North Fork Siuslaw Sediment & Habitat Assessment

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Prepared by Demeter Design
Prepared for the Siuslaw Watershed Council

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Executive Summary

The North Fork Siuslaw River (NFS) is listed as water quality limited by sedimentation, habitat modification, and temperature under section 303(d) of the Clean Water Act. The primary focus of this study was to evaluate the NFS with respect to sedimentation. Data relevant to the habitat and temperature listings were also collected and analyzed. Five streams are listed as impaired by sediment within the NFS watershed; the North Fork Siuslaw Mainstem, Morris Creek, Porter Creek, Drew Creek, and McLeod Creek. The mainstem NFS is listed as impaired by temperature and the almost the entire NFS basin excepting Morris Creek is listed as impaired by habitat modification. In 2006, the Siuslaw Watershed Council (SWC) in collaboration with the Oregon Department of Environmental Quality (ODEQ), initiated an effort to investigate the extent of these listings and to support the Total Maximum Daily Load (TMDL) development process. A sediment and physical habitat assessment of the NFS was conducted in 2007 using a process adapted from the Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) protocol. Water quality and physical habitat was evaluated using a variety of metrics. The sediment metrics included; relative bed stability, percentage of sands and fines, percentage of gravels, percentage of bedrock, and the distribution of this data. Habitat metrics included; residual pool depth, bankfull width to depth ratio, large wood volume, bank condition, and canopy cover. Data collected was compared to existing ODEQ reference data collected from streams with minimal anthropogenic disturbance. Excess fine sediments were found throughout the stream network in conjunction with near reference bed stability. These results indicate moderate impairment by sedimentation. This result is consistent with the existing 303(d) listing and previous water quality assessments. Furthermore, significant alteration and loss of habitat complexity was observed. Wood levels throughout the stream network were far below reference conditions, particularly in the mainstem where excessive streambed armoring was observed. Finally, width to depth ratios were significantly elevated indicating degradation of riparian vegetation.

Although this study was not designed to quantitatively identify sediment sources, field observations indicate several possible causes of the excess fine sediments. Historical logging practices resulted in significant upland and riparian disturbances. In particular, large woody debris (LWD) was actively removed from stream channels and clear-cutting decreased recruitment potential throughout the stream network. Lack of LWD may have disrupted the natural process of sediment input, delivery, and deposition. The United States Forest Service (USFS), the SWC, and other local partners have implemented numerous LWD placement projects throughout the watershed but more work is needed to meet reference levels. Road construction has likely contributed excess sediments to the system although the USFS has improved and decommissioned a number of the roads identified as problems in the NFS Watershed Analysis. Further, grazing in the lower watershed has reduced much of the vegetative cover on the banks and large portions of the banks along the mainstem are actively slumping into the river. In regards to temperature, shade values were below reference throughout the watershed and channel widening was observed in most of the watershed. The SWC has placed temperature loggers in several portions of the watershed and is addressing temperature issues separately. In summary, the results of this study indicate moderate impairment by sedimentation, strong impairment from habitat modification, and likely impairment by temperature. It is recommended that a sediment TMDL be developed for the basin with a focus on restoring natural channel processes and aquatic habitat conditions.

Introduction

Background

A watershed analysis was conducted in 1994 by the USFS to address five key issues; terrestrial habitat fragmentation and degradation, loss of old-growth habitat and the impact on dependent species, road management, instream habitat degradation, and sustainable commodity production.[1] These issues were addressed by examining past and current resource extraction practices and by conducting field surveys of instream and terrestrial habitat conditions. The entire NFS basin excepting Morris Creek is listed as water quality limited by habitat modification, the NFS mainstem is listed as water quality limited by temperature, and five streams within the NFS are listed as water quality limited by sedimentation based on data presented in the 1994 North Fork Siuslaw Watershed Analysis. The rivers listed as impaired by sediment are the North Fork Siuslaw River Mainstem, Morris Creek, Porter Creek, Drew Creek, and McLeod creek (See maps 2, 3, and 4) The SWC, in collaboration with the ODEQ, initiated an effort to investigate the extent of impairment and to support the TMDL development process in 2006. A sediment and physical habitat assessment of the NFS stream network was conducted in 2007 using a process adapted from the EPA's EMAP protocol.[2] The ODEQ is in the process of formally adopting this protocol as the standard for future sediment assessments throughout Oregon.

Physical Description

The North Fork of the Siuslaw River is located Northeast of Florence in the Oregon Coast Range. The highest point, Saddle Mountain, sits at 2200 feet. The NFS runs through a temperate coastal rain forest and joins the main Siuslaw River estuary before flowing into the Pacific Ocean. The geology is dominated by the erodible Tyee Sandstone formation although scattered volcanic extrusions are present throughout the watershed. The majority of the terrestrial habitat is dominated by conifers (Douglas Fir) mixed with deciduous hardwoods (Oregon Big Leaf Maple and Red Alder.) The Umpqua fire of 1846 burned the majority of the NFS watershed which at the time was dominated by old growth Western Hemlock with Wester Red Cedar, Sitka Spruce, and Douglas Fir as secondary species. The current understory consists primarily of Evergreen Huckleberry, Salal, Oregon Grape, Vine Maple, Sword Ferns, and Rhodedendrons. The most common edible mushroom species within the watershed are Chantrelle with Oysters and many species of Bolete are present as well. [3]

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[1] Karnes et. al 1994.

[2] Peck et. al. 2003.

[3] Karnes et. al 1994.

Landuse

Prior to European settlement, Native Americans used the area for hunting and gathering. A population of ~900 Siuslawan Indians lived near the mouth of the NFS and would travel by boat up the river to gather food and hunt game. European trading began with the fur industry in the 1790s and incoming settlers had displaced most of the Native tribe by 1875. Euro-American timber harvest began around this time for settlement purposes although widespread logging did not begin until the middle of the next century as most of the basin was difficult to access and the timber too small for harvest due to the devastating fire. By 1900 there were five sawmills that produced as much as 200,000 board feet per day. Logs were floated down the NFS to these sawmills. While most logs were hauled to the stream with a steam donkey from cold decks and floated down river during high flows, at least one splash dam was used at the base of Wilhelm Creek. When more efficient harvest methods were coupled with an increased road network, harvest levels within the watershed jumped from an average of 30 acres per year prior to 1960 to 423 acres per year between 1960 and 1969. Numerous landslides caused by road failures degraded instream habitat by introducing excess sediments to the system. Ground based yarding and the use of heavy equipment resulted in channel disturbance and soil compaction. The decades following these massive clear cuts saw changes in both harvest methods and beliefs about instream habitat. New logging methods allowed for logs to be cabled over the valley rather than yarded through the stream. During the same time however, LWD was actively removed from the stream channel. Dairying was also common prior to 1950. Many hillsides along the lower NFS mainstem were leveled to provide increased pasture outside of the floodplain. While these pastures are still evident, several have gone fallow and are overrun with invasive weeds such as Himalayan Blackberry. Dairying has been slowly replaced with beef cattle grazing, which remains a dominant land use within the NFS. Additionally, hunting is common within the watershed and many USFS roads are used and maintained to allow access to hunting areas.[1]

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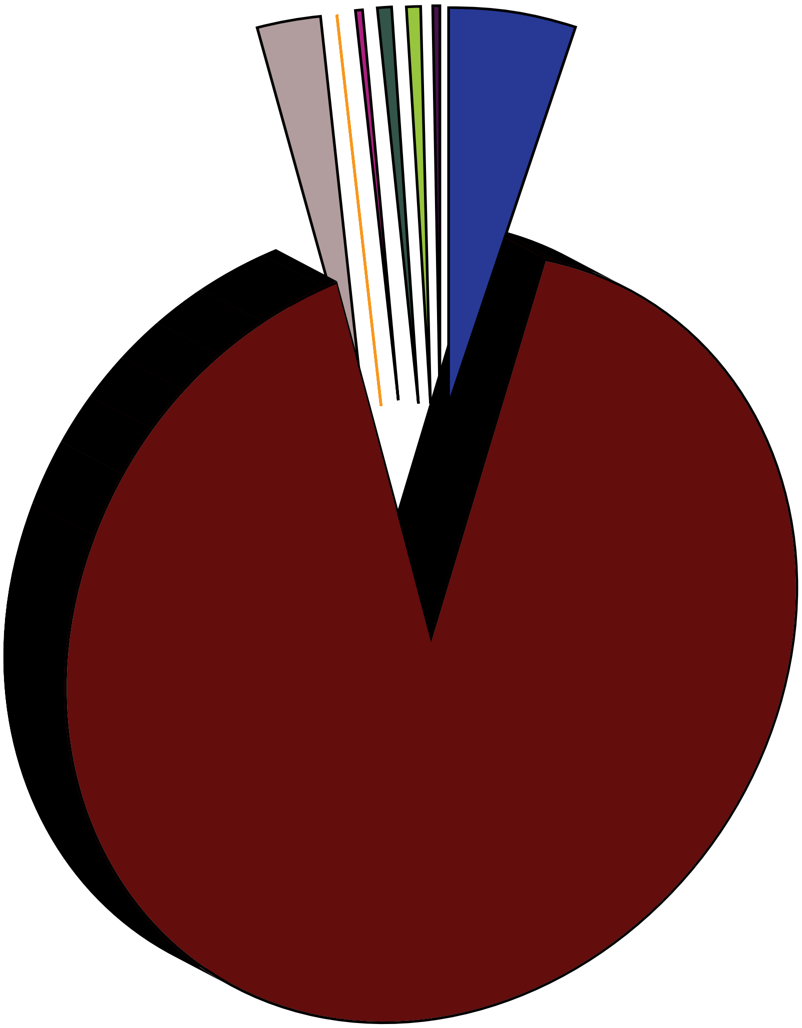
[1] Karnes et. al 1994.

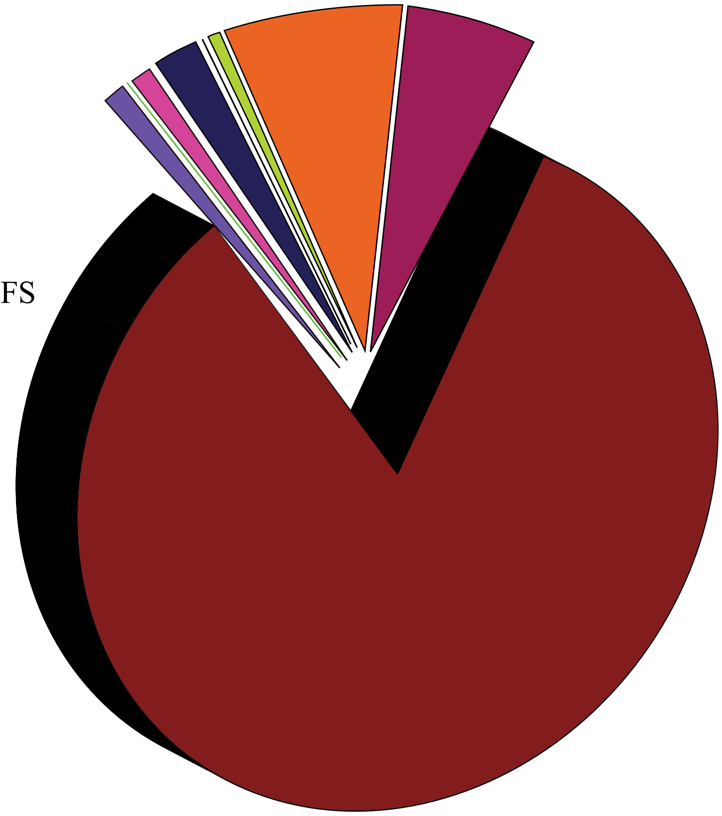


90.71%	Forestry
5.27%	Agriculture
2.38%	Natural Resource
0.36%	Park and Recreation
0.04%	Rural Industrial
0.44%	Rural Residential
0.65%	Urban
0.14%	Water

Figure 1 - Landuse in the NFS

Figure 2 - Forestry Ownership in the NFS

74.94%	ForestryUSFS
7.39%	Forestry PRIVATE
5.34%	Forestry PRIVATE
1.85%	Forestry DAVID
0.18%	Forestry
0.47%	Forestry BLM
0.51%	Forestry CHAMP
0.00%	Forestry FIBRE
0.03%	Forestry IP



Based on data obtained from the SWC

Restoration Efforts

Prior to 1969, excess logging debris was discarded into streams resulting in a stream network choked with wood which blocked fish passage and decreased dissolved oxygen. In the 1970s, an effort was initiated by various agencies to remove debris from the stream network. Although this effort was intended to improve fish habitat, too much debris was removed. The result was stream channel simplification and the loss of critical instream habitat complexity. Subsequent research clearly indicated the importance of LWD in developing and maintaining healthy aquatic habitat conditions[1]. To correct the situation, the USFS and partners initiated an aggressive effort to replace LWD throughout the stream network. These restoration efforts are still underway. In 2006 the USFS identified a need to plan restoration projects specifically within the NFS.[2] The SWC is an active partner in log placement and riparian planting projects throughout the basin. A map of completed restoration projects can be found on page 52, Map 8. The photographs below are two examples of wood placement in the NFS basin.

The following four pictures were taken in the NFS basin on USFS land and are examples of some of the restoration activity in the watershed. While many of the log structures observed were providing key habitat components such as refuge from predators and potential overwintering shelter during high flow events, it appears that no log placements occurred in headwater channels. The high average gradient in headwater channels prevents effective sediment storage without the presence of large wood and/or boulders. The lack of large wood due to the Umpqua fire, extensive timber harvests, and management induced debris flows has likely disrupted the natural sediment storage capacity of these headwaters.[1] See the map of known restoration projects on page 52, Map 8.

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[1] e.g. Benda et. al. 2003, 2005

[2] USFS Assessing Needs & Locations for Future Projects, 2006

Materials and Methods

Sampling Methods

Throughout the State of Oregon TMDLs are commonly developed at a watershed scale. A logical approach to 303(d) listing assessment is to aggregate listings to that same watershed scale. Four of the streams listed for sediment (Drew, McLeod, Morris, and Porter) are upstream of the NFS Mainstem listing. For this reason the five NFS listings along with the Taylor Creek (also within the Siuslaw River 4th field) were originally aggregated into a single 30 site sample. This approach is consistent with previous work in the Nestucca River and discussions with the ODEQ.[1,2] Taylor Creek was ultimately removed from the sample to increase the coverage within the North Fork. See Appendix B for a discussion on Taylor Creek and future plans for addressing the 303(d) listings in that basin. Sites were originally stratified by stream order to include an even number of National Hydrography Database Plus (NHD+) first and second(+) order streams. While the initial sample plan was created to balance first and second(+) order streams, it was adjusted due to landowner denial of access, depth of water, or tidal influence. The assessment protocol used is for wadeable, freshwater streams, therefore streams that could not be accessed by field staff or were tidally influenced were removed from the sample. Aerial photos and existing data layers were used to remove sites on portions of the river too large to sample or within tidal influence. Field truthing was conducted to validate this process. This resulted in the removal of all sites located on 3rd order stream reaches. No sites were sampled below the confluence of McLeod Creek with the mainstem NFS river. An additional site was added from the Master Sample to McLeod Creek to increase sampling density in the eastern portion of the watershed. The final sample included 22 sites within the NFS basin, 14 of which were on first order streams and 8 of which were on second order streams.

Sites were selected from the “Master Sample” produced by the EPA research lab in Corvallis Oregon. The “Master Sample” was developed in support of statewide efforts to coordinate aquatic resource monitoring. It is a statewide sample of random sites drawn from the NHD+ stream layer using the General Random Tesselation Stratified (GRTS) algorithm.[3] It contains thousands of sites seeded at 1 km intervals along the stream network. By utilizing a subsection of the “Master Sample”, the data collected in this study can be easily integrated into regional assessments and future monitoring projects. Sites were clipped from the statewide “Master Sample” using the NFS Watershed 5th field HUC Polygon. The geology was evaluated using existing geology data layers obtained from the Siuslaw National Forest. [4] The NFS watershed is dominated by an erodible lithology, with Tyee Formation the dominant geologic type. For this reason the sample was not stratified based on lithology. It was anticipated that the appropriate reference sites for the NFS watershed would be erodible sites within the Coast Range Ecoregion. It was observed that 1st order streams on the NHD+ are generally 3rd or even 4th order based on the stream network defined in the Coastal Landscape Analysis and Modeling Study (CLAMS) or Bureau of Land Management (BLM) hydro coverages. This should be considered when interpreting the results of the study. The first 22 sites in the NFS Watershed were ultimately defined as the panel and the remaining sites were defined as the oversample. Sites were re-weighted during analysis to account for changes in the sample frame and study design so that the sum of the weights was equal to the total length of the stream network based on the NHD+.

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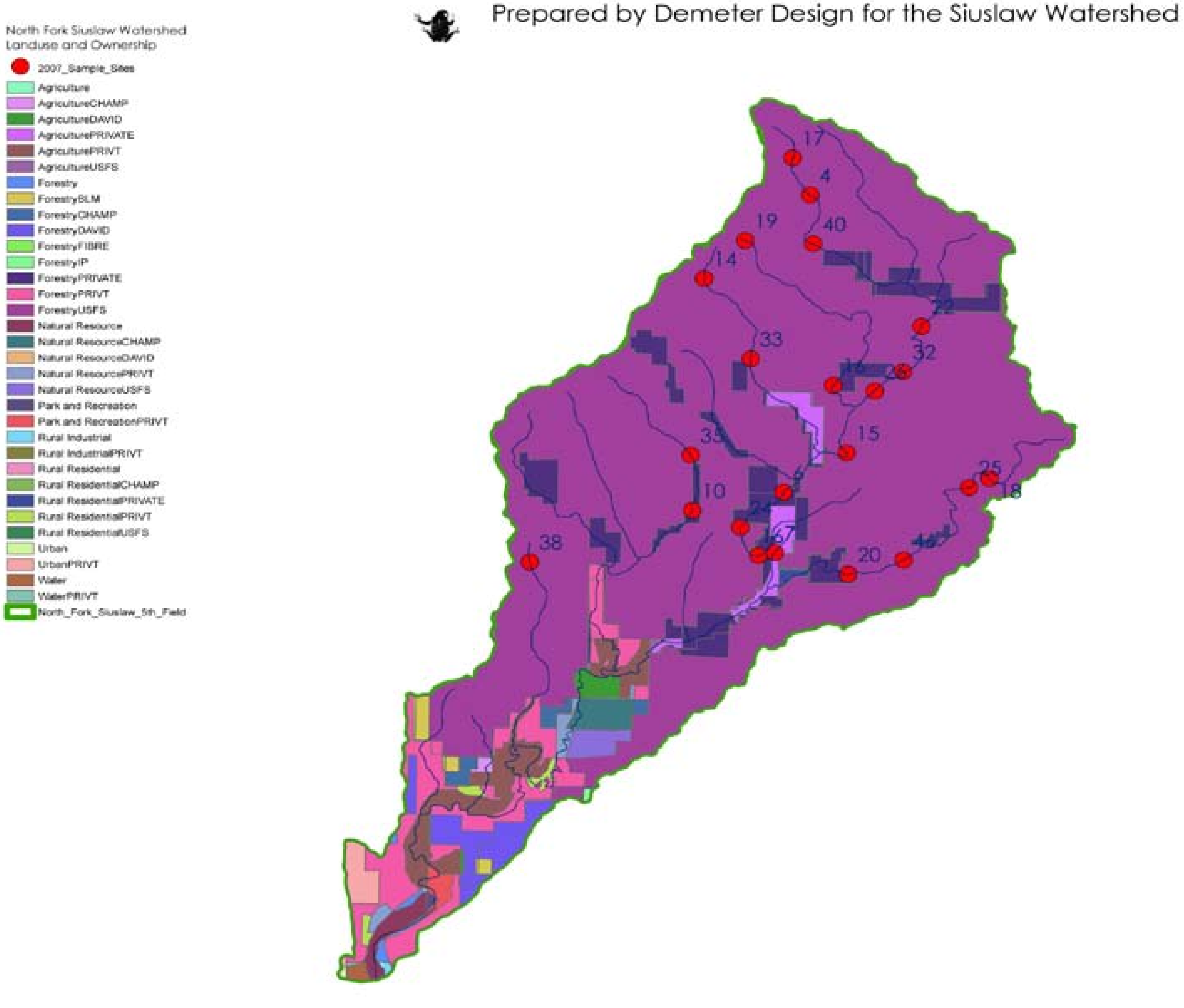
[1] Mico & Mico 2007.

[2] Personal Communication, Doug Drake and Ryan Michie, ODEQ.

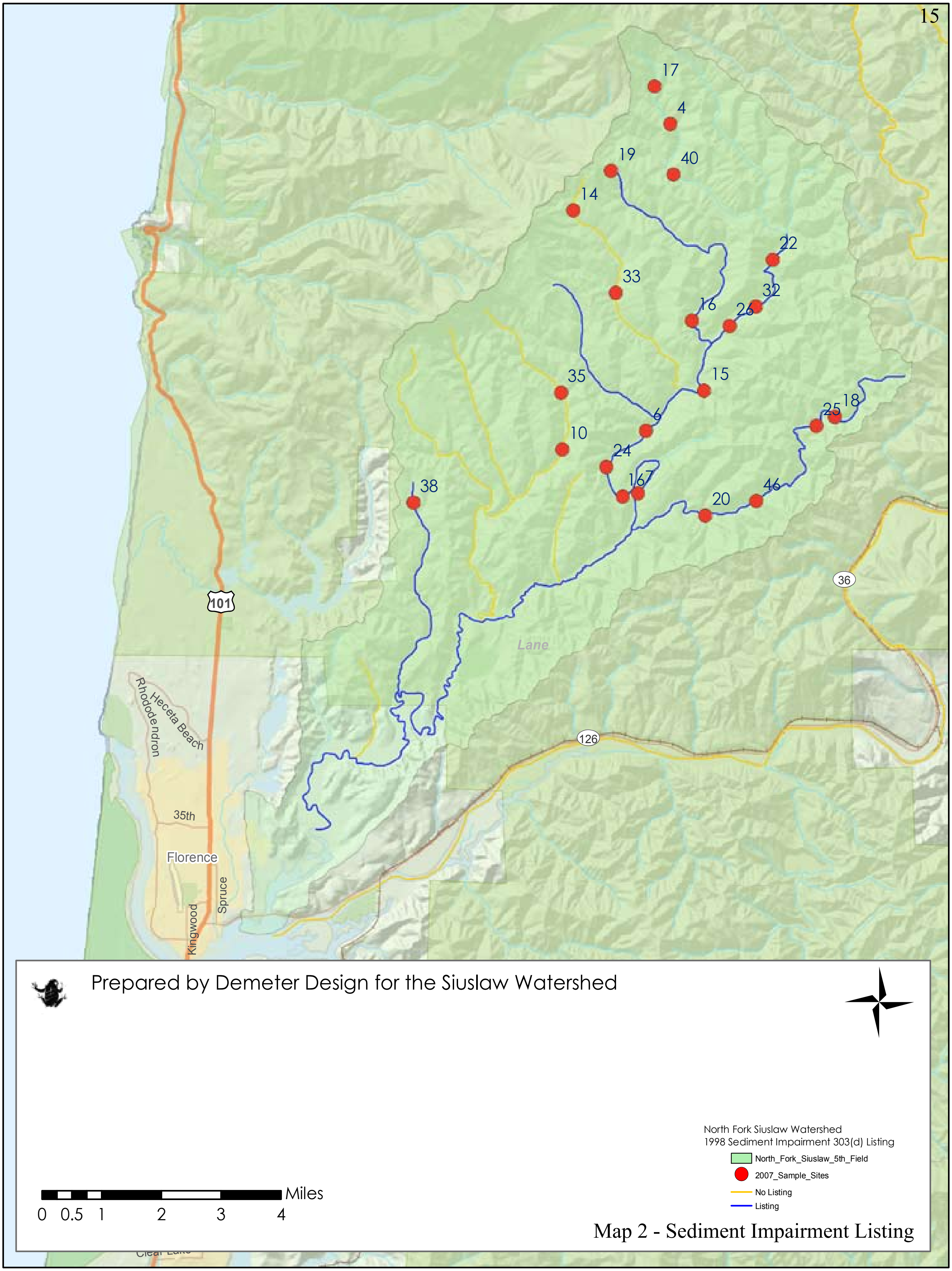
[3] Stevens & Olsen (B)

[4] USFS

Significant modifications were made to the original sampling plan to accommodate operational constraints encountered during field surveys. Road access was limited throughout much of the watershed. Many roads depicted as accessible on existing USFS map products as well as standard GIS layers (e.g. ESRI road coverages) were in fact inaccessible due to recently installed earth berm closures. In combination with the extreme relief encountered throughout the study area, this limited access to numerous sites. This included all sites within the Drew Creek watershed where access was also denied to private roads. In general, few private landowners granted access to their property. All first order sites were located on public land and 3 second order sites were on private land. Many landowners did not respond to the SWC requests for access permission, few responded with a no. No private timber companies or small woodlot owners granted access permission although only one responded with a no. Despite these limitations, the overall coverage of the watershed was quite good as can be observed in Map 2 - Sediment Impairment Listing on page 15. While sites 10 and 20 appear to be on private land on Map 1 shown below, they are on USFS land that borders private land.



Map 1 - Landuse and Ownership



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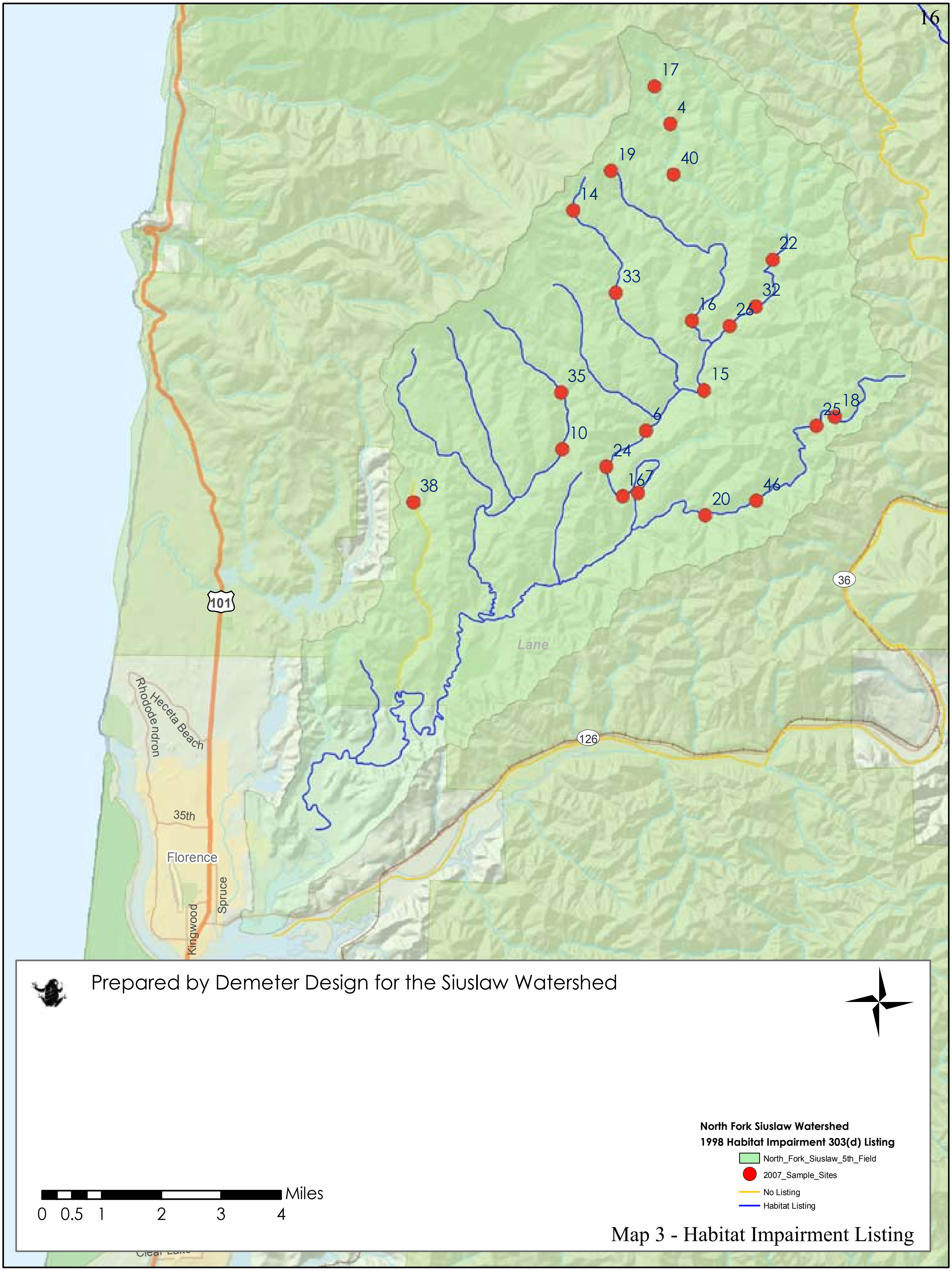
Map 2 - Sediment Impairment Listing



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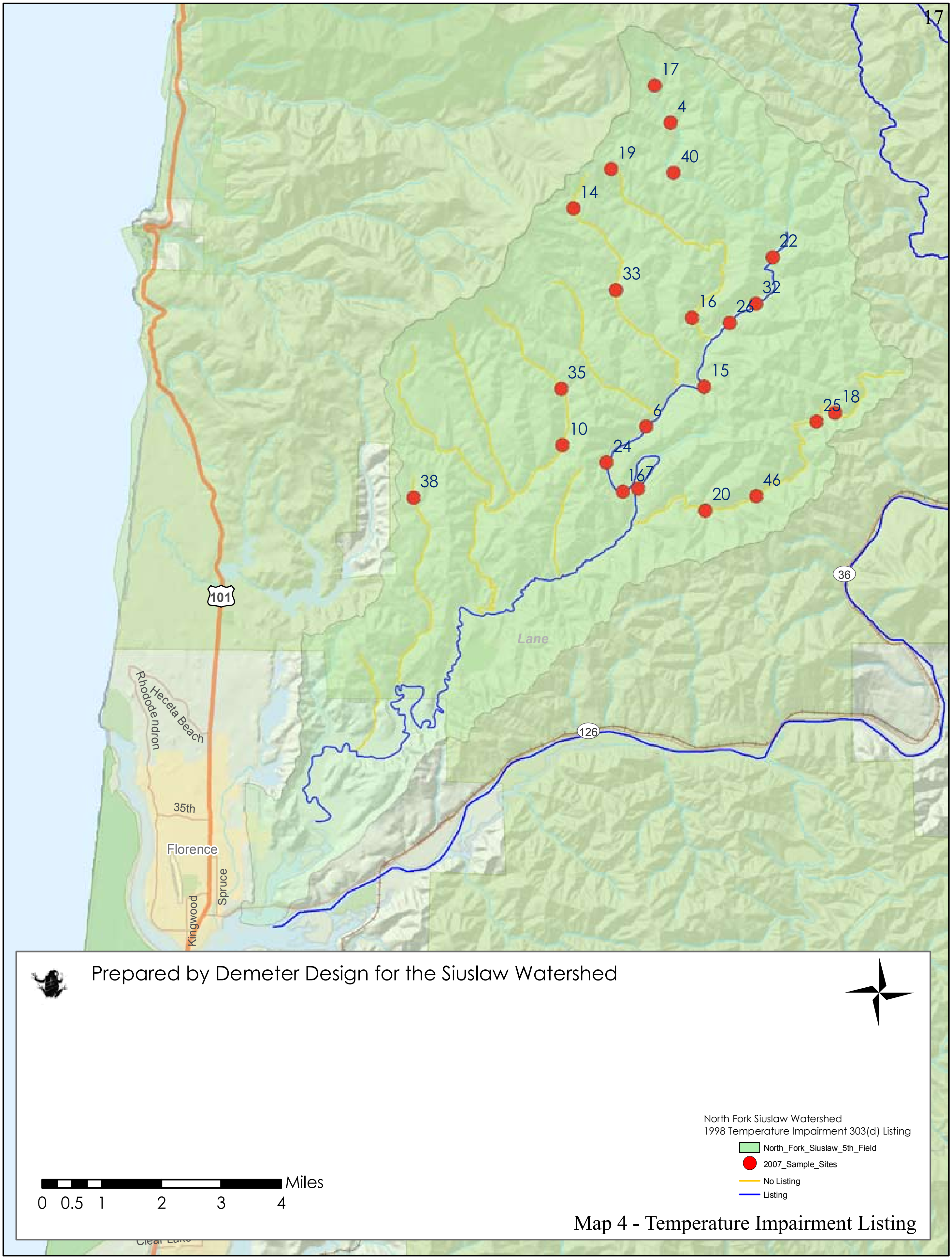
Map 3 - Habitat Impairment Listing



Map 4 - Temperature Impairment Listing

Prepared by Demeter Design for the Siuslaw Watershed

Field Data Collection

The field protocol used in this study is described in detail in the EMAP field manual.[1] The full EMAP protocol includes measures of biological, chemical, and hydraulic function in addition to the physical habitat data used for sediment assessment. Section 7 of this manual describes the Physical Habitat protocol. A quantitative analysis of the process is available as well from the EPA's website.[2] Bank condition was evaluated by classifying the left and right banks as a 1,2,3,4,5 with 1 representing no active erosion and 5 complete active erosion. An alternate measure of bank condition was also evaluated where the banks were classified as an "A" for no human presence or a "B" for human presence in addition to the numerical classification. Photographic examples of each class are provided in Appendix A. The following measurements were made at each site;

- Slope
- Pebble Count
- Bankfull Height
- Thalweg Depth
- Large Woody Debris Tally
- Bankfull Width
- Habitat Unit
- Anthropogenic Disturbance
- Bank Condition
- Canopy Cover

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[1] Peck et. al. 2003.

[2] Kaufmann et. al. 1999.

Reference Conditions

The watershed assessment division of the ODEQ has collected data from hundreds of minimally disturbed sites across the state using the EMAP protocol. This includes the 22 erodible reference sites within the Coast Range Ecoregion used for this study. To collect reference data a sample is generated which ideally covers all of the gradients in each ecoregion such as elevation and vegetation type. All reference sites are required to have minimal anthropogenic disturbance in the riparian zone and upland areas. The ODEQ's approach explicitly includes natural disturbance regimes as it is assumed that the biota of an area evolved in conjunction with these regimes. The metric values found in sites with minimal anthropogenic disturbance are used to judge the quality of physical habitat in the areas assessed. This approach is described in detail in DEQ Technical Report S04-002.[1] The locations of all available erodible coast reference sites are listed in Table 1 below and shown in map 5 on the following page.

ODEQ KEY	EPA SITE ID	SITE NAME AND LOCATION
11845	**ORNC99-R008**	**Little NF Wilson River at RM 1.5**
12518	**OR025S**	**Trout Creek at RM 0.2 (Alsea)**
12521	**OR031S**	**Trib to Bernhardt Creek at RM 3.0**
12530	**OR053S**	**Butler Creek at RM 2.1**
12531	**OR055S**	**Elk River at RM 24.0 (Sixes)**
13201	**ORMC98-0549**	**Haight Creek at RM 1.20 (Siuslaw)**
13206	**ORSC98-3751**	**Trib to SF Lobster Creek (Lower Rogue)**
13227	**ORSC98-R038**	**Red Cedar Creek at Mouth (Sixes)**
13265	**ORNC98-R144**	**Trib to NF Wolf Creek at RM 0.45 (Nehalem)**
17016	**ORSC98-5662**	**SF Winchuck River at RM 4.23**
17031	**ORSC98-R037**	**NF Elk River at RM 3.3 (Sixes)**
17124	**ORMC98-2640**	**Youngs Creek at RM 1.11 (Siletz)**
21799	**ORMS98-4304**	**Hall Creek at RM 1.48**
21842	**ORMC99-R025**	**Flynn Creek at RM 1.71 (Alsea)**
23830	**ORMS98-0805**	**Pyburn Creek (SF Coquille)**
23832	**ORMS98-3085**	**Bear Creek at RM 13.30 (Coquille)**
23833	**ORMS98-3358**	**Upper Rock Creek at RM 11.5 (MF Coquille)**
23838	**ORUM98-1311**	**MF NF Smith River at RM 0.29 (Smith, Umpqua)**
23927	**ORMC98-1244**	**Cerine Creek at RM 0.4 (Mill, Siletz, Yaquina)**
26828	**ORMS98-0761**	**Slater Creek**
26846	**ORUM98-0274**	**Lost Creek (Umpqua)**
29937	**ORNC98-2154**	**Trib to Gilmore Creek (Nehalem)**

Table 1 - Reference Locations

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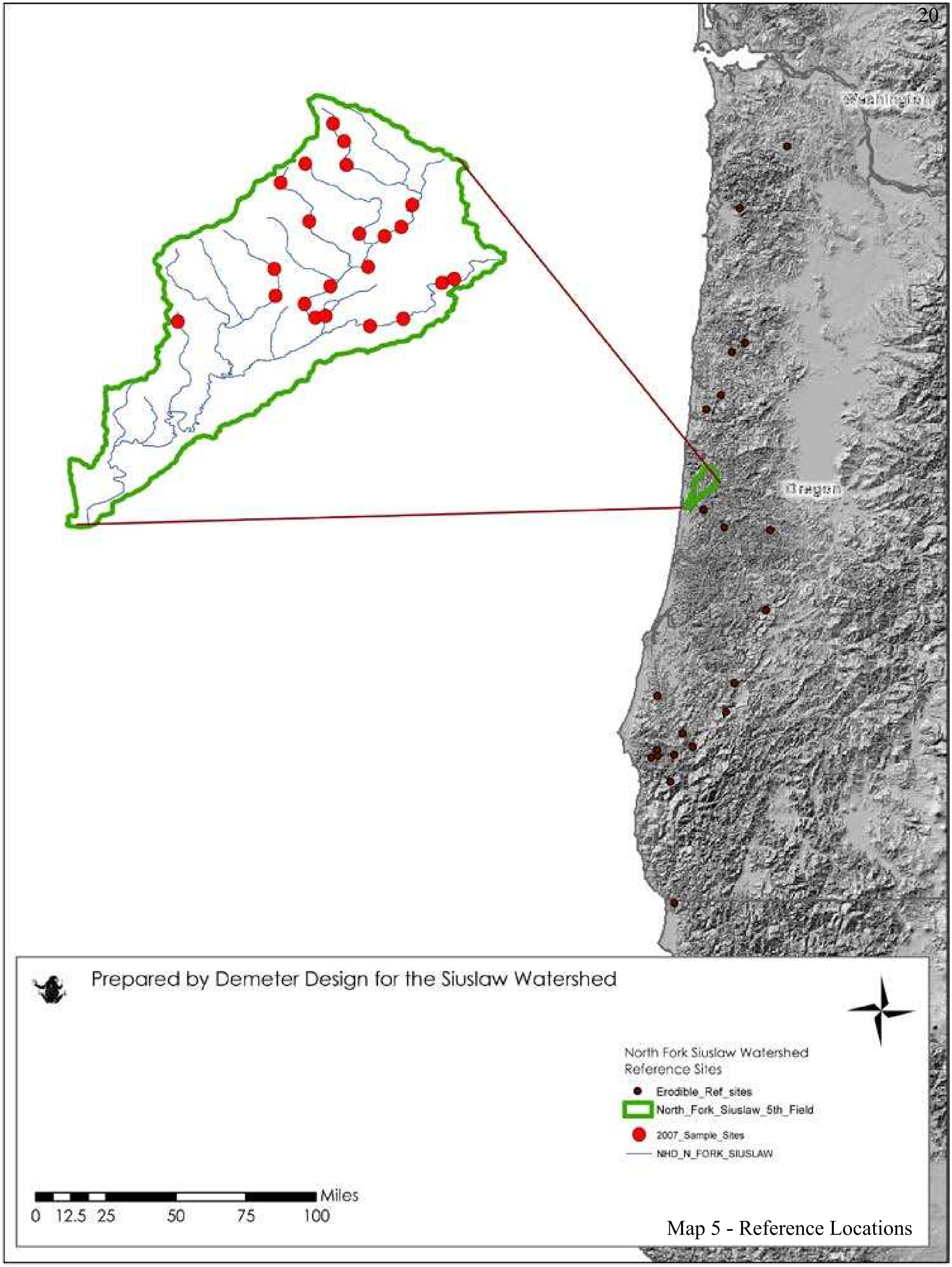
[1] Drake 2006.



Map 5 - Reference Locations

Estimates of Mean and Variability

Data was analyzed using custom built spreadsheets for data entry and metric calculation. All subsequent data analysis was carried out using the spsurvey package developed by the EPA for the R statistical program. All data analyzed in this way was weighted according to the fraction of the stream network which it represents. Weighted averages were calculated for the NFS. Variances for the NFS were calculated using the Neighborhood Based Variance (NBV) estimator developed by the EPA.[1] NBV is a more precise estimate of variance when there is a spatial pattern to data, thus capitalizing on the spatial balance of the GRTS sample. The practical effect of utilizing the NBV is to decrease the variance. Modeling conducted by the EPA has shown that standard statistical procedures may result in substantial over estimates of variance when there is a spatial pattern to the data. In contrast to the NFS data, means and variances for the reference data were calculated using standard statistical procedures to provide a conservative estimate of the variance of the reference population. This was done to account for potential error due to a lack of a consistent sampling plan for the reference data. NBV estimation was conducted for the reference data, and relatively small differences were found in comparison to standard procedures. The end result of this approach is that the variance of the NFS was estimated as precisely as possible, but deviation from reference was slightly harder to demonstrate.

Significance Testing

Significance testing is a common approach to statistical analysis but it is not the only one possible. While it is a useful component of the analytical process, over reliance on significance testing may yield misleading or erroneous results. First, a major weakness is the pervasive use of the arbitrarily chosen value of 5% to indicate significance. This begs the question of whether a p value of 4% is meaningful and a value of 6% is not. A stronger approach is to report the p value directly, as is done in this paper. Second, significance testing over emphasizes the probability of error (i.e. the p value) over the size of the effect. In most cases, including biology and ecology, it is the size of the effect that is most important. Third, any difference can be made significant with a large enough sample. The practical ramification of this is that significance can be purchased, which puts a burden on smaller organizations that do not have funding for a large study. Finally, numerous authors have elaborated on the shortcomings of significance testing. An excellent summary of the issues can be found in the following paper, “The Insignificance of Statistical Significance Testing” by Douglas Johnson.[2] Hypothesis testing was used in this study as one component of a holistic approach to analyzing and understanding the NFS data.

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[1] Stevens & Olsen (B) 2004

[2] Johnson 1999.

Sediment Indicators

The Relative Bed Stability (RBS) metric was developed specifically to address the effects of bedded sediments on wadeable stream channels. RBS is defined as the ratio of the observed mean substrate diameter to the predicted competence of the channel at bankfull. Channel competence is calculated from field measurements of slope, hydraulic radius, and channel roughness. RBS is a unitless ratio of values, and is commonly expressed as log RBS or LRBS to compress the values and to normalize the variance. When the observed mean particle diameter is equal to the predicted diameter of the largest particle the system can move at bankfull (D_CBF), the RBS ratio is equal to 1 and LRBS is equal to 0. The observed mean particle diameter and the D_CBF are primarily dependent on disturbance regimes, channel morphology, geology, and climate. For example, small channels with low gradients are expected to have a small mean particle diameter and are not expected to have enough stream power to move larger particles during a bankfull event. The expected RBS score in these circumstances would be similar to a channel with large sediments and steep gradients. In other words, RBS controls for stream power at a coarse level. By logging the RBS value, the data is normalized so that parametric statistical methods can be applied. Previous studies have shown that increases in sediment input result in a fining of the streambed by overwhelming the capacity of the water column to move sediments. Decreases in the RBS score are often correlated with an increased sediment supply. Therefore RBS is a useful measure of current sediment input as well as instream conditions. Extremely low values indicate over-sedimentation (an example would be -2) whereas large values indicate armoring of the stream bed (an extreme example would be +2.) However, this is not always the case. For instance some systems have naturally high RBS scores. Within the Mid-Atlantic highlands, RBS scores are commonly greater than 0. In the coastal reference data, a few sites had LRBS scores between -1 and -3. Evaluation of the system as a whole, including past disturbances, is necessary in order to understand the significance of the LRBS score. An additional strength of RBS is that it is a composite metric calculated from numerous independent observations. This significantly increases the signal to noise ratio and reduces interobserver bias. One caveat to using the RBS metric is that streams can adjust to elevated sediment inputs over long periods of time (e.g. decades) resulting in stable beds that nonetheless contain unnaturally large quantities of fine sediments.[1] RBS is most useful as an indicator of sediment impacts due to current rather than past anthropogenic disturbance. As seen in the photographs below the substrate can be dominated by large gravels, cobbles, or bedrock while still exhibiting poor sorting or being embedded with fine sands. These photographs were taken at two first order streams in the NFS.

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[1] Kaufmann, P. Personal Comm.

RBS CALCULATION

$RBS = Dgm/D{*}cbf$

where;

Dgm = geometric mean diameter from systematic pebble counts

$D{*}cbf = (0.604{*}R\_STARbf{*}S{*})/\theta c$ or

critical substrate diameter at bankfull flow averaged over reach and adjusted for shear stress reductions related to LWD and pool depth and frequency.

where;

$\theta c = .044$, Shield's number for critical shear stress

S = energy slope ≈ slope of reach water surface

$R\_STARbf = Rbf - Wd - dres$

where;

$Rbf \approx 0.5{*}$(Mean Thalweg Depth + Mean Bankfull Height) or

bankfull hydraulic radius

$dres$= residual pool depth

Wd = wood volume divided by the surface area of the reach or

mean wood "depth" over the reach

In addition to using the RBS metric, the percentage of instream bedded fine sediments (%SAFN) (<2 mm), the percentage of gravels (%GRAVELS), and the percentage of bedrock (%BEDROCK) were also evaluated as was the distribution of this data and the proportion of sands to gravels. These metrics are a direct and intuitive measure of fine sediment impairment and habitat modification. In contrast to RBS, %SAFN may be more sensitive to historic disturbance. It is also more directly tied to the narrative standard for sediment impairment which refers to the accumulation of fine sediments on the stream bed.

Habitat Complexity

Quantitative indicators of habitat complexity are generated as part of the RBS calculation. Three indicators were used in this study to assess habitat complexity; residual pool depth (RP100), width to depth ratio (W:D), and wood radius (RW). The aquatic habitat of many streams is degraded due to a lack of large woody debris (LWD) and channelized as a result of historic logging practices or active stream cleaning. These modifications serve to decrease the hydraulic roughness of the channel. Roughness elements trap fine sediments and decrease the competence of the channel to move sediments. It is theoretically possible to mask an increase in sediment input with an increased competence due to lack of hydraulic roughness. In this scenario fine sediment would not be considered a primary stressor, but elements critical to maintaining healthy aquatic ecosystems would be lacking. If those elements were restored, fine sediment could become a local stressor if the elevated sediment input was not corrected first. It is critical that hydraulic roughness be evaluated when interpreting data on sediment impairment.

W:D – The width to depth ratio changes as a function of disturbance. In some instances it will increase with disturbance due to sustained bank erosion and elevated sediment inputs. Generally, this is related to decreased bedform complexity and degraded riparian vegetation. As a consequence, streams with a width to depth ratio greater than reference conditions could result in increased peak temperatures. In other instances, the width to depth ratio will decrease substantially as the channel down-cuts due to channel confinement. Geology is a controlling factor on channel responses to disturbance. A decreased width to depth ratio could potentially indicate loss of over-wintering fish habitat, increased downstream flood potential, and loss of floodplain connectivity. The metric used in this study was the bankfull width divided by the bankfull height.

RW – The benefits and importance of LWD are well established in the field of restoration biology.[1] Under the protocol used in this study, all wood inside the bankfull channel with a diameter greater than 10 centimeters and a length greater than 1.5 meters was tallied and assigned to a size class. These measurements were then converted to a statistic representing the total volume of wood inside the channel at bankfull height. This volume was divided by the surface area of the stream reach to give an estimate of wood volume per square meter. This controls for the absolute difference in wood volume between large and small channels.

RP100 – Residual pool depth can be conceptualized as what would be left over in a stream reach if all flow stopped. It is a measure of reach-scale bedform complexity and is directly proportional to pool frequency. Qualitative classifications of reaches into habitat units such as riffle, glide, or pool are flow and observer dependent.[2] In contrast, residual pool depth is a flow-invariant metric and is a quantitative measure. It is therefore more suitable for use in sediment transport and regression analyses.

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[1] e.g. Benda et. al. 2003.

[2] Kaufmann et. al. 1999.

A multi-test approach requiring a "weight of evidence" was used to determine the presence and level of fine sediment impairment and habitat modification. Seven metrics were used to assess instream and riparian habitat function and condition; %SAFN, LRBS, RW, RP100, W:D, SN:GR, and Shade. Several tests were conducted on each of the seven metrics used to evaluate impairment. This is consistent with the ODEQ's approach to assigning benchmarks for judging impairment.[1] The 25th and 75th percentiles were used to judge impairment. For some metrics a low score indicates impairment, for example a lack of wood volume, in this case the 25th percentile was used as the benchmark. For other metrics a large score indicates impairment, for example the percentage of sands and fines, in which case the 75th percentile was the benchmark. All sites exceeding these benchmarks were considered potentially impaired. Hypothesis testing was conducted to answer several questions. The first question was whether or not the mean values of the various habitat and sediment indicators differed from the reference means. The second question was whether or not the indicators were significantly different than the benchmarks for impairment. The third question was whether or not the NFS means were significantly different from the reference means in the direction of impairment. For example, "was the NFS %SAFN greater than references," and "was the NFS RW less than reference." The correlation between sands and bedrock for the NFS and reference was also evaluated as an indicator of natural sorting processes.

In the case of bed stability low scores (e.g. -2) often indicate a current source of sediment inputs at a population level. Over time watersheds reach new equilibriums adjusting for these disturbances. Changes in channel morphology, such as channel widening, can result in stable beds which still contain excess sediments from the initial disturbance.[2] Therefore LRBS is a good indicator of current disturbance, with low values often correlating with higher sediment inputs and high values often correlating with channelization. Conversely %SAFN is a good indicator of both past and present disturbances. While LRBS might not detect a major watershed wide disturbance 40 years in the past, excess %SAFN coupled with a stable system might indicate a past disturbance that the system has adjusted for. An understanding of historical landuse practices is critical to interpreting the results of the statistical analysis.

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[1] Drake, D. Personal Comm, ODEQ

[2] Kaufmann, P. Personal Comm. EPA

Tests used to evaluate impairment

1. Two Tailed Two Sample Welch t testing – Two tailed testing evaluates whether the means of two populations are different from one another. Two sample Welch t testing controls for differences in sample size and variance between populations.
2. Two Tailed One Sample testing – Two tailed one sample testing was used to test for significant differences between the 25th or 75th percentile (benchmark) of the reference data and the mean of the NFS. For instance, we are interested in whether or not the NFS mean %SAFN is significantly different than the 75th percentile of the reference data.
3. One Tailed Two Sample Welch t testing – One tailed testing is justified when there is an interest in deviation in one direction. In this case the interest was impairment.

    - One Tailed Two Sample t testing was used to determine if the means of %SAFN, W:D, and SN:GR were significantly greater than references means.
    - One Tailed Two Sample t testing was used to determine if the means of LRBS, RW, RP100, and Shade were significantly less than reference means.

4. Calculate the percentage of NFS sites that are outside the benchmark.
5. Visually evaluate the distribution of the NFS data to Reference.
6. Evaluate the correlation between sands and bedrock.
7. Assign a numerical value to qualitative measures of bank condition. These are coupled with photographic documentation throughout the watershed.
8. Evaluate other documentation within the watershed including a USFS Watershed Analysis, Siuslaw River Watershed Assessment, Rapid Bio-Assessment Data, evidence of restoration activities, photographic documentation, and anecdotal evidence.

REFERENCE DATA SUMMARY						
Indicator	N	Mean	SD	SE	UPPER 95% CB	LOWER 95% CB
LRBS	19	-0.44	0.89	0.20	-0.04	-0.84
%SAFN	22	19.95%	18.58%	3.96%	27.71%	12.19%
%GRAVEL	16	33.85%	12.55%	3.14%	40.00%	27.71%
%BEDROCK	23	15.35%	17.23%	3.59%	22.39%	8.31%
RP100	19	14.24	17.93	4.11	22.30	6.18
RW	19	0.06	0.02	0.00	0.07	0.05
W:D	21	8.68	2.97	0.65	9.95	7.41
CANOPY	22	85.76%	17.62%	3.76	8.22	-6.51
SANDS:GRAVELS	16	0.92	1.10	0.27	1.46	0.38

Table 2 - Reference Data Summary

1ST ORDER DATA SUMMARY						
Indicator	N	Mean	SD	SE	UPPER 95% CB	LOWER 95% CB
LRBS	14	-0.41	0.35	0.09	-0.23	-0.60
%SAFN	14	31.07%	18.36%	4.91%	40.69%	21.45%
%GRAVEL	14	38.43%	12.57%	3.36%	45.02%	31.84%
%BEDROCK	14	10.29%	9.06%	2.42%	15.03%	5.54%
RP100	14	12.30	7.31	1.95	16.13	8.46
RW	14	0.035	0.026	0.007	0.049	0.021
W:D	14	11.42	3.10	0.83	13.04	9.80
BANK	14	1.25	0.26	0.07	1.38	1.11
CANOPY	14	75.62%	12.60%	3.37%	82.22%	69.03%
SANDS:GRAVELS	14	1.03	0.87	0.23	1.48	0.57
2ND ORDER DATA SUMMARY						
Indicator	N	Mean	SD	SE	UPPER 95% CB	LOWER 95% CB
LRBS	8	0.02	0.29	0.10	0.22	-0.18
%SAFN	8	29.13%	7.06%	2.50%	34.02%	24.23%
%GRAVEL	8	38.63%	11.13%	4.45%	47.14%	29.72%
%BEDROCK	8	16.13%	10.72%	3.20%	16.56%	4.01%
RP100	8	27.47	6.40	2.26	31.90	23.03
RW	8	0.010	0.016	0.006	0.021	0.000
W:D	8	16.09	2.19	0.78	17.60	14.57
BANK	8	1.41	0.37	0.13	1.67	1.16
CANOPY	8	54.25%	14.21%	5.03%	64.10%	44.40%
SANDS:GRAVELS	8	0.88	0.21	0.07	1.02	0.73
WATERSHED DATA SUMMARY						
Indicator	N	Mean	SD	SE	UPPER 95% CB	LOWER 95% CB
LRBS	22	-0.31	0.38	0.08	-0.15	-0.47
%SAFN	22	30.60%	16.40%	3.50%	37.46%	23.75%
%GRAVEL	22	38.48%	12.24%	2.61%	43.59%	33.36%
%BEDROCK	22	11.69%	9.81%	2.09%	15.78%	7.59%
RP100	22	15.93	9.62	2.05	19.95	11.91
RW	22	0.027	0.081	0.02	0.061	0.000
W:D	22	12.54	3.52	0.75	14.01	11.07
BANK	22	1.29	0.3	0.06	1.41	1.16
CANOPY	22	70.50%	15.89%	3.39%	77.14%	63.86%
SANDS:GRAVELS	22	0.99	0.76	0.16	1.31	0.67

Table 3 - NFS Data Summary

Test 1 – Two Tailed Two Sample Welch t testing.

The null hypothesis is that there is no difference between the means. The alternate hypothesis is that there is a difference between the reference mean and the NFS mean. This test puts the burden of proof on demonstrating a significant difference between the means of the two populations. This is the most stringent of the 9 tests for impairment.

– **%SAFN** –

- The NFS Watershed %SAFN mean is significantly different than reference at 30.6% vs. 19.95% (p=.02)
- The NFS Second Order %SAFN mean is significantly different than reference at 29.13% vs. 19.95% (p=.02)
- The NFS First Order %SAFN mean is significantly different than reference at 31.07% vs. 19.95% (p=.04)

– **W:D** –

- The NFS Watershed W:D mean is significantly different than reference at 12.54 vs 8.68 (p=.00)
- The NFS Second Order W:D mean is significantly different than reference at 16.09 vs. 8.68 (p=.00)
- The NFS First Order W:D mean is significantly different than reference at 11.42 vs. 8.68 (p=.02)

– **SN:GR** –

- The NFS Watershed SN:GR mean is not significantly different than reference at .99 vs. .92 (p=.45)
- The NFS Second Order SN:GR mean is not significantly different than reference at .88 vs. .92 (p=.75)
- The NFS First Order SN:GR mean is not significantly different than reference at 1.03 vs. .92 (p=.46)

– **LRBS** –

- The NFS Watershed LRBS mean is not significantly different than reference at -.31 vs -.44 (p=.56)
- The NFS Second Order LRBS mean is trending towards a significant difference at .02 vs. -.44 (p=.056)
- The NFS First Order LRBS mean is not significantly different than reference at -.41 vs. -.44 (p=.91)

– **RW** –

- The NFS Watershed RW mean is trending towards a significant difference at .03 vs .06 (p=.10)
- The NFS Second Order RW mean is significantly different than reference at .01 vs .06 (p=.00)
- The NFS First Order RW mean is significantly different than reference at .04 vs .06 (p=.01)

– **RP100** –

- The NFS Watershed RP100 mean is not significantly different than reference at 15.93 vs 14.24 (p=.71)
- The NFS Second Order RP100 mean is significantly different than reference at 24.47 vs 14.24 (p=.01)
- The NFS First Order RP100 mean is not significantly different than than reference at 12.30 vs 14.24 (p=.67)

– **Shade** –

- The NFS Watershed Shade mean is significantly different than reference at 70.50% vs 85.76% (p=.00)
- The NFS Second Order Shade mean is significantly different than reference at 54.25% vs 85.76% (p=.00)
- The NFS First Order Shade mean is significantly different than reference at 75.62% vs 85.76% (p=.03)

TWO TAIL TWO SAMPLE SUMMARY OF ALL POPULATIONS VS REFERENCE				
METRIC	POPULATION	RESULT	POPULATION	P VALUE
LRBS	WATERSHED	N.S.	REFERENCE	0.5590
%SAFN	WATERSHED	>	REFERENCE	0.0196
RW	WATERSHED	< (TREND)	REFERENCE	0.1014
RP100	WATERSHED	N.S.	REFERENCE	0.7140
W:D	WATERSHED	>	REFERENCE	0.0000
CANOPY	WATERSHED	<	REFERENCE	0.0034
%SAFN:GRAVELS	WATERSHED	N.S.	REFERENCE	0.4454
LRBS	1ST ORDER	N.S.	REFERENCE	0.9130
%SAFN	1ST ORDER	>	REFERENCE	0.0422
RW	1ST ORDER	<	REFERENCE	0.0120
RP100	1ST ORDER	N.S.	REFERENCE	0.6710
W:D	1ST ORDER	>	REFERENCE	0.0150
CANOPY	1ST ORDER	<	REFERENCE	0.0343
%SAFN:GRAVELS	1ST ORDER	N.S.	REFERENCE	0.4608
LRBS	2ND ORDER	> (TREND)	REFERENCE	0.0560
%SAFN	2ND ORDER	>	REFERENCE	0.0178
RW	2ND ORDER	<	REFERENCE	0.0000
RP100	2ND ORDER	>	REFERENCE	0.0090
W:D	2ND ORDER	>	REFERENCE	0.0000
CANOPY	2ND ORDER	<	REFERENCE	0.0000
%SAFN:GRAVELS	2ND ORDER	N.S.	REFERENCE	0.7474

Table 4 - Two Tail Two Sample Summaries for All Populations

Test 2 – Two Tailed One Sample t testing.

The null hypothesis is that the mean of the NFS data is not significantly different from the benchmark. The alternate hypothesis is that the mean of the NFS is significantly different from the benchmark. This test puts the burden of proof on demonstrating a significant difference from the benchmark. This test is more protective than two tailed two sample testing in that if the mean of the NFS data is at the benchmark or different in the direction of impairment we conclude potential impairment.

– **%SAFN** –

- The NFS Watershed %SAFN mean is not significantly different from the benchmark (p=.99)
- The NFS Second Order %SAFN mean is not significantly different from the benchmark (p=.60)
- The NFS First Order %SAFN mean is not significantly different from the benchmark (p=.99)

– **W:D** –

- The NFS Watershed W:D mean is significantly outside the benchmark (p=.00)
- The NFS Second Order W:D mean is significantly outside the benchmark (p=.00)
- The NFS First Order W:D mean is significantly outside the benchmark (p=.01)

– **SN:GR** –

- The NFS Watershed W:D mean is not significantly different from the benchmark at (p=.32)
- The NFS Second Order W:D mean is not significantly different from the benchmark at (p=.51)
- The NFS First Order W:D mean is not significantly different from the benchmark at (p=.40)

– **LRBS** –

- The NFS Watershed LRBS mean is significantly inside the benchmark (p=.00)
- The NFS Second Order LRBS mean is significantly inside the benchmark (p=.00)
- The NFS First Order LRBS mean is significantly inside the benchmark (p=.00)

– **RW** –

- The NFS Watershed RW mean is not significantly different from the benchmark (p=.33)
- The NFS Second Order RW mean is not significantly different from the benchmark (p=.35)
- The NFS First Order RW mean is not significantly different from the benchmark (p=.20)

– **RP100** –

- The NFS Watershed RP100 mean is significantly inside the benchmark (p=.00)
- The NFS Second Order RP100 mean is significantly inside the benchmark (p=.00)
- The NFS First Order RP100 mean is significantly inside the benchmark (p=.00)

– **Shade** –

- The NFS Watershed Shade mean is not significantly different from the benchmark (p=.33)
- The NFS Second Order Shade mean is significantly outside the benchmark (p=.00)
- The NFS First Order Shade mean is not significantly different from the benchmark at (p=.52)

TWO TAIL ONE SAMPLE SUMMARY OF ALL POPULATIONS VS BENCHMARKS				
METRIC	POPULATION	RESULT	CRITERIA	P VALUE
LRBS	WATERSHED	>	BENCHMARK	< 0.0001
%SAFN	WATERSHED	N.S.	BENCHMARK	0.9992
RW	WATERSHED	N.S.	BENCHMARK	0.3340
RP100	WATERSHED	>	BENCHMARK	< 0.0001
W:D	WATERSHED	>	BENCHMARK	0.0000
CANOPY	WATERSHED	N.S.	BENCHMARK	0.3292
%SAFN:GRAVELS	WATERSHED	N.S.	BENCHMARK	0.3198
LRBS	1ST ORDER	>	BENCHMARK	< 0.0001
%SAFN	1ST ORDER	N.S.	BENCHMARK	0.9938
RW	1ST ORDER	N.S.	BENCHMARK	0.2048
RP100	1ST ORDER	>	BENCHMARK	< 0.0001
W:D	1ST ORDER	N.S.	BENCHMARK	0.0075
CANOPY	1ST ORDER	N.S.	BENCHMARK	0.5234
%SAFN:GRAVELS	1ST ORDER	N.S.	BENCHMARK	0.3974
LRBS	2ND ORDER	>	BENCHMARK	< 0.0001
%SAFN	2ND ORDER	N.S.	BENCHMARK	0.6026
RW	2ND ORDER	N.S.	BENCHMARK	0.3466
RP100	2ND ORDER	>	BENCHMARK	< 0.0001
W:D	2ND ORDER	>	BENCHMARK	< 0.0001
CANOPY	2ND ORDER	<	BENCHMARK	< 0.0001
%SAFN:GRAVELS	2ND ORDER	N.S.	BENCHMARK	0.5106

Table 5 - Two Tail One Sample Summaries for All Populations vs. benchmarks

Test 3 – One Tailed Two Sample Welch t testing.

The null hypothesis is that NFS mean is not significantly different from the reference data in the direction of impairment. The alternate hypothesis is that the NFS mean is significantly different from the reference data in the direction of impairment. This test puts the burden of proof on demonstrating impairment. This test is in between the two tailed two sample and two tailed one sample test in terms of protecting natural resources in that a difference must still be shown but it becomes easier to show that difference with a smaller sample size.

– %SAFN –

- The NFS Watershed %SAFN mean is significantly greater than reference (p=.02)
- The NFS Second Order %SAFN mean is significantly greater than reference (p=.00)
- The NFS First Order %SAFN mean is significantly greater than reference (p=.02)

– W:D –

- The NFS Watershed W:D mean is significantly greater than reference (p=.00)
- The NFS Second Order W:D mean is significantly greater than reference (p=.00)
- The NFS First Order W:D mean is significantly greater than reference (.01)

– SN:GR –

- The NFS Watershed W:D mean is not significantly greater than reference (p=.22)
- The NFS Second Order W:D mean is not significantly greater than reference (p=.37)
- The NFS First Order W:D mean is not significantly greater than reference (p=.23)

– LRBS –

- The NFS Watershed LRBS mean is not significantly lower than reference (p=.72)
- The NFS Second Order LRBS mean is not significantly lower than reference (p=.97)
- The NFS First Order LRBS mean is not significantly lower than reference (p=.54)

– RW –

- The NFS Watershed RW mean is significantly lower than reference (p=.05)
- The NFS Second Order RW mean is significantly lower than reference at .01 vs .06 (p=.00)
- The NFS First Order RW mean is significantly lower than reference at .04 vs .06 (p=.01)

– RP100 –

- The NFS Watershed RP100 mean is not significantly lower than reference (p=.36)
- The NFS Second Order RP100 mean is not significantly lower than reference (p=.99)
- The NFS Second Order RP100 mean is not significantly lower than reference (p=.34)

– Shade –

- The NFS Watershed Shade mean is significantly less than reference (p=.00)
- The NFS Second Order Shade mean is significantly less than reference (p=.00)
- The NFS First Order Shade mean is significantly less than reference (p=.02)

ONE TAIL TWO SAMPLE SUMMARY OF ALL POPULATIONS VS REFERENCE				
METRIC	POPULATION	RESULT	POPULATION	P VALUE
LRBS	WATERSHED	N.S.	REFERENCE	0.72
%SAFN	WATERSHED	>	REFERENCE	0.02
RW	WATERSHED	<	REFERENCE	0.05
RP100	WATERSHED	N.S.	REFERENCE	0.36
W:D	WATERSHED	>	REFERENCE	0.00
CANOPY	WATERSHED	<	REFERENCE	0.00
%SAFN:GRAVELS	WATERSHED	N.S.	REFERENCE	0.22
LRBS	1ST ORDER	N.S.	REFERENCE	0.54
%SAFN	1ST ORDER	>	REFERENCE	0.02
RW	1ST ORDER	<	REFERENCE	0.01
RP100	1ST ORDER	N.S.	REFERENCE	0.34
W:D	1ST ORDER	>	REFERENCE	0.01
CANOPY	1ST ORDER	<	REFERENCE	0.02
%SAFN:GRAVELS	1ST ORDER	N.S.	REFERENCE	0.23
LRBS	2ND ORDER	N.S.	REFERENCE	0.97
%SAFN	2ND ORDER	>	REFERENCE	0.02
RW	2ND ORDER	<	REFERENCE	0.00
RP100	2ND ORDER	N.S	REFERENCE	>.99
W:D	2ND ORDER	>	REFERENCE	0.00
CANOPY	2ND ORDER	<	REFERENCE	0.00
%SAFN:GRAVELS	2ND ORDER	N.S.	REFERENCE	0.37

Table 6 - One Tail Two Sample Summaries for All Populations

Test 4 – The percentage of NFS sites that are outside the benchmark.

This test puts the burden of proof on demonstrating differences in the distribution. Percentiles were calculated using two sets of assumptions for RW. First, percentiles were calculated using reference population means and standard deviations. This approach requires the population be relatively normal which can be achieved through various tranformations such as an arcsin transformation. The %SAFN were transformed in this way. Under some conditions, transformations can distort means and percentiles relative to untransformed values. In many cases, these distortions are relatively minor and do not obscure the original pattern of the data. For example, the unstransformed percentile for %SAFN was ~32%, where the transformed percentile was ~30%. For RW however, a log transformation was required to normalize the values. Very large differences were observed between the transformed (.0097 m) and untransformed (.044 m) percentiles. It is likely that decreases in wood volume will have deleterious impacts on aquatic habitat well before they fall below this transformed value. Percentile analysis may be less appropriate than the comparison of mean values for wood volume.

– %SAFN –
- Watershed – 45.45% exceed the 75th percentile
- Second Order – 50.00% exceed the 75th percentile
- First Order – 42.86% exceed the 75th percentile

– W:D –
- Watershed – 81.82% exceed the 75th percentile
- Second Order – 100.00% exceed the 75th percentile
- First Order – 71.43% exceed the 75th percentile

– LRBS –
- Watershed – 0% fall below the 25th percentile
- Second Order – 0% fall below the 25th percentile
- First Order – 0% fall below the 25th percentile

– RW – Non-normal population.
- Watershed – 77.27% fall below the 25th percentile
- Second Order – 87.50% fall below the 25th percentile
- First Order – 71.43% fall below the 25th percentile

– Log RW – Normalizes population
- Watershed – 36.36% fall below the 25th percentile
- Second Order – 62.50% fall below the 25th percentile
- First Order – 21.43% fall below the 25th percentile

– RP100 –
- Watershed – 4.55% fall below the 25th percentile
- Second Order – 0% fall below the 25th percentile
- First Order – 7.14% fall below the 25th percentile

% OF NFS SITES WHICH EXCEED BENCHMARKS			
Indicator	Benchmark	# Sites	% Sites
LRBS	-1.04	0	0.00%
%SAFN	30.17%	10	45.45%
RP100 (cm)	2.15	1	4.55%
RW (m)	0.044	17	77.27%
LOG RW (m)	0.0097	8	36.36%
W:D	10.68	18	81.82%
% OF 1st ORDER SITES WHICH EXCEED BENCHMARKS			
Indicator	Benchmark	# Sites	% Sites
LRBS	-1.04	0	0.00%
%SAFN	30.17%	6	42.86%
RP100 (cm)	2.15	1	7.14%
RW (m)	0.044	10	71.43%
LOG RW (m)	0.0097	3	21.43%
W:D	10.68	10	71.43%
% OF 2nd ORDER SITES WHICH EXCEED BENCHMARKS			
Indicator	Benchmark	# Sites	% Sites
LRBS	-1.04	0	0.00%
%SAFN	30.17%	4	50.00%
RP100 (cm)	2.15	0	0.00%
RW (m)	0.044	7	87.50%
LOG RW (m)	0.0097	5	62.50%
W:D	10.68	8	100.00%

Table 7 - Percentage of NFS sites which exceeded benchmark percentiles

Test 5 – Visual inspection of the distribution of the NFS data to Reference.

This test puts the burden of proof on demonstrating a gross difference in the distributions. Although highly informative, this test is not quantitative and must be used in conjunction with quantitative testing.

In systems minimally disturbed by anthropogenic sources, it is expected that some portions of the stream network will have high levels of fine sediments (e.g 60%) while others will have very low levels of fine sediments (e.g 4%.) Erodible reference scores for %SAFN range from 0% to 60% with an average of 19.95%. The range for the NFS Watershed is from 4% to 89% with two outliers at 4% and 89% and an average of ~30% . The clumping and the skew of the population to the right suggest that the NFS population is significantly different from the reference data and has an increased %SAFN. In general, there is very little variation in the %SAFN within the NFS. Almost 60% of the NFS sites sampled fall within the 26%-35% range for %SAFN (mean of this range was 30.8%) while only two fall within this range for the reference data (mean of this range was 28.95%.) More reference sites fall between the 0 and 10% range for %SAFN (mean of this range was 5.6%) while only one NFS site fell within this range, see figures 3 and 4 below. Within the reference data, it is clear that the average is driven by a relatively small number of sites with a high percentage of sands while half of the sites are between 0 and 10%. In contrast, one site within the NFS was below 10%. See the Cumulative Distribution Functions (CDF's) and the histograms below.

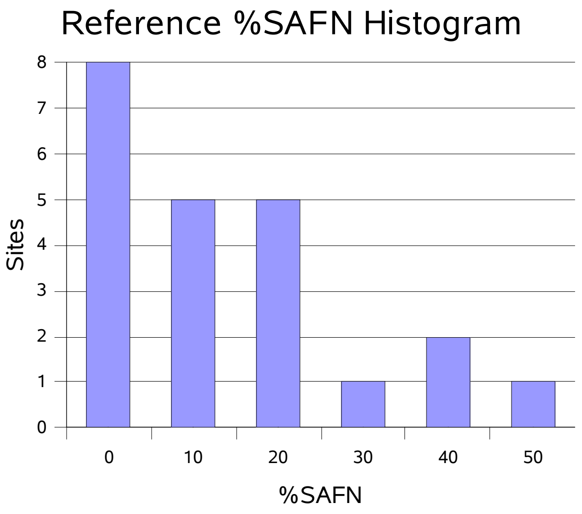


Figure 3 - Reference %SAFN Histogram

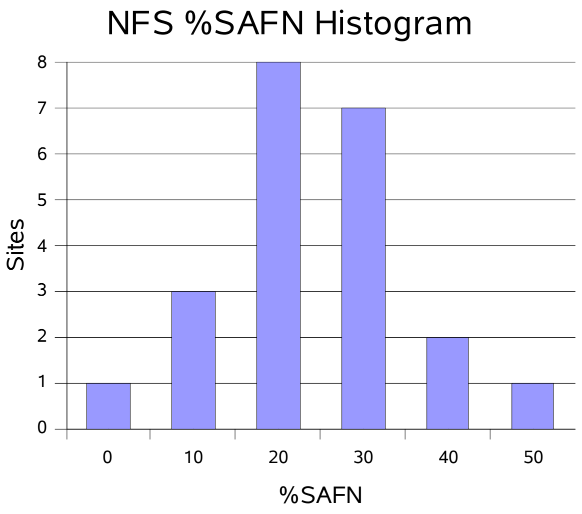


Figure 4 - NFS %SAFN Histogram

Figure 5 - **Reference %SAFN Distribution**

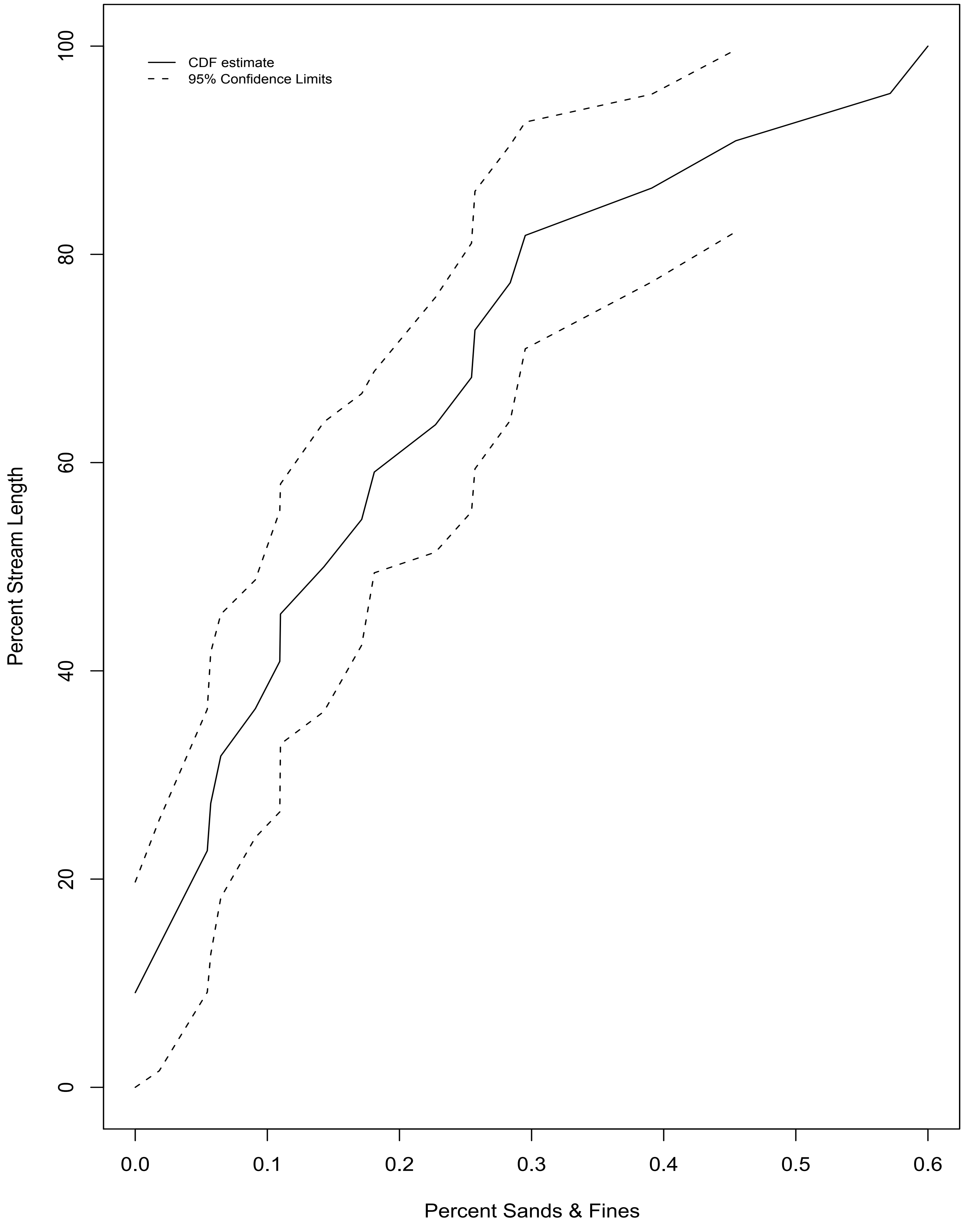


Figure 6 - **Watershed %SAFN Distribution**

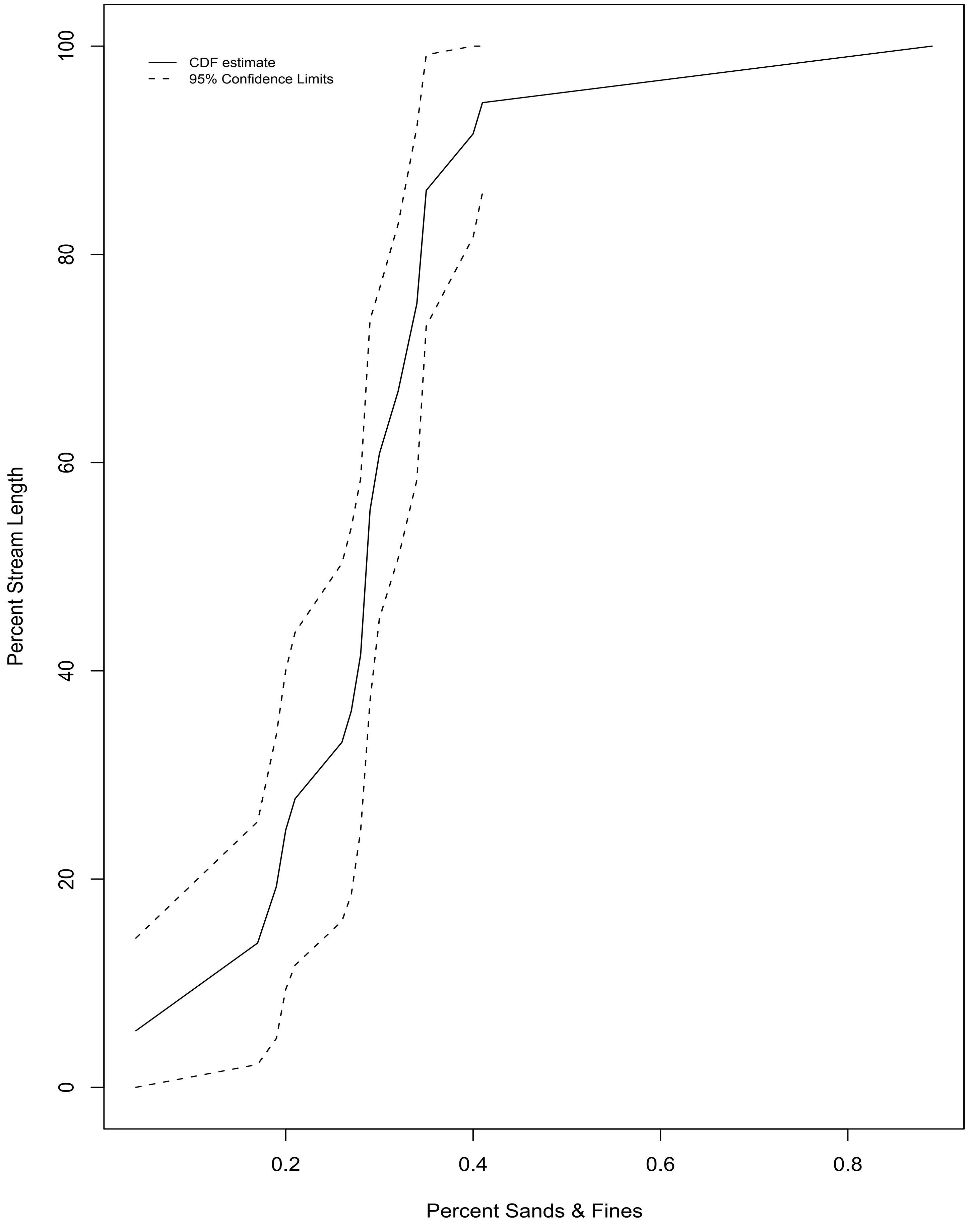


Figure 7 - **Reference RW Distribution**

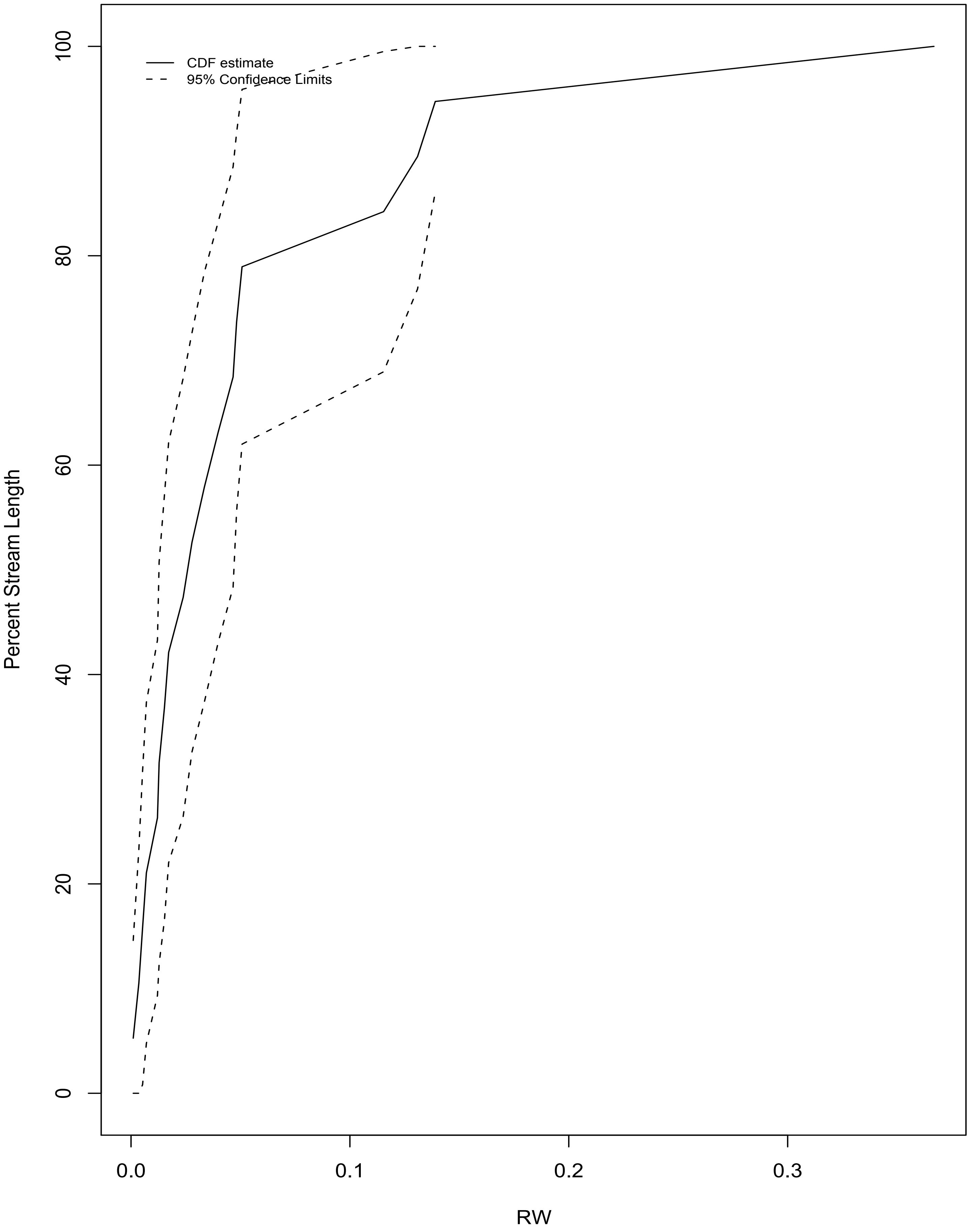


Figure 8 - **Watershed RW Distribution**

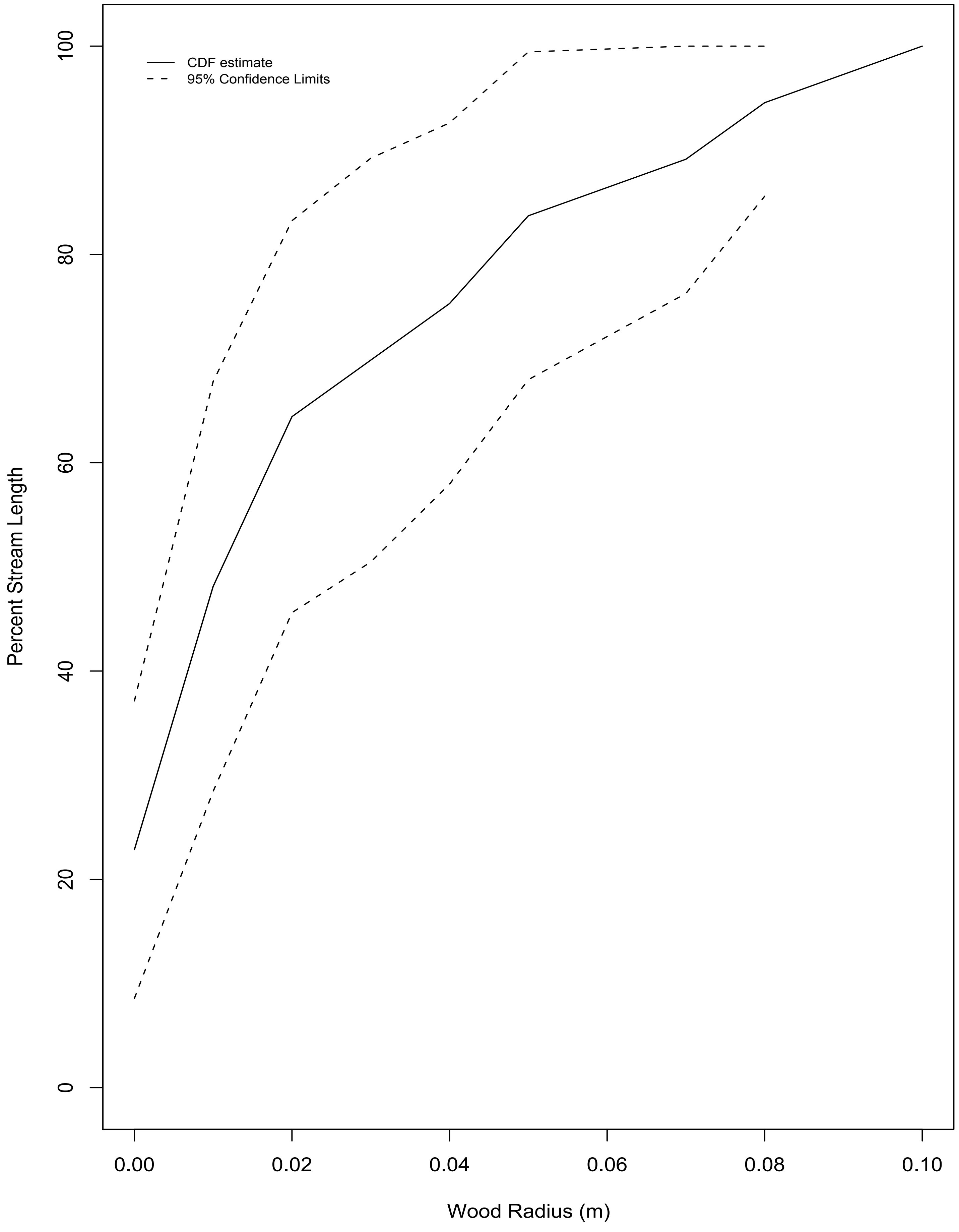


Figure 9 - **Reference W:D Distribution**

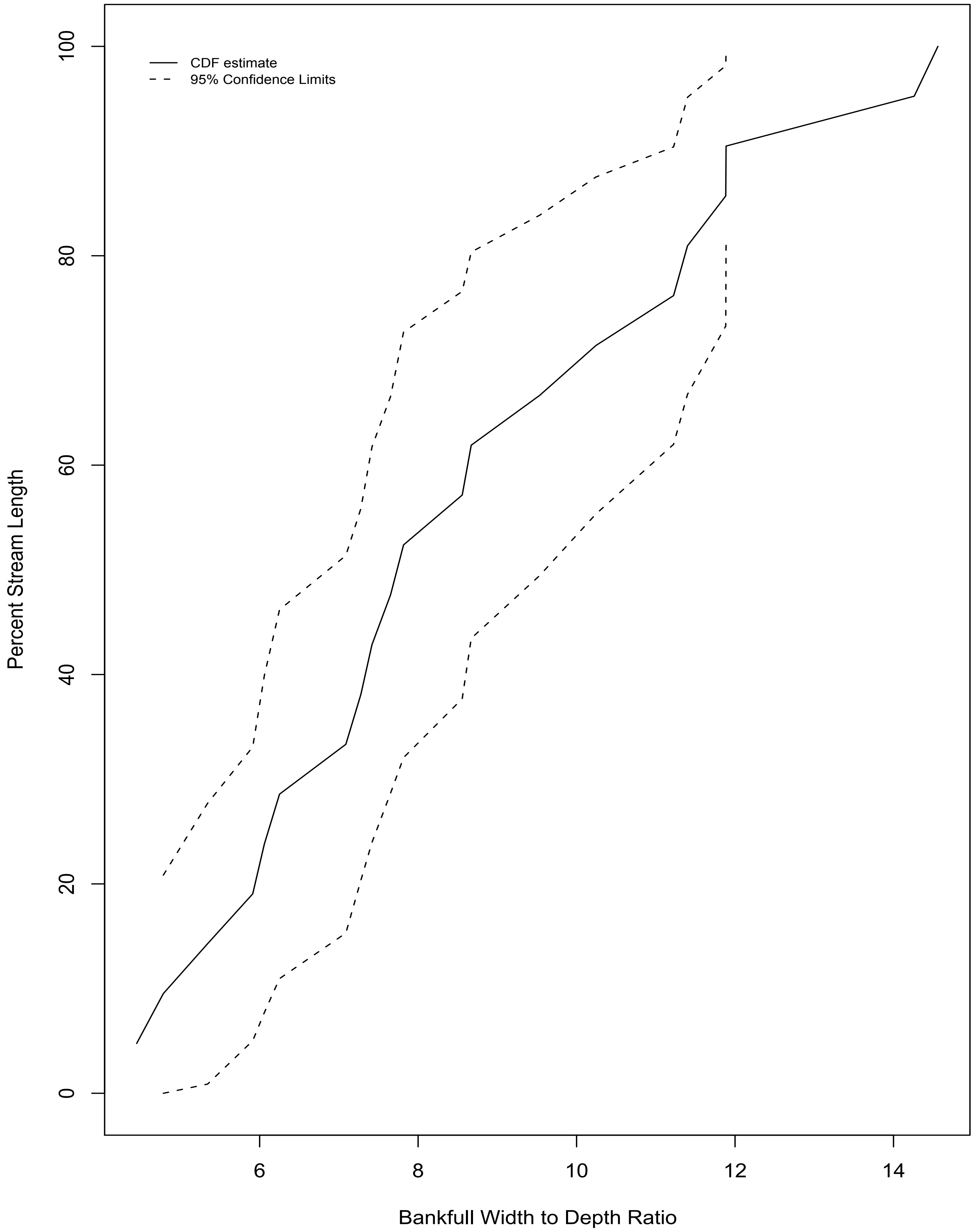


Figure 10 - **Watershed W:D Distribution**

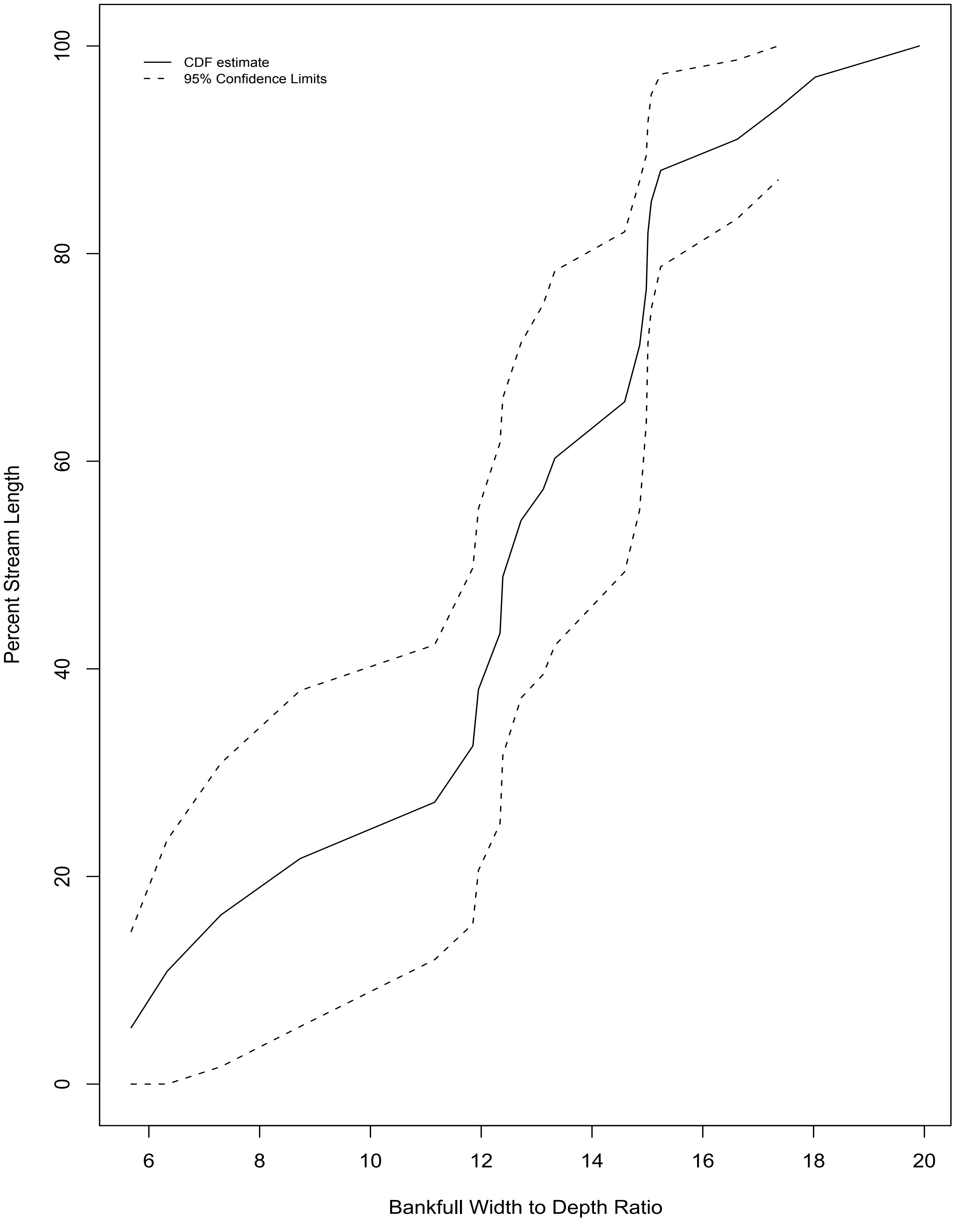


Figure 11 - **Reference LRBS Distribution**

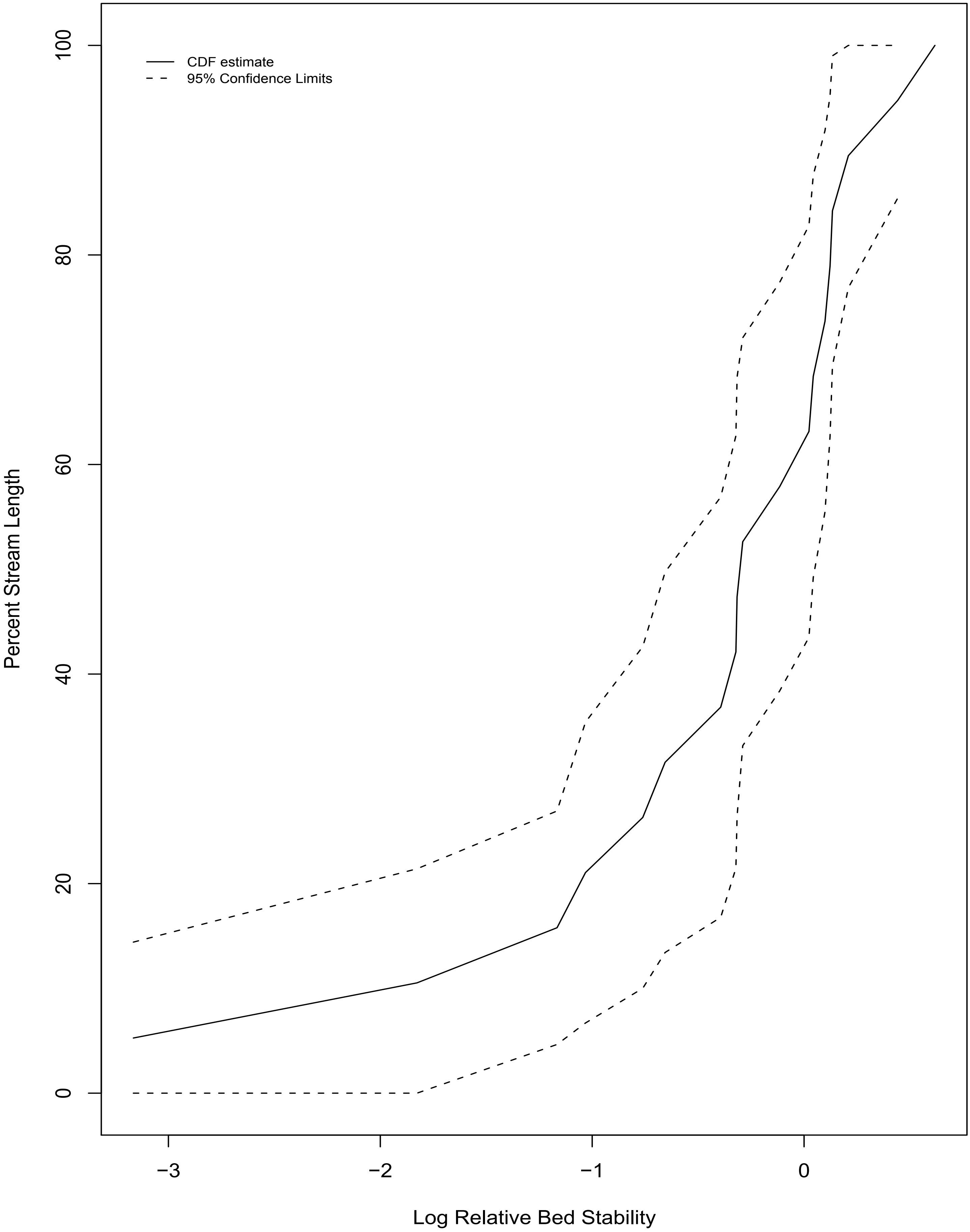


Figure 12 - **Watershed LRBS Distribution**

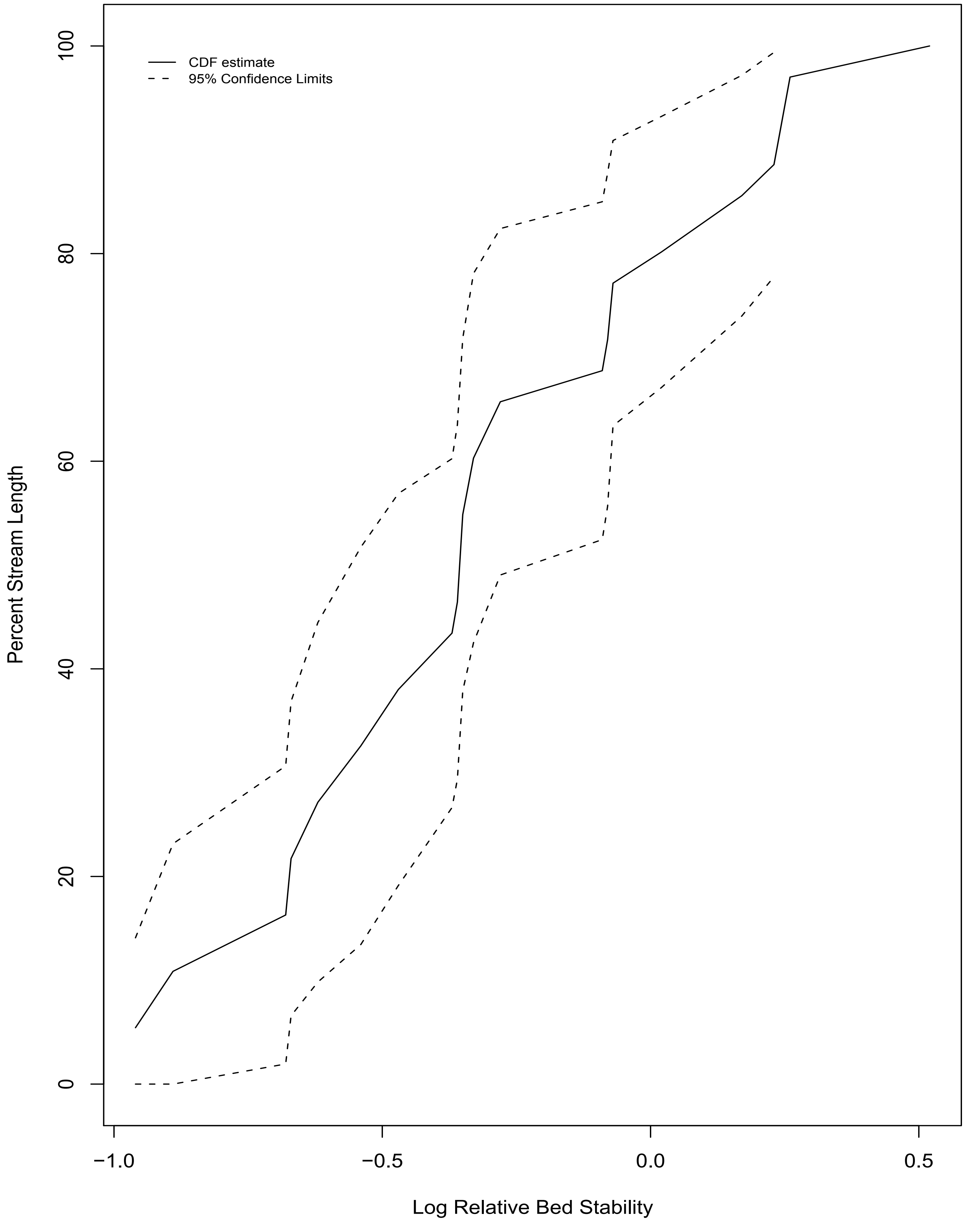


Figure 13 - **Reference RP100 Distribution**

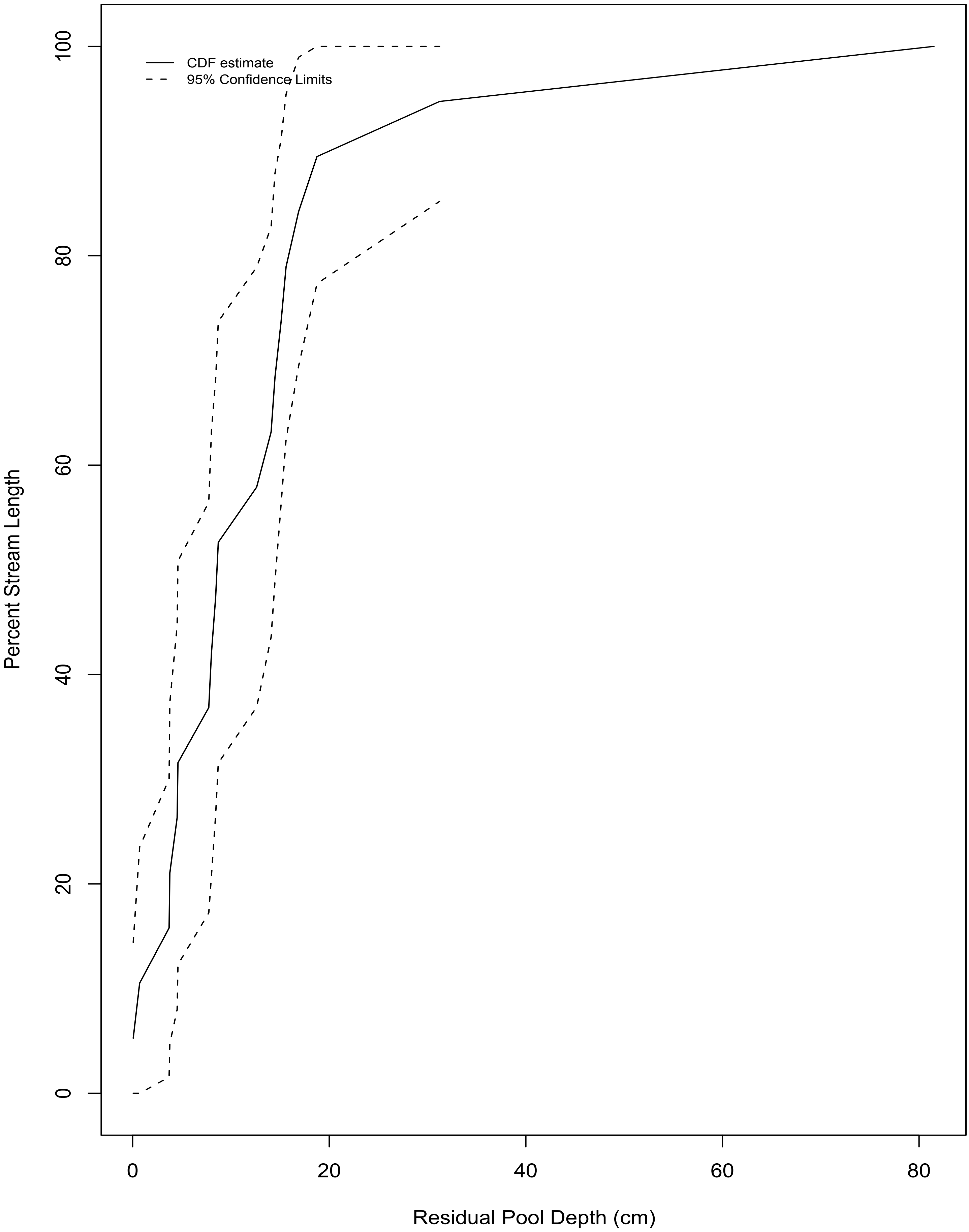
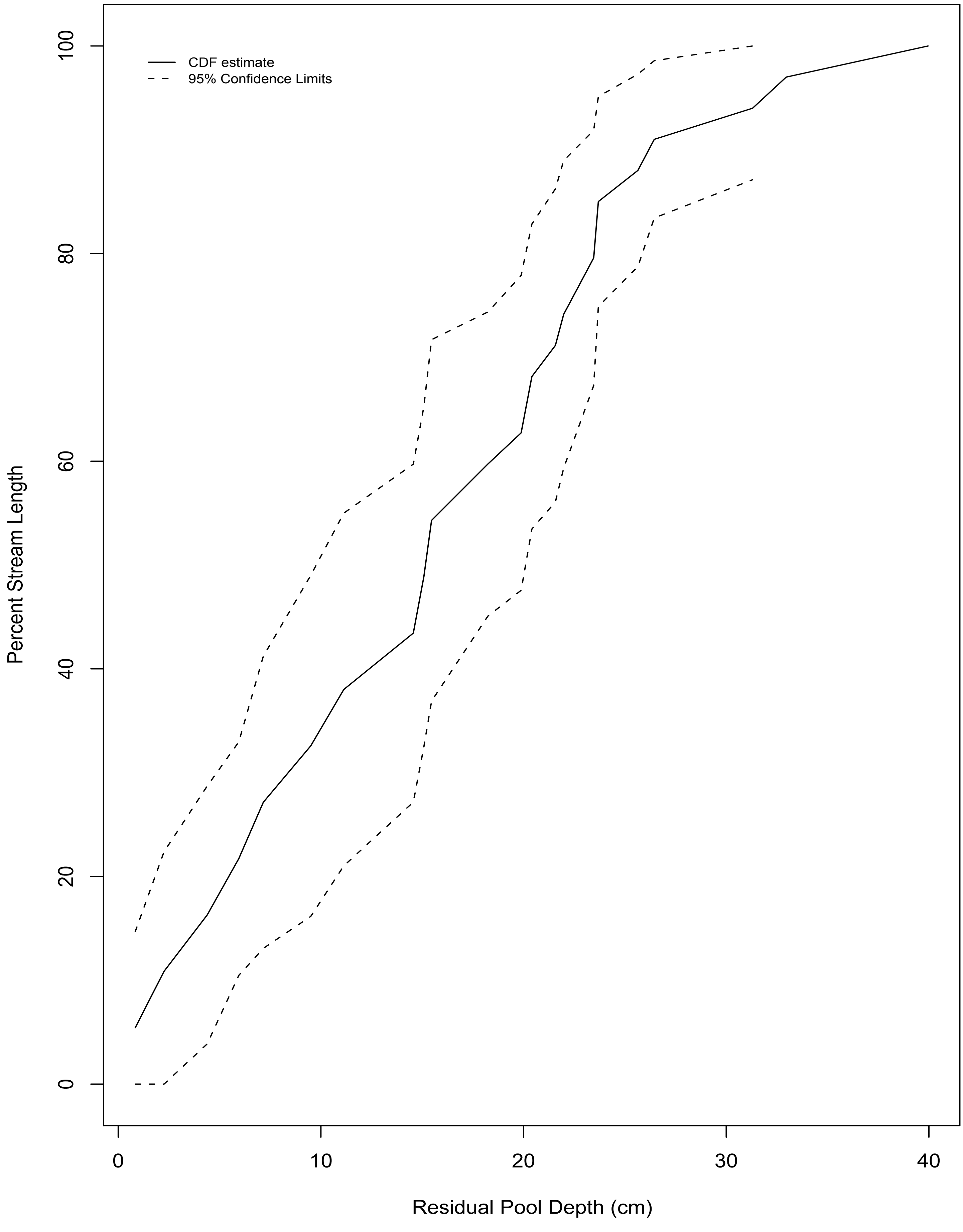


Figure 14 - **Watershed RP100 Distribution**



Test 6 – Evaluate the correlation between sands and bedrock.

This test puts the burden of proof on demonstrating the expected inverse proportionality of sands to bedrock. This is consistent with protective measures in that if the relationship is not found, even with a small sample size, it appears that the relationship does not exist.

Within the erodible reference data, there is a significant negative correlation between %SAFN and the %BEDROCK. No correlation between these metrics was observed within the NFS. This suggests a breakdown of natural sediment sorting processes within the NFS.

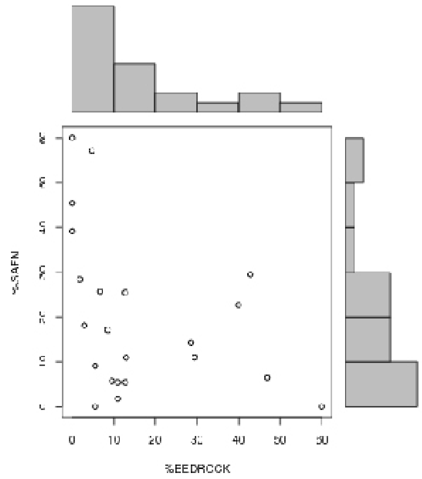


Figure 15 - %SAFN vs. %BED Reference

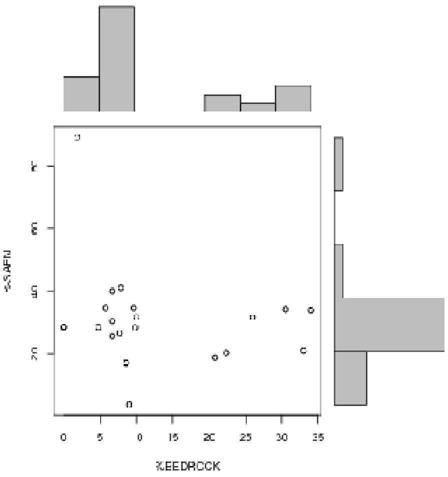


Figure 16 - %SAFN vs. %BED NFS

REFERENCE %SAFN VS %BEDROCK	
CORRELATION	-.38
DETERMINATION	.14
P VALUE (1 SIDED)	.04
DEGREES OF FREEDOM	20

Table 8 - %SAFN vs. BED Reference

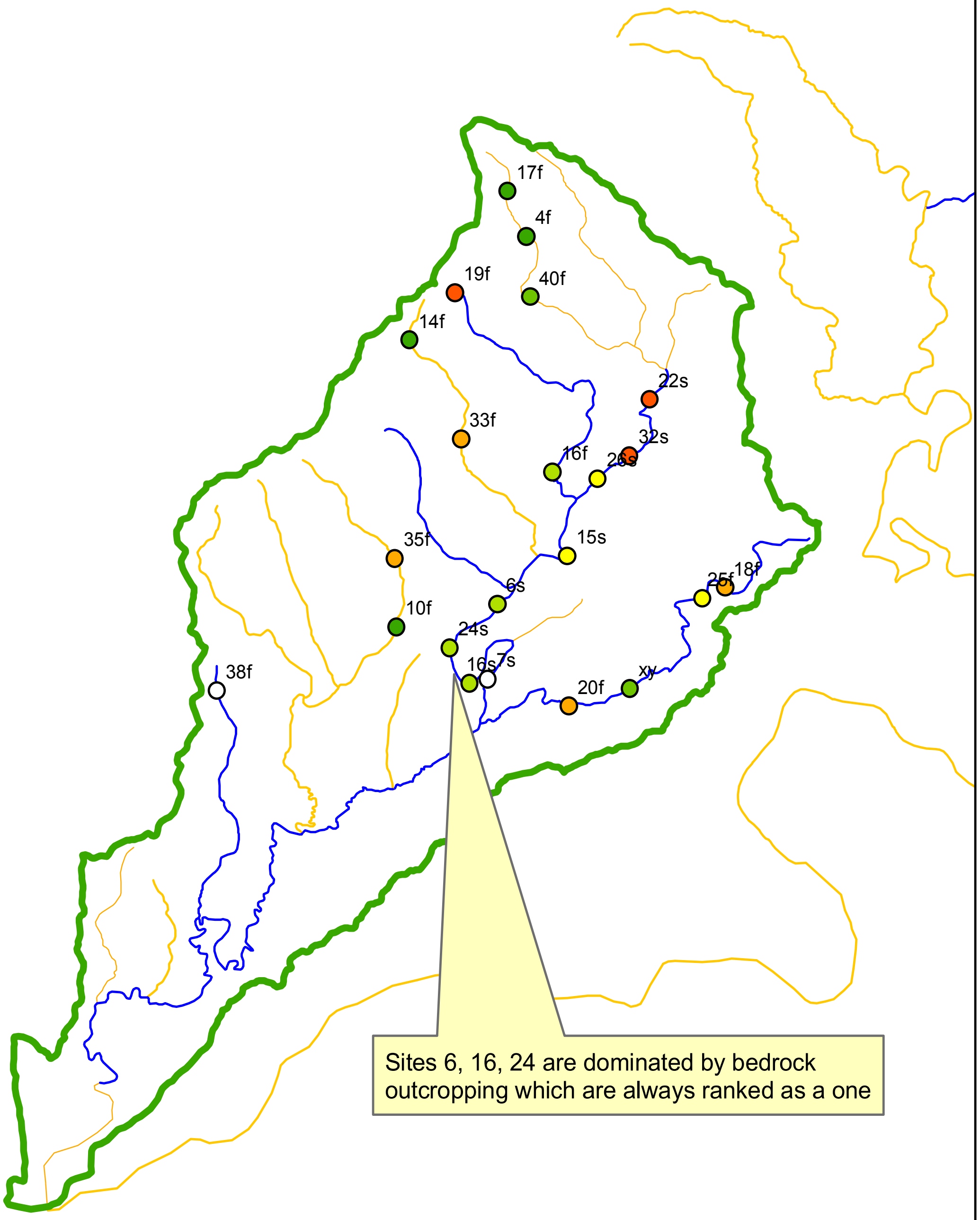
NFS %SAFN VS %BEDROCK	
CORRELATION	-.2
DETERMINATION	.04
P VALUE (1 SIDED)	.18
DEGREES OF FREEDOM	20

Table 9 - %SAFN vs. BED NFS

Test 7 – Assign a numerical value to qualitative measures of bank condition.

These are coupled with photographic documentation throughout the watershed. This is a semi-quantitative test and is similar to visually evaluating the distribution of the data in that it must be used in conjunction with other measures of impairment.

Bank Condition was scored on a scale from 1 to 5 and evaluated in several ways. The average bank condition for the watershed was 1.29. It was greater in the second order streams at 1.45 vs. 1.25 in the first order streams. Within the second order streams, bank condition scores were primarily driven by the presence of a road that ran along the entire length of the NFS mainstem. Rip rap often prevented any erosion in addition to limiting natural channel migration. Confinement by road proximity is decreasing the natural sinuosity of the NFS mainstem and is also increasing channel competence. Bank condition was also calculated by scoring banks with no disturbance as 0 and averaging all scores greater than 0. The result of this analysis indicated that 4 sites appeared to have no disturbance on any transect whereas 18 sites had at least one bank per transect with active erosion ranging on a scale from 2-5. Additionally sites were classified as either an “A” for no human presence or a “B” for human presence. All second order sites and two first order sites were listed as “B” sites and 12 first order sites were listed as “A” sites. No sites visited had banks actively affected by cattle grazing. This practice appeared to be more prevalent lower on the NFS mainstem where the river became unwadeable. The lower portion of the NFS was photo-documented in order to capture this missing information. The photograph shown below is an example of the bank condition on the unwadeable NFS mainstem. Additional photographic data is available upon request from Demeter Design and the Siuslaw Watershed Council.



Sites 6, 16, 24 are dominated by bedrock outcropping which are always ranked as a one

Prepared by Demeter Design for the Siuslaw Watershed

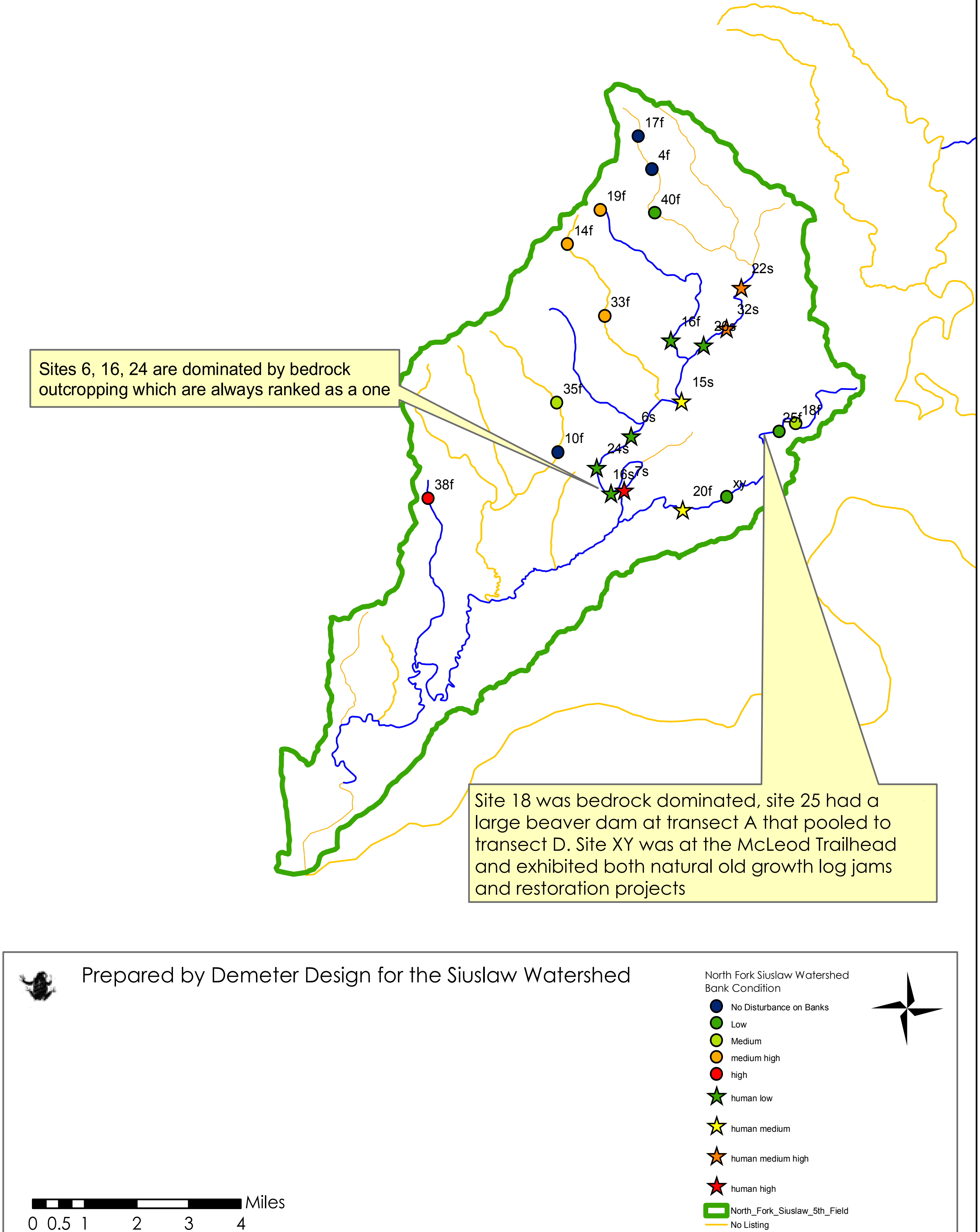
North Fork Siuslaw Watershed
Bank Condition

Final_Siuslaw_NFORK_Sites
Erosion

- ● None
- ● Lowest
- ● Low
- ● Medium
- ● Medium High
- ● High
- ○ Highest
- ▭ North_Fork_Siuslaw_5th_Field
- — No Listing
- — Listing

Miles
0 0.5 1 2 3 4

Map 6 - Bank Condition



Sites 6, 16, 24 are dominated by bedrock outcropping which are always ranked as a one

Site 18 was bedrock dominated, site 25 had a large beaver dam at transect A that pooled to transect D. Site XY was at the McLeod Trailhead and exhibited both natural old growth log jams and restoration projects

Prepared by Demeter Design for the Siuslaw Watershed

Map 7 - Alternate Measure of Bank Condition

Test 8 – Evaluate other documentation for the watershed.

This test was conducted to evaluate evidence not collected in the EMAP protocol including a USFS Watershed Analysis of the North Fork Siuslaw, a Watershed Assessment of the Siuslaw Basin including the North Fork, evidence of restoration activities, Rapid Bio-Assessment data, photographic documentation, and anecdotal evidence. This data is incorporated throughout this report. The Watershed Analysis is available upon request from the Siuslaw National Forest. From the available documentation, it appears that the USFS has targeted much of their stream restoration in areas of medium to high intrinsic potential for Coho, as seen in Maps 8 and 9 on pages 52 and 53. While this is a critical effort necessary to support the struggling Coho population, restoration of natural processes should take place concurrently in order to support the entire biotic community. The Watershed Analysis and Assessment suggest that the natural sediment storage capacity of the watershed has been altered.[1] Headwaters should be evaluated for their condition and compared to reference. Lee Benda et. al.[2] provides a useful summary of headwater processes and implications for management,

> "If forest management activities are increasing the occurrence of debris flows, then headwater streams may be transformed to a bedrock state more frequently. The reduction of wood recruitment to headwater streams due to harvesting of large trees should lead to a reduction in sediment storage. Hence headwater streams may become more of a chronic source of sediment to downstream, fish bearing systems because bedrock streams have a high transport efficiency and the lack of large wood reduces their storage capacity."

The Watershed Analysis of the North Fork Siuslaw River identified debris flows as a primary source of fine sediments. From field observations it appears that few headwater channels contain enough LWD to effectively store fine sediments, reduce peak flows, and provide for future large wood recruitment. As seen on the map following this page, there are few reported restoration projects taking place near headwater channels.

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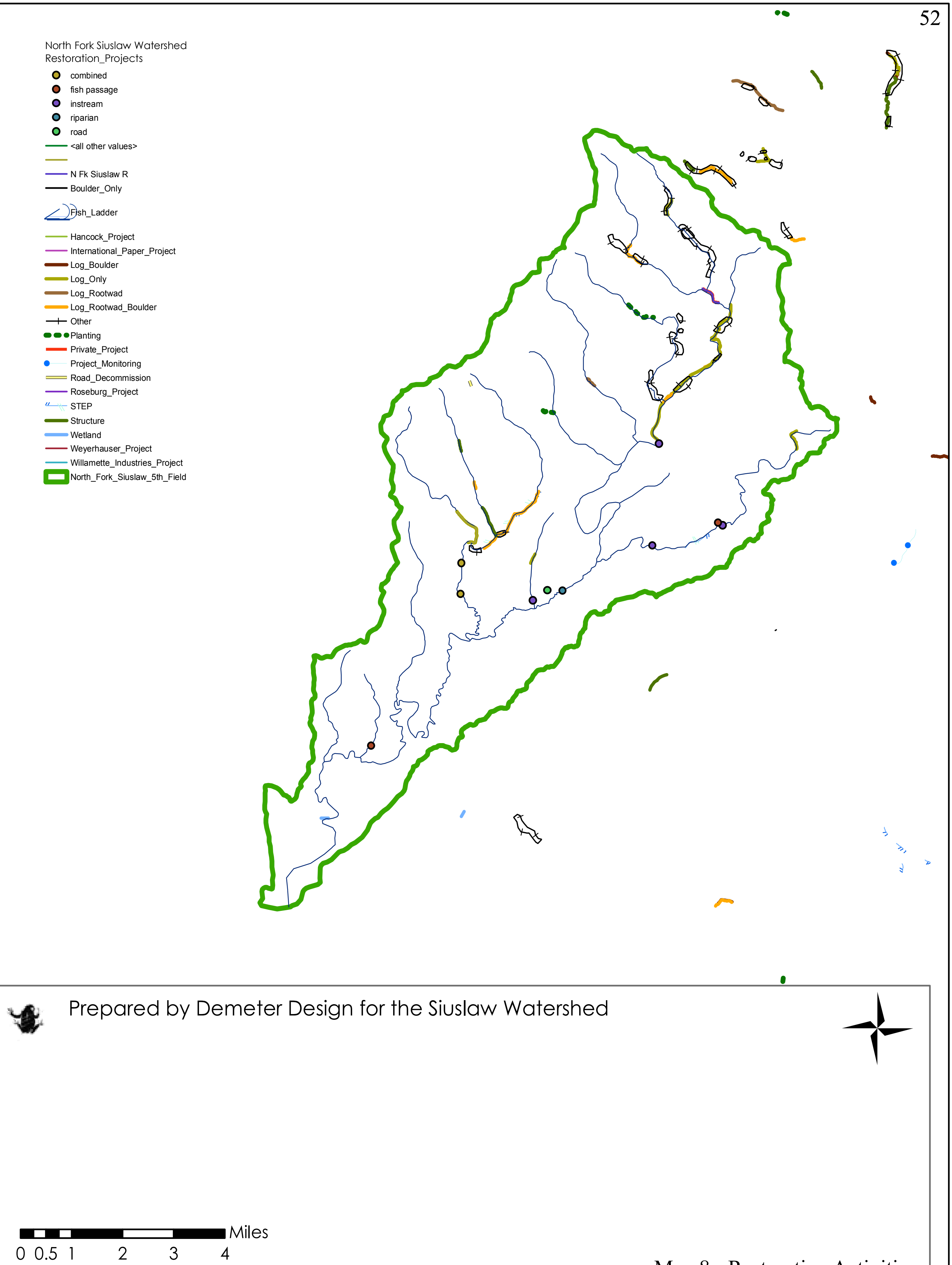
[1] Ecotrust. A Watershed Assessment for the Siuslaw Basin. 2002

[2] Benda, L. et. al. 2005



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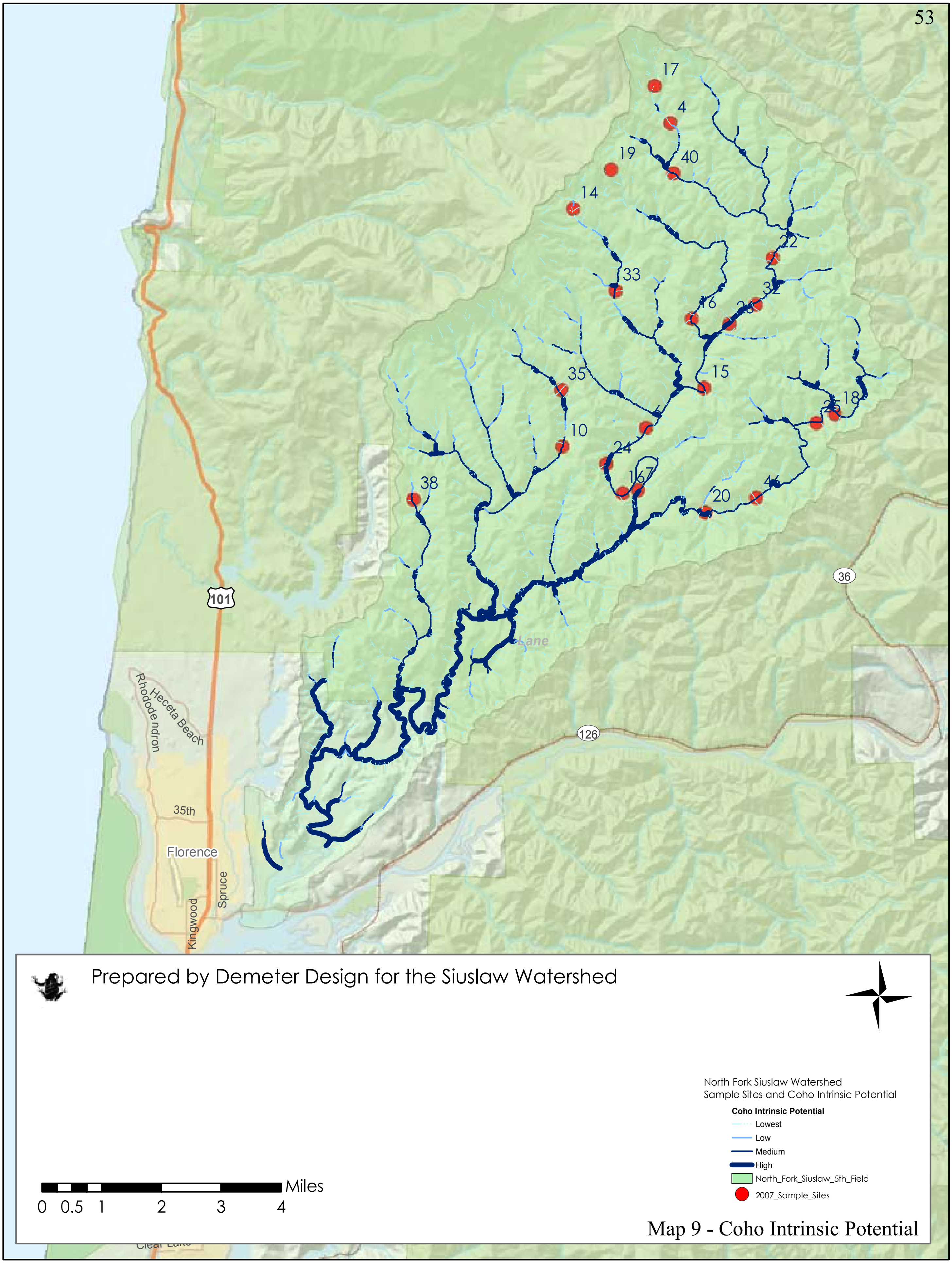
Map 8 - Restoration Activities



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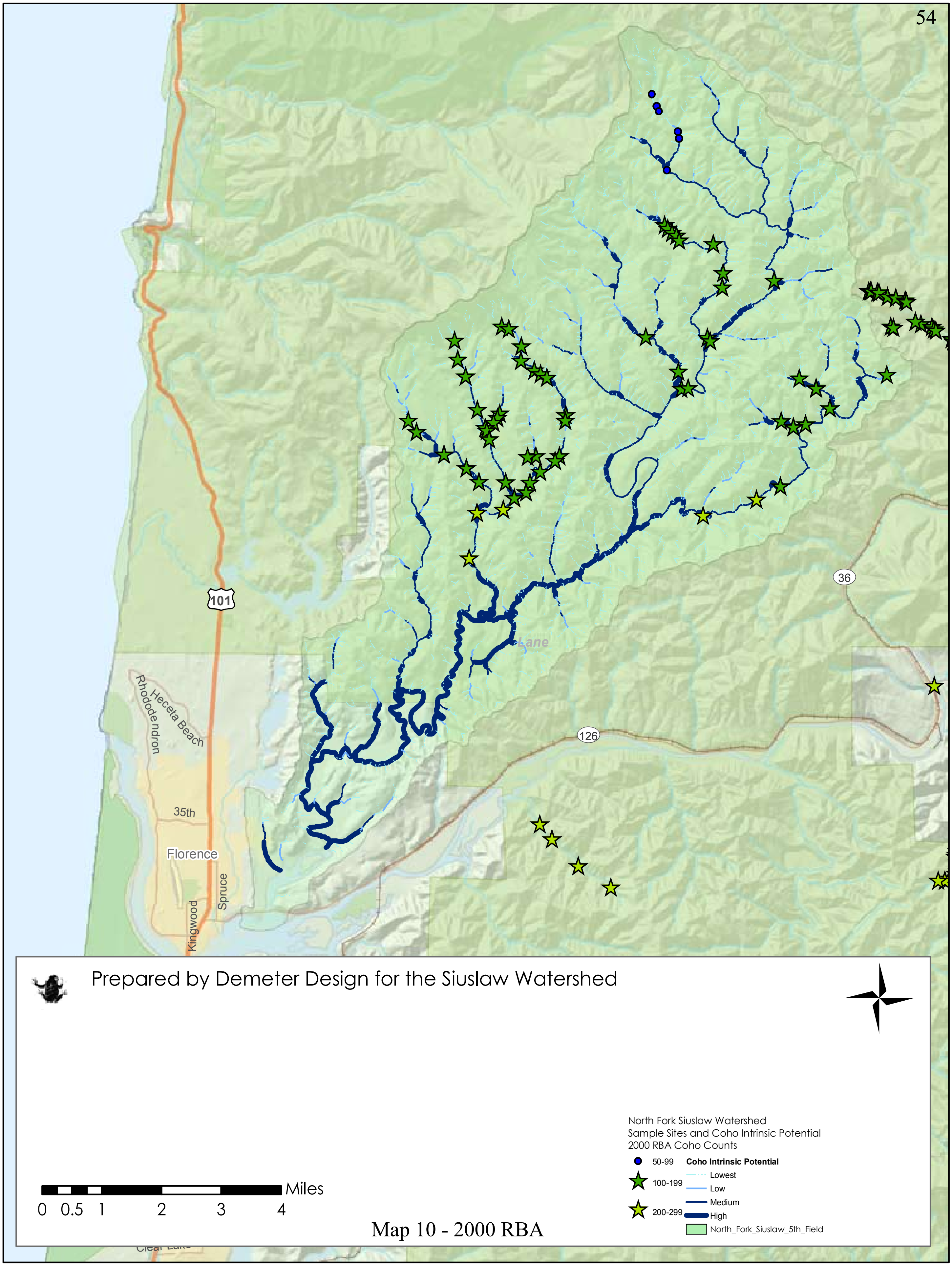
North Fork Siuslaw Watershed
Sample Sites and Coho Intrinsic Potential

Coho Intrinsic Potential

- Lowest
- Low
- Medium
- High
- 🟩 North_Fork_Siuslaw_5th_Field
- ● 2007_Sample_Sites

Map 9 - Coho Intrinsic Potential



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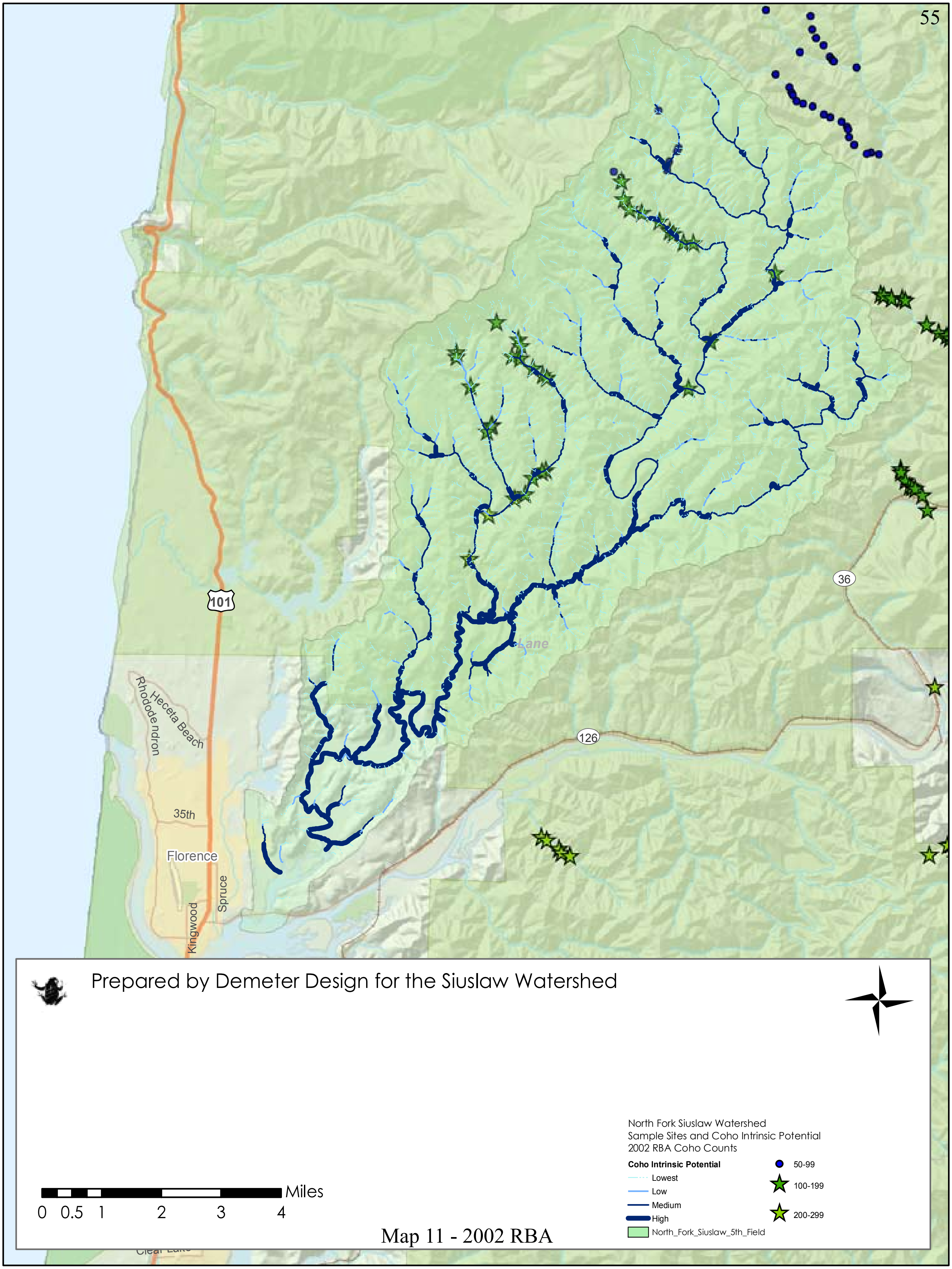
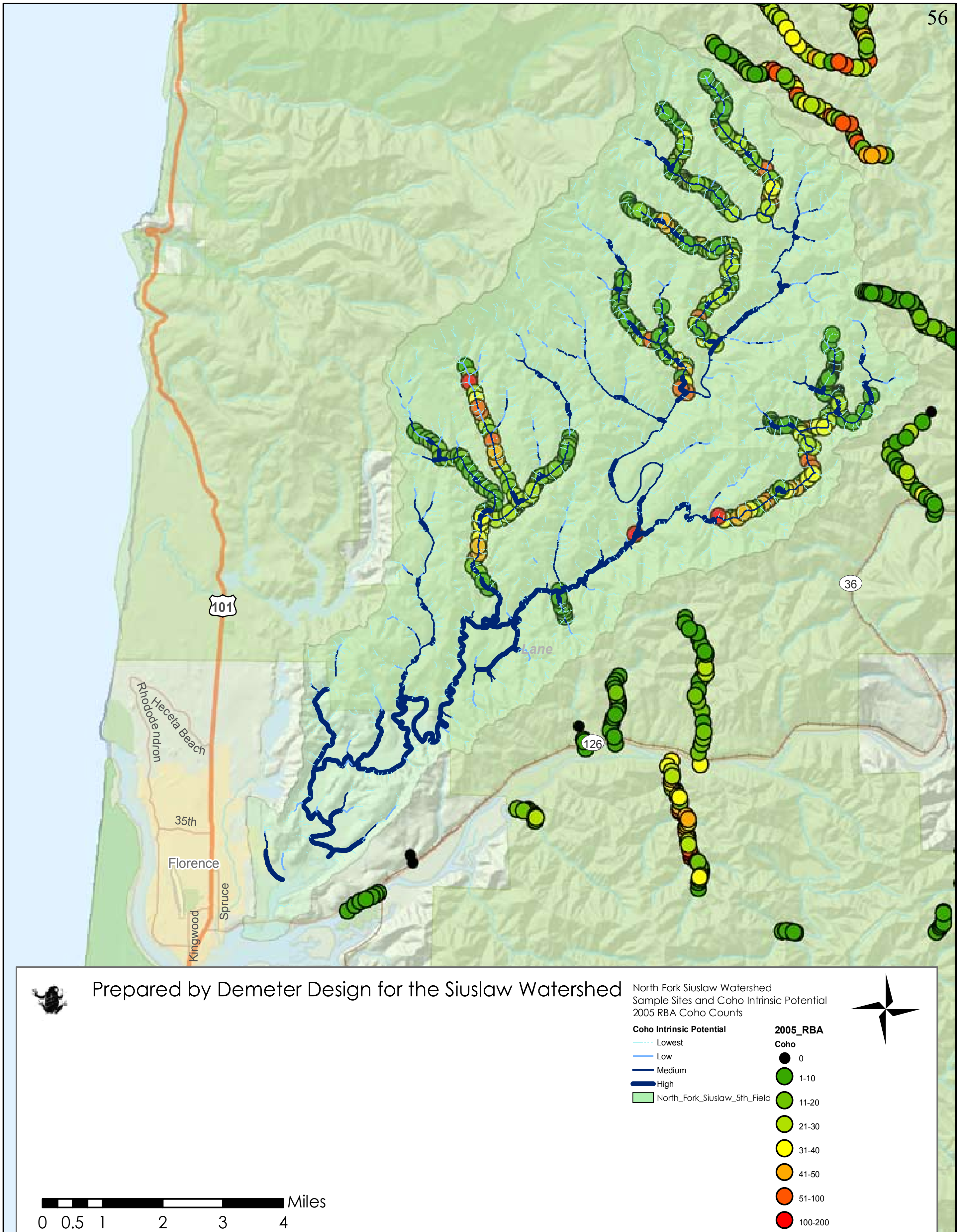
Map 10 - 2000 RBA



Map 11 - 2002 RBA



Map 12 - 2005 RBA

Embeddedness was observed throughout the study area. Photographs on page 59 are examples of the embeddedness within the NFS watershed. Increased LWD recruitment into headwaters will reduce fine sediment inputs. Novel silvicultural treatments and wood placement strategies may be needed to meet this goal. As wood volume increases in transport and depositional reaches, the increase in hydraulic roughness is expected to lead to increases in fine sediment accumulation. Restoration efforts within these transport and depositional reaches should proceed concurrently in the upper watershed in anticipation of this expected effect.

The banks of every mainstem site and two first order sites were impacted in some way by human presence, most being covered with Reed Canary Grass and many lacking shade. The photographic evidence coupled with the qualitative measures of bank condition and quantitative measures of shade suggest that riparian habitat needs to be restored. Some riparian planting projects were observed but large sections of the mainstem have little vegetation other than grasses. While fields provide important habitat for many species, the lack of quality riparian habitat is detrimental to the local aquatic and terrestrial ecosystem. To this end, the SWC is aggressively addressing shade conditions throughout the watershed through a planting program.

Discussion

The original 303(d) listing was based on the 1994 North Fork Siuslaw Watershed Analysis completed by the USFS. That document concluded that the lack of quality aquatic habitat was limiting the production of most salmonid species within the watershed.[1] Specifically the Watershed Analysis concluded probable over-fining of the stream bed, entrenchment and floodplain disconnection, a misproportioned ratio of sands to gravels, and stream channel simplification. This study validated many of these conclusions. Additionally, the Watershed Analysis concluded that the amount of complex pools and over wintering habitat was likely lacking. Although the pool volume within the NFS equal to reference levels, few side channels, backwaters, and natural log jams were observed. Pools within the mainstem NFS were rarely associated with large wood and were dominated by bedrock control points. The results of this study with respect to wood volume are generally consistent with the Watershed Analysis.

The Watershed Analysis identified both roads and timber harvesting as possible sources of sediments. Many of the roads within the system were identified as unstable and prone to future failure in the Watershed Analysis. Numerous roads encountered in this study had been closed with earth berms and/or were no longer maintained. Field observations suggest that failure of roads managed by the USFS is not a primary source of excess fine sediments to the system. This conclusion is has not been directly verified and should be considered provisional. A majority of roads within the watershed were built on ridge tops where they have minimal impacts to the stream network. However, a major road does parallel the mainstem NFS and impedes natural stream channel migration and wood delivery processes. Habitat conditions were similar throughout the watershed suggesting that instream sedimentation was not controlled by point sources such as rotational slides. Although debris torrents are considered a primary source of sediments to stream networks throughout the Coast Range, little evidence of recent debris torrents was observed in the field.

The NFS Watershed Analysis suggests that ground based disturbance may directly result in a sediment pulse which may take 20-40 years to be flushed through a system. As a major increase in timber harvests within the watershed occurred between 1960 and 1969, it is reasonable to assume that the majority, although not all, of the sediment resulting from early harvest activities should have pushed through the system by 2007. Although timber harvests still occur, harvest techniques improved after 1969 and presumably have less of an impact to the aquatic ecosystem. The stable bed conditions observed in this study may be the result of the system reaching a new equilibrium state in response to a constant but elevated sediment supply resulting from the initial disturbances. Channel widening as seen in this study is a common response to increased sediment supply.[2] By spreading the stream power over a larger area, total sediment transport is maximized and bed stability is increased. Under this scenario it is possible to have a stream channel with a stable bed but an excess of fine sediments. It is hypothesized that the cumulative effects of a severe burn in the 19th century, widespread ground based disturbance, historic road construction practices, and active wood removal has disrupted natural processes of sediment input, storage, and delivery. The end result is an excess of fine sediments throughout the watershed concurrent with a stable bed.

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[1] Karnes et. al. 1994.

[2] e.g. Harvey 2006

Sedimentation

The results of the tests used to judge impairment suggest moderate impairment by sedimentation and severe impairment due to habitat alteration. Roughly 32% of the stream network surveyed within the NFS exceeded benchmarks for impairment based on the distribution of reference data. Furthermore, the average %SAFN was ~50% greater than the reference mean. The expected relationship between sand and bedrock was not observed in the NFS, suggesting a breakdown of natural sediment sorting properties. Finally, the distribution of %SAFN scores within the NFS was highly skewed to the right relative to reference data. In a healthy watershed, the expectation is for a wide diversity of habitat types to be present. In contrast, %SAFN values were similar throughout the NFS. This suggests a lack of complex habitat necessary to support a healthy aquatic ecosystem. This is consistent with field observations indicating a lack of complex pools and well sorted spawning gravels.

While the quality of physical habitat was generally lower throughout the mainstem, a greater quantity and proportion of the first order streams exceeded the 25th percentile for %SAFN. Despite this result, field observations suggest that the substrate within most first order streams was better sorted than second order streams. High levels of embeddedness were observed throughout the mainstem, and in some places there was a layer of sand on top of bed rock from 1-100+ cm thick. This is illustrated in the photos below. What was most striking was the location of sands. Although %SAFN within the NFS greatly exceeded the average for the coastal reference data, the RBS scores indicated significant armoring in the second order streams. RBS scores for the tributaries are similar to reference conditions but the amount of wood is low relative to reference and W:D is elevated. As previously mentioned lack of LWD increases stream competence and disrupts natural sediment sorting processes.

Although very stable, the mainstem NFS still contained high levels of fine sediments. Because of the extreme habitat modification as indicated by the lack of LWD, degraded vegetation, and large width to depth ratios, it is difficult to conclusively determine the presence and extent of sediment impairment. The high stability is driven by the very low gradients within the mainstem. Geomorphologically, the mainstem is a depositional reach and is expected to have high levels of fine sediments. However as mentioned field observations suggest that poor sorting and embeddedness are pervasive throughout the mainstem. For these reasons and the high levels of fine sediments found in its tributaries, a conservative determination of impairment is warranted for the mainstem. As habitat conditions improve, it is recommended that additional data be collected to reevaluate this determination. Finally, long term alterations in sediment supply may induce alterations in channel morphology which result in stable beds that nonetheless contain an excess of fines.

The results of this study suggest that the stream network is still impaired by fine sediments. This finding is based on the above average %SAFN, the percentage of sites within the NFS that exceeded the 25th percentile benchmark, and the concurrent lack of complex habitat. These findings clearly indicate that sedimentation remains a serious concern within the watershed. Multiple salmonid (e.g. Coho, Chum, Steelhead) species utilize the stream network for spawning in the areas surveyed. The high levels of fine sediment throughout the NFS may have significant deleterious impacts on salmonid abundance. Assuming a conservative approach to protecting natural resources, the existing 303(d) listing appears to be valid. These findings are based on the data collected in this study and are subject to re-evaluation if additional data is collected.

The findings of this study suggest that fine sediments are still be entering the system as a result of alterations caused by historical disturbance. This study did not directly evaluate source and this conclusion should be considered a hypothesis. As federal practices prohibit timber harvest over any stream channel, it is unlikely that the primary source of these excess sediments is coming from USFS timber harvest[1]. This conclusion was not directly evaluated in this study and remains also provisional. It is a possibility that private timber operations, which are not required buffer strip on non-fish bearing streams including ephemeral, intermittent, and perennial streams, are one source of excess sediments. Private timber lands were not directly evaluated in this study due to access limitations and any conclusions regarding their impact to the stream network remain provisional. It is hypothesized that current instream conditions are most likely a response to past land management practices and the resulting habitat modification. Although access was not granted to a significant portion of the study area, it is unlikely that the conclusions of this study were adversely affected. In general, protective measures are greater on federal lands than on private lands. For that reason, the results presented in this report should be considered a 'best case scenario'. Field observations indicate that clear-cutting is a common harvest method on private timber lands. Given the finding of sediment impairment on lands predominantly owned by the USFS it is likely that private lands also suffer from fine sediment impairment. The conclusions of this study are explicitly based on the assumption that the protection of natural resources is of paramount importance. In general, the authors recommend erring on the side of caution when evaluating water quality impairment.

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[1] Benda et. al. 2005

In-stream Physical Habitat

Physical habitat was impacted throughout the NFS. The W:D ratio was much greater than reference, and wood volume and canopy cover was below reference. In many places, lack of LWD increased channel competence resulting in channel scour. This altered the bedform complexity and prevented the channels from connecting to its floodplain which led in turn to an increased W:D. This effectively decreased the bankfull height thus decreasing channel competence and increasing stability. This is particularly evident in the mainstem where the LRBS score indicated significant armoring. It is hypothesized that these impacts were caused primarily by past land management practices and are exacerbated in some areas by current practices. Portions of the NFS were splash dammed, no riparian buffer was left along many streams, wood was actively removed from the channel, ground based logging compacted soils and disturbed headwater channels, and bank vegetation was degraded by stream-side grazing. Downcutting and bank instability are pervasive throughout the lower watershed. Pool volume within first order streams was not significantly different from reference while the pool volume within the mainstem was almost two times greater than reference. However field observations of the mainstem indicated that there was little complex pool habitat (i.e. pools associated with instream wood, undercut banks, and overhanging riparian vegetation) within this portion of the stream network. Pools within the mainstem were commonly formed by bedrock control points rather than natural woody debris, resulting in extremely large but infrequent pools. In other words, although pool volume was very high, the diversity of habitat within the mainstem was relatively low.

Large wood appeared to be a major factor influencing both habitat function and sediment dynamics within the NFS watershed. In ephemeral headwater channels, lack of woody debris is critical to regulating sediment storage and input.[1] Although wood volume in headwater channels was not directly measured, numerous were observed while accessing the survey sites. Of the headwater channels observed, few met the criteria for minimal anthropogenic disturbance. It is hypothesized that lack of wood in these channels has disrupted natural processes of sediment storage and input. Furthermore, all the placed wood observed was located outside of the headwaters and did not effectively reduce the overall input of sediments into the stream network. Although this placement strategy is consistent with standard restoration design protocols aimed at restoring complex habitat for over wintering of salmonids, it may not be sufficient to restore natural sediment dynamics to the watershed. Of the wood that was observed in first and second order streams, a large percentage was placed by the USFS. Although all structures appeared to meet standard wood placement guidelines, the wood used generally lacked branches or rootwads, and was often placed above of the active stream channel thus reducing its impact on channel morphology and sediment transport. Although wood placed above the active channel may catch incoming debris, past disturbances have significantly decreased recruitment potential throughout the watershed. Furthermore, the need for the effect of large wood on the channel are immediate. It is recommended that instream structures be surveyed to evaluate their effectiveness. Structure designs that appear to have a positive effect should be applied broadly. Additionally, wood placement in the upper stream reaches should be included as an alternative when planning restoration projects. Wood placement within headwater reaches will act to trap sediments and act as a future supply of large wood. The Watershed Analysis identified areas that are prone to debris torrents as well as source reaches that empty directly into depositional reaches. Finally, targeted silvicultural treatments may be an effective strategy for increasing wood density adjacent to headwater drainages.

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[1] Benda et. al. 2005.

Conclusions

The results of this study suggest that excess sedimentation is one component of widespread aquatic and riparian habitat degradation throughout the NFS watershed. Field observations and quantitative data indicate that excess sedimentation is one component of more general habitat degradation. In other words, the primary cause of impairment within the watershed is not sedimentation but the lack of habitat complexity. To facilitate improvement of instream habitat conditions, it is recommended that a TMDL be developed which focuses on restoring natural channel processes. Many of the metrics evaluated did not meet reference standards. Existing regulations governing private forestry and agriculture do not include the stringent protective measures required under federal legislation and it is unlikely that all private land owners with stream frontage will voluntarily set aside a riparian corridor. The USFS as the dominant land manager within the watershed has worked aggressively for many years to improve conditions throughout lands under their management. By continuing and expanding on these efforts it may be possible to mitigate some of the effects of past practices and current regulations. However a comprehensive solution will be possible through extensive outreach and education efforts aimed at securing cooperation from private land owners throughout the basin. It is recommended that instream habitat be used as a primary surrogate for sedimentation. By characterizing the wood volume, width to depth ratio, riparian vegetation, and instream sediment metric within functioning habitat, it will be possible to set quantitative targets for the NFS. Additionally, conditions within headwater drainages require explicit evaluation and consideration. Finally explicit identification of best management practices (BMPs) aimed at reducing sediment inputs and preventing habitat modification should be included as a component of the TMDL development process.

Recommendations

To address sediment impacts, wood placement and riparian planting is recommended throughout the watershed, including headwater channels. It is hypothesized that this will reduce the overall sediment input from these supply reaches and increase the potential for future large wood recruitment. In addition to placing new wood it is recommended that instream structures which are not directly influencing channel morphology, sediment sorting, and floodplain connectivity be reconfigured. Wood placed above the active channel does not capture new wood or trap and sort sediments as wood placed inside the stream channel. It is recommended that trees with rootwads be widely incorporated into future instream projects. Finally, to reduce active erosion, improve cover, and decrease solar input, a rigorous planting regime is recommended on both USFS and private lands. While active erosion was more common on the banks of agricultural fields and pastures, it was also observed that the banks of many lower gradient USFS managed streams were heavily impacted by Reed Canary Grass and other invasive weeds. Plantings throughout the watershed and an outreach program that works with local landowners to fence and plant riparian zones as well as LWD placement to increase channel migration are recommended. Finally, the development of reference standards for wood volume in headwater channels is recommended. Headwater reaches compose the majority of the stream network by length, and exert a strong influence on sediment dynamics. The influence of headwaters on larger stream channels need to be considered when developing and implementing restoration plans. These recommendations are generally consistent with ongoing restoration efforts in the NFS by the SWC, the USFS, and others. Aggressive continuation and expansion of these efforts are critical to restoring functional aquatic habitat within the basin. Future water quality planning and restoration efforts should closely support efforts already underway by the USFS, SWC, and partners.

Summary of Recommendations

- Develop a TMDL which focuses on restoring natural channel processes
- Increase wood volume throughout the watershed (including headwater channels) to help trap sediments
- Heavily plant the most disturbed banks and riparian areas
- Work with private landowners to set aside a wider riparian area through fencing and/or acquisition
- Develop reference conditions for headwater streams
- Evaluate alternative benchmarks for wood volume
- Utilize the TMDL process to support ongoing restoration activities by the USFS, SWC, and partners

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Appendix A

Bank Condition Assessment

Bank condition was assessed visually by classifying active erosion into one of 5 categories; on a scale of one to five with one representing no active erosion and 5 representing complete active erosion. At each transect, both the left and the right banks were classified individually using this scale. Bedrock was always scored as a 1A_2 or 1B_2 and landslides were always scored as a 5A or 5B. This guide depicts photographic representations of 1, 2, 3, 4, and 5 type banks. Additionally, banks can also be classed as either an A or B where A represents sites with minimal human presence and B represents human activity on the bank. Human presence is defined as the presence of a road, agriculture, a dwelling, recreation, or non-native vegetation.

This is an example of a 1A. At this point, there is no sign of active erosion or human presence. This photograph was taken in the NFS.

This is an example of a 1A_2. At this point, there is no sign of active erosion or human presence but the stability is driven by the bedrock outcropping. This photograph was taken in the NFS.

This is an example of a 1B. At this point, there is no sign of active erosion but strong human presence, Himalayan Blackberries and Reed Canary Grass on the bank of a private residence. This photograph was taken in the NFS.

This is an example of a 2A. At this point, there is little sign of active erosion and no human presence. While not visible in this photograph, the erosion is occurring behind the overhanging vegetation. This photograph was taken in the NFS.

This is an example of a 2B. At this point, there is little sign of active erosion with human presence with Reed Canary Grass on the bank of an unused pasture. This photograph was taken in the NFS.

This is an example of a 3A. At this point, there is clear evidence of active erosion and no human presence. This photograph was taken in the Wilson River Basin in Tillamook Oregon.

This is an example of a 3B. At this point, there is clear evidence of active erosion with human presence. While not visible in this photograph, the erosion is occurring behind the overhanging Himalayan Blackberry. This photograph was taken in the NFS.

This is an example of a 4A. At this point, active erosion is nearly taking place on the entire bank. There is little vegetation and the presence of Salmon Berry which correlates strongly with disturbance. There is no human presence. This photograph was taken in the NFS.

This is an example of a 4B. At this point, active erosion is nearly 100% of the bank with human presence. This photograph was taken next to a bridge in the Tillamook River basin in Tillamook Oregon.

This is an example of a 5A. At this point, there active erosion is complete with minimal human presence. It is important to note that 5A sites are much less common than 5B sites. This channel was a confined bedrock chute along HWY 6. The road is greater than 30 vertical meters from the channel but less than 30 horizontal meters away. This landslide is not directly caused by the presence of a road. This photograph was taken in the Wilson River Basin in Tillamook, Oregon.

This is an example of a 5B. At this point, active erosion is complete with human presence. This pasture was being actively grazed at the time this photograph was taken. There was no clear cattle exclusion. This photograph was taken in the NFS.

Appendix B

Indian Creek

Of the seven 303(d) listings within the Siuslaw River Watershed, six are within the North Fork 5th Field, and one (Taylor Creek) is within the adjacent Indian Creek 5th Field. Taylor Creek is a roughly 3 mile stream segment listed independently of the remaining watershed. The initial study plan was to include Taylor Creek within the same panel of sites as the North Fork. Three sites from the Master Sample located on Taylor Creek were identified for sampling. These three sites represent all of the available Master Sample sites on Taylor Creek. Two sites (the upper two) were on USFS land with the lower site on private property. Under this plan, no independent determination of impairment would have been possible for Taylor Creek. EMAP data is most appropriately used at a population rather than a single site scale. The two or three sites available on Taylor Creek would not have provided the necessary statistical power to evaluate sediment and habitat impairment. A census would have been necessary, which was outside the scope of the project for 2007.

Operational constraints also played a role in the decision to postpone sampling in Taylor Creek. During 2007, permission was not granted to access the private site, or to pass through the stream channel to access the upper sites. Road access to the upper Taylor Creek basin is limited, making access impossible within the logistical constraints of the 2007 field work. Additionally, time constraints had reduced the total scope of field work during the 2007 field season from 30 sites to 22. For these reasons, a decision was made by the SWC following consultation with Demeter Design to postpone sampling in Indian Creek and apply those sites to the North Fork Population. Based on similar patterns of land use and ownership, the existing 303(d) listing, and clear similarities in channel morphology in the lower watershed, a new plan was formulated to address the Indian Creek Watershed as a whole in a subsequent field season with a separate 30 site sample. This strategy of evaluating impairment at a watershed scale is consistent with the existing Siuslaw Sediment Sampling Plan and ongoing discussions with the ODEQ.