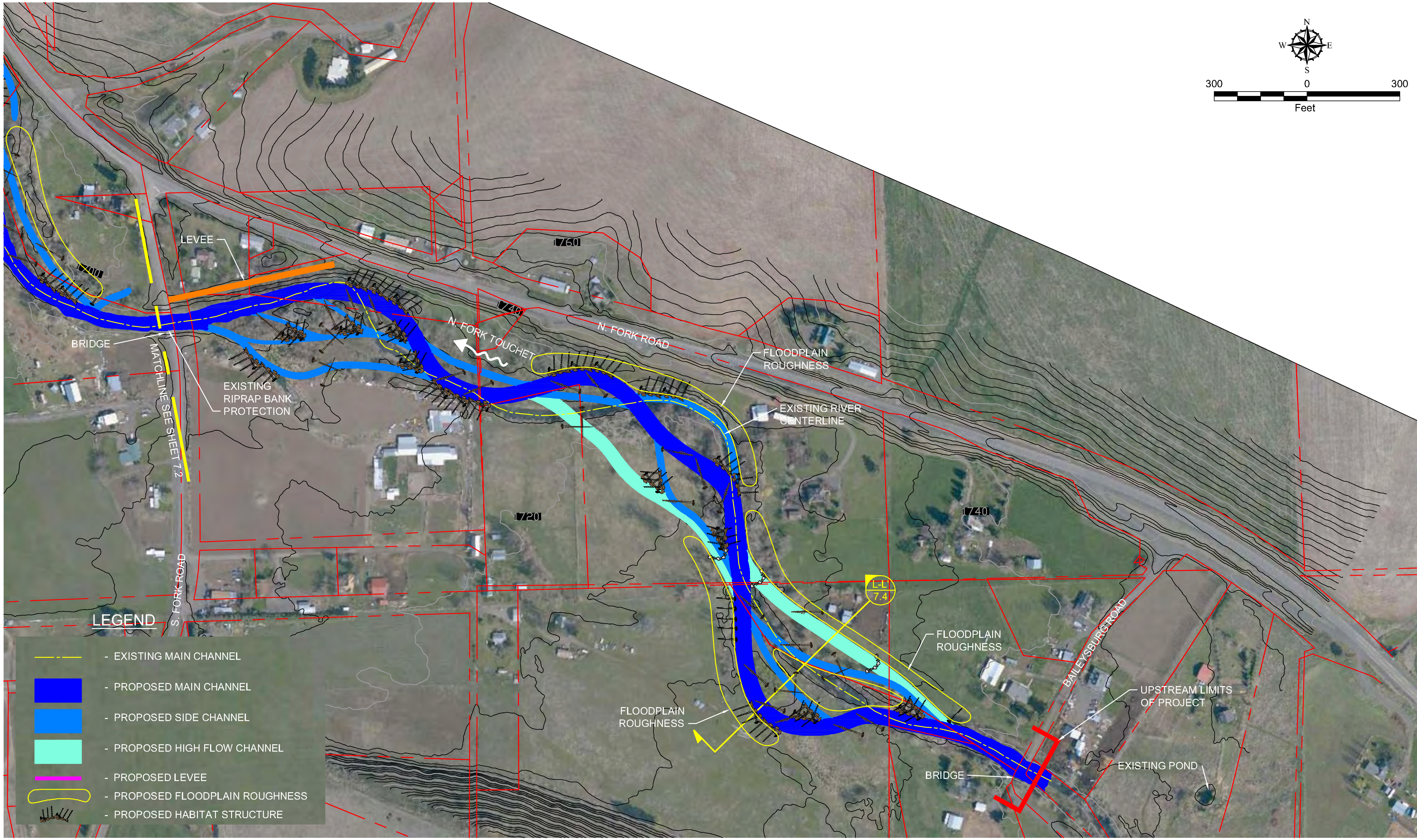
Alternative 4 - Plan View

Touchet River Alternatives Analysis

Sheet
7.2



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				Project No: 10291-002-00

Touchet River
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City of Dayton, Washington

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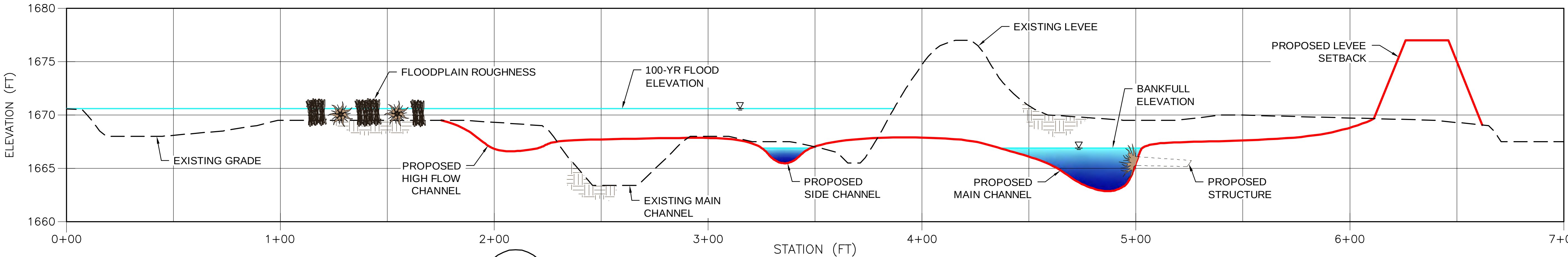
Alternative 4 - Plan View

Touchet River Alternatives Analysis

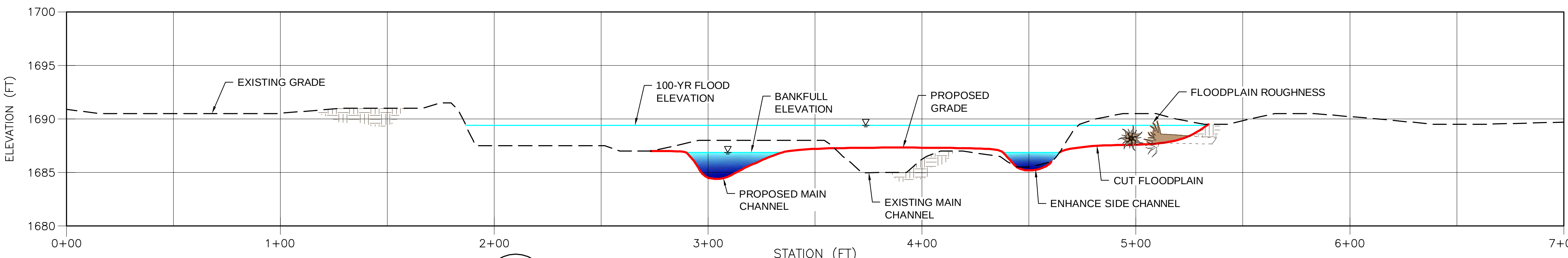
Sheet
7.3



J–J'
7.2

CROSS SECTION J–J'

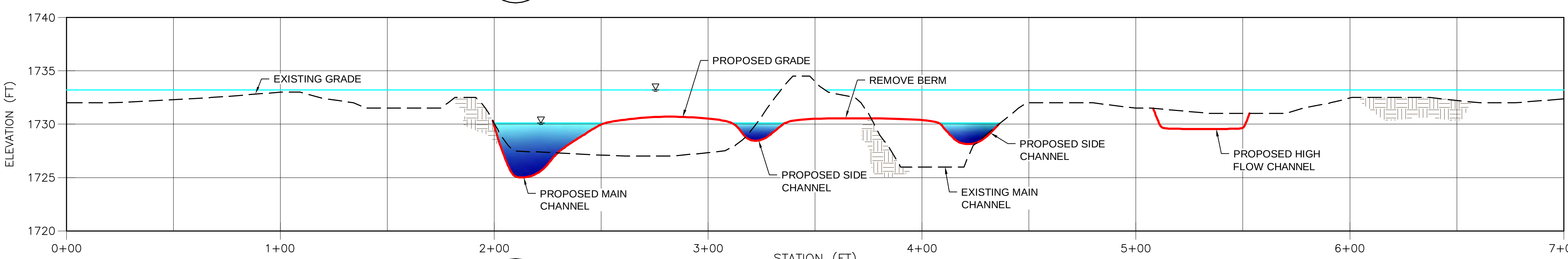
SCALE: 1" = 50' HORIZONTAL, 1" = 10' VERTICAL



K–K'
7.2

CROSS SECTION K–K'

SCALE: 1" = 50' HORIZONTAL, 1" = 10' VERTICAL



L–L'
7.3

CROSS SECTION L–L'

SCALE: 1" = 50' HORIZONTAL, 1" = 10' VERTICAL

JJF : JJF

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City of Dayton, Washington

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Alternative 4 - Sections

Touchet River Alternatives Analysis

Sheet
7.4

APPENDIX H
GIS Database (submitted on portable hard drive)

APPENDIX H
GIS DATABASE (SUBMITTED ON PORTABLE HARD DRIVE)

The following GIS data layers are included in the GIS Database, Appendix G.

Cities
River miles
Facility Dams
Dayton Rearing Ponds
Geomorphic Reaches
River Segments
USACE levees
Star Levee
Main Water courses
Water Courses
Parcels (Columbia County)
WA WRIA Boundary
Contours(20 feet)
Level 6 HUC
Landslides (2008)
NRCS Soil Data
Flood Maps
Migration Potential Area
Conceptual Alternatives
FEMA Food
Waterbody
Geology
Historic Topography (1946)
Aerials
Implementation Reach Relative Surface Model (100-year recurrence interval)
LiDAR Heights of CMZ
LiDAR Heights
LiDAR Hill Shade First Return
LiDAR Hill Shade Bare Earth

APPENDIX I
Report Limitations and Guidelines for Use

APPENDIX I
REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

Stream and River Design Engineering Services Are Performed for Specific Purposes, Persons and Projects

This report has been prepared for the City of Dayton and their authorized agents. The information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. No party other than the City of Dayton and their authorized agents may rely on the product of our services unless we agree to such reliance in advance and in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the City of Dayton executed on August 2, 2010, Addendum No. 1 dated December 28, 2010 and generally accepted practices in this area at the time this report was prepared. Use of this report is not recommended for any purpose or project except the one originally contemplated.

A Stream or River Design Engineering Report is Based on a Unique Set of Project-Specific Factors

This report has been prepared for the City of Dayton and their authorized agents. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, it is important not to rely on this report if it was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site, or
- completed before important project changes were made.
- For example, changes that can affect the applicability of this report include those that affect:
- the function of the proposed design and/or structure;
- elevation, configuration, location, orientation or weight of the proposed structures;
- composition of the design team; or
- project ownership.

1 Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org.

If important changes are made after the date of this report, we recommend that GeoEngineers be given the opportunity to review our interpretations and recommendations. Based on that review, we can provide written modifications or confirmation, as appropriate.

Conditions Can Change

This report is based on conditions that existed at the time the study/design was performed. The findings and conclusions of this report may be affected by the passage of time, by man-made events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability, stream flow fluctuations or stream channel fluctuations. If more than a few months have passed since issuance of our report or work product, or if any of the described events may have occurred, please contact GeoEngineers before applying this report for its intended purpose so that we may evaluate whether changed conditions affect the continued reliability or applicability of our conclusions and recommendations.

Report Recommendations and Designs Are Not Final

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual site-specific conditions revealed during construction.

We recommend that you allow sufficient monitoring and consultation by GeoEngineers during construction to provide recommendations for design changes if the conditions revealed during the work differ from those anticipated and to evaluate whether construction activities are completed in accordance with our recommendations. GeoEngineers is unable to assume responsibility for the recommendations in this report without performing construction observation.

The designs depicted herein are approximate and are intended to express the overall design intent of the project. These designs will need to be adjusted in the field during construction in order to meet the specific-site conditions and intended function.

Report Could Be Subject to Misinterpretation

Misinterpretation of this report by members of the design team or by contractors can result in costly problems. GeoEngineers can help reduce the risks of misinterpretation by conferring with appropriate members of the design team after submitting the report, reviewing pertinent elements of the design team's plans and specifications, participating in pre-bid and preconstruction conferences, and providing construction observation.

To help prevent costly problems, we recommend giving contractors the complete report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report's accuracy is limited. In addition, encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer.

Instream Habitat Structures

Instream habitat, stabilization, enhancement and/or restoration structures and artificial (Structures) involve the placement of large logs, logs with root wads, large rocks and other natural and artificial materials and/or features in and adjacent to creeks, streams and rivers (streams). They are designed for various purposes including but not limited to: improvement of aquatic and riparian habitat; stabilization of eroding stream banks and channels; restoration of stream channels; creation or improvement of recreational uses; irrigation; and flood management.

Hazards of Instream Habitat Structures

Instream habitat structures create potential hazards, including, but not limited to: humans falling from the Structures and associated injury or death; collisions of recreational users' watercraft with the Structures and associated risk of injury or death, with partial or total damage of the watercraft; mobilization of a portion or all of the structures during high water flow conditions and related damage to downstream properties, utilities, roads, bridges and other infrastructure, and injury or death to humans; flooding; erosion; and channel avulsion. In some cases, instream habitat structures are only intended to be temporary, providing temporary stabilization while riparian vegetation becomes established or stream/river processes stabilize. This gradual deterioration with age and vulnerability to major flood events make temporary Structures inherently dangerous with increasing age.

It is strongly recommended that the Client address the necessary safety concerns appropriately. This would include warning construction workers of hazards associated with working in or near deep and fast moving water and on steep, slippery and unstable slopes. In addition, signs should be placed along the enhanced stream reaches in prominent locations to warn recreational users of the potential hazards noted above and pamphlets should be distributed to nearby residents warning of the potential hazards to children and adults posed by these Structures.

Increased Flood Elevations and Wetland Expansion Are Possible

The proposed stream enhancements may result in increased flood elevations and expansion of wetlands. The analysis of these impacts, which are generally considered advantageous for aquatic and riparian habitat in the project locations of these stream systems, may need to be considered and quantified if they were beyond the context of GeoEngineers' scope of services.

Channel Erosion and Migration Are Possible

In general, river and stream enhancements are intended to result in more stable streambeds, banks and floodplains. In some cases, stream enhancement and channel stability means reestablishing the natural balance of sediment erosion, distribution and deposition, which induces channel meandering and migration. Therefore, channel erosion, channel migration and/or avulsions can be expected to occur over time.

Importance of Monitoring and Maintenance

Piles, anchors, chains, cables, reinforcing bars, bolts and similar fasteners may have purposely been excluded from woody habitat structures with the intent of mimicking naturally-occurring instream wood structures. Conversely, such fasteners may have purposely been included in woody habitat Structures if considered appropriate. While the Structures are designed to be relatively stable during flood events, movement of these Structures should be expected. As noted in the text of this report, we recommend that the Client implement appropriate monitoring and maintenance procedures to minimize potential adverse impacts at or near areas of concern, such as at downstream road, bridge and/or culvert crossings. This would include replacing, adjusting and removing damaged, malfunctioning or deteriorated components of Structures, particularly following a major storm event.

Contractors Are Responsible for Site Safety on Their Own Construction Projects

Our recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and adjacent properties.

Have we delivered World Class Client Service?

Please let us know by visiting **www. geoengineers.com/feedback**.

GeoEngineers