YUKON PLACER SECRETARIAT

Fish Habitat Management System for Yukon Placer Mining

Aquatic Health Monitoring Protocol

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1. 0 AQUATIC HEALTH MONITORING PROTOCOL

1.1 INTRODUCTION AND OBJECTIVES

A new system for managing placer mining activity under the *Fisheries Act* is being implemented by the Yukon Placer Secretariat. Founded on principles of adaptive management and incorporating a risk-based approach to decision-making, the Fish Habitat Management System for Yukon Placer Mining is intended to balance the objectives of a sustainable Yukon placer mining industry with the conservation and protection of fish and fish habitat supporting fisheries.

As part of the new management system, a set of protocols have been designed to guide three effects-monitoring programs. These are the Aquatic Health Monitoring Protocol, the Water Quality Objectives Monitoring Protocol and the Economic Health Monitoring Protocol. The monitoring programs will assist in verifying the effectiveness of the management system in meetings its objectives and provide a rational basis for future changes, if appropriate.

The Aquatic Health Monitoring Protocol has been designed to assess how effective the new management system is for maintaining aquatic health for fish and fish habitat, and to generate monitoring results which will be used in the adaptive management framework assessment and adjustment phases.

The aquatic health monitoring program has been closely integrated with the water quality objectives (WQO) monitoring program. This combination goes beyond coordinating monitoring activities for logistical reasons. The water quality objectives and thresholds serve as an indicator of aquatic health, and are based on the best, currently available science to maintain overall stream health. Comparisons between the results of aquatic health monitoring and WQO monitoring are an obvious but important step in assessing whether the WQO thresholds lead to healthy streams. Data from the WQO monitoring program will also be important to review when evaluating sites that appear to be affected.

1.2 KEY QUESTIONS TO BE ADDRESSED

1. **Are there stream systems and watersheds exposed to placer mining where aquatic health is not being maintained in reference condition (i.e. the same condition as streams not exposed to human activity)?**

   It is important that the findings of the aquatic health assessment and monitoring can differentiate between streams that have been affected by placer mining activity and those affected by either natural causes or some other activity.

2. **Are the test sites in habitats of higher sensitivity in reference condition?**

   While most decisions under the Adaptive Management Framework will be made at the watershed scale, little or no risk is tolerated in these habitats and all test sites are expected to be in reference condition.

3. **Are there watersheds and streams where the Water Quality Objectives (WQO) are being exceeded to a significant degree, but aquatic health is in reference condition?**

   This circumstance could allow for changing the WQO so that sediment discharges could be higher where there are placer mining viability issues.

4. **Are there watersheds and streams where WQO are being met consistently, but aquatic health is not being maintained in reference condition?**

   Under these circumstances, the WQO threshold may need to be lowered in order to help maintain aquatic health in reference condition.

5. **Where historically mined sites are not in reference condition is there an overall improvement over time?**

   For habitats of higher sensitivity this would be based on the condition of individual test sites, while for moderate to low sensitivity habitats the trend in condition of a number of sites in a watershed would be considered.

1.3 SAMPLING DESIGN

After consideration of a number of methods, the Reference Condition Approach (RCA) has been selected for assessing and monitoring aquatic health. There are a number of reasons for this choice:

- It is the most robust of many bio-monitoring methods which makes it useful as a predictor of aquatic health across Yukon watersheds with differences in environmental conditions.

- It is the basis of several national and programs in Canada (it is an accepted design under the federal Environmental Effects Monitoring program), several USEPA programs in the United States, national programs in Australia and the United Kingdom, and has been adopted under the European Water Directive.

- An RCA program has been underway in the Yukon for a number of years that could be immediately applied to the placer mining areas and augmented by future field work.

- Preliminary analysis indicates that RCA models developed for the Fraser River over the last 10 years will be applicable with some modifications to the Yukon context.

The RCA involves collecting data from a number of stream sites that are relatively unexposed to stressors (reference sites), determining the range of variability in their environmental conditions, and correlating variations in biota with variation in natural environmental conditions. Models can then be applied to data collected from sites known to be exposed to stressors (test sites) to determine if the sites fall inside or outside the expected range of variability for reference sites. Test sites are considered to be in "reference condition" if they have close to the expected value of the biota descriptor (Figure 1.). If the test site does not have close to the expected value of the biota descriptor it is considered to be outside the reference condition and requires further study to conclude true impact (Figure 1). This more detailed look at the site will allow a better characterization of the nature of the stressor(s) affecting the stream.

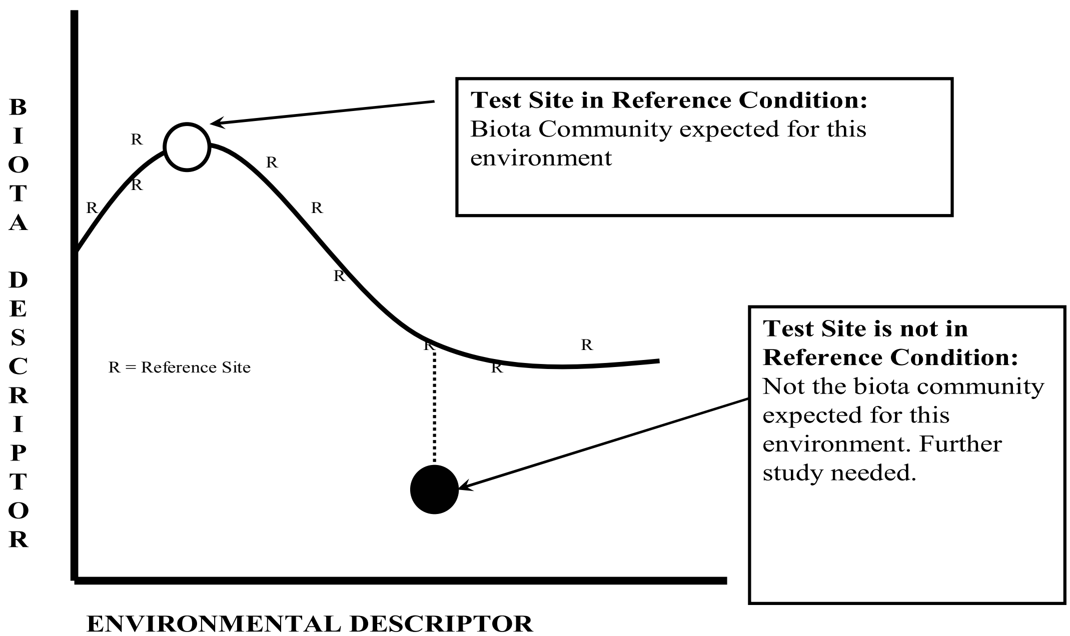

Figure 1 – The "R"s represent reference sites that have been sampled and used to build a predictive model. The white circle represents a test site found to be in reference condition (it has the biota expected, given its environment) while the black circle shows a test site not in reference condition (it does not have the biota expected, given its environment) that requires further study. (Adapted from Bailey et al. 1998).

Program Steps:

The Aquatic Health Monitoring program has seven steps that will be carried out on an annual basis, explained in greater detail below:

1. Assemble and review existing site data and select priority reference and test sites for sampling during the upcoming placer mining season.

2. Collect GIS and other available data for all potential sample sites.

3. Collect field data.

4. Develop RCA models.

5. Apply models to test sites and determine which are in reference condition and which are not.

6. Carry out additional study of any test sites determined to be outside the reference condition and compare RCA model results with water quality monitoring results. Provide input to assessment and adjustment phases of adaptive management framework as required.

7. Prioritize sites for sampling in the upcoming season based on the RCA model and water quality monitoring results, the need for additional reference site coverage and investigation of annual or seasonal variations. Consider modifications of the program based on recent relevant research.

1.3.1 SPATIAL DISTRIBUTION OF SAMPLING

Available data is gathered for all sites sampled in accordance with the methods outlined in Appendix 1. Data is reviewed for completeness and additional relevant information (e.g. GIS data) assembled. The locations of all sites considered to be in reference condition will be plotted on maps to determine where sites should be sampled in future years to provide adequate coverage. Existing data that has been identified to date include sampling by the University of Western Ontario in 2002 – 2005 inclusive, some of the Bio-Monitoring Information System for the Yukon (BISY) data, and data collected annually by Yukon Department of Environment and Department of Fisheries and Oceans personnel in 2004 to 2008.

A powerful approach to the design of a bio-assessment study is to stratify the allocation of sampling effort so that all watersheds, stream reaches and eco-regions that contain potential test sites are adequately represented in the set of reference sites. This strategy should be used in this case, since this will strengthen the effectiveness of the RCA models by capturing a broader range of natural variation in the reference sites and enable application of the models to test sites exposed to placer mining in all parts of the territory. Watersheds, stream reaches and eco-regions should be identified where there are few or no previously sampled reference sites. Sampling effort can then be directed towards these gaps in our knowledge of natural variation (e.g. there are few previously sampled sites in the McQuesten River watershed so this is a priority area for sampling reference sites).

In choosing reference sites to sample, a second level of stratification should insure that in a given sampling watershed, stream reach and eco-region, all types of streams (in terms of size, basin area, geology, and other natural attributes) that are affected by the stressor(s) of interest are included. Stream types and their biota that are underrepresented should be identified and a priority can be placed on selecting sites with the underrepresented stream environments.

Once priority regions have been identified, stream catchments within those regions are delineated using a GIS. Reference sites are identified *a priori* by identifying sites on streams with upstream catchments that are not known to be exposed to any anthropomorphic stressors (e.g. mining, timber harvesting, road building, or urbanization). This identification can be done by consulting with people familiar with the area and through GIS analysis. Final selection of reference sites should be coordinated closely with the WQO monitoring program to ensure that at least some reference sites are subjected to more intense water sampling and to coordinate timing and logistics to the extent possible. There may also be sites considered to be “points of interest” that would place a higher priority on their use as reference sites.

The selection of test sites should also be done by working closely with the WQO monitoring program. GIS analysis can identify the existence of placer mining claims in stream catchments and additional investigation must be done by consulting local mining inspectors and others regarding expected placer activity in selected areas. Sites where there is a stream class change may be accorded a higher priority or there may be test sites considered “points of interest” by First Nations, industry, government agencies or non-governmental organizations that would receive priority attention for sampling.

In the preliminary stages of the program (2006 and 2007), priority was placed on sampling reference sites to improve the models that will be applied to test sites. However, a significant number of priority test sites exposed to placer mining were sampled as well. Priority test sites are located in watersheds and stream reaches that have a history of extensive placer mining over long periods and should exhibit the greatest deviation from the reference condition. These initial priority test sites will be used to determine the effectiveness of the RCA approach in consistently detecting deviations from the reference condition at the most affected test sites. The ability of the RCA to detect smaller deviations from the reference conditions will then be investigated at less affected test sites. It will also be important to re-sample some reference and test sites each year to measure the magnitude and nature of their annual variation.

Final site selection will need to consider access and other logistics, coordination with water-quality monitoring, priority of stream systems for fish and avoiding duplication with other recently initiated sampling projects.

The sampling crew(s) should go into the field with at least 25% more potential sites than they intend to sample. This excess will allow for in-the-field decisions not to sample a site for access or other reasons.

RCA models are improved when more reference sites are used for their development. Modeling on a regional or sub-catchment basis should only be considered where analysis of the entire dataset indicates that the region is distinct environmentally and biologically, and there are enough reference sites to adequately characterize the reference condition.

Where test sites are found to be outside of reference condition, they should be re-sampled in subsequent years to provide greater insight into the nature, extent and duration of the impacts. Water-quality sampling should also be increased for these streams, if necessary. Environmental data collected can be used to determine or narrow down the reasons sites are not in reference condition, thus providing guidance for possible mitigation or restoration measures.

In this type of study, the assumption is made that what is observed of the stream and biota communities during sampling is reflective of its condition throughout the year. To investigate this assumption, it is important that a number of sites (reference and test) are sampled over more than one year and at different times of the year.

1.3.2 TEMPORAL DISTRIBUTION OF SAMPLING

Although there is variation in the flow regimes in Yukon River basin tributary and stream systems, most in the Yukon River catchment flood in late spring, with discharge tapering off through the summer with occasional increases in discharge in late August or September. Most previous sampling that has included collection of BMI and fish has been conducted from about the beginning of the second week of July through to the first week of August. It is important to be consistent in terms of timing. **Sampling will take place over a 3-week period beginning no earlier than the second week of July and extending no later than the start of the second week of August.**

1.3.3 SAMPLING FREQUENCY

Sites are sampled once per season. Repeat sampling at a site may occur (following site selection consideration noted in section 1.3.2) to investigate annual variation or to follow up on sites determined to be out of reference condition.

1.3.4 DATA COLLECTION

Field data collected during sampling visits include fish (number and species), benthic macro invertebrates (samples collected for laboratory identification and counting), basic water chemistry (pH, temperature, conductivity, dissolved oxygen), stream dimensions (width, depth and flow) and an in-stream and riparian zone habitat assessment. In addition to the invertebrates collected for subsequent laboratory analysis, water samples are also collected for laboratory analysis for nutrients, physical and chemical properties and metals.

There are many techniques available for field data collection. Consistency in methods is key and people sampling must take care to adhere closely to the details (this is where protocols are critical so that there is written documentation of the methods employed). Most sites sampled since 2002 (and virtually all reference sites) have been sampled using the methods detailed in Appendix 1, and these will be used in this program. It is critical that all samplers are proficient in the use of this methodology and that QA/QC protocols and procedures are applied to all phases of data collection, analysis and management on an ongoing basis as outlined in section 1.5.

All data collected will be checked, transferred to a database and routinely backed-up for subsequent analysis. This database will be updated with data generated after the sampling visit (e.g. invertebrate identification, water analysis, GIS data, placer mining activity verification).

A considerable amount of data for sites can be assembled before field data collection takes place, including GIS data available through Yukon Geomatics, such as catchment morphology, forest fire history, bedrock and surficial geology, and land cover (e.g. percent of the catchment that is forest, meadow, alpine, etc.). Assuming the catchments for potential sites have already been delineated in the site selection process, it is a relatively simple matter to collect these other data, either before or after the sampling season. A protocol for delineation of watersheds and determining other characteristics is provided in Appendix 2.

1.4 DATA ANALYSIS

1.4.1 INDICATORS

The indicators of aquatic health and quality of fish habitat are descriptors of the fish and benthic macro invertebrate communities such as taxon richness (the number of species or taxonomic groups) or ordination scores (based on the proportional composition of the community). If a site is sampled and the biota predicted through RCA modelling is found, that site is considered to be in reference condition. If the predicted community is not found, further investigation is warranted to determine if the site has been affected and if these effects are due to placer mining activity. This is detailed in following sections.

ANALYTICAL METHODS

Once all data have been collected and catalogued, the first step in developing RCA models is to build a relationship between the biota and their natural environment at reference sites. There are two basic approaches to this (Bailey et al. 2004):

Classification

- Group the reference sites on the basis of their biota (e.g. BMI or fish communities) with a statistical classification technique and create faunal groups.

- Use stepwise Discriminant Function Analysis (DFA) with the environmental descriptors from each reference site to allow prediction of a site's faunal group based on its environment.

Regression

- Use stepwise multiple regression to allow prediction of a descriptive index of a reference site's biota based on its environment.

With each approach, the candidate environmental descriptors (e.g. bedrock geology) in the predictive models must be unaffected by human activity. A descriptor affected by human activity (e.g. suspended solids), even if applied only to reference sites in model building, will be inappropriate for predicting the biota that a test site with a given environment would have if it was in reference condition.

The RCA models should be re-calibrated each year to take advantage of additional reference sites and to repeat sampling of a small number of reference sites. Year to year temporal variation in the biota at reference sites must be included in the predictive model, although caution must be exercised in identifying longer term and larger spatial scale trends in the reference condition because of factors like climate change and long range transport of air pollutants (LRTAP).

Once the RCA models are built using sites that are not exposed to human activity, they are applied to test sites (sites exposed to some level of stressors). Both the classification and regression approaches described above lead to a prediction of the biota expected at a test site if it is in reference condition. This is summarized as either the ratio of an observed to expected value for a biota descriptor (O:E score) or the difference between the observed and expected value (O-E residual). Depending on the biota descriptor, test sites in either the upper or middle range of the scores are considered to be in reference condition. For example, if the biota descriptor is fish species richness, test sites that have either many more species (high value of O-E residual) or substantially fewer species (low value of O-E residual) than expected given the natural environment will be considered to be outside of reference condition.

No model will perfectly predict the biotic of a site in reference condition, so it important to consider how close the observed value at a test site must be to the predicted value for one to conclude that the site is or is not in reference condition. The management action consequences of judging a site to be either in or out of reference condition should be considered. For example, concluding that a test site is in reference condition will mean that it is only periodically monitored. The consequence of concluding that a site is not in reference condition might be detailed study of the site to confirm this decision and identify potential causes of the deviation from reference condition. If a site is actually not in reference condition (but sampling concludes that it is; known as a Type II error), there is an opportunity to elucidate why it is not and how the impacts might be managed. If a site is in reference condition but sampling concludes that it is not (a Type I error), resources will be wasted in further detailed sampling and analysis of the site.

In establishing the appropriate values for Type I and Type II error, consideration will be given to the level of habitat sensitivity and risk associated with the test site. For habitats of higher sensitivity the probability for Type I error (a site is in reference condition but the sampling concludes that it is not) will be set higher than for sites of low sensitivity habitats. The levels for Type II error (a site is not in reference condition but the sampling concludes that it is) will be set lower for high sensitivity habitats than for low sensitivity habitats. This is consistent with the risk assessment approach and the assumption that the risk of error is greater for habitats of higher sensitivity than for low sensitivity habitats.

Sites that the RCA models consider to be outside the reference condition will be more closely examined to determine what caused that outcome and, specifically, whether there is evidence of an impact from placer mining activity. Other data collected during sampling visits (e.g. habitat scores and basic water chemistry) should be reviewed to see if a cause is readily determined. Models of the changes in deviation from reference conditions (O-E residuals) with changes in stressor levels reflected by environmental conditions (e.g. water quality) may provide evidence of how the stressor(s) have affected the biota. Also, characteristics of the biological communities can be examined in light of general understanding and numerous studies that consider and quantify sensitivities of the organisms. For example, composition and relative abundance of invertebrates can give a clear picture of what characteristics of the environment are affecting the biota. These follow-up evaluations can help to determine if a site outside the reference condition is, in fact, impaired by placer mining or if there is some other explanation for the condition of the stream.

The RCA modeling results will be compared with those from the Water Quality Objectives (WQO) monitoring program. It is important to identify streams that the RCA models show to be in reference condition where WQO have been exceeded as well as streams the RCA models show to be outside reference condition where WQOs have not been exceeded. If either of these circumstances occurs on a widespread or repeated basis, the WQO and allowable sediment discharge standards will need to be re-examined and reconsidered.

1.5 QUALITY ASSURANCE (QA)/QUALITY CONTROL (QC) PROCEDURES

The need to develop and integrate QA/QC procedures and manuals into data collection, data input and data analysis is recognized. This is especially important as multiple agencies and different samplers will be involved in various aspects of the program over time. This will involve the development of field sampling manuals and standardized procedures and data requirements, and regular training of staff. There are already well established QA/QC procedures associated with critical areas of the aquatic health monitoring program, such as the laboratory analysis of benthic invertebrate samples, the input of data into the data base, data analysis for the RCA approach and the use of the Canadian Aquatic Biomonitoring Network (CABIN) and its tools. Close coordination and planning between field crews for aquatic health and water quality objectives monitoring will assist in the consistent application of QA/QC procedures.

1.6 WHAT THE PROGRAM PROVIDES TO THE ADAPTIVE MANAGEMENT DECISION-MAKING PROCESS

Following detailed examinations of sites that are not in reference condition, an annual report will be prepared that includes a list of streams and watersheds where aquatic health is considered to be impaired by placer mining activity. While determining a site is affected after one sampling indicates there may be a problem and follow-up is warranted, such results must be seen as a pattern in multiple years for further action to be taken under the adaptive management process.

Furthermore, the adaptive management process will not normally be applied on a site by site basis but will consider the overall conditions of test sites within a stream reach or watershed. An exception to this are test sites located in habitats of higher sensitivity. Criteria will be established on a watershed level to determine whether aquatic health is being maintained. For example, test sites in habitats of higher sensitivity are expected to be in reference condition 100% of the time.

Where such criteria are not met for an individual site or at a stream reach or watershed level and the WQO monitoring reveals a pattern of WQO being exceeded and this can be attributed to mining activity, steps will be considered under the Adaptive Management Framework to bring water quality in line with objectives. Changes to WQO under the adaptive management process will be considered in instances were there is a pattern of failure of test sites over a period of 3 or more years but where WQO monitoring data indicates that water quality objectives are consistently being met over the medium (3-5 year) term.

The determination and monitoring of trends in aquatic health under the new system over the medium to long term for individual mined watersheds and overall for all mined watersheds is an important consideration. There is some indication that aquatic health improved under the *Yukon Placer Authorization* (YPA) since 1993, based on increased utilization by juvenile Chinook and increased diversity of fish species in heavily minded watersheds such as the Indian River, as well as Hunker and Bonanza Creeks. While the largest gains in aquatic health may well have been achieved under the YPA, it is anticipated that these improvements will be maintained and continued under the new management system (given its stricter discharge standards, improved site management requirements and an early detection and response mechanism for failing settling ponds under the Action Level approach. The most sensitive and most useful trend indicators for aquatic health will be at a watershed level, where the changes of all test sites in the watershed are monitored over the medium to long term with the application of appropriate statistical and analytical techniques.

A final annual monitoring report will be completed and provided to the Yukon Placer Mining Secretariat no later than December 31st of each year. This report will include any conclusions regarding effects on aquatic health as noted above, and will be used by the Secretariat in the assessment and adjustment phases of the adaptive management process. This report will be included in the Secretariat's annual Adaptive Management report and will be available to the general public.

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APPENDIX 1

FIELD SAMPLING METHODS

A sampling crew is ideally made up of 3 or 4 members, though the work can be done by 2 people if necessary. Most important is consistency in sampling and consequently, crew members should perform the same tasks at every sampling visit. It is particularly important that the same individual complete the CABIN field data sheets for all sites.

On arrival at a potential site location, it should be examined visually for suitability. A "site" is considered to be approximately 50 metres of the stream length. However, the most critical criterion is that there is a stream surface area of approximately 60 metres² within the site for collection of fish and benthic macro invertebrates.

Fish sampling and water chemistry and sample collection are the first two tasks and can be done simultaneously if there are adequate crew members. These are followed by sampling benthic macro invertebrates, measurement of stream dimensions and finally habitat assessment. Notes should be taken regarding features of the site (e.g. existence of cabins, proximity to mining operation, etc.) and digital photographs of the site (up and downstream from the middle of the site and the substrate) should be taken.

The individual tasks are carried out using the following methods:

1. Fish Sampling

a) A section of approximately 60m² at the site should be blocked off using ¼" seine nets. Natural barriers to fish movement may preclude the need for one or both nets. The blocked off section of the stream should contain all representative habitats for the stream site.

b) Fish are sampled with a backpack electrofisher with a qualified operator and at least one netter catching shocked fish. The samplers enter the blocked off section of the site at its downstream end and fish upstream. The fishing duration is 600 seconds and should average 10 s/m². All habitats in the blocked off section should be fished with equal effort. Power and frequency settings on the electrofisher will vary, mostly depending on conductivity of the water in the stream. They should be adjusted to ensure all fish in the site are caught while minimizing mortality or effect on invertebrates. The netter catches shocked fish and transfers them to a bucket with stream water carried by the electrofisher operator. In some cases where fish are seen but not captured by the samplers, they should be identified and counted if possible. After the 600 seconds are complete, the downstream block net should be checked for fish that may have been shocked, but were not caught.

c) After sampling, all collected fish are identified and counted, and returned to the stream. Voucher samples and unidentified fish are preserved for subsequent identification or verification. Retained samples should be preserved in a 10% formalin solution, unless they are to undergo genetic analysis, in which case they should be preserved in 95% ethanol.

2. Water Chemistry and Sample Collection

a) Upstream of the fishing area, basic water chemistry is measured using electronic meters. pH, temperature, conductivity and dissolved oxygen. Three water samples are collected: one litre of untreated stream water and 250 ml. that is acidified with 3 drops of nitric acid. These samples for laboratory analysis and must be chilled (on ice or in a refrigerator) until delivered to the laboratory.

b) Laboratory analysis includes chemistry (pH, conductivity, dissolved oxygen, alkalinity), physical properties (Total dissolved solids, total suspended solids), organic nutrient content and metals.

3. Benthic Macro Invertebrate (BMI) Sampling

a) BMI are sampled at the same site as the fish were sampled. A 500 µm kick-net is used and a 3-minute kick, sampling all represented habitats is carried out. Samples are cleaned of large debris and then preserved for identification in 10% formalin and transferred after at least 3 days to 70% ethanol unless otherwise specified by the identification laboratory.

b) BMI are sub-sampled in order to estimate abundance, picked and identified to lowest possible taxon group, with at least 200 specimens sub-sampled.

4. Site characteristics, stream measurements and habitat scores

a) Complete sampling site CABIN field data sheets.

APPENDIX 2

GEOGRAPHICAL INFORMATION SYSTEM (GIS) DATA

1. Determine the location (latitude and longitude) of potential sites and convert to a point file using ARCGIS 9.0 (ESRI 2005)

2. Assemble the required 1:50.000 digital elevation maps (DEMs) required to cover the anticipated catchment(s) of one or more potential sites (available from Yukon Geomatics).

3. Delineate upstream catchments using the ArcHydro 1.1 extension for ArcGIS 9.0 (ESRI 2005). ArcHydro can also delineate watersheds in every sub- basin (confluence of two streams) within the DEM as well as the outflow points of these catchment areas. This is another way of cataloguing potential reference and test sites in a given area.

4. Use Hawth Tools with ARCGIS 9.0 to determine the perimeter and area of each delineated catchment. These are used as environmental descriptors of the site.

5. Overlay the shapefiles of the catchment areas of the potentially sampled sites onto layers with both natural (e.g. geology, stream network, climate) and potential stressor (e.g. roads, mining claims, forest fire history). Use ArcGIS with Microsoft Access to catalogue the landscape information for each potentially sampled catchment into a flat (spreadsheet) file.

6. Using ArcGIS, create a map with the potential sampling sites and other GIS information, and use this and other information (satellite imagery, local and regional knowledge, data from previously sampled sites) to determine which sites will be candidates for sampling.