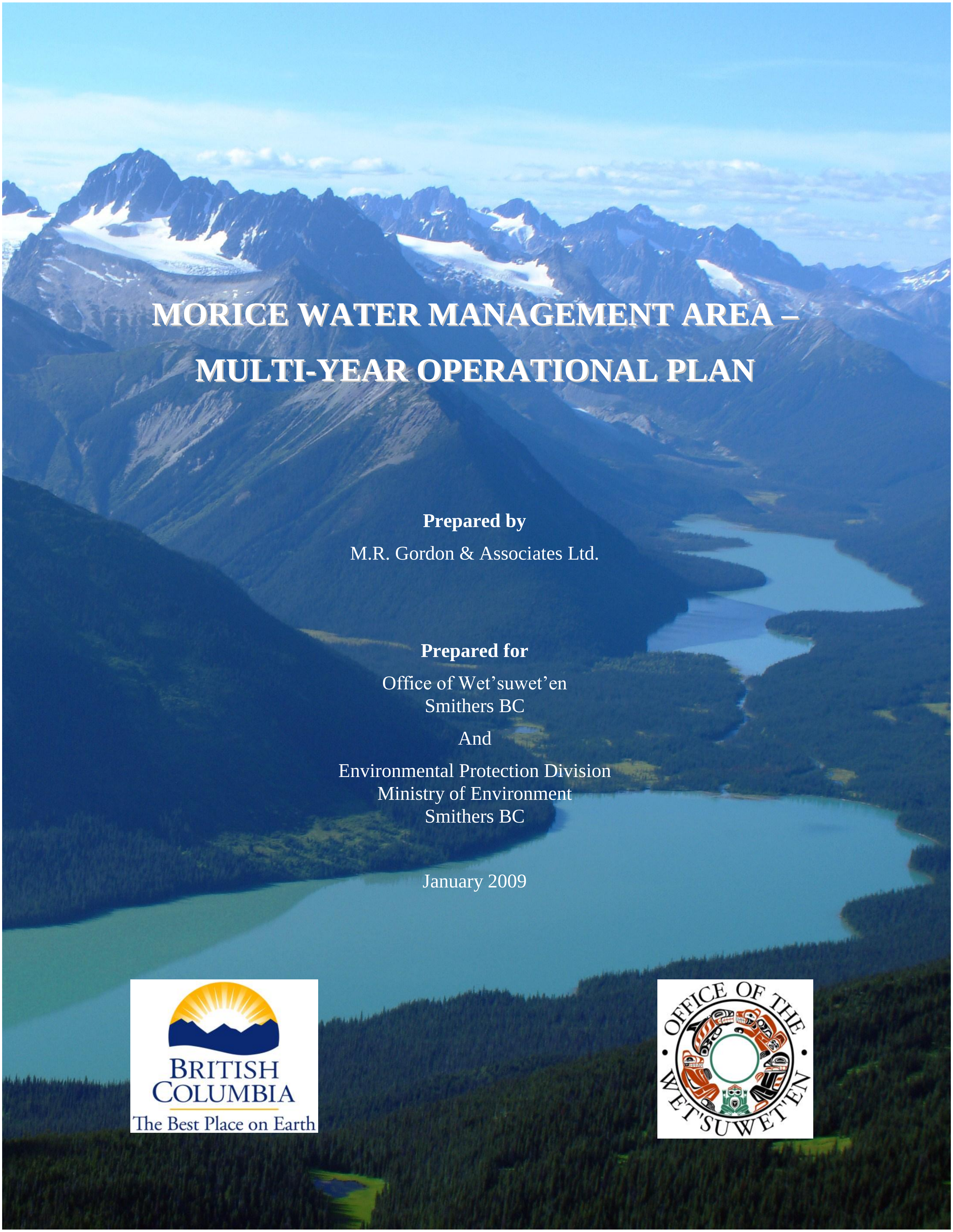

MORICE WATER MANAGEMENT AREA – MULTI-YEAR OPERATIONAL PLAN

Prepared by

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Cover photo – Stefan Schug

EXECUTIVE SUMMARY

This operational plan is the initial product of a partnership between the Office of the Wet'suwet'en and the Province of British Columbia to develop a water monitoring and assessment system for the recently established Morice Water Management Area (MWMA). This document will move the partners forward from a 2007 draft agreement that describes the basis for a shared decision making process for land use planning and implementation related to the Morice Land and Resource Management Plan. Specifically, the intent of this operational plan and accompanying framework is to satisfy one component of that draft agreement, and lead to a jointly signed agreement outlining how the Wet'suwet'en and the Province will obtain and use aquatic monitoring information in the management of water resources in the upper Morice watershed.

The MWMA was established as part of the Morice Land and Resource Management Plan to protect the water quality and fisheries resources of the upper Morice watershed. The area is to be managed to maintain water quality and hydrological integrity to sustain salmon and other fish habitat and populations, and as an extension, the Wet'suwet'en people.

The primary monitoring objective for the MWMA is to undertake a survey that will establish a baseline set of water quality and biological data for the watershed from which water quality objectives can be developed. Other objectives include water quality objectives attainment monitoring and developing an impact assessment system to determine the effects of land use activities such as logging, agriculture, and mining on aquatic resources. Ultimately, the goal of the monitoring program is to identify any trends occurring in water quality and biological conditions for specific water bodies over time.

The MWMA is a relatively pristine environment with little development and high fisheries values with extensive opportunities for monitoring and research. Unique opportunities exist for government and academic institutions to study undisturbed habitat that sustains valuable salmon and other aquatic resources. In the areas of the MWMA where industrial activity is occurring or proposed, expectations are that industry will assist with the monitoring program to ensure environmental values are maintained. The management area also provides opportunities to study spatial and temporal effects of specific development projects. At the same time, the pristine characteristics of the MWMA allows researchers to validate new aquatic monitoring and impact assessment techniques developed under laboratory conditions.

This document is divided into three sections. The first is a relatively detailed multi-year operational monitoring plan, based on the current understanding of land and water use proposals and activities in the MWMA. This plan includes a list of over 40 current and proposed core monitoring sites distributed throughout the MWMA and provides details required to establish an annual sampling program.

The second section (Appendix 2) is the monitoring framework developed for the MWMA in June 2008. The framework addresses the considerations necessary to develop a scientifically valid monitoring and assessment program appropriate for the MWMA. It outlines the concepts and principles for setting program objectives, designing a monitoring program, collecting data and assessing and interpreting the results in the context of resource development issues and decision making. It also proposes a model by which to include partners from industry, academia and governments.

The third section (Appendix 3) builds on the framework, providing detailed guidance on specific monitoring and assessment objectives, experimental design considerations, budget constraints, and personnel and training requirements necessary to develop a detailed monitoring program for the MWMA. Finally, it discusses how the system may evolve as resource management issues and impact assessment tools develop and evolve.

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1.0 BACKGROUND

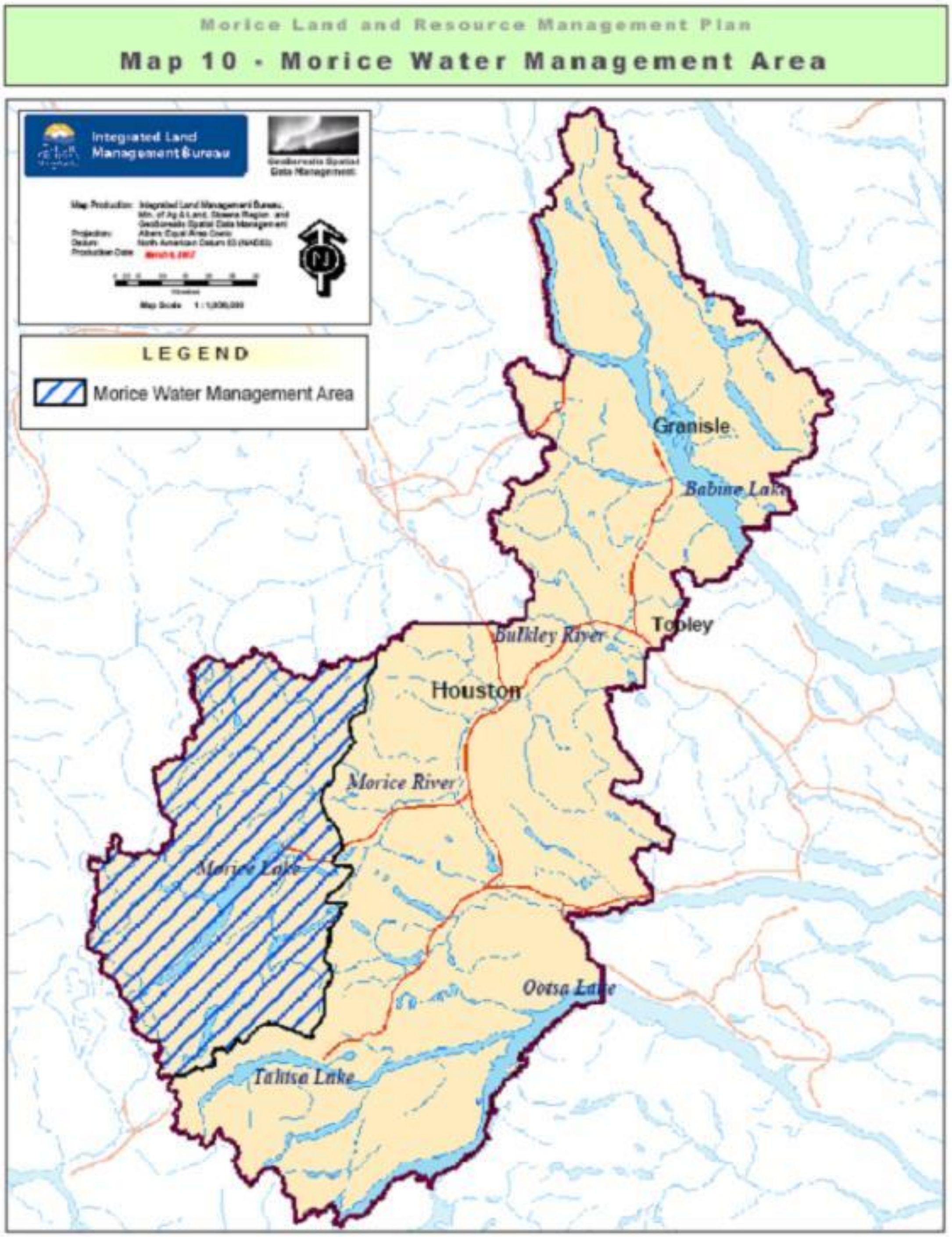
The Morice Land and Resource Management Plan (LRMP) public process was undertaken from October 2002 through March 2004 when recommendations for a draft plan were forwarded to the province. However, the Wet'suwet'en abstained from any consensus on the Draft LRMP Plan, since many of their aboriginal interests and environmental concerns had not yet been addressed. The Office of the Wet'suwet'en (OW) then engaged in government-to-government discussions with the Province of British Columbia as a continuation of the Draft LRMP Plan. These discussions resulted in proposed modifications to, or the development of, land use zones and designations, resource management areas and objectives, and the development and implementation of management and monitoring plans.

One outcome of the government-to-government discussions has been a Draft Agreement between the Wet'suwet'en and the Government of BC with respect to the Morice LRMP that describes the basis for a shared decision making process with regard to land use planning and implementation. The Draft Agreement is intended to be incremental to the Morice LRMP and provides for:

- Expansion of Protected Areas to be managed as wilderness areas where forestry and mining are not allowed, including the creation of a large contiguous area in the Morice watershed;
- Creation of a Water Management Area to be managed for hydrological integrity, including water quality and quantity, to ensure that salmon and other fish are not negatively impacted and that the water quality of streams and lakes is maintained and enhanced for spawning and rearing;
- Management of any proposed mine exploration, operations and closure within Wet'suwet'en territory consistent with Wet'suwet'en values and principles, and within the intent and objectives of the Draft Agreement;
- Management of agriculture and ranching within Wet'suwet'en territory consistent with Wet'suwet'en values and principles, and within the intent and objectives of the Draft Agreement;
- Development of procedures to avoid, limit or restrict pesticide and herbicide use within Wet'suwet'en territory including development of alternative control methods;
- Specific guidance on how the elements of the Draft Agreement will be implemented and monitored; and
- The need to define or update working relationships with provincial ministries or agencies through the development of interim agreements.

As part of the implementation strategy for the Morice LRMP, the Integrated Land Management Bureau (ILMB) and the OW signed a grant agreement (February 13, 2007) outlining projects to be completed jointly between the Government of BC and the OW with respect to the Morice LRMP. One of these projects is to develop a water monitoring and management plan for the Morice Water Management Area (MWMA) (Figure 1). The LRMP states "the desired outcome

Figure 1: Morice Water Management Area



[of the Morice Water Management Area] is to ensure that the habitat and water quality supporting salmon and other fish is not negatively impacted" (Min. Agriculture & Lands, 2007). Beyond this, the goals intended for the MWMA include:

- Water quality and quantity suitable to sustain the health and well being of the Wet'suwet'en (the intent being the protection of water quality, hydrologic integrity and salmon habitat);
- Water quality that supports aquatic life at reference state;
- Sustainable water use practices; and
- Integrated land and water resource planning that utilizes the Wet'suwet'en Territorial Stewardship Plan.

The MWMA was created to identify and delineate the minimum area of sensitivity for the Wet'suwet'en, and represents a significant compromise by the Wet'suwet'en whose interests extend throughout their entire territory. The intent is to provide the maximum amount of security for sustaining water quality and quantity necessary for the health and well being of the Wet'suwet'en, as well as to protect the salmon and other fish in the area and the aquatic life on which they depend. Losses to habitat or hydrological integrity are expected to be addressed promptly through restoration activities. The MWMA overlaps other land use zones, including proposed Protected Areas, all other Area Specific Resource Management Zones within the Wet'suwet'en territory, and some areas under General Management Direction. The management of these other areas in conjunction with the MWMA is expected to enhance water quality and fish habitat protection.

Another outcome of the government to government discussions was a workshop in 2007 to identify and discuss priority issues for water quality management in the upper Morice watershed. Selected experts were invited to meet with OW chiefs, OW staff and local provincial government specialists. Discussions included Wet'suwet'en values about water quality and fish resources; existing and potential impacts from logging, mining and other development; approaches to risk assessment of water quality impacts; developing site-specific criteria for water quality standards; and defining the reference state for the MWMA.

The Draft Agreement between the Wet'suwet'en and the government of B.C. indicates that a Collaborative Management Agreement will be developed to guide the implementation of the MWMA plan. It is intended that specific activities related to monitoring, establishing site-specific criteria or standards and enforcement thereof will be managed through shared decision making within the MWMA, and through the development of an Area Based Plan provided for under the *Environmental Management Act*. A fundamental step for implementation of the MWMA plan was the development of a water quality monitoring and assessment framework.

A Water Quality Monitoring and Assessment Framework for the upper Morice Watershed was prepared in June 2008. This Framework outlined the basic elements that would need to be included in a monitoring program. The Framework included discussion of developing monitoring objectives, selection of measurement parameters, data collection techniques, assessment and interpretation of data, practical considerations and creation of partnerships to undertake the work. An initial operational monitoring plan was included in the Framework as an appendix. The initial Operational Monitoring Plan for the MWMA discussed more specifically defining objectives, determining statistical requirements, providing training requirements, developing sampling procedures, determining site selection, providing quality assurance and quality control, and maintaining proper record keeping and documentation.

Initial field monitoring was undertaken during the summer of 2008. This experience and the data collected provided the basis for developing the multi-year operational plan proposed here.

2.0 OBJECTIVES

The objectives of this multiyear operational plan are:

- To establish a long-term water quality monitoring program that will provide the opportunity to maintain the unique environmental quality and valuable fisheries resource base of the MWMA through cooperative management between the Wet'suwet'en and the responsible Crown agencies;
- To establish a long-term water quality monitoring program that will provide reference data that can be used for trend analysis, impact assessment and compliance decisions;
- To establish a long-term water quality monitoring program that will provide reference data that can be used to develop site-specific water quality objectives for the protection of aquatic life;
- To measure at selected sites water quality parameters and analyze sediment and biological samples in order to provide reference data that can be used to assess potential impact pathways;
- To undertake research on relevant issues (new methods, the fate and effect of metals, sublethal biological effects on salmon life-stages, etc.) as the monitoring program expands;
- To sustain and expand the monitoring program through the development of partnerships with private sector interests, non-governmental foundations and environmental organizations, and educational institutions with established research programs;
- To create the basis for skill development, training, and educational and career opportunities for the Wet'suwet'en in water quality management, fisheries management, habitat conservation and other related fields consistent with their cultural values and principles; and
- To fund the program through cost sharing initially with government based programs (e.g. Strategic Engagement Agreements) and in the long-term through funding from companies intending to develop in the region; from non-governmental organizations and foundations

that recognize the unique environmental characteristics and valuable fisheries resource base of the area; and from universities interested in the unique research opportunities available in this area.

3.0 PROPOSED APPROACH

The initial focus of the MWMA monitoring program will be to establish a scientifically valid baseline of reference water quality data that accounts for natural variation. Based on preliminary field work undertaken in 2008, standard procedures will be established for field sampling and analysis of water, sediment and biological specimens based on current guidance documents, including quality assurance/quality control protocols for field and laboratory samples. Representative monitoring and sampling sites will include pristine undisturbed locations important for fish habitat; sites that were previously disturbed due to logging, agriculture or mining; and locations where impacts from potential development of mines or pipelines could occur.

Based on experience during the 2008 sampling program, selected locations in rivers, streams and lakes will be guided by logistical and well as scientific considerations. Sampling frequency, the type of sample, the number of replicate samples, the sampling methods and analytical methods will meet scientific standards while ensuring keeping costs within budget. It is expected that it will require 3 to 5 years to develop a database of reference water quality data that accounts for natural variation and can be used for impact assessment, compliance decisions, trend analysis and development of site-specific water quality criteria.

The number of variables to monitor will vary depending on the type of habitat impact and the specific characteristics of the local environment. Greater focus and attention will be given to any site-specific variables that are likely to be altered or are already elevated within the receiving environment. There are routine core measurements that will be included for most sampling sites. Other measures will be dictated by local conditions and any potential or existing impacts. Significant changes found for core and other baseline measures would be expected to trigger additional measurements.

3.1 CORE MEASURES

For initial monitoring in the MWMA, core measurements will include:

- In the water column - temperature, dissolved oxygen, specific conductivity, pH, turbidity and suspended sediments (rivers and streams), Secchi depth (lakes), metals analysis (using inductively coupled plasma-mass spectrometry [ICP-MS] or another more sensitive analytical method) and nutrient levels for phosphorus and nitrogen;
- In sediment - ICP-MS metals analysis and selected organic analyses for pesticides and other possible contaminants; and

- In biota - surveys of distribution, abundance and community characteristics of benthic invertebrates, zooplankton, phytoplankton, periphyton, and/or selected fish species, as well as fish tissue/organ analyses.

The scope of biological effects monitoring and testing will be dependent on the budget, the results of initial surveys of biota and fish tissue/organ analyses. Sculpin would be a candidate for tissue/organ analyses in rivers and streams while char, trout or burbot would be a candidate for similar analyses in lakes. Target tissues or organs will depend on what type of constituent or substance is of concern. Where elevated levels of contaminants were evident, early life-stage testing with salmon and/or trout species could also provide added insight on the potential for effects.

Additional analyses may be added to the sampling program on a watershed specific basis depending on existing or potential development activities and the types of impacts that they typically create (known risks in watersheds of interest are listed in Appendices 1a and 1b. For example, mine development and operations are known to affect aquatic habitat in a variety of ways. These effects can include: increased suspended solids and turbidity, altered conductivity, increased heavy metals concentrations, altered temperature, altered pH, increased nitrogen (from blasting), changes to benthic invertebrate communities, decreased juvenile fish abundance, etc. Therefore, the choices of variables of concern are to some extent dictated by these potential effects.

A consequence of habitat disturbance from development such as mining, logging and clearing for pipeline corridors can be alterations in hydrological dynamics. Turbidity and suspended sediment measures are helpful to monitor for effects due to erosion and upslope instability. However, alterations in stream/river peak and low flows as well as run-off patterns, altered stream channel characteristics and increase of total water yield would need to be monitored by a hydrologist and are not included in this plan.

In lakes, it is desirable to do additional water quality and sediment analyses. For water quality monitoring, depth profiles (surface, mid-depth and lower depth) that account for temperature stratification will provide valuable baseline data. For sediment analyses, sediment cores taken at selected locations within the lake will provide a historical time series that will be valuable for future trend analysis and impact assessment. While depth profiles would be done as part of routine water quality monitoring, the sediment cores would only be done once at the start of the monitoring program although analysis of the cores could be done over two or three years depending on the work plan and budget.

3.2 Sampling Timing and Frequency

The timing and frequency of monitoring is critical for understanding the range of natural variation within the MWMA. In river and streams, measurements will be taken during winter low flow (February), spring freshet (May), summer low flow (August), fall flush (October) and where possible during the interim months of January, March April, June and November. In lakes, measurements will be taken under ice, during spring turnover and in mid-summer. Of particular importance will be additional opportunistic monitoring during specific conditions including the onset of heavy rains after a prolonged dry period or during periods of rapid warming when snow melt and rainfall can combine.

4.0 WORK PLAN

4.1 Monitoring

Monitoring will include replicate measurements and sampling from at least 14 locations. Sampling will be undertaken a minimum of 3 times in lakes and 6 times in rivers or streams throughout the year in order to capture seasonal variations, as noted in the previous section. Replicate field measurements and samples will be collected during each round of sampling, with the goal being 10-15% of samples to be replicates. Opportunistic measurements and sampling will be undertaken at least 3 times during the specific conditions that are being monitored. Locations of sampling sites will be marked with ribbon and coordinates collected using a hand held GPS.

Reference sites will be established in the upper Morice and Gosnell rivers, Nanika Lake and Nanika River (below the falls), McBride Lake and the Bernie lakes area. Key areas where possible effects of existing habitat disturbance can be measured include logging in the Thautil watershed, pesticide application in the Gosnell watershed and mine exploration near Nanika Lake (Fenton Creek). Other focus areas important for assessing future impacts include the upper Gosnell watershed, the upper Morice River watershed and the Nanika Lake chain when either mine development or a pipeline corridor is proposed. Any project proposal within the MWMA will, based on the nature of the development and on its contamination potential, trigger a series of monitoring programs within the receiving environment potentially affected. While new project proposals will shift monitoring priorities to these specific areas, monitoring efforts will relax in areas where development has ceased and risks abated.

Priority will be given to sampling in the upper Morice watershed and the Nanika system, including selected sites in Morice and Nanika lakes. Sampling sites in the upper Gosnell watershed will also be given priority, particularly sites selected to compare disturbed vs. undisturbed habitat. Other sampling sites will be given consideration based on whether the habitat is critical for sustaining the life cycle of important aquatic species.

Risks, values, access, sampling parameters and priority for sites sampled in 2008 and proposed for sampling in 2009 are listed in Appendix 1a.

If feasible, we will incorporate water quality sample locations and the data generated for water chemistry, sediment analyses and biological variables into existing GIS databases. This approach allows for identification of unique site characteristics along with mapping and comparing key variables. Funding not accounted for in this plan may be needed to coordinate this.

The monitoring program including sample sites and frequency of sampling will be reviewed on an annual basis; reduced frequency will be considered for sites with little seasonal variability in water quality parameters of concern.

4.2 QUALITY ASSURANCE/QUALITY CONTROL

The MWMA monitoring program will have a QA/QC manual that outlines all activities and procedures for the sampling program. The manual will include detailed explanations of procedures, define responsibilities for staff and provide contact information for resolution of problems or emergencies. It will also provide general guidelines to ensure that any problems are identified and resolved in a timely manner. The manual will be reviewed and updated regularly and any revisions should be documented and dated.

Data quality objectives (DQOs) will be specified within the QA/QC manual before any samples are collected to ensure that samples can be analyzed with confidence. The DQOs will specify what the range of acceptable variability should be for control/reference samples as well as how to determine the existence and magnitude of any contamination problem. Quality control measures will be implemented in close consultation with the laboratory undertaking analyses. Quality control samples will be collected in addition to samples being collected to meet the program objectives. For samples collected and forwarded to the laboratory for analysis, essential quality control samples will include:

- Field and transport blanks to monitor potential contamination prior to receipt at the lab;
- Duplicate or multiple replicate samples to measure any field sampling error and/or local environmental variation; and
- Laboratory reference samples (blanks and spikes) to monitor accuracy in laboratory analysis.

The quality control requirements for the MWMA program will depend on the number and types of samples that are collected. It is expected that 10-20% of the project budget will be dedicated to QA/QC. The analytic lab will have its own QA/QC process including blanks, spikes, and replicates.

4.3 DATA COLLECTION AND MANAGEMENT

A system for recording and retrieving field samples will be devised to provide easy access to when, where, how and by whom samples were taken. Sample coding and numbering will be used to avoid any bias during analyses, and will be designed to avoid any possibility of mixing up samples. Tracking of the sample history will be documented including:

- Method of sample collection;
- Location, date and time of sample collection;
- Who collected the sample;
- Sample container used;
- Sample Code and required analyses;
- Storage conditions prior to transport for analyses;
- Transport used to send sample for analysis; and
- Time and condition of sample when received for analysis.

Methods documentation will include an inventory of current methods, previous methods and when any change in methods occurred. The documentation will include:

- An explanation of the specific procedure in sufficient detail that experienced field personnel not familiar with the specific procedure could successfully undertake the necessary work;
- Instructions for preparation and use of any reagent water, preservative chemicals or other reagents needed for sample collection;
- Specific instructions necessary for operating sampling equipment;
- Quality control sample preparation and collection procedures; and
- Specifications for DQOs.

Checklists will be used for equipment maintenance and calibration, sampling protocols, and other technical procedures. Checklists are intended to reinforce the need for a systematic approach to field work and create a basis for greater consistency in program data quality. Internal audits will also be conducted annually or if problems arise to ensure that field sample collection and QA/QC control procedures are meeting expectations.

4.4 PARTICIPANTS

Presently, the MWMA is a partnership between the OW and the Province of BC. While the current arrangement provides a starting point for implementing a monitoring program, it is advisable to consider how to involve other institutional or private sector partners in order to expand the capacity of the program to address the priorities and objectives of the program. The current partnership in effect sets a precedent and provides a context for other parties to become involved. The initiatives contemplated by new partners should be guided by the existing agreements or proposals for an Area Based Plan, and should be consistent with objectives of the ongoing monitoring program.

It is important to note that the MWMA offers unique opportunities to study undisturbed habitat that sustains valuable and important salmon and other aquatic resources. It also provides the opportunity to study the effects of specific impacts that can be defined spatially, temporally and with respect to specific environmental variables and introduced substances. This is particularly attractive to institutional researchers because there are not many relatively undisturbed areas where trends in natural variability can be monitored and at the same time human impacts and effects can be isolated and studied.

Institutional partners should provide scientific expertise that is complementary to the priorities and objectives of the program. For example, toxicological studies on the effects of metals on early life stages of fish using site specific receiving waters and testing might provide better definition of site specific water quality objectives that are incorporated into an Area Based Plan. At the same time, the unique characteristics of the MWMA allow researchers to validate techniques they may have applied under laboratory conditions but were unable to use in most field situations because of habitat disturbance or pollution. Institutional researchers also have access to funding that would not be available to the OW. In addition, training and education provided by institutional partners should be identified and incorporated into partnership agreements so that community members will have opportunities to develop new skills and careers.

Potential partners from the private sector will be those parties interested in development within or adjacent to the MWMA. It will be important to use the existing agreements and proposals for an Area Based Plan, as well as the priorities and objectives for the water quality monitoring program, as a prerequisite for development. For example, more comprehensive terms of reference could be required for determining the extent and degree of habitat disturbance from any proposed development. In addition, more stringent criteria could be required for determining potential impacts and effects from a proposed development. All of this work would be paid for by the private sector parties interested in development and would be designed to complement the ongoing monitoring program. It should be established that all information and data resulting from this work would be available to the partnership to enhance the knowledge base for the area. Investments in training and educational opportunities for local community members, as well as service contracts for field assistance, could also be part of the partnership agreement with private sector interests.

Non-governmental organizations and foundations can also play a role in funding program activities. It is important to understand the philosophy and orientation of potential third party donors to ensure that the partnership does not result in any conflicts about or misrepresentations of the program. These potential partners will often be more willing to support activities once most of the initial development and funding of the program is in place and there are working partnerships already set up if not ongoing. Proposal development and reporting are often required for establishing this type of support. Therefore, it is important to recognize that there will be additional time and effort needed to solicit and obtain funds as well as maintain required communications and reporting once funds are in place.

5.0 BUDGET

Table 1 shows potential funders and their percent contribution through time to run the long-term monitoring program in the Morice Water Management Area.

Table 1: Potential scenario of monetary contributions (%) to Multi-Year Monitoring Program

PARTNER	YEAR					
	2009	2010	2011	2012	2013	2014
OW	50	40	30	25	10	
GOVERNMENTS	50	40	30	20	15	15
UNIVERSITIES/COLLEGES		5	10	10	15	15
FOUNDATIONS/NGO		5	10	15	25	30
COMPANY 1		5	10	10	10	10
COMPANY 2			5	10	10	10
COMPANY 3				5	10	10
COMPANY 4					5	10

Given that the financial circumstances of current and prospective partners in this monitoring program are subject to external influences, the size of the program in any given period may fluctuate. This is especially true of commercial entities such as mining companies subject to monitoring requirements under a range of regulatory requirements (*Environmental Assessment Act*, *Environmental Management Act* permitting, Federal Metal Mine Effluent Regulation – *Fisheries Act*). As a consequence, the year-to-year refinement of the operational plan must take this into account, yet remain scientifically defensible in terms of the overall plan.

As of March, 2009, it is certain that there will be a hiatus in funding from all sources, as we contend with a global recession. This means that annual planning must include means of incorporating gaps in data streams from some of the sites. It also adds importance to the concept of establishing core sites which would be monitored to the exclusion of others, given their utility for a range of purposes. These sites have been defined and prioritized (Appendix 1a). Additional proposed sites are listed in Appendix 1b.

It is also important to recognize that the budget for this ongoing program is likely to increase over the long-term as additional issues are identified and new developments are proposed for the area. Therefore, the contributions of various participants are likely to increase even when their relative contribution to the overall cost of the program remains the same. In-kind support from Crown agencies for analytical services or field support is assumed as part of their relative contributions. The relative contribution of various companies could include specific monitoring requirements incorporated into their permit or as part of a separate accommodation agreement with the OW. University contributions are assumed to be research oriented and based on graduate student studies or faculty research funded by NSERC or similar grants. Contributions from foundations or NGOs could be based on support for cooperative efforts between the OW and the other participants.

Conceptual Budget Details

The current budget for the Wet'suwet'en portion of the project is based on the use of dedicated field crews provided by the OW with support from Ministry of Environment staff for scientific and analytical procedures. The breakdown of the formula to fund this is as follows:

Labour

OW staff

- Program Manager, Field Technicians (5), OW Staff Advisors (2)

Supplies

- Equipment for sample collection and in situ field measurements
- Boat usage (lease, rental, etc.)
- Vehicle usage (lease, rental, etc.)
- Fuel usage for vehicles and boats

Services

- Analytical services
    - Sample analysis, QA/QC support
- Air Transport
- Other Contract services

APPENDIX 1A: SITES SAMPLED IN 2008

Site #	Site Name	EMS #	Land use risks	Access	Values	Cultural values/other	Monitoring focus	Priority VH-H-M-L	Partnership possibilities
1	Morice R 66 km bridge	E 272549	Harvest, Mining exploration	Road	Fish spawn/rear, near and far, All	Lots, Trails, Village Sites	Basic*, Sediment, BI, Fish Tissue	H	Later: DFO, Pipeline, Sport Fisheries
3	Gosnell Cr u/s Thautil FSR bridge	E 272551	Erodible Soils, Old and New Harvesting	Road Summer, Snowmobile Winter	Fish spawn/rear	Hunting, Camps, Trails	Basic*	H	Forest companies
9	Nanika R u/s of Cutthroat FSR Br.	E 272557	Mining, Forestry, Pesticides, Roads	Road	Fish spawn/rear near & far; Bull Trout spawning.	Very high, Fishing, Camps, Trails, Homeplace, Fish Production, Hunting	Basic*, Sediment, BI, Fish Tissue	VH	MOE, DFO, Universities, New Cantech, MOF, Canfor Research
7a	Joshua Cr u/s Joshua FSR bridge	E 272553	Erodible Soils, Forest Harvest	Road Summer, Snowmobile Winter	Fish spawn/rear	Hunting, Camps, Trails	Basic*, BI site existing	H	Forest companies
8a	Crystal Cr u/s bridge	E 272554	Forest harvesting, Stability Fans	Road Summer, Snowmobile Winter	Fish spawn/rear	Hunting, Camps, Trails, Homeplace	Basic*	H	MOF Research - Fen Stability, MOE B.T.
8b	Gosnell Tributary South	E 272555	Forest harvesting, Stability Fans	Road Summer, Snowmobile Winter	Fish spawn/rear near & far d/w	Hunting, Trails	Basic*	M-H	MOF Research - Fen Stability, MOE B.T.
13	Cutthroat Cr u/s Cutthroat FSR Br.	E 272556	Mining, Potential Forest Harvest	Road	Coho Spawning/Rear near& far	Trails, Hunting	Basic*, Fish Tissue	H	MOE, DFO, Universities, New Cantech, MOF, Canfor Research
18	Shea Cr u/s Gosnell FSR Br.	E 272563	Erodible Soils, Forest Harvest	Road Summer, Snowmobile Winter	Fish spawn/rear	Hunting, Camps, Trails	Basic*	H	Forest companies
21	New Moon Cr	E 272565/ E 272564	Mining (New Moon)	Boat	Fish spawn/rearing	Graveyard site	Basic*, tissue, BI, sediment metals	H	New Moon
22	Atna R	E 273267	Mining (potential)	Helicopter	SK, CO, CH spawn/rear	High - trails, hunting	Basic*; fish tissue (resident)	M	MOE/DFO
24	Atna Lk	E 273266	Park	Plane	Fish - spawn/rearing; hunting; wildlife	Trails	Program 1** + benthic invertebrates	L-M	MOE - Parks; outfitters - access and work together
27	Morice Lk - east of Atna Bay	I 131112	Park	boat	Fish - spawn/rearing; Fishing, boating	Fishing; trails in area, gravesites around shore, village sites	Program 2***	M	MOE - Parks; New Moon
29	Morice Lk at Cliff Cr	E 272564	Park	boat	Fish - spawn/rearing; Fishing, boating	Fishing; trails in area, gravesites around shore, village sites	Program 2***	M	MOE - Parks; New Moon
35	Anzac Lk	E 273265	Park	Plane / boat	Canoeing, some fishing	Trails in area; hunting; fishing	Program 1**	L-M	MOE - Parks
37	Kidprice Lk (deep site)	E 273263	Park	Plane / boat	Canoeing, some fishing	Trails in area; hunting; fishing	Program 1**	L-M	MOE - Parks
39	Nanika Lk - north end	I 131113	Park	Plane / boat	Some rec value	Trails in area; grave sites	Program 1**	L	
44	Delta Cr	E 272567	Park	Boat or helicopter	Fish spawn/rearing	Moose hunting??	Basic*; fish tissue	M	MOE - Parks
45	Cabin Cr	E 272568	Park	Boat or helicopter	Fish spawn/rearing	Moose hunting??	Basic*; fish tissue	M	MOE - Parks
46	Lamprey Cr. u/s Morice R. Rd Br.	E 256980	Forestry	Road	Fish; campsite	High - fishing (eels)	Basic*; TSS, turbidity, bedload; integrity of restoration site	M	Forest companies; MOE or DFO - lamprey

Basic*: Water quality – metals, nutrients, general ions, pH, specific conductance and DO

Program 1**: DO, temp profile; secchi, surface, mid, bottom WQ - nutrients, gen ions; fish tissue; sediment sampling (metals); phyto and zooplankton composition

Program 2***: DO, temp profile; secchi, surface, mid, bottom?? WQ - nutrients, gen ions; fish tissue (lake trout); sediment sampling (metals); phyto and zooplankton composition

APPENDIX 1B: POSSIBLE FUTURE MONITORING SITES

Site #	Site Name	Land use risks	Access	Values	Cultural values/other	Monitoring focus	Priority VH-H-M-L	Partnership possibilities
2	Upper Morice-Chinook Island	Harvest, Mining exploration	Boat	Chinook, Coho, other, spawn	Lots, Fishing	All	H	DFO, Universities Research
7b	Upper Gosnell from Joshua FSR	Erodible Soils, Pot. Pipeline, Old and New Harvesting	Road Summer, Snowmobile Winter	Fish Spawn/Rear	Hunting, Camps, Trails	Basic*	H	Pipeline, Forest Co.
10	Nanika river above cutthroat crk confluence	Forestry	Road, Bush trail	Fish Spawn/Rear near & far d/w	Very high, Fishing, Camps, Trails, Homeplace, Fish Production, Hunting	Basic*, Sediment, BI, Fish Tissue	H	MOE, DFO, University, U. of M., New Cantech, MOF, Canfor Research
19	Thautil River upstream Gosnell confluence	Pipeline, Watershed Harvesting	Trail/Road	Spawn/Rear Coho, bull trout	Fishing; trails in area, village sites	Machinery, Sediment, Pesticides	H	Pipeline, Forest Co.
20	Upper Thautil	Old Harvesting	Road?	Spawn/Rear Coho, bull trout, Chinook,	TBD	Bedload, Sediments	H	Forest companies
31	McBride Lake - west	Mining - tailings pond	Boat	Fish - sp and rearing - resident and coho	High - camps, hunting, village, grave sites	Program 1**	H	New Cantech
32	McBride Lake - middle (deep station)	Mining - tailings pond	Boat	Fish - sp and rearing - resident and coho.	High - camps, hunting, village, grave sites	Program 1**	H	New Cantech
33	McBride Lake - east	Mining - tailings pond	Boat	Fish - sp and rearing - resident and coho.	High - camps, hunting, village, grave sites	Program 1**	H	
15	Bergland Creek (site to be chosen)	Mining	Helicopter	Fish; park	Trail?, hunting	Basic*; fish tissue, sediments	M	Mining company (Berg property); MOE
26	Morice Lake at Nanika River	Park	Boat	Fish - spawning and rearing; Fishing, boating	Fishing; trails in area, gravesites around shore, village sites	Program 2***	M	MOE - Parks; Nanika Ridge
28	Morice Lake - south L	Park	Boat	Fish - spawning and rearing; Fishing, boating	Fishing; trails in area, gravesites around shore, village sites	Program 2***	M	MOE - Parks
30	Morice Lake - north end	Park	Boat	Fish - spawning and rearing; Fishing, boating	Fishing; trails in area, gravesites around shore, village sites	Program 2***	M	MOE- Parks; New Cantech
12	Objective Creek (site to be chosen)	Forestry, mining (potentially)	Road?	Fish - spawning and rear	High - trails, structures?	Basic* (fish tissue?)	L-M	New Cantech; MOE
14	Glacier Creek (location to be chosen)	None now - mining long run	Helicopter , boat up Nanika, difficult access	Fish – Bull trout spawning	Limited	Basic*; BT in future	L-M	MOE - BT in future
17	Kidprice Creek (site to be chosen)	Mining; park?	Helicopter	Bull trout, Cutthroat trout; Park, canoeing	Limited - trails	Basic*	L-M	MOE - Parks, Fish
23	Atna Lake Deep Station	Park	Plane	Fish - spawning and rearing; hunting; wildlife.	Trails	Program 1**	L-M	MOE - Parks; outfitters - access and work together

Site #	Site Name	Land use risks	Access	Values	Cultural values/other	Monitoring focus	Priority VH-H-M-L	Partnership possibilities
25	Morice Lake - Atna bay	Park	Boat	Fish - spawning and rearing; Fishing, boating	Fishing; trails in area, gravesites around shore, village sites	Program 2***	L-M	MOE- Parks
36	Stepp Lake (deep station)	Park	Plane / Boat	Canoeing, some fishing	Trails in area; hunting; fishing - resident spawning	Program 1**	L-M	MOE - Parks
38	Nanika Lake - near Fenton Creek	Park	Plane / Boat	Some recreational value	Trails in area; several grave sites	Program 1**	L-M	
41	Nanika Lake - south end / deep station??	Park	Plane / Boat	Some recreational value	Trails in area; several grave sites	Program 1**	L-M	
47	Julian Holland Lake	Logging	Road / Boat	Fishing	Trails, hunting	Program 1**	L-M	Canfor
11	Nanika River 6 km downstream from waterfall	Forestry	??	Spawn&Rear sockeye, Chinook, coho, pink.	Very high, Fishing, Camps, Trails, Homeplace, Fish Production, Hunting		L	
34	McBride Lake inlet east end	Mining - possible tailings pond; forestry	Road	Fish spawning and rearing in lake; use of stream?	Trails, burial sites	Basic*; fish tissues	L	New Cantech
42	Burnie Lake North	Park	Plane	Recreation; tourism, park, resident fish, tourism, park.	Trails	Program 1**	L	Christoff Dietzfelbinger
43	Burnie Lake South	Park	Plane	Fishing	Trails	Program 1**	L	

Basic*: Water quality – metals, nutrients, general ions, pH, specific conductance and DO
Program 1**: DO, temp profile; secchi, surface, mid, bottom WQ - nutrients, gen ions; fish tissue; sediment sampling (metals); phyto and zooplankton composition
Program 2***: DO, temp profile; secchi, surface, mid, bottom?? WQ - nutrients, gen ions; fish tissue (Lk trout); sediment sampling (metals); phyto and zooplankton composition

APPENDIX 2: WATER QUALITY MONITORING AND ASSESSMENT FRAMEWORK FOR THE UPPER MORICE WATERSHED

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A1.0 INTRODUCTION

The Morice Land and Resource Management Plan (LRMP) public process was undertaken from October 2002 through March 2004 when recommendations for a draft plan were forwarded to the province. However, the Wet'suwet'en abstained from any consensus on the Draft LRMP Plan, since many of their aboriginal interests and environmental concerns had not yet been addressed. The Office of the Wet'suwet'en (OW) then engaged in government-to-government discussions with the Province of British Columbia as a continuation of the Draft LRMP Plan. These discussions have resulted in proposed modifications to, or the development of, land use zones and designations, resource management areas and objectives, and the development and implementation of management and monitoring plans.

One outcome of the government-to-government discussions has been a Draft Agreement between the Wet'suwet'en and the Government of BC with respect to the Morice LRMP that describes the basis for a shared decision making process with regard to land use planning and implementation. The Draft Agreement is intended to be incremental to the Morice LRMP and provides for:

- Expansion of protected areas to be managed as wilderness areas where forestry and mining are not allowed, including the creation of a large contiguous area in the Morice watershed;
- Creation of a water management area to be managed for hydrological integrity, including water quality and quantity, to ensure that salmon and other fish are not negatively impacted and that the water quality of streams and lakes is maintained and enhanced for spawning and rearing;
- Management of any proposed mine exploration, operations and closure within Wet'suwet'en territory consistent with Wet'suwet'en values and principles, and within the intent and objectives of the Draft Agreement;
- Management of agriculture and ranching within Wet'suwet'en territory consistent with Wet'suwet'en values and principles, and within the intent and objectives of the Draft Agreement;
- Development of procedures to avoid, limit or restrict pesticide and herbicide use within Wet'suwet'en territory including development of alternative control methods;
- Specific guidance on how the elements of the Draft Agreement will be implemented and monitored; and
- The need to define or update working relationships with provincial ministries or agencies through the development of interim agreements.

As part of the implementation strategy for the Morice LRMP, the Integrated Land Management Bureau (ILMB) and the OW, signed a grant agreement (February 13, 2007) outlining projects to be completed jointly between the Government of BC and the OW with respect to the Morice LRMP. One of these projects was to develop a water monitoring and management plan for the Morice Water Management Area (MWMA).

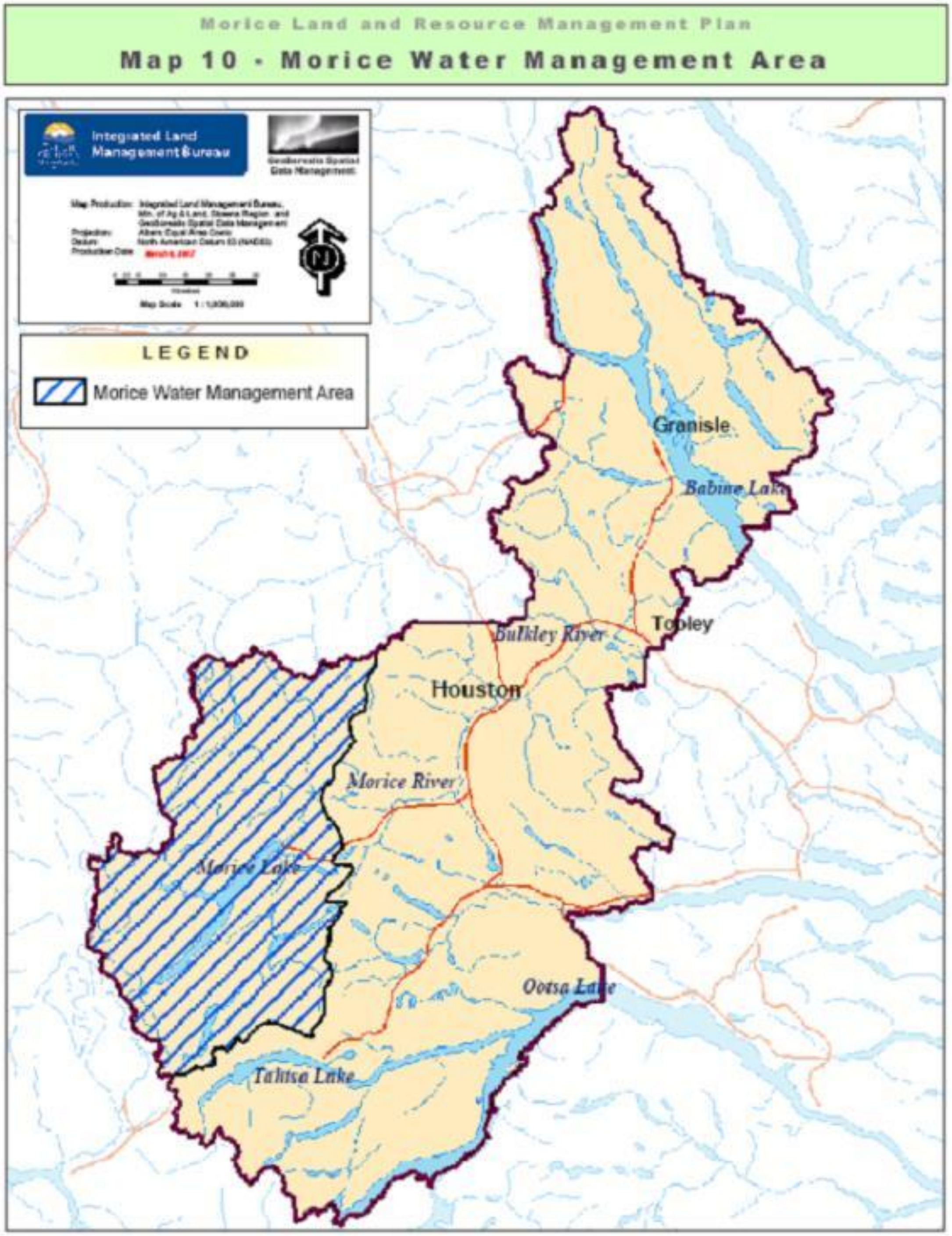
The LRMP states "the desired outcome [of the Morice Water Management Area] is to ensure that the habitat and water quality supporting salmon and other fish is not negatively impacted" (Min. Agriculture & Lands, 2007). Beyond this, the goals intended for the MWMA include:

- Water quality and quantity suitable to sustain the health and well being of the Wet'suwet'en (the intent being the protection of water quality, hydrologic integrity and salmon habitat);
- Water quality that supports aquatic life at reference state;
- Sustainable water use practices; and
- Integrated land and water resource planning that utilizes the Wet'suwet'en Territorial Stewardship Plan.

The MWMA (Figure 1) was created to identify and delineate the minimum area of sensitivity for the Wet'suwet'en, and represents a significant compromise by the Wet'suwet'en whose interests extend throughout their entire territory. The intent is to provide the maximum amount of security for sustaining water quality and quantity necessary for the health and well being of the Wet'suwet'en, as well as the protection of the salmon and other fish in the area and the aquatic life on which they depend. Losses to habitat or hydrological integrity are expected to be addressed promptly through restoration activities. The MWMA overlaps other land use zones, including proposed Protected Areas, all other Area Specific Resource Management Zones within the Wet'suwet'en territory, and some areas under General Management Direction. The management of these other areas in conjunction with the MWMA is expected to enhance water quality and fish habitat protection.

The Draft Agreement indicates that a Collaborative Management Agreement will be developed to guide the implementation of the MWMA plan. It is intended that specific activities related to monitoring, establishing site-specific criteria or standards and enforcement thereof will be managed through shared decision making within the MWMA, and through the development of an Area Based Plan provided for under the *Environmental Management Act*. A fundamental step for implementation of the MWMA plan is the development of a water quality monitoring and assessment framework. This document is intended to fulfill that requirement.

Figure 1: Morice Water Management Area



A2.0 SCOPE OF FRAMEWORK DOCUMENT

This framework document will address the scientific considerations for developing a water quality monitoring and assessment program appropriate for the MWMA. It is assumed that the monitoring program will ultimately be designed based on the best information currently available for the MWMA, including scientific principles and data, traditional ecological knowledge, land development and resource trends, and community values. Priorities for program objectives, monitoring design, sampling, data collection and assessment of results will be discussed with respect to the land, resource and development issues within the MWMA. This framework document includes a bibliography, which directs the reader to additional resources for further guidance in developing a monitoring program and determining appropriate methods.

The framework is intended to provide specific guidance on how to convert the goals outlined for the MWMA into a monitoring plan. The goals previously mentioned for the MWMA can be transposed into several questions such as:

- Is the water safe for drinking?
- Is the water and associated habitat capable of sustaining fish?
- Is the water quality getting better or worse?
- Is water quality changing because of changes in land use or management practices?
- If water quality problems exist, what are the causes of those problems?
- Are regulatory requirements for water quality being met?

While these might appear to be simple questions, there are not necessarily easy answers for these questions. Answering each question requires specific measurements taken at appropriate locations with appropriate frequency using appropriate sampling and measurement procedures, analyzed using appropriate statistical methods and interpreted based on existing standards or other appropriate information. At the same time, the monitoring program must account for natural variability and unique local conditions, and adhere to the practical constraints of timing and budgets.

It is important to keep in mind that any monitoring program cannot be a static process. A good monitoring plan emphasizes the need for feedback at every step of the process. Are the results sufficient to answer the questions posed by the monitoring objectives? Usually, not right away. Often more time and more data may be required. Is the monitoring design adequate to realistically address the monitoring objectives? This question must be asked each time data is collected and results are interpreted. It is also likely that the monitoring results will raise new questions that need to be answered. The essential point is that there should be frequent analysis and review of results and procedures to ensure that the desired objectives are achieved.

A3.0 MONITORING OBJECTIVES

For the purpose of this framework document, monitoring objectives are discussed in terms of four general categories. These categories vary in their level of complexity and the amount of data collection required for assessment, but each category is critical for answering key parts of any overall assessment.

A3.1 WATER QUALITY BASELINE (REFERENCE STATE)

The most basic approach to water quality assessment is to determine the current conditions in a selected water body. This might include measurements of physical characteristics such as temperature, flow, hardness, alkalinity, pH, dissolved oxygen, etc. These measures would be related to measurements of selected chemicals or elements, which in turn could be related to measures of uptake in, and/or effects of these same substances on aquatic species. Analysis of sediments, soils and/or groundwater might also be included. Comparisons of these measures must then be made with nearby or far-field reference sites and/or with known standards and criteria for any identified substances of concern.

An example of this approach might be to determine the levels of selenium in water and fish tissues at various locations upstream and downstream of a surface coal mining operation. Another example might be determination of nitrate levels in soils, surface waters and ground waters relative to agricultural operations and how the measured levels compare to levels where no development exists. The first example refers to a point source that might affect water quality and aquatic life. The second example refers to a non-point source for water quality impacts. Each example would require very different strategies and plans for sampling and assessment.

A3.2 TREND ANALYSIS

Consistency is the key when determination of water quality trends is the objective. Sample locations, sampling procedures, analytical methodologies and other choices are made with the intent that they will be repeated season after season and/or year after year, usually over many years. When done properly this approach can help to clarify natural variations in water quality within selected areas and confirm unique characteristics of water bodies or habitats.

Trend analysis can be used to develop baseline data for reference locations. Trend data can also be valuable for developing reliable predictive models for assessing potential impacts from proposed developments. Depending on the range of natural variation and seasonal changes that occur, it might take several years of monitoring to capture the range of variation for the parameters selected for monitoring.

A3.3 CONTAMINANT ASSESSMENTS

A well designed monitoring program will help to identify the possible impacts or effects of land development and use on water quality or aquatic life. For point source or localized impacts, a comparison of measures from a reference or undisturbed location with measures taken at various locations closer to the development is often applied to determine a zone of impact or effects. For non-point sources, it can be difficult to define a zone of impact or effects. For example, whole lake systems may be affected by nutrient addition from agriculture and nearby undisturbed lakes might have to be used for reference sites.

When land use activities create multiple sources of contaminants, the complexity of the monitoring design and interpretation of results can be very challenging. Determining the benefits of changes designed to mitigate impacts or effects can also be difficult. In these situations, monitoring programs that have collected water quality baseline and/or trend data can be particularly valuable. Generating information prior to land use changes is always preferable when trying to determine impacts and effects. Baseline and trend data can also help to inform specifications for permit requirements for new land use developments.

Seasonal changes, rainfall, water flow and other variations can be significant for the release of undesirable substances. Therefore, it is important to account for natural fluctuations that may create higher releases of contaminants. Biological effects of contaminants can vary due to water chemistry or physical characteristics, species, life stage of organisms, duration of exposure and level of exposure. Determination of potential effects can require laboratory tests combined with field sampling and analyses to account for the interaction of these variables.

A3.4 MODEL CALIBRATION OR VALIDATION

A wide range of water quality models are used to predict water quality conditions under varying circumstances. Models are typically used to account for interactions of several variables in order to predict if water quality will meet objectives, criteria or permit limits. This is usually done in anticipation of proposed land use changes and/or waste discharges.

Data generated by a water quality monitoring program can be used to ensure that the model is designed based on known variations in water quality that have occurred prior to changes in land use. Water quality data can also be used to confirm if the predicted conditions produced by the model are realistic. With a good database generated by a monitoring program, a model can be important for calculating water quality conditions at times or places outside the range observed during field monitoring. In order to calibrate or validate a model, detailed monitoring, intensive data collection or special studies might be required.

A3.5 OTHER CONSIDERATIONS FOR DEFINING OBJECTIVES

All sources of variability, naturally occurring or due to human activities should be accounted for when developing water quality monitoring objectives. Documenting unique characteristics of natural water conditions can be crucial for understanding whether water quality is suitable or not for aquatic life or human use. However, the level of effort required to account for variability and increase the reliability of results can sometimes exceed the time and budget constraints allocated for monitoring.

While all of the above noted objectives could be relevant for the MWMA monitoring program, there is no sense in setting objectives that cannot be achieved because of budget limitations. This can lead to incomplete data that cannot be used for assessment purposes. Time and budget constraints are a significant consideration however objectives can be defined in a staged approach. This can also allow for necessary adjustments over time as new data and information comes to light. In addition, new partnerships or agreements with those who are proposing new land use developments can provide additional resources that can increase funding and capacity for addressing more issues.

As noted earlier, any monitoring program should be reviewed constantly to ensure that the monitoring design is capturing the necessary information accurately and completely. It is not uncommon to still have unanswered questions remaining after data has been collected and analyzed. Often new questions arise once the data is analyzed. The need for ongoing review of monitoring objectives is consistent with an adaptive management approach to ensure that the principle objectives of the MWMA are achieved.

A4.0 MONITORING DESIGN

The scope of effort required to undertake a monitoring program is typically a matter of deciding:

- What is being monitored?
- What kind of samples will be collected?
- What will the samples be measured for?
- Where, when and how often will sampling occur?

There is a balance that needs to be maintained between practical and scientific needs. The monitoring design must be sufficient to allow for scientifically valid data analysis. However, the field equipment and crew capacity, and budget available for the program, will necessarily dictate how much can be accomplished.

A4.1 WHAT IS BEING MONITORED?

The MWMA is a large area with lakes, rivers and streams of varying sizes. Often monitoring programs are focused on a single water body or localized habitat, which allows for flexibility with sampling location and frequency. In more broad based monitoring programs, random sampling programs that quantify the relative percentage of streams, rivers and/or lakes that meet water quality criteria within a designated area have been implemented in some areas.

In the MWMA, it is important to decide what the priorities and decisions for developing a monitoring design will be. If the program is focused on specific habitat issues, then priorities for sampling can be dictated by such things as sensitive fish habitat, drinking water sources, habitat already impacted by land use, habitat not impacted by land use and habitat where new land use development has been proposed. If the program is also focused on a broader characterization of the MWMA then it will be important to determine how well the data collected at the selected habitat sites represents the water quality of the larger area.

A key issue in the design process is to understand what is meant by a representative sample. For example, a reference condition for a specific habitat within the MWMA is representative of that habitat but might have unique characteristics that are not representative of the larger geographic area. However, there are various approaches that can be used to inter-relate sub-regions of a larger geographic area based on the distribution of the most strongly related environmental factors.

A4.2 WHAT KIND OF SAMPLES WILL BE COLLECTED?

Aquatic resources involve complex ecosystems that can be viewed from many perspectives. Assessing conditions will depend on the measurement of selected water quality parameters in relation to in-stream physical habitat, riparian habitat, chemical contaminants, sediment contamination, benthic macro-invertebrate community, fish community, periphyton community, as well as other factors. It is important to agree on which measurements will constitute the monitoring program's concept of reference state.

The monitoring objectives should be precise about what water quality parameters need to be measured for all sampling sites within the MWMA. Decisions should be made about where and what kind of additional water quality parameters should be measured for selected sampling sites along with any biological sampling, analysis or testing. Sediment and benthic invertebrate sampling might also be appropriate in some locations.

A4.3 WHAT WILL THE SAMPLES BE MEASURED FOR?

All water samples should be measured for pH, alkalinity, hardness and particulates (suspended and dissolved solids). Variations in these parameters can affect the toxicity of chemical pollutants on aquatic species, particularly for metals. Metals are generally more toxic to aquatic species at lower pH, lower alkalinity and lower water hardness. Lower pH promotes the release of metals bound to particulates or sediments and fine silty particles can provide a large surface area for the distribution and release of metals.

Water temperature can be an important factor when toxic chemicals are present. Toxicity increases as water temperature increases. Warmer temperatures increase the respiratory rate, membrane permeability and absorption rates of aquatic species because as cold-blooded (poikilothermic) animals their metabolism is tied to the temperature of the water they inhabit. An increase of 10°C in water temperature causes a doubling of metabolic rate for aquatic organisms. This can in turn cause more rapid uptake of some chemicals.

Dissolved oxygen (DO) in the water is another important parameter. The availability of oxygen in the water for aquatic species can be reduced naturally by warmer temperatures or in some cases from surface runoff of sediments and nutrients into water bodies. Some metals and other contaminants affect gill tissues and thereby reduce the ability of aquatic species to absorb oxygen or tolerate lower oxygen conditions.

Metals are a concern in the MWMA because of high natural levels in the land base and the potential for mine development in the area. Metals dissolve in water and can be easily absorbed into fish and other aquatic organism. Small concentrations can be toxic. Metals can increase in concentration in an organism compared to its concentration in water or sediments through bioconcentration. Some metals (chromium, copper, zinc, nickel, manganese and selenium) are needed for good health in low concentrations but high concentrations are toxic. Other metals (mercury, tin, cadmium, lead, silver, aluminum and arsenic) are not needed for good health.

Some organic chemicals such as pesticides (organophosphates and chlorinated hydrocarbons) might be of concern in the MWMA. Organic chemicals are typically persistent in air, water, soil, sediments and food and might contaminate water, soil, sediment or biota far from their original source. They are usually lipophilic or fat soluble and therefore can be rapidly absorbed through cell membranes and accumulate in fatty tissues. Organic contaminants can be bioconcentrated by individual organisms similar to metals, but they can also be biomagnified through the food chain such that the highest concentrations are found in the top predators within an ecosystem. Some metals (mercury, cadmium, manganese and selenium) can also be biomagnified.

Along with analysis for selected contaminants in water, biological monitoring for contaminants is often necessary because of the potential for some contaminants to accumulate, bioconcentrate or biomagnify in different species. Sampling and analysis of selected resident species (plant, invertebrate and fish) can provide a basis for screening for the presence of contaminants in biota and the potential for biological effects.

In fish, analysis of specific tissues and organs can be used to selectively look for contaminants based on their mode of metabolism or accumulation in the animal. If significant levels of contaminants are found through biological monitoring, then the use of biological effects testing, such as early life stage testing with fish or invertebrates, can be important for assessing if the concentration of a particular contaminant in the environment might be consequential for aquatic life.

Sampling and analysis of sediments for particular contaminants can also be useful for correlating with results of water column and biological analyses. For point source releases of contaminants or for proposed development at a specific location, benthic sampling and community characterization can be important for defining baseline conditions or potential impacts.

A4.4 Where, When and How Often will Sampling Occur?

Reference conditions are usually required to adequately assess and interpret water quality monitoring results. A reference condition can be related to specific environmental characteristics, to a specific water body, to specific habitats utilized by aquatic species, to an area likely to be impacted by proposed land use or compared to an area of known impact. The location(s) chosen to define the reference state should remain an important reference point for future monitoring.

Sites are often selected to represent large geographic areas. Various approaches have been used to classify large areas into smaller regions of similar water quality. If this is part of the monitoring objectives, then it is important to know how well the data collected at the selected sites represent the water quality of the larger areas they were chosen to represent.

When and how frequently to monitor will depend on the specific question to be answered and several factors specific to what is being monitored, such as the expected variability of the parameter, response time of the parameter and the system, and how the parameter fluctuates with season and flow (if streams are being monitored). Generally, many established monitoring programs concerned with pollution monitoring typically monitor monthly or quarterly for specific pollutants. A standard might specify that a certain pollutant cannot exceed a limit for the entire monitoring period or no more than 10% of the time. Any biological measures would be done less frequently and usually related to seasonal events in the environment or sensitive life cycle conditions.

It is important to understand the variability of the constituent(s) or substance(s) being measured in order to determine the frequency of sampling. For long-term monitoring programs, it is important to consider the variability in water quality and how long it will take to detect a change in water quality of a specified magnitude prior to defining the sampling frequency. Some guidance exists on how to define the appropriate frequency for a monitoring program based on how various temporal sampling strategies affect the estimates of concentrations and loads in streams. However, it is often necessary to establish some estimate of variability for selected sites within a region during the first few years of monitoring.

A5.0 DATA COLLECTION AND MANAGEMENT

A5.1 Planning for Data Collection

Before fieldwork begins, it is important to establish a formal plan for quality assurance regarding all activities and procedures that will be employed in the monitoring program. Details on field crew training, field sampling and measurement protocols, sample handling and transport, laboratory testing and analysis protocols, and data management are essential topics that need to be covered. Use of checklists, forms and simple reporting sheets can be use to ensure the quality assurance plan becomes a routine part of the monitoring program.

Emphasis should be on data quality first. This means that decisions on the approach and methods will be informed by the specifications for data quality. The level of detection for constituents of concern, the type of sampling (grab, composite, etc.), the level of change (1%, 10%, 50%, 100%) and the statistical certainty (95%, 99%) are all examples of critical considerations when specifying data quality.

Focusing on specifications for data quality will allow for a better means of data comparability. In other words, this makes the data useful for other investigators even if their monitoring objectives are different; and for data sharing and synthesis at a local, regional or even national level. Ensuring data comparability is particularly important for long-term monitoring programs intended to define trends across sampling locations. Emphasis on data quality can also result in greater flexibility in methods selection and greater latitude in using and comparing new data collection technologies as they become validated and available.

A5.2 Managing Data

Management of data is about ensuring the accuracy, security and preservation of information generated from a monitoring program. Routine calibration or checks of field equipment used for measuring water chemistry and physical characteristics is critical. Creating routine procedures for labeling, dating, transcribing, downloading and backing up data should ensure that raw data is not confused or lost.

Database systems are typically designed for two purposes: data input and data retrieval. Data input is often time sensitive and organized chronologically to ensure that all the data is complete. Data retrieval is usually designed to allow for selection or sorting of data according to individual parameters, geographical location, exceedances of critical parameters. Some hierarchically arranged databases can allow for integration of data such that data collected for one purpose can be associated or compared with data collected for another purpose. GIS databases are an example of this.

For the MWMA monitoring program, it is assumed that the data collection and management will be consistent with the existing provincial database system. Formats and procedures for this system should be provided in detail prior to initiation of the program and training provided to field personnel and others as required.

A6.0 ASSESSMENT AND INTERPRETATION

Assessment and interpretation of data is a fundamental part of good science. If we think we see a change or difference or trend, we want to know if it is meaningful. Unlike laboratory experiments that control for most variables in order to determine the effect of a single change or difference, environmental monitoring studies as proposed for the MWMA typically try to measure the effect of variables that are not controlled such as climate or human interactions with the environment. This can provide strong associations with location, increased inputs of constituents, time, weather, etc. However, it might be difficult to demonstrate cause and effect.

For example, detection of a trend does not prove that the change is caused by time, though time is the primary variable. It might be that other associated changes were measured or identified and thereby provide a possible explanation as to why the trend is occurring. But it is also possible that the true causes are unknown, and may not have been measured. As a result, quantification of a past change may not guarantee that the trend will continue to occur, especially if future trends of the underlying causes are not known or understood.

A6.1 NON-PARAMETRIC OR PARAMETRIC METHODS

When we want to know if one location has higher levels of some substance compared to another location or other locations, this is essentially about trying to understand how often higher values are found at one location vs. another. In other words, we want to know if higher values are occurring more frequently at one location vs. another. This is a typical scenario for data generated from environmental monitoring studies.

Questions of frequency are most often analyzed statistically using non-parametric methods. Non-parametric methods are based on percentiles in which data are ranked relative to their frequency of occurrence. Questions of accumulated mass or volume are usually analyzed using parametric methods. Parametric methods are based on a mean and standard deviation in which the total sum and the range of variance for different treatments or situations are compared.

Another way to think of how to apply one method or the other is to determine if the question is in terms of either how often or how much. When we want to know how often there are higher levels at one location vs. another, then non-parametric methods are the right approach. If we want to know whether a greater amount of a substance is being released or deposited in one area vs. another, then parametric methods are the right approach.

Questions about how one wants to analyze, assess and interpret results should be part of the monitoring objectives and monitoring design. It is important to be clear on what kind of question you want to ask before the monitoring design is finalized. Otherwise, you might find that you could use the wrong method to answer the question.

A6.2 APPLICATION OF STATISTICAL METHODS

A common situation in environmental monitoring is to compare data for selected parameters collected from and grouped according to different land use types. The obvious question is whether some land use types show generally higher levels of certain parameters than other types. Another typical situation in environmental monitoring is to determine how concentrations of selected substances at background or reference sites compare with potentially contaminated areas. The question again is whether higher values are found more often at the contaminated sites compared to the reference sites. In both cases, non-parametric methods can be used to assess the data.

When monitoring data is compared to compliance standards for water quality or contaminants there are different approaches that can be considered. In one case, the amount released averaged over shorter or longer time periods is specified and monitored levels are compared to the specified limits. This is a direct parametric analysis. However, the tendency in recent years has been to set standards based on the fact that releases cannot exceed a certain concentration more than 5% or 10% of the time, assuming that frequent monitoring is required. This then is a question of how often exceedances occur and thus is best analyzed using a non-parametric method.

Trend analysis is essentially a question of determining whether water quality is getting better or worse. Put another way, the question is whether high levels of substances of concern are becoming more frequent or less frequent. This again can be assessed using non-parametric analysis. In this case, it is important to recognize that there are other variables such as seasonal effects that can influence the data. In the statistical analyses, it is possible to either account for this influence or ignore it depending on the objectives.

There are numerous other approaches that can be taken to analyze monitoring data and various sources for guidance on statistical applications. What is important to understand is that the assessment and interpretation of results is dictated by the monitoring objectives or the questions that one wants to answer. The way a question is posed will have a direct bearing on how the results can be assessed or analyzed. Therefore, it is critical to clarify the question being asked and use a statistical analysis that properly addresses the question.

A7.0 PRIORITIES FOR THE MWMA

Based on the foregoing discussion of considerations necessary for developing a monitoring program for the MWMA, it will be important to review and clarify the intent and objectives of the program for the foreseeable future. The desire to define a reference state for water quality and provide protection of salmon resources in the MWMA is clear. Implementing a monitoring plan that helps to achieve this is the challenge.

A8.0 CLARIFICATION OF MONITORING OBJECTIVES

What is the reference state for water quality in the MWMA? This is the primary question for the monitoring program at this stage. It is important to understand that the reference state is the current state of the environment. The Wet'suwet'en have noted that there are already impacts to water quality in some locations due to logging, agriculture or other land use activities. Further activities are proposed that could impact the water quality in the MWMA.

The reference state can be defined with different environmental components in mind. In the upper Morice watershed there are various lakes, rivers and streams. Consideration should be given to which of these water bodies would be the best indicators for water quality in the watershed. Selection of which water bodies to focus on can be guided by specific habitat characteristics (e.g., fish spawning or rearing habitat) or their location relative to existing land use activities (e.g., logged vs. unlogged areas).

Another consideration is to clarify what a representative sample will be for the MWMA. One way to think of this is in terms of the geography of the watershed. What is a geographically representative sample for the MWMA? Another approach could be in terms of biologically relevant habitats such as areas within the watershed known to be utilized by salmon. Another perspective is to have a representative sample that accounts for areas that have been important for traditional use.

There is no single approach to define a reference state. The appropriate approach requires clear decisions about what the priorities are or will be in the future. In formulating these priorities, it should be recognized that our knowledge of environmental interactions is incomplete and that there are other factors beyond maintenance of water quality that can influence environmental conditions locally. A realistic approach will allow for ongoing review and modification as global or local changes occur.

A8.1 SELECTION OF SAMPLING LOCATIONS

One approach to making decisions about sampling locations would be to look at the MWMA in terms of geography, hydrology and biology. Geographical decisions could revolve around which water bodies would be the best indicators of water quality in the MWMA and what locations within those water bodies would be most representative of the water quality in them. Hydrological decisions could be related to which locations would best demonstrate the influences from weather conditions (freezing, thawing, and rainfall or lack thereof) that alter water levels or flow; the influence of groundwater inputs to surface waters; or the influence of inputs from tributaries on rivers and inputs from rivers on lakes. Biological decisions could be based on important locations for salmon habitat or locations where resident species (e.g., sculpin, bull trout, etc.) are prevalent.

Selection of sampling locations could also be influenced by what has been done before. Are there areas or locations within the MWMA that have been monitored or sampled before? Are there areas or locations within the MWMA for which in-depth traditional ecological knowledge exists? This information can be valuable for defining the sampling design, the monitoring design and the monitoring objectives.

A8.2 Selection of Parameters for Measurement

The standard physical and chemical measurements for water analysis are well established and their importance for understanding the potential effects of contaminants was discussed earlier. Likewise, there are standardized methods for routine analyses of dissolved metals in water. However, the concentration of a metal in water is not necessarily a good predictor of its potential for biological effects. Most water quality criteria for the protection of aquatic life do account for this potential but some biological monitoring might be important to confirm water quality assessments.

In order to effectively use biological monitoring as a tool for assessing water quality, a good understanding of how contaminants are taken up by organisms is necessary. Generally, contaminants are taken up by aquatic organisms directly across membranes (through gills or skin in fish or through cell walls in plants), by ingestion of sediments or through the food chain. For example, cadmium is bioconcentrated from water by all organisms and will accumulate in the liver, kidneys and bone of fish where it can impair development and growth. Cadmium is also biomagnified such that fish and shellfish have higher concentrations of cadmium than zooplankton or algae. In contrast, selenium is accumulated in ovaries of fish and can lead to reproductive failure. Selenium is also bioconcentrated and biomagnified by aquatic organisms; and it appears that it is more toxic to fish when they are exposed through the food chain than through water. So for determining cadmium uptake, one might want to analyze the liver and kidneys of fish, but for determining selenium uptake, analysis of ovaries would be more appropriate.

Similarly, a good understanding of the solubility, mode of transport, bioavailability, environmental fate and potential for biological effects of organic contaminants is important in order to effectively use biological monitoring. A selective and customized approach to organic analyses is required because many of these chemicals are very persistent in the environment, have spread widely and cannot be related to a specific source or location. Polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) are examples of manufactured compounds that have become a global problem. They are accumulated in fish, wildlife and humans worldwide and can have consequential biological effects.

The Wet'suwet'en have voiced concerns about the problems associated with contamination of water and food by organic chemicals. The potential exposure to pesticides used locally has also been noted. In addition, the effects of endocrine disruption chemicals (EDCs) on fish has been raised as a concern since PCBs, PBDEs, some types of pesticides and other organic chemicals are known to be or suspected to be EDCs. These concerns are well founded but the important question will be whether and to what extent this can be addressed through biological monitoring in the water quality program for the MWMA.

A8.3 APPLICATION OF RESULTS

There has been some discussion about using the results of the monitoring program as a basis for developing site-specific water quality criteria. There has also been discussion about how the findings from the monitoring program could prompt specific ideas for research studies. Perhaps the more fundamental question is how the results will be used. It is intended that specific activities related to monitoring, establishing site-specific criteria or standards and enforcement thereof will be managed through shared decision making within the MWMA, and through the development of an Area Based Plan provided for under the *Environmental Management Act*. Under this type of plan, data collected from sampling locations identified as reference sites and affected sites would be compared to existing ambient criteria for the protection of aquatic life. Depending on the results obtained, site specific water quality objectives might be developed and/or sensitive zones might be designated where no dilution zone effects would be permitted.

It is expected that specific management objectives would be developed based on the findings from the water quality monitoring program. Initial data would be used to determine the selection of sampling locations, water quality parameters, sentinel species, biological endpoints and methodologies as key indicators of environmental quality. The development of management objectives would be based on data from both field and laboratory testing and rely on a weight of evidence approach for assessing the potential for risks and environmental effects. As new information comes to light, principles of adaptive management would be applied in order allow for new or more intensive monitoring and testing to be undertaken where needed. Collaboration with government, academic institutions and companies interested in development would provide a basis for expanded activities, particularly to address less tried and true methods of analysis or unique research opportunities. It is expected that this type of approach will be documented as part of the Collaborative Management Agreement that is being developed between the OW and the province.

A8.4 PRACTICAL CONSIDERATIONS

The MWMA is a relatively large and environmentally complex area. Access to some locations might affect decisions about sampling location and frequency. The available budget, personnel, monitoring equipment, sample collection supplies, boats, trucks and other miscellaneous material and supplies should be worked out as soon as possible. From this it will become more apparent what the scope of the initial monitoring plan can be.

Ideally, measurements should be taken at specified locations at least quarterly at times that are representative of seasonal conditions. However, there might be difficulties with access during winter. Ideally, there would be more than one field crew to obtain samples and measurements – one crew might do water quality measurements while another crew does biological sample collections. However, budget constraints and the availability of personnel, monitoring equipment, boats, etc. will ultimately dictate this. Development of a budget, equipment inventory and work plan will be necessary before it is possible to rationalize a monitoring design with the monitoring objectives.

While the practical constraints of budgets, personnel, equipment, supplies and site accessibility must necessarily guide any operations plan, it is important not to lose sight of the fact that the intent of the program is to characterize the environmental health of the upper Morice watershed. The water resources should include both surface water and groundwater. Biological assessments must account for the most sensitive life stages and species as well as unique local habitat conditions and cumulative effects, where water chemistry, soil or sediment chemistry, weather, and previous habitat impacts may combine to cause additive or synergistic effects. The amount of baseline data required to detect a change must be based on scientifically acceptable statistical criteria.

The monitoring priorities must be established with long-range goals in mind. At what locations samples are collected. The types of samples collected. The methods you choose for analyses and tests. The number of samples required to make statistically valid assessments. The relevance the data has for preserving water quality and aquatic life. The relevance the data has for providing a basis for management of an Area Based Plan, including site specific criteria for water quality and the protection of aquatic life and identification of sensitive zones where no impact can occur. All of these factors must be carefully considered even when the monitoring program has practical constraints. Even a more limited program can be designed to determine the potential effects of the most disturbed habitats relative to undisturbed areas. This can form the basis for more expanded studies as more resources become available.

A8.5 DEALING WITH UNCERTAINTY

Case 1) Monitoring data may identify small or moderate differences in water quality or habitat utilization for similar types of undisturbed reference sites located in different areas within the watershed. It may not be apparent what the basis for the differences are until sediment, soil and/or tissue analyses are completed. Even then there might not be any data that clarifies why differences exist. In such cases, it might be necessary to consider such differences as part of the natural variability within the watershed. Further research might help to understand why these similar habitats differ.

Case 2) There might also be situations where the data shows moderate or larger differences in water quality for a disturbed or degraded habitat vs. an undisturbed reference site but no apparent effect on habitat utilization by fish and no benthic alterations. Ambient water quality criteria for protection of aquatic life are exceeded for some substances. Subsequent sediment and/or tissue analyses demonstrate increased levels of certain elements or contaminants. From this data, there appears to be an impact but no apparent effect. Additional toxicity testing may help to clarify the potential for effects.

Case 3) Finally, there are situations where the monitoring data shows moderate or larger differences in water quality for a disturbed or degraded habitat vs. an undisturbed reference site including decreased habitat utilization by fish as well as benthic alterations. Subsequent sediment and/or tissue analyses confirm contamination at the degraded site. This data shows an impact and a direct effect. To develop site specific water quality criteria, it may be helpful to undertake selected toxicity tests and further tissue analyses.

These three hypothetical cases are given to illustrate how different triggers for further monitoring and testing could occur. Case 2) is an example where findings are ambiguous. If additional toxicity testing is pursued, it must be carefully designed to approximate the local conditions and use sensitive indicator life stages or species. If standardized tests do not demonstrate effects, it could suggest that there are other mitigating factors about local water chemistry or habitat conditions and that the criteria might not be applicable in this case.

When our knowledge of all mechanisms for biological effects may not be addressed with existing techniques and methods, consideration could be given to undertaking further research. The decision process to determine if further work is worthwhile would depend on the importance of the habitat and species potentially affected; the substances of concern and how much is already understood about their potential for biological effects; and what expertise is available to assist with study design. Of course, the ability to involve other partners and obtain additional funding would facilitate additional work but that would depend on how novel or intriguing it might be to other researchers to investigate the problem.

Since it is not possible to account for all the possible variables that might affect measurements, sampling decisions and results, it is important to review and revise monitoring objectives routinely. Annual and multi-year reviews of data will enable revisions to be made. The monitoring program should be a dynamic process, which allows for modifications, changes or additions, but continues to consistently collect the essential baseline information necessary to distinguish between natural variability and changes in environmental quality due to identifiable impacts.

The scope of work will rely primarily on standard methods and techniques for obtaining reliable data. However, a review of findings could identify opportunities to further clarify or confirm results by adapting or modifying existing methods or applying more novel research techniques. Allocation of resources for monitoring should remain focused on the primary monitoring objectives using accepted methods of assessment but more speculative approaches to evaluating environmental integrity and biological effects may also be warranted, particularly when the development of site specific water quality objectives are under consideration.

A8.6 CREATING PARTNERSHIPS

Presently, the MWMA is a partnership between the OW and the Province of BC. While the current arrangement provides a starting point for implementing a monitoring program, it is advisable to consider how to involve other institutional or private sector partners in order to expand the capacity of the program to address the priorities and objectives of the program. The current partnership in effect sets a precedent and provides a context for other parties to become involved. The initiatives contemplated by new partners should be guided by the existing agreements or proposals for an Area Based Plan, and should be consistent with objectives of the ongoing monitoring program.

It is important to note that the Morice watershed offers unique opportunities to study undisturbed habitat that sustains valuable and important salmon and other aquatic resources. It also provides the opportunity to study the effects of specific impacts that can be defined spatially, temporally and with respect to specific environmental variables and introduced substances. This is particularly attractive to institutional researchers because there are not many relatively undisturbed areas where trends in natural variability can be monitored and at the same time human impacts and effects can be isolated and studied.

Institutional partners should provide scientific expertise that is complementary to the priorities and objectives of the program. For example, toxicological studies on the effects of metals on early life stages of fish using site specific receiving waters and testing might provide better definition of site specific water quality objectives that are incorporated into an Area Based Plan. At the same time, the unique characteristics of the MWMA allow researchers to validate techniques they may have applied under laboratory conditions but were unable to use in most field situations because of habitat disturbance or pollution. Institutional researchers also have access to funding that would not be available to the OW. In addition, training and education provided by institutional partners should be identified and incorporated into partnership agreements so that community members will have opportunities to develop new skills and careers.

Potential partners from the private sector will be those parties interested in development within or adjacent to the MWMA. It will be important to use the existing agreements and proposals for an Area Based Plan, as well as the priorities and objectives for the water quality monitoring program, as a prerequisite for development. For example, more comprehensive terms of reference could be required for determining the extent and degree of habitat disturbance from any proposed development. In addition, more stringent criteria could be required for determining potential impacts and effects from a proposed development. All of this work would be paid for by the private sector parties interested in development and would be designed to complement the ongoing monitoring program. It should be established that all information and data resulting from this work would be available to the partnership to enhance the knowledge base for the area. Investments in training and educational opportunities for local community members, as well as service contracts for field assistance, could also be part of the partnership agreement with private sector interests.

Non-governmental organizations and foundations can also play a role in funding program activities. It is important to understand the philosophy and orientation of potential third party donors to ensure that the partnership does not result in any conflicts about or misrepresentations of the program. These potential partners will often be more willing to support activities once most of the initial development and funding of the program is in place and there are working partnerships already set up if not ongoing. Proposal development and reporting are often required for establishing this type of support. Therefore, it is important to recognize that there will be additional time and effort needed to solicit and obtain funds as well as maintain required communications and reporting once funds are in place.

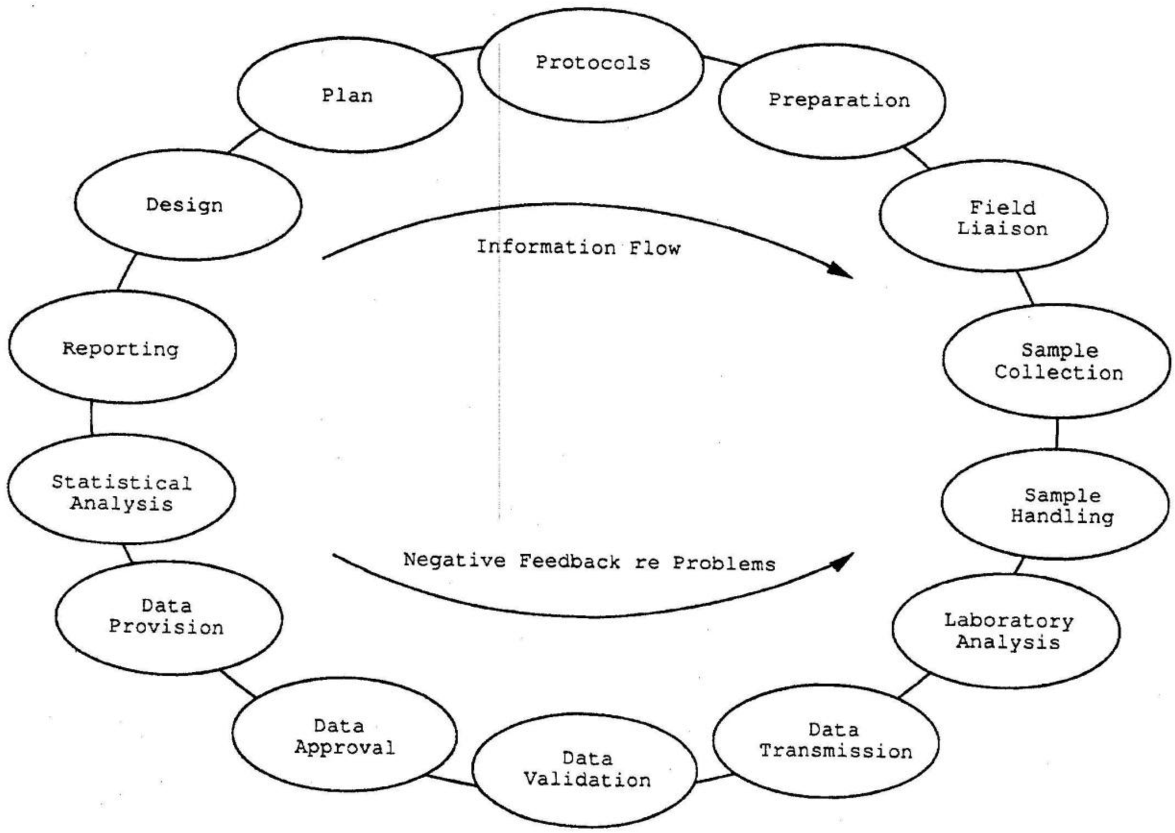
A8.7 Development of an Operational Monitoring Plan for the MWMA

In previous sections, this framework document discussed, in general terms, what is necessary to design a scientifically valid monitoring program that is focused on specific objectives. The primary monitoring objective for the MWMA is to undertake a survey that will establish a baseline set of water quality and biological data for the watershed. Other ancillary objectives for the MWMA include an impact assessment to determine the effects of land use activities such as logging and agriculture, and compliance monitoring of existing or proposed mine development to determine if ambient water quality objectives are being met. Ultimately, another objective would be to identify if there are trends occurring in water quality and biological data for specific water bodies over a specified length of time.

A specific objective must be clearly defined and should be expressed in terms of a question. Sampling and testing protocols must be standardized and subject to ongoing quality assurance and quality control. Statistical requirements for the program should be determined as part of the monitoring design as a basis for defining sampling strategies that will account for natural variability and determine what to sample, where to sample and how much to sample. All aspects of the monitoring program should be part of an iterative cycle.

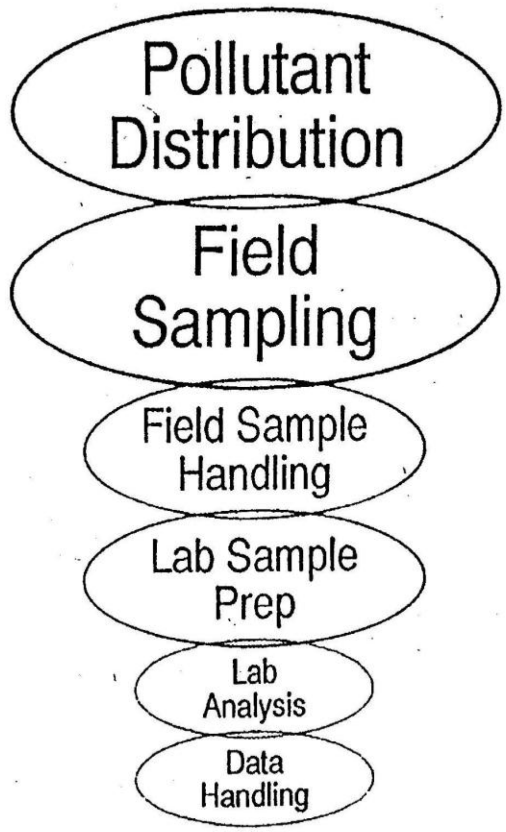
Figure 2 provides an example of how the elements of a monitoring program should interact. The flow of reliable information that results in verifiable data requires continuous feedback that identifies problems with specific aspects of the monitoring program. Figure 3 provides a graphic representation of the likeliest sources of error that may occur. The largest sources of variability are often due to temporal and/or spatial changes in pollutant levels, inconsistencies in field sampling and sample handling, and variation in lab sample preparation. It is important to keep these potential sources of error to a minimum.

Figure 2: Interactive Elements of an Environmental Monitoring Program



From: Clark, M. and P. Whitfield. 1993. A practical model integrating quality assurance into environmental monitoring. Water Res. Bull. 29 (1): 119-130.

Figure 3: Relative Sources of Error (Variability) in Environmental Sampling and Analysis



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An operational monitoring plan for the MWMA is provided in Appendix 3. This plan is intended to be modified and added to as the program evolves. It is simply a starting point to provide an initial focus for defining activities. The scope, objectives and elements of the plan are based on meetings and discussions with the OW chiefs and staff, Ministry of Environment staff and a review of recent monitoring plans used in other jurisdictions.

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APPENDIX 3: OPERATIONAL COMPONENTS OF THE MORICE WATER MANAGEMENT AREA

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B1.0 SPECIFIC OBJECTIVES

Specific objectives are posed as a question. They are usually associated with specific locations, activities, variables, data analysis requirements and other monitoring design components. The following specific objectives are based on issues raised for the MWMA. It is assumed that all the objectives listed below cannot be addressed simultaneously. There is a natural progression from survey objectives to impact assessment objectives through to compliance and trend objectives. It is usually necessary to address survey objectives in order effectively address impact assessment objectives as well as establish a basis for addressing trend objectives. Compliance objectives also rely on results obtained addressing survey objectives and impact assessment objectives but compliance objectives may be addressed in isolation with respect to criteria, objectives or permit limits specified for developments and operations known to have habitat impacts.

B1.1 SURVEY OBJECTIVES

Are there distinguishing water quality characteristics within the MWMA that are unique to specific streams or lakes?

What historical data and mapping is available that can help to define normal limits of natural variability and identify sensitive areas within the MWMA that are prone to slides or subject to transient flooding, dewatering, significant inputs of sediment or debris, or other extreme events that would alter habitat utilization for aquatic species.

Can a range of natural variability be defined for standard water quality measurements and specific substances of concern (metals, organic contaminants, suspended sediment, etc.) in the MWMA?

What are the best reference sampling sites for water quality, sediment and biological monitoring?

What are the best sampling sites for impact assessment, compliance and trend monitoring?

B1.2 IMPACT ASSESSMENT OBJECTIVES

Are there exceedances of the ambient criteria for the protection of aquatic life that are associated with known habitat disturbances from human activities?

Are there exceedances of the ambient criteria for the protection of aquatic life that are not associated with known habitat disturbances from human activities?

Is there evidence that forestry activities have adversely altered water quality conditions such that aquatic life is impaired?

Is there evidence that pesticide/herbicide use has adversely altered water quality conditions such that aquatic life is impaired?

Is there evidence that agricultural activities have adversely altered water quality conditions such that aquatic life is impaired?

B1.3 COMPLIANCE OBJECTIVES

Have conditions changed at designated locations within the MWMA such that variables or substances of concern no longer comply with water quality objectives?

Have pre-determined objectives and/or permit specifications for specific activities at designated locations been complied with?

Have non-compliance events occurred in which measurable impacts to water quality were identified?

Have non-compliance events occurred in which fish habitat alteration, damage or destruction occurred?

Have non-compliance events occurred in which biological effects on aquatic species were identified associated with measurable impacts to water quality?

B1.4 TREND OBJECTIVES

Is there a long-term trend in the standard water quality measurements (pH, turbidity, conductivity, dissolved oxygen, etc.) in lakes or streams within the MWMA?

Is there a long-term trend in fish abundance that is associated with specific areas or water bodies within the MWMA?

Is there a long-term trend in fish habitat utilization that is associated with specific areas or water bodies within the MWMA?

B2.0 STATISTICAL REQUIREMENTS

The statistical aspects of the monitoring program need to be determined prior to designing the other aspects of the program. There are usually compromises that must occur to balance scientific and statistical requirements with the budget constraints of most environmental monitoring programs. In order to understand if a significant change has occurred, it is necessary to determine the normal limits of natural variability within the MWMA. However using historical and other background data on the MWMA, it should be possible to select sampling locations, choose sample sources (water, sediment and biota) and prioritize specific parameters and substances for measurement that will increase the ability to distinguish the effects of human activity from natural events (i.e., minimize the effects of natural variability).

In order to ensure a high level of confidence when any apparent statistical difference is found, certain factors must be adequately accounted for. These include natural variability, the level of significance, power and sample size. A brief summary of how these factors affect the analysis of results and how they interact follows. More specific recommendations on sampling for the MWMA are provided in subsequent sections. Note that it is important to obtain the advice of a statistician to ensure that the monitoring design issues such as sample site selection, sampling frequency, sample size, level of significance and power will meet the program objectives.

B2.1 Natural Variability

There are many reasons why regular normal differences might occur at different locations within the watershed or over time at a single location. Differences between two sample sites can occur if there is an input that alters the conditions between the two sites. Inputs from tributaries into rivers or lakes would be more obvious than groundwater inputs.

Diurnal changes in temperature or seasonal changes due to freshet can create distinct differences over time. Biological cycles such as fish spawning and carcass degradation can also cause temporal changes. In addition, high rainfall and other storm events can cause marked differences for extended periods of time when otherwise there would be little variability.

It is necessary to identify when there might be critical periods for natural variability and to determine what the range of variability might be during those critical periods. For example, it would be important to measure the level of suspended sediment that occurs monthly in order to determine how it changes in relation to seasonal conditions such as spring freshet or fall rainfall. It would then be important to do more intensive sampling during those critical periods in order to determine the range of variability during those seasonal events.

B2.2 Level of Significance

The level of significance is the probability that an apparent difference is significant when it is actually due to chance. Typically, the level of significance assumes a 5% (0.05) chance that a statistically significant result is due to chance. Conversely, it assumes that there is a 95% chance that the result is true. The assignment of probability can be arbitrarily lowered so that the probability of a chance result is 1% (0.01) and increase the chance that the result is true to 99%. However, it may be necessary to increase the probability of a chance result to 10% (0.10) or 20% (0.20) when there is a concern about the risk of incorrectly concluding that there is no significant difference when one actually exists.

A balance must be found between the risk of concluding that there is a significant statistical difference when there is not one (Type I error), and the risk of concluding that there is not a significant statistical difference when there is one (Type II error). When you have a fixed sample size, reducing the probability of a Type I error increases the probability of a Type II error, and vice versa. In some cases, it may be more important to take a more precautionary approach by reducing the probability of a Type II error instead.

B2.3 Power

The power of a statistical test refers to the probability of detecting a difference when one exists. Another way to think of it is that power is the probability of avoiding a Type II error. Larger samples will result in statistical tests with greater power. Increasing sample size is the only way to reduce both Type I and Type II errors at the same time.

B2.4 SAMPLE SIZE

The larger the sample size, the more the uncertainty of results is reduced. However, budget and practical constraints mean that large sample sizes are not usually possible. There are various ways to determine a sample size to provide reliable results by pre-specifying the margin or error and the probabilities for Type I and Type II errors. This approach relies on advice from a qualified statistician.

Another approach is to undertake pilot studies to determine what sample size is needed to capture the range of variability inherent to the variable being measured. For example, it might be found that the mean and variance results from a 5 day sample period are not statistically different from a 30 day sample period. When it is not possible to undertake pilot studies, it is sometimes assumed that a sample size of 10 can be adequate. This can be used at least as a starting point until better data is developed, and is a reasonable temporary compromise between cost and the need to reduce the uncertainty of results.

B3.0 BUDGET CONSTRAINTS

It is often challenging to fit the monitoring objectives and design within the budget constraints. Input from a statistician about the statistical tools and design necessary to answer the specific objectives will also help to clarify where monitoring effort should be concentrated. Cost decisions about what to monitor for, where to monitor and how frequently to monitor can then be made while ensuring that minimum statistical requirements are met.

Generally, it can be assumed that the analytical laboratory costs will be a key limiting factor and can consume as much as half the budget. However, it is often the case that field sampling costs can be as much as the analytical costs. Quality assurance/quality control costs can add another 10 to 30% to the overall cost. For a new program like the MWMA, the QA/QC costs will likely be at the high end until routine procedures are established and the consistency of sample quality is confirmed.

B4.0 PERSONNEL AND TRAINING

At this stage, the MWMA program is assumed to require an operational manager and three people dedicated to field sampling. Walter Joseph and Stefan Schug will be responsible for project management and scientific management, respectively. Field personnel should have a basic knowledge of program objectives, proper use and maintenance of field equipment, sampling protocols and QA/QC requirements, and expected ranges for field measurement values. Otherwise, a training component should be included for field staff. This training component should be developed and coordinated with those responsible for laboratory analyses.

Ideally, field sampling techniques should be carried out by the same people throughout the entire sampling schedule. Individual field staff can be assigned to be responsible for specific activities such as boat operation and maintenance, calibration and maintenance of oxygen, pH and conductivity measuring equipment, organizing and coding sample collection materials, and record keeping and data management. At least one crew member should be trained in boat operations and safety. If chemicals are used for sample preparation, staff should be trained in appropriate use of potentially hazardous materials in accordance with BC Work Safe requirements and/or appropriate regulations or legislation.

B5.0 SAMPLE COLLECTION

It is important to develop a sampling strategy that provides scientifically and statistically valid monitoring results from the onset. At the same time, the sampling strategy should provide a basis to expand the program. Necessarily, the MWMA program must start by addressing the survey objectives in order to capture the normal range of variability. However, decisions about where to sample, what to sample and what to measure must be made with impact assessment objectives, compliance objectives and trend objectives in mind.

A sampling strategy should be developed with at least a 5 year outlook in mind. Basic measurement parameters for water quality must be monitored consistently wherever and whenever sampling is undertaken. More selective decisions about sediment and biological sampling should be made based on existing habitat disturbances, known sources of pollution or proposed development. Once the normal range of variability is better understood then some of the basic measurements can act as triggers for additional sampling. Identification of any unique characteristics in water quality and aquatic habitats within the MWMA is also important to guide subsequent decisions on sampling.

B5.1 WHERE TO SAMPLE

The MWMA is characterized by a number of sub-basins, which have unique characteristics or provide habitat for important aquatic species. Morice Lake and the upper Morice River watershed are central to the area but the Nanika Lake chain is an important input into Morice Lake that provides spawning habitat for sockeye salmon. McBride Lake and tributaries, the upper Gosnell watershed, the Thautil River, Bernie River and lakes, and Atna Lake and tributaries are other important habitats within the MWMA.

Some of these sub-basins have existing habitat disturbance while other areas do not. Other areas are identified for potential development. Some of these areas are readily accessible while others are more difficult to access. Some of these areas provide unique habitat for Bull Trout, Sockeye Salmon, Chinook Salmon, Cutthroat Trout, Steelhead Trout and other species. All these factors need to be considered when selecting where to sample.

As a starting point, suggested reference sample sites for surface waters could include the upper Morice River; Nanika Lake and Nanika River (below the falls); the upper Gosnell River, McBride Lake and the Bernie lakes area. Potential reference sample sites for ground waters have been identified in Morice and Nanika lakes as well. Suggested focus areas where existing habitat disturbance has occurred include logging in the Thautil watershed, pesticide application in the Gosnell watershed and mine exploration near Nanika Lake (Fenton Creek). Other focus areas where mine development or a pipeline corridor is proposed include the upper Gosnell watershed, the upper Morice River watershed and the Nanika Lake chain.

Based on current information, it is suggested that sampling priority should be given to the upper Morice watershed and the Nanika system, including selected sites in Morice and Nanika lakes. Sampling sites in the upper Gosnell watershed should also be given priority, particularly sites selected to compare disturbed vs. undisturbed habitat. Other sampling sites should be given consideration based on whether the habitat is critical for sustaining the life cycle of important aquatic species. Specific sampling locations should be defined using GPS locating devices to ensure that the same locations are consistently sampled.

Some discussion was given to incorporating water quality sample locations and the data generated for water chemistry, sediment analyses and biological variables into existing GIS databases. This approach would allow for identification of unique site characteristics and data for key variables to be mapped and compared. It is expected that additional funding may be needed to coordinate this.

B5.2 When to Sample

While the sample size and sampling frequency should be guided by statistical considerations and advice, it is important to consider what the minimum data requirements might be in order to better estimate what the workload and costs will be. Initial monitoring could be considered as pilot studies designed to capture the range of normal variability and to identify critical periods for important variables. Thus, monthly sampling would identify seasonal variation. High levels in certain months for key variables such as suspended particulates during peak flow periods (freshet or fall rains) would trigger more intensive sampling during these periods in order to capture any increased variability during these events.

Previous discussions have identified a starting point for sampling frequency. During open water seasons (non-winter months), sampling should occur at least once per month. During high flow events (spring freshet [mid to late June] or fall rains [mid-September – mid-October) sampling should occur at least 5 times during the period. During low flow periods (summer [mid-August – mid-September] and winter [February]) sampling should be undertaken at least 5 times throughout the period. Depending on logistics during winter, sampling should occur at least once per month. If possible, it is recommended that the sampling frequency during high flow or low flow events should be increased from 5 to 10 times in order to better capture the range of variability.

Opportunistic sampling based on weather conditions or changes in human activities can be important for future monitoring design and will provide better guidance for determining changes beyond the normal range of variation. An obvious opportunity for sampling is during storm events when heavy precipitation occurs. Another is when heavy or prolonged precipitation first occurs after a prolonged dry period. This “first flush” event can often mobilize higher amounts sediments and associated elements and substances than would otherwise occur, particularly in disturbed habitats.

B5.3 WHAT TO SAMPLE

Initial monitoring is intended to delineate the variables of concern and the natural range of variability for those variables that are likely to be the most sensitive indicators of change. Survey monitoring would include a general suite of variables that covers water, sediment and biological indicators. Impact assessment monitoring is intended to link any current or proposed land use activities within the MWMA with variables of concern. Trend monitoring can be based on selected survey and impact assessment measurements.

The number of variables to monitor will vary depending on the type of habitat impact and the specific characteristics of the local environment. Greater focus and attention should be given to any site-specific variables that are likely to be altered or are already elevated within the receiving environment. There are routine core measurements that should be included for most if not all sampling sites. Other measures would be dictated by local conditions and any potential or existing impacts. Significant changes to core and other baseline measures would be expected to trigger additional measurements.

For initial monitoring in the MWMA, suggested core measurements could include:

In the water column: temperature, dissolved oxygen, specific conductivity, pH, turbidity and suspended sediments (rivers and streams), Secchi depth (lakes), metals analysis (using inductively coupled plasma-mass spectrometry [ICP-MS] or another more sensitive analytical method) and nutrient levels for phosphorus and nitrogen.

In sediment: ICP-MS metals analysis and selected organic analyses for pesticides and other possible contaminants.

In biota: surveys of distribution, abundance and community characteristics of benthic invertebrates, zooplankton, phytoplankton, periphyton, and/or selected fish species; and tissue/organ analysis with fish.

The scope of biological effects monitoring and testing will be dependent on the budget, the results of initial surveys of biota and fish tissue/organ analyses. Sculpin would be a candidate for tissue/organ analyses. Target tissues or organs will depend on what type of constituent or substance is of concern. Where elevated levels of contaminants were evident, early life-stage testing with salmon and/or trout species could also provide added insight on the potential for effects.

Another focus for selecting what measurements to consider is with respect to potential development and the types of impacts that they typically create. For example, mine development and operations are known to affect aquatic habitat in a variety of ways. These effects can include: increased suspended solids and turbidity, altered conductivity, increased heavy metals concentrations, altered temperature, altered pH, increased nitrogen (from blasting), changes to benthic invertebrate communities, decreased juvenile fish abundance, etc. Therefore, the choices of variables of concern are to some extent dictated by these potential effects.

A consequence of habitat disturbance from development such as logging, mining, or clearing for pipeline corridors can be alterations in hydrological dynamics. Turbidity and suspended sediment measures are helpful to monitor for effects due to erosion and upslope instability. However, alterations in stream/river peak and low flows as well as run-off patterns, altered stream channel characteristics and increase of total water yield would need to be monitored by a hydrologist.

B6.0 QUALITY ASSURANCE/QUALITY CONTROL

The MWMA monitoring program should have a QA/QC manual that outlines all activities and procedures for the sampling program. The manual should provide detailed explanations of procedures, define responsibilities for staff and provide contact information for resolution of problems or emergencies. It should also provide general guidelines to ensure the any problems are identified and resolved in a timely manner. The manual should be reviewed and updated regularly and any revisions should be documented and dated.

B6.1 Data Quality Objectives

The study objectives are developed with specific criteria or data quality objectives (DQOs) in mind. The DQOs are data quality specifications that establish the maximum amount of uncertainty or error that is acceptable. The DQOs should be specified within the QA/QC manual before any samples are collected in order to avoid time and money being spent collecting samples that cannot be analyzed with confidence.

For example, it is critical that any control or reference samples are not contaminated during field sampling. This can occur due to contamination from sample containers, preservation agents or from incidental contamination associated with sample collection, sample handling and sample transport. If this occurs it can compromise the ability to determine changes or differences in the field. The DQOs would specify what the range of acceptable variability should be for control/reference samples as well as how to determine the existence and magnitude of any contamination problem.

The MWMA monitoring program should be guided by this approach. Staff should participate in ongoing training programs that emphasize and demonstrate the importance of following QA/QC procedures. The involvement of qualified personnel from the analytical laboratory being used for sample analysis, in training and ongoing review will help to ensure high quality data is consistently generated. Ongoing coordination of field sampling and laboratory analysis is a key factor for achieving consistent and reliable results.

B6.2 Basic Design Considerations

All study design considerations must be developed with QA/QC objectives in mind. It is best to assign someone the responsibility for monitoring and reinforcing these objectives. However, this individual should not be responsible for budget management since QA/QC objectives can often be in conflict with budgeting objectives and constraints. This individual would prepare and issue QA/QC reports on a regular basis.

It is important to ensure that each step of the sampling and post-sampling process follows documented protocols. Any deviations or modifications from procedures should always be documented. The priority should always be to obtain samples that are representative of the location, conditions and time being sampled.

Common sense is needed to ensure that the effort to sample or monitor at a particular location is not influencing the results. Some local environments may be particularly susceptible to alteration due to boat prop action or other actions taken during the sampling process. The same common sense approach should be applied to keeping sample collection and monitoring equipment clean and running properly to avoid Similarly, all field personnel should know what to do or whom to contact if something does go wrong.

Essentially every facet of the field sampling process should be documented and field personnel familiarized with practices before field work begins. Use of sample containers, sampling methods, monitoring equipment, calibration practices and record keeping are some of the more obvious aspects of the process. Individual members of the field crew can be assigned primary responsibility for specific aspects or tasks but all field personnel should know how to undertake the necessary procedures and protocols properly.

B6.3 Record Keeping

A system for recording and retrieving field samples must be devised to provide easy access to when, where, how and by whom samples were taken. Sample coding and numbering is often used to avoid any bias during analyses, but it must be designed to avoid any possibility of mixing up samples. Tracking of the sample history should be documented including:

- Method of sample collection;
- Location, date and time of sample collection;
- Who collected the sample;
- Sample container used;
- Sample Code and Key;
- Storage conditions prior to transport for analyses;
- Transport used to send sample for analysis; and
- Time and condition of sample when received for analysis

Record keeping for field sampling is an obvious requirement but databases for other aspects of the program must also be maintained. Water quality monitoring data must be accurately and reliably recorded and transferred into a database that can be used for a variety of purposes. In addition, precise records of monitoring equipment calibrations are critical for ensuring that accurate and reliable data is collected.

B6.4 QUALITY CONTROL

While quality assurance measures are intended to anticipate and prevent problems with data quality, quality control measures are intended to provide a means to quantitatively check if sample quality has been maintained or compromised. Quality control measures must be implemented in close consultation with the laboratory undertaking analyses. It is critical that there is timely identification of any problems through direct communication between those responsible for collecting samples and those responsible for analyzing samples.

Quality control samples are collected in addition to samples being collected to meet the program objectives. For samples collected and forwarded to the laboratory for analysis, essential quality control samples include:

- Field and transport blanks to monitor potential contamination prior to receipt at the lab;
- Duplicate or multiple replicate samples to measure any field sampling error and/or local environmental variation; and
- In-house reference samples to monitor accuracy.

The analysts will also undertake additional quality control measures at the laboratory to check the consistency and accuracy of their analytical equipment.

The quality control requirements for the MWMA program will depend on the number and types of samples that are collected. It should be expected that between 20% and 30% of the analyses will involve quality control samples. If consistent and repeatable results are regularly achieved then the number of quality control samples may be reduced. However, if sample quality problems do arise, the requirements for additional quality control samples can rise to 50% or more of the samples. Therefore, strict adherence to quality assurance practices can save the program significant costs.

B6.5 METHODS DOCUMENTATION

While it is important to document and follow standardized methods and protocols when undertaking field sampling, it is not uncommon for procedures to require some minor modification or adaptation because of practical or logistical constraints. It may also be scientifically desirable or necessary to apply new and improved modifications to techniques before the standard documented procedures have been updated. Whether the sampling methods are new or modifications of existing methods, the important thing is to validate the technique. Validation would require comparison with established techniques as well as verification of its application over the range of conditions encountered during sampling.

Methods documentation should include an inventory of current methods, previous methods and when any change in methods occurred. Typically, sampling methods and procedures documentation should include:

- An explanation of the specific procedure in sufficient detail that experienced field personnel not familiar with the specific procedure could successfully undertake the necessary work

- Instructions for preparation and use of any reagent water, preservative chemicals or other reagents needed for sample collection
- Specific instructions necessary for operating sampling equipment
- Quality control sample preparation and collection procedures
- Specifications for DQOs.

B6.6 AUDITS

It is standard practice to regularly review program activities and procedures to ensure that accurate and reliable results are being obtained. Internal audits should be undertaken at least once per year or more frequently if problems arise. External audits by an independent auditor are also advisable at least every 5 years or as frequently as every 2 years.

There are three types of audits that need to be considered when reviewing QA/QC standards. Systems audits are simply observational to see that all aspects of the QA/QC requirements are being done. Performance audits are a more detailed review in which sample preparation and/or collection is duplicated and compared. Data audits are done to check how well field sample collection is tracked and documented. An internal data audit should be done at the start of a new program such this one.

B7.0 CHECKLISTS

One way to reinforce the need for a systematic approach to field work and create a basis for greater consistency in program data quality is to use checklists. Much like airline pilots go through a checklist every time they prepare for takeoff and landings, field staff should use checklists to ensure that all procedures are followed. Checklists can be used for equipment maintenance and calibration, sampling protocols, etc. They should be part of the record keeping for sampling and data collection. An example of how a checklist can be itemized for use by the sampler or a field auditor is shown below in Figure 1 (from: Ministry of Water, Land and Air Protection. 2003. BC Field Sampling Manual. Water, Air and Climate Change Branch, Victoria, BC.).

B8.0 SCOPE OF OPERATIONAL PLAN

The preceding sections are intended to provide specific guidance for developing work plans for the MWMA monitoring program. The components and considerations discussed in the preceding sections are focused on the elements that should be given priority to begin with. As the program develops and hopefully expands, there are likely to be other components and considerations that must be addressed. Additional guidance to help define the operational plan further are cited in the Water Quality Monitoring Framework bibliography.

Figure 1 Sampling Evaluation Checklist

Date: Site: Sampler: Observer:

STEP or PROCEDURE

- ☐ All equipment and sample bottles are packed prior to going to the field.
- ☐ Waterproof field sheets / notebook
- ☐ Weather, field measurements, general observations, possible contamination sources, details about the site, sampling crew names etc. recorded in field notebook or specialized field sheets.
- ☐ Safety protocols planned to minimize transit delays
- ☐ Bottles clearly labelled & dated using a permanent marking pen.
- ☐ Sampling equipment (and associated items such as ropes) cleaned before use.
- ☐ Sample taken at designated sampling site; any deviations from site location recorded.
- ☐ Bottle caps removed just before sampling, are protected from contamination (i.e. placed in a clean, dry plastic bag; touching inside of caps & bottles avoided).
- ☐ Caution exercised when sampling; generally safety conscious around site.
- ☐ Samples collected from deep, well-mixed & flowing water whenever possible (in streams).
- ☐ Samples collected facing upstream when wading; stirred-up water avoided.
- ☐ Debris from falling from bridge onto the sampling unit avoided.
- ☐ Sample bottles are not rinsed before collection (i.e. are lab pre-cleaned).
- ☐ Bottles filled to correct level & securely capped immediately after filling (i.e. room for preservatives, small air space for coliforms).
- ☐ Preservatives handled carefully with appropriate safety equipment (i.e. gloves & glasses; demonstrates technique that minimizes preservative contamination; empty preservative vial re-capped, placed inside secondary container and returned to cooler).
- ☐ No contact between preservative vial or dispenser & sample water or sample bottle.
- ☐ No contact of sample water, inside of bottles or caps with anything!
- ☐ Thermometer allowed to equilibrate 3 or 4 minutes in field bottle before reading;
- ☐ Thermometer or probes never inserted into any sample bottle.
- ☐ Sampling time recorded as hh/mm (24-hour clock); sample date as yy/mm/dd on all lab requisitions.
- ☐ Bottles packed carefully with enough ice packs to cool temperature sensitive samples to $4^{o}C$ during transit.
- ☐ Shipping coolers secured (taped) for transit; destination clearly labelled on cooler(s).
- ☐ Reusable sampling & safety equipment is kept clean & stored for future use in such a manner as to minimize damage or contamination.