April 2004

Technical Report WAS04-002

Selecting Reference Condition Sites

An Approach for Biological Criteria and Watershed Assessment

Opal Creek, a Cascades ecoregion stream.

Doug Drake
Watershed Assessment Section
Laboratory Division
Oregon Department of Environmental Quality
drake.doug@deq.state.or.us
April 2004

Executive Summary

This paper describes the approach the Oregon Department of Environmental Quality Watershed Assessment Section uses to select reference condition sites. The purpose of selecting reference condition sites is to establish an objective and systematic method for finding water bodies minimally disturbed by human activities for a given basin or region. The approach consists of using geographic information systems (GIS) and site specific information to characterize human disturbance. Selected reference sites are then used to describe "reference condition" for a specific region for the purposes of stream and watershed assessment.

Reference Condition versus Reference Sites

Reference condition is based on the idea that for any given water body (stream, lake, wetland, etc.) there exists a range of natural conditions unaffected by human activity. Reference condition is best characterized by a set of attributes at undisturbed or minimally disturbed sites characteristic of a water body type in a region. Within a basin or region, reference condition is described by a group of sites that have relatively unaltered biology, chemistry, and physical habitat. Therefore "reference condition" is represented by a group of "reference sites" with minimal human disturbance.

Scope - 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. Most reference streams represent minimally disturbed conditions where human disturbance is low. However, in some regions or stream types, human disturbance is significant and widespread. In these areas, reference condition may be based on historical conditions or sites that represent least disturbed or "best available" conditions.

There are many types and sizes of streams and the ecological expectation for them varies depending upon natural features (i.e., geology, stream size). Comparison of streams of greatly differing sizes or regions is not appropriate. At present we stratify reference site comparison groups by non-anthropogenic variables. These include, but are not limited to: ecoregion, hydrologic basin, stream size, elevation, geology and slope.

Uses - Defining reference condition establishes an appropriate benchmark for assessing the ecological status and trends of wadeable streams. Originally reference sites were used as site specific upstream controls. Much of the work was point source discharge studies where an upstream/downstream approach was required. However, the upstream-downstream approach is not adequate for non-point source pollution problems (e.g., forestry, agricultural, urbanization). Given the history and extent of human disturbance an upstream reference site is rarely available or appropriate for non-point source evaluations.

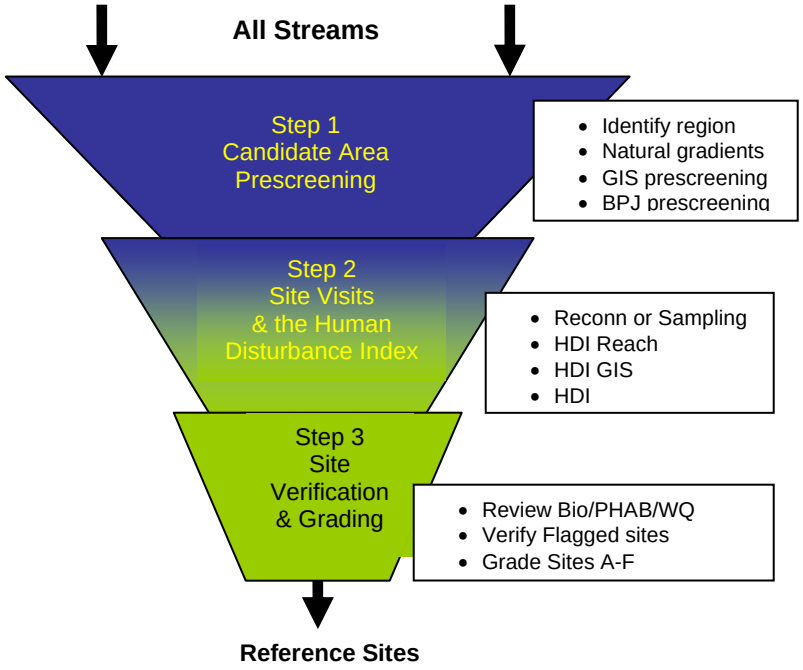
The concept of reference condition for bioassessments is also used in both predictive modeling and multi-metric analysis techniques (i.e., River InVertebrate Prediction And Classification

System (RIVPACS), and Index of Biotic Integrity (IBI)). These analysis techniques are widely used to assess biological conditions in a number of states and countries. Reference condition can also be used to set benchmarks for chemical and physical habitat conditions.

The Department has built a database of reference sites to establish expectations for different natural stream types. Data from these reference sites are used to describe a reference condition applicable to evaluate a range of sites from particular regions. Reference condition is an integral component of any robust regional approach developed for the application of numeric biocriteria. Other uses for the reference condition approach and biological data include: assessing the effectiveness of water quality management programs in protecting stream beneficial use (e.g., discharge permits, Total Maximum Daily Loads, agricultural water quality management plans), identification of stressors, and the tracking of stream habitat restoration effectiveness.

Site Selection - a Three Step Iterative Process

The diagram below shows the three steps followed in selecting reference sites: 1) candidate area prescreening, 2) site visits and the human disturbance index, and 3) site verification and grading.



Step 1 - Candidate Area Prescreening

Pre-screening involves selecting a region (ecoregion, basin, etc.), identifying the primary natural gradients, and then using geographic information system (GIS) information and best professional judgment (BPJ) to identify watersheds and streams with minimal human disturbance, and mapping these candidate areas.

Identifying a Region – The first part of candidate area pre-screening involves designating a specific region where reference sites are desired. Since the early 90's the ODEQ has used both ecoregion and basin as study area scales. We have relied on Omernik's Level III ecoregion (Thorson et al, 2003; Omernik, 1986) as a framework in which to establish reference sites. The use of ecoregion as an appropriate geographic framework has been suggested (Bryce et al, 1999; Hughes and Larsen, 1988) and used in a number of state and EPA programs (Griffith, 1999). This allows for an appropriate distribution of sites across both state and watershed boundaries. Ecoregions are recognized as a consistent and pragmatic tool for stream management, but does not imply that ecoregions are the most appropriate stratification approach (pers. comm. Stoddard/Larsen).

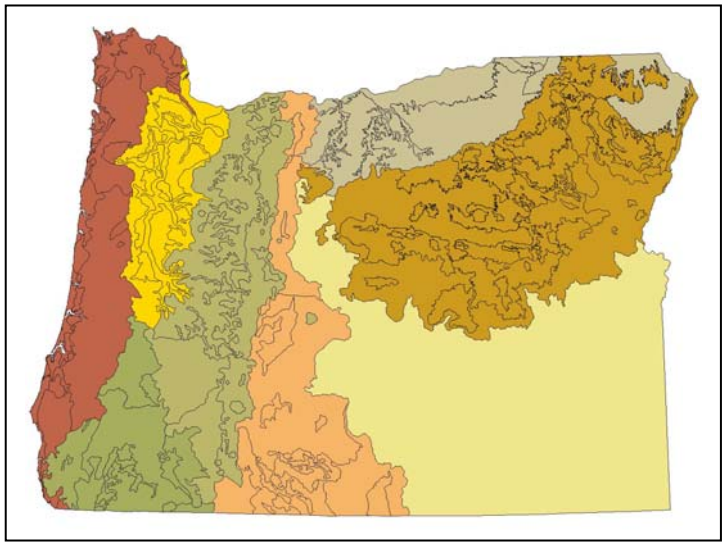


Figure 1 – Level III Ecoregions of Oregon (Omernik, 1986)

Basin and sub-basin (e.g. Upper Deschutes, Upper Grande Ronde, John Day) areas have also been used for delineating regional assessment areas. Basins however may extend across several ecoregions, which means that reference sites are needed in each ecoregion of those basins.

Natural gradient(s) - In each region the primary natural gradients (e.g., elevation, stream size, and geology) are examined and incorporated into the selection of reference sites and sampling stratification scheme. This insures that reference sites will represent both the region and the dominant natural gradients that exist. For example, the Blue Mountain ecoregion (which extends across five basins) was divided into three elevation categories for reference site selection in a northeast Oregon study.

Geographic Information System Pre-screening (GIS) - GIS data layers are used to pre-screen for indicators of human disturbance at the watershed or stream scale. Other sources of information like air photos (Ortho Digital Quads) and thematic mapping (TM) could also be used. Potential areas are mapped where one might expect to find streams with minimal human activity. We have used statewide coverages for road density, population, forest fragmentation, agricultural and urban land use, and grazing allotments to help identify candidate areas (Vogelmann, 2001; USGS TIGER files; Kagan & Caicco, 1992).

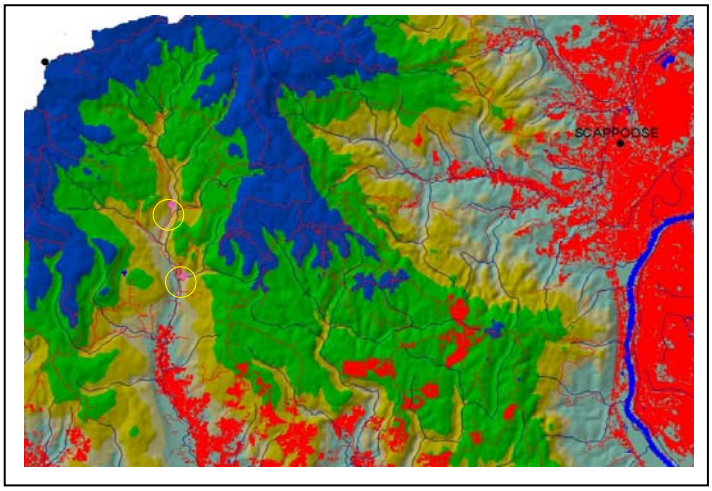


Figure 2 - Example of Prescreening map and sites (yellow circles) for area NW of Portland. Red denotes disturbed landscape (roads, developed land (Ag or Urban) and forest fragmentation. Blue, green, tan, and gray are elevation classes.

Using results from the above coverages, maps are generated that identify candidate watersheds. These maps are then used by reconnaissance crews to help guide them toward streams in the least disturbed watersheds (See Figure 2). These coverages have provided the most utility in identifying watersheds with minimal disturbance. Other coverages (i.e., road crossing, forest stand age, and improved grazing data) may be used to help identify potential reference areas in the future.

Best Professional Judgment Pre-screening (BPJ) – Another useful source for candidate reference streams and watersheds is the knowledge of local groups and state and federal agency staff.

Resource managers from state and federal land management agencies have helped to identify a number of the reference sites to date. The process involves contacting local natural resource specialists and surveying them about streams or watersheds in their region. Identification of candidate areas can be based on objective criteria (e.g., less than x% of the upstream basin logged, proximity to roads or trails, etc.) or more often, best professional judgment. Ideally, candidate areas should have these qualities (C. Hawkins, pers. comm.):

- High water quality, minimal riparian, channel, hydrologic, or biological degradation.
- Minimal logging, grazing, mining or recreational activity
- Characteristic of sites found elsewhere in your region
- Spatially dispersed within a region
- Represent a range of natural conditions for these features

stream size	elevation
channel slope	substrate composition
dominant basin geology	riparian type

GIS and BPJ Candidate Areas- Streams and watersheds identified using GIS can be combined with the areas identified through the BPJ survey to produce a combined set of candidate areas. A comparison of the combined areas versus natural gradients can show whether or not there is a sufficient number of candidate watersheds and streams for a given region.

Step 2 - Site Visits and the Human Disturbance Index

Site visits during reconnaissance or sampling are used to identify reach level human disturbance missed with the office based candidate area pre-screening step.

The Human Disturbance Index (HDI) is a process that uses reach level observations and watershed scale geographic information to evaluate the relative human disturbance at a site. Reach level disturbance (HDIreach) and watershed level disturbance (HDIgis) is scored, averaged for each, and added together to produce an overall Human Disturbance Index score. The index score is used to help select and rank reference sites in a basin or region.

Field Reconnaissance and Sampling - The pre-screening activity is largely an office based procedure, therefore actual site visits are critical. The reach level assessment (HDIreach) is based on a modification of the proximity weighted human disturbance metric scoring used in EPA's Environmental Monitoring and Assessment Program (Kaufmann et al, 1999).

Human Disturbance Index Reach (HDIreach) - The reach level human disturbance scoring and ranking method was developed as an objective procedure for scoring and ranking all potential reference sites (Drake, 2003). It consists of a site level assessment that is performed during a reconnaissance or sampling visit. The reach level checklist is a tool intended to document the significant human disturbance activities observed at a given stream reach. It has also been used to ground-truth the watershed scale GIS coverages. The HDIreach together with a follow-up assessment of the specific watershed disturbance patterns (HDIgis, described below) makes up the composite HDI score.

The reach level checklist evaluates 30 different human disturbance activities that could occur in a stream or watershed (Appendix 1). The EMAP method summarizes human activities into 11 categories. (Kaufmann et al, 1999). Analysis of data for Oregon streams showed some redundancy and/or few examples of urban and agricultural EPA categories; therefore the 11 EPA categories were reduced to 5 categories for Oregon (Table 1). None of the activity data is lost, just translated into fewer categories for assessment purposes.

Table 1
Comparison of Human Disturbance Categories

EPA Human Influence categories	**Oregon Human Disturbance categories**	**Comments**
Wall/Dike/Revetment/Rip/Rap/Dam	Ag+Urban (Category 1)	Few examples
Buildings	Ag+Urban (Category 1)	Few examples
Pavement/Cleared Lot	Ag+Urban (Category 1)	Few examples
Pipes (Inlet/Outlet)	Ag+Urban (Category 1)	Includes effluent & irrigation
Park/Lawn	Ag+Urban (Category 1)	Few examples
Row Crops	Ag+Urban (Category 1)	Few examples
Road/Railroad	Roads – Category 2	Common
Pasture/Range/Hay Field	Range – Category 3	Now includes open range
Logging Operations	Logging – Category 4	Common
Landfill/Trash	Misc (Category 5)	Common, but unique
Mining Activity	Misc (Category 5)	Few examples, but unique

Each activity is scored based on its presence and proximity to the stream bank (not observed = 0; observed in watershed = 1; within 10 meters of the stream bank = 3; and activities observed on the stream bank = 5). The highest score for a given activity in a category is the disturbance category score. The sum of the five category scores is the HDIreach score.

Human Disturbance Index GIS (HDIgis) - The drainage area of each site is delineated using ArcView (Huff, 2003) in order to evaluate available GIS data. At present, three GIS coverages are being used to establish watershed level land use disturbance patterns; road density, urban and agricultural land use, and forest fragmentation.

Three GIS based disturbance metrics were developed using a continuous scoring scheme. The metric values are based on the entire population of sites sampled up through 2003 (n =975). The road density population had a maximum value of 38% (percent of 10x10 meter cells in watershed with road segment present); therefore 40% was used as maximum metric score of five. The minimum was zero percent roads setting the minimum metric score of zero. Figure 2 below shows the road density scoring.

Percent Urban+Agricultural land use had a maximum value of 100% (100% = metric score of five). Urban+Agricultural land use consists of 10 land use classes taken from the Oregon National Land Cover Data (Voglemann et al, 2001). It includes the following classes; low and

high intensity residential, commercial-industrial-transportation, quarries/strip mines/gravel pits, orchard/vineyards, pasture/hay, row crops, small grains, fallow, urban/recreational grasses.

Forest fragmentation coverage is made up of three categories of fragmentation; high (more than 2/3 of a polygon recently harvested), medium (between 1/3 and 2/3 of polygon recently harvested), and low (up to 1/3 of a polygon recently harvested). Each of the categories are weighted by the following factors; 5 times % high fragmentation, 3.34 times the % medium fragmentation, and 1.67 times the % low fragmentation. The metric is the sum of these values.

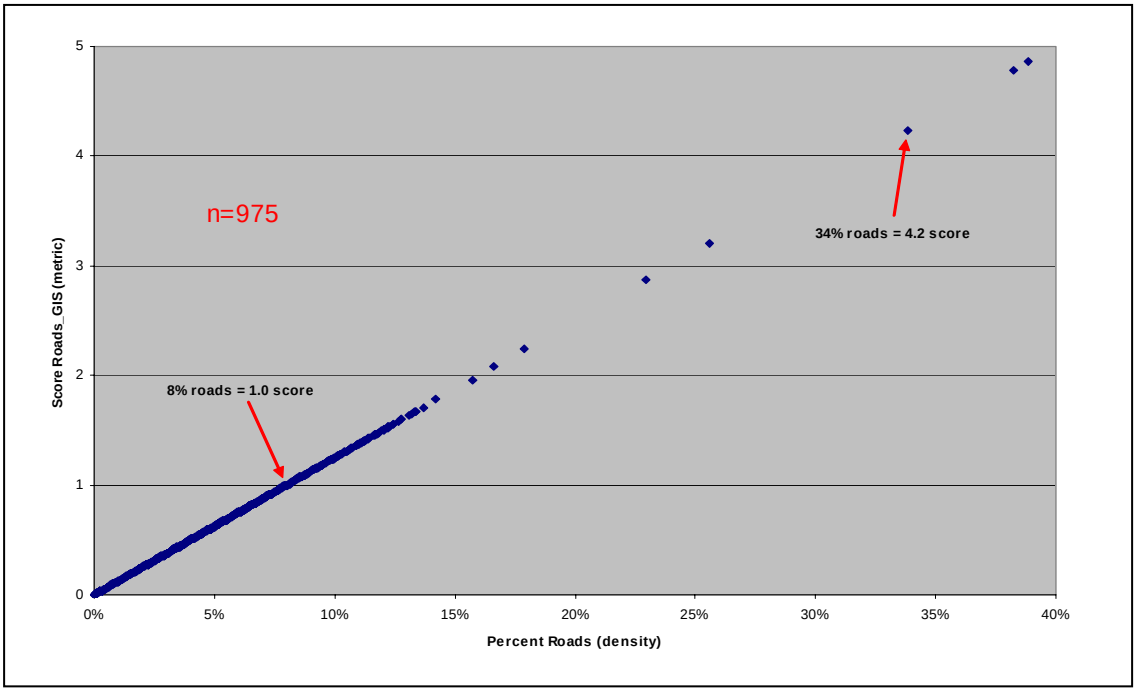


Figure 2. HDIgis metric scoring breakdown for road density.

HDI Score – The watershed information (HDIgis) of each site can be used in conjunction with the reach level data (HDIreach) to verify the level of human disturbance, and also generate an overall human disturbance index score (HDI) for each site. To calculate the HDI, the average of the HDIreach score and the HDIgis score is summed. The maximum possible with this index is 10, however to date the maximum observed is 6.1. Table 2 shows the HDI scoring for three typical stream types: a coastal lowland site with grazing, roads, residences, and some logging; a forested site with logging and roads in watershed but not close to stream; and a Cascade Range wilderness site.

Table 2 Human Disturbance Index Score Examples				
Activity	**Scale**	**Cascade Range wilderness stream**	**mid elevation Coast Range stream**	**Low elevation mixed use stream**
Ag/Urban	reach	Not present = 0	Present = 1	Within 10 m = 3
Logging	reach	Not present = 0	Present = 1	Within 10 m = 3
Range	reach	Not present = 0	Not present = 0	Within 10 m = 3
Roads	reach	Not present = 0	Present = 1	On the bank = 5
Misc	reach	Not present = 0	Trail on bank = 5	Trash on bank = 5
Ag/Urban	watershed	0.07% = 0.003	3% = 0.15	6% = 0.32
Forest Frag	watershed	0 = 0	84% = 4.2	62% = 3.1
Road	watershed	0 = 0	13% = 1.7	5.4% = 0.68
HDI Score		**0.001**	**3.6**	**5.2**

Step 3 - Site Verification & Grading of Sites

Site verification involves examining site results for any anomalies by reviewing the site-specific watershed disturbance information, site visit reach disturbance assessment, and sampling data. If discrepancies between watershed landscape condition, reach disturbance assessment and sampling data are observed then further evaluation of the site is done. While reference site selection is not based on in-stream conditions, final verification includes an evaluation of the biological, physical habitat, and water quality data for outliers that might indicate unidentified problems. Data that indicate disturbance (e.g., alien species, excessive nutrients) are carefully reviewed to insure that no sites with excessive human disturbance are classified as reference. Verification is completed with the assignment of a "site classification" grade.

Site Data Verification - After sampling has occurred and data quality assurance procedures are complete, a final verification step evaluates the biological, physical habitat, and water quality data. The sampling data from each site is reviewed for agreement with the pre-screening and site visit information. That is, information that indicates little or no human disturbance activity should yield sampling data that concur. If a disagreement between the amount of disturbance and the subsequent data is found (for example low disturbance but extreme temperatures, high sediment, alien species) that site is "flagged" as needing further review. A careful review of both the sampling data and the disturbance information will be performed on every flagged site.

A site is removed from the reference pool when closer examination documents a disturbance activity that was missed in earlier screens. A site will stay in the pool if no human disturbance can be documented even if the flagged parameter is atypical of other reference sites in that region.

Grading of Sites - Verification is completed with the assignment of a site classification grade (Table 3). The grade reflects the combined information of pre-screening, site visit and

verification evaluation. Sites assigned A, B, or C represent near natural, minimally disturbed, and best available (or marginal) reference sites, respectively. Sites assigned D, E, or F are sub-marginal, poor, and very poor streams (non-reference sites), respectively. The grade also formalizes that the site selection process has been completed.

Appendix 2 illustrates the biological condition versus the site grade in box-plot format. Both of the two biological indices (Index of Biotic Integrity and RIVPACS) show a decrease in biological condition with an increase in human disturbance. This data is from 1994 to 2003 and represents 697 vertebrate community samples and 407 benthic community samples. The median for the A graded sites in the vertebrate plot is influenced by the fact that a portion of these streams have only amphibians present and the IBI may not be performing as well in these streams types (non-fish bearing).

Table 3
Site Grading Descriptions

Grade	Description – Reference sites
A	Site represents ideal watershed and stream conditions, a **wilderness** area or watershed with **virtually no human disturbance**. These sites represent "natural" conditions and characterize biological integrity.
B	Site represents good watershed and stream conditions; **some human disturbances but not extensive**, and/or best management practices are well implemented. These sites represent "minimally disturbed" conditions and may characterize biological integrity.
C	Sites represent marginal watershed and stream conditions for a reference site. Human disturbance is present, but the site was the **best available for the basin/region**. These sites represent "least disturbed" conditions, and generally do not characterize biological integrity. These sites will be replaced if better quality reference sites are located.
	Description - Non-reference sites
D	Site represents sub-marginal stream and watershed conditions. **Considerable human disturbance** is present at **reach or** in large portions of the **watershed**.
E	Site represents poor stream and watershed conditions. **Considerable human disturbance** is present at **reach and** in large portions of the **watershed**.
F	Site represents very poor stream and watershed conditions. **Human disturbance** is **extensive throughout stream and watershed.**

Final Considerations

Sampling - We have used several approaches for the final selection of reference sites to sample. The primary approach has been to "hand-pick" sites using the GIS and BPJ information. We have also selected previously sampled randomly selected sites that, based on GIS and reach information, rank as reference sites. Finally, we have used a hybrid of the two approaches. In this case we begin the screening process and identify reference watersheds (6^{th} field HUCs) and then randomly select sites to sample from the selected watersheds.

In projects where the objective is to "hand-pick" reference sites, HDI score can be used to rank potential sites prior to sampling. Site ranking appears to be an efficient selection process. It allows for the ground-truthing of pre-screening information. It also helps identify non-target

sites and potential access issues. Sufficient sites are sampled to obtain good spatial distribution of regional natural gradients. The actual number of sites sampled depends on the objectives of the specific project and the relative quality of the sites.

Natural Disturbance versus Human Disturbance - The primary goal of establishing reference sites is to determine whether or not a stream is impaired. Streams affected by natural disturbance events, such as flood, fire or mass wasting of hillslopes could be mistaken for a human caused disturbance. Naturally disturbed reference sites will not be excluded from our development of a regionally based set of reference sites. The occurrence of naturally caused disturbances within a region will likely be infrequent and not significantly affect the outcome of stream assessments. Including naturally disturbed sites in any assessment should improve our ability to discern human caused from naturally caused impairment. The categorization of reference sites will include information on natural disturbance events. In practice these sites could range from those recently and obviously disturbed to those sites partially or completely recovered from a given event. At this point the goal is to track the influence of naturally disturbed sites on the overall outcome of stream assessments and the application of biocriteria.

Number of Reference Sites - The number of reference sites needed to fulfill the objectives of a bioassessment program depends on several factors. Ohio EPA has demonstrated that the relative homogeneity or heterogeneity of an ecoregion should dictate the number of reference sites per region (Yoder and Rankin, 1995). Regions with homogeneous landscape (e.g. Huron Erie Lake Plain) require fewer reference sites than more heterogeneous regions. Analysis techniques may also influence the number of sites needed. Finally sampling precision and accuracy and natural variability affect the number of sites needed. At present the goal is to obtain a minimum of 10-20 reference sites per region/gradient grouping.

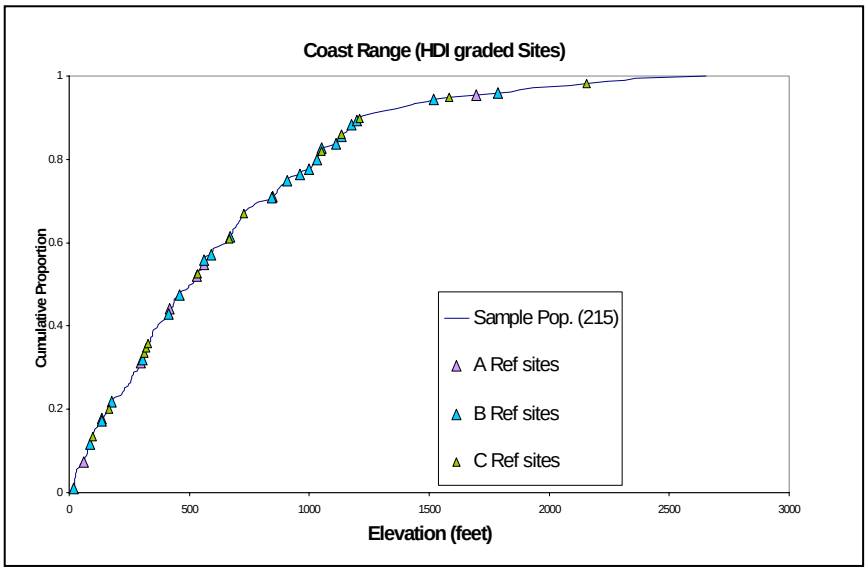


Figure 3 – Cumulative frequency distribution plot of Coast Range Ecoregion sites versus elevation. Subset of reference sites are shown as colored triangles.

Assuming nine ecoregions, three elevation gradient groups per ecoregion, and a minimum of ten sites per group would equate to 270 reference sites for the state of Oregon. This is a very conservative estimate in that some ecoregions are much larger than others and the natural gradient may not always be elevation. More analysis will be necessary to determine the appropriate number of reference sites needed for each region (Figure 3 example).

Frequency of Sampling - Related to the number of reference sites needed is the question of frequency of sampling. A subset of reference sites will be re-sampled annually. If analysis shows a significant shift in reference site conditions from past site data, then a resampling of reference sites may be needed.

Reporting - It is the intent of the Watershed Assessment Section to develop and publish a Reference Site Status Report every 3-5 years that includes the number, status, and trend of reference sites for each region of the state, analysis of natural disturbance effects on stream assessments, documents improvements or changes in the reference site selection process, and makes future recommendations.

Acknowledgments

I would like to thank the members of the Oregon DEQ Biocriteria Technical Advisory Committee. Special thanks to Phil Larsen and Bob Hughes for tolerating my steep learning curve; Rick Hafele for discriminant use of the cattle prod, and Dave Huff for all the Arcview hours he will never get back.

References

Bryce, S.A., Omernik, J.M. and Larsen, D.P. 1999. Ecoregions: A Geographic Framework to Guide Risk Characterization and Ecosystem Management. Environmental Practice 1 (3) September 1999 141-155

Bryce, S.A., D.P. Larsen, R.M. Hughes, and P.K. Kaufmann. 1999. Assessing relative risks to aquatic ecosystems: A Mid-Appalacian case study. Journal of the American Water Resources Association. 35:23-36.

Drake, D.L., 2003. Human Disturbance Index Reach (HDIreach) Checklist Procedures. Oregon Dept. Of Environmental Quality, Watershed Assessment Section. Portland, OR.

Griffith, G.E., J.M. Omernik, and A.J. Woods. 1999. Ecoregions, watersheds, basins and HUCs: How state and federal agencies frame water quality. Journal of Soil and Water Conservation. 54(4):665-677

Huff, D.D. 2003. Protocol for delineating catchments using Arcview. Oregon Dept. of Environmental Quality, Watershed Assessment Section SOP.

Hughes, R.M., and D.P. Larsen. 1988. Ecoregions: An approach to surface water protection. Journal of the Water Pollution Control Federation 60:486-493.

Hughes, R.M. 1995. Defining acceptable biological status by comparing with reference conditions. Pages 31-47 in W.S.Davis and T.P. Simon, editors. 1995. Biological assessment and criteria. Lewis Publishers, Boca Raton, Florida, USA.

Hughes, R. M., D. P. Larsen, and J. M. Omernik. 1986. Regional reference sites: a method for assessing stream potentials. Environmental Management 10:629-635.

Kagan, J., and S. Caicco. 1992. Manual of Oregon Actual Vegetation. Idaho Cooperative Fish and Wildlife Research Unit, Moscow, ID, 190 pages.

Kaufmann, P.R., P. Levine, E.G. Robinson, C.S. Seeliger, and D.F. Peck. 1999. Quantifying Physical Habitat in Wadeable Streams. EPA 620-R-99-003. U.S. Environmental Protection Agency, Corvallis, Oregon.

Omernik, J.M, and A.L. Gallant. 1986. Ecoregions of the Pacific Northwest. EPA/600/3-86/033. U.S. Environmental Protection Agency, Corvallis, OR. 39p.

Peck, D. V., J. M. Lazorchak, and D. L. Klemm (editors). 2001. Unpublished Draft. Environmental Monitoring and Assessment Program – Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams. EPA/xxx/x-xx/xxxx. U.S. Environmental Protection Agency

Stoddard, J. and P. Larsen. 2001 Unpublished Draft - EMAP's Proposed guidelines for selecting reference sites. U.S. Environmental Protection Agency, Corvallis, OR.

Thorson, T.D., Bryce, S.A., Lammers, D.A., Woods, A.J., Omernik, J.M., Kagan, J., Pater, D.E., and Comstock, J.A., 2003. Ecoregions of Oregon (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,500,000).

USGS, 2000. TIGER Road Density Files. Website: edc.usgs.gov/products/map/dlg.html

Vogelmann, J.E., S.M. Howard, L. Yang, C.R. Larson, B.K. Wylie, N. Van Driel, 2001. Completion of the 1990s National Land Cover Data Set for the Conterminous United States from Landsat Thematic Mapper Data and Ancillary Data Sources, Photogrammetric Engineering and Remote Sensing, 67:650-652.

Yoder, C. O. and E.T. Rankin. 1995. Biological criteria program and implementation in Ohio. Pages 109-144 in Davis W.S. and T.P. Simon (eds). Biological Assessment and Criteria: Tools for Water Resource Planning. CRC Press. Boca Raton, Florida.

Appendix 1

Oregon DEQ Watershed Assessment Section

Human Disturbance Index Reach Checklist

Stream Name: **SITE ID/STATION KEY:** **DATE:**

Crew: **Comments:** (Reconn or Sampling)

Activity Checklist: Circle all that apply

Agriculture-Urban					**Silviculture**				
CAFOs (Cattle,Poultry)	0	1	3	5	Logging Ops - Active	0	1	3	5
Channelization	0	1	3	5	Logging Ops -Recent (< 5 years ago)	0	1	3	5
Chemical treatment/Liming	0	1	3	5	Logging Ops -History (> 5 years ago)	0	1	3	5
Construction/storm water	0	1	3	5	Other:	0	1	3	5
Cropland	0	1	3	5	**Miscellaneous (Mining, recreational, etc.)**				
Dams	0	1	3	5	Angling pressure	0	1	3	5
Industrial plants/commercial	0	1	3	5	Dredging	0	1	3	5
Irrigation equipment	0	1	3	5	Dumping/garbage/trash/litter	0	1	3	5
Maintained Lawns/run-off	0	1	3	5	Exotic Plant species	0	1	3	5
Orchards, Tree farms	0	1	3	5	Fish stocking	0	1	3	5
Pavement/cleared lot	0	1	3	5	Hiking trails	0	1	3	5
Power plants/oil/gas wells	0	1	3	5	Mines/Quarries	0	1	3	5
Residences/buildings	0	1	3	5	Parks, campgrounds	0	1	3	5
Riprap/Wall/Dike	0	1	3	5	Primitive parks, camping	0	1	3	5
Sewage/pipes/outfalls/drains	0	1	3	5	Surface films/Odors	0	1	3	5
Water level Fluctuations	0	1	3	5	Other:	0	1	3	5
Other:	0	1	3	5	**Natural Disturbance**				
Rangeland					**Fire**	0	1	3	5
Cattle, Livestock use	0	1	3	5	**Flood Effects**	0	1	3	5
Pasture/Range/Hayfield	0	1	3	5	**Mass Wasting** (landslides)	0	1	3	5
Other:	0	1	3	5	Other:	0	1	3	5
Roads					**Legend -Proximity Score**				
Bridges/culverts/RR crossings	0	1	3	5	Activity **absent**			O	0
Railroads	0	1	3	5	Activity **present in watershed but > 10 meters from bank**			P	1
Roads paved/gravel/dirt	0	1	3	5	Activity **present within 10 meters from bank**			C	3
Other:	0	1	3	5	Activity **present on stream bank (or channel)**			B	5

Rank Score calculation (For each category, enter maximum proximity score)

Disturbance Category		
Agriculture & Urban	Maximum proximity score -------->	
Rangeland	Maximum proximity score -------->	
Roads	Maximum proximity score -------->	
Silviculture	Maximum proximity score -------->	
Miscellaneous (Mining, recreational, etc.)	Maximum proximity score -------->	
	HDIreach Score (sum) --------->	

Reference Site Candidate Category

Stream a candidate reference site? (Circle One) If no, state reason why	YES	NO
Best Professional Judgment Grade (Check one):		
A = Ideal watershed & stream conditions - **wilderness** area or watershed with **virtually no human disturbance**.		
B = Good watershed & stream conditions; **some human disturbances but not extensive**, and/or BMPs are well implemented.		
C = Marginal watershed & stream conditions for a reference site. Human disturbance is present, site is **best available for basin/region**.		
D = Sub-marginal stream & watershed conditions. **Considerable human disturbance** is present at **reach or** in large portions of **watershed**.		
E = Poor stream & watershed conditions. **Considerable human disturbance** is present at **reach and** in large portions of **watershed**.		
F = Very poor stream & watershed conditions. Completely **unraveled stream and watershed.**		

Methods/Forms/HDIreach Checklist Apr03