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Document No. WMP APp99002

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WATERSHED MANAGEMENT PROGRAM

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Document No.:	WMP App99002
WMS Project No.:	97001
Prepared for:	Watershed Management Project Management and Engineering Department of Public Works Municipality of Anchorage
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Problem Statement

Introduction

The Municipality of Anchorage (MOA) is undertaking a receiving water assessment to describe qualitatively the biological condition of waters with respect to human impacts and management practices over time. The overall Management Goal is to characterize Anchorage waterways in terms of potential and existing fish productivity. This task is referred to as the Bioassessment task (Task 4.2.3.3 of the NPDES permit). The specific task collects information from specific streams to characterize the streams' potentialities. The causes of each specific degradation will be assessed and reported for use in the overall Watershed Management (WSM) goals as part of the Watershed Characterization task (Task 4.2 of the NPDES permit).

The information gathered during the efforts of the Assessment Program will be integrated into the overall WSM strategy of continually refocusing on the worst pollutant sources and select the most efficient control practices. This information will be used along with other data gathered on watershed characteristics to identify the primary factors causing stream impairment with respect to biotic integrity. This information will also support modeling efforts that will examine possible options for future watershed management and protection strategies for improving water quality in MOA streams.

Management Problem and Use of Monitoring Information

Degradation of aquatic habitats by nonpoint source activities is recognized as one of the major causes for the decline in anadromous and resident fish stocks in the Pacific Northwest (Williams et al., 1989, Nehlsen et al., 1991).

The bioassessment program will help the MOA watershed managers characterize the aquatic biotic communities of discrete stream reaches for comparison to reference reaches and other stream reaches. Observations of Anchorage biotic communities will be described for the probable condition of local aquatic habitat relative to conventional interpretation of community conditions. Site specific stream reach biotic integrity factors shall be used to identify long term trends in the quality and character of stream biotic communities.

The information collected under this bioassessment program will be used as a direct measurement of stream ecosystem character. The development of long term time series of biotic indices will be part of this program. The Watershed Analysis project (Section 4.14. of the NPDES Permit) will also use this data in conjunction with in-stream, near stream, and drainage basin mapping information to link stream impacts to watershed activities and conditions for use in cost / benefits analysis of watershed management enhancement alternatives.

System Description

Landscapes and stream geomorphic features strongly influence aquatic habitat variables. Classification systems provide a way to partition and account for the variability observed in aquatic habitats as a result of these features. Ecoregions and stream classification systems provide a framework for organizing habitat components, habitat variables, and numeric indicators. Large scale ecoregions, Level III (1:250,000 scale) categorization may provide a sufficient first iteration for categorizing watersheds in order to evaluate potential reference conditions for many habitat variables. Further sub-division of ecoregion organization may be useful in providing a more homogeneous organization of watersheds but may also be a daunting task due to the limited amount of data on reference conditions. A nested hierarchical classification system provides a tool to categorize potential natural conditions and establish expected target conditions in which fish and aquatic communities have developed; yet a meaningful organization of stream networks ultimately depends on the identification of geomorphically similar stream reaches. Fundamental factors in organizing stream reaches are stream gradient, confinement, and stream power (bankfull width or basin area). The classification system used needs to incorporate these factors to be useful in developing a spatial framework for habitat indicators (EPA, 1999).

- The habitat indicator needs to be assessed at a spatial scale appropriate to the management or programmatic question, (i.e. stream reach). Habitat variables are generally measured at the habitat unit scale (e.g. pool, riffle, or glide), but they should also be assessed at the stream reach scale. While localized, site-specific factors can influence the habitat at the habitat unit level, comparison between stream segments or to reference watersheds should be done at the stream reach scale, a level of organization more meaningful to interpretation of external factors. The stream reach is defined by recognizable, geomorphic characteristics that influence habitat quality. Biological communities within reaches of streams reflective of common sets of in-stream, near-stream, and basin-wide factors, which could reasonable, impact those communities. These units can then be scaled up to address questions at the sub-watershed or watershed level. This mapping data will be collected under the Watershed Mapping task (Task 4.2.2 of the NPDES permit).

- Bioassessments may be used within a planning and management framework to prioritize water quality problems for more stringent assessments and to document "environmental

- recovery" following control action and rehabilitation activities (Plafkin, 1989). Some of the advantages of using bioassessments for this type of monitoring are:
- Biological communities reflect overall ecological integrity (i.e., chemical, physical, and biological integrity). Therefore, bioassessment results directly assess the status of a waterbody relative to the primary goal of the Clean Water Act (CWA).
- Biological communities integrate the effects of different stressors and thus provide a broad measure of their aggregate impact.
- Communities integrate the stresses over time and provide an ecological measure of fluctuating environmental conditions.
- Routine monitoring of biological communities can be relatively inexpensive, particularly when compared to assessing the cost of toxic pollutants, either chemically or with toxicity tests.
- The status of biological communities is of direct interest to the public as a measure of a pollution free environment, whereas reductions in chemical pollutant loadings are not as readily understood by the layperson as positive environmental results.
- Where criteria for specific ambient impacts do not exist (e.g., nonpoint source impacts that degrade habitat), biological communities may be the only practical means of evaluation.
- Assesses current character of the waterbody.

Bioassessment methods have a long-standing history of use for "before and after" monitoring. However, the intermediate steps in pollution control, (i.e. identifying causes and limiting sources), require integrating information of various types, such as chemical, physical, toxicological, and / or bioassessment data. These data are needed to:

- Identify the specific stress agents causing impact,
- Identify and limit the specific sources of these agents, and
- Design appropriate treatment to meet the prescribed limits and monitor compliance.

The emphasis of this specific bioassment task is to provide data on biota to be used in conjunction with data collected under other tasks. The entire data set will be analyzed under the Watershed Characterization task.

Problem Representation

Representation of the Critical Elements

Bioassessment will be a compilation of assessing biotic integrity. To assess biologic integrity, assessment of five interacting classes of factors must be approached: physiochemical conditions, trophic base, temporal variations, habitat structure, and biotic interactions.

There are four major characteristics to consider in assessing each class of factors as measures of environmental indicators, the indicator must:

1. Be relevant to the environmental / biotic endpoint,
2. Be applicable to the landscape and stream network in which they are used,
3. Be responsive to human-caused stressors, and
4. Exhibit adequate measurement and reliability and precision.

A compilation for each of these factors, some from each class, will be used to assess the biotic integrity of Anchorage waterways. Representatives of the five classes of factors that organize ecological systems and provide a framework for assessing ecological integrity are given below.

Physiochemical conditions include assessing one or more of the following factors: temperature, pH, insolation, nutrients, salinity, precipitation, oxygen, and contaminants. Many of these factors will be assessed in other tasks of the NPDES permit.

Trophic base conditions include factors such as: energy source, productivity, food particle size, energy content of food, spatial distribution of food, and energy transfer efficiency.

Temporal variations include diurnal, seasonal, annual, and flow regime variations.

Biotic interactions may include factors such as competition, parasitism, predation, disease, mutualism, and coevolution.

Habitat structures include spatial complexity, cover and refugia, topography, soil composition, vegetation height, vegetation form, basin and channel form, substrate composition, water depth, and current velocity.

Three routinely measured habitat variables – large woody debris frequency, pool frequency, and residual pool depth – are used to evaluate the component of habitat categorized as Habitat Space and Channel Structure. These habitat variables also serve to evaluate flow effects, since the alteration of water quantity is manifested in the change in channel habitat space. Large woody debris and pool frequency are relevant to aquatic biota, are representative of human impacts over the long term, and can be measured quantitatively.

Salmonid species in forested ecosystems have evolved in streams in which large woody debris plays a major role in forming habitats, providing cover, influencing sediment processes, and altering stream energy and nutrient cycling (EPA, 1999). Pool frequency is a critical indicator of habitat space, and residual pool depth is a quantitative measure of pool quality influenced by flow alteration and sedimentation.

Fine sediment deposited in critical spawning habitat has a demonstrated effect on reducing egg-to-fry survival and can fill in the voids in substrate utilized by juvenile fish as cover. However, there are unresolved questions regarding the applicability of field measurement protocols, their precision, and the interpretation if this kind of data in relationship to laboratory defined sediment impacts. While a large body of literature supports the fact that fine sediments are detrimental to salmonid and other aquatic biota, remaining questions about the adequacy of field methods and their comparability to laboratory studies need to be resolved.

A similar consideration applies to the current evaluation methods for rating bank stability. Naturally stable banks result from the protection afforded by bank material and protective riparian vegetation which resists the force of flowing water and are recognized as providing important space for hiding cover for fish. The majority of bank stability methods involve a subjective rating of some combination of vegetative cover, bank material, and evidence of slumping or sloughing. The concern with the current bank stability evaluations is the subjective nature of the measurement system (EPA, 1999).

The assessment of these classes of factors will be completed amongst the various NPDES tasks, with an overall biotic assessment being completed as part of the Watershed Characterization Task. The bioassessment task will focus primarily on macroinvertebrate assessment as a watershed indicator.

Problem Resolution

Understanding the purpose of the rationale for addressing habitat within the CWA is the initial step in selecting applicable indicators. Two different, but related, objectives for habitat indicators are evident in CWA programs. The first is the assessment of the status of the aquatic environment in supporting beneficial uses. The second is to gauge the effectiveness of management practices in preventing pollution and protecting beneficial uses. These objectives can entail the selection of different sets of indicators (Karr, 1997).

The goal of the CWA is to "restore and maintain the chemical, physical, and biological integrity of the nation's waters." James R. Karr, Ph.D. highlighted the shortcomings of relying solely on nonbiological measures, such as chemical quality, to evaluate attainment of this goal. Since that time EPA and state agencies have increased efforts to incorporate biological criteria and bioassessment into the water quality programs (EPA, 1999).

Bioassessment results can help to evaluate the overall condition of streams. Bioassessment can also be used as an educational tool to provide and demonstrate basic information about watershed health. Results can be used for several purposes: to establish baseline characteristics, to identify potential stressors to water quality, to target areas for more intensive testing efforts, to support land use planning and zoning management decisions, and to prioritize areas that warrant special protection, restoration, or rehabilitation. Because environmental conditions in Alaska are different than in other areas of the United States, these differences have been considered in the development of specific sampling methodologies tailored to our environment. Some of these differences include limited types of organisms and diverse microclimates and streams.

Project Approach

The scope of work for the Bioassessment Task (Task 4.2.3.3 of the NPDES permit) includes the following major elements:

- Survey of macroinvertebrates and possibly other biota using RBP or IBI protocols,
- Use the results for specific stream habitat factors to represent larger stream reaches for biota.

Related elements will be collected during other watershed tasks that will be used in the overall Watershed Assessment. These related elements include:

- Sample selected Anchorage streams for representative biotic integrity components,
- Identify specific anthropogenic sources to stream degradation indicators,
- Quantify the cost/benefit analysis to restore specific stream degradation factors.

To implement biological criteria, formal methods for sampling the biota of streams, evaluating the resulting data, and clearly describing the condition of sampled stream reaches are needed. James R. Karr, Ph.D. has developed a measurement system, called the index of biological integrity (IBI), to fill this need. The complexity of biological systems, and the varied impacts humans have on them, require a broadly based, multimetric index that integrates information from individual, population, and assemblage levels.

Bioassessments can involve a variety of components of the stream biological community, including algae, benthic macroinvertebrates, and fish. Monitoring each of these components has it's own advantages, and they all have published protocols. The WSM bioassessment will focus on macroinvertebrates. Macroinvertebrate communities tend to have greater diversity than fish communities in the same stream, which makes evaluation with some community diversity and integrity metrics more meaningful. Also, the natural integrity of fish communities is often compromised by sport fishing, stocking of sport fish, and the introduction of exotic species. Macroinvertebrates are fairly stationary, easy to collect, and are of interest to the fishing public as fish food. In addition, the relative sensitivity or tolerance of many macroinvertebrates is well known.

IBI can be used to assess benthic macroinvertebrates. IBI, like conventional economic indexes such as the index of leading economic indicators, provides a convenient measure of the status of a complex system. Both require an index time or baseline state against which future conditions are assessed. For IBI, that baseline of biological integrity, is the condition at a site with a biota that is the product of evolutionary and biogeographic processes in the relative absence of the effects of modern human activity.

IBI metrics are chosen because they reflect specific and predictable responses of the stream biota to human activities across the landscapes those streams drain. These responses are similar to dose-response curves measured by toxicologists; an organism's response varies with the dose of a toxic compound. Because they provide an integrative measure of the cumulative impacts of all human activities in a study watershed, IBI metrics can be viewed as ecological dose-response curves. IBI is based in empirically defined metrics because (1) such metrics are biologically and ecologically meaningful; (2) they increase or decrease as human influence increases; (3) they are sensitive to a range of stresses; (4) they distinguish stress-induced variation from natural sampling variation; (5) they are relevant to societal concerns; and (6) they are easy to measure and interpret (Karr, 1997).

IBI metrics evaluate species richness; indicator taxa (stress intolerant and tolerant); relative abundances of trophic guilds and other species groups; presence of exotic species; or the incidence of hybridization, disease, and anomalies such as lesions, tumors, or fin erosion (fish) and head capsule abnormalities (stream insects).

To determine an IBI for a stream, metric values from the stream are compared with values expected for a relatively undisturbed stream of similar size in the same geographic region. Each metric (or as discussed earlier, factor) is assigned a value of 5,3, or 1 depending on whether its condition is comparable to, deviates somewhat from, or deviates strongly from the "undisturbed" reference condition. Metric scores are then summed to yield an index (based on 12 metrics) that ranges from a low of 12 in areas with no remaining fish to 60 in areas with fish faunas equivalent to those in pristine or relatively undisturbed areas.

An important key to successful restoration, mitigation, and conservation efforts is having an objective way to assess and compare the biological integrity of damaged sites. IBI provides a tool for doing so and, at the same time, allows managers to set specific biological integrity targets for restoration programs (Karr, 1997).

For each metric condition that scores a 1 or 3, the cause for that degradation shall be linked to a specific source or condition.

Scheduled activities shall include:

- Year 1:
  1) design
- Year 2 (in sequence with Watershed Mapping, Hydrology and Receiving Water Chemistry tasks):
  1) first year field sampling,
  2) graphic data analysis, and
  3) data report,

- Year 3 (allowing calibration of first year data):
  1) second year field sampling,
  2) graphic data analysis, and
  3) final data report.

A similar data collection sequence for other watersheds is anticipated to take place over a five to ten year cycle in the following permit terms.

Project Network Locations

Monitoring Station Selection

Prior to sampling, possible sampling sites will be identified using topographic maps. In most cases, sites should be easily accessible for sampling. In all cases, sites should be wadable and safe for sampling. Nonpoint source discharges documented through other programs will be identified in order to locate the exact positions of point source discharges, so that these areas can be avoided. Previous studies will also be reviewed to locate historical data and sampling stations. A list of potential sites will then be generated with potential sampling locations marked on the map (Majors, 1998).

Site selection and sampling involves collecting and analyzing a small portion of the total population and then extrapolating these results to describe the total population. Statistically valid sampling requires that the samples be randomly collected, representative of the larger population, and that the results of the sampling are repeatable.

Two types of sites will be selected in the bioassessment survey. These are 1) impacted sites that are influenced by some land or pollution (impacts can be from both point source and nonpoint source), and 2) reference sites that reflect the least impacted conditions possible. An ideal reference site would be in pristine, natural condition. A realistic reference site usually represents the best attainable conditions and has experienced some level of human affect.

The sampling sites should be representative of 1) different degrees of urbanization (pristine, low-density development, and high-density development), 2) different stream types (land use, geology, and gradient), 3) provide a range of stream conditions from good to poor, and 4) identifiable sources of biotic degradation.

The sampling stations (specific reaches and sub-reaches) will also be linked with, and based on, information collected from the Watershed Mapping task to be completed in the year 2000. Representative locations include sampling 25+/- sites along Rabbit, Ship, Chester, and Campbell Creeks. One or more additional creeks will be sampled in Eagle River and/or Girdwood.

Stream habitats will have different macroinvertebrate communities, habitat conditions, and chemical water quality at different times of the year. The bioassessment surveys for this task shall be done over two years, so it is important to replicate sampling at the same time of year to make year-to-year comparisons. Each site should be sampled with proper QA/QC procedures. Sampling will be conducted during periods of low flow over a two or four week period beginning in mid-May.

Sampling Procedures for Macroinvertebrates

Method Overview

The goal of the field sampling technique is to collect an unbiased, random, representative sample of macroinvertebrates from the stream. The following procedure is based on the Oregon Department of Environmental Quality Stream Bioassessment Protocols for Macroinvertebrates (revised 1997). Representative sample habitats are selected from a stream reach of 30 channel widths or less. From within this reach two riffles and two pools are chosen. Two 0.18 square meter (2 square feet) kick samples are randomly selected in each of the four habitat units. The four kick samples from each separate habitat type are composited to make a single macroinvertebrate sample for that habitat. Each site will have one riffle and one pool habitat composite benthic samples to preserve and bring back to the lab for further processing.

EQUIPMENT

- Tape measure, 100 feet
- Random number table, or other random number generator
- Kick net, 30 cm. Wide D-shaped hoop net with 500 micrometer mesh opening and long handle
- Plastic sieve bucket with a 500 micrometer mesh bottom
- Plastic jars with tight fitting lids or zip-lock bags, 0.5 to 1.0 liter
- Denatured ethanol
- Labeling tape and alcohol-resistant marking pens

Macroinvertebrate Sampling Procedure

1. Stretch the tape measure along one bank of the pool or riffle.

2. Randomly select two sample collection sites. A four digit random number generator is best. The first two are the number of feet along the tape and second two are the percent of stream width where the sample is located. For example, a random number of 3225 would place the sample at 32 feet along the tape measure and one quarter (25%) across the stream width.

3. Place the net into the stream with the flat part of the hoop resting on the bottom and perpendicular to the stream flow. Collect the macroinvertebrate sample by disturbing a 30 by 60 centimeter area of stream bottom directly in front of the net so that the current carries the macroinvertebrates into the net.

4. Substrate larger than five centimeters is rubbed carefully by hand in front of the net to dislodge any clinging macroinvertebrates. After rubbing, the substrate is placed outside the sample plot.

5. The remaining fine substrate is thoroughly disturbed to a depth of five to ten centimeters with the hands or feet.

6. Collecting a sample in slow moving water is a little more difficult. It may involve pulling the net through the water as the substrate is disturbed to capture suspended organisms.

7. After the sample is collected and the net removed, the large substrate is returned to the sample plot.

8. The contents of the net are placed in a sieve bucket and the sampling procedure is repeated at three more plots. The preferred order for sampling is from downstream to upstream.

9. All four stream bottom samples for the same habitat type are composited in the sieve bucket. Large organic material and rocks are rinsed, carefully inspected for clinging macroinvertebrates, and removed. As much fine sediment as possible is washed away. Leaf packs from pool samples may require considerable rinsing and removal of debris before preserving the composite sample.

10. The composite sample is placed in a labeled jar or double zip-lock bag and preserved with 90% ethanol for sorting and subsampling in the lab. It is recommended that the alcohol in the composited sample be changed after about one week to ensure adequate preservation. A paper and pencil label inside the jar is recommended as well as an exterior label.

11. Rather than preserving the composite sample for processing in the lab, the composite sample can be sorted in the field. The sorting methods are similar. Field sorting is faster since live, moving specimens are easier to see. Field sorted macroinvertebrates also tend to be in better condition than lab sorted specimens, making identification easier. The disadvantage to field sorting is that it can take a lot more time, especially in low productivity streams.

Sub-sample and laboratory sorting shall be in accordance with generally accepted scientific methods.

Quality Assurance

Quality assurance procedures (QA) assess the environmental variability, sampling procedures validity, repeatability of the sample methods, and identification quality. The quality assurance procedures involve a system of following standard methods and protocols, duplicate sampling, and identification reviews.

FIELD QA SAMPLING

Ten percent of all stream sites sampled or one sample per survey (which ever is greater) have a duplicate set of field samples collected. The duplicate sample is from the same sample reach. This is called a field quality assurance sample (FQA). Field QA samples look at the natural variability within a riffle and ensures that the field sampling method is repeatable.

LABORATORY QA

Ten percent of all composite samples, or one sample per survey (which ever is greater) is resorted for an additional 100 specimen sub-sample from the original preserved composite sample. The result is duplicate samples from the same composite. This is a laboratory quality assurance sample (LQA). Lab QA samples look at the variability inherent in the sub-sampling method, and ensures that the sub-sampling method is repeatable. The sample is identified as described above.

TYPE COLLECTION

A macroinvertebrate type collection will be maintained for each major basin or ecoregion studied. This collection will have a representative of each taxon and will serve to act as a basin record and as a reference for checking identifications.

IDENTIFICATION REVIEW

The senior aquatic entomologist will review all sample tally sheets for anomalous identifications. Ten percent of the samples are reidentified and counted by a senior aquatic entomologist independently of the first identification.

Index of Biotic Integrity

The complexity of biotic systems dictates that integrity assessments should incorporate a variety of indicators from multiple organizational levels and spaciotemporal scales. The index of biotic integrity (IBI) represents a successful approach for incorporating information from multiple indicators (metrics) into a single numeric index. An IBI for specific reaches will be calculated based on the macroinvertebrate assessment and metric analysis from other NPDES permits tasks. The numerical criteria on species composition and diversity, trophic composition, population density, tolerance to human impacts, and individual health to assess the integrity of lotic fish communities.

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