# Valued Component – Water and Sediment Quality (FINAL DRAFT)

## STATE OF KNOWLEDGE – WHAT IS HAPPENING?

**A very brief overview of the state of knowledge with respect to water and sediment quality in the NWT is presented below. This overview is preliminary and not intended to be exhaustive.**

↪ **What are the baseline conditions with respect to water and sediment quality?**

✻ Water and sediment quality are important to the health of both the natural and cultural environment. Water and sediment quality are inextricably linked, particularly in the Mackenzie River, which has the largest sediment load of any river in the Arctic circum-polar world. Its sediments contain large amounts of non water-soluble organics and metals. Sediment quality monitoring has been very limited compared to water quality monitoring.

✻ More intensive local research results have only partially been integrated with regional monitoring due to budget limitation, coordination challenges and logistics. Baseline water and sediment quality conditions can be expressed statistically and graphically for long-term stream water quality sites for variables such as total suspended solids, water temperature, pH, conductivity, turbidity, dissolved organic carbon and trace metals, but not for variables rarely or not measured (bacteriologia, organics, radionuclides, some physicals). There is little data for lake/pond water quality and stream/lake/pond sediment quality. It has been noted as early as 1990 (D. Gregor, NWRI, Northern Hydrology) that there is little water and sediment quality data and information for lentic (lake/pond/marsh) water bodies relative to current data for lotic (flowing water) water bodies. Recently however, limnological research has been carried out on lakes of the Mackenzie Delta/Tuktoyaktuk Peninsula as part of the Nothern Energy MC funded Aquatic Quality Program, largely in response to the historic Mackenzie Gas Project (MGP). Other similar studies are being carried out in other areas including the Great Bear Lake area, Fort Simpson-Trout Lake area, and Nahanni,Tuktut Nogait and Aulavik National Parks.

✻ Numerous factors can affect the quality of freshwater. Affects can be natural – underlying surficial and bedrock geology, topography, sediment load, etc. Affects can be

### *KEY MONITORING INDICATORS*

*Primary Parameters:*

*Physicals:*
- *Water Temperature*
- *pH*
- *Conductivity*
- *Turbidity/Color*
- *Dissolved Oxygen*
- *Total Suspended Solids*
- *Total/Dissolved Organic Carbon*

*Major Ions*
*Nutrients*
*Total/Dissolved Metals*

*Organics:*
- *Polyaromatic Hydrocarbons (PAH)*

*Bacteria:*
- *Fecal Coliform*
- *Fecal Strep.*
- *E. coli.*

***Secondary Parameters:***

- *Clarity*
- *Total mercury*

***Organics :***
- *Extractable Organochlorine*
- *Pesticides (e.g. lindane)*
- *Polychlorinated Biphenyls (PCB)*
- *Dioxins/Furans*
- *BTEX*

also the result of nearby and even distant human activities – long range transport of atmospheric pollutants and primary resource industries, such as industrial and municipal effluent, forestry, mining and exploration, petroleum and hydro power development, etc. Water quality in the Northwest Territories is generally good to excellent, varying with the seasons.

**What are the spatial and temporal trends in standard water and sediment quality variables?**

✻ Temporal and spatial trends can be discerned given statistically large numbers of sample analyses with appropriate quality assurance and quality control. Trend analyses at various long term (10+ years) sites are possible but published Government information has been limited. Diamond mines in the Northwest Territories are obligated under specific Acts and Regulations to report on water quality as part of their Aquatic Effect Monitoring Programs.

✻ Recently, Environment Canada and its partners have introduced the CCME Water Quality Index (CCME WQI) to the Canadian public. The CCME WQI is a tool that allows water quality experts to translate large numbers of complex water quality data into a simple overall rating (poor, marginal, fair, good and excellent) for a given location and time period. It provides a method for assessing surface waters to support aquatic life and can be applied across Canada. Although there are strict protocols to follow when using the index, water quality can be tracked and assessed over time. The CCME WQI has been applied to a few sites in the Northwest Territories. Water quality was rated as excellent at 4 sites, good at 16 sites, fair at 6 sites and marginal at 4 sites. No "poor" sites were reported. Further work is being conducted to assess the degree to which exceedances at the fair and marginal sites can be attributed to human activities or natural processes, such as flows rich in suspended sediments (CESI, 2006).

✻ Given the high analyses costs and low number of samples, trend analyses for non-natural organic compounds in water and sediment has not been undertaken.

**⤷ How are levels of contaminants (non-natural) in water and sediment changing over time and space?**

✻ The five-volume Canadian Arctic Contaminants Assessment Report II (2003) by DIAND and its partners has added significant knowledge of Arctic contaminants in water and sediments. The two-volume Mackenzie River Basin Board's State of the Aquatic Ecosystem Report (2004) also does.

✻ Changes in levels of contaminants in sediment over time can be seen on a decadal basis using lake/pond sediment results from age-dated core slice samples. Temporal trends of contaminants within both water and sediment samples may be highly seasonal as well as inter-annual long-term, and related to natural biogeochemical backgrounds and cycling processes.

**⤷ Can local sources of contaminants be distinguished from long-range transport sources?**

✻ Research has taken place to discern long-range transport sources from local sources (including natural) for specific contaminants found in water and sediment. The majority of contaminants arrive through long-range transport. For example, only one type of PCB, which was used at DEW line sites, originated in the Northwest Territories. All other PCBs, which are likely to “cold condense” in northern waters, sediment and biota, arrive through long range transport. Similarly, concentrations of herbicides and pesticides (e.g. lindane) are indicators of long-range transport of contaminants as they are not used in the NWT. In addition, concentrations of different polycyclic aromatic hydrocarbons (PAHs) provide a “fingerprint” of various natural and anthropogenic sources of contaminants, and are therefore useful indicators. This is becoming more important due to an unprecedented rate of northern petroleum, mining and hydropower developments.

✻ Mercury levels can be naturally high in some fault-controlled lakes of the Canadian Shield and in the Mackenzie Mountains, thus it can be difficult to distinguish it from long-range transport sources. Still, other total mercury levels in lake sediments are indisputably anthropogenic in origin. NCP and Northern Ecosystem Initiative (NEI) funded research to calculate mercury, lead and cadmium enrichment factors (higher enrichments denote greater anthropogenic inputs over and above natural biogeochemical background levels), comparing present-day levels to pre-Industrial Revolution levels. Latitudinal and longitudinal spatial trends in these enrichment factors across Northern Canada, Southern Canada and Northern USA have also been examined (Muir et al, 2004, 2005).

✻ Chemically-resistant, siliceous microfossils are found within pond/ lake sediment slices. From enumerating the various species found and their community structures in each slice, it is possible to reconstruct palaeochemical (e.g. acidity, nutrient trophic status) and palaeoclimatic (e.g. temperature, precipitation) conditions for water bodies. Sedimentation rates in the North are slow (e.g. 0.5-1.0 cm per decade). Thus, 45 cm. of age-dated pond/lake sediment core slices can reconstruct 800 years of palaeochemistry and palaeoclimate. Tree rings (dendrochronology) and ice cores, support annual, not decadal, detail, but trees and long-term glaciers are required to do this. Canada has more lentic water bodies than any other country in the World and they are found in all 13 Canadian jurisdictions and in all 15 terrestrial ecozones.

→ **How do water and sediment quality variables and contaminant levels relate to current guidelines and standards?**

✻ The CCME (Canadian Council of Ministers of the Environment) Guidelines for water and sediment quality have existed for 25 and 10 years, respectively. Both are regularly refined and improved and emphasis is placed on guidelines that are considered a priority at the time. Water and sediment quality values are routinely compared to CCME water and sediment quality guidelines. Because the guidelines are not site-specific, exceedances do not necessarily indicate that a problem exists.

✻ Site-specific guidelines are more appropriate means of assessing water quality as they are locally relevant and meaningful. There are several methods of deriving site-specific guidelines and the jury is still out as to the most appropriate. Median values (+ 40 years of monitoring) can be set as site specific objectives, thus extreme values can be noted as an early warning for detecting environmental change. Percentiles and means (+/- 2 standard deviations) as well as various others have also been considered.

✻ The CCME WQI is also another means of assessing water quality. As described earlier, rating scores can be derived for key sites, resulting in a number from 0 to 100 (poor to excellent) which characterizes water quality.

⤷ **What are the major unconfined and confined aquifers in the NWT, and what are their depths, thickness, and volumes?**

✻ Unconfined aquifers come to the ground surface in springs and recharge areas on the earth surface, while confined aquifers are completely underground. Major aquifers are not well-known in the NWT due to the high costs of drilling wells/holes, carrying out high-tech down-hole geophysical measurements and geological analyses of rock formations, including regional structural geological analyses of faults and folds in those same rock formations.

✻ Geophysical surveys, followed by drilling, are performed to find reservoirs and rock formations that might contain oil and gas, coal and uranium. Reviews of down-hole well logs determine the location, depths, and thicknesses of these geologic formations. They also show where rock formations are folded and faulted to create "geological traps" for water, oil and natural gas petroleum deposits, or metal, uranium and coal mineral deposits. These steps would need to be undertaken to find and subsequently monitor aquifers in the NWT.

⤷ **What is the baseline ground water quality like in the NWT, including karst?**

✻ Baseline ground water quality, and to a greater extent baseline karst formation water quality, are also poorly known in the NWT. There are no specific monitoring programs.

✻ The existence of karst formation water is known in the Ram Plateau, Nahanni National Park Reserve, Wood Buffalo National Park, Great Bear Lake and Fort Smith-Fitzgerald areas. Karst formations are described by Parks Canada in their 1999 Wood Buffalo NP and 2000 Nahanni NPR Ecological Integrity Statements.

## RECENT AND CURRENT MONITORING

**Recent and ongoing monitoring programs with respect to water and sediment quality in the NWT are found below.**

✓ Northern Rivers Basin Study (NRBS) and Northern Rivers Ecosystem Initiative (NREI). The NREI (1998-2003) was a follow-up to the Northern River Basins Study (NRBS). The Ministers agreed with the direction of the NRBS recommendations and committed to focus their efforts in the areas of pollution prevention, science-based ecological management, resolving contaminant and nutrient issues, endocrine disruption, long-range transport of atmospheric pollutants and continuing environmental research in northern rivers. The NREI worked with industry, Aboriginal peoples, academia, communities and others to address the recommendations from the NRBS. The main partners were Environment Canada, Government of the Northwest Territories, Government of Alberta. Other key partners were Indian and Northern Affairs Canada, Health Canada and Alberta Health. NREI completed information reporting on its water, sediment and biota data and that information is stored in and displayed by Eco Atlas CE IMS/GIS.

✓ Northwest Territories water quality monitoring program (Environment Canada since 1960). This program includes water quality sites on most of the major rivers throughout the Northwest Territories. Samples are collected up to 6 times a year at various sites across the Northwest Territories. Samples are analyzed for a variety of variables including pH, turbidity, conductivity, alkalinity, total suspended and dissolved sediments, nutrients, major ions and total and dissolved metals.

✓ Inter-Jurisdictional Rivers (IJR) Aquatic Quality Monitoring Program (Environment Canada, GNWT and Alberta Environment since 1984)

✓ Nahanni National Park Reserve Aquatic Quality Monitoring Program (Environment Canada and Parks Canada since 1992). A third Nahanni NPR report is currently being written.

✓ Water and sediment quality programs have also been carried out in, Tuktut Nogait and Aulavik National Parks as well as the Husky/Eskimo Lakes areas in the NWT. Reports by EC, Parks Canada and DFO have been completed for Tuktut Nogait NP (2002) and Husky/Eskimo Lakes (2005).

✓ The National Canadian Aquatic Bio-Monitoring Program (CABiN) was introduced to the NWT in summer 2005 to the Mackenzie Gas Project (MGP) Regional Study Area (RSA), using a Reference Condition Approach (RCA) with 80-90% unimpacted (control) sites, CABiN Protocol bio-monitoring involves water, sediment, and benthic invertebrate sampling over 200 metre reaches of tributaries and (sometimes) main stem watercourses, while making miscellaneous hydrometric measurements and sketches of water course reaches. Since 2005, there are new national CABiN Protocol Bio-Monitoring training courses, accredited chemical and (benthos) taxonometric ID/enumeration laboratories, and databases/IMS'. There are nationally accepted indices of abundance, species richness, and degree of contamination - using contamination-sensitive species (e.g. mayflies, stoneflies, caddisflies). After the 2005 and 2006 field seasons, there are currently 50 DFO and seven EC (Water Quality Monitoring & Surveillance Division, WQMSD) CABiN Bio-Monitoring sites in the MGP RSA. This work is funded by Northern Energy/Oil & Gas Memoranda to Cabinet (MC).

✓ CABiN Protocol bio-monitoring, involving both RCA and a more reactive Before-After-Control-Impacted (BACI) approach, are just beginning in Nahanni NPR and surrounding South Nahanni River-Flat River Watershed, with an estimated 30-40 sites proposed. Some of this work involves Prairie Creek and Flat River sites above and below actual/proposed metal mine sites, upstream of Nahanni NPR. The partners are/will Parks Canada (Tate), EC (Dessouki/Halliwell) and University of Saskatchewan (Spencer/West/Dubé).

✓ To assess metal inputs on water quality and biota from Prairie Creek mine, a standard Environmental Effects Monitoring (EEM) control-impact sampling program will be conducted at reference, near-field and far-field sites. One water and sediment quality sample will be collected at each area. Five replicate benthic invertebrate samples will be collected from each area consistent with EEM methods. Twenty males and 20 females for one sentinel species (slimy sculpin) will also be collected at each site and analyzed for standard EEM fish survey endpoints. Algal samples will be collected at each site and analysed for biomass and taxonomy. Fish tissues will also be analysed for metal content. This research will contribute to the development of site-specific guidelines for certain metals of interest (Spencer/Dubé, U of S).

✓ National programs involving HydroLabs and YSIs (automated real-time water quality data loggers for physicals variables such as temperature, pH, conductivity, turbidity, dissolved oxygen, salinity/total dissolved solids) are being augmented. Current activities involving HydroLab and YSI multi-sensors in the NWT build upon previous testing by EC and INAC during the late 1990s on the Yellowknife, Cameron and Slave Rivers and in the Lac de Gras area. Recently (2006/07), two automated water quality sites were activated within the MGP RSA with two new ones to be added in 2007/08. The automated water quality monitoring sites are co-located with the automated hydrometric stations, utilizing shared infrastructure, training, personnel, computer software and websites. This work is funded by Northern Energy/Oil & Gas MC.

✓ Spatial and temporal trends in loading and historical inputs of mercury (and other trace metals and organics) from age-dated pan-northern lake/pond sediment cores (Environment Canada and Parks Canada since 1998). Transects being sampled in the Northwest Territories include Ft. Liard/Fisherman Lake area, Nahanni NPR, Tuktut Nogait NP, and Aulavik NP.

✓ Aquatic effects monitoring program (BHP Diamonds Inc. since 1998). Lakes and streams near the EKATI mine are monitored to determine potential affects from the mine. A surveillance network program monitors the water quality of downstream lakes and streams, providing an early warming system.

✓ Coppermine Cumulative Effects Monitoring Program (Indian and Northern Affairs Canada since 2000). The Coppermine River Basin is the focus of this monitoring program. A water quality sampling program is underway which includes monthly sampling at 6 to 8 sites, seasonal sampling at several other sites, and continuous monitoring at the outlet of Lac de Gras.

✓ Slave River Environmental Quality Monitoring Program (Indian and Northern Affairs Canada since 1990). Water, suspended sediment and fish quality are monitored on the Slave River at Fort Smith, to address transboundary issues. Five year follow ups are conducted to determine if changes in water/sediment quality have occurred.

✓ Liard River Environmental Quality Monitoring Program (Indian and Northern Affairs Canada, since 1992). Water, suspended sediment, and fish tissue quality are monitored on the Liard River above the Kotanelee River, to address transboundary issues. Five year follow ups are conducted to determine if changes in water/sediment quality have occurred

✓ Peel River Water & Sediment Quality Monitoring Program (Indian and Northern Affairs Canada, since 1999). Water and suspended sediment are monitored on the Peel River above Fort McPherson, to address transboundary issues including community concerns about contaminants. Sampling has been conducted in March 1999, July 2002, June 2003 August 2004, July 2005 and August 2006. Sampling in 2007 is planned.

✓ Hay River Water & Sediment Quality Monitoring Program (Indian and Northern Affairs Canada and Environment Canada, since 2004). Water and suspended sediment are monitored on the Hay River at the NWT/Alberta Border, to address transboundary issues.

✓ Ecological Monitoring and Assessment Network (EMAN) (coordinated by Environment Canada). Water and sediment quality is monitored at selected EMAN sites in the NWT.

✓ Collecting baseline environmental information in lakes near the Mackenzie Gas Project Anchor Sites in the Mackenzie Delta/Tuktoyaktuk Area (Environment Canada – Environmental Conservation Branch and National Hydrology Research Council since 2004). The studies include water and sediment quality monitoring as well as biota characterization including zooplankton, phytoplankton, and benthic invertebrates.

✓ A 1999-2004 EC-ECB and EC-MSC study was completed to characterize the pre-construction baseline conditions in waterfowl (e.g. lesser scaup)-utilized ponds and borrow pits in CWS' Yellowknife Study Area (YKSA) along the Yellowknife-Rae Highway. The report collates four field seasons of water, sediment, invertebrate and waterfowl data collection within the YKSA.

✓ Northern Energy MC-funded aquatic quality research has been carried out by Evans (EC-NWRI), Rempel (DFO), Halliwell (EC-WQMSD) and others within lentic and lotic water bodies of the MGP RSA:

- In the lentic project; water, sediment, benthic invertebrate, zooplankton, phytoplankton studies were collected (and measurements made) in Mackenzie Delta-Tuktoyaktuk Peninsula lakes and ponds near proposed MGP Gas Production Sites (Niglintgak, Taglu, Parsons Lake) in summer 2004 (Halliwell et al) and summer 2006 (Evans et al). One exercise involves comparison of lake sediment trace metal and trace organic chemistry results from 2004 grab samples collected at the top of the sediment column to (1950-1995 age-dated) lake sediment core results from the 1990s Northern Oil & Gas Project (NOGAP) study reported on in 1997 by Graf-Pannatier (University of Geneva-Switzerland), Gregor (EC-NWRI) et al to discern if lake sediment chemistry has been affected by petroleum activities in the last decade or not.

- In the lotic project in both the Mackenzie valley and Mackenzie Delta, Evans, Rempel, et al sampled Mackenzie Valley/Sahtu Region water courses for water, sediment and biota (including benthos and fish) in summer 2005. Evans et al carried out similar studies in the Gwich'in and Inuvialuit Regions/Mackenzie Delta in summer 2006. Benthos ID and enumeration have been carried out with assistance from Waterloo University (Barton) and University of Saskatchewan.

- Final selection of sites required a literature review including the MGP 2004 Environmental Impact Statement and related literature. All four water course classifications (Large, Type I Active, Type II Active, Vegetated Channels) were selected. Water courses selected included those most likely to be impacted and those with the best fish stocks/habitats were given preference. These would be crossed by MGP pipelines using (relatively benign?) horizontal directional drilling (HDD) techniques, (moderately benign?) trenchless techniques and (potentially environmentally-malignant) isolated/trenched techniques were chosen over the entire 1220 km length of the RSA. Special attention was given to small vegetated channels with resident sculpin, completely overlooked by MGP Consortium.

- Several papers concerning the above research have been written by Evans (EC-NWRI), deBoer (Uof S), Lockhart (DFO-Retired), Halliwell (EC-WQMSD), Conly (EC-NWRI), Keating (EC-NWRI), Barton (Waterloo), Scott (Waterloo) Waiser (EC-NWRI), Ali (EC-NWRI), Kilgeour (Jacques Whitford), Ogbedo (EC-NWRI), Froess (EC-NWRI), Davis (Hatfield). Four new publications have been submitted for presentation at CWRA 2007 in Saskatoon in June 2007 and one presentation for IUGG in Perugia, Italy in July 2007.

## GAPS AND RECOMMENDATIONS FOR MONITORING

**A list of monitoring gaps and recommendations for future monitoring under the NWT Cumulative Impact Monitoring Program is found below.**

***Gaps***

➙ Intensive sampling of water, sediment and biota on specific streams and lakes in the NWT is not complete.

➙ Continual automated real-time monitoring of physical water quality variables is lacking at all existing water quality monitoring stations in the North. Exceptions to this include the headwaters of the Coppermine River, the Slave River at Fort Smith and the recently established real-time monitoring sites in the Mackenzie RSA.

➙ Data on organics such as PCBs, pesticides, polycyclic aromatic hydrocarbons (PAHs), Dioxins/Furans and heavy metals in water and suspended sediment is poorly known, with the exception of the transboundary sites on the Slave, Liard, Peel and Hay Rivers. MGP Consortium will be required to do intensive monitoring for these and other variables in MGP Local Study Areas (LSAs) throughout all phases of the 30+ year ("far-future") project. LSAs include areas near production areas, barge sites, dredging sites, collection facilities, disposal sites, long-lived "camps" (more like NWT towns-up to 950 and 1350 people!), water course crossings and compressor stations. Details will start to be worked out at the MGP Monitoring and Cumulative Effects Hearings in Inuvik in March 2007 and April 2007, respectively. EC, INAC, DFO and MGP will collaborate in similar (though less intensive) monitoring throughout the larger 1220 km long MGP RSA.

➙ Some aquatic biological studies were done by INAC (Peddle-Sanderson et al) in the Slave River Environmental Quality Monitoring Program during the 1990s. EC (Walsh-Pippy et al) carried out benthic invertebrate work in 2000 in the CWS Yellowknife Study Area (YKSA). However, <u>regional</u> aquatic bio-monitoring programs in the NWT have 45 years of catching up to do with water quality (chemistry) programs which began in 1960. Since 2005, DFO, EC, Parks Canada, INAC, and University of Saskatchewan are closing this data gap in the MGP RSA and South Nahanni River Watershed. This data gap is only now beginning to be closed.

➙ Traditional knowledge about water and sediment quality is poorly documented. The NWT Cumulative Impacts

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Monitoring Program (CIMP) and Mackenzie River Basin Board (MRBB) have begun to close this gap with the Mackenzie Valley Tariuq Inventory/ Metadatabase, and MRBB 2003 State of the Aquatic Ecosystem Report (2004) - where TK indicators where described and rated.

➙ Basin-wide mapping of unconfined and confined aquifers is very limited.

➙ Unconfined and confined aquifers have not been identified.

➙ Groundwater and karst formation water quality, isotope and chemistry data is lacking, with the exception of specific work in Mackenzie Valley, Mackenzie Delta, Nahanni National Park Reserve and Lower Hornaday River.

***Recommendations***

➙ Longer term (>10 years) temporal trends require open-ended water and sediment quality monitoring at selected sites. Monthly water quality sampling and quarterly suspended sediment sampling is recommended

➙ Conduct automatic hourly real-time water quality monitoring for physical water quality variables in areas of development on a year round basis. With future developments, additional sites should be added as needed.

➙ Environmental effects monitoring of multiple developments, including water quality monitoring, should be considered for the diamond mining and petroleum industry. Northern Energy MC research is beginning to help with this. Plans will accelerate after the April 2007 MGP Cumulative Effects Hearings in Inuvik.

➙ Incorporate site specific ground water monitoring for NWT developments, within water license applications.

➙ Finish entering all recent water quality data (late 1990s) from the entire Northwest Territories, including quality assurance and quality control information, in the new Aquatic Chemistry and Biological Information System (ACBIS). EC-ECB Yellowknife and Regina completed this in October 2004 and are keeping ACBIS current and correct to permit annual national CCME WQI reporting.

➙ Gather traditional and local knowledge about water and sediment quality in the Northwest Territories. This will be addressed in the next  Mackenzie River Basin Board State of the Aquatic Ecosystem Report (due 2009).

➙ For selected sites compare median values of water quality variables in each decade (1960s to 1990s) to discern trends. Subsequently, compare these trends with trends shown in Eco Atlas CE (Cumulative Effects) display module software for updated ACBIS data. Projects are underway, mostly along the Mackenzie and Liard Rivers in 2004, funded by Northern Energy MC (Aquatic Quality Science) and Northern Ecosystem Initiative (NEI) Resource Use/Cumulative Effects Assessment Table and Northern Thresholds Project, and led by EC's Dr. M. Dubé,

➙ Collect strategically located water and sediment quality samples at least three years prior to a development to help distinguish contaminants originating in the Northwest Territories from those resulting from long-range transport. This was carried out by DIAND and EC in the Slave Geologic Province for current diamond mines. It is now being carried out by INAC and EC in the Mackenzie Delta/Valley and Liard Valley for future petroleum developments.

➙ With respect to monitoring programs, incorporate community participation and training, where applicable. Environmental Monitors and Technicians are currently being trained by DIAND and EC (e.g. 2-week Taiga Lab/Field Course in Yellowknife, EMAN-North plain language Northern Water Quality Manual). CCHREI is asking DIAND, EC and other scientists/managers to help write Canada-wide use job descriptions for Environmental Monitors and Technicians. The BEAHR Program now trains and graduates Environmental Monitors and Technicians at Aurora College in Fort Smith, NWT.

## REFERENCES

**Relevant monitoring reports, past monitoring programs, research documents, and scientific publications are found below. This list is a SAMPLE of what is available. The references listed below are not necessarily the most important nor are they the most recent research and monitoring projects in the NWT. The list is not comprehensive and requires a significant amount of time and knowledge to make it complete and final.**

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*Arctic Monitoring and Assessment Programme (1998).* ***Arctic Monitoring and Assessment Programme (AMAP) assessment report: Arctic pollution issues*** *Oslo, Norway, 859pp.*

*Bicknell, D. and R.E-check with Bob!. Reid (2001).* ***Summary of hydrometeorological and water quality data collection in the Coppermine River Drainage Basin and the Central Arctic Region.*** *Water Resources Division, Indian and Northern Affairs Canada, Yellowknife, NT. (in prep)*

Canadian Arctic Contaminants Assessment Report (CACAR) II (2003). DIAND et al. 5 Volume & 1 CD-ROM set.

*Coulombe-Pontbriand, M., R.E. Reid and F. Jackson (1998).* ***Overview of the hydrology and water quality of the Coppermine River****. Water Resources Division, Indian and Northern Affairs Canada, Yellowknife, NT.*

*Environment Canada (Blachford, D.P., B. Olding et al.) (1991).* ***Nahanni National Park resource aquatic quality study – Protecting the water of Nahanni National Park Reserve, NWT.*** *Environment Canada, Inland Waters Directorate and Parks Canada. Report C&P-IWD-NWT-91-002, TR-I/NAH.*
*An intensive study was undertaken between 1988 and 1991 to collect baseline water, sediment and fish tissue quality data in Nahanni National Park Reserve.*

*Evans, M.S., R.A. Bourbonniere, D.C.G. Muir, W.L. Lockhart, P. Wilkinson and B.N. Billeck (1996).* ***Depositional history of sediment in Great Slave Lake: spatial and temporal patterns in geochronology, bulk parameters, PAHs, and chlorinated contaminants****. Northern River Basins Study project report 99. 173 pp.*

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*Fisheries and Oceans Canada.* ***Norman Wells aquatic monitoring program*** *(1983-1987).*

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*Fisheries and Oceans Canada.* ***Physical and chemical data for water and sediment of the Mackenzie and Porcupine watersheds*** *(1971-1974).*

*Government of the Northwest Territories and Environment Canada.* ***Hay river basin overview*** *(1984). 63pp.*

*Graf-Pannatier, E. et al. (1997).* ***Sediment accumulative and historical deposition of trace metals and trace organic compounds in the Mackenzie Delta (NWT, Canada).*** *Terre et Environnement, Institue Forel, Universite of Geneva, Switzerland. Volume 10, 222pp. Assistance from Environment Canada (D. Gregor, J. Jasper and D. Halliwell).*

*Gulley, A.L. (1993).* ***Rabbitkettle hot springs, Nahanni National Park Reserve, NWT: A hydrogeologic study****. Carleton Geoscience Centre, Carleton University thesis, Ottawa, ON.*

*Hamilton, S.M., F.A. Michel and C.W.Jefferson (1988).* ***Groundwater geochemistry, South Nahanni resource assessment area****. Geological Survey of Canada, Current Research Paper 88-1E, pp. 127-136.*

*Halliwell, D.R. and Catto (1998).* ***Protecting the aquatic quality of Nahanni National Park Reserve, NWT.*** *Environment Canada, Atmospheric and Hydrologic Sciences Division, Yellowknife, NT. 96pp.*

> *Baseline water, sediment and fish tissue quality data were collected in Nahanni National Park Reserve as part of a monitoring program (1992-1997) following-up on an intensive study undertaken from 1988 to 1991. The results are presented in this report.*

Halliwell, D.R., Bucher, C., Fehr, A., McDonald, I., and Harwood, L. (2002). ***Protecting the Aquatic Quality of Tuktut Nogait national Park & Lower Hornaday River, NWT.*** Environment Canada, Parks Canada, Fisheries & Oceans Canada, 71pp.

*Indian and Northern Affairs Canada.* ***AES Baseline Water Quality Monitoring Program*** *(1991-1997).*

> *The Government of Canada provided $100 million for the Arctic Environmental Strategy (AES), of this, $15 million was used for water-related research in the Northwest Territories and Nunavut. This research resulted in the production of 218 publications, including several on water quality. The Arctic Science and Technology Information System (ASTIS) produced "An Annotated Bibliography of the Northwest Territories Action on Water Component of the Arctic Environmental Strategy", available at http://www.aina.ucalgary.ca/aes/.*

*Indian and Northern Affairs Canada and AquaIchtus Consultants.* ***Liard River Environmental Quality Monitoring Program – Final study report and appendices*** *(1990-1995, 1998).*

*Indian and Northern Affairs Canada and Government of the Northwest Territories.* ***Slave River Environmental Quality Monitoring Program – Summary report, final five year study report and data volumes*** *(1990-1995, 1998).*

> *The objectives of this five year investigation of contaminants in the aquatic ecosystem of the Slave River were to: address concerns of northerners regarding possible contamination of fish, water and suspended sediment from pulp mill, hydrocarbon and agricultural developments upstream; and, provide baseline data on contaminant levels in fish, water and suspended sediment at the territorial boundary to support transboundary water negotiations with Alberta. An annotated bibliography of the Northwest Territories Action on Water component of the Arctic Environmental Strategy, which includes information on the SREQMP, is available at http://www.aina.ucalgary.ca/aes/.*

*Indian and Northern Affairs Canada et al. (1997).* ***Canadian arctic contaminants assessment report (CACAR)****. Northern Contaminants Project (NCP) Phase 1, 460pp.*

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