Water Quality Data to Support Cumulative Effects Decision-Making in the Mackenzie Valley, Northwest Territories

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Abstract

Freshwater systems have come under increasing stress as a result of anthropogenic activities and climate change. Across Canada's North, the assessment and management of cumulative effects to freshwater systems remain an enduring challenge to responsible resource management decisions. Recent practice and research indicates a clear need to improve how cumulative effects are assessed and managed, and to bridge the gap between the science conducted inside and outside environmental assessments. Science inside environmental assessment refers to monitoring conducted for environmental assessments and under water license requirements and science outside environmental assessment refers to monitoring conducted for environmental effects monitoring programs. This research examined how environmental monitoring programs in the Mackenzie Valley, Northwest Territories, contribute to the identification, understanding and management of cumulative effects to freshwater systems.

The research methods involved a document review to assess the nature of monitoring conducted by project proponents under water licensing requirements as well as the monitoring conducted, and supported, by government agencies for environmental effects monitoring. Semi-structured interviews complemented the review to determine the utility of existing data to develop environmental baselines and to predict cumulative effects. Interviewees included staff from land and water boards, industry proponents, consultants, independent mine oversight boards and various levels of government.

Key findings suggest that there are several challenges, including the lack of common understanding of cumulative effects, uncertainty over responsibility for them, degree of participation required among stakeholders and inaccessibility of both government- and proponent-based data. Ultimately, this may be preventing cumulative effects from being assessed, and appropriately managed, in a comprehensive, consistent and systematic manner. While it is evident that a great deal of environmental monitoring is conducted in the Northwest Territories, results indicate it requires a more deliberate approach to ensure that the data collected support cumulative effects assessment and management initiatives at both the local (i.e. project) and more regional scales. These results will both aid in advancing the integration of government- and proponent-based environmental monitoring and be of direct value for regulatory decision-making by land and water boards in the North.

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Dedication

To Mama and Yeayea

Table of Contents

List of Appendices

List of Tables

List of Figures

List of Abbreviations

CE	Cumulative effect
CEA	Cumulative effects assessment
EA	Environmental assessment
EEM	Environmental effects monitoring
ENR	Department of Environment and Natural Resources
GNWT	Government of the Northwest Territories
MVEIRB	Mackenzie Valley Environmental Impact Review Board
MVLWB	Mackenzie Valley Land and Water Board
MVRMA	Mackenzie Valley Resource Management Act
NWT	Northwest Territories
NWT CIMP	Northwest Territories Cumulative Impact Monitoring Program
SEA	Strategic environmental assessment

Chapter 1
Introduction

Freshwater resources across the globe are under increasing stress due to anthropogenic land use and climate change. Changes to water quality and quantity and resulting threats to aquatic health, access to clean drinking water, and impacts to recreational and cultural activities are of increasing concern (GNWT, 2010). Though sparsely populated, the Northwest Territories (NWT) is not immune to these threats; the proliferation of resource development projects coupled with a changing Arctic environment, has put a spotlight on the territory's freshwater resources. A significant portion of the Mackenzie River watershed, the largest drainage basin in Canada and the second largest in North America, lies within the NWT. Most of the streams, rivers and lakes in the territory flow into the Mackenzie River watershed (INAC, 2010). Freshwater resources in the Arctic are relatively pristine compared to many southern regions, but are also highly sensitive to perturbations (Miltenberger, 2014). The low temperatures, limited sunlight, and prolonged ice cover that are prevalent in the region can serve to limit the amount of algal growth (Keatley et al., 2007). Because algal growth is limited in Arctic waterbodies, they are highly responsive to anthropogenic impacts, such as mine or municipal wastewater discharge or runoff, that can quickly change the trophic status of these lakes and impact aquatic life (Ogbebo et al., 2009). Fish communities that are native to Arctic lakes are also highly vulnerable to metals and ore processing chemicals, when compared to those found in warmer climates (Lemly, 1994).

Mining is perhaps the dominant and most concentrated anthropogenic source of stress to aquatic systems in the NWT. There are currently three actively producing mining operations in the NWT, all of them diamond mines, with 15 new diamond and mineral mines either planned, proposed or under review (Cairns et al., 2017; GNWT, 2018). Technological advances in mining have permitted the exploration and extraction of mineral deposits from traditionally inaccessible and remote locations (Haley et al., 2011), and a growing appetite for metals globally has substantially increased the profitability of mineral deposits in the NWT (Lemly, 1994; Humphreys, 2010; Haley et al., 2011). Mining can exert heavy stress on water resources, including the direct loss of aquatic systems and habitat (e.g. drainage, dewatering, fragmentation) due to mine construction, water extraction for project operations, discharge from tailings ponds and potential runoff or leaching from active and abandoned sites (Instanes et al., 2015; Medeiros et al., 2017; Atlin and Gibson, 2017). A prominent example of the latter is the Giant Mine project, a gold mine that operated from 1948-1999 in Yellowknife, NWT on the shores of Back Bay on Great Slave Lake. When the gold ore was roasted, arsenic dust was produced as a by-product and emitted into the atmosphere, which poses ongoing concerns due to arsenic leaching into water, sediment and vegetation (Fawcett et al., 2015). Residents have been left with the lasting effects – contaminated water, elevated arsenic in fish and chronic exposure to pollution (Cott et al., 2016; Sandlos and Keeling, 2016).

Other, perhaps less obvious, sources of anthropogenic stress to aquatic systems also exist – including municipal water use and wastewater discharge (INAC, 2010; Krumhansl et al., 2015), oil and gas (Yunker et al., 2002), hydroelectric development (Kreutzweiser et al., 2013; Schartup et al., 2015), sedimentation from surface disturbances such as forestry, roads and seismic lines, and climate change (Post et al., 2009). Climate change is arguably the biggest threat to freshwater resources in the NWT, with changing precipitation patterns affecting both water quantity and quality, and thawing permafrost altering water hydrology, biology, and chemistry (Evengard et al., 2011; Thienpoint et al., 2013; Jones et al., 2014). Though the severity of many individual sources of threat to aquatic systems can be mitigated, the potential cumulative effects may be significant across space and over time.

Cumulative effects (CE) are broadly defined as effects to the environment caused by the combination of past, present and future actions, either by natural or anthropogenic stressors (Hegmann et al., 1999; Squires and Dubé, 2013). Environmental monitoring provides the foundation for CE assessment, management and informed decisions about development; yet, monitoring is amongst the most deficient aspects of CE initiatives worldwide (Dubé et al., 2013). Cronmiller and Noble (2018) report that the monitoring is often less effective than intended for cumulative effects assessment and management decisions for a variety of reasons: the institutions established to support monitoring, often created in response to crisis or a specific political trigger, do not always accommodate the longer-term, science-based needs of CE monitoring programs (O’Neill, 2008; Lindenmayer and Likens, 2010; Biber, 2011; Schindler, 2013); monitoring may be occurring in a given region by different actors and for a variety of purposes (Lott and Jones, 2010; Lindeman et al., 2011; Hutto and Belote, 2013), resulting in fragmented or incompatible CE data (Vörösmarty et al., 2010; Ball et al., 2013*b*; Dubé and Wilson, 2013); and what is being monitored, and the types of questions asked, do not always align with the needs of government decision-makers responsible for land use planning and regulatory approvals (Hegmann and Yarranton, 2011; GNWT, 2015; Jones, 2016).

There are two primary instruments that provide monitoring data to support decisions about the assessment and management of cumulative effects – environmental assessments (EA) and environmental effects monitoring (EEM) programs. In the NWT, under the Mackenzie Valley Resource Management Act (MVRMA), proponents conduct baseline studies and monitoring as part of their EA requirements to track water withdrawal or discharge and to ensure that project mitigation measures are effective; monitoring is required for any developer (e.g. mine operator, municipality) who requires a water license under one of the NWT land and water boards. Government agencies also conduct environmental monitoring programs, usually focused on regional baseline knowledge about water quality and quantity, with an emphasis on understanding aquatic ecosystem health.

Both types of monitoring, project-specific for identifying and mitigating stress, and regional for understanding baseline conditions, are required to understand and effectively manage cumulative effects (Dubé, 2003; Ball et al., 2013*a*). However, tensions arise when attempting to reconcile monitoring data from EA and EEM programs because their purposes and scales differ (Lindenmayer and Likens, 2010). The problem is exacerbated in Canadian regulatory systems, including in the NWT, as monitoring under EA and EEM have typically been carried out in isolation (Kilgour et al., 2007; Dubé et al., 2013*a*). Various aspects of monitoring data and parameters to support cumulative effects have been discussed in the scholarly literature (e.g. Ball et al., 2013*a*; Schultz, 2012; Noble et al., 2016), but there has been limited direction on the integration of monitoring under EA and EEM programs to support cumulative effects assessments (Cronmiller and Noble, 2018; Kilgour et al., 2007).

1.1 Purpose and objectives

This research set out to examine the attributes of monitoring data and parameters that are necessary to support the assessment and management of cumulative effects. In doing so, the specific **purpose** of this research was to examine how environmental monitoring programs in the

Mackenzie Valley, NWT, contribute to the identification, understanding and management of cumulative effects to fresh waterbodies. The objectives were to:

i. Examine the nature and availability of water quality data collected by government- and proponent-based environmental monitoring programs;

ii. Assess the utility of these data for the development of environmental baselines and the assessment of cumulative impacts of development projects to freshwater bodies; and

iii. Identify priority areas for water quality monitoring to support cumulative effects management.

This research is a part of a larger research program examining decision maker needs regarding cumulative effects – a project supported by the NWT Cumulative Impact Monitoring Program (CIMP). Key areas of focus for CIMP are to strengthen science support for cumulative effects assessment (CEA) in the NWT, and to assess the value of long-term monitoring to inform cumulative impacts decision-making. Science, in the context of this research, refers broadly to monitoring data, parameters, baseline information and the methods used to generate these data and information to support assessment and decision-making.

1.2 Thesis organization

This thesis is presented in six chapters, including the Introduction chapter. Chapter 2 provides background regarding cumulative effects, monitoring programs to support cumulative effects, and challenges associated with assessing cumulative effects. Chapter 3 introduces the study area and the research methods. Chapter 4 presents the research findings. Chapter 5 discusses the research results, including recommendations. Chapter 6 presents the study conclusion, key research contributions, study limitations, and future research directions.

Chapter 2
Literature Review

This chapter explores the nature of monitoring required to support cumulative effects assessments. First, the role of science 'inside' the EA process, which refers to the monitoring data generated for EA and under water license requirements, is discussed. The role of science 'outside' the EA process, which refers to the monitoring data generated in EEM programs, is then discussed. Following this, the case for a more integrated system using both science inside and outside the EA process for understanding CEs is presented. The merits of an integrated system have been widely discussed by scholars as it capitalizes on the benefits of the science generated inside and outside the EA process. However, the integration of these sciences is dependent upon seven attributes of monitoring data and parameters. The consistency of parameters monitored, the compatibility of sampling and reporting protocols as well as the observability, detectability, adaptability, accessibility and usability of monitoring data and parameters are areas that need to be examined if the science from inside and outside the EA process are to be integrated to understand and manage CEs.

2.1 Role of science in assessment

It was relatively early in the history of EA that Robinson (1989) identified the importance, yet complexity, of the nature and role of science in evaluating the impacts of development projects. Although EA is not a purely scientific exercise, it relies heavily upon good scientific information, as well as values and interpretation, to make well-informed decisions (Robinson, 1989; Lee et al., 1995; Duinker et al., 2012). The importance and complexity of science is amplified when assessing and managing potential cumulative effects, as the nature and amount of scientific information required must capture complex linkages between environmental components and consider the contributions of multiple activities across space and over time (Canter and Atkinson, 2011; Jones, 2016).

Cashmore (2004) describes the role of science in EA as a series of nebulous models with varying degrees of emphasis on natural scientific methods versus stakeholder involvement and value judgments. The author suggests that EA can be perceived as an applied science, in which the focus is on scientific processes, or as a civic science, in which the focus is on the public's role in the decision-making process. The current and most common interpretation of the role of science in EA may fall in the middle, recognizing both the need for good science and the importance of societal values to support decision-making. This is supported by Morrison-Saunders and Sadler (2010), who suggest that the blending of scientifically credible information with the art of accommodating community values is important to the credibility of EA. Science in EA is not necessarily to be a rigorous hypothesis-testing exercise, but sound scientific knowledge is an essential part of EA and decision support (Morrison-Saunders and Bailey 2003; Cashmore, 2004).

Science in EA is typically pragmatic; while scientific principles are employed to generate information about the environment, stakeholder values influence the use and interpretation of that information in the decision-making process (Cashmore, 2004). Morrison-Saunders and Bailey (2003) note that though practitioners are generally content with the *level* of science in impact assessments, there is room to improve the use of science, particularly at the decision-making stage and after an EA is approved. This highlights the necessity of using both the data gathered throughout the EA process, as well as drawing on necessary and available scientific information generated external to the EA process. The use of science from inside the EA process, combined with science from outside the EA process, is essential to the understanding and management of cumulative effects (Beattie, 1995; Folkeson et al., 2013; Wright, 2014; Noble, 2015; Jones, 2016).

Science from *inside* EA refers to the monitoring activities (e.g. data collection, information generation) conducted for EA purposes by project proponents as part of their licensing and permitting requirements. Science from *outside* EA refers to EEM programs, usually undertaken by government agencies, for ‘state-of-the-environment’ reporting. Greig and Duinker (2011) stress that science outside EA must support the science inside EA, and vice versa. In their view, it would be ideal if the science outside EA could provide the science-based tools and models to predict for effects, while science inside EA could test these models to understand environmental responses. Duinker et al. (2012) support the need for a similar reciprocal relationship between science inside and outside CEAs. The authors state that this relationship, and the knowledge it generates, is particularly important due to the complexity of CEs and the need to understand numerous stressors.

Calls for integrating science inside and outside assessment have proliferated in recent literature (Cronmiller and Noble, 2018), but have not broached the 'nuts and bolts' of scientific requirements – the types of monitoring data, parameters, baseline information, and methods used to currently generate data and information that may need to change to better support CE understanding and decision-making. Improved coordination is required between and among EA and EEM programs (Damman et al., 1995; Dubé et al., 2006; Duinker et al., 2012; Cronmiller and Noble, 2018).

2.2 Science of monitoring and assessment in project-based EA

Project-based EAs employ predictive, stressor-based monitoring to assess the type and magnitude of physical and chemical effects on baseline conditions (Karkkainen, 2002; Dubé, 2003; Noble and Hanna, 2015; Roach and Walker, 2017). This type of monitoring relies on a solid understanding of the interactions between stressors and effects to understand the impacts that stressors will have on particular ecosystem components (EIP, 1998; Dubé and Munkittrick, 2001; Ramos et al., 2004). Dubé and Munkittrick (2001) note that stressor-based approaches centre on known stressors rather than examining external factors that may be impacting the ecosystem. Currently, stressor-based approaches have focused on the source of stress (e.g. effluent discharge) versus the receiving environment (e.g. ambient water quality) because there is often limited data available to characterize and understand baseline conditions (Wright, 2014). The monitoring conducted by proponents is designed to ensure that the project and its activities are within the allowed limits of stress dictated by the regulatory authority (Spalding et al., 1993; Harrington and Canter, 1998; Vaughan et al., 2003). In Canada, many jurisdictions require project proponents to assess the cumulative effects of their project during an EA or under monitoring requirements. However, the limitations to assessing cumulative effects at the project-level EA are at least three-fold – its primary focus on project approval and regulatory compliance, variability in monitoring requirements for EAs and their narrow spatial and temporal scopes.

The idealized vision of project-level, stressor-based monitoring is to ensure the broader protection of the environment, but its most common purpose is to gain project approval and to comply with regulatory requirements (Duinker and Greig, 2006; Noble, 2010). The prevailing assumption among some regulatory bodies and proponents is that projects that are compliant with regulatory requirements are presumed to have minimal effects on the environment (Foran et al., 2015). Scholars (e.g. Contant and Wiggins, 1991; Noble, 2008; Foran et al., 2015) highlight the weakness in this assumption as the effects of minor projects can go largely unaccounted for, yet can be cumulatively significant. This is consistent with the view of Duinker and Greig (2006), who note that monitoring conducted by proponents is intended to determine whether project-specific effects are acceptable, not whether the project-specific contributions to CE are acceptable. Consequently, project proponents focus on reducing their impacts to the environment and ensuring that their mitigation measures are effective as opposed to a comprehensive understanding of how the environment is being impacted due to cumulative effects (Noble et al., 2011; Seitz et al., 2011). Arguably, proponents cannot be faulted for conducting monitoring to address their own needs; they are required to monitor and mitigate their effects, but not to understand *how* project stressors are impacting the environment (Noble and Storey, 2005). Hegmann and Yarranton (2011) agree that proponents are rightfully focused on fulfilling their own objectives and should not be expected to address the shortcomings of planning and regulatory processes. Furthermore, the authors note that since proponents are focused on project approval, there is an impetus for any project-based CEA to be found insignificant by the proponent. Duinker and Greig (2006) and Atlin and Gibson (2017) agree with this assessment and note that 'minimizing effort' with CEA is closely associated with obtaining project approval. The former authors note that while some proponents have a genuine interest in minimizing their project's impacts to the environment, profit generation remains their principal objective.

The level of variability in monitoring requirements for EAs has been another limitation to assessing cumulative effects. Ball et al. (2013*b*) commented that the transfer of information from EA to CEA is limited when the parameters monitored under various EAs are inconsistent. Data collected for stressor-based monitoring are typically based on the terms of reference established for individual projects – either their EAs or licensing agreements – and have shown to vary considerably from one project to the next (Ball et al. 2013*b*). The methods employed for modeling and monitoring are defined by the proponent or their consultants, resulting in the inconsistency of parameters and sampling techniques between projects. Noble et al. (2016) confirm this; in examining the case of a single proponent with multiple hydroelectric projects in the same watershed, they found that there was limited consistency in the parameters monitored.

The authors state that the responsibility lies with the regulatory authority to ensure consistency in monitoring requirements for EAs. The ability of EAs to feed into the overall knowledge about the environment to understand and assess cumulative effects should become one of its key undertakings (Contant and Wiggins, 1991; Bjorkland, 2013; Noble et al., 2016).

Even if EA was able to incorporate effects-based monitoring to supplement current stressor-based monitoring, the narrow spatial and temporal scales of project-based approaches and associated monitoring remain a challenge to assessing CEs (Dubé, 2003; Noble et al., 2011). Bérubé (2007) outlines the inherent difficulty of an individual proponent to foresee the impacts from other proponent projects beyond a 10-year timeframe. The spatial and temporal scope of EA does not align with the scope required to understand cumulative change and to attribute change to specific projects (Thérivel and Ross, 2007). Atlin and Gibson (2017) argue that even if project proponents had the motivation to assess for CEs, it is unlikely that proponents have the capacity and access to information that is required to assess for cumulative effects beyond their project's scope. Harriman and Noble (2008) concur with this assessment and suggest that only mega projects are able to examine the spatial and temporal scales required to gain an understanding of CEs. The authors warn that a simple expansion of spatial and temporal boundaries is not adequate and that an examination of broader regional scales should be used as an opportunity to understand the relationship between the environment and resource development.

2.3 Science of monitoring and assessment in EEM

Environmental effects monitoring is an effects-based approach that centres on the 'performance' of parameters and the condition of the receiving environment (Power et al., 1995; Roux et al., 1999; Kilgour et al., 2007). Effects-based monitoring is a retrospective approach that assesses the accumulated state of the environment for comparison against reference sites, which can limit its predictive capacities (Dubé, 2003). A principal purpose of EEM programs is to understand cumulative change over time and to develop the science necessary to understand environmental thresholds (Contant and Wiggins, 1991). The strength of EEM programs is that they can provide long-term data about aquatic ecosystems and help to characterize the spatial extent of environmental effects (Walker et al., 2003).

However, a major challenge is that the data derived from EEM has not typically been incorporated with other programs to support cumulative effects assessments – including project EAs. Cronmiller and Noble (2018) commented that it is a relatively novel idea to use regional data to support CE understanding, and the majority of these programs have been designed to fulfill their own mandates and obligations. Scholars have lamented the disconnect of EEM programs from other monitoring interests as EEM program data have struggled to provide useful science for project-based, assessment needs as well as regulatory decision-making (Johnson et al., 2011; Noble, 2015; Noble and Basnet, 2015). Lindenmayer and Likens (2009) agree, noting that scientists responsible for designing long-term monitoring programs are not always cognizant of the science that these programs can, and should, provide to regulatory decision makers and resource managers. This highlights the fact that EEM programs have generally operated in isolation from the everyday operations of monitoring conducted for EA (Kilgour et al., 2007). Furthermore, the regional scale data that EEM programs have limited use outside of its intended purpose because the data these programs produce are often not sensitive enough to meet a proponent's assessment needs (Lindenmayer and Likens, 2010). A key issue to using coarser, regional scale data is that they are not always suited to being extrapolated to other regions and smaller spatial scales (Lindenmayer and Likens, 2010). Thus, EEM program data have not been able to help proponents understand their project's specific effects, which would help proponents mitigate stress to acceptable levels. The ability to leverage data from EEM programs would be beneficial for the development of the changing baseline conditions required for EAs to link effects with stressors. Walker et al. (2003) and Curran et al. (2006) noted that EEM programs have been effective at identifying the effects of project effluents and at coordinating the lessons learned from individual sites to support the assessment of cumulative effects, respectively.

2.4 Toward a more integrative system for understanding CEs

EA and EEM programs operating in isolation are not enough to fulfill the data requirements to understand cumulative effects (Dubé and Munkittrick, 2001; Dubé, 2003; Kilgour et al., 2007). Contant and Wiggins (1991) offered an early, prescient approach to combine effects- and stressor-based monitoring to support CEAs. Effects-based monitoring would be used to understand the regional environment and its response to stressors. Stressor-based monitoring would be used to understand the impacts of the proposed development along with other development activities. Contant and Wiggins (1991) argue that effects-based, regional monitoring permits for a greater understanding of the environment's 'responses, thresholds and interactions' (p. 304). The authors highlight the importance of understanding the regional context instead of the overwhelming focus of proponents to simply understand their project's effects with the effects of other projects. The use of regional data in assessments is a more comprehensive approach that allows for cumulative effects to be examined outside the confines of data that are generated solely by the project proponents. Harrington and Canter (1998) agree and state that EEM programs should be designed with consideration to support EA, while Kilgour et al. (2007) propose that EA should be designed to leverage data from EEM programs. Roux et al. (1999) and Dubé and Munkittrick (2001) are also advocates of an integrated framework of effects- and stressor-based monitoring to support CEA. These authors state that a holistic approach capitalizes on the strengths of both monitoring approaches. Roux et al. (1999) also comment that the complexity of natural systems requires comprehensive monitoring, which will enable the assimilative capacities of waterbodies to be better understood. Since CEAs require large amounts of data to understand the effects of multiple stressors, the use of data generated by EA and EEM programs appear necessary if CEs are to be meaningfully assessed. Seven attributes of monitoring data and parameters can be identified to support CEA: consistency, compatibility, observability, detectability, adaptability, accessibility and usability.

2.4.1 Consistency of monitoring parameters

There are two areas of consistency that are necessary if an integrated approach is taken to support the assessment of cumulative effects – consistency of parameters monitored by proponents within EA and under water license requirements and consistency of parameters monitored by proponents and government agencies.

Ball et al. (2013*b*) determined that parameter selection was dependent upon fulfilling regulatory obligations rather than gaining an understanding of the environment. This led to variability in the parameters monitored, limiting its use to support the assessment of cumulative effects. Olagunju and Gunn (2015) similarly found that parameters were inconsistent in EAs required for road construction projects; the project-level challenges to CEA can carry through to the regional level. The challenge to selecting consistent parameters may be attributed to the differences in project types or environments. Lindenmayer and Likens (2011) discussed the use of indicator species to assess biodiversity or ecosystem change. They found that a given indicator species was not necessarily suitable when sampled in different landscapes and even in modestly different spatial and temporal scales. This example can be broadly applied to the selection of parameters in EA as well as CEA. Parameter selection can be a challenging exercise since the parameters must be useful and relevant at the project-level scale, larger regional scales and across different project types.

The need for a streamlined parameter selection process for EA and EEM programs has been proffered by Kilgour et al. (2007). However, the main obstacle to consistent parameter selection is likely not the varying levels of stakeholder participation as the authors suggest, but the different temporal and spatial scales of the monitoring programs. There is an inherent challenge to an integrated selection of parameters because monitoring under EA is limited by the lifespan and spatial scope of the project, whereas EEM programs are typically conducted over much longer time periods and attempt to understand change at larger spatial scales. Project proponents are able to participate in parameter selection only once the project has been approved, which may not coincide with EEM parameter selection.

2.4.2 Compatibility of sampling and reporting methods

The compatibility of data is necessary to assess CEs and is dependent on the consistency of sampling and reporting methods used by various monitoring programs. Walker et al. (2003) suggest that while there is a level of standardization for some monitoring techniques, there are cases where different techniques must be used to reflect site-specific conditions. For instance, ice over in some lakes may occur earlier than others, which may require an adjustment in the method or timing of sampling. In the case of a single proponent with multiple hydroelectric projects in the same watershed, Noble et al. (2016) determined that inconsistent sampling and analytical methods resulted in incompatible data that could not be used to support CE understanding. This case highlights the fact that even the same proponent can generate incompatible data, and it would be unsurprising if the data generated by different proponents were incompatible. Karkkainen (2002) reinforces this finding, and states that each EA document is a 'self-contained universe of information' making it nearly impossible to synthesize the data to understand CEs (p. 923). The author contends that incompatible monitoring data and reporting can result in the repetitious exercise of generating data that essentially exists, only in another form. However, Noble et al. (2016) warn that it is beyond the scope of proponents to ensure that their monitoring and reporting methods are consistent, resulting in data that are compatible with other datasets. Lonsdale et al. (2017) suggest that monitoring and reporting protocols should be developed to standardize data across sectors to improve data compatibility.

2.4.3 Observability

To effectively understand cumulative effects, it is necessary to characterize a baseline and a reference condition for change assessment, which remains a point of contestation among practitioners (Squires et al., 2010; Briggs and Hudson, 2013). Baselines can be established based on historic, pre-development or pristine conditions, but these terms are open to interpretation and data are not consistently available (Squires and Dubé, 2013; Foley et al., 2017) or available in the format needed (Piper, 2001). The selection of parameters to characterize baseline conditions must be evaluated carefully since they must be capable of detecting change due to project-specific effects (Harriman and Noble, 2008). Seitz et al. (2011) agree that particular parameters play an important role in baseline characterization, but the time and costs associated with data collection can often be significant. Thus, the use of secondary data sources to support baseline development is particularly helpful when they are available (Seitz et al., 2011). Despite the acknowledgement of the inconsistency of baseline condition development, it is uncertain how practitioners can be encouraged to use a consistent method or assure consistency in data over time. Furthermore, the baselines provided by the majority of EAs are insufficient to assess the effects of a project (Spalding et al., 1993) and subsequently, its contributions to cumulative effects (Noble et al., 2016).

Squires et al. (2010) examined the challenges with developing baselines and determining significance in CEA by developing a method to quantify change relative to baselines. A lack of consistent and reliable data at the provincial and federal levels was a key challenge in the study, and the authors called for improved monitoring programs. Masden et al. (2010) confirm these challenges, and comment that the data that are available are typically not sufficient to characterize baseline conditions, requiring compromises to be made. While baseline characterization should ideally involve the integration of historical data, the lack of this data or its unavailability results in baseline conditions being characterized at the time of assessment, which may already be impacted by anthropogenic stressors (Pauly, 1995). The author refers to this as ‘shifting baseline syndrome’ since these baselines are not typically representative of the ecological conditions that existed prior to human-induced impacts. Masden et al. (2010) concur and argue that it is difficult to quantify or understand the degree of change that an ecosystem has previously undergone due to anthropogenic impacts. These authors note that shifting baselines can eventually lead to the degradation of the environment or parameter being monitored. Harrington and Canter (1998), however, caution that monitoring should not occur for the sake of monitoring. They argue that monitoring programs need to be designed to answer specific questions if they are to be effective.

2.4.4 Detectability

Both EA monitoring and EEM programs have struggled with assessing when environmental thresholds have been met (Duinker and Greig, 2006; Kilgour et al., 2007; Schultz, 2012). Statistics have typically been used as a means of determining significance in water quality trend assessments (Power et al., 1995). However, Jones (2016) warned that statistical significance merely indicates deviation from a normal range, which may not equate to any meaningful change in the environment. This has led to the development of graduated thresholds that would require different mitigation efforts according to the threshold reached (Kilgour et al., 2005). The authors describe three levels of criteria used by Environment Canada – ‘warning-level’, ‘unacceptable’ and ‘severe’ effects to assess fish and benthic invertebrates. Mitigation efforts or changes to project design would be warranted if unacceptable or severe effects are identified. Duinker and Greig (2006) believe that the underlying issue with identifying thresholds is that the current understanding of the environment is inadequate. The authors further outline that the environment does not function in a simplistic, linear fashion, which has led to arbitrary thresholds that have not always been able to detect an effect to the environment when it occurs. Foley et al. (2017) agree that a better understanding of the environment is necessary to define thresholds and significance, and call for useful parameters for CEs to be identified. Bérubé (2007) note that a better understanding of the environment involves the consideration of the area’s historical and regional context to determine whether a significance threshold has been met. This consideration permitted another layer of information that Hydro-Québec used to base its significance determination for two projects impacting wetlands. Overall, it is evident there are various ways to assess significance and little consensus on how to address this issue.

2.4.5 Adaptability

Lindenmayer and Likens (2010) characterized long-term monitoring programs as being passive, question-driven or mandated. Monitoring under EA – a question-driven program – produces project-level data focused on monitoring stress. Its primary purpose is to ensure that stress levels (e.g. discharge) are not exceeded or to ensure that mitigation standards are met. EEM programs – a mandated program – produce coarser scale data that focus on understanding the current state (i.e. accumulated state assessment). Its ideal purpose over time is to link effects to dominant drivers or causes. Integrating monitoring data from EA and EEM programs can be a challenge because their purposes and scales differ (Lindenmayer and Likens, 2010). The authors recognized that a one-size-fits-all solution to ensure data adaptability may not be suitable, but no alternative solution is suggested. Research by Zwart et al. (2015) suggested that the adaptability of monitoring data collected for EAs and effects-based programs to answer other ecological questions at larger spatial and temporal scales has been limited. These researchers acknowledged that significant amounts of environmental information are underutilized and they sought to determine whether data collected under different monitoring programs could be combined. Zwart et al. (2015) confirmed that these data could be combined to inform development decisions, but stated that some of the data were not capable of determining cause-effect relationships because they were not designed for that purpose.

A challenge with enhancing the adaptability of monitoring data collected for EAs and under water license requirements is that project-level EA data must still be capable of fulfilling its original purpose of detecting and mitigating project-specific effects (Ball et al., 2013*a*). The spatial and temporal scales of monitoring conducted for project-level EAs are dependent on the activity and the site-specific context, resulting in the variability of spatial and temporal scales across projects (Folkeson et al., 2013). Spatial and temporal scales of monitoring undertaken by proponents for EAs and under water license requirements may not align with the spatial and temporal scales that are necessary to assess CEs (Baxter et al., 2001; Harriman and Noble, 2008). MacDonald (2000) agrees that spatial and temporal scales for EA are highly variable because interacting ecosystem processes result in impacts at varying spatial and temporal scales. Though monitoring data adaptability is important to support the CEAs, Masden et al. (2010) note that the ability to assess cumulative effects at the local level is crucial to understanding cumulative effects at larger regional scales.

2.4.6 Accessibility

The accessibility of different sources of monitoring data and science-based tools permit disparate datasets to be leveraged, which can improve the quality of cumulative effects assessments (Willsteed et al., 2016). The fundamental challenge to accessing various datasets is that strong coordination is needed to know what data exist and how to access them (Harriman and Noble, 2008). Zwart et al. (2015) confirmed this challenge when they attempted to integrate data from multiple monitoring programs and remarked that six proponents had to be contacted for their data, and only one of them provided the requested data. Similarly, Creasey and Ross (2009) discussed the challenges of assessing data from different sectors for the Cheviot Coal Mine case and found that it was virtually impossible to expect a single proponent to assess for CEs when the data were not available to them. Kennett (2002*b*) acknowledged the difficulty of assessing for cumulative effects when proponents have only the 'goodwill' of other proponents to rely upon to furnish relevant data if no formal mechanism for data sharing exists. Nevertheless, it is unclear how data collected from EAs should be coordinated to understand cumulative effects when proponents are often unwilling to share data (Dixon and Montz, 1995; Piper, 2001; Zwart et al., 2015; McKay and Johnson, 2017). Proponent unwillingness may stem from the perceived risk of exposure, time required to share the data and a lack of incentive.

The accessibility of science generated from monitoring programs is also essential for resource managers and regulatory decision makers. Wright (2014) highlighted the need for regulators to have the tools to procure the scientific data necessary to make informed decisions without depending solely on the proponent. The author observes that regulators need regional data to understand the site context and to develop appropriate compliance standards. Furthermore, Noble et al. (2011) described that the lack of accessible information about planning and regulatory controls has hindered the ability of regulators to design appropriate monitoring programs to assess and mitigate CEs.

2.4.7 Usability

EAs are required to consider cumulative effects of a project, but this consideration can often be a cursory afterthought resulting in data that are not sufficient to support CE understanding (Duinker and Greig, 2006; Thérivel and Ross, 2007). For effective CEAs, Sinclair et al. (2016) state that the mentality towards cumulative effects must change and that they must be considered early in the EA process. Early consideration of cumulative impacts allows for a meaningful assessment (Burris and Canter, 1997), particularly in the selection of parameters (Olagunju and Gunn, 2015). Because subsequent stages of cumulative effects assessments, such as parameter selection and scoping, rely on consideration for cumulative effects, it is important that monitoring programs are designed with sufficient forethought to generate usable data (Baxter et al., 2001). An issue with cumulative effects that has been identified by a number of impact assessment practitioners is that their assessment is often ‘added on’, resulting in an assessment that is haphazard and incomplete (Duinker and Greig, 2006).

Cronmiller (2017) suggests that CE monitoring has focused on either EA or EEM monitoring programs to support CE understanding, and attempts to improve the usability of monitoring data generated from these two programs have been rare. However, scholars have suggested *how* EA or EEM monitoring program data can be adapted to uses other than their original purpose. Kilgour et al. (2007) proposed that project proponents could use EEM program data to develop the baseline conditions necessary to assess the effects of their projects to the environment. On the other hand, Willsteed et al. (2016) recommended that project-level monitoring could be used to provide finer resolution data to understand environmental responses at specific sites. While it has been recognized that monitoring data under EA and EEM programs can be used effectively to assess for cumulative effects, the individual challenges with using these data are compounded and magnified when CEs are assessed.

2.5 Summary

There is a large body of literature addressing many aspects of cumulative effects, but a great deal of debate rages over the types of monitoring data and parameters collected in monitoring programs, their utility and application. The need for good science in cumulative effects assessment was identified relatively early in its history. Practitioners understand the need to use scientifically credible evidence to support assessments, but the role of science in EA, and consequently in CEA, are variable. Monitoring under EA and EEM are fit-for-purpose programs that are wholly capable of achieving their primary purposes, and often succeed in doing so (Walker et al., 2003; Willsteed et al., 2016). These programs have been increasingly relied upon to assess cumulative effects, but there has been little guidance as to how these programs can or should support it (Masden et al., 2010; Duinker et al., 2012). Numerous scholars have outlined the need for greater consistency and coordination so that environmental assessments can collectively contribute to an understanding of cumulative effects to the environment. It is also necessary that EA and EEM programs are able to provide mutual support to better assess and manage cumulative effects. However, the challenges of CEA remain because monitoring under EA and EEM programs have evolved separately. This has led to a compounding of issues because CEAs need support from both processes, each of which has their individual issues. Several challenges exist with integrating monitoring data collected under stressor- and effects-based methods; the consistency of monitoring parameters, compatibility of monitoring and reporting methods, observability, detectability, adaptability, accessibility and usability of monitoring data are key challenges.

It is important that freshwater resources are responsibly managed as they are the foundation of healthy ecosystems, safe drinking water and cultural activities. The responsible management of freshwater resources depends on water quality monitoring programs to assess CEs. Because resource development in the NWT is still comparatively nascent, it is an ideal context to capitalize on improved understandings of cumulative effects to mitigate impacts on the environment. However, the vastness of the NWT lends itself to unique challenges. Environmental monitoring is costly and time consuming in the region, so data that can be used for multiple purposes is particularly valuable. Current literature has addressed the contributions of science from inside the EA process, particularly its shortcomings and narrow focus, *or* outside the EA process, particularly its disconnect from project needs (Canter and Atkinson, 2011; Connelly, 2011; Squires and Dubé, 2013; Ball et al., 2013*a*), but there has been limited research on their collective contributions and mutual support the two processes may provide. It remains unclear how science inside and outside the EA process should support CEA and what CEA needs from science (Duinker et al., 2012). This highlights a key issue to understand the attributes of monitoring data and parameters that will support the development of environmental baselines and prediction of cumulative effects.

Chapter 3
Research Methods

The research commenced with a scoping meeting with CIMP and various GNWT staff to understand the regulatory system, monitoring programs and priorities in the Mackenzie Valley, and to identify a sample of monitoring data sets and documents for review. This informed both the basis for a document analysis and semi-structured interviews to explore the potential of government- and proponent-based datasets and monitoring programs to support CE management and decisions.

3.1 Study area

The Mackenzie Valley covers most of the NWT – including the settled land claim areas of the Gwich'in, Sahtu, and Wek'eezhii, and the unsettled land claim areas of the Akaitcho First Nations, Deh Cho First Nations, and NWT Métis Nation (MVLWB, 2016). Two territory-wide boards, the Mackenzie Valley Environmental Impact Review Board (MVEIRB) and the Mackenzie Valley Land and Water Board (MVLWB), and three regional co-management boards, the Gwich'in, Sahtu, and Wek'eezhii Land and Water Boards, operate in the Mackenzie Valley. The MVEIRB is responsible for conducting EAs for proposed developments that may cause significant adverse impacts or are of public concern (MVEIRB, 2018). The MVLWB is responsible for issuing land use permits and processing transboundary water license applications in unsettled land claim areas (MVLWB, 2016). The MVLWB is also responsible for ensuring that the MVRMA is applied consistently across the Mackenzie Valley (MVLWB, 2018).

The Gwich'in, Sahtu, and Wek'eezhii Land and Water Boards play a similar role to the MVLWB, in their respective land claim areas (MVLWB, 2016). Each land and water board has five members; two nominated by the tribal council(s) in the land claim area, one nominated by the Government of the Northwest Territories (GNWT), one nominated by the Government of Canada, and a chair is nominated by these four members (MVLWB, 2018). The MVLWB is collectively composed of the members from the Gwich'in, Sahtu and Wek'eezhii Land and Water Boards, four members nominated to the MVLWB, and a chairperson (MVLWB, 2018).

The land and water boards derive their authority to regulate the use of water and the deposition of waste into waterbodies from the MVRMA and Waters Act (MVLWB, 2003). The land and water boards and GNWT share responsibility for the issuance, administration, and enforcement of water licenses (GNWT, 2017). There are eight categories of undertakings in the Mackenzie Valley that require water licenses: industrial, mining and milling, municipal, power, agricultural, conservation, recreation, and miscellaneous (MVLWB, 2003). Type ‘A’ water licenses are required for more significant uses of water, while Type ‘B’ water licenses are required for less significant uses (MVLWB, 2003). For example, a municipal undertaking with 2,000 m^3 or more per day of direct water use requires a Type A water license, whereas a Type B license applies to initiatives requiring less than the prescribed threshold (MVLWB, 2003). The process of obtaining a water license requires the proponent to complete a Type A or B application, which is reviewed in a preliminary screening by the land and water board that is responsible for water licenses in the proponent’s proposed development area (MVEIRB, n.d.*a*). A public hearing is convened to allow for the public to express any concerns regarding the proposed project (MVLWB, 2003). Following this, the land and water board can write the terms and conditions for a license, refer the application to the MVEIRB for review, or reject the license accompanied with reasons for the decision (MVLWB, 2003). The Minister of Aboriginal Affairs and Northern Development must approve the water license (MVEIRB, n.d.*a*). When the water license is issued, proponents must design their aquatic effects monitoring plans in accordance with the terms and conditions outlined in the license (INAC, 2009).

In cases where a land and water board refers an application to the MVEIRB, an EA is needed to determine whether the project can proceed. The MVEIRB can recommend that the proposed project is approved, approved subject to certain recommendations, or rejected. Each one of these recommendations requires approval from the responsible minister (MVEIRB, n.d.*a*; MVEIRB, n.d.*b*). It is also possible for a project to be referred to an independent review panel for an environmental impact review, which requires a more in-depth examination of the issues outlined in the EA. Overall, fewer than 5% of all projects that have been through preliminary screening in the NWT require an EA; fewer than 1% of projects that have been through an EA require an environmental impact review (MVEIRB, n.d.*b*). Once a project is approved, the responsible land

and water board will issue the water license stipulating the terms and conditions that proponents must adhere to in terms of project operations and monitoring and reporting requirements.

3.2 Data collection

An initial scoping meeting was held in Yellowknife in October 2016 with staff from NWT CIMP, the land and water boards, the review board, and the GNWT's Environment and Natural Resources (ENR) division. The purpose was to gain an understanding of the regulatory structure of monitoring and management under the MVRMA, to identify a preliminary list of water quality monitoring databases, to scope potential issues around monitoring data which would inform interview questions, and to identify potential participants. This scoping meeting was essential for determining the key questions that the semi-structured interviews were intended to address.

3.2.1 Document review

The first phase of data collection and analysis was a document review, a systematic procedure to identify and analyze documents for their relevance or significance (Altheide and Schneider, 2013). It involves a thorough examination of documents to categorize information according to the research questions (Bowen, 2009), permitting a deeper understanding of wide cross-sections of data (Curry et al., 2009). Document reviews have been used widely by EA scholars. For example, Burris and Canter (1997) conducted a document review to analyze environmental assessments to understand how often cumulative impacts were mentioned and the challenges associated with assessing cumulative impacts. Bérubé (2007) also used this method to analyze the consistency of 12 cumulative effects assessments conducted in Québec to identify areas of improvement. This method proved useful to identify underlying challenges with the monitoring data and parameters used to assess cumulative effects.

First, Type A water licenses were examined to gain an understanding of the water quality and quantity monitoring conducted by project proponents. Type A water licenses stipulate the parameters that the land and water boards require project proponents to collect when proponents are using water and/or depositing waste into waterbodies. Since NWT CIMP is familiar with prominent projects in the territory, they provided an initial list of 11 Type A water licenses and one Type B water license to review. The list of water licenses was expanded by searching for Type A water licenses on the Mackenzie Valley Land and Water Board's registry, which houses water licenses for projects across the NWT. This search yielded 15 more Type A water licenses, in addition to the 11 water licenses initially provided by CIMP. A total of 26 Type A water licenses and one Type B water license were reviewed to determine the water quality and quantity parameters monitored by proponents.[1] There were more than 26 Type A water licenses identified on the MVLWB's registry, but only 26 of them had an associated water quality monitoring program (Table 3.1).

Of the 27 water licenses, 16 were new applications and 11 were renewals. Four of the water licenses also had amendments, and the most recently amended version was reviewed for the type and frequency of monitoring conducted. The monitoring requirements for the amendments were almost exactly the same, or very similar to, the original water license. Most of the water licenses were related to diamond, gold, lead, zinc and other metal mine and mine remediation projects. There were also dam construction, hydroelectric generation, geothermal power generation, municipal undertaking and oil and gas projects.

Second, government-based (i.e. government-led or government-supported, community-based) water quality monitoring programs were examined. Government-led monitoring refers to monitoring conducted by GNWT; government-supported monitoring refers to monitoring conducted by communities with the support of GNWT. There are four major networks of water quality monitoring conducted by the Government of NWT's ENR division – Transboundary, North Slave, South Slave, and Local Lake. ENR staff provided access to the Liard River dataset, which is representative of the Transboundary network and the Lockhart River dataset, which is representative of the North Slave, South Slave, and Local Lake monitoring networks. The Mackenzie DataStream website houses government-supported, community-based monitoring programs conducted across the NWT.

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[1] Subsequent references to Type A water licenses will include the Type B water license. The single Type B water license was included in the review as it was initially identified by NWT CIMP as a project of interest.

Table 3.1 Type A and B water licenses included in the document review

Project Proponent	**Water License Type**	**Year of Water License Issue**	**Status of Water License**	**Project Type**
Northwest Territories Power Corporation – Bluefish	A	2011	New	Hydroelectric Dam Construction
Dogrib Power Corporation – Snare Cascades	A	2014	Renewal	Hydroelectric Power
Northwest Territories Power Corporation – Taltson River	A	2012	New	Hydroelectric Power
Northwest Territories Power Corporation – Bluefish	A	2006	Renewal	Hydroelectric Power
Northwest Territories Power Corporation – Snare River	A	1999	Renewal	Hydroelectric Power
Borealis Geopower Inc.	A	1999	New	Geothermal Power Generation
Tlicho Community Government of Behchoko	A	2014	New	Municipal Undertaking
Town of Fort Smith	A	2011	Renewal	Municipal Undertaking
Town of Fort Smith	A	2003	New	Municipal Undertaking
Town of Hay River	A	2010	Renewal	Municipal Undertaking
Town of Inuvik	A	2016	New	Municipal Undertaking
City of Yellowknife	A	2010	Renewal	Municipal Undertaking
Imperial Oil Resources Ltd. – Norman Wells	A	2015	New	Oil and Gas
Paramount Resources Ltd. – Cameron Hills	B	2002	New[1]	Oil and Gas
Canadian Zinc Corporation	A	2013	New	Mining
BHP Billiton Diamonds Inc.	A	2002	New	Diamond Mining and Milling
De Beers Canada Inc. – Snap Lake	A	2012	Renewal[1]	Diamond Mining and Milling
De Beers Canada Inc. – Snap Lake	A	2004	New	Diamond Mining and Milling
De Beers Canada Inc. – Gahcho Kue	A	2014	New	Diamond Mining
Fortune Minerals Ltd.	A	2016	New[1]	Gold-Cobalt-Bismuth-Copper Mining
Miramar Northern Mining Ltd.	A	2008	New[1]	Gold Mining
North American Tungsten Corporation Ltd.	A	2016	Renewal	Mining and Milling
North American Tungsten Corporation Ltd.	A	2003	New	Mining and Milling
Department of Indian and Northern Affairs	A	2016	Renewal	Mine Remediation and Reclamation
Department of Indian and Northern Affairs	A	2009	Renewal	Mine Remediation and Reclamation
Department of Indian and Northern Affairs	A	2005	Renewal	Mine Remediation and Reclamation
Tamerlane Ventures Inc.	A	2008	New	Lead-Zinc Mining

[1] The most recent amendment was used in the document review.

All seven water quality datasets, which included various types of water quality monitoring, were obtained from the Mackenzie DataStream website. The nature and availability of the data was assessed on the consistency of the parameters monitored, and the compatibility of the data through the monitoring approach taken (e.g. frequency of monitoring). This helped determine how easily these data could be combined with proponent-based datasets and ultimately factored into how the data could be used to assess cumulative effects.

3.2.2. Semi-structured interviews

The strength of high quality qualitative data is that it can provide direct insight about a specific research problem (Miles et al., 2013) and help to understand its complexities (Geertz, 1973). Semi-structured interviews are a commonly used qualitative research method and rely on a set of pre-determined questions along with other open-ended questions to probe themes that emerge to explore certain subject matter (DiCicco-Bloom and Crabtree, 2006). These types of interviews have been widely used in explore various aspects of environmental assessments and cumulative effects assessments (e.g. Wärnbäck and Hilding-Rydevik, 2009; Briggs and Hudson, 2013; Runhaar et al., 2013; Kågström, 2016; McKay and Johnson, 2017). Semi-structured interviews are an appropriate method to understand the scientific contributions of monitoring programs to cumulative effects assessments. They can reveal insights about the challenges that various stakeholders face when accessing and utilizing monitoring data to support cumulative effects, which a document analysis alone cannot not provide. This type of interview permits flexibility to explore themes that may not have been identified at the outset of the research.

An initial list of potential interviewees was provided by NWT CIMP, as the organization is familiar with various groups responsible for water quality monitoring conducted in the Mackenzie Valley. This list was expanded by consulting the MVLWB and the MVEIRB websites for proponents or practitioners that had participated in water quality monitoring programs. Snowballing was also used to expand the list of participants; this technique involves participants referring others who may be interested in participating (Gubrium and Holstein, 2002).

There were 35 potential participants that were invited by email to participate in the interview process. A total of 24 interviews, totaling 26 participants, were conducted from May to July 2017. Two of the interviews involved two participants because the participants had worked closely on monitoring programs or with the regulatory process and were able to share and confirm information. Some potential participants felt they would be poorly suited to answer the interview questions since their expertise was in an area other than water quality. Others felt that they did not have enough experience in the NWT to effectively answer the questions.

However, a cross-section of stakeholders involved in water quality monitoring or regulation did participate, including representatives from government agencies, independent mine oversight boards, industry, academia, land and water boards, the review board and consultants (Table 3.2). The experience of the interviewees varied from one year to almost 40 years, providing a broad perspective of cumulative effects to freshwater resources. They were also from a variety of backgrounds; a mix of policy advisors, environmental scientists, aquatic biologists and managers from industry and government agencies participated. Seventeen interviews were conducted in person; the remainder were conducted by telephone (n=7) for logistical and financial reasons. Results from in-person and telephone interviews have been found to be comparable (Rogers, 1976). The interviews ranged in length from 17 to 71 minutes. All the interviews were recorded with a Sony digital voice recorder. They were then transcribed using Microsoft Word to facilitate data analysis.

Table 3.2 Number of participants interviewed according to stakeholder type

Stakeholder Type	**Number of Participants**
Consultant	9
Territorial Government	
• Environment and Natural Resources	6
• Cumulative Impact Monitoring Program	1
Proponent	3
Independent Mine Oversight Board	3
Land and Water Board	2
Academia	1
Review Board	1
Total	26

3.3 Framework for data collection and analysis

Document reviews and semi-structured interviews were guided by an overarching analytical framework to provide consistency in the approach, and to ensure that the analysis focused on those characteristics of monitoring programs (and the data generated) most important to facilitating CE understanding (Figure 3.1). The analytical framework was developed based on an understanding of the nature of, and challenges to, monitoring programs to support CE assessment and management, as presented in Chapter 2, combined with aspects of evaluation frameworks used to assess user experience of eSystems and software, which have increasingly focused on improving user experience (Petrie and Bevan, 2009; Lew et al., 2010). Petrie and Bevan (2009) note that the shift towards usability has centred on the premise that software should be carefully designed to fulfill the goals of the user. Similarly, monitoring programs should be able to fulfill the goals of its users, which include the understanding and support of cumulative effects. The evaluation framework of eSystems and software provides a useful basis for the assessment of data used in cumulative effects because it uses universal characteristics that are fundamental to how data are managed and accessed.

There are effectively two different means in which data can support CEAs – the development of baseline trends and the prediction of cumulative impacts. Characteristics of effective environmental monitoring data have been widely studied. Van Oudenhoven et al. (2012) developed a framework to systematically select parameters and found that consistency, sensitivity to change, scalability and credibility were valuable characteristics. Though the authors were investigating parameters that would aid in assessing the effect of different land management techniques on ecosystem services, the fundamental purpose of the parameters was to assess change. Parameters possessing these characteristics would likely be useful in developing baselines for EEM programs and quantifying change. Beliaeff and Pelletier (2010) also cited sensitivity to change as and feasibility as some of the important characteristics. The presence of reference values would certainly aid in quantifying changes from the baseline, but it should not preclude the selection of certain parameters if other criteria are met. Donnelly et al. (2007) formulated a framework to aid in the selection of parameters for strategic environmental assessments (SEA) and cited some of the same characteristics as Van Oudenhoven et al. The criteria for selecting parameters include their ability to be relevant, applicable in different environments, show trends, be easily understood, provide early warning, be practical (e.g. cost-effective and logistically feasible) and be adaptable. These criteria were designed for SEA, which considers the broader effects of projects and policies, but these criteria can be applied to the cumulative effects context since many of the same characteristics of parameters are required to assess for effects. Based on this review of parameter selection frameworks, some overlap in the attributes of parameters to support baseline characterization and effects assessment emerge. These include sensitivity to change or ability to provide early warning, scalability or adaptability and feasibility or practicality of monitoring. Some characteristics of data to support CEAs can also be inferred from the literature. These include parameter consistency, data compatibility, accessibility and usability (MacDonald, 2000; Cooper and Sheate, 2002; Vaughan et al., 2003; Harriman and Noble, 2008; Noble et al., 2011; Ball et al. 2013*b*; Dubé et al., 2013*b*; Zwart et al., 2015).

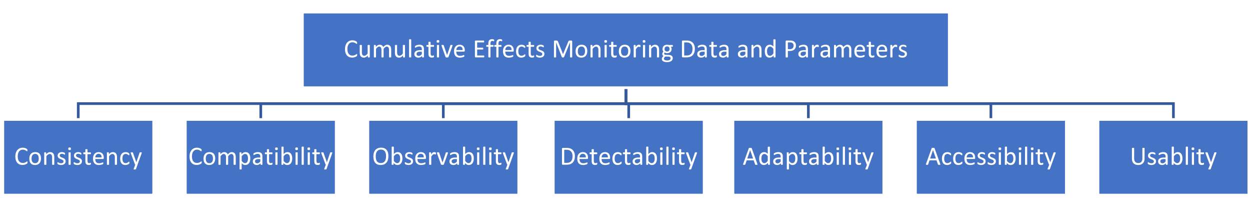

Figure 3.1 Framework used to assess monitoring data and parameters to support cumulative effects assessments

The framework consists of seven criteria, as follows:

- *Consistency:* The suite of parameters collected under government- and proponent-based monitoring programs, and within proponent-based monitoring programs, must be sufficiently consistent (i.e. common) to support cumulative effects understanding

- *Compatibility:* It must be possible for monitoring data to be integrated with other datasets / monitoring / assessment systems to support CE analysis. Compatibility refers to the consistency of the approach taken to sample and analyze data

- *Observability:* Monitoring data and parameters must be able to support observations / tracking of baseline change / change over time and / or across space

- *Detectability:* Monitoring data and parameters must be capable of, and available to, supporting the early detection of change or potential threats

- *Adaptability:* Monitoring data and parameters must be useful at multiple spatial scales, and applicable across multiple project or disturbance types

- *Accessibility:* Monitoring data need to accessible, retrievable, and available in a usable format

- *Usability:* Monitoring data must be relevant to / meet end user demands / needs based on specified objectives (e.g. CE assessor, regulator, manager, decision maker)

The document analysis provided insights largely into consistency and compatibility. Interviews provided insight across all seven criteria. The interview questions are included in Appendix A. Initially, interview transcripts were analyzed manually to identify recurring themes, opposing views, and other insights. NVivo 11.0 © was then used to analyze the transcripts again and to highlight quotes that were relevant to each theme. The use of software can improve the consistency of the analytical process and simplify the data management and search process, particularly with large volumes of data (Flick, 2014). NVivo permitted the data to be organized according to the interview question and seven attributes – consistency, compatibility, observability, detectability, adaptability, accessibility and usability – of monitoring data and parameters to support CEA. The ability to organize the data in different ways was useful as it allowed for the identification of general themes, and themes according to their respective questions. Coding the interview transcripts permitted the identification of secondary or related themes and also helped to identify patterns among the interviewees according to their affiliation.

Because of the varying degrees of experience related to cumulative effects to water quality in the NWT, interviewees only responded to the questions they felt they were able to answer. As a result, there were certain interview questions that were answered more frequently, or more in depth, than others. The manual analysis of the interview transcripts, coupled with analysis using NVivo, were ideal techniques to understand the contributions of environmental monitoring programs to support cumulative effects assessments in the context of the seven attributes.

Chapter 4
Results

This chapter presents results from the review of monitoring programs and semi-structured interviews. Participants that agreed to an interview were forthcoming and often volunteered specific examples. Representatives from the four land and water boards in the Mackenzie Valley were invited to participate and are well-positioned to provide regional insight about monitoring because of their direct oversight of regulatory requirements. However, the land and water boards collectively decided that staff from one board would be responsible for representing all four land and water boards in the interview. The level of participation from the boards was concerning given the important role they could potentially play in supporting the assessment and management of cumulative effects.

Overall, there was consensus among interviewees that the purpose of government-led water quality monitoring in the NWT is to conduct long-term, regional baseline monitoring; however, some participants mentioned that the stated purpose of government-led monitoring may reflect its intent rather than reality. Government-led monitoring programs were generally seen as effective at characterizing baseline conditions, but not necessarily in detecting condition change. Interviewees, regardless of affiliation, reported that the purpose of proponent-based monitoring is to conduct baseline monitoring, determine natural variability of a waterbody, fulfill EA commitments, detect change associated with a project, and confirm whether EA predictions are correct. Most interviewees commented that proponents conduct the 'best and most intense' water quality monitoring in the NWT. Results are presented below, organized based on the seven attributes of monitoring data adopted for this research, namely that monitoring programs (data, parameters) are: consistent, compatible, observable, detectable, adaptable, accessible, and usable.

4.1 Consistency

Consistency is about *what* is monitored – i.e. a common suite of parameters across monitoring programs; it is not indicative of similar monitoring procedures or protocols. There are two principal areas of consistency for monitoring programs to support cumulative effects: first, consistency in what is being monitored by proponents across projects; second, consistency in what is being monitored between proponent- and government-based monitoring programs.

There were 86 monitoring parameters identified across the sample of 27 Type A water licenses issued to proponents, excluding the suite of heavy metals. Forty-nine (56%) were chemical parameters (e.g. total dissolved solids, total organic carbon), 23 (26%) were physical (e.g. temperature, pH), and 15 (17%) biological (e.g. rainbow trout, fecal coliform). No parameters were common to all water licenses (Table 4.1). Of the 86 parameters, 22 (25%) were monitored at one or more monitoring station for at least 50% of the water licenses issued. The most commonly monitored physical parameters were pH, total suspended solids (TSS), conductivity, water pumped (volume), water temperature, and water flow (Table 4.2). pH was monitored in 82% of water licenses, conductivity in 75%, and TSS in 54%. Chemical parameters were the most variable, with many (e.g. % dissolved oxygen saturation, acidity, dissolved hydrogen sulfide, and dissolved methane) monitored in only one water license (Table 4.3a). Sulphate, ammonia nitrogen, metals, total dissolved solids (TDS), nitrate and nitrite, dissolved phosphorus, hydrocarbons, major ions, total organic carbon, and hardness were measured in at least 50% of all water licences (Table 4.3b).

The most monitored major ions were calcium, chloride, sulphate, magnesium, potassium, and hardness (46% of water licenses), and sodium and alkalinity (43%). Of the biological parameters, fecal coliform was the only one measured in 50% or more of all water licenses (Table 4.4). Rainbow trout was monitored in 37% of water licenses, and *Daphnia magna* in 30%. For nutrients, some form (e.g. total or dissolved) of ammonia, phosphorus, ortho-phosphorus, and organic carbon were monitored in approximately 40% of Type A water licenses. Biological parameters were not monitored as consistently as physical or chemical parameters. There were 15 parameters (17%) that were monitored in only a single water license. This included methyl tert-butyl ether, radionuclides and total heterotrophic plate counts. The most commonly monitored metals were cadmium, copper, lead, nickel, and zinc – in 78% or more of all licenses.

Table 4.1 Monitoring parameters identified in at least 50% of the sample of 27 Type A water licenses reviewed.

Proponent	Project Type	Monitoring Parameters																									
		Water flow rates	Water pumped	Water temperature	TSS	pH	Conductivity	Oil and grease	Ammonia nitrogen	Dissolved inorganic/organic phosphorus	Total organic carbon	Nitrate and nitrite, nitrogen	Major ions	Chloride	Calcium	Sodium	Potassium	Magnesium	Hardness	Sulphate	TDS	Total hydrocarbons	ICP-MS metal scan	Total Mercury	Total arsenic	Total copper	Fecal coliform
Northwest Territories Power Corporation	Bluefish: Dam Construction				✓	✓			✓			✓											✓		✓		
Dogrib Power Corporation	Hydroelectric Power	✓																									
Northwest Territories Power Corporation	Taltson River: Hydroelectric Power	✓																									
Northwest Territories Power Corporation	Bluefish: Hydroelectric Power				✓	✓			✓			✓											✓		✓	✓	
Northwest Territories Power Corporation	Snare River: Hydroelectric Power	✓																									
Borealis Geopower Inc.	Geothermal Power Generation		✓	✓	✓	✓	✓							✓		✓	✓	✓		✓	✓		✓		✓	✓	
Tlicho Community Government of Behchoko	Municipal Undertakings		✓		✓	✓	✓	✓	✓	✓					✓	✓	✓	✓		✓		✓		✓		✓	✓
Town of Fort Smith	Municipal Undertakings		✓		✓	✓	✓	✓	✓	✓		✓								✓			✓	✓	✓	✓	✓
Town of Fort Smith	Municipal Undertakings		✓	✓	✓	✓	✓	✓	✓				✓	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓
Town of Hay River	Municipal Undertakings			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Town of Inuvik	Municipal Undertakings		✓		✓	✓	✓	✓	✓						✓		✓	✓		✓				✓		✓	✓
City of Yellowknife	Municipal Undertakings		✓	✓	✓	✓	✓	✓	✓	✓[2]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Imperial Oil Resources Ltd. - Norman Wells	Oil and Gas		✓	✓	✓	✓	✓			✓[1]			✓	✓	✓		✓	✓	✓	✓	✓	✓	✓			✓	
Paramount Resources Ltd. - Cameron Hills (Type B)	Oil and Gas		✓		✓	✓	✓	✓						✓	✓	✓	✓	✓		✓						✓	
Canadian Zinc Corporation	Mining	✓			✓	✓	✓	✓	✓	✓[1]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
BHP Billiton Diamonds Inc.	Diamond Mining and Milling	✓	✓	✓	✓	✓	✓		✓	✓[2]	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
De Beers Canada Inc. - Snap Lake	Diamond Mining and Milling	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓[3]	✓	✓	✓	✓	✓
De Beers Canada Inc. - Snap Lake	Diamond Mining and Milling	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
De Beers Canada Inc. - Kennady Lake	Diamond Mining	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓[3]		✓[2]	✓[2]	✓[2]	✓
Fortune Minerals Ltd.	Gold-cobalt-bismuth-copper Mine	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓[3]		✓	✓	✓	✓
Miramar Northern Mining Ltd.	Gold Mine	✓	✓	✓	✓	✓	✓		✓	✓[1]		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
North American Tungsten Corporation Ltd.	Mining and Milling	✓	✓		✓	✓			✓	✓	✓	✓		✓					✓	✓	✓	✓	✓		✓	✓	✓
North American Tungsten Corporation Ltd.	Mining and Milling	✓	✓	✓	✓	✓	✓		✓		✓	✓								✓	✓		✓		✓		✓
Department of Indian and Northern Affairs Canada	Gold Mine Remediation		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Department of Indian and Northern Affairs Canada	Gold Mine Remediation			✓	✓	✓	✓		✓	✓[1]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		
Department of Indian and Northern Affairs Canada	Mine Remediation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Tamarlane Ventures Inc.	Lead/zinc Mine	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓								✓		✓		✓	✓	

[1]Total; [2]Total and dissolved; [3]Extractable petroleum

Table 4.2 All physical parameters identified for monitoring in the sample of 27 Type A water licenses reviewed.

Proponent	Project Type	Physical Parameters																					
		%sand, silt, clay	CBOD	Power Production	Net Solar Radiation	Relative Humidity	Water Clarity	Evaporation	Weather Conditions	Air Temperature	Precipitation	Water/Sewage Discharge	Ambient Wind	DO	Water Levels	Turbidity	BOD5	Water Flow Rates	Water Temperature	Water Pumped	Conductivity	pH	TSS
Northwest Territories Power Corporation	Bluefish: Dam Construction															✓						✓	✓
Dogrib Power Corporation	Hydroelectric Power			✓											✓			✓					
Northwest Territories Power Corporation	Taltson River: Hydroelectric Power																	✓					
Northwest Territories Power Corporation	Bluefish: Hydroelectric Power															✓						✓	✓
Northwest Territories Power Corporation	Snare River: Hydroelectric Power														✓			✓					
Borealis Geopower Inc.	Geothermal Power Generation																		✓	✓	✓	✓	✓
Tlicho Community Government of Behchoko	Municipal Undertakings		✓														✓			✓	✓	✓	✓
Town of Fort Smith	Municipal Undertakings											✓					✓			✓	✓	✓	✓
Town of Fort Smith	Municipal Undertakings											✓		✓			✓		✓	✓	✓	✓	✓
Town of Hay River	Municipal Undertakings											✓		✓	✓		✓		✓		✓	✓	✓
Town of Inuvik	Municipal Undertakings																✓			✓	✓	✓	✓
City of Yellowknife	Municipal Undertakings													✓			✓		✓	✓	✓	✓	✓
Imperial Oil Resources Ltd. - Norman Wells	Oil and gas																		✓	✓	✓	✓	✓
Paramount Resources Ltd. - Cameron Hills (Type B)	Oil and gas																			✓	✓	✓	✓
Canadian Zinc Corporation	Mining									✓	✓		✓			✓	✓	✓			✓	✓	✓
BHP Billiton Diamonds Inc.	Diamond Mining and Milling								✓		✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
De Beers Canada Inc. - Snap Lake	Diamond Mining and Milling				✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓		✓	✓	✓
De Beers Canada Inc. - Snap Lake	Diamond Mining and Milling						✓		✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
De Beers Canada Inc. - Kennady Lake	Diamond Mining	✓						✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fortune Minerals Ltd.	Gold-cobalt-bismuth-copper Mine				✓	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Miramar Northern Mining Ltd.	Gold Mine															✓		✓	✓	✓	✓	✓	✓
North American Tungsten Corporation Ltd.	Mining and milling																✓	✓		✓		✓	✓
North American Tungsten Corporation Ltd.	Mining and milling											✓	✓					✓	✓	✓	✓	✓	✓
Department of Indian and Northern Affairs Canada	Gold Mine Remediation													✓	✓	✓	✓		✓	✓	✓	✓	✓
Department of Indian and Northern Affairs Canada	Gold Mine Remediation															✓			✓		✓	✓	✓
Department of Indian and Northern Affairs Canada	Mine											✓				✓	✓	✓	✓	✓	✓	✓	✓
Tamerlane Ventures Inc.	Lead/zinc Mine														✓			✓	✓	✓	✓	✓	✓

Table 4.3a All chemical parameters identified for monitoring in the sample of 27 Type A water licenses reviewed.

Proponent	Project Type	Chemical Parameters																						
		Fluoride	Nutrients	BTEX	Oil and Grease	Total Alkalinity	Hardness	Total Organic Carbon	Dissolved Inorganic/Organic phosphorus	Major Ions	Sodium	Total Hydrocarbons	Total Mercury	Nitrate and Nitrite	Calcium	Chloride	Magnesium	Potassium	TDS	Total Arsenic	ICP-MS Metal Scan	Ammonia Nitrogen	Total Copper	Sulphate
Northwest Territories Power Corporation	Bluefish: Dam Construction													✓						✓	✓	✓		
Dogrib Power Corporation	Hydroelectric Power																							
Northwest Territories Power Corporation	Taltson River: Hydroelectric Power																							
Northwest Territories Power Corporation	Bluefish: Hydroelectric Power													✓						✓	✓	✓	✓	
Northwest Territories Power Corporation	Snare River: Hydroelectric Power																							
Borealis Geopower Inc.	Geothermal Power Generation										✓					✓	✓	✓	✓	✓	✓		✓	✓
Tlicho Community Government of Behchoko	Municipal Undertakings			✓	✓				✓[5]		✓	✓	✓		✓		✓	✓				✓	✓	✓
Town of Fort Smith	Municipal Undertakings				✓				✓				✓	✓						✓	✓	✓	✓	✓
Town of Fort Smith	Municipal Undertakings			✓	✓	✓				✓		✓	✓		✓	✓			✓	✓	✓	✓	✓	✓
Town of Hay River	Municipal Undertakings	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Town of Inuvik	Municipal Undertakings				✓								✓		✓		✓	✓				✓	✓	✓
City of Yellowknife	Municipal Undertakings	✓	✓	✓	✓	✓	✓	✓	✓[2]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Imperial Oil Resources Ltd. - Norman Wells	Oil and gas	✓		✓		✓	✓		✓[4]	✓		✓[6]			✓	✓	✓	✓	✓		✓		✓	✓
Paramount Resources Ltd. - Cameron Hills (Type B)	Oil and gas				✓						✓				✓	✓	✓	✓					✓	✓
Canadian Zinc Corporation	Mining	✓			✓	✓	✓	✓[3]	✓[4]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
BHP Billiton Diamonds Inc.	Diamond Mining and Milling	✓	✓			✓	✓	✓	✓[2]	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
De Beers Canada Inc. - Snap Lake	Diamond Mining and Milling	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓[7]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
De Beers Canada Inc. - Snap Lake	Diamond Mining and Milling	✓	✓	✓			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
De Beers Canada Inc. - Kennady Lake	Diamond Mining	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓[7]	✓[2]	✓	✓	✓	✓	✓	✓	✓[2]		✓	✓[2]	✓
Fortune Minerals Ltd.	Gold-cobalt-bismuth-copper Mine	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓[7]	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Miramar Northern Mining Ltd.	Gold Mine		✓	✓		✓	✓		✓[4]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
North American Tungsten Corporation Ltd.	Mining and milling	✓		✓		✓	✓	✓	✓			✓		✓[8]		✓			✓	✓	✓	✓	✓	✓
North American Tungsten Corporation Ltd.	Mining and milling			✓				✓						✓[8]					✓	✓	✓	✓		✓
Department of Indian and Northern Affairs Canada	Gold Mine Remediation		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Department of Indian and Northern Affairs Canada	Gold Mine Remediation		✓	✓		✓	✓	✓	✓[4]	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Department of Indian and Northern Affairs Canada	Mine		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Tamerlane Ventures Inc.	Lead/zinc Mine				✓			✓		✓									✓	✓	✓	✓	✓	

[1]F1 and F2; [2]Total and dissolved; [3]Dissolved only; [4]Total only; [5]Phosphate; [6]Petroleum; [7]Extractable; [8]Nitrogen

Table 4.3b All chemical parameters identified for monitoring in the sample of 27 Type A water licenses reviewed (continued).

Proponent	Project Type	Chemical Parameters: % DO Saturation	Acidity	Dissolved Hydrogen Sulfide	Dissolved Methane	Ion Balance	Methyl tert-butyl ether	Radionuclides	Salinity	Sulphide	Total and Dissolved Boron	Bicarbonate	CCMS Scan	Hydroxide	Redox Potential	Thiocyanate	Total Residual chlorine	Total Volatile Hydrocarbons	WAD Cyanide	Carbonates	Total Cyanide	Metals	Orthophosphorus	Silica	Total phenols	Orthophosphate	Total Kjeldahl Nitrogen
Northwest Territories Power Corporation	Bluefish: Dam Construction																										
Dogrib Power Corporation	Hydroelectric Power																										
Northwest Territories Power Corporation	Taltson River: Hydroelectric Power																										
Northwest Territories Power Corporation	Bluefish: Hydroelectric Power																										
Northwest Territories Power Corporation	Snare River: Hydroelectric Power																										
Borealis Geopower Inc.	Geothermal Power Generation			✓	✓				✓		✓									✓				✓			
Tlicho Community Government of Behchoko	Municipal Undertakings																					✓			✓		
Town of Fort Smith	Municipal Undertakings																										
Town of Fort Smith	Municipal Undertakings																										
Town of Hay River	Municipal Undertakings																✓						✓		✓		✓
Town of Inuvik	Municipal Undertakings																								✓		
City of Yellowknife	Municipal Undertakings						✓																✓		✓		✓
Imperial Oil Resources Ltd. - Norman Wells	Oil and gas																✓								✓		
Paramount Resources Ltd. - Cameron Hills (Type B)	Oil and gas																										
Canadian Zinc Corporation	Mining																	✓									
BHP Billiton Diamonds Inc.	Diamond Mining and Milling	✓													✓								✓	✓			✓
De Beers Canada Inc. - Snap Lake	Diamond Mining and Milling												✓													✓	✓
De Beers Canada Inc. - Snap Lake	Diamond Mining and Milling																									✓	✓
De Beers Canada Inc. - Kennady Lake	Diamond Mining							✓				✓		✓						✓		✓[2]		✓		✓	✓
Fortune Minerals Ltd.	Gold-cobalt-bismuth-copper Mine		✓			✓						✓		✓				✓[1]		✓		✓	✓	✓			✓
Miramar Northern Mining Ltd.	Gold Mine									✓			✓								✓	✓					✓
North American Tungsten Corporation Ltd.	Mining and milling																									✓	✓
North American Tungsten Corporation Ltd.	Mining and milling																										
Department of Indian and Northern Affairs Canada	Gold Mine Remediation														✓											✓	
Department of Indian and Northern Affairs Canada	Gold Mine Remediation															✓			✓		✓					✓	
Department of Indian and Northern Affairs Canada	Mine															✓			✓		✓					✓	
Tamerlane Ventures Inc.	Lead/zinc Mine																										

[1]F1 and F2; [2]Total and dissolved; [3]Dissolved only; [4]Total only; [5]Phosphate; [6]Petroleum; [7]Extractable; [8]Nitrogen

Table 4.4 All biological parameters identified for monitoring in the sample of 27 Type A water licenses reviewed.

Proponent	Project Type	Biological Parameters: *Microcystin-LR*	Total Heterotrophic Plate Count	Fecal Streptococci	Microbial Pathogens	*Selenastrum capricornutum*	*Lemna minor*	*Giardia*	*Cryptosporidium*	Fathead minnow	*Pseudokirchneriella subcapitata*	*Ceriodaphnia dubia*	*E. coli*	*Daphnia magna*	Rainbow Trout	Fecal Coliform
Northwest Territories Power Corporation	Bluefish: Dam Construction															
Dogrib Power Corporation	Hydroelectric Power															
Northwest Territories Power Corporation	Taltson River: Hydroelectric Power															
Northwest Territories Power Corporation	Bluefish: Hydroelectric Power															
Northwest Territories Power Corporation	Snare River: Hydroelectric Power															
Borealis Geopower Inc.	Geothermal Power Generation															
Tlicho Community Government of Behchoko	Municipal Undertakings															✓
Town of Fort Smith	Municipal Undertakings															✓
Town of Fort Smith	Municipal Undertakings														✓	✓
Town of Hay River	Municipal Undertakings			✓												✓
Town of Inuvik	Municipal Undertakings															✓
City of Yellowknife	Municipal Undertakings			✓										✓	✓	✓
Imperial Oil Resources Ltd. - Norman Wells	Oil and gas															
Paramount Resources Ltd. - Cameron Hills (Type B)	Oil and gas														✓	
Canadian Zinc Corporation	Mining												✓			✓
BHP Billiton Diamonds Inc.	Diamond Mining and Milling													✓	✓	
De Beers Canada Inc. - Snap Lake	Diamond Mining and Milling				✓			✓	✓	✓	✓	✓	✓	✓	✓	✓
De Beers Canada Inc. - Snap Lake	Diamond Mining and Milling		✓		✓	✓		✓	✓			✓	✓	✓	✓	
De Beers Canada Inc. - Kennady Lake	Diamond Mining									✓	✓	✓	✓	✓	✓	✓
Fortune Minerals Ltd.	Gold-cobalt-bismuth-copper Mine	✓				✓	✓					✓	✓	✓	✓	✓
Miramar Northern Mining Ltd.	Gold Mine													✓	✓	
North American Tungsten Corporation Ltd.	Mining and milling						✓			✓	✓	✓				✓
North American Tungsten Corporation Ltd.	Mining and milling															✓
Department of Indian and Northern Affairs Canada	Gold Mine Remediation												✓	✓	✓	✓
Department of Indian and Northern Affairs Canada	Gold Mine Remediation															
Department of Indian and Northern Affairs Canada	Mine															✓
Tamerlane Ventures Inc.	Lead/zinc Mine															

The majority of monitoring under Type A water licenses involved monitoring at more than one monitoring station, and some projects had over 45 monitoring stations. A total of 427 monitoring stations was captured by the 27 Type A water licenses. Although a parameter may be monitored at least once in a water license, the number of stations monitoring a certain parameter was variable. Physical (e.g. pH, TSS, conductivity) and chemical parameters (e.g. sulphate, major ions, metals) that were identified in at least 50% of Type A water licenses were also monitored in at least 50% of all the monitoring stations in the licenses reviewed. However, the only biological parameter monitored at least once in 50% of the Type A water licenses, fecal coliform, was monitored at only 12% of monitoring stations in all of the water licenses. Rainbow trout and *Daphnia magna* were monitored at least once in 37% and 30% of Type A licenses, respectively, but rainbow trout was monitored at only 5% of all monitoring stations in the licenses reviewed and *Daphnia magna* in only 3%.

Greater consistency in the general categories of parameters monitored under Type A water licenses was observed when project type was considered (Table 4.5). Water licenses for the four hydroelectric projects included only physical parameters, such as water flow, water level and power production; they typically did not include water quality parameters. Type A water licenses for municipal undertakings monitored for all the general categories of parameters, with biological parameters, such as fecal coliform, monitored at 60% of the municipal undertaking monitoring sites. Mine or mine remediation projects focused on all the general categories of parameters. Given the small project sample size for dam construction, geothermal, and oil and gas, conclusions cannot be drawn about consistency across these three project types.

pH is monitored in all municipal, oil and gas, and mine or mine remediation water licenses, and conductivity monitored in all municipal and oil and gas water licenses. Copper, nickel, and zinc were monitored in all municipal, oil and gas, and mine or mine remediation licenses. Cadmium, chromium, copper, iron, lead, nickel, and zinc were monitored in all municipal undertakings, and in both oil and gas water licenses –except iron. Aluminum, cadmium, copper, iron, lead, manganese, molybdenum, selenium, strontium, and zinc were monitored in 85% or more of all mine or mine remediation Type A water licenses. There were no parameters in the major ion or nutrient categories that were common based on project type, but certain parameters were measured more often. Forms of ammonia, phosphorus, orthophosphorus and organic carbon were measured in 69% of all mine or mine remediation Type A water licenses.

Table 4.5 General categories of parameters monitored in 50% or more of Type A water licenses reviewed, by project type[1]

Project Type	Number of Projects	Physical Parameters	Major Ions	Metals	Nutrients	Biological Parameters	Hydrocarbons
Dam Construction	1	✓		✓		✓	
Hydroelectric Power	4	✓					
Geothermal Power Generation	1	✓	✓	✓			
Municipal Undertaking	6	✓				✓	✓
Oil and Gas	2	✓	✓	✓			✓
Mine or Mine Remediation	13	✓	✓	✓	✓	✓	✓

[1] ✓ indicates that at least 50% of water licenses for projects in that category (e.g. mine or mine remediation) monitored for the specified category of parameters (e.g. metals).

A total of 34 parameters (excluding heavy metals) were identified from a sample of datasets representative of two of the four government-led monitoring networks in the NWT, namely the North Slave and Transboundary.[2] These two government-led monitoring programs sampled for 12 (35%) physical parameters and 22 (65%) chemical parameters. They did not sample for biological parameters, but they did sample for large suites of phenols, PCBs, organochlorine compounds, and other groups of chemical compounds. Government agencies in the NWT also support four types of community monitoring programs – grab, Sonde, Diffusive Gradients in Thin-films, and Polyethylene Membrane Devices, in the near Fort Nelson First Nation, Mikisew Cree First Nation, the Upper Athabasca, and in four other regions across the territory.[3] These

[2] Major monitoring networks include the North Slave and Transboundary programs. Community-based monitoring networks include Fort Nelson First Nation, Mikisew Cree Nation, Upper Athabasca and grab, Sonde, DGT and PMD water quality monitoring conducted at multiple locations across the NWT.
[3] The Mackenzie DataStream describes grab samples as being collected just beneath the surface of the water while Sondes continuously measure water quality in streams, DGTs passively sample for dissolved metals and PMDs passively sample for hydrocarbons.

programs sampled for 27 parameters, excluding the heavy metal suite, of which 7 (26%) were physical parameters and 20 (74%) chemical. There were no biological parameters identified.

The major government-led and government-supported community monitoring programs sampled for similar physical parameters, nutrients, major ions, metals and polycyclic aromatic hydrocarbons. Oxidation-reduction potential was the only parameter that government-supported, community-based monitoring programs sampled for that government-led monitoring networks did not. Overall, government monitoring networks and government-supported community monitoring programs tended to focus on the same general categories identified in proponent water licenses. Interviewees similarly reported that the parameters monitored by proponents were generally consistent with what government agencies were monitoring, but proponents typically monitored a broader range of parameters. Physical parameters for monitoring conducted by proponents under water license requirements and monitoring conducted or supported by government agencies were almost identical (Table 4.6). Chemical parameters in government-led and government-supported monitoring programs included major ions and nutrients, which were largely the same parameters monitored by proponents (Table 4.7). For major ions, 59% of the parameters in government-led and government-supported monitoring were also monitored by proponents under Type A water license requirements. The common major ions monitored were calcium, chloride, fluoride, hardness, magnesium, potassium, reactive silica, sodium, sulphate and total alkalinity.

Nutrients monitored by proponents under Type A water licenses and government-led and government-supported community programs were also similar, though different forms of nutrients were monitored. For instance, government-led and government-supported community programs monitored total nitrogen, and proponents monitored Kjeldahl nitrogen. Chlorophyll A was the only nutrient that was consistently monitored by government-led and government-supported community programs that was *not* monitored by proponents under Type A water license requirements. Government-led, government-supported and proponent-based monitoring programs sampled for nearly the same suite of metals, with the exception of tin, which was not sampled by proponents under Type A water license requirements. Some government-led monitoring is intended to address specific concerns, such as impacts of wildfire on water quality.

This may explain the array of phenols, polychlorinated biphenyls, pesticides and herbicides that were monitored by government programs and not monitored by proponents.

Table 4.6 Physical parameters identified in 50% of more of Type A water licenses, and in government-led and government-supported community monitoring programs.

Monitoring Program	**Physical Parameters**										
	Depth	% Dissolved Oxygen Saturation	Dissolved Oxygen	Specific Conductivity	Temperature	Total Dissolved Solids	Turbidity	pH	Clay - Soil Texture	Sand - Soil Texture	Silt - Soil Texture
Proponent											
Type A water licenses		✓	✓	✓	✓	✓	✓	✓			
Government											
Major Monitoring Networks	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Government-supported (Community-based)											
Grab					✓	✓		✓			
Sonde	✓	✓	✓	✓	✓		✓	✓			
DGT											
PMD											

Table 4.7 Chemical parameters identified in 50% of more of the Type A water licenses, and in government-led and government-supported community monitoring programs.

Monitoring Program	**Chemical Parameters**																									
	Total Suspended Solids	Oxidation/Reduction Potential	Dissolved Organic Carbon	Total Organic Carbon	Dissolved Nitrogen	Nitrate	Nitrate/Nitrite	Nitrite	Total Ammonia	Total Nitrogen	Dissolved Phosphorus	Total Phosphorus	Orthophosphate	Chlorophyll a	Calcium	Chloride	Fluoride	Hardness	Magnesium	Potassium	Reactive Silica	Sodium	Sulphate	Total Alkalinity	Metals	Polycyclic Aromatic Hydrocarbons
Proponent	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Government																										
Major Monitoring Networks			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Government-Supported (Community-based)																										
Grab	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
Sonde		✓												✓												
DGT																									✓	
PMD																										✓

4.2 Compatibility

Consistency provides a simplified view of the presence or absence of water quality parameters monitored; it does not indicate whether the *approach* to monitoring is consistent and, consequently, whether monitoring data are compatible. Monitoring data among proponents and monitoring data across proponent and government programs must be consistent *and* compatible if they are to support cumulative effects understanding. However, results indicate that government-led, government-supported community monitoring, and proponent-based (water license) monitoring shared many of the same parameters, but proponent-based monitoring was more diverse and more frequent than government monitoring programs. Interviewees explained that the diversity in project types, site specific issues (effects, water chemistry, etc.), the local nature of the receiving environment, and thus different monitoring needs (e.g. methods, timing, etc.) ultimately limits the compatibility of monitoring data.

In the sample of Type A water licenses, for example, mine or mine remediation projects often monitored the most parameters, monitored under more specific conditions (i.e. monitoring after a heavy rainfall), and monitored at multiple frequencies at the same monitoring station. DeBeers Canada Inc.'s Snap Lake project monitored for 63% of the 86 parameters identified in the water licenses reviewed, and Fortune Minerals Inc. sampled 60% of them. On average, municipal projects sampled for the next highest number of parameters, followed by the geothermal, oil and gas, dam construction and hydroelectric projects. One of the hydroelectric project water licenses reviewed monitored for only 1% of the 86 parameters identified in the review. For projects that were undertaking the same activity on the same waterbody, there were still some differences in the parameters monitored and the frequency of monitoring. Even for the same project, there was a wide range of monitoring frequencies; monitoring could be specified based on frequency (e.g. hourly, every three months, every two years), and under specific conditions (e.g. daily during discharge, before and after ice over, after a storm event (Table 4.8). Certain parameters were measured every week, while other parameters were measured every month. Also, the timing of monitoring was specified for some parameters, but the timing was left open to interpretation. For instance, one water license asked for a sample of parameters once a year in the late summer, but did not specify the months that constituted summer. Similarly, some of the timing of the monitoring would be variable depending on a particular year. Water licenses asked for samples of parameters before ice over, which can be highly variable from year to year.

The frequency of monitoring varied also within and between government-led monitoring networks and government-supported community programs – from almost daily during certain months, but annually at other times. Because of the variability of government-led and government-supported community monitoring, it was difficult to discern whether the monitoring was specific to certain times, such as monitoring during the open water season. The differences in monitoring frequency between proponent-based water licensing and government-led monitoring programs also made it difficult to directly compare them. Government-supported monitoring data available on the Mackenzie DataStream also ranged from one to four years in length, which is relatively short-term and may not coincide temporally with proponent-based monitoring. Temporal mismatches with government-led data may have been less of a problem since it was typically longer-term and would likely coincide with proponent-based monitoring.

The nature of the receiving environment also appeared to impact the parameters monitored in the Type A water licenses. It was not surprising that monitoring parameters differed to some degree depending on the monitoring environment, since different effluents are being discharged. Receiving environments varied from natural ponds and waterways to artificial landfill ponds and sewage facilities; there was roughly the same number of monitoring stations in natural environments as artificial environments. Physical parameters, such as pH, conductivity and TSS, as well as major ions, nutrients and metals, were sampled in more artificial receiving environments than natural ones. Overall, biological parameters were also sampled more frequently in artificial receiving environments than natural environments. However, natural receiving environments were sampled for Microcystin-LR, *Pseudokirchneriella subcapitata* and *Cryptosporidium,* which artificial environments were not sampled for or sampled less frequently for. Government-led and government-supported community monitoring were typically associated with natural waterbodies, focused on baseline water quality conditions. This contrasted proponent-based monitoring under water licenses, which typically monitored discharge and water quality in both natural and artificial receiving environments.

Table 4.8 Water quality parameters monitored in 50% or more (shaded cells) of all monitoring stations, from an illustrative sample of two Type A water licenses, showing monitoring frequency and occurrence.

		Dissolved Inorganic/Organic Phosphorus	Water Temperature	Major Ions	Calcium	Sodium	Total Mercury	Total alkalinity	Potassium	Magnesium	Nitrate and nitrite	Chloride	TDS	Total copper	Hardness	ICP-MS metal scan	Ammonia nitrogen	Total arsenic	Conductivity	Sulphate	TSS	pH
North American Tungsten Corporation Ltd.	Mining and milling																					
SNP station 4-1	Flat River																					
SNP station 4-5	Flat River							M			M[1]	M	M	M	M	M	M	M		M	M	M
SNP station 4-6	Wastewater treatment facility inflow	M[2]						M			M[1]	M	M	M	M	M	M	M		M	M	M
SNP station 4-20	Drainage culvert							M			BW[1]	BW	BW		M		BW			M	BW	BW
SNP station 4-27-4	Groundwater monitoring well							Other			Other[1]		Other	Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-7	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-8	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-9	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-10	TP4-07-MW01							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-11	TP5-07-MW01							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-12	TP3-07-MW01							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-13	TP3-07-MW02							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-14	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-15	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-16	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-17	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-18	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-19	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-20	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-21	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-22	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-27-23	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-28-1	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-28-2	Groundwater monitoring well							Other			Other[1]			Other	Other	Other	Other	Other		Other	Other	Other
SNP station 4-29	Flat River							M			Other[1]	M	M	M	M	M	M	M		M	M	M
SNP station 4-30	Mill tailings							M			Other[1]		M	M		M	M	M		M		
SNP station 4-32	Sardine Creek							M				M	M	M	M	M	M	M		M	M	M
SNP station 4-33	Flat River							M			M[1]	M	M	M	M	M	M	M		M		M
SNP station 4-33R	Flat River							M			M[1]	M	M	M	M	M	M	M		M		M
SNP station 4-34	Seepage from fuel berm							M			M[1]	M	M	M	M	M	M	M		M	M	M
SNP station 4-36	Tailings Pond 3							M			M[1]	M	M	M	M	M	M	M		M	M	M
SNP station 4-37	Tailings Pond 4							M			M[1]	M	M	M	M	M	M	M		M	M	M
SNP station 4-38	Tailings Pond 1							M			M[1]	M	M	M	M	M	M	M		M	M	M
SNP station4-39	Tailings Pond 2							M			M[1]	M	M	M	M	M	M	M		M	M	M
SNP station 4-40	Flat River							M			M[1]	M	M	M	M	M	M	M		M	M	M
SNP station 4-41	Flat River							M			M[1]	M	M	M	M	M	M	M		M	M	M
SNP station 4-42	Mine water sampling							M			M[1]	M	M	M	M	M	M	M		M		M
SNP station 4-43	Wastewater treatment facility outflow	W[2]						W			M[1]	W	W	W	W	W	W	W		W	W	W
SNP station 4-44	Flat River							W, M			W, M[1]	W, M	W, M	W, M	W, M	W, M	W, M	W, M		W, M	W, M	W, M
SNP station 4-45	Middle Bridge																					
SNP station 4-46	Thickener overflow																				M	
SNP station 4-47	Tailings storage facility 7							W-Di			W-Di[1]	W-Di	W-Di	W-Di	W-Di	W-Di		W-Di		W-Di	W-Di	W-Di
SNP station 4-48	Tailings storage facility 6							W-Di			W-Di[1]	W-Di	W-Di	W-Di	W-Di	W-Di		W-Di		W-Di	W-Di	W-Di
SNP station 4-49	Flat River							M			M[1]	M	M	M	M	M	M	M		M	M	M
SNP station 4-50	Flat River							M			M[1]	M	M	M	M	M	M	M		M	M	M

[1]Nitrogen; [2]Total; [3]Open water

Table Legend

Monitoring Frequency:
W – Weekly
BW – Biweekly
Q – Quarterly
M – Monthly
Other – June, August, October only
B – Biannually
A – Annually
T – Once prior to dewatering/prior to discharge, once on final day of dewatering/discharge period

Occurrence-based Monitoring:
R – Rainfall
Di – Discharge
Fr – Freshet
W-Di – Weekly during discharge
M-Di – Monthly during discharge
B-Fr – Biannually during freshet

Table 4.8 Water quality monitoring parameters monitored in 50% or more of all monitoring stations in a sample of two Type A water licenses, showing frequency and occurrence (continued).

Project	Monitoring Environment	Monitoring Parameters																				
		Dissolved Inorganic/Organic Phosphorus	Water Temperature	Major Ions	Calcium	Sodium	Total Mercury	Total alkalinity	Potassium	Magnesium	Nitrate and nitrite	Chloride	TDS	Total copper	Hardness	ICP-MS metal scan	Ammonia nitrogen	Total arsenic	Conductivity	Sulphate	TSS	pH
Department of Indian and Northern Affairs	Gold Mine Remediation																					
SNP station 1563-1	Steeves Lake		M																M			M
SNP station 1563-2	Outlet from Steeves Lake		Q	Q		Q	Q		Q	Q			Q		Q	Q		Q	Q	Q	Q	Q
SNP station 1563-4	Steeves Lake to Truck Lake		M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]		M[3]	M[3]		M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]
SNP station 1563-5	Tailings	M[2]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]		M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]
SNP station 1563-10	Fuscum Lake before and after discharge	T	T	T		T	T		T	T	T		T		T	T	T	T	T	T	T	T
SNP station 1563-11	Sewage disposal facility		W-Di										W-Di				W-Di		W-Di		W-Di	W-Di
SNP station 1563-12	Cone Pond	BW, M	BW, M	BW, M	BW, M	BW, M	BW, M	BW, M	BW, M	BW, M	BW, M	BW, M	BW, M		BW, M	BW, M	BW, M	BW, M	BW, M	BW, M	BW, M	BW, M
SNP station 1563-13	Tailings	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]		M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]
SNP station 1563-14	North Pond	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]		M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]
SNP station 1563-15	Waste rock runoff		B-Fr, R	B-Fr, R	B-Fr, R	B-Fr, R	B-Fr, R	B-Fr, R	B-Fr, R	B-Fr, R	B-Fr, R	B-Fr, R	B-Fr, R		B-Fr, R	B-Fr, R	B-Fr, R	B-Fr, R		B-Fr, R	B-Fr, R	B-Fr, R
SNP station 1563-20	Steeves Lake																					
SNP station 1563-21	Area - fuel tank and lake																					
SNP station 1563-23	Truck Lake		A	A	A	A	A	A	A	A	A	A	A		A	A	A	A	A	A	A	A
SNP station 1563-24	Tailings Lake	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-25	Supernatant Discharge	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di		W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di
SNP station 1563-26	Zone 2.0 Pit	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-27	Dyke Lake		M[3]		M[3]		M[3]	M[3]			M[3]	M[3]	M[3]			M[3]	M[3]	M[3]	M[3]		M[3]	M[3]
SNP station 1563-29	Baton Lake		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-30	Spot Lake		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-31	Paddle Lake	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-32	Lake 315	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-33	Spanner Lake	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-34	Natural depression		W-Fr										W-Fr				W-Fr[3]		W-Fr		W-Fr	W-Fr
SNP station 1563-35	Heart Lake	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-36	Indin River east of Colomac	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-37	Indin Lake, 3 km south of Leta Arm	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-38	Dragon Lake	A[2]	A	A	A	A	A	A	A	A	A	A	A		A	A	A	A	A	A	A	A
SNP station 1563-39	Tailings Lake surface	M-Di[2]	M-Di	M-Di	M-Di	M-Di	M-Di	M-Di	M-Di	M-Di	M-Di	M-Di	M-Di		M-Di	M-Di	M-Di	M-Di	M-Di	M-Di	M-Di	M-Di
SNP station 1563-40	L-shaped Lake	W-Di[2]	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di		W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di
SNP station 1563-41	Outlet of L-shaped Lake	W-Di[2]	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di		W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di	W-Di
SNP station 1563-42	Steeves Lake		M[3]																M[3]			M[3]
SNP station 1563-43	Tailings Lake North	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-44	Outfall of dyke 7 into Tailings Lake	M[2,3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]		M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]	M[3]
SNP station 1563-45	Natural depression		W-Fr										W-Fr				W-Fr		W-Fr		W-Fr	W-Fr
SNP station 1563-46	L1 lake sample	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-47	L2 lake sample	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-48	L3 lake sample	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-49	L4 lake sample	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-50	W1 monitoring well	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-51	W2 monitoring well	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-52	W3 monitoring well	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q
SNP station 1563-53	W4 monitoring well	Q[2]	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q

[1]Nitrogen; [2]Total; [3]Open water

Table Legend

Monitoring Frequency:
W – Weekly
BW – Biweekly
Q – Quarterly
M – Monthly
Other – June, August, October

B – Biannually
A – Annually
T – Once prior to dewatering/prior to discharge, once on final day of dewatering/discharge period

Occurrence-based Monitoring:
R – Rainfall
Di – Discharge
Fr – Freshet
W-Di – Weekly during discharge
M-Di – Monthly during discharge
B-Fr – Biannually during freshet

Interviewees also cited detection limits as a potential source of incompatibility, noting that detection limits are not standardized for monitoring conducted by project proponents and governments and have changed over the years. Detection limits have become much lower with time, but one government interviewee expressed concern over detection limits that remained too high to detect change, particularly in a relatively pristine environment like the NWT. One independent mine oversight board interviewee observed that even when detection limits were consistent, the representation of values below the detection limit can introduce a source of incompatibility (e.g. representing the value as half the detection limit or representing the value as the detection limit itself). While many interviewees expressed that detection limits hindered compatibility, one government participant believed that bringing detection limits in line would be a challenge, noting that it's not likely possible to prescribe that the labs used by proponents meet certain detection limits; thus there will always be incompatibilities between proponent-based and government monitoring.

A final issue concerning compatibility was the lack of metadata or standards for reporting metadata – describing where and how data was collected, what types of quality assurance/control were performed, the analytical techniques, and any other information that would help a user decide if the data was suitable for their purposes. Participants noted that since speaking with the field technician who collected the data is not always a feasible option, incomplete metadata can adversely impact the confidence that a user has in a dataset about its compatibility.

4.3 Observability

Interviewees were cognizant of the crucial role that baseline monitoring plays in being able to observe a departure from baseline conditions. Participants offered parameters that would be helpful to track baseline change in space and over time. Nonetheless, they appeared to be conflicted about the level of science – both the length of time and accepted practices – required for baseline water quality monitoring. Interviewees suggested that baseline guidance would be helpful to ensuring that the collection of baseline data and the characterization of baseline conditions are consistent. While participants agreed that earlier baseline monitoring would be helpful to gain a better understanding of the natural environment, it would not likely be feasible because of the uncertainty of a project's viability.

Physical parameters, such as pH and turbidity; major ions, such as total dissolved solids and chloride; nutrients, such as phosphorus and nitrogen compounds; and metals, such as arsenic and mercury, were identified by participants as general categories of parameters that would be helpful to track baseline change over time and space. When participants suggested specific parameters within these general categories that would be helpful to track baseline change, TSS, temperature, conductivity, and hardness were the most commonly mentioned. Half of the participants felt that the most useful parameters to detect water quality change was dependent on project type. For instance, diamond mines would sample chloride, while gold mines would sample arsenic.

Most participants identified the standard length of time for baseline monitoring to be 2-3 years as sufficient for observing change, with 3 years being favoured by some. Proponents and some consultants felt that the current standard of baseline monitoring was a sufficient amount of time to reasonably characterize baseline and to understand natural variability of a water system. However, participants indicated that the length of baseline monitoring is restricted because the viability of a project, specifically for mining or energy developments, generally rests heavily on being able to process product relatively quickly as the impetus of industry is to generate profit. Non-proponent participants were acutely aware of the importance of reasonable timelines to conduct baseline water quality monitoring, particularly because water quality monitoring in the North is expensive.

A proponent argued the need to strike a balance between academic wants for science, and realistic requirements for monitoring under water licenses. Still, several interviewees expressed uncertainty that current monitoring provides an accurate picture of the system. One consultant expressed concern this way: ‘The problem with going out two years before an EA or when the EA is beginning is that you don’t have any idea if there are any long-term temporal trends and if you’re catching a system in an upswing or downswing.’ This highlights the imperfect nature of baseline monitoring and the crucial challenge to capture the system in a representative state. Some interviewees also mentioned the complications that climate change can create for observing baseline conditions. The divergent opinions of interviewees about the level of science required for baseline monitoring calls into question the length of monitoring that is both realistic and capable of detecting a departure from normal range of variability.

Accepted practices for baseline water quality monitoring did not seem to be clearly established. Interviewees from independent mine oversight boards were highly attuned to the importance of robust baseline monitoring to be able to observe whether projects are having an effect on the environment. Nonetheless, a practitioner recalled a case in which the proponent had one year of baseline data and was attempting to augment it with post-baseline data. The consultant asserted: 'Obviously, just by definition alone, you can't do that…all of this could have been avoided by having clear baseline data requirements before going through an EA.' Evidently, the opportunity to collect baseline data after the project has commenced is lost. One independent mine oversight board participant proffered an instance where baseline data were inadequate and the proponent needed to 'extrapolate backwards' in an attempt to characterize the baseline. Proponents collect monitoring data in advance of the environmental assessment process, but some interviewees believed that the current approach is not deliberate enough. Other interviewees thought there was a lack of baseline monitoring guidance from government in terms of parameters, as well as the length, timing and frequency of monitoring for adequately observing baseline conditions.

Most interviewees agreed in principle that earlier baseline monitoring would be a good idea, but that it would be an unrealistic requirement. Proponents recognized the value of long-term data; however, the nature of resource development projects in the NWT, and mining projects in particular, preclude earlier baseline monitoring because of financial considerations. A consultant characterized the predicament of earlier baseline monitoring this way: 'They [proponents] recognize the value of it and they recognize that it saves them money in the future, but they're also okay with spending more in the future than spending now.' Interviewees across affiliations stated that proponents must be certain of a project's viability before they begin baseline monitoring. They reported that when proponents were confident that a project is viable, they started to collect baseline monitoring knowing that they will need 2-3 years of data in advance of the environmental assessment process.

4.4 Detectability

Parameters and data that help identify the early detection of baseline change are necessary to support the assessment of cumulative effects. Participants were able to offer parameters that would support the early detection of baseline change, but warned that they may not be able to detect all types of change. The concept of detectability of effects is closely related to the observability of baseline change. Consequently, participants identifying ‘detectability’ parameters that would provide early warning of effects also suggested the same parameters for the tracking of baseline change. Participants believed that physical parameters, major ions, nutrients and metals were suitable parameters to support detection of cumulative effects since they are inexpensive and relatively easy to collect. Interviewees felt that these groups of parameters would be valuable for signaling a perturbation to a waterbody, which would then trigger closer examination of other parameters; still, these parameters would not always be able to pinpoint specific issues.

Among participants who suggested that there were parameters that were most useful in terms of detecting change, they again cited physical parameters, major ions, nutrients and metals. Participants specifically listed TSS, temperature, conductivity and hardness as parameters that were useful to track baseline change *and* provide early detection of risk. Some participants also added TDS as another parameter that would support the detectability of effects. Half of the participants also suggested that the most useful parameters to provide an early warning of risk were dependent on the project. Participants agreed that both change detection and early warning parameters were essential to assessing cumulative effects. One consultant stressed that since ‘cumulative effects are predicated upon individual effects’, it is first necessary to be able to detect a departure from baseline conditions or to identify an early warning of risk.

Many participants noted that while there were parameters that could help detect change or provide early warning of risk, it can be difficult to pinpoint the ‘right’ parameters to monitor. Participants shared experiences where substances that were never on the radar of regulators or proponents became a concern. Contaminants from atmospheric deposition, such as dioxins and furans, were detected by some proponents though it was not a part of their monitoring requirements. Requiring proponents to monitor for parameters that they were not discharging seemed to be a source of friction. From a cumulative effects perspective, atmospheric pollutants can combine with project effluents, but some participants considered these pollutants to be outside their control and responsibility. An interviewee from an independent mine oversight board confirmed hesitancy among proponents to monitor parameters that are not linked to their project. According to one proponent, however, sampling for potential pollutants that may interact with project effluents was necessary to understand and predict the types of cumulative effects that may occur. Interviewees stated that there also may be contaminants of potential concern in certain waterbodies or areas that would be important to monitor. Some participants thus warned that though having the ‘right’ parameters is important to being able to detect cumulative change, other considerations such as compatible collection and analytical methods, and ensuring broad geographic coverage, were equally or more important for change detection as adopting a common suite of parameters. Greater consistency in baseline characterization and wider coverage of monitoring networks were thus identified as other important considerations to aid the early detection of baseline change.

Participants also suggested that detecting when an effect has occurred was a challenge because of the difference between statistically significant and ecologically relevant trend assessments. Many interviewees made a clear distinction between ecologically relevant and statistically significant thresholds in water quality data. Interviewees explained that the understanding of trend assessments remained incomplete if the trends were not translated into real world impacts on the environment. A consultant mentioned that modern monitoring equipment and techniques ‘leapfrog over whether there’s a biological effect or not.’ Another consultant supported this idea and said, ‘You’re left shrugging your shoulders saying statistics told us some things that are useful, they may or may not be environmentally relevant’, but then added, ‘You may have a good gut sense that things are changing, but it’s not showing up [statistically].’ One proponent felt that water quality data is incapable of providing a true representation of a waterbody since biomagnifying material may only be seen in something like fish tissue. They elaborated on this by saying that: ‘You can’t assess it [cumulative effects] looking at water quality really, because the concentrations may not be changing at all, but you may be seeing the effects of bioaccumulation.’ Participants suggested that determining when a threshold was met was frequently uncertain since trend assessments often fall into a purgatory between an ecologically relevant and statistically significant.

4.5 Adaptability

Overall, interviewees indicated that the current spatial and temporal scales and intensity of government and proponent-based monitoring restricted their adaptability. Participants were able to identify parameters that were adaptable across different development types and scales, but noted that these parameters have not always been consistently monitored. Proponent-based monitoring was said to permit more specialized parameters to be collected, and permit basic parameters (i.e. some combination of physical parameters, major ions, nutrients and metals) to be collected more frequently. Some interviewees believed that government monitoring had limited capacity for adaptation, since it was not always rigorous enough for the purposes of proponents.

Physical parameters, major ions, nutrients and metals were also the most adaptable across different project types, as some combination of them was being monitored in the majority of proponent and government sites. Some interviewees also cited basic meteorology data, such as temperature, precipitation and ambient wind, as adaptable because it is able to provide a better understanding of the conditions in which monitoring occurred. Interviewees stated that wet or dry seasons can result in high or low parameter concentrations and help explain unusual fluctuations in baseline conditions. Some interviewees stated that there were parameters that would be adaptable depending on the project type.

The current temporal and spatial scales of government and proponent-based monitoring programs seem to prevent data from being adapted to other uses. Some participants stated that proponent-based monitoring efforts were mostly shorter and more intense, while government-led monitoring efforts were longer term and further apart. Project-specific monitoring is intended to identify project effects on the environment while more regional, government monitoring is intended to identify large-scale change. Some consultants and a government participant acknowledged that government monitoring was usually limited to detecting the 'grossest change'. Interviewees stressed that proponents were required to detect change at finer scales, limiting the use of government data for project assessments. A consultant described the spatial scale of proponent-based monitoring as 'very small, localized areas and…very different from the watershed scale…By the time you get into the larger watershed…there's been so much dilution [it] can muffle the change you can detect.' The fine resolution of proponent data was described as needed and valuable for detecting project-specific effects, but inherently limited its adaptability and application to support the assessment of regional trends and cumulative effects.

The varying intensities of the two primary types of monitoring was another area that was said to limit adaptability. A few participants commented that the shorter and more frequent nature of proponent-based monitoring lent itself to a wider examination of specialized parameters, such as benthic organisms or fish tissue. One consultant put it this way: 'You need specific [proponent] programs to do the water quality programs because mercury in water isn't particularly useful as a parameter…Water quality effects don't necessarily cover the same spatial extent as impacts on particular fish species.' Some participants felt that *only* the proponent would be able to conduct the monitoring necessary to fulfill water license requirements and identify project-specific effects. While proponents could use basic data collected by government, a consultant explained the challenge is that government 'can collect a lot of information about a waterbody and make qualitative statements, but when it comes to testing hypotheses and defending the conclusions rigorously, those monitoring programs often fail.' A proponent supported this perspective, reporting that government sampling was not frequent enough to make broad inferences about a waterbody. This may explain the hesitancy among proponents to adapt government data for their own use, which may not be rigorous enough for the assessment needs of proponents.

4.6 Accessibility

Participants described data collected by government agencies and project proponents as relatively inaccessible – but for different reasons. Many interviewees were unfamiliar with accessing or using data collected through government-led monitoring programs. Interviewees that were familiar with government-led monitoring data said that it was difficult to find the data or that limited data were available on the Mackenzie DataStream or the Discovery Portal, which house community-based and government-supported datasets, respectively. There was broad consensus that it was difficult to know the types and locations of monitoring conducted by government and to determine what monitoring data existed. A government participant commented that they might need to improve information dissemination and ensure that people know that the government data exist. A proponent relayed an interesting instance where they were seeking data for a project that had gone under the care and maintenance of the federal government to try to understand the potential cumulative impacts with their project. The proponent stated that the government would not provide the data. Some government participants believed that proponents were responsible for assessing cumulative effects; yet, in this case, a government agency was unwilling or unable to provide proponents with data that would support the assessment of cumulative effects. Another consultant noted that ‘sometimes they [government agencies] collect the data and they’re doing good work or reports and you try to get the reports, but they can’t release the reports because one branch of government isn’t happy with what it says.’ The inaccessibility of government data was a source of frustration for one proponent that remarked that there was an expectation for proponent data to be open, accessible and quality assured even though government data could be both difficult to find and access.

With the exception of proponents, all interviewees reported that monitoring data collected by proponents for EA and under water license requirements was generally not accessible or usable. Proponents are required to make the data that they collect under water license agreements available on the appropriate land and water board website. However, the most common data format was a PDF, which made the data difficult to use and manipulate. Interviewees highlighted that data in PDF file format required excessive time and effort to transfer into a spreadsheet format and were prone to transcription error. Interviewees emphasized a need for proponent data to be made accessible in practice – not simply ‘in theory.’ Since proponents likely store their data in a spreadsheet or database, participants believed that it would not be onerous to request that the data be made available in a spreadsheet format. A few participants stated a reliance on the goodwill of proponents to make data available for another project’s assessments. Proponents, however did not find their data to be inaccessible even though it was provided in PDF file format. Proponents and some consultants stated that accessing the data would be as simple as searching for it on the land and water board website.

It seemed that a primary motivation of proponents to present the data in PDFs was to minimize the potential for misuse of their data. Proponents fulfilled their obligations by providing data on the land and water board site in PDF file format to ensure that it remained in a relatively static format. A government participant suggested that proponents were hesitant to provide their data in a usable, accessible format because ‘they’re losing control of their data and what the analysis is. They want to control the narrative and what’s being said about it. They don’t want the data to be used against them.’ This concern was echoed by an independent mine oversight board participant who stated that proponents do not want others to come to conclusions about their data other than the ones initially identified by the proponents themselves. However, the participant also said that other conclusions should be examined, and that is one of the purposes of independent mine oversight boards, adding that that proponent data should be used ‘whenever, however’.

Other participants felt that if outside data users came to negative conclusions about proponent data, proponents believed that it could impact their project’s operations and how effluents are managed. Conversely, proponents offered an alternative explanation for keeping their data in PDFs. They stated that they were concerned that data could be misinterpreted without solid understanding of the project’s context. One proponent clarified this position when they said: ‘If someone says there’s been a thousand-time increase in cesium levels and meanwhile, you’re at one-tenth of the water quality guidelines, does it matter?’ It draws attention to the issue voiced by another proponent who stressed the ‘reputational aspect and cost’ associated with statements made about projects that were not fully understood. Proponents were quick to point out that it is much easier to make damaging statements about a project than it is to attempt to undo the damage.

Most participants agreed that project monitoring data should be open and accessible to other project proponents and to the GNWT. Proponents also agreed, but tended to believe that their data were already open and accessible. Some interviewees suggested that the greatest obstacles to having open and accessible data would be getting proponents to support such a requirement and having the resources to maintain a database. Convincing proponents that the data would be useful to proponents seemed foremost on the minds of government interviewees. One government participant noted a previous attempt to have land and water boards require that proponent data be open and accessible. According to this interviewee, the proposition was met with skepticism from both the land and water boards and proponents. Land and water boards did not want to impose requirements that would upset proponents while proponents that were consulted were not interested in using other proponents’ data. Another government participant corroborated this sentiment when they said that proponents were more comfortable and confident in using their own data. Interviewees suggested that while open and accessible data would have varying degrees of utility for consultants and proponents, it would help strengthen the regulatory process in the Mackenzie Valley overall if properly carried out.

Interviewees were typically strongly opposed to incentives to make project monitoring data open and accessible, reiterating that if open and accessible data is a goal of the regulatory process then it should simply be made a requirement. One consultant suggested that incentives may be appropriate if proponents were willing to conduct expanded monitoring – either through increased sampling frequency or sampling locations – that would be useful for assessing cumulative effects. Most interviewees were strongly opposed to financial incentives, but believed social license incentives were appropriate. Proponents thought both financial or social license incentives that encouraged open and accessible data were suitable.

Interviewees also suggested that a central repository of water quality monitoring data collected in the NWT would be helpful. Participants were aware of the Mackenzie DataStream and the Discovery Portal, but only a few datasets were available. Government participants noted an intention to eventually have all monitoring data collected by ENR available on the DataStream, with monitoring data collected by proponents on the respective land and water board websites. Consultants as well as government and land and water board representatives favoured a central repository for all data that could be easily accessed. This would allow proponents to more easily access data from previous projects instead of having every proponent start baseline characterization from square one. Participants that recommended a central repository did not specify a party that should be responsible for funding or maintaining this repository, or which parties would have access to the repository. However, one government participant noted that proponents may be more willing to share their data on a central repository if access was restricted to certain parties. Based on the lukewarm response of proponents to open and accessible monitoring data, it was hardly surprising that a central repository of data was not identified as important.

4.7 Usability

Interviewees generally reported that both government and proponent data were of limited use to support the assessment of cumulative effects. They were clear that the primary challenge associated with proponents using government data, or government using proponent data, was that they have fundamentally different purposes and interests. As one independent mine oversight board participant summarized: ‘There are different purposes, one [proponent] is just to monitor, to not spend money where they don’t have to and to not find issues… The other [government] perspective is to see what’s happening, compare it to other areas and to do more land use planning to see how many mines could be supported in an area.’

A review board participant suggested that the land and water boards needed to balance the tensions of monitoring for project-specific concerns with a basic standard suite of data that is consistent with other proponent data to support cumulative effects. Thus far, the participant explained, land and water boards have largely reinforced the narrow monitoring interests of proponents. A consultant seconded this thought, reporting: ‘that’s a result of regulatory agencies that delve into detailed questions. The bigger picture of cumulative effects tends to get lost.’

According to interviewees, government data has typically been ineffective at supporting proponents to assess for cumulative effects. There seemed to be a number of barriers, including: the data were not available, accessible, or consistent with proponent data. The data were said to not be available because government monitoring networks were focused in certain watersheds and rarely intersected with projects. Others simply reported that proponents preferred to collect and use their own data since they could be confident in its collection methods while eliminating the need to ensure that outside data was compatible with their own. Some government interviewees said they hoped that government data would be useful to proponents, but conceded that it likely wasn’t useful due to the limited network of government monitoring data. On the occasions where proponents did seek government data, they often used it to fill in gaps in baseline monitoring and for a better understanding of natural variability, but not to support the assessment of cumulative effects. To ensure greater usability of government data, several interviewees thought it was important for government agencies to strategically monitor in areas in which development is likely to occur.

Though government and proponent-based monitoring infrequently overlap, some government participants noted the reluctance of government agencies to monitor, or continue monitoring, in the same area as proponents. Government agencies were motivated to monitor in the same watershed area as proponents to compare water chemistry results with proponents’ results or simply because it was a significant waterbody in the NWT. Some government interviewees stated that proponents have tried, or would try to, avoid their monitoring obligations knowing that it was being conducted by a government agency nearby. They felt that proponents should still be required to monitor to fulfill their water license obligations.

The use of proponent data by government to support cumulative effects in the Mackenzie Valley has been limited for the simple reason that proponent-based monitoring programs were never designed for that purpose. Despite affiliation, participants were explicit in stating that the purpose of proponent-based monitoring was to determine whether a project is having an effect. An independent mine oversight board participant described the mindset of some proponents with: 'It [Cause and effect of their project]'s not some altruistic thing that they really want to know… They [Proponents] essentially want to know 'no, we're not having an impact.'' Another independent mine oversight board participant went further and summarized that, 'setting it up for the purpose of monitoring the specific effect of that project is not necessarily going to set it up best for looking at what the cumulative effects of that project are with other projects, unless you're basically measuring everything.' One proponent noted that even the most comprehensive monitoring programs for the large diamond mine projects were not designed to, nor capable of, identifying stressors or determining cause-effect relationships.

That said, several participants also identified the need for buy-in from proponents and land and water boards to improve usability of proponent data to support cumulative effects assessments. It appeared that a common vision for cumulative effects was lacking, resulting in monitoring programs being conducted in isolation. A government participant called for a common vision for cumulative effects to improve data usability without 'finger-pointing' or proponents claiming, 'you're contributing too much or I should be doing as much as you.'

Non-proponent participants mentioned a fear of cumulative effects among proponents due to the potential implications for their project. A consultant described this sentiment with: 'When you start to find cumulative effects, what does that say about how you need to manage your individual project? That means you have to ratchet your discharges and nobody wants that.'

An independent mine oversight board participant confirmed this sentiment and thought that 'part of it would be trying to get rid of their [proponents'] fear of that term [cumulative effects].' Participants stressed a need for a common vision for cumulative effects that would create an amenable environment for proponents and government to work collectively to ensure greater data usability.

However, participants cautioned that ‘slapping requirements’ onto proponents would not be the best method to get proponents to support cumulative effects monitoring. One independent mine oversight board participant further highlighted the challenge of linking projects to impacts on the environment, which contributed to an unwillingness to support cumulative effects. Participants felt that proponents need to be convinced of the utility of monitoring efforts to support cumulative effects for the interests of their project and for the broader protection of the environment. A government participant noted that buy-in from the land and water boards is also crucial, because they have not seemed to incorporate the possibility for cumulative effects into the majority of water license requirements. The relationship between the land and water boards and proponents in the eyes of a government participant was embodied by: ‘We [Land and water boards] don’t want to upset industry by asking them to do any more than we already ask them to do.’

The quality control (QC) of data is an essential factor in determining whether it is usable in analysis. Non-government participants were asked to comment on whether government data were usable with minimal time and effort devoted to quality control (QC). Because most participants were unfamiliar with using government-led monitoring data, they did not encounter issues with QC. One participant stated that very little QC was necessary since the amount of government data was so limited. The few participants that had used government monitoring data found that there were no major issues with QC, but had to conduct their own QC simply due to the fact that they were unfamiliar with the data.

Non-proponent participants were also asked to comment on whether proponent data was usable with minimal time and effort devoted to QC. The government participants tended to believe that proponent data needed significant amounts of time dedicated to QC. One participant went further and said that the data were ‘absolutely not’ usable with minimal time and effort devoted to QC, while another alluded to instances in which nearly as much time was spent on QC as data analysis. Yet another government participant seemed frustrated to note that QC issues were evident even in the monitoring conducted for larger projects. However, it seemed that participants were referring to specific proponents whose data needed more QC as opposed to a wholesale need for proponent data to require unnecessary time devoted to QC.

4.8 Cross-cutting issues

Several cross-cutting issues also emerged from interview results, that ultimately, supersede the seven attributes for cumulative effects monitoring data. This included the lack common understanding of cumulative effects, unclear responsibility for cumulative effects, the degree of participation required from stakeholders in assessing cumulative effects, and the types of cumulative effects that can currently be assessed. First, results suggest that a narrow definition of cumulative effects as including only anthropogenic stressors, or more specifically the interaction of two projects, was more prevalent among interviewees than a definition that included natural stressors or the interaction of other land uses. For example, participants noted that the opportunity for cumulative effects was limited in the NWT because few projects are located in the same watershed. Only one participant mentioned the potential cumulative impacts from natural events (e.g. fires), while a few noted long-range atmospheric deposition as a potential source of contaminants. The idea of cumulative effects in time seemed to be secondary to cumulative effects in space, though the former is equally important to understanding and managing cumulative effects. One participant suggested that it was necessary to have a more common understanding of cumulative effects across the NWT; specifically, to have explicit examples of cumulative effects that would enable understanding.

Interviewees from all affiliations expressed uncertainty over the responsibility to lead cumulative effects monitoring and assessments in the NWT. Of those participants who volunteered a responsible organization, almost all referred to an agency or organization different than their own. The land and water boards alluded to government as responsible; however, one government participant reported that government did not have the capacity to assess for cumulative effects for all projects in the NWT. Other government participants held that proponents should ultimately be responsible. However, most proponents tended to absolve themselves of responsibility for cumulative effects; others believed that proponents were only responsible for their ‘contribution’ to cumulative effects. According to interviewees, there appears to be an unwillingness of some proponents, but also an inability of others, to assess for cumulative effects. One consultant explained that proponents were hesitant about cumulative effects; from the proponent's perspective, their project is not having an impact on the environment and thus not contributing to cumulative impacts. The prevailing sentiment of proponents was characterized by one consultant with: 'We're not out here to look for cumulative impacts, we're here to manage our own impacts, which I think is a bit self-serving. Because at some point, if there is a cumulative impact, they [proponents]'ll be contributing to it.'

An area of some agreement among proponents and consultants was that a government agency, either ENR or CIMP, should probably be responsible for assessing cumulative effects. One consultant believed that 'government has the best purview to look at cumulative effects because they're looking across the territory and they have the ability to work on it top down.' Overall, participants stressed a necessity to designate a party that would lead the process, which one consultant suggested would require an update to the MVRMA. It appeared that no single organization in the NWT was systematically assessing, or necessarily considering, cumulative effects.

According to interviewees, one case of cumulative effects that has drawn greater participation from proponents and the land and water board is the expansion of the Ekati Diamond Mine, located in the same region as the existing Diavik Diamond Mine. Diavik shared concerns about the parameters that the Jay Project would be monitoring, since the risk for cumulative effects from another project was a genuine possibility. An independent mine oversight board participant noted that the land and water board was acutely aware of the potential for cumulative effects and worked to ensure that Diavik and Ekati's monitoring efforts were coordinated. However, an independent mine oversight board participant described the challenge of assessing cumulative effects from the two mines with: 'I don't know that we're [stakeholders] really clear on how to manage them beyond the individual project.' Diavik seemed to be more concerned about cumulative impacts from the Jay Project that could affect their project, as opposed to the protection of valued environmental components. Cumulative effects appeared to be able to win a meaningful audience with proponents and the land and water board when there was a threat to the operations of a large development project in the NWT.

Since monitoring parameters are to some degree linked to public values, it was not surprising that participants recognized their influence on the cumulative effects that could be assessed. Some participants noted a focus on particular contaminants of public concern, such as mercury and arsenic, which may not be the most ideal parameters to assess for cumulative effects. Another participant also observed a tendency for the public to place greater concern on distant industrial projects rather than smaller, nearby projects (including municipal activities), which collectively contribute to cumulative effects. As a participant from one of the independent mine oversight boards commented, larger industrial projects are more heavily scrutinized despite undertaking more comprehensive monitoring than smaller projects. This participant suggested that more comprehensive monitoring at larger projects allows for a better understanding of the environment and thus, an improved ability to mitigate effects, while the effects of many smaller activities or disturbances can go unchecked.

Chapter 5
Discussion

This thesis examined the contributions of environmental monitoring programs in the Mackenzie Valley, NWT to the identification, understanding and management of cumulative effects to freshwater systems. Though several solutions have been suggested to improve and advance monitoring programs to support cumulative effects, no framework currently exists to guide the evaluation of monitoring programs and identification of means to best support the assessment of cumulative effects. The framework introduced in this thesis is a start; it evaluates seven attributes of monitoring data or parameters to support cumulative effects understanding: consistency, compatibility, observability, detectability, adaptability, accessibility and usability. Applying this framework to the NWT presented a number of opportunities and lessons for improving the state of monitoring for cumulative effects in the region, but also raises a number of broader issues and challenges. Each of these is discussed below.

5.1 Improving consistency and compatibility of monitoring data

Results show that proponent-based monitoring conducted under Type A water license requirements, government-led monitoring, and government-supported community monitoring programs sampled for many of the same general categories of parameters – physical parameters, major ions, nutrients and metals. Consistency among monitoring parameters is essential to identifying the impacts of resource development on the environment and understanding their potential contributions to cumulative effects (Kilgour et al., 2007; Noble et al., 2011; Ball et al., 2013*a*; Dubé et al., 2013*b*; Noble et al., 2016). However, the specific parameters *within* these general categories were frequently variable. This is not surprising. For example, a review of monitoring programs across the South Saskatchewan by Ball et al. (2013*a*) found similar inconsistencies in monitoring due to the lack of an overall, coordinated monitoring strategy for cumulative effects, which hindered the ability to meaningfully assess cumulative effects. Similarly, Noble et al. (2016) illustrated that even in the case of a single proponent with multiple projects in the same watershed, there are often issues with inconsistency in the indicators used to support cumulative effects assessments. To improve consistency, better coordination and communication is required among all stakeholders in the regulatory process. This is particularly important between the land and water boards and GNWT, to ensure that monitoring conducted in preparation for EAs and under water licenses is consistent with GNWT data and fit into the broader regional monitoring picture.

The need for coordination of monitoring efforts to improve consistency has emerged in the scholarly literature as essential to supporting cumulative effects understanding (e.g. Noble and Basnet, 2015; Sinclair et al., 2016). One option to improve the consistency of what is being monitored across different monitoring programs is to introduce a requirement of a minimum list of parameters, whether impacted or not, that all monitoring programs must include, which specify monitoring and reporting protocols (Ball et al. 2013*a*). This would improve consistency among monitoring programs and, in turn, introduce compatibility across datasets that is presently limited in the NWT to support better characterization of baseline conditions and a stronger understanding of effects. Results from this study suggest that in the NWT, a core set of parameters may be supported by proponents, because most Type A water licenses already require monitoring for many basic, common parameters, which include some combination of physical parameters, major ions, nutrients and metals. The main challenges tend to lie in differences in sampling protocols, sampling periods, metadata, data management and baseline sampling designs.

That said, the reliance on a limited set of standard or 'key' parameters can provide a false sense of security, while not being wholly sufficient for detecting potential cumulative effects. Though a limited set of standard parameters is important to provide a certain level of consistency, equally important is an adaptive approach that can be tailored to a specific monitoring environment and is responsive to unforeseen threats (Noble, 2000; Walker et al., 2003). Ideally, the set of key parameters would be able to provide an indication of departure from baseline conditions and would signal to proponents (and government agencies) that other parameters may need to be examined, or that certain parameters need to be monitored more intensely in certain regions.

It is probably not possible to collect and analyze *all* water quality data in the same way to ensure complete compatibility. The frequency and location of monitoring conducted by proponents under water license requirements is dependent on the size and type of activity being undertaken and thus cannot adopt a one-size-fits-all monitoring approach. It is probably not reasonable to require a hydroelectric project to monitor water quality with the same frequency and intensity as a large mine project. Nevertheless, there should be a means to ensure that the data are sufficiently compatible so that they can be combined in analysis even if some differences in detection limits or sampling protocols exist. To introduce a minimum level of compatibility, Ball et al. (2013*b*) and Lonsdale et al. (2017) recommend greater consistency and compatibility among sampling methods, analytical methods, data management protocols and reporting protocols. For example, guidance on reporting protocols, such as representation of values below detection limits and complete metadata would enhance the compatibility of data collected by proponents and government agencies. Land and water boards have made efforts to improve the consistency of parameters sampled by proponents, but greater efforts are required to ensure the consistency and compatibility of government and proponent data.

5.2 Utilizing multi-scaled monitoring

The ideal parameters for monitoring or detecting effects are adaptable to multiple spatial or temporal scales (João, 2002; Harriman and Noble, 2008; CCME, 2009; Ball et al., 2013*a*). For example, MacDonald, (2000), Noble (2010) and Burton et al. (2014) discussed the need for multi-scaled monitoring that is both useful and relevant at the individual project and watershed levels to support cumulative effects assessments. At the same time, however, lessons from the Mackenzie Valley indicate that data collected at larger spatial or temporal scales, such as the data generated by regional or government-led monitoring programs, don't necessarily meet the local, immediate, and regulatory needs, or the rigour required by project proponents to meet their monitoring commitments to appropriately detect, and avoid, adverse effects. This is not to suggest that proponents abandon local level monitoring to support a regional understanding of cumulative effects or that all monitoring is adaptable, but rather that proponents *can* monitor certain parameters to support cumulative effects. Willsteed et al. (2016) recognize that project-specific data can provide higher resolution data to support regional baselines while Ball et al. (2013*a*) assert that certain data should be collected to allow for local *and* regional trends to be distinguished. It is crucial to not let local-level monitoring stray from its original purpose as it remains necessary to detect and mitigate effects at the appropriate level (Burris and Canter, 1997), and monitoring at the local level can help in understanding the drivers that may be causing regional change (Noble, 2008). Government agencies should thus consult with proponents to determine if the frequency of government-based monitoring can be increased in key locations to enhance the adaptability of their data to support the assessment needs of proponents. Results indicate that parameters such as pH, conductivity, TDS and sulphate have been widely monitored by both government- and proponent-based monitoring programs. More discussion is needed to determine if these parameters, and what other parameters, would be the most useful and adaptable to support cumulative effects assessments.

5.3 Improving data accessibility and data sharing

Data accessibility, and data sharing, can add significant efficiencies to cumulative effects assessment and provide for an accumulated understanding of baseline conditions as new proponents enter a region. Sharing data is necessary for baseline characterization and significance determination to understand both project and cumulative effects (Baxter et al. 2001). A lack of information regarding the types and locations of monitoring conducted in the territory was identified as a major challenge to data accessibility. The importance of accessible monitoring data for cumulative effects is discussed in the literature (Noble, 2010; Ma et al., 2012), but consistent with previous research (e.g. Creasey and Ross discuss the Cheviot Coal case as an example), the NWT case also reflects challenges regarding the limited accessibility or sharing of proponent data to support cumulative effects (Duinker and Greig, 2006; Schultz, 2012; Kristensen et al., 2013; Noble et al., 2014; Noble et al., 2016). No formal mechanism or regional database currently exists to facilitate data sharing and accessibility in the Mackenzie Valley. Currently in the NWT, proponents meet their obligations to report data, but present it in PDF documents, making it relatively inaccessible to other potential data users. However, the case also reveals *why* proponents may often be reluctant to make their data readily accessible to any users. Proponents believed there was the potential for their data to be misused if it was presented in a non-static format; they commented that making their data open and accessible would result in its misuse (even though it would improve transparency). The mindsets of proponents and government towards open and accessible data seem to be divergent. Proponents have seemed to be largely unconvinced of the benefits while government is working to have their data open and accessible. Improved data sharing and accessibility could be particularly beneficial in the Mackenzie Valley, NWT, given the vastness of the territory and the costs associated with monitoring in remote locales.

Expanding the Mackenzie DataStream to accommodate water quality monitoring data collected by proponents for EAs and under water license requirements could help to improve data sharing and accessibility in the Mackenzie Valley, NWT. It could also simplify the process of determining where other resource development projects exist and what types of water quality data are being collected. Dubé and Munkittrick (2001) and Olagunju and Gunn (2015) support the idea of a regional database, which could improve data usability through consistent reporting and increase efficiency since proponents could potentially rely upon previously collected data for their assessment needs. It could strengthen the science behind EAs, and thus CEAs because greater data access would allow for better characterization of natural variability (Maas-Hebner, 2015). The knowledge generated in subsequent EAs could permit for a better understanding of ecosystem processes (Greig and Duinker, 2011). Furthermore, a central repository of water quality data, such as an expanded Mackenzie DataStream, could help to develop a more comprehensive understanding of waterbodies in the NWT and eliminate the current need to rely on the goodwill of other proponents for their data. It would be necessary, however, to get buy-in from stakeholders, assign an organization responsible for the development and upkeep of the repository, establish funding mechanisms to support this initiative, and develop QA/QC protocols to guarantee that data are of similarly high quality. It may be a challenge to get buy-in from the land and water boards and proponents since the idea of improving data accessibility has previously been met with skepticism from these parties. Devising a strategy to limit the potential for data misuse would be important to foster buy-in from proponents. Further conversations between government agencies and stakeholders along with greater data availability on the Mackenzie DataStream and Discovery Portal would ideally help to convince stakeholders that greater data accessibility would be beneficial for their assessment needs.

5.4 Enhancing monitoring data usability

Current water quality data collected by both proponents and government agencies in the NWT were said to be of limited use for cumulative effects assessments because their respective monitoring programs were fit-for-purpose. This is not a new revelation, as monitoring programs in many jurisdictions have evolved separately, resulting in cumulative effects being inadequately addressed (Dubé, 2003; Kilgour et al., 2007). Water quality data collected by proponents *and* government agencies are necessary to support the assessment of cumulative effects (Baxter et al., 2001; Dubé and Munkittrick, 2001; Greig and Duinker, 2011; Dubé et al., 2013*a*). Although monitoring programs of every organization are designed to address their own obligations (Dubé et al., 2013*a*), greater recognition for the usability of these data to support cumulative effects is essential (Johnson et al., 2011). Canter and Ross (2010) commented that data from previous assessments can be useful for future assessments in the same project area, but the utility of these data has not been recognized. Part of the issue with the limited usability of proponent and government data may stem from a lack of guidance from a lead agency. Noble et al. (2016) make the case that proponents cannot be faulted for their data's lack of consistency and comparability with those of other proponents or government agencies, since such oversight is the responsibility of the regulatory authority. In the Mackenzie Valley, proponents are responsible for monitoring based on Type A water licenses that are designed by land and water boards, and have little control over their data's usability beyond their own project. The need for standards to specify how data are generated and presented to facilitate data synthesis for cumulative effects assessments has been highlighted by Karkkainen (2002). Evidently, foresight from appropriate leadership is essential to ensuring that the monitoring data collected by proponents and governments complement each other to support the assessment of cumulative effects. Some participants noted that government should undertake monitoring in areas where development is likely to occur to ensure greater usability of their data. This would be an ideal scenario, and perhaps viable to some degree, but it is likely not realistic for government agencies to monitor in *all* the areas in which development *may* occur. Open discussion between government and proponents may be helpful to assess the potential for government to conduct regional monitoring in key areas of the NWT, based on future scenarios of land use and development.

To improve monitoring data usability, proponents could be responsible for partially funding monitoring – either through royalties or funding provisions – to support cumulative effects assessments in the NWT. More dependable funding sources have been widely recommended by scholars to support the monitoring and management of cumulative effects (e.g. Piper, 2001; Bjorkland, 2013; Lonsdale et al., 2017; McKay and Johnson, 2017).

Another suggestion to improve usability is that each project should have a reference site that ties into a regional baseline, possibly based on the ecological regions identified by the Department of Environment and Natural Resources division. All proponents would then be contributing to an understanding of the natural variability in a region prior to development on that waterbody. This would allow for change detection 'farther afield', which would be helpful for cumulative effects assessments. Alternatively, there could be a model in which proponents contribute funding for a shared reference site, which would be monitored by the government. This would alleviate the need of proponents to have their own reference sites while permitting the government to monitor parameters that are relevant to assessing cumulative effects. Although there may be other details that need to be discussed with a shared reference site model, it would merit further consideration.

5.5 Developing monitoring guidance documents

Based on the NWT results, it was unclear what length of time was required, and what practices were accepted, for characterizing baseline conditions to ensure that departures from baseline were observable. Good baseline monitoring is crucial to determining whether a resource development project has had an effect on the environment, and whether it may contribute to a potential cumulative effect (McCold and Saulsbury 1996; Bérubé, 2007; Canter and Atkinson, 2011; Schultz, 2012). Results from the Mackenzie Valley indicate that participants are unsure that the standard 2-3 years of baseline monitoring in preparation for an EA was sufficient to characterize natural variability. Dubé et al. (2013*a*) noted that the limited spatial and temporal scope that is common in most EAs in Canada is inadequate for characterizing baseline conditions. The authors suggested that greater availability and accessibility of regional data would aid in supplementing baseline data of proponents. However, Brack et al. (2009) argue that ecosystems are in a constant state of flux, which makes it difficult to truly capture its natural variability and then translate that to local, or point-specific development locations. These authors proposed a shift in focus from simply characterizing baseline conditions to attempting to understand how the ecosystem responds to stressors. While it may not be possible to gain a perfect understanding of the ecosystem, this method attempts to provide context for ecosystem change (Brack et al. 2009). For example, a proponent may identify an unusual increase in turbidity when conducting their water quality monitoring. Instead of simply explaining the increase in turbidity as part of the 'natural variability' of the waterbody, they could examine possible causes, such as nearby forest fires that recently occurred, which may have contributed to the increase.

Though various methods of characterizing baseline conditions and measuring departure from baseline conditions have been discussed in depth in scholarly literature, there is no clear consensus on best methods or approaches. This has often led to differences in baseline monitoring practices (Squires et al., 2010; Ma et al., 2012; Squires and Dubé, 2012; Foley et al., 2017), which appears to reflect the current situation in the Mackenzie Valley. The lack of guidance has resulted in baseline conditions that have insufficiently characterized natural variability and, consequently, have made it difficult to observe departures from baseline conditions. It is a challenge to implement appropriate mitigation measures to manage cumulative effects if departures from baseline conditions cannot be identified. Foley et al. (2017) advocate for guidance to standardize the characterization of baseline conditions, which would be jointly developed by stakeholders and scientists. In the Mackenzie Valley, baseline guidance would help stakeholders clearly understand the rigorousness of science needed for characterizing baseline conditions to assess for cumulative effects while promoting greater consistency in baseline monitoring practices.

5.6 Identifying and assessing the significance of trend assessments

The ability to determine significance is foundational to cumulative effects, but has been a recurring challenge because of the subjectivity involved (Foley et al., 2017; Joseph et al., 2017). Results from the Mackenzie Valley indicate that when participants are able to observe a departure from baseline conditions or detect early warning of change, they are frequently unable to determine the significance of that change. Study participants noted that trend assessments sometimes fall into purgatory between statistically significant and ecologically relevant. This occurs since statistically significant trend assessments do not necessarily equate to meaningful changes to ecological condition (Kilgour et al., 2007; Jones et al., 2016). Dubé et al. (2013*a*) recommend that further investigation is warranted (e.g. determining spatial and temporal extent of change) when statistically significant trend assessments are made. This helps to ensure that statistically significant change is sufficiently examined to minimize or eliminate the opportunity for ecologically relevant change. The Canadian Environmental Assessment Agency (2015) previously developed criteria to aid in determining significance, which include assessing the magnitude, geographic extent, duration and frequency, degree of irreversibility and ecological context of adverse environmental effects. Similar criteria or guidance would likely be helpful to practitioners in the Mackenzie Valley. Joseph et al. (2017) advocate for conceptual thresholds that are not tied to specific numbers and are jointly developed by stakeholders, relieving proponents of this responsibility. Conceptual thresholds may be helpful as Squires and Dubé (2012) have remarked that scientists are reluctant to develop thresholds since it assumes that our knowledge of the environment is sufficient to determine assimilative capacity of waterbodies. Consequently, guidance on thresholds could help reduce ambiguity while working to promote consistency in significance determinations across the Mackenzie Valley.

5.7 Enduring challenges

The lack of common understanding of cumulative effects, unclear responsibility for monitoring and manage them, and participation required of different stakeholders are enduring challenges to managing cumulative effects. Many definitions of cumulative effects exist (Wärnbäck and Hilding-Rydevik, 2009; Noble et al., 2011; Judd et al., 2015; Willsteed et al., 2016; Kirkfeldt, 2017), and the understanding of cumulative effects among NWT interview participants was variable. Folkeson et al. (2012) note that a lack of common understanding of cumulative effects can lead to confusion among stakeholders resulting in cumulative effects assessments being arbitrarily conducted. Duinker et al. (2012) argue that adopting a common 'definition' of cumulative effects is not sufficient; rather, stakeholders must also agree on the fundamental nature, principles and characteristics of cumulative effects, including such matters as responsibility for monitoring and managing them.

A major challenge, however, is the often lack of clarity about who is responsible for leading guidance on monitoring, and conducting assessments of, cumulative effects. Currently, proponents are expected to fulfill the aspirations of cumulative effects assessments and often with little guidance. This is hardly unique to the Mackenzie Valley. Kristensen et al. (2013) and Noble et al. (2014) noted that a lack of lead agency has constrained cumulative effects processes in watersheds in British Columbia and Saskatchewan, respectively. The need for a lead agency has been well-established in scholarly literature (e.g. Cooper and Sheate, 2002; Dubé, 2003; Canter and Ross, 2010; Lindenmayer and Likens, 2010; Sheelanere et al., 2013). It must have the capacity, mandate and authority for guiding monitoring programs to support cumulative effects monitoring and assessments, fostering relationships, and implementation and reporting (CCME, 2009; Noble, 2010; Pölönen et al., 2011; Sheelanere et al., 2013).

The territorial government, and more specifically the Department of Environment and Natural Resources, may be the most suitable lead agency in the NWT. They conduct monitoring across the territory, may be positioned to coordinate their efforts with proponents and land and water boards, and have a direct stake in effectively managing cumulative effects. This would be consistent with suggestions by Seitz et al. (2011) that governments assume a leadership role for cumulative effects. Sheelanere et al. (2013) note that only government is capable, in principle, of balancing competing interests as well as enforcing the consistent implementation of and compliance with cumulative effects practice. In the NWT, this would require ENR to develop guidance documents which define roles and responsibilities of stakeholders, and for baseline monitoring practices to support cumulative effects understanding at multiple scales as baseline monitoring practices have seemed to been largely conducted at the discretion of individual proponents.

Clearly defined stakeholder roles are a requisite to support cumulative effects assessments (Damman et al., 1995; Piper, 2001; Kennett, 2002*a*; Gunn et al., 2014). Defining the roles of stakeholders in supporting cumulative effects appears to be a necessary next step in the Mackenzie Valley. The land and water boards must recognize that they have a crucial role to play in supporting cumulative effects as they dictate the terms of monitoring under water license requirements for resource development projects. They should coordinate and collaborate with the territorial government and other stakeholders to determine the location, frequency and parameters that would be relevant to understand cumulative effects beyond the scope and scale of individual projects. It is unlikely that government can meet the challenge of cumulative effects through their monitoring efforts alone (MacDonald, 2000; Dubé, 2003; Ball et al., 2013*b*). Thérivel and Ross (2007) thus maintain that proponents should be responsible for managing the effects of their project, but not the effects of others. Proponents should be responsible for conducting monitoring to support cumulative effects understanding and for mitigating project effects when thresholds are met, but these activities must be coordinated by a larger, overarching agency or consortium. It may be reasonable for proponents to conduct expanded monitoring to support the management of their contributions to cumulative effects (Seitz et al., 2011), but government (or an independent oversight agency) must play a coordinating and enforcement role. Assessing for cumulative effects requires a collaborative effort among government agencies, the land and water boards and other stakeholders. Additionally, clear stakeholder roles minimize duplication of efforts and help to delineate the various elements required for the effective assessment of cumulative effects.

Chapter 6
Conclusion

Research from the Mackenzie Valley confirmed that the scientific requirements of cumulative effects assessments are extensive and the level of coordination and collaboration required goes well beyond that required for project-level EAs (Noble, 2010; Canter and Atkinson, 2011; Jones, 2016). Several frameworks have been developed to address various issues pertaining to the science of cumulative effects (e.g. Bedford and Preston, 1988; Culp et al., 2000; Hewitt et al., 2003; Sinclair et al., 2016; Willsteed et al., 2016). These frameworks have been helpful to understand and advance cumulative effects practice in Canada, and elsewhere in the world. Nonetheless, a closer examination of the nuts and bolts of scientific contributions (i.e. monitoring data, parameters, baseline information and the methods to generate these data) to support cumulative effects appeared warranted.

6.1 Lessons learned from the Mackenzie Valley, NWT

The purpose of this research was to examine the contributions of environmental monitoring programs in the Mackenzie Valley, NWT, to the identification, understanding, and management of cumulative effects to freshwater systems. This research developed a framework to evaluate government- and proponent-based monitoring data and parameters based on seven attributes: consistency, compatibility, observability, detectability, adaptability, and accessibility. At present, these seven attributes of monitoring data and parameters to support cumulative effects assessments appear to be inchoate or generally absent. Interviews with stakeholders engaged in monitoring, assessment or CE processes revealed that assessments of cumulative effects to freshwater systems in the Mackenzie Valley, NWT, often appeared nominal at best, and non-existent at worst. Nearly all the participants recognized the possibility for, and threat of, cumulative effects, but no single agency appeared to be able, or currently have the mandate, to assess for them. Key impediments to CEA in the Mackenzie Valley appear to be varying interpretations of cumulative effects, uncertainty over responsibility for them, data inaccessibility, and the lack of standardized data and sampling protocols.

Science from inside and outside EAs should support the assessment of cumulative effects (Greig and Duinker, 2011; Duinker et al., 2012); accordingly, both stressor and effects-based monitoring are required to effectively understand and manage cumulative effects (Dubé, 2003). There have been persistent calls for the integration of stressor and effects-based monitoring programs (Dubé and Munkittrick, 2001; Dubé, 2003; Kilgour et al., 2007; Cronmiller and Noble, 2018), but there has been limited progress (Dubé et al., 2013*a*; Cronmiller and Noble, 2018). Practice in the Mackenzie Valley has shown that monitoring programs conducted by governments and proponents share a relatively tenuous link and collectively may be of limited value, in their current form, for assessing cumulative effects. Ideally, the effects-based monitoring conducted by government agencies would be used by proponents for understanding the baseline conditions of a site (Harrington and Canter, 1998; Kilgour et al., 2007). Stressor-based monitoring conducted by proponents would be used by government agencies to better understand the local conditions of monitoring sites (Dubé and Munkittrick, 2001). The use of government data for the assessment needs of proponents appeared to be limited to filling gaps in baseline data, while the use of proponent data beyond the project-scale by government agencies appeared to be generally non-existent.

Arguably, however, a main impediment to effective CE monitoring or assessment in the Mackenzie Valley is the lack of a lead agency to guide the process. This has often led to haphazard assessments of cumulative effects (Arnold, 2018) as no party has assumed responsibility for them. When proponents have attempted to take responsibility for their project's contribution to cumulative effects, a key message they conveyed in this research is that little support was provided to them in the form of guidance to conduct these assessments or access to the data of government agencies and other proponents. However, these challenges to cumulative effects practice in the Mackenzie Valley is, in many ways, similar to other jurisdictions in Canada; this research reinforced the ubiquity of the challenges that face CEAs.

Aside from the lack of lead agency to provide oversight for the usability of monitoring data, there was a recognition among study participants that the roles of stakeholders must be better defined. The research indicated that proponents and land and water boards need to see the value of cumulative effects monitoring. The inclination of proponents to expand monitoring for the benefit of CEA is likely to remain low if proponents aren't able to recognize its value. Naturally, improving the usability of data collected by proponents also requires that proponents understand their project's potential contribution to cumulative effects and, in turn, take steps to support the assessment of cumulative effects. A related issue is that the land and water boards need to recognize the importance of cumulative effects and the role they play to support them.

Because the land and water boards develop the Type A water licenses that stipulate monitoring requirements to proponents, it seems imperative for the land and water boards to include provisions for proponents to support cumulative effects monitoring through, for example, the identification of standard indicators, reporting requirements, and enhanced data sharing arrangements. Without buy-in and cooperation from proponents and the land and water boards, it is questionable whether cumulative effects can be assessed effectively in the Mackenzie Valley. This will be an ongoing challenge because the mindsets of proponents will undoubtedly be different, but it is hoped that by gradually illustrating the benefits of cumulative effects monitoring to proponents, there will be increasing support. Currently, the sole focus of proponents is to detect project-specific effects with their monitoring; cumulative effects will continue to be a back-burner issue without stronger guidance from and coordination between government agencies and the land and water boards.

This research also found that the two areas of consistency needed to support CE understanding and assessment were wanting: consistency among parameters monitored by proponents, and consistency across monitoring programs conducted by government and proponents. There was not a single parameter that was common to all water licenses and, thus, not a single parameter was common across government and proponent-based monitoring. Consistency of parameters is essential to CEA and has been discussed at length in scholarly literature (Van Oudenhoven et al., 2012; Ball et al., 2013*a*; Olagunju and Gunn, 2015).

An issue that naturally accompanies consistency is the compatibility of data, which refers to the approach to monitoring. Sampling protocols, detection limits, and analytical methods were some of the predominant factors identified in the NWT leading to incompatible data. Collaboration and coordination have been prescribed as a remedy to many cumulative effects problems (Culp et al., 2000; Piper, 2001; Morrison-Saunders and Bailey, 2009; Canter and Ross, 2010; Connelly, 2011; Noble, 2015), and seem necessary to improve the consistency and compatibility of parameters monitored by government agencies and proponents.

Another major impediment to CE assessment and understanding in the NWT is the difficulty of accessing the data of both proponents and government. To leverage the data collected by different programs for cumulative effects, there needs to be a central repository of data, or a formal mechanism to share data (Dubé and Munkittrick, 2001; Kennett, 2002*b*; Briggs and Hudson, 2013; Zwart et al., 2015). A notable finding of this research was that proponents found it difficult to determine what monitoring programs were being conducted by government. An unnecessary amount of time and effort was then needed to explore what relevant government data existed to support a proponent's assessment needs, and whether this data could be obtained. The state of proponent data was no better as they were commonly presented in PDF file format, making the data 'available, but not accessible'. The time required to transcribe the data from PDF file formats can be lengthy and error-prone. The lack of knowledge about the monitoring programs being conducted, coupled with the inability to readily access the data could work to reinforce the isolation of government- and proponent-based monitoring programs. The ability to easily find and access monitoring data is essential to ensuring that government- and proponent-based monitoring programs collectively support the assessment of cumulative effects.

The challenges facing cumulative effects assessments in the Mackenzie Valley, NWT are numerous and varied. While cumulative effects practice in Canada has advanced in fits and starts, there is the recognition that it is a concept worthy of pursuit to ensure responsible resource development (Wärnbäck and Hilding-Rydevik, 2009; Connelly, 2011; Sinclair et al., 2016). Improving the state of cumulative effects science and practice can often be complex as issues are interconnected and cannot be easily addressed in isolation. Thus, it must be acknowledged that addressing the scientific requirements necessary to support meaningful CEAs and monitoring initiatives will not always be simple or straightforward. It is likely that different challenges will arise and require innovative research and solutions to solve them. To advance the scientific contributions of monitoring programs in the Mackenzie Valley, NWT to support cumulative effects assessments, the recommendations are to:

- Assign a lead agency, likely GNWT's Department of Environment and Resources, to develop the tools and supports for the land and water boards, allowing the land and water boards to ensure that the water licensing requirements support monitoring that will result in improved CE understanding. The lead agency will work closely with land and water boards to develop a definition of cumulative effects with stakeholders, guide monitoring programs to support cumulative effects assessments and collaborate and coordinate with other stakeholders.

- Define the roles of stakeholders, and work to ensure that land and water boards and proponents support cumulative effects monitoring. The land and water boards could develop common parameters and reporting requirements in Type A licenses that would enhance compatibility and CE understanding. They could also provide a level of standardization for the Terms of Reference that stipulate monitoring requirements and sampling protocols for both baseline and post-EA. Proponents could be responsible for expanded monitoring to support CE understanding.

- Determine whether the existing Mackenzie DataStream website is able to accommodate monitoring data collected by proponents for EAs and under water license requirements. An expanded Mackenzie DataStream or another central repository of data, which includes the data collected by proponents, would work to improve data sharing and accessibility with an agency responsible for its development and upkeep. This may require the development of mechanisms to finance this initiative and the development of appropriate QA/QC protocols to standardize data quality.

- Explore the potential for shared/jointly funded reference sites to improve consistency of monitoring in these sites and to gain a better regional understanding of waterbodies across the NWT. This regional understanding of waterbodies could be delineated by the ecological regions currently identified by the Department of Environment and Natural Resources.

6.2 Research contributions

Limited research has been conducted on the scientific contributions (i.e. monitoring parameters and data, baseline information and methods used to generate these data) of government- and proponent-based monitoring programs to CEA. As a result, this work served to advance the understanding of scientific contributions by developing a framework to evaluate monitoring parameters and data needed to support CEAs. It responded to a need for improved cumulative effects management, which was identified by the 2015 Northwest Territories Environmental Audit (ENR, 2016). This report is published every five years by an independent auditor who assesses the management of cumulative impacts and the effectiveness of the regulatory system in the Mackenzie Valley.

Participants from industry, government agencies, land and water boards and independent oversight board mines shared valuable insight about the monitoring data and parameters based on the seven attributes of the framework, along with other cumulative effects challenges. Furthermore, the examination of monitoring data collected by proponents under water license requirements, and monitoring data collected by government agencies provided a direct comparison of the consistency and compatibility of these datasets. Understanding the data challenges faced by government agencies as well as the challenges faced by project proponents were important elements of the research. The research also highlighted areas for improvement to the consistency, compatibility, observability, detectability, adaptability, accessibility and usability of monitoring data and parameters collected in the Mackenzie Valley. Consequently, one of the intents of this research was to address those data challenges and to improve the effectiveness of cumulative effects assessment in the NWT by integrating the data collected from different monitoring programs. Though this framework was specifically applied to the Mackenzie Valley, NWT, it can be applied and adapted to other jurisdictions as the seven attributes to support cumulative effects are widely universal.

This research also contributed to scholarly literature by helping to bridge the disconnect between science conducted by government- and proponent-based monitoring in preparation for EAs and under water license requirements (Roux et al., 1999; Dubé, 2003; Ball et al., 2013*a*). The monitoring data generated by EAs and EEM programs, as standalones, cannot be expected to solve the problem of cumulative effects assessments. This research sought to assess how an integrated approach that leverages the benefits of stressor and effects-based approaches could be operationalized by better understanding how the programs complement each other. It served to understand how EA and EEM could be situated more effectively within each other so that the two processes are complementary. Furthermore, it provided insight into how data collected by monitoring under environmental assessments could feed into subsequent assessments. This research identified steps that can be taken to help streamline monitoring data and parameters to support the development of baselines and the prediction of cumulative impacts.

6.3 Limitations

A primary limitation of this research was the amount of time that was spent in the Northwest Territories to administer semi-structured interviews in person, and the inability to travel to remote regions. The interviews were scheduled in Yellowknife during a two-week period and attempted to accommodate as many potential interviewees as possible. The interviewees that were unavailable during this time were interviewed by telephone.

Though this research had the initial support of the land and water boards, not all of them were able to participate in the interviews. Four land and water boards exist in the NWT and they opted to be represented by participants from one land and water board. Throughout this research, the land and water boards have been recognized as essential to the management of cumulative effects and their full participation would have been ideal to understand the challenges they face. Additionally, greater participation among proponents may have also been useful to understand the unique challenges they face when developing baseline conditions or predicting for cumulative effects. Nevertheless, consultants that have conducted a wide-range of work for the assessment needs of proponents participated and were able to corroborate many of the insights shared by proponents.

A review of Type A water licenses allowed for an understanding of the types of data that proponents have been required to collect, but it did not provide access to the actual proponent-managed databases. Access to the databases may have allowed for a more detailed look at the data and its characteristics. However, project proponents did not grant access to these data and this was not a surprise since land and water boards often do not have access to them. Semi-structured interviews of project proponents and consultants helped to understand detail about the consistency and compatibility of the monitoring data collected by proponents under water license requirements.

6.4 Future research

Based on this research, it is a recommendation to investigate the parameters that are useful and relevant at multiple spatial scales for CEA in the Mackenzie Valley. It is necessary to identify a core set of parameters and to provide the rationale for their selection. Additional research regarding sampling, analytical and reporting protocols are required to assess how they can be made more consistent, which would allow for monitoring data to be more compatible. This would help reduce the amount of discretion that individual proponents exercise when conducting their monitoring programs in preparation for EAs and under water license requirements. Similarly, more research is needed to strengthen the characterization of baseline conditions to facilitate the identification of departures from baseline. It remains essential to retain a balance between academic wants and realistic requirements for the development of baseline conditions and monitoring stipulated in water licenses. Determining reasonable frequencies and locations for monitoring to support cumulative effects assessments is an area that requires greater attention. Moreover, enhancing greater data accessibility while limiting the potential for its misuse may be an area requiring further research. The issue of data accessibility was a divisive one because proponents were concerned about their data being misused while non-proponents thought that greater accessibility would lead to transparency in trend assessments. More research may be required to determine the capacity and assess the mandate of the Department of Environment and Natural Resources to act as a lead agency for cumulative effects assessments in the Mackenzie Valley. Alternatively, it may be necessary to identify an agency or group of agencies that would be appropriate to lead these assessments. Since this framework to evaluate monitoring data and parameters has only been applied to the Mackenzie Valley, it requires further validation in other jurisdictions. The framework may need to be refined according to the local context of the area being examined.

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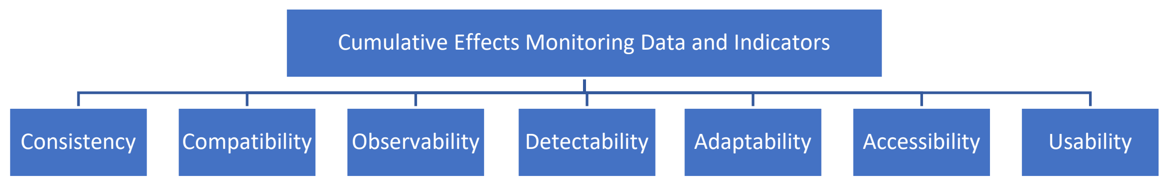
Appendix A: Semi-structured interview questions

<u>Interview Questions – Cumulative Effects Indicators and Monitoring Data</u>

Interviewees: project proponents; consultants; government (LWB, MVEIRB, CIMP, WRD) technical / science staff; other independent scientists/advisors/researchers/consultants identified by participants

The interview questions are intended to probe six aspects of data (indicators, monitoring) for cumulative effects:



Consistency: parameters are sufficiently similar in government- and proponent-based monitoring programs
Compatibility: can be integrated with other data sets / monitoring / assessment systems
Observability: supports observations / tracking of baseline conditions/change over time / space
Detectability: provides early warning of risk / threat / change
Adaptability: useful at multiple spatial scales / across multiple project / disturbance types
Accessibility: accessible and in a usable format
Usability: meets end user demands / needs based on specified objectives

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Background information

- What is your current professional affiliation / position?
- About how long have you been engaged in practice / work / operations in the NWT?

Interview questions

1. Optional lead in: Monitoring programs can serve multiple functions, depending on the specific questions they are designed to address. For example, tracking baseline change, determining cause-effect relations, or monitoring stress – such as discharge.
    a. What do you see as the primary purpose(s) of water quality monitoring conducted by project proponents – either in preparation for EAs or under water license requirements?
    b. What do you see as the primary purpose of water quality monitoring conducted by government agencies, such as WRD, CIMP, or ECCC?

2. Are the water quality indicators monitored by proponents consistent among development types or sectors?
    a. Are they generally consistent with what is being monitored / collected by government agencies, such as WRD, CIMP, or ECCC?

3. Are there certain indicators that are more broadly applicable than others, or most useful across different types of projects or locations, for tracking water quality condition or change over time?
    - *If YES, ask for specifics / suggested indicators*
    - *If NO, explore why / reasons*

4. Are there certain indicators that are more broadly applicable than others, or most useful across different types of projects or locations, for monitoring or detecting potential risks or possible threats to water quality – i.e. early warning indicators?
    - *If YES, ask for specifics / indicator suggestions*
    - *If NO, explore why / reasons*

5. Is the monitoring currently conducted by project proponents useful for identifying and managing potential cumulative effects to water quality at larger spatial (e.g. sub-watershed) scales? More specifically:
    a. [*If YES to main question*] What indicators monitored by project proponents are most useful for understanding cumulative effects?
    [*If NO to main question*] What indicators could be monitored by project proponents that would be useful for understanding cumulative effects?
    b. Do data at the project scale currently support regional baselines or assessment of cumulative effects to water quality?
    [If YES: In what ways – explain how it is done / operates/ what agency(ies) are responsible]?
    [If NO: Why? What needs to be done to ensure that it does – i.e. how can monitoring programs be better connected to other, more regionally-focused monitoring interests and what agency(ies) should be responsible?]
    c. What do you see as the major challenges or obstacles to better connecting project monitoring programs to other, more regionally-focused monitoring interests?
    d. What are solutions to these challenges and what roles should the different agencies play in better connecting project monitoring programs to more regionally-focused monitoring interests?

6. Is monitoring currently conducted under government-led monitoring programs (optional: WRD, CIMP) useful for project proponents to help identify and manage the potential cumulative effects of their projects to water quality?
    a. [*If YES to main question*] What indicators monitored by government programs are most useful for project proponents during their assessments?

[*If NO to main question*] What indicators monitored by government programs could be most useful for project proponent during their assessments?

b. Do data collected by government programs feed into or support project assessments for water quality?
   [If NO] How could data collected by government programs feed into or better support project assessments for water quality?
c. Is there an opportunity for it do so?
d. What do you see as the major challenges to better connecting regional monitoring programs to project-focused monitoring and assessment interests?
e. What are possible solutions?

7. <u>For non-government only</u>: Are the data collected and housed by GNWT easily accessible to you (i.e. require minimal time and effort to find/access)?
   a. Is it in a format that is useful for your project assessment or evaluation needs? If not, what would be a more useful format?
   b. Are there major obstacles to accessibility? Are there solutions?
   c. Is the data usable with minimal time and effort devoted to QC?

7. <u>For GNWT only</u>: Are the data collected and housed by project proponents easily accessible to you (i.e. require minimal time and effort to find/access)?
   a. Is it in a format that is useful for your project assessment or evaluation needs? If not, what would be a more useful format?
   b. Are there major obstacles to accessibility? Are there solutions?
   c. Is the data usable with minimal time and effort devoted to QC?

8. Which best describes monitoring currently conducted under government-led monitoring programs in the Mackenzie Valley:
   a. Is effective at detecting change in baseline water quality conditions that may be occurring over large spatial scales, such as sub-watersheds?
   b. Allows for an understanding of cause-effect, in terms of how project developments affect water quality condition?
   c. Provides an indication of potential risks or threats to water quality because of land use or land cover change (e.g. land use / disturbance metrics)?

9. This question focuses on opportunities for improving monitoring in the Mackenzie Valley to support cumulative effects assessment. There have been many suggestions by researchers about how to improve practice. Some of them have been discussed already. What are your thoughts on the feasibility of the following suggestions?
   a. Implementing a requirement that project monitoring data collected in preparation for EAs, and under water licensing and impact management are open / accessible to GNWT <u>and</u> available to other project proponents.

b. Providing incentives that project monitoring data collected in preparation for EAs, under water licensing and impact management are open / accessible to GNWT and available to other project proponents.
c. Requiring that all projects monitor a minimum specified set of indicators (whether impacted or not), to contribute to a common database for tracking water quality change
d. Proponents investing in baseline data collection at a much earlier state of the project design process, long before an EA commences.
e. Other suggestions for improving monitoring data for cumulative effects in the Mackenzie Valley?

10. Is there anything else that you would like to add, key issues, or areas where improvements are needed that we haven't already discussed?