

Appendix A – Reference Site Selection & Uses

Reference Site Selection and Use

Though the concept of reference condition applies to all waters, to date in Oregon reference sites have only been systematically identified and sampled for wadeable streams. Wadeable streams are typically 1st through 3rd or 4th order streams (Strahler stream order), which represent 84 to 92 percent of total stream miles in the state. To date DEQ has identified and sampled about 250 reference sites on wadeable streams statewide, of which 60 are in the Coastal Coho ESU and 29 fall within the distribution of coastal coho as defined by the Oregon Department of Fish and Wildlife (Table 1). Reference sites and random sites are sampled for the same set of parameters (physical, chemical and biological) using the same set of protocols.

Oregon DEQ has defined a process for finding and selecting reference sites that includes evaluating GIS information about human activities, feedback and input from local land managers and land owners, and on-site reconnaissance and evaluation. Following site reconnaissance a Human Disturbance Index (HDI) score, based on 34 human disturbance categories, is calculated. Natural disturbance due to fire, floods, or slides etc., is not considered in the evaluation of potential reference sites. Based on the HDI results a site is classified as a high (A), medium (B), or low (C) quality reference site, or a non-reference site (Drake 2004). "C" reference sites are only sampled when necessary because there are too few "A" or "B" reference sites within a particular region or basin. "A" and "B" reference sites can be thought of as representing "minimally disturbed conditions," and "C" reference sites as representing "least disturbed conditions" (Stoddard et al. in press). Within the coho distribution of the Coastal Coho ESU all but one reference site was a "C" reference site. This points out that the level of human activity is relatively high in the area used by coho.

For reference sites to be effective they should be representative of the range of stream types and natural landscape conditions found within the region they are used. Figures 1 - 4 compare natural landscape conditions at random and reference sites within the ESU for sites within the distribution of coho. These figures show that the range of natural landscape conditions (gradient, watershed area, elevation, and seral stage) at reference sites within the ESU is similar to random sites in the ESU. Even when compared across different land use classes there is considerable overlap between landscape characteristics at the reference sites compared to the random sites (Table 2). As a result the reference site data can be compared with the results from the random sites.

Use of reference site data

Data from reference sites provide several important functions. First, reference site data are used to develop biological indices and check that indices account for natural gradients across the landscape (e.g. geology, elevation, stream size), but are still sensitive to anthropogenic disturbances. Two biological indices are used by DEQ to assess biological condition. For fish and amphibian assemblages an Index of Biotic Integrity (IBI), a

multi-metric index, was developed by Hughes et al. 2004. A multivariate assessment model following the methods of Hawkins was used for macroinvertebrates (Hawkins 2000).

Second, for parameters that have established numeric water quality standards (e.g. temperature and dissolved oxygen), the standards provide a benchmark against which site conditions can be evaluated. For parameters without numeric standards (e.g. nutrients, fine sediment and biological indices), the results from reference sites provide a benchmark or baseline for site evaluations (Karr and Chu 1999). Because many biological, physical habitat and chemical parameters have no formal standards, this is an important tool for site assessments. Even for parameters with established standards, the results from reference sites provide a context for comparison to non-reference sites.

Finally, the condition at reference sites provides a point of comparison that is important in assessing changes in stream conditions due to restoration, land management actions and/or regulatory programs. In this sense reference sites act like “control sites” normally used in laboratory experiments. This can be particularly useful in detecting shifts due to natural factors, such as annual droughts or floods, versus human factors. For example a downward trend in water quality might be due to an increase in human caused disturbance or due to natural factors like low stream flows during droughts. If results from reference sites show a similar decline in water quality as non-reference sites then human factors are not likely the cause. Likewise improving water quality trends can be compared to trends at reference sites, which will help determine if the improvement is the result of restoration and management actions or a period of more favorable natural conditions.

Limitations of reference site results

Even though reference site results can be compared with random site results, there are limitations to the reference site data set. First, not all reference sites represent sites with minimal human disturbance. Reference sites are needed across the full range of landscape characteristics, but some areas within the landscape are more heavily influenced by human activity than other areas. Low elevation and low gradient areas, for example, are typically the same areas most intensively used by people for farming or housing. As a result it is difficult to find reference sites with minimal human activity in such areas. When the majority of reference sites fall into class “C,” the reference condition in those areas is based on streams with higher levels of human disturbance than in areas with a majority of “A” and “B” reference sites.

Table 1. Number of unique reference sites per reference site class across monitoring areas and land uses within coho distribution area streams.

Monitoring Area/Land Use	# of "A" Ref Sites	# of "B" Ref Sites	# of "C" Ref Sites	Total
ESU	1		28	29
North Coast			9	9
Mid Coast	1		7	8
Mid-South Coast			5	5
Umpqua			7	7
State Forested			6	6
Federal Forested	1		8	9
Private Industrial Forest			12	12
Private Non-Industrial Forest			1	1
Agriculture			1	1
Urban				0

Another limitation of reference site data is a result of sample size. While the range of natural landscape conditions at reference sites is similar to the range at random sites, the actual number of reference sites that represent certain classes of streams can be small (Table 2). This makes a comparison of reference site data to some finer levels of landscape classification (e.g. some land uses) problematic. Three to five reference sites have been suggested as a minimum to assess a particular waterbody class in a homogenous region (Davis et al. 1995). As a result reference site data for the ESU have limited application in characterizing conditions for urban land uses (Table 2).

Table 2. Number of reference sites within the range of landscape characteristics found across different land uses.

Primary Land Use	# Random Sites	Site Elevation Range (feet)	Site Gradient Range (%)	Basin Area Range(hectares)	Mean Basin Seral Stage (inches dbh)	# Reference Sites in Same Range
Agriculture	17	21 to 1,842	0.2 to 6.5	443 to 11,107	4 to 21	12
Federal Forested	29	79 to 2,193	0.2 to 17.4	66 to 34,582	10 to 30	16
Private Industrial Forested	44	14 to 1,838	0.1 to 11.1	9 to 41,042	4 to 33	19
Private Non Industrial Forested	18	21 to 1,153	0.1 to 4.3	506 to 15,819	6 to 22	10
State Forested	16	134 to 1,308	0.4 to 17.0	43 to 10,608	3 to 20	10
Urban	5	40 to 742	0.5 to 4.0	220 to 15,976	6 to 14	5

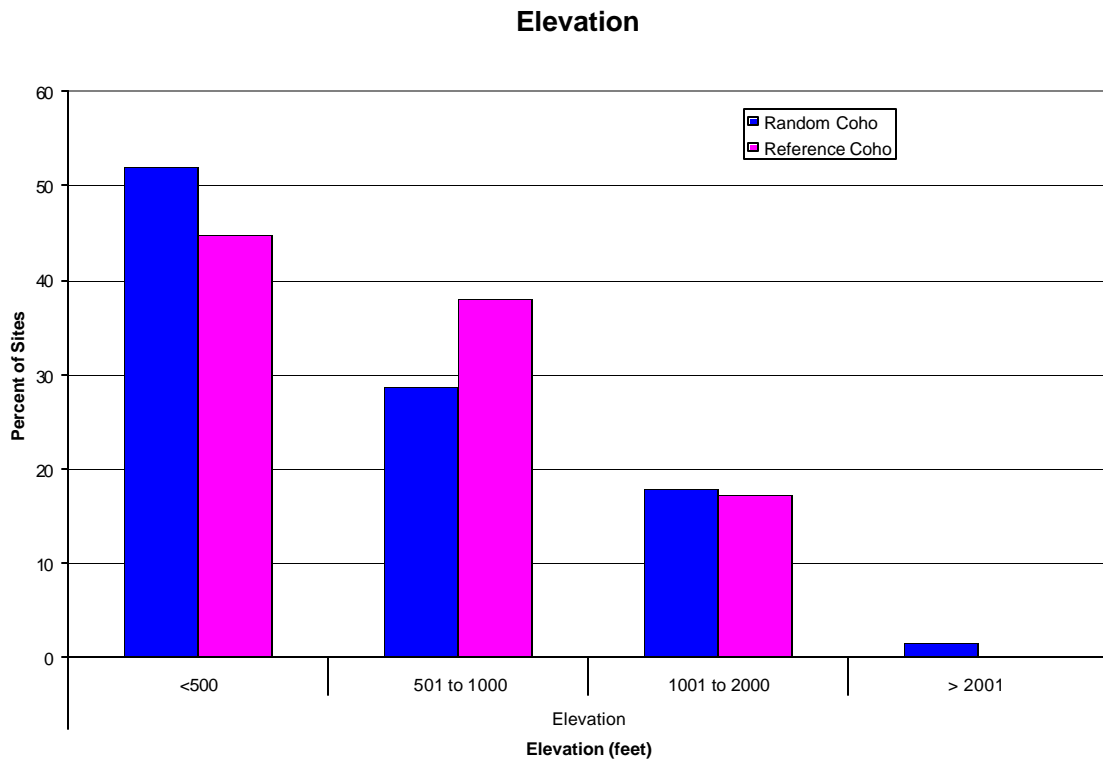


Figure 1. Reference & Random site comparison for elevation.

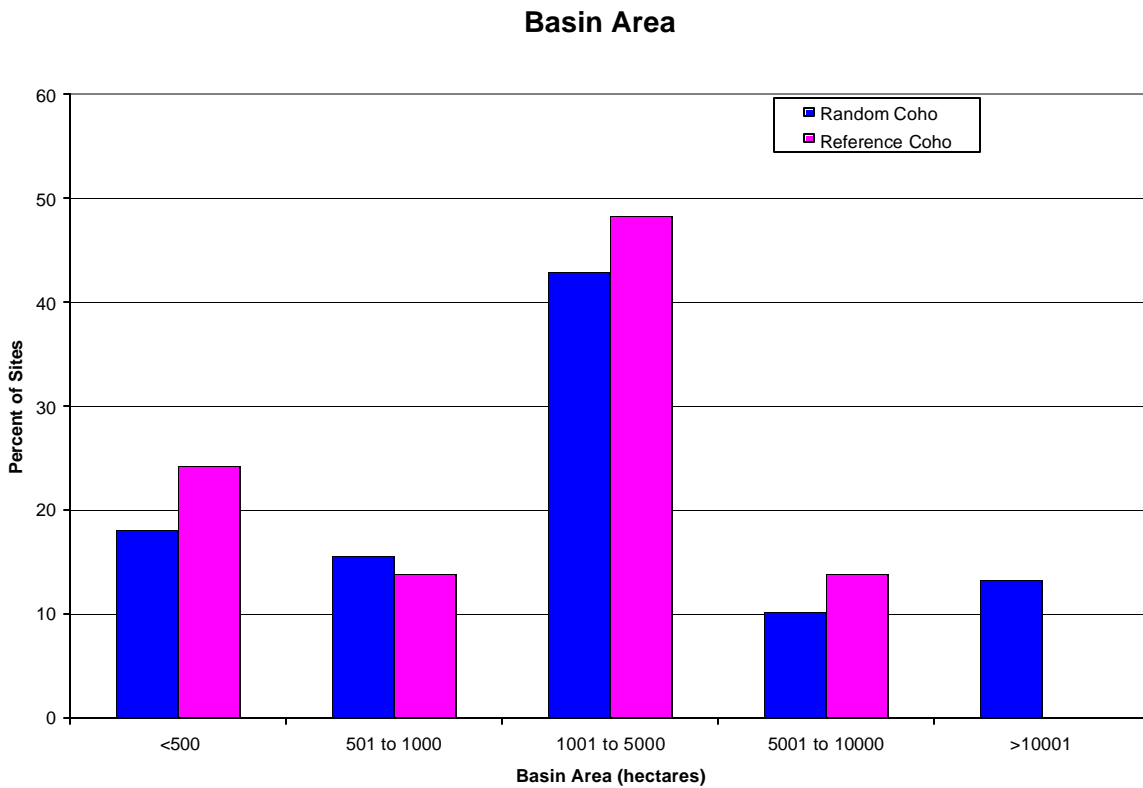


Figure 2. Reference & Random site comparison for basin area.

Channel Gradient

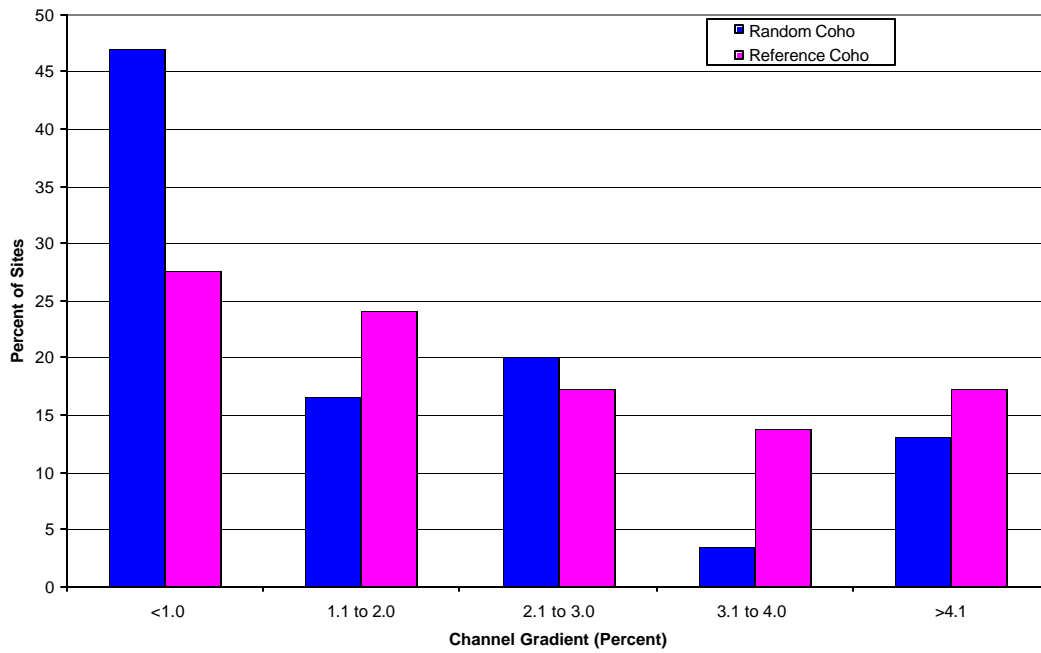


Figure 3. Reference & Random site comparison for channel gradient.

Seral Stage

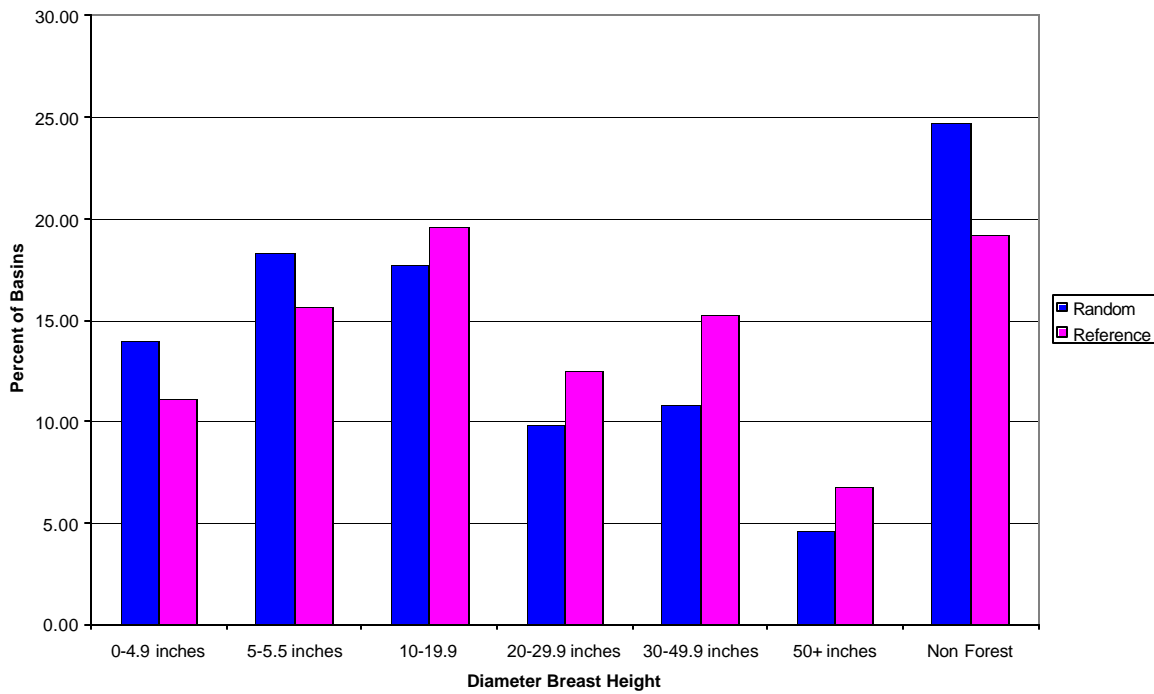


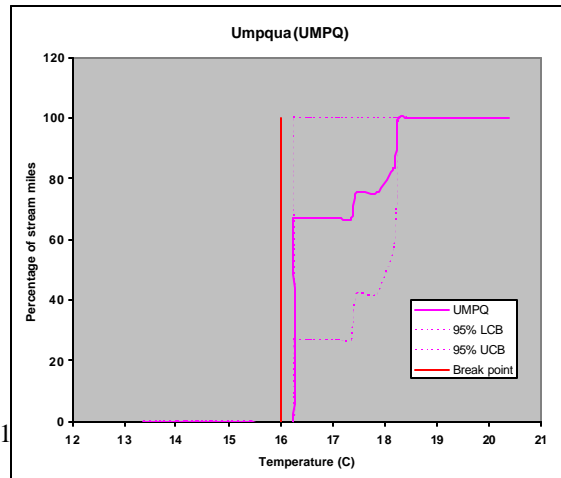
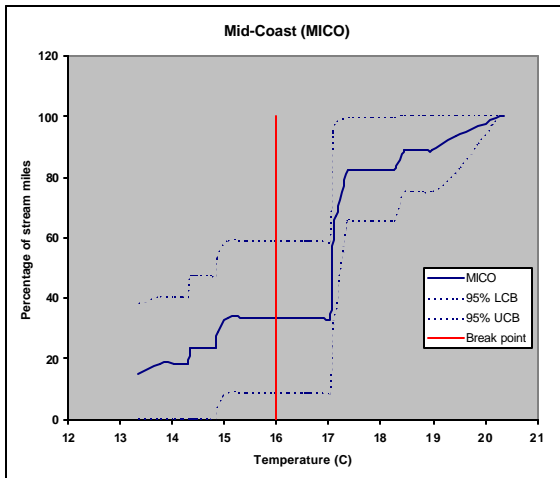
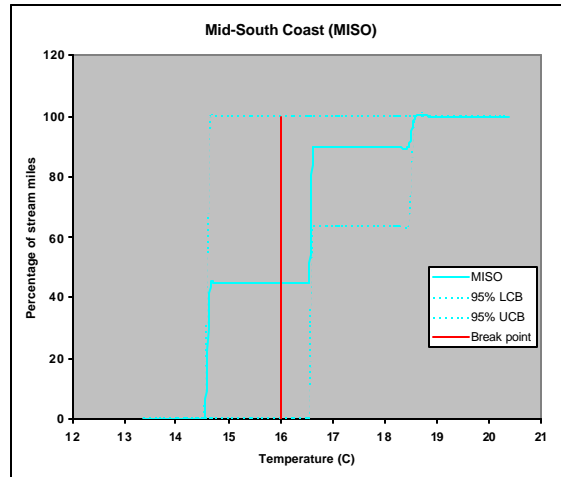
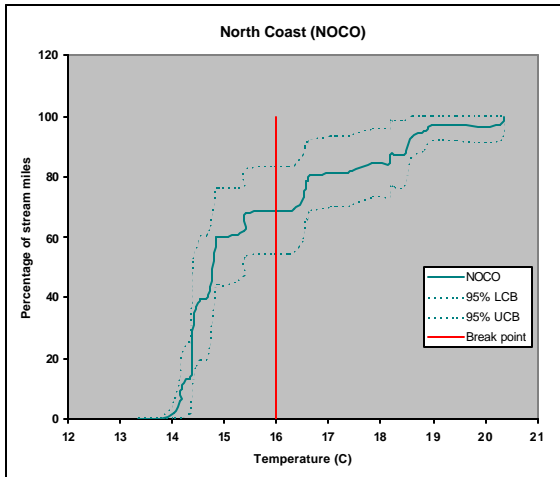
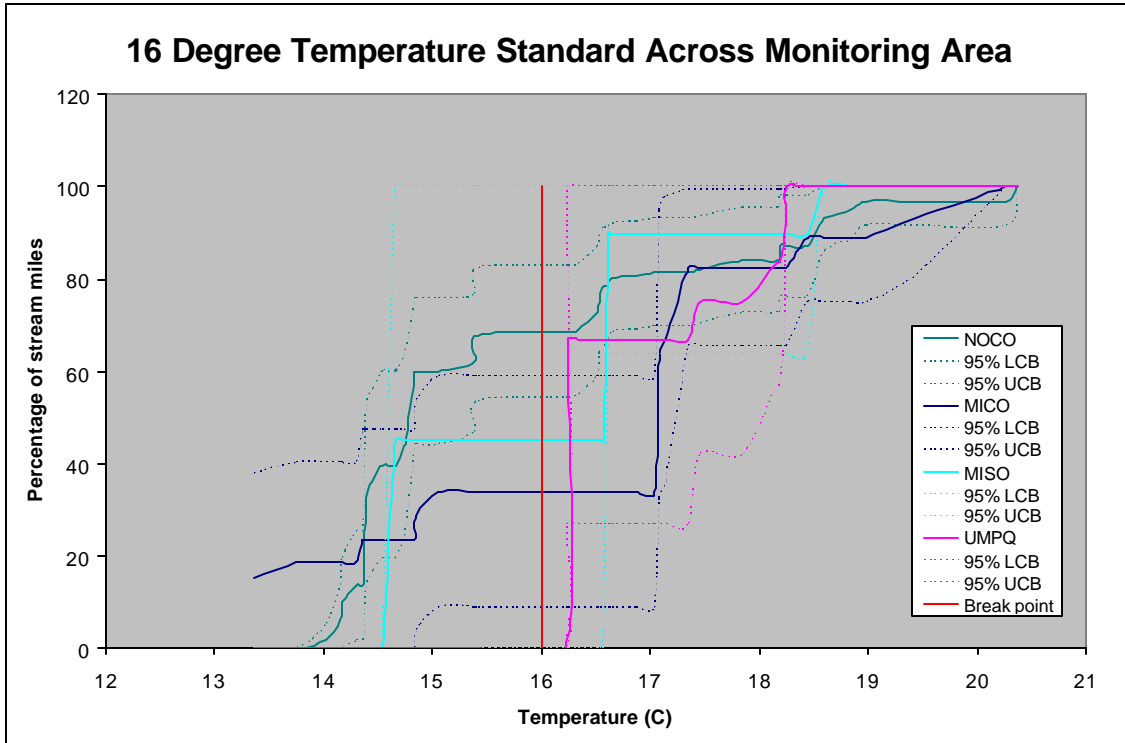
Figure 4. Reference & Random site comparison for seral stage.

References

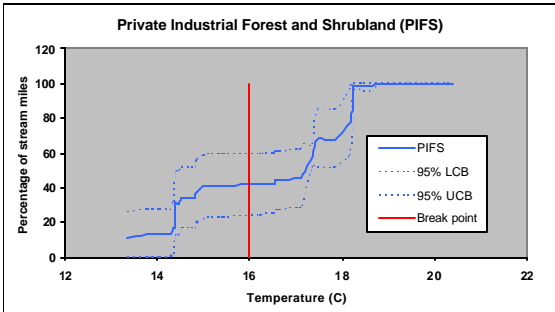
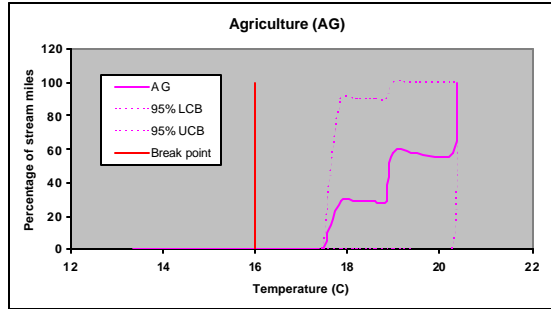
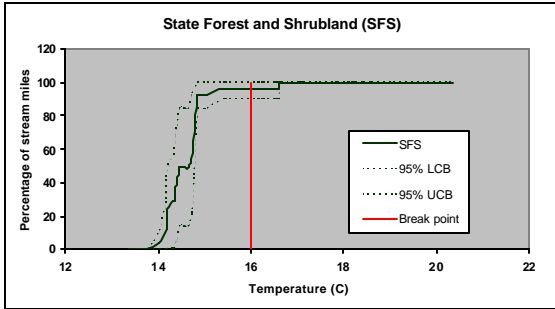
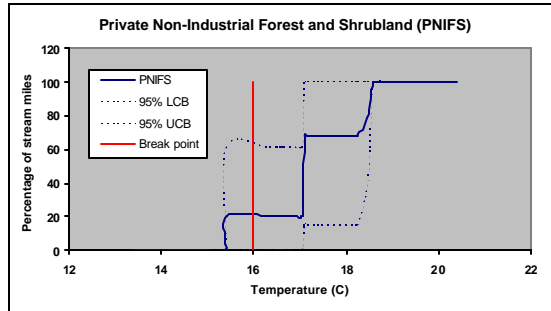
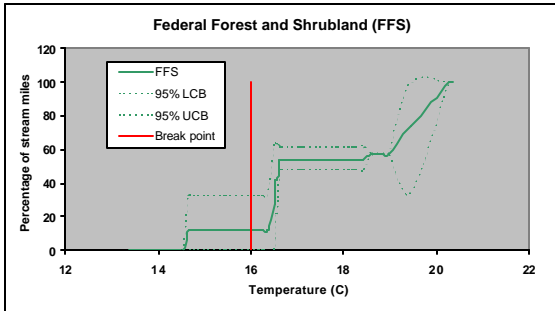
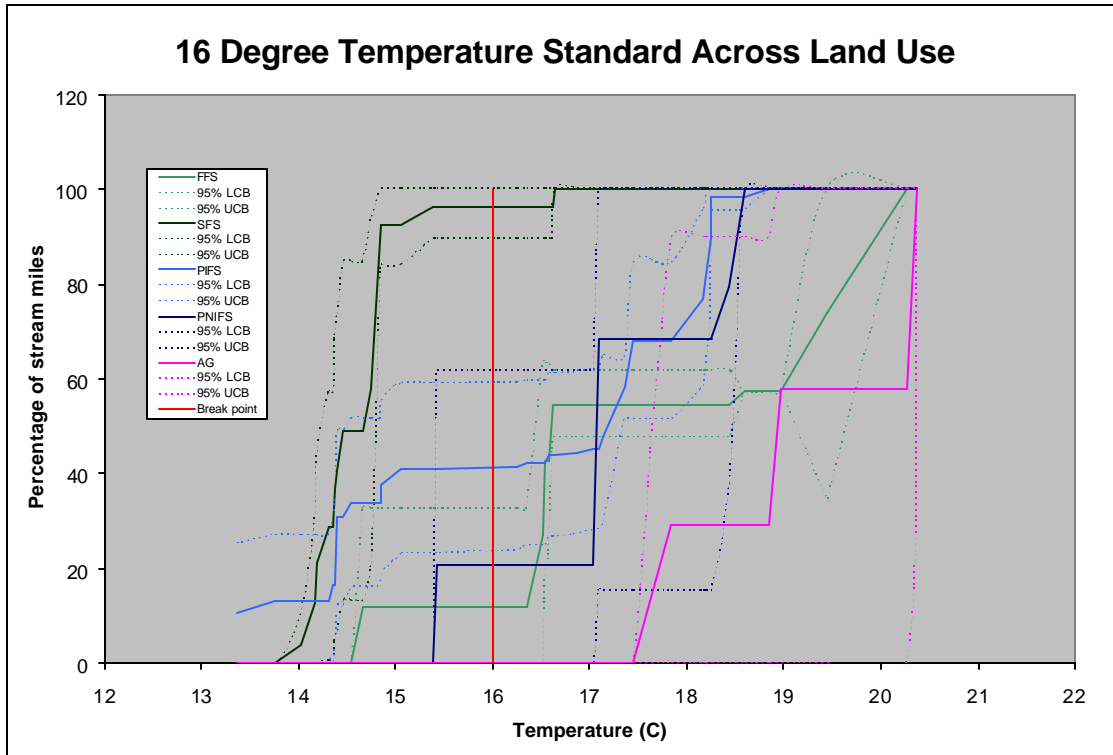
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Appendix B – CDF Graphs

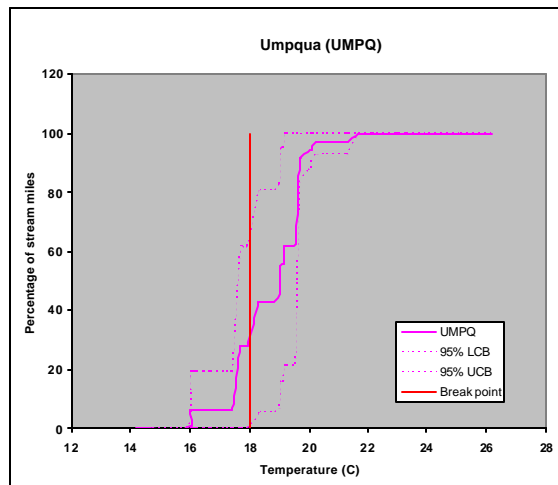
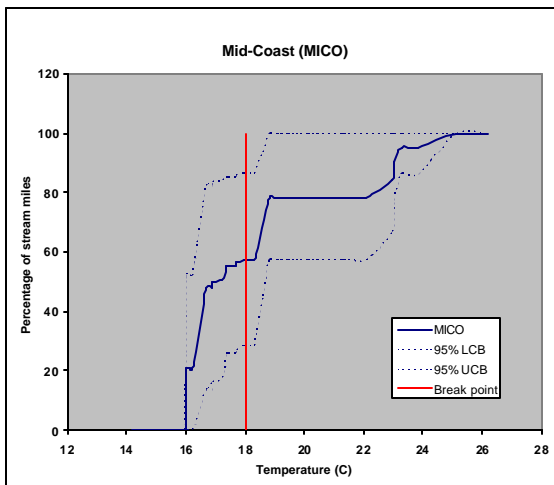
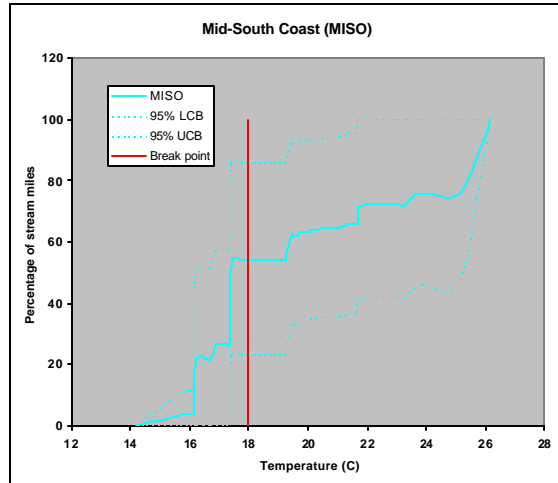
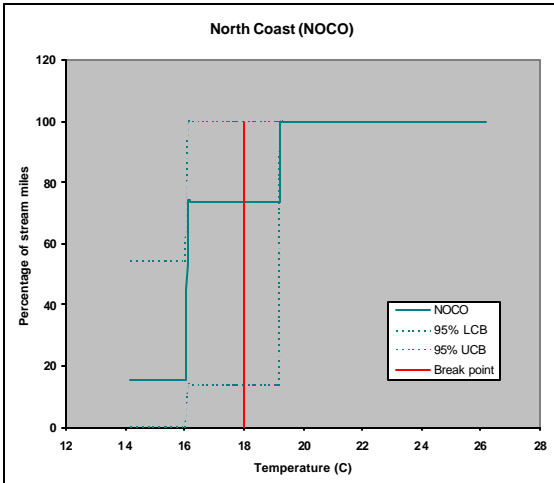
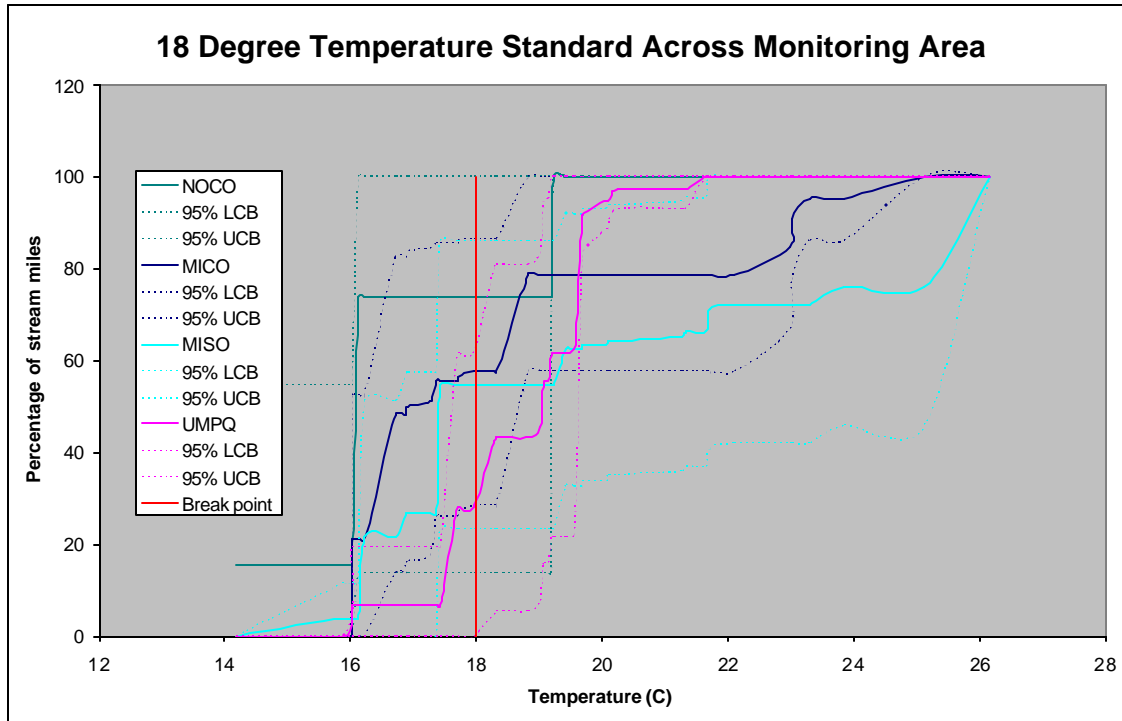
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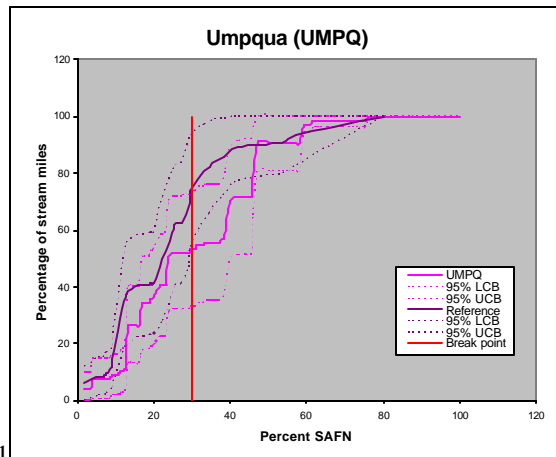
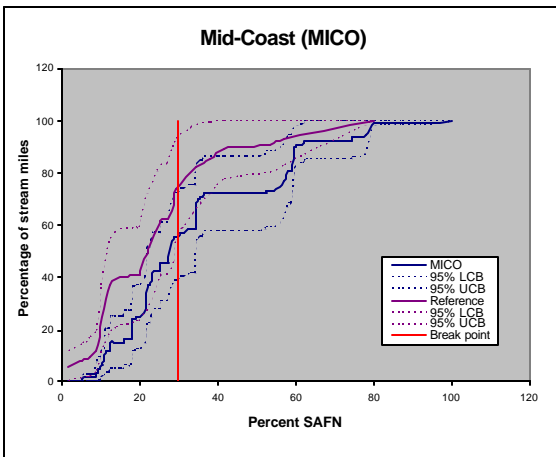
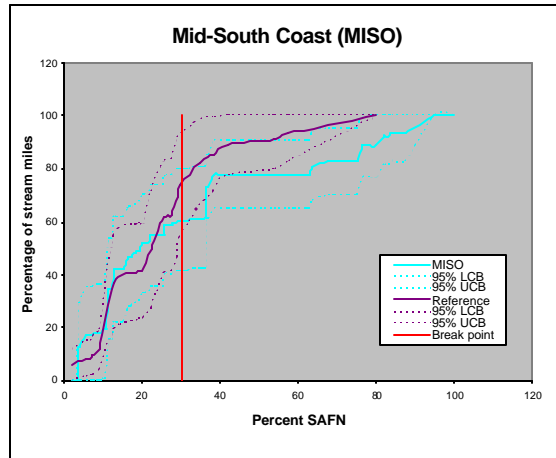
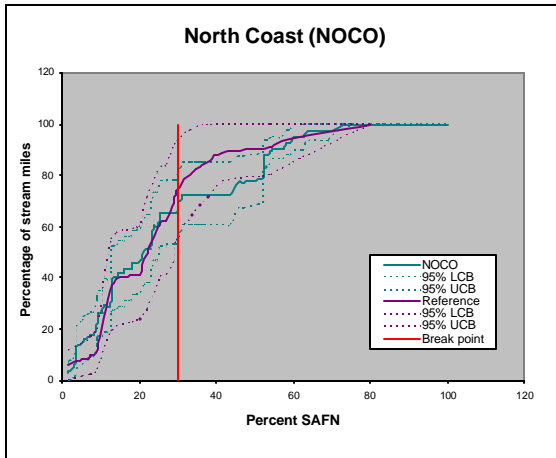
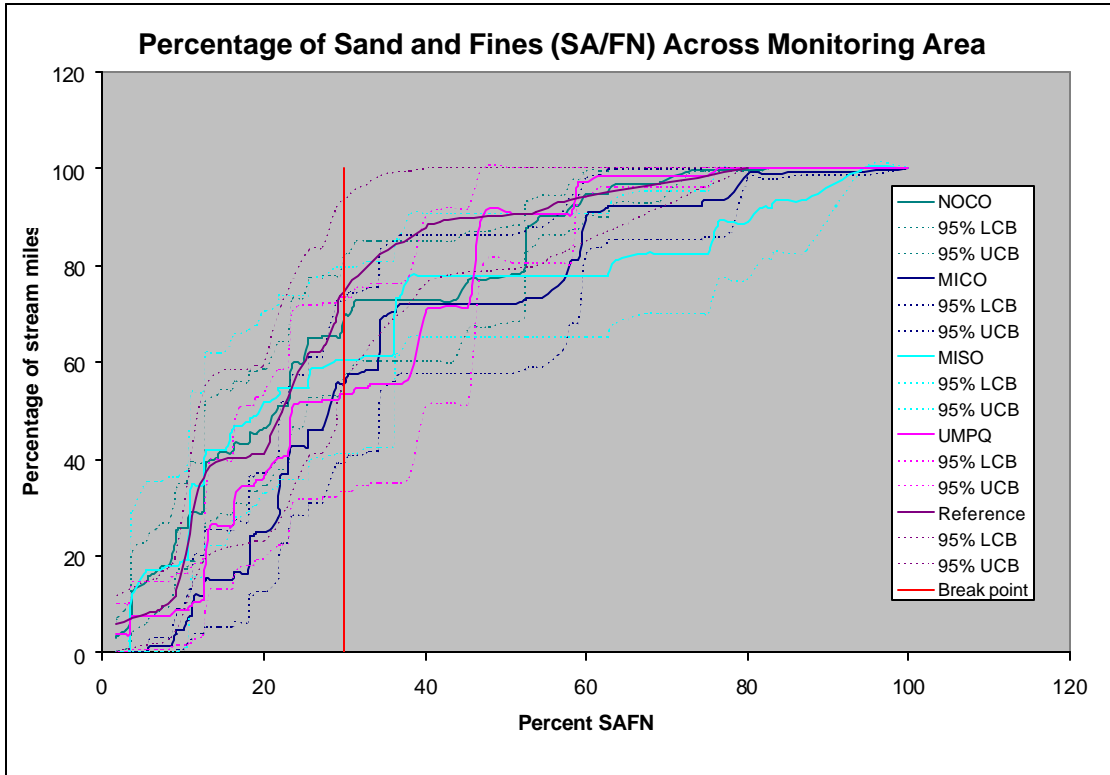
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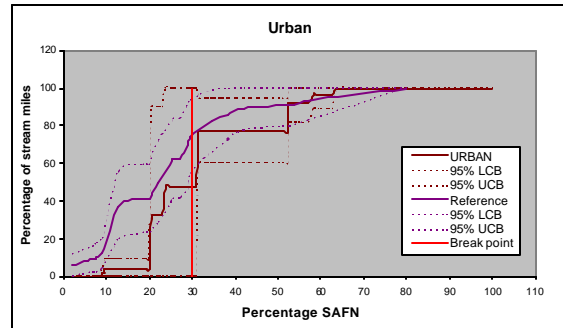
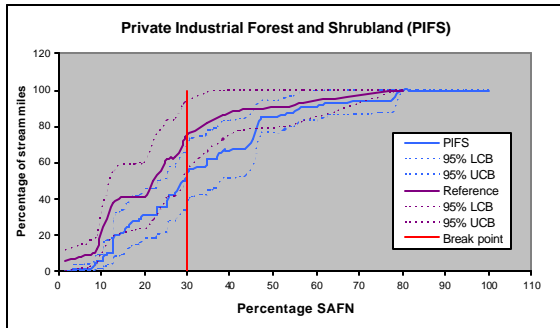
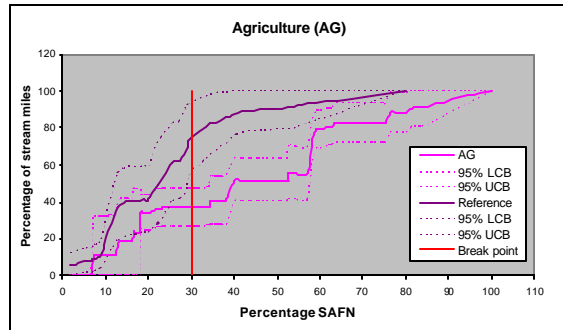
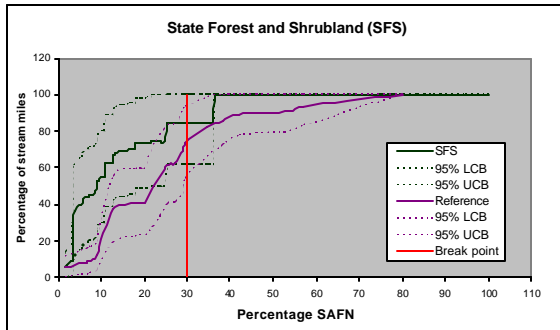
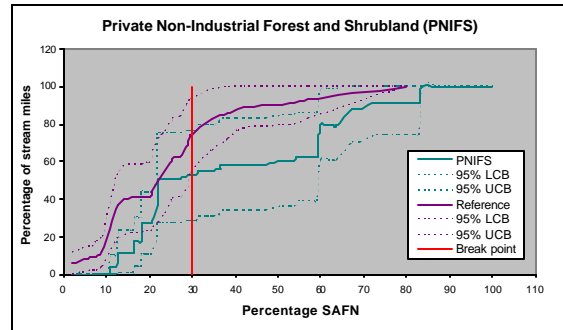
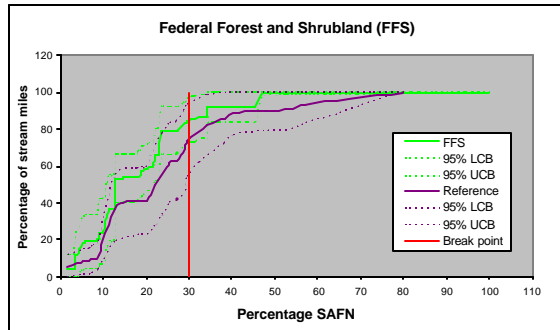
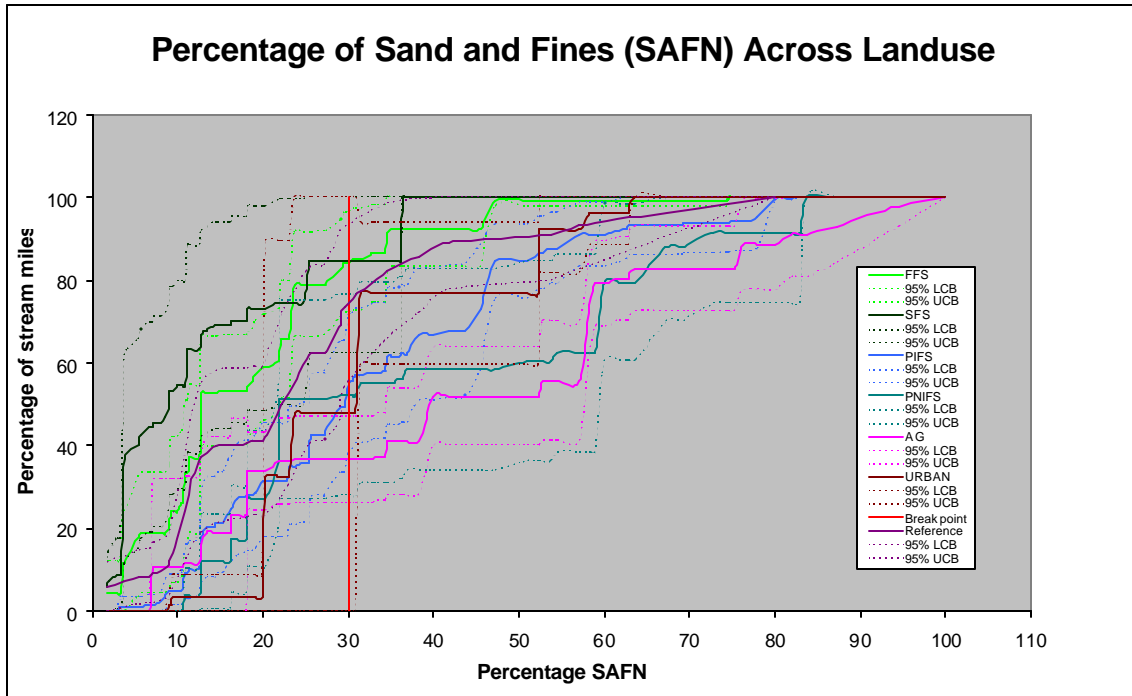
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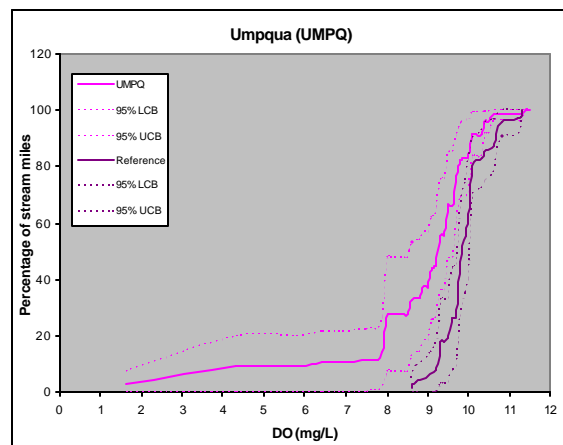
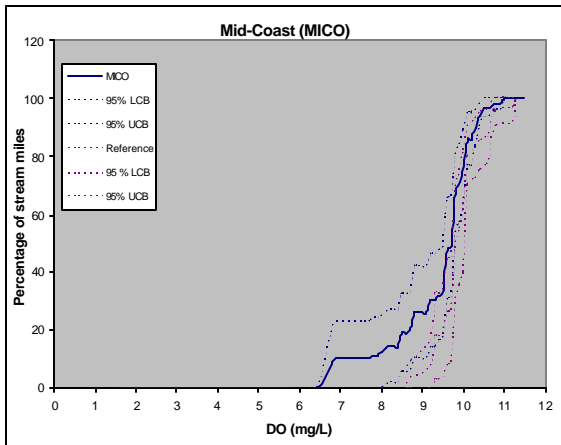
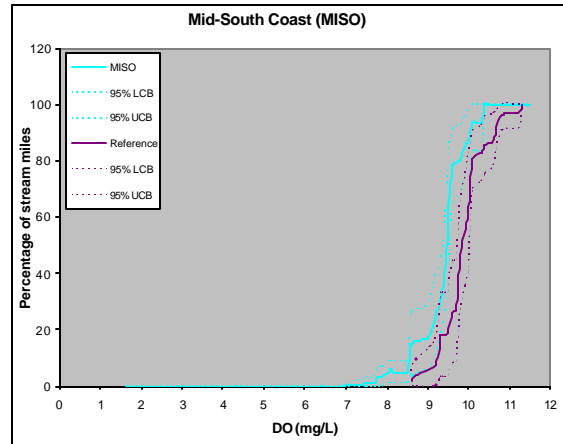
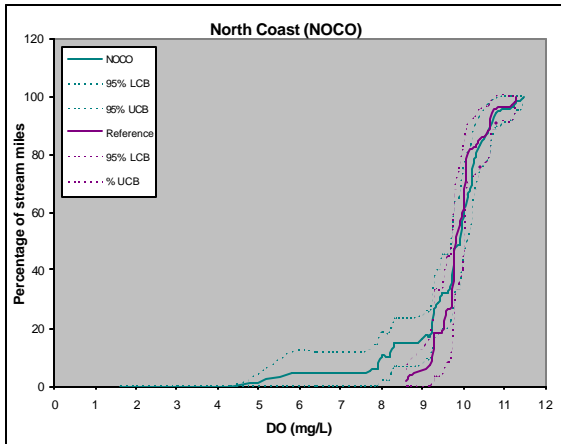
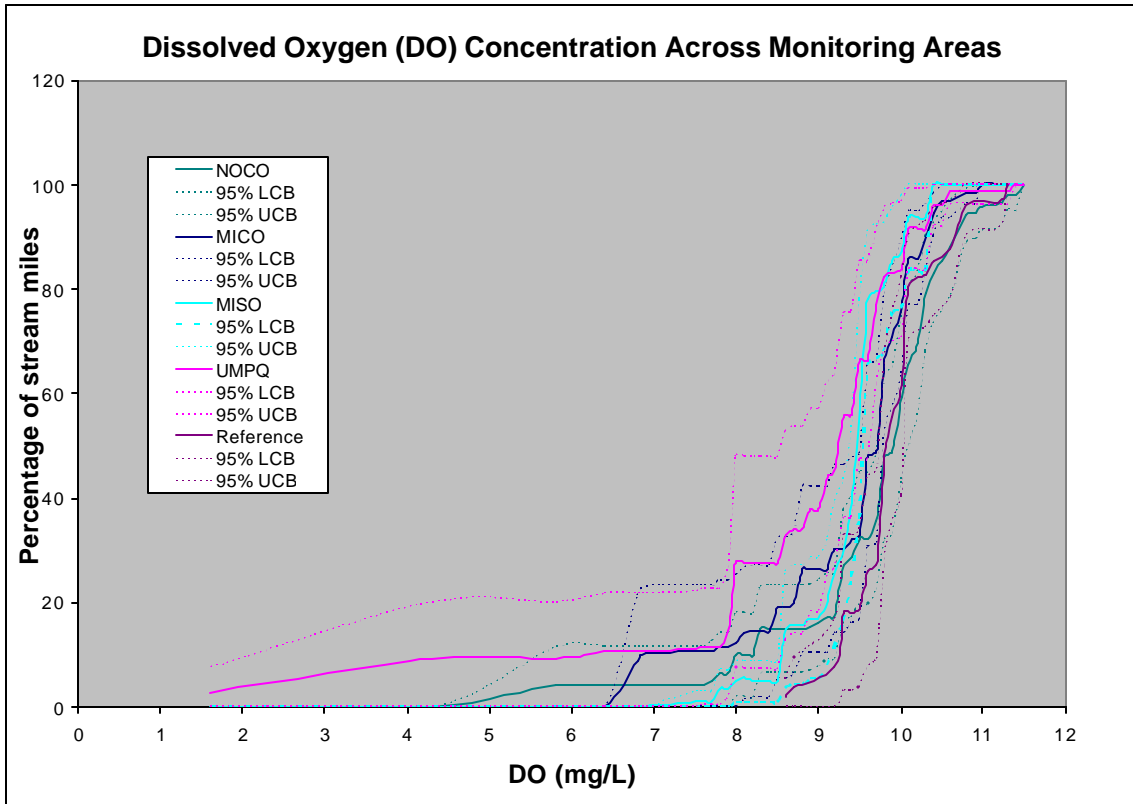
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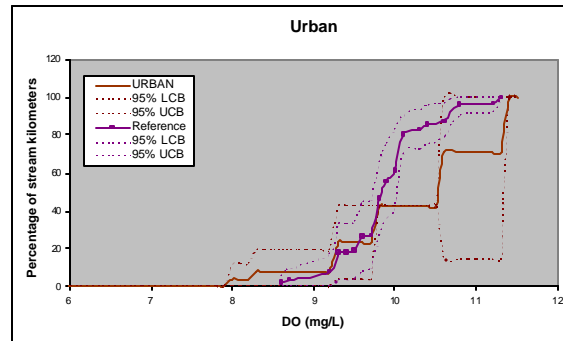
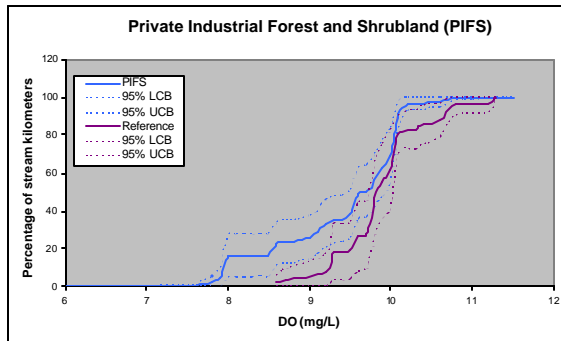
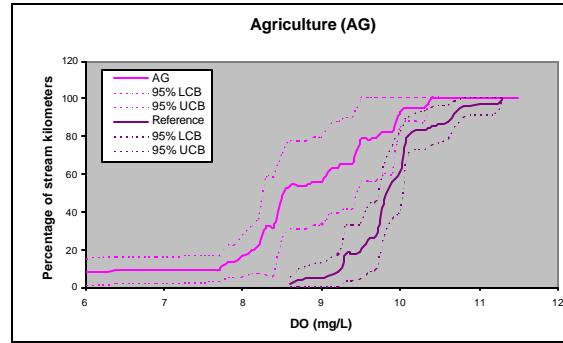
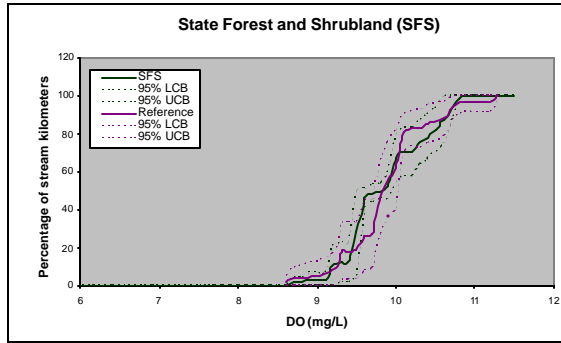
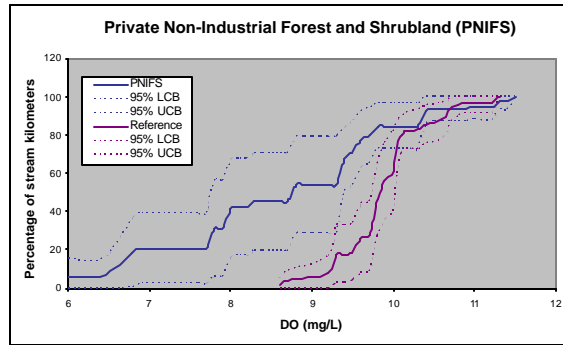
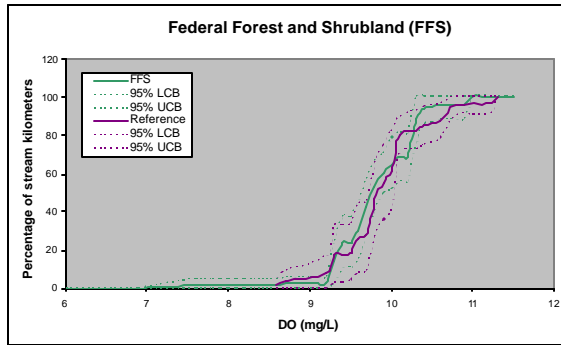
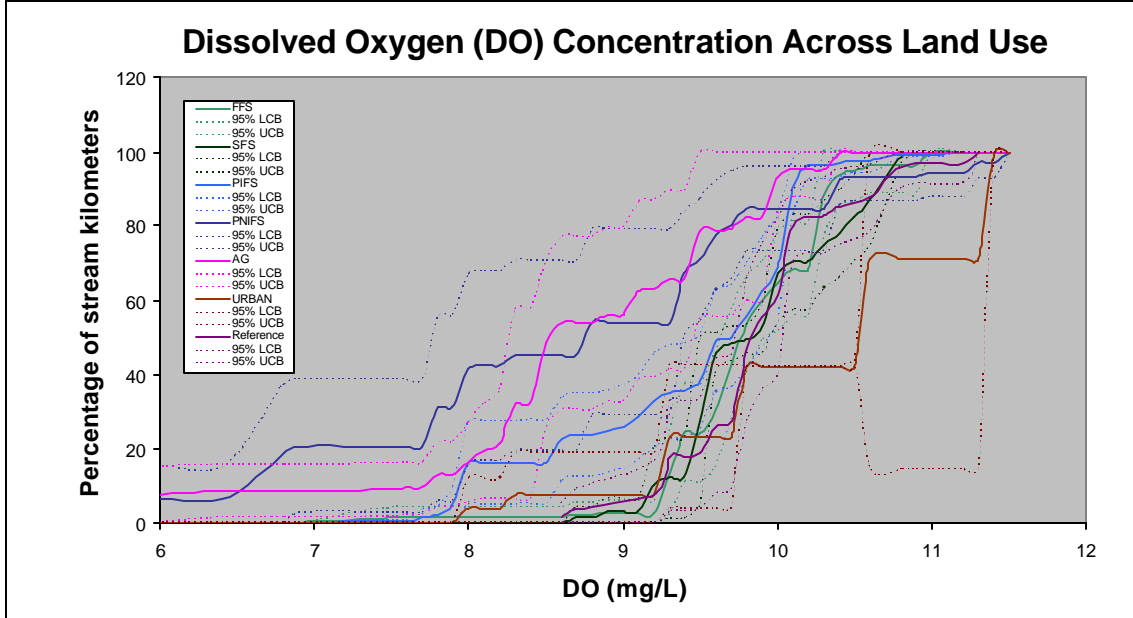
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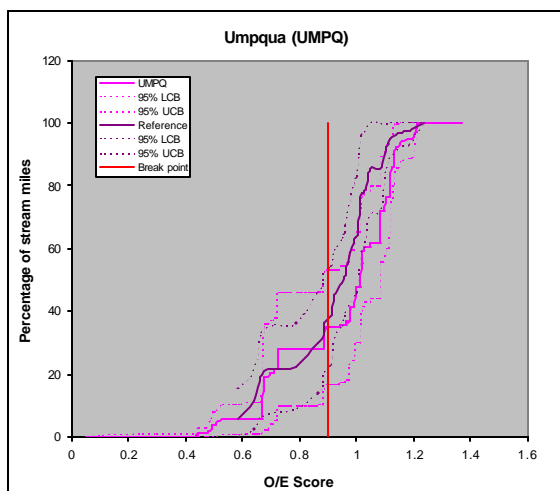
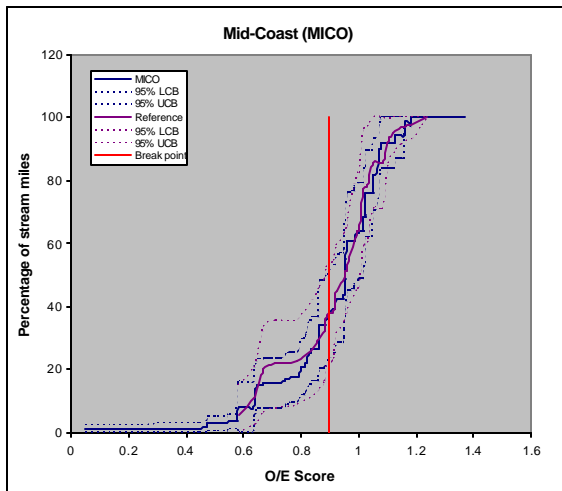
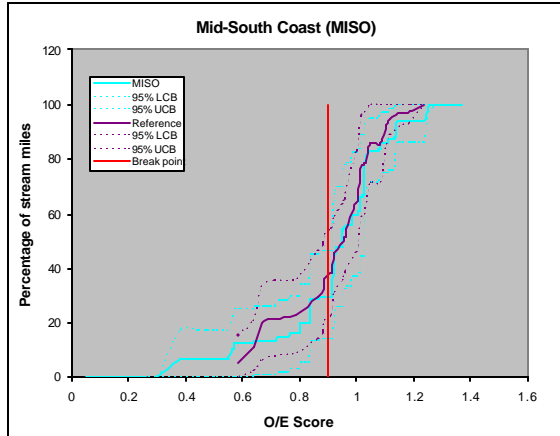
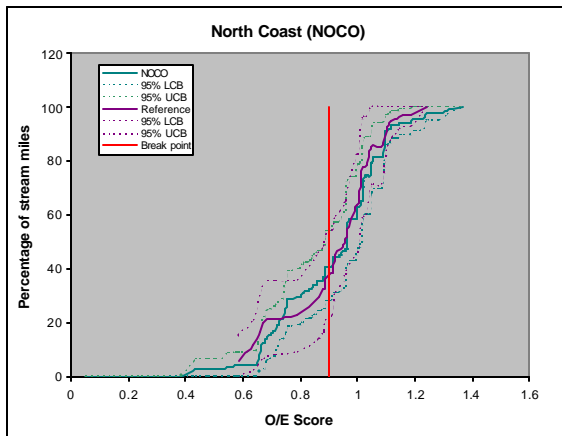
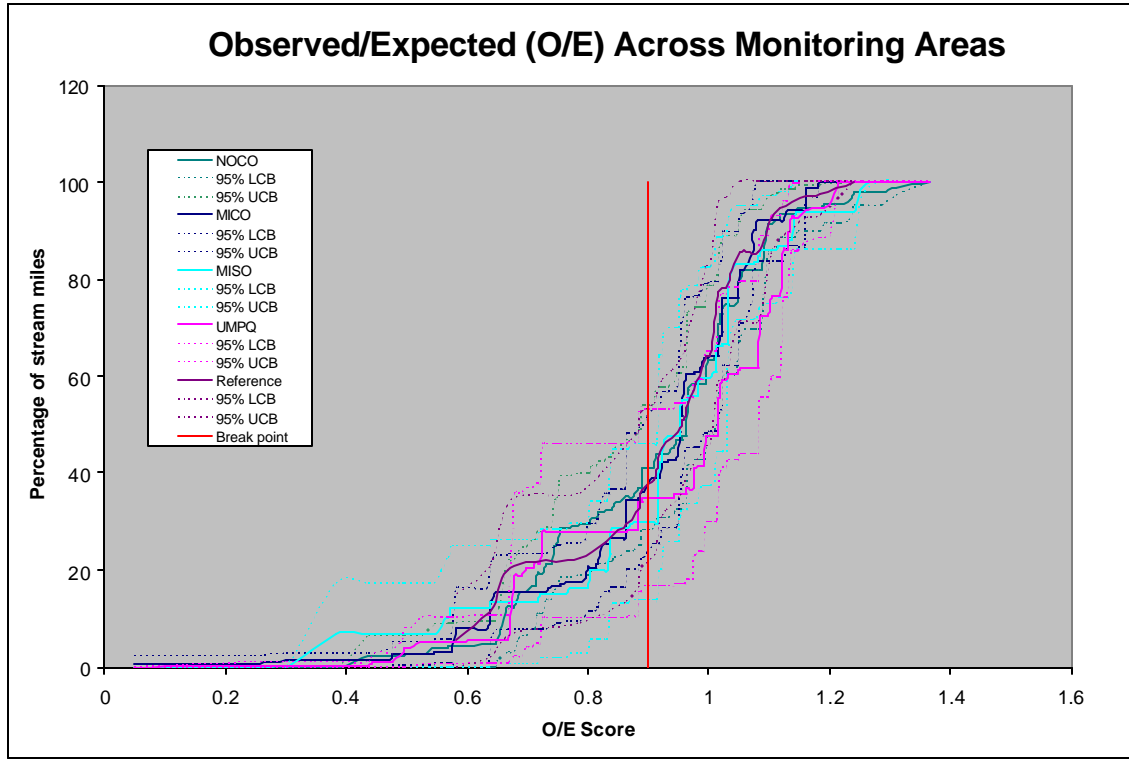
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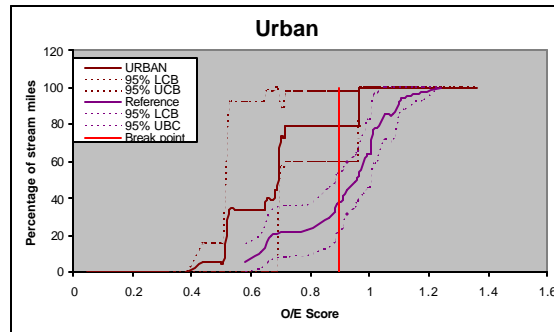
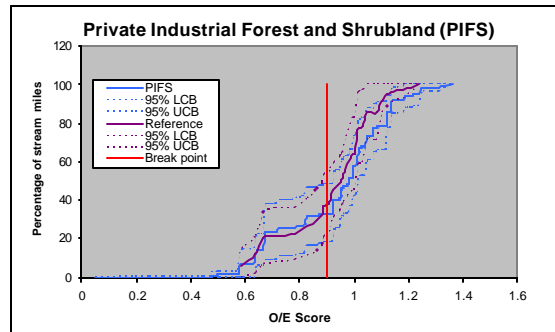
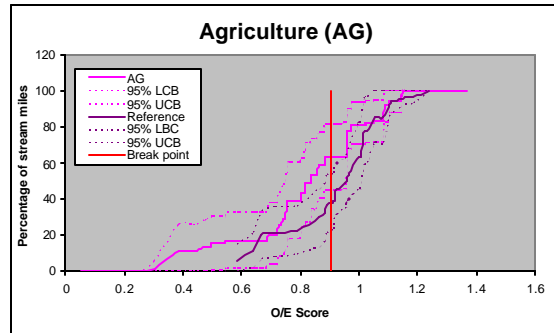
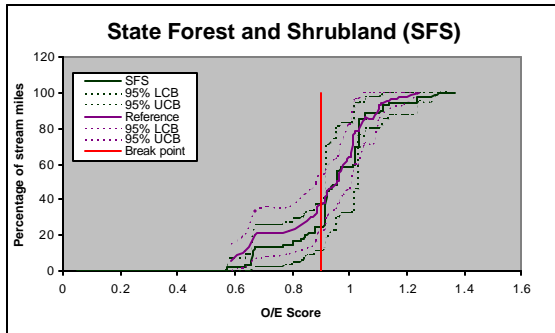
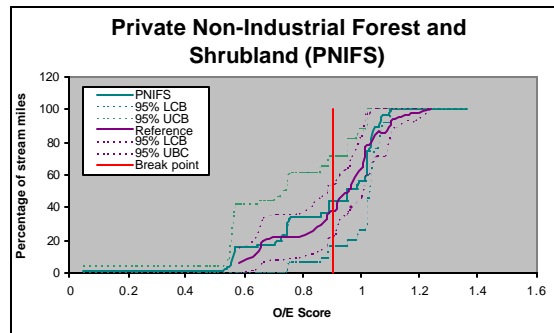
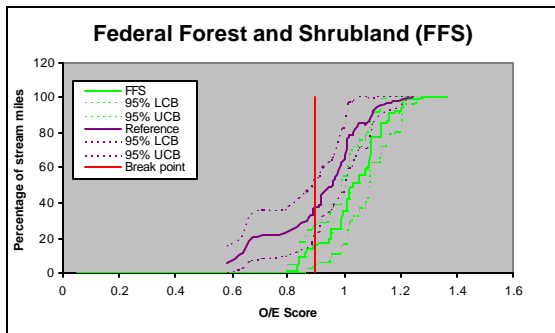
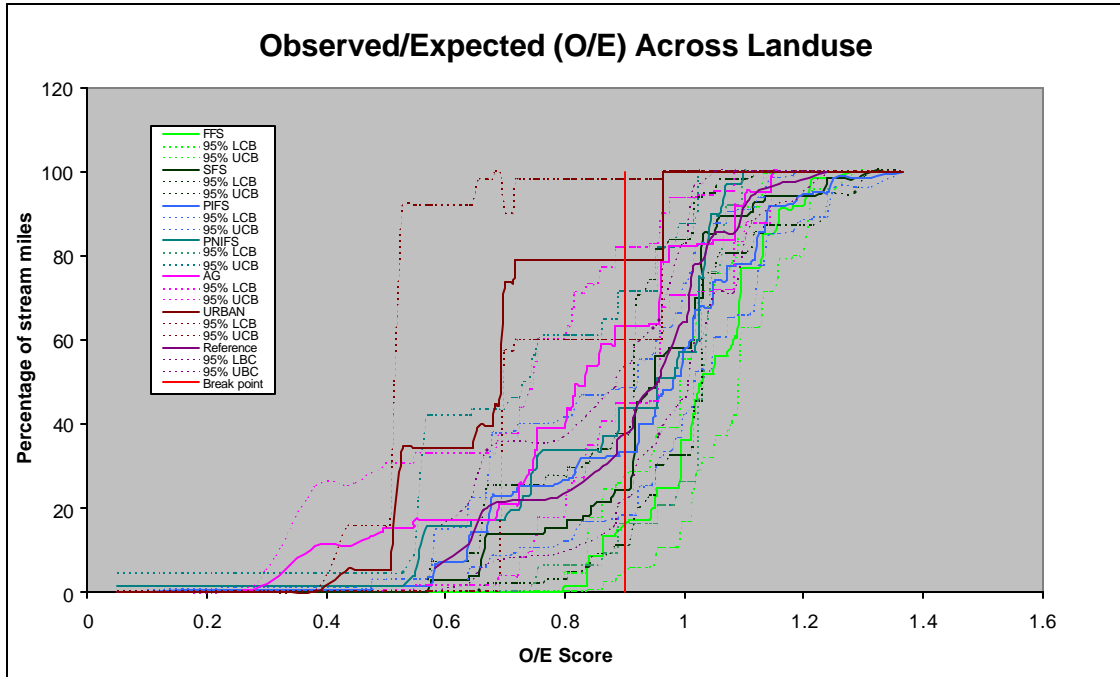
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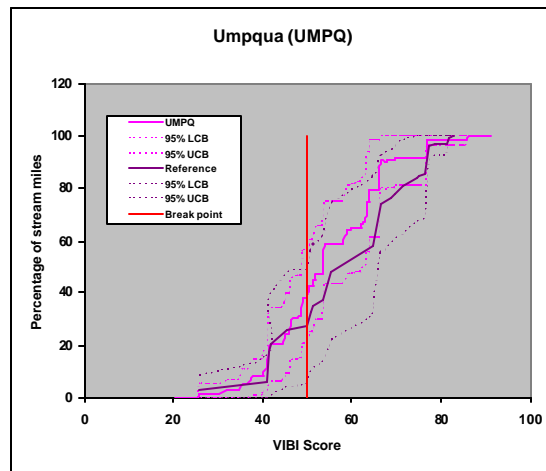
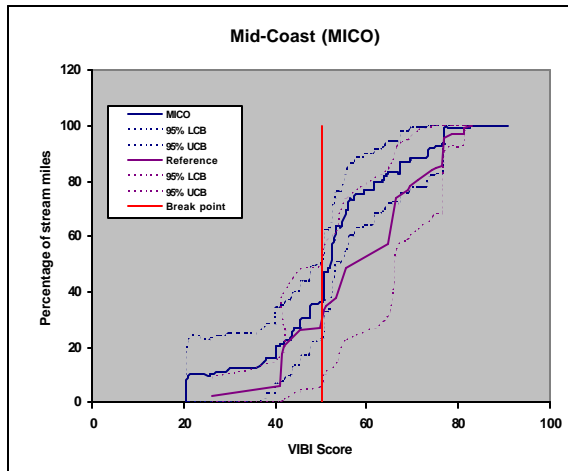
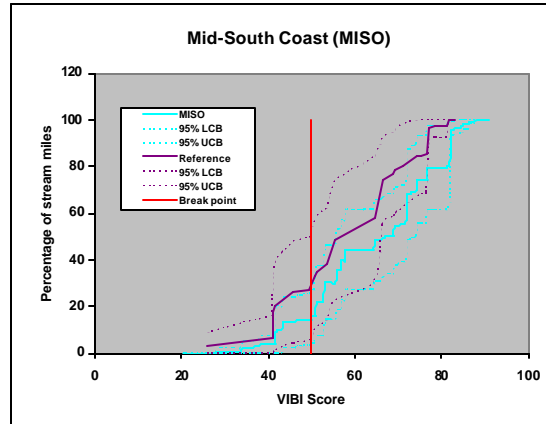
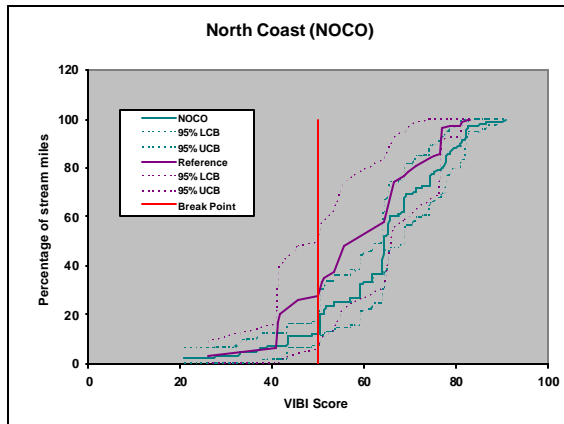
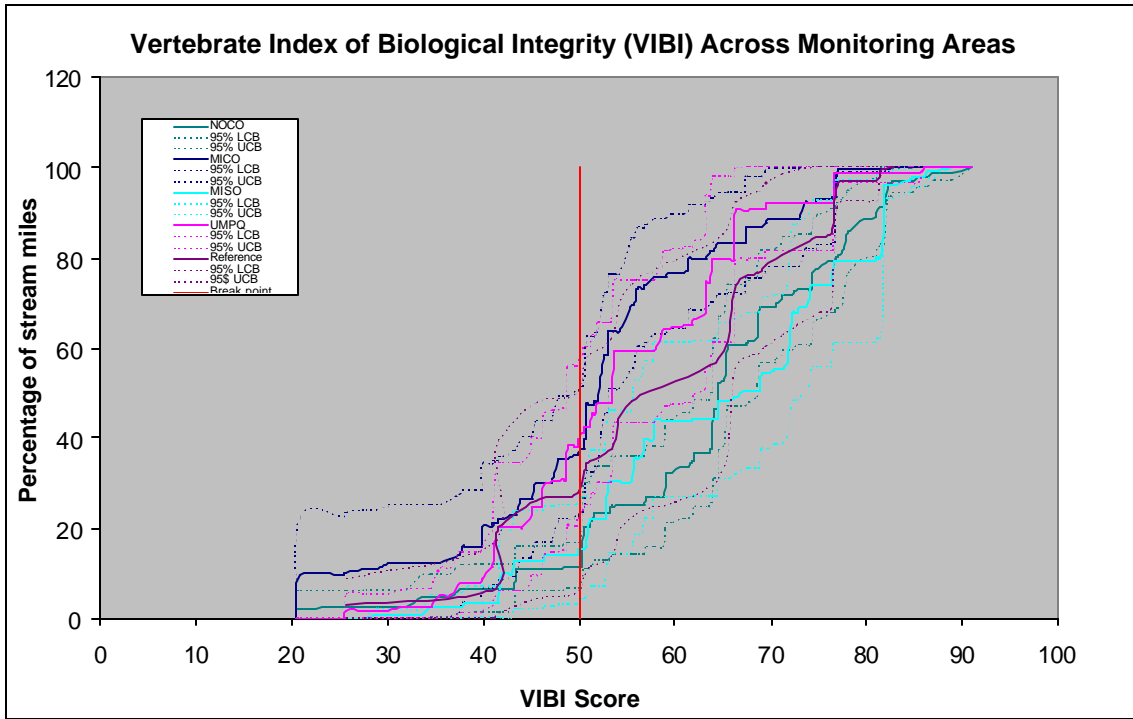
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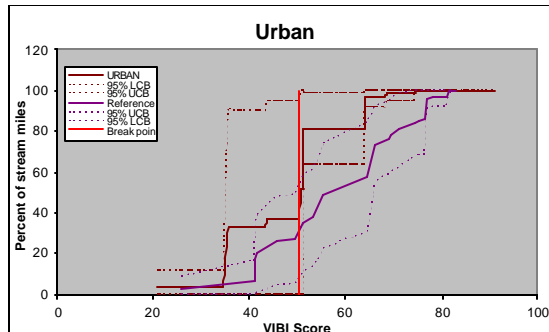
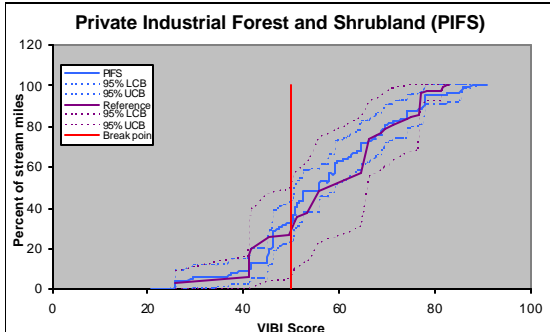
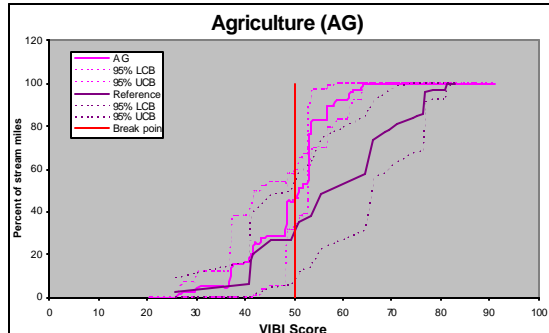
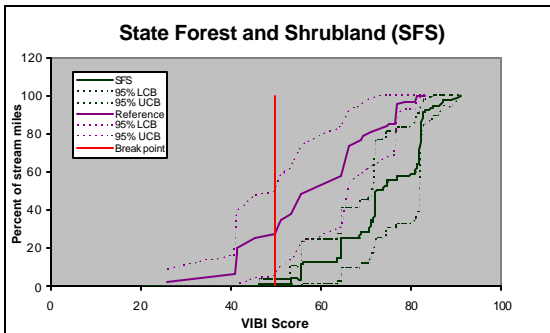
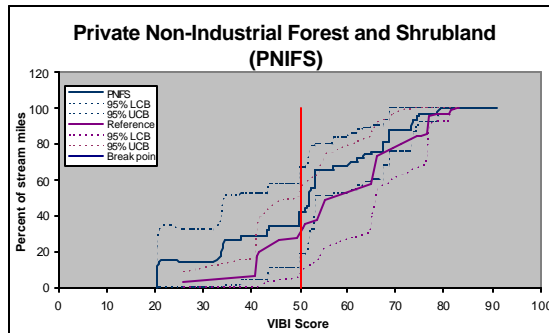
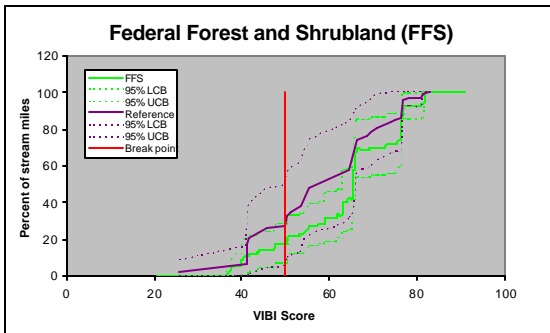
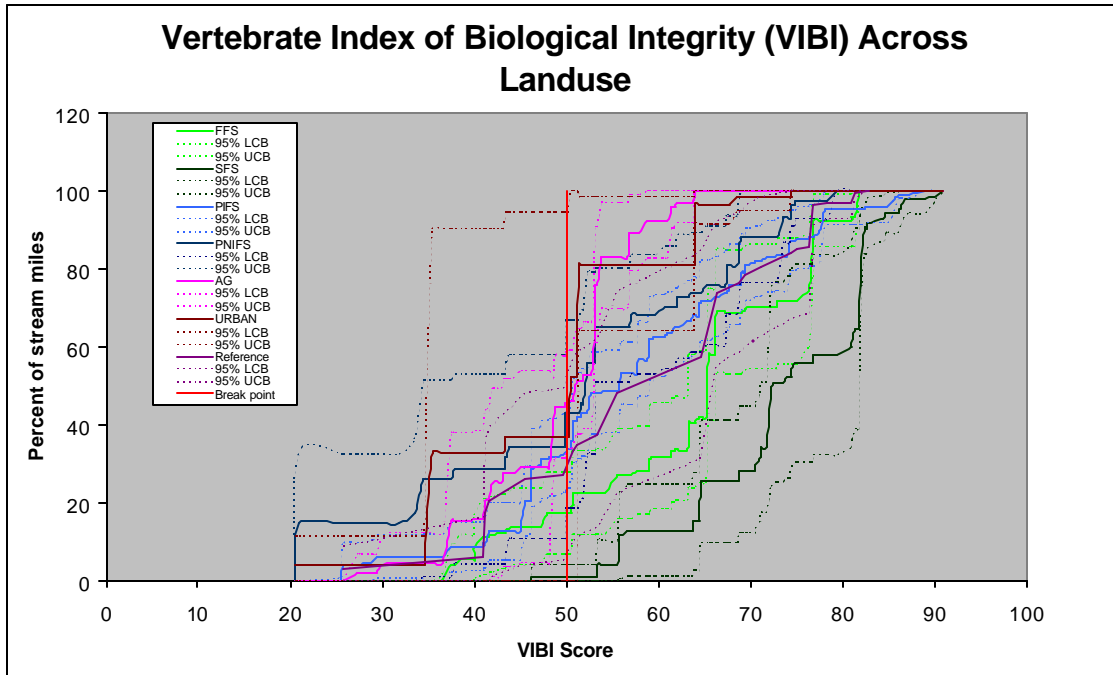
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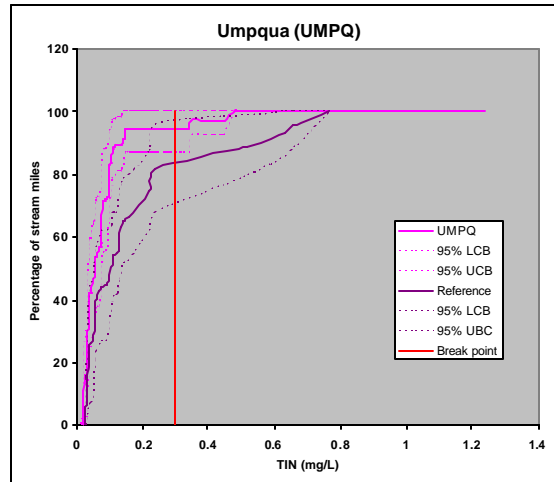
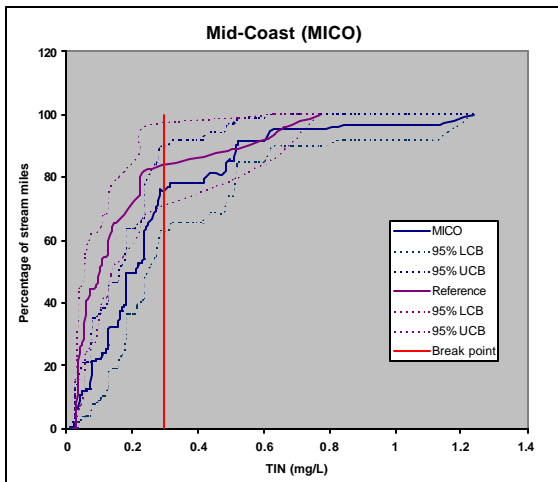
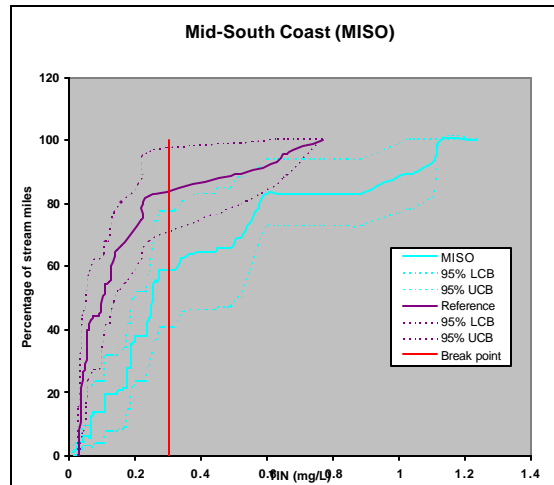
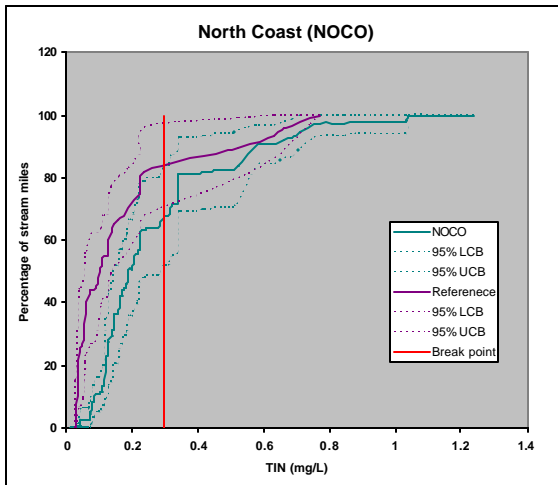
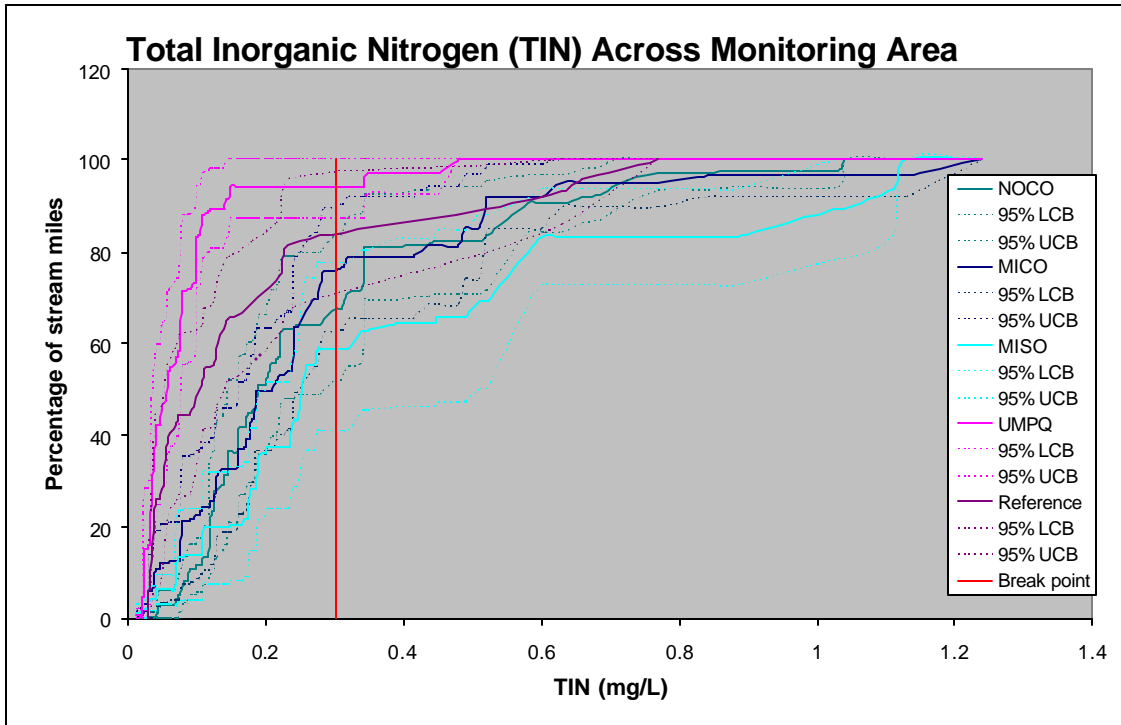
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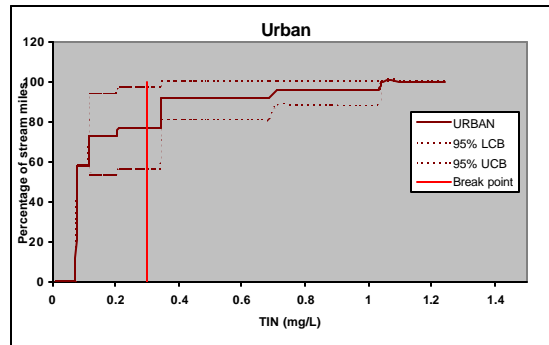
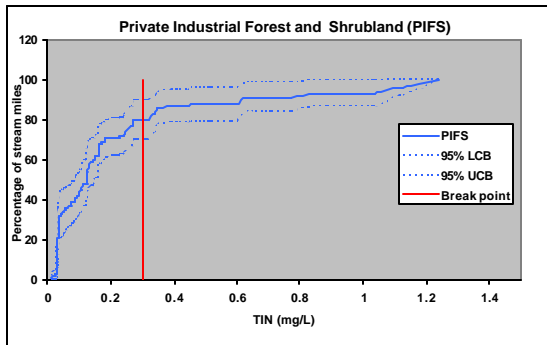
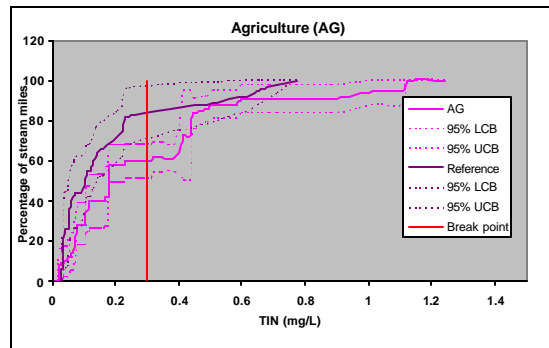
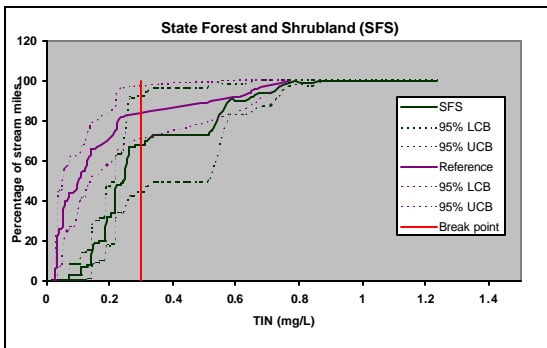
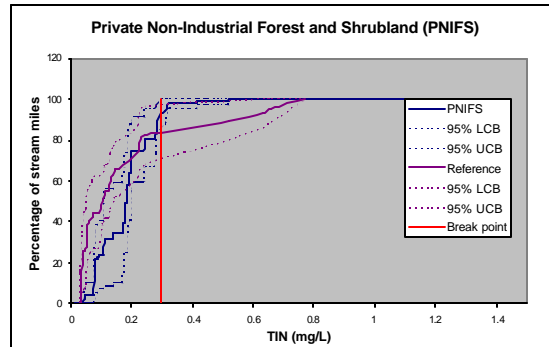
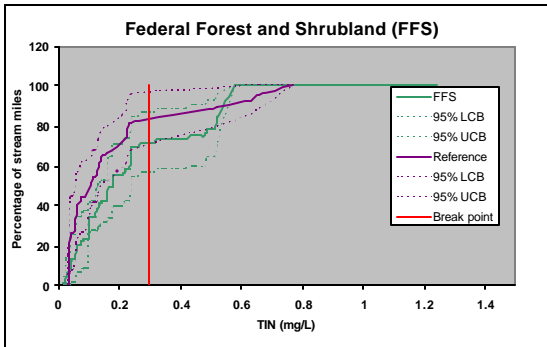
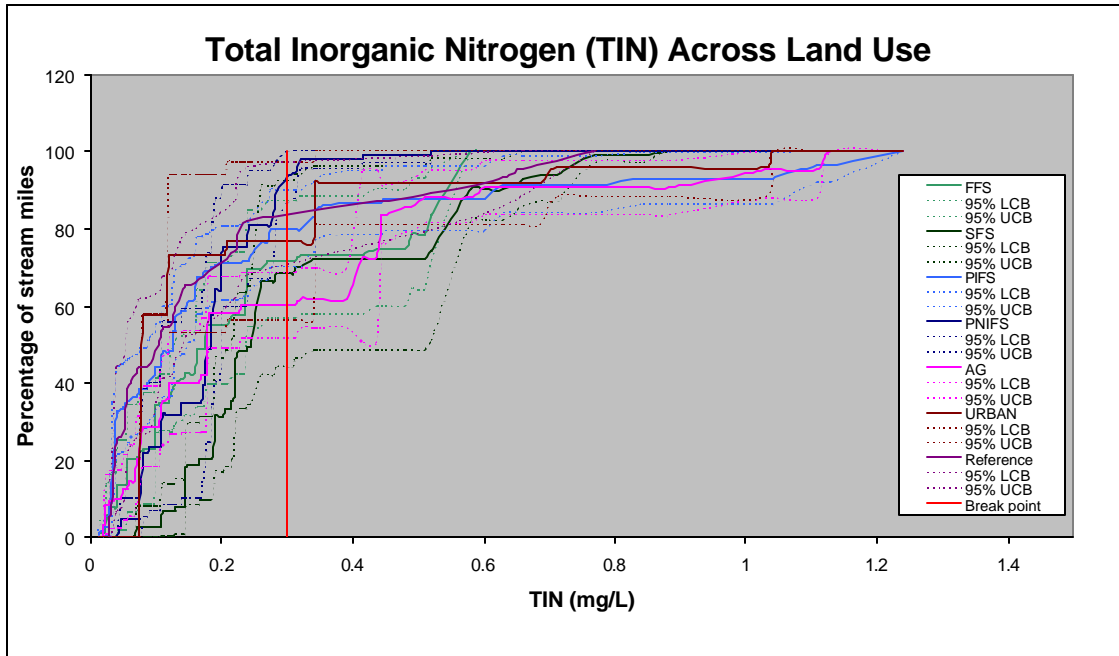
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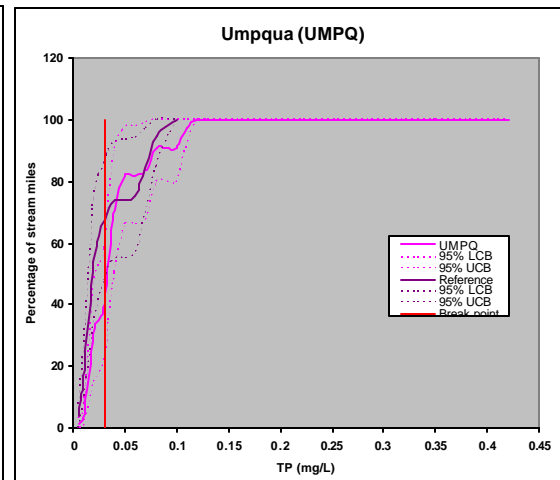
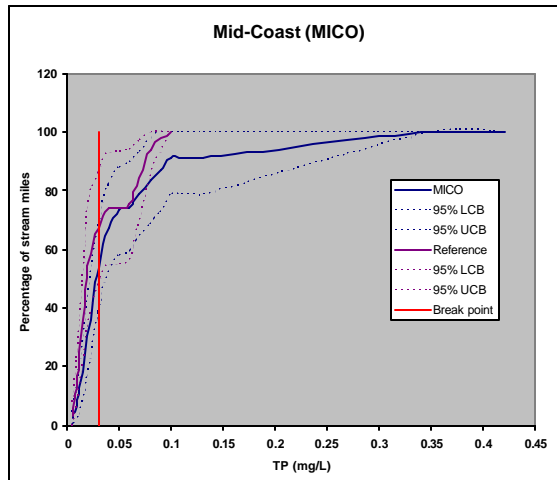
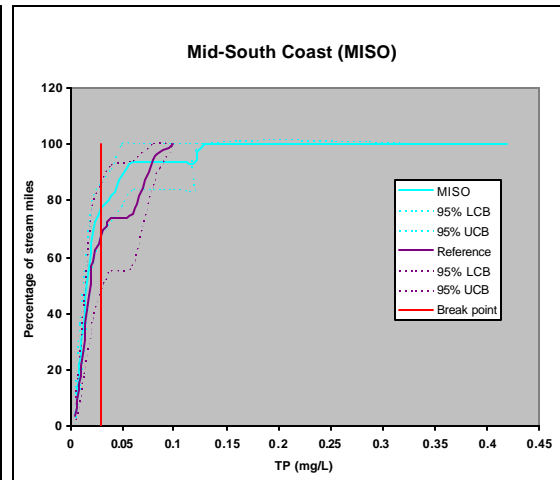
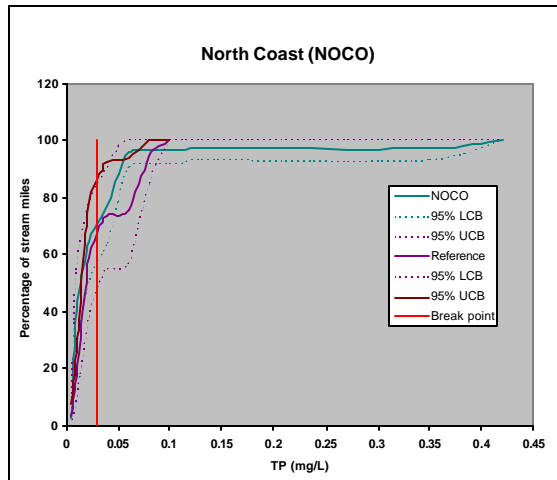
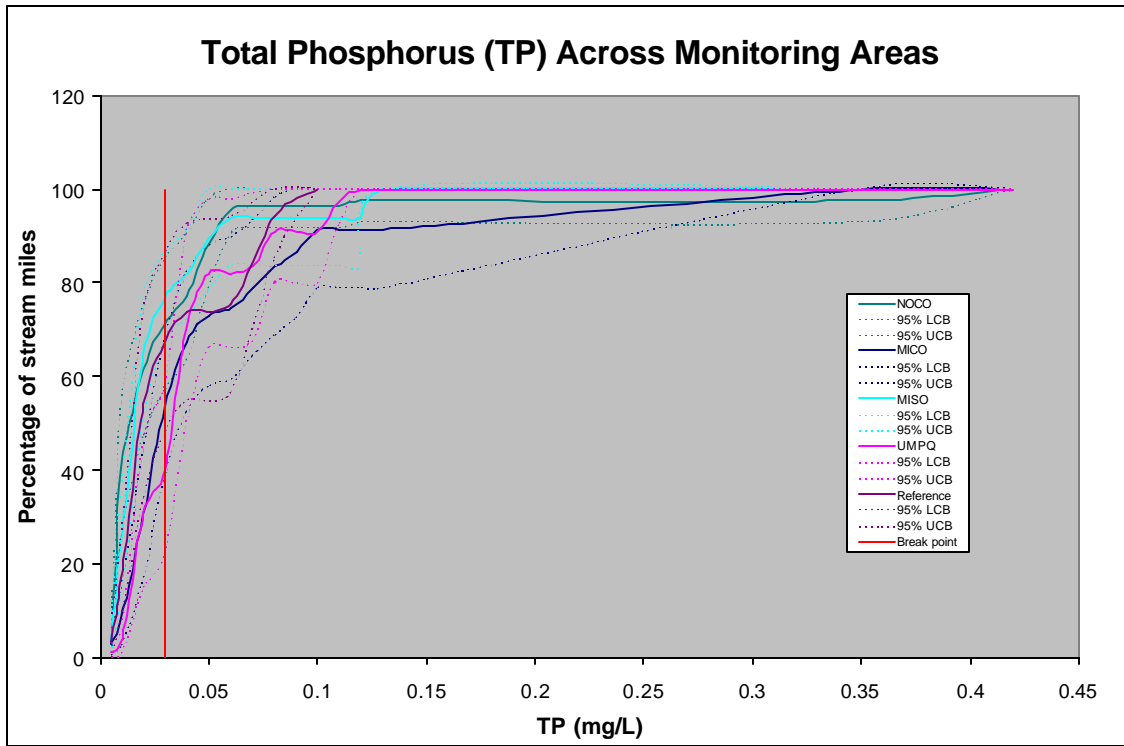
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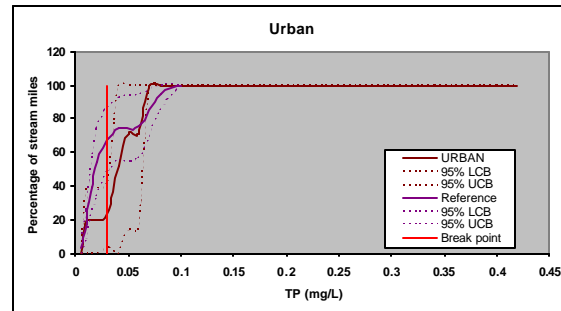
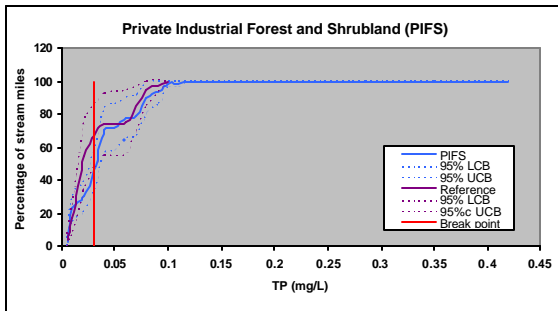
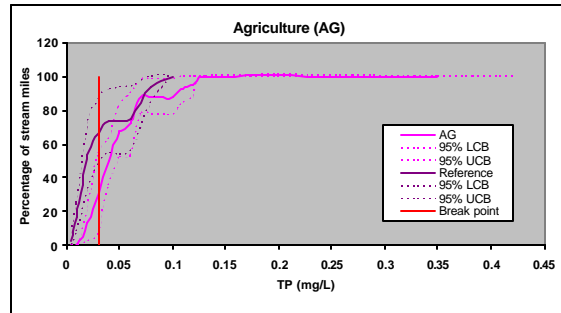
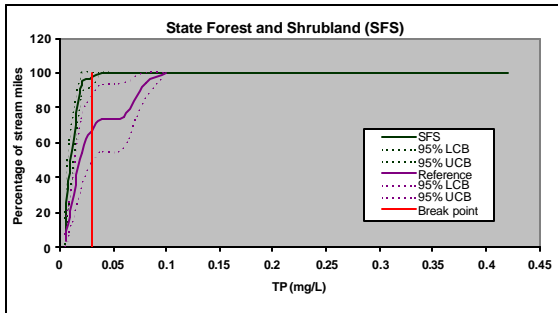
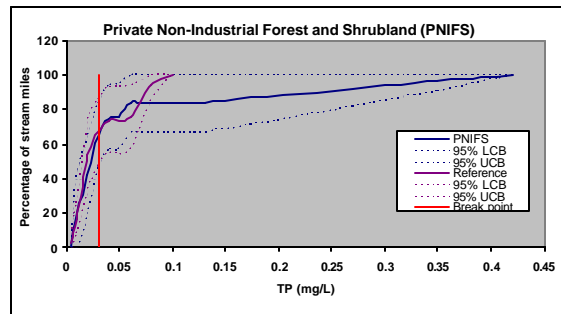
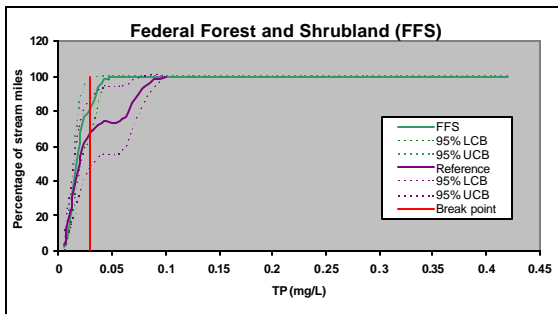
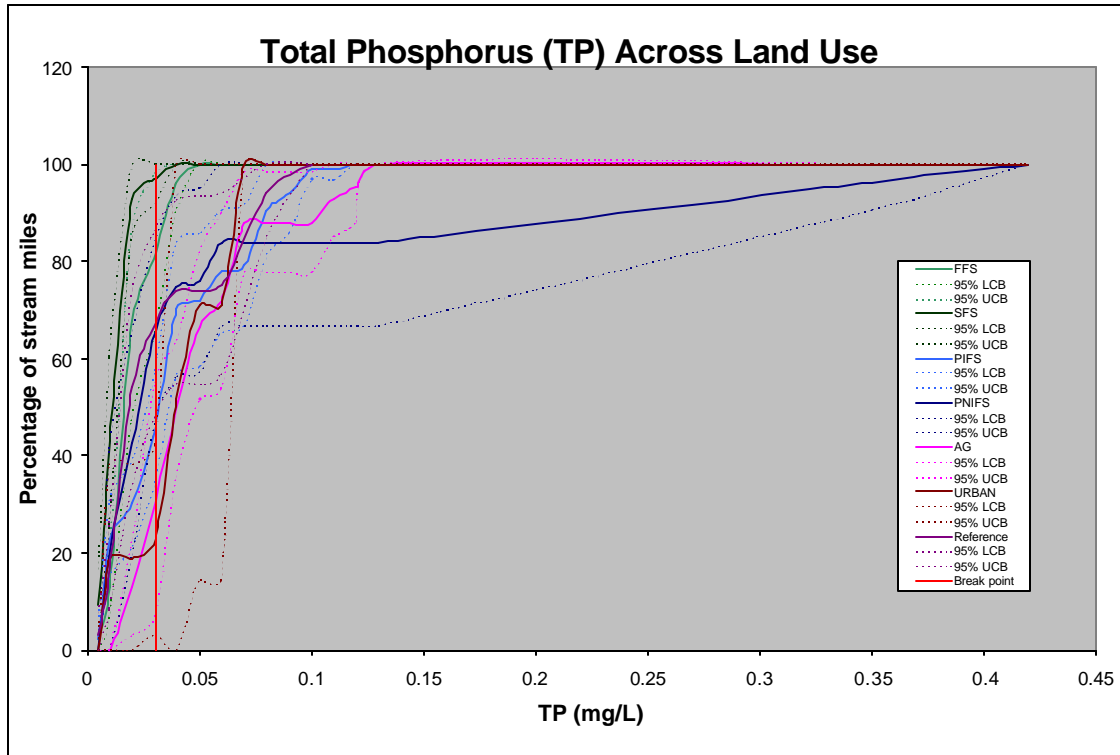
B-13



B-14



B-15



Appendix C – Relative Risk

Relative Risk:

In this section we look in more detail at the definition of relative risk and present two example calculations. Relative risk is a useful approach of evaluating the severity of a stressor on some response. This approach has been widely used in the medical field.

Relative risk is the ratio of two probabilities:

$$\text{Relative Risk} = \frac{\text{Probability of a Poor Condition given Poor Stressor value}}{\text{Probability of a Poor Condition given Good Stressor value}}$$

The example below is a hypothetical study of the relative risk of cigarette smoking and lung disease. In this study, researchers followed the lung health of 100 smokers (poor stressor value) and 100 non-smokers (good stressor value). Lung disease is the condition. Good condition would be the absence of lung disease and poor condition would be the presence of lung disease. The results of this study are summarized below.

Number of study subjects		Cigarette use (Stressor)	
		Non-smoker, N=100 (Good)	Smoker, N=100 (Poor)
Lung health (Condition)	Healthy lungs (Good)	95	60
	Diseased lungs (Poor)	5	40

Not all cigarette smokers got lung disease and not all non smokers had healthy lungs. The probability of a smoker getting lung disease (Poor condition given poor stressor value) is 40/100 or 40%. The probability of a non-smoker getting lung disease is 5/100 or 5%. The relative risk of smoking to lung disease is the ratio of these two probabilities: 40%/5%=8. In this fictitious example, lung disease is 8 times more likely to occur when a person is a smoker than when a person is a non-smoker.

In an example from our probabilistic stream survey data, we evaluated the relative risk of poor vertebrate community score (condition) given poor concentration of dissolved oxygen (stressor). Instead of individual study subjects as in the previous smoker study example, we have the percent of stream miles.

Percent of Stream Miles		Dissolved oxygen standard attainment (Stressor)		Total
		Standard attained: DO \geq 8.0 mg/l (Good)	Standard not attained: DO < 8.0 mg/l (Poor)	
Vertebrate Community Score (Condition)	Score exceeds benchmark: IBI \geq 50 (Good)	72.5%	2.7%	75.2%
	Score below benchmark: IBI < 50 (Poor)	21.3%	3.5%	24.8%
	Total	93.8%	6.2%	100.0%

$$\begin{aligned}
 \text{Relative Risk} &= \frac{\text{Probability of a Poor IBI Score given Poor Dissolved Oxygen value}}{\text{Probability of a Poor IBI Score Condition given Good Dissolved Oxygen value}} \\
 &= \frac{3.5/6.2}{21.3/93.8} \\
 &= \frac{0.56}{0.23} \\
 &= 2.43
 \end{aligned}$$

In this example, we would say that the risk of a poor vertebrate community score is 2.4 times more likely when the dissolved oxygen standard is not attained than when the dissolved oxygen standard is attained.

Appendix D – Oregon Plan Field Crew Personnel

Heidi Beard
Julie Berry
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Paul Gill
Rick Hafele
Eric Hansen
Lisa Hewlett
John Howington
Shannon Hubler
Dave Huff
Won Kim
Joel Klump
Robin Leferink

Sharon Lewis
Thomas Lossen
Jamie Ludwig
Cordel Manz
Allen May
Tonya McLean
Tsegay Mengistu
Daria Mochan
Sarah Mohler
Andrew Mowrey
Mike Mulvey
Rebecca Myers
Jesse Naymik
Rene Ripley
Virginia Robinson
Angie Schwab
Darlene Siegel
Paul Seilo
Lori Spencer
Dave Stewart
Todd Strobel
Tyler Tappenbeck
Chris Walker