SCALING-UP
VALUED ECOSYSTEM
COMPONENTS
FOR USE IN
WATERSHED CUMULATIVE
EFFECTS ASSESSMENT

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By

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ABSTRACT

The accumulating impacts from human development are threatening water quality and availability in the watersheds of Western Canada. While environmental impact assessment (EIA) is tasked with identifying such cumulative impacts, the practice is limited to individual projects, is not widely applied, overlooks activities occurring on the landscape, and fails to capture the effects of multiple projects over time. Limitations of the project-by-project approach are spurring the emergence of a regional framework for assessing aquatic cumulative effects within watershed boundaries. Watershed-based cumulative effects assessment (WCEA) will need a standard set of ecosystem components and indicators for assessment across the watershed, but it is not clear how such valued ecosystem components (VECs) and related measurable parameters should be identified. This study examined how aquatic VECs and indicators were used within project-based EIA in the South Saskatchewan River watershed and considered whether they could be scaled up for use in WCEA. A semi-quantitative analysis compared a hierarchy of assessment components and measurable parameters identified in the environmental impact statements of 28 federal screening, 5 federal comprehensive and 2 provincial environmental assessments from the South Saskatchewan River watershed, and examined factors affecting aquatic VEC selection. While provincial assessments were available online or at a central archive, federal assessments were difficult to access. Results showed that regulatory compliance was the dominant factor influencing VEC selection, followed by the preferences of government agencies with different mandates, and that provincial licensing arrangements interfered with VEC selection. The frequency of VECs and indicators used for aquatic assessment within EIA does not reflect the aquatic cumulative effect assessment (CEA) priorities for the watershed. The effective selection of VECs and indicators for aquatic cumulative effects assessment in practice requires both the implementation of WCEA and updating of guidelines for project-based EIA.

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AAFC: Agriculture and Agri-Food Canada
AB: Province of Alberta
CEA: cumulative effects assessment
CEAA: Canadian Environmental Assessment Act
CEAR: Canadian Environmental Assessment Registry
CEARC: Canadian Environmental Assessment Research Council
DFO: Department of Fisheries and Oceans
DND: Department of National Defence
EIA: environmental impact assessment
EIS: environmental impact statement
EUB: Alberta Energy and Utilities Board
NRC: Natural Resources Canada
NEB: National Energy Board
PAH: polycyclic aromatic hydrocarbon
PCA: Parks Canada Agency
SK: Province of Saskatchewan
TC: Transport Canada
TEK: traditional ecological knowledge
VEC: valued ecosystem component
VSC: valued socio-economic component
WCEA: watershed-based cumulative effects assessment
WD: Western Economic Diversification Canada

CHAPTER 1

INTRODUCTION

The accumulating impacts from human activities are putting water security at risk in western Canada, where both water availability and water quality are subject to increasing stresses related to watershed development (Schindler 2001, Schindler & Donahue 2006, St. Jaques et al. 2010). In principle, such impacts should be addressed through the regulatory environmental impact assessment (EIA) system; in practice, EIA in Canada is typically limited to certain project undertakings and does not capture the full range of stress to watersheds and river systems. As a consequence, cumulative impacts to the aquatic environment have been assessed through *ad hoc* processes outside of EIA using watershed boundaries, such as the Northern River Basins Study (Dubé et al. 2006), a government sponsored initiative that examined aquatic impacts of development in northern Alberta. One of the key challenges facing watershed-based assessment of cumulative effects is the necessity of sharing information over time and across geographic scales from specific projects to river reaches to watersheds. In particular, there is a need to standardize environmental components and aquatic indicators used for assessment so that information can be exchanged within and between assessments at the project, river reach, and watershed scales.

Cumulative effects are the combined impacts from all human-driven environmental stresses acting over time and space (Spaling 1997 cited in Noble 2006, Hegmann et al. 1999). Contaminants from different sources, arriving through different transport mechanisms may all affect surface water quality, for example, on the same reach of a river at the same time, with the overall impact to the aquatic environment exceeding the sum of the impacts from individual pollutants. Cumulative effect assessment (CEA) is tasked with accounting for the combined stresses affecting a particular environmental component regardless of the origin, and must consider past, present and future human activities.

Current practice in Canadian EIA includes requirements for CEA under certain jurisdictions, and for certain types of projects, but the practice is seen as ineffective because it lacks the temporal and spatial capacity to properly capture all sources of environmental stress (Duinker & Grieg

2006). A number of attempts to account for cumulative impacts to the aquatic environment have therefore adopted watershed boundaries to better match the study area to the geographical scale of the stresses affecting water. In the United States, for example, Reid (1993) conceptualized various pathways that characterize off-site and on-site cumulative effects in a watershed, and defined cumulative watershed effects in two ways. First, cumulative watershed effects includes those changes occurring to resources influenced directly or indirectly by watershed processes, so processes of water and sediment transport are functionally responsible for the expression of cumulative impacts. Second, cumulative watershed effects could be simply interpreted as changes/impacts that take place in the drainage area and not necessarily due to watershed processes. In this second case, the watershed is simply a location and does not play a role in the expression of impacts. In the Canadian context, CEA has also been conducted for aquatic ecosystems on a watershed basis through the Northern River Basins Study on the Athabasca River, and the Mackenzie River Basin State of the Aquatic Ecosystem Report (Dubé 2006). Those studies have spurred research that has advanced the science required for regional aquatic CEA and supported the application of watershed-based cumulative effects assessment (WCEA) for the aquatic environment across Canada. Even with the emergence of WCEA, however, CEA will continue to be practiced within EIA where it remains a regulatory requirement.

The current practice of EIA, and CEA within EIA, in Canada is to focus each assessment on a limited number of valued ecosystem components (VECs), which may be biophysical (the actual biological and physical elements of the environment) or socio-economic in nature, and are selected for their ecological significance or value to the public (Beanlands & Duinker 1983, Hegmann et al. 1999, Noble 2006). Different VECs are appropriate for different scales of assessment (Therival & Ross 2007), and the selection of VECs may vary locally depending on the ecological priorities in a given time period. VEC selection may also vary with changing public perceptions (Hegmann et al. 1999). The science used in EIA for assessing impacts to VECs is largely stressor-based, where the focus is on anticipated impacts from introduced environmental stress (Beanlands & Duinker 1983, Dubé 2003). The science used in WCEA, on the other hand, is effects-based, where the focus is on measurable aspects of the aquatic environment (Dubé 2003, Kilgour et al. 2006). The two approaches are complementary and each could benefit from information made available by the other. Together, the two approaches may have the capacity to help identify cause-effect mechanisms, or at least statistical associations, by allowing a comparison between known stressors and observed effects. It is therefore desirable to link WCEA to project-based EIA with a mechanism to facilitate the flow of quantitative information: the adoption of a common set of indicators applicable to both scales of assessment and understanding.

A standard set of VECs and indicators would allow the integration of regional aquatic CEA, for watersheds, with project EIA and also have the potential to integrate other aquatic science and aquatic management programs operating within a watershed, such as environmental effect monitoring programs conducted for pulp mills and mines, state-of-the-watershed reporting conducted by watershed stewardship organizations, and integrated water resource management initiatives such as those currently under development in Alberta, Canada. Arguably WCEA in this context has the potential to act as a unifying framework rather than an additional layer of assessment. Successful integration, however, will require consistency of VEC and indicator use and the selection of VECs capable of serving both project-based and watershed-based CEA, as well as indicators capable of serving stressor-based and effects-based science.

1.1. Study Objectives

The purpose of this research is to evaluate the consistency and quality of biophysical VECs and indicators used to assess the aquatic environment within project-based EIA, and whether they can be ‘scaled-up’ to support WCEA. The study is limited in scope to the aquatic environment as a matter of practicality. The study objectives are to: (i) identify the biophysical VECs that have been used in EIA practice; (ii) identify the biophysical VECs linked to the aquatic environment; (iii) identify common aquatic biophysical VECs and indicators across assessments; and (iv) determine whether aquatic VECs and indicators used in project EIA can inform WCEA. The focus is on the South Saskatchewan River watershed in Canada, a multi-jurisdictional watershed reaching across the southern portions of the provinces of Alberta and Saskatchewan.

CHAPTER 2

LITERATURE REVIEW

Environmental assessment was developed in North America in the early 1970s; under legislation in the U.S., and as a cabinet directive in Canada (Hanna 2005). The Canadian government replaced the cabinet directive first with a ‘Guidelines Order’ in 1984, and then with the Canadian Environmental Assessment Act (CEAA) in1995. The province of Saskatchewan similarly advanced from the *ad hoc* assessments in the early 1970s through the adoption of environmental assessment policy in 1976, to introduction of EIA legislation in 1980 (Bowden & Weichel 2005). The province of Alberta moved from policy-based EIA to regulatory-based EIA with the passing of the Environmental Protection and Enhancement Act in 1993 (Creasey & Hanna 2005).

At first EIA was practiced regionally in Canada, assessing northern development initiatives such as the proposed McKenzie Valley pipeline (Gibson & Hanna 2005). Regional application has continued for claims-based assessments, such as the Northeastern Quebec Agreement and the Inuvialuit Final Agreement, but has been virtually lost for project-based assessments conducted under the *Canadian Environmental Assessment Act* (CEAA). Under CEAA, environmental assessments are conducted on a project-by-project basis for developments that trigger its application. Project proponents are permitted under section 16.2 of CEAA to consider regional studies conducted outside of CEAA, particularly when addressing cumulative effects, but ‘regional EIA’ is not required under the act (see CEAA 1992).

Soon after the inception of EIA, environmental organizations, the public, and regulators recognized that the accumulating impacts from several projects, where each one was approved separately, were not being taken into account (Noble 2006). The U.S. response was to legislate a requirement to assess cumulative effects (US CEQ 1978). The Canadian response, seven years later, was to launch a study through the Canadian Environmental Assessment Research Council (CEARC) to determine what aspects of cumulative effects should be further studied (Sonntag et al. 1987, Peterson et al. 1987). It is interesting to note that scholars planning the research were concerned with particular difficulties identified in EIA practice that remain issues today, including limited geographic and temporal scales, lack of regional planning, the need for a more multidisciplinary approach, and ineffective monitoring (Sonntag et al. 1987, Duinker & Greig 2006). The resulting research prospectus was followed up with studies that clarified the purpose of CEA, and examined the strength of science used for CEA (see Spaling & Smit 1993, Smit & Spaling 1995). These studies were completed after the introduction in 1992 of the federal CEAA, with its requirement to conduct CEA within the scope of project-based EIA. Legislation in Alberta in 1993 also enshrined the requirement for conducting CEA within provincial EIA. Saskatchewan does not formally require CEA within EIA although guidelines under the act recommend consideration of cumulative impacts (Sheelanere 2010).

2.1. Nature of Cumulative Environmental Effects

Cumulative effects are “the accumulation of human-induced changes in VECs across space and over time that occur in an additive or interactive manner” (Spaling 1997, cited in Noble 2006: 158). An example of additive effects is the accumulation of phosphorous, a stressor, along a river continuum, where the VEC is surface water quality. The incremental addition of phosphorous through sheetwash of agricultural fields, run-off from livestock feeding areas, discharge of industrial cooling water and effluent releases from municipal wastewater treatment contribute to a cumulative phosphorous loading. The stress from phosphorous accumulation may interact with other stressors to surface water quality such as atmospheric deposition of heavy metals, thermal loading from industrial cooling, and groundwater transport of landfill leachate. When these stresses impact the same reach of a river at the same time, they may have a synergistic cumulative effect on water quality and aquatic life.

The practice of CEA, however, is more than assessing current conditions and monitoring what has already happened, it is also about examining the implications of potential future stress and interactions. Under CEAA, for example, when cumulative effects are assessed there is a requirement that anticipated future actions and impacts must be included. Similarly, cumulative effects are defined in the Cumulative Effects Assessment Practitioner’s Guide (Hegmann et al. 1999: 3) as “changes to the environment caused by an action in combination with other past, present, and future actions”.

2.1.1. Role of VECs in Assessing Cumulative Effects

Spaling (1997, cited in Noble 2006) defines cumulative effects in terms of changes in VECs. While the term VEC is not used in the CEAA, VECs have supposedly formed the backbone of environmental assessment practice in Canada since they were introduced to the environmental assessment lexicon by Beanlands and Duinker in 1983, in response to a general frustration that EIA practice was investing too much in data collection on too many aspects of the environment with insufficient analysis of the effects on key environmental components. The VEC-centered approach to EIA was subsequently promoted for CEA through the adoption of the Cumulative Effects Assessment Practitioners Guide (Hegmann et al. 1999) by the Canadian Environmental Assessment Agency. Under the VEC-based model, environmental assessment begins with a scoping phase where both scientific expertise and social evaluation are used to identify the biophysical and socio-economic environmental components that will be the focus of assessment: those environmental components most likely to be affected by the proposed project, and those with high social or analytical value. Impacts to biophysical components are assessed first, and consequent impacts to socio-economic components resulting from changes in the biophysical components are then considered. In theory, attention is focused on indicators of significant ecological change rather than on all ecological change, producing quality results tailored to social values, while avoiding unnecessary time and resource investment. One problem with this approach, from a cumulative effects perspective, is that incremental impacts may be missed for the VECs that are not highly valued for a particular project (Baxter et al. 2001, Contant & Wiggins, 1991). Hegmann et al. (1999) therefore recommended the adoption of distinct CEA VECs, and also of VECs established on a regional scale. The importance of regional VECs for CEA has been highlighted in subsequent studies, such as the review of the Transboundary Crown of the Continent Manager's Partnership regional cumulative effects assessment (Harriman & Noble 2009) that noted a tendency in practice to move toward the identification of VECs that could act as regional indicators of ecosystem health.

2.2. State of CEA in Canadian Watersheds

There are limits to the effectiveness of CEA conducted within project-based EIA. Recent studies clarified some of the underlying issues and highlighted a continuing concern regarding the varied scales of assessment required for CEA and the difficulty of addressing them within EIA. The following sections examine the conflicts of scale, and an emerging challenge related to the assessment of cumulative effects in the aquatic environment.

2.2.1. Limits of Project-Based CEA

The only regulatory requirement for CEA in Canadian watersheds is within project-based EIA, where it is employed one development project at a time, and where it is generally seen as ineffective (Duinker & Greig 2006, Spaling & Smit 1993). There are serious obstacles to CEA conducted only within the context of individual projects. These are summarized by Duinker and Greig (2006) as follows: 1) an inability of proponents to access information about other developments; 2) an interest by proponents in minimizing the scope of assessment for increased efficiencies; 3) insufficient background analysis and understanding of thresholds; 4) a tendency to discount effects that are not seen as significant for the project under consideration; 5) a failure to embrace a quantitative and systems oriented approach; and 6) a failure to consider the full range of potential future conditions. Difficulties with a project based approach to CEA were first discussed in the 1980s in studies sponsored by the CEARC, when the role of science and the institutional requirements for CEA were first considered in Canada (Smit & Spaling 1995, Sonntag et al. 1987). There has since been a consistent message in the literature that CEA can not work if it is limited to individual projects in its scale of application (Therival & Ross 2007, Duinker & Greig 2006, Spaling & Smit 1993, Sontaag et al. 1987).

2.2.2. Regional Imperative

Studies by the CEARC highlighted the difficulty of conducting CEA without adopting a regional approach (Sontag et al. 1987, O’Riordan et al. 1988), but Spaling and Smit (1993) went further in emphasizing the regional imperative by suggesting that the essential purpose of CEA has always been to move EIA to a regional application. CEA is intended to capture the shortcomings inherent in project-based EIA related to its limited scale of application, and must therefore be practiced regionally. A number of advantages to adopting a regional approach to CEA have been identified in the literature. First, the regional scale would provide a framework for capturing the incremental impacts that are not addressed within project-based EIA (Grzybowsky & Associates 2001). Second, regional CEA would accomplish the long-standing need of establishing a regional presence for EIA that would complement regional planning, promote sustainable development, and provide an opportunity for strategic environmental assessment (Spaling & Smit 1993, Noble 2003, Harriman & Noble 2008). Third, the regional scale is best situated for identifying cumulative assessment and management priorities, understanding ecological limits and developing thresholds (Rees 1995, Braat 2001, Kilgour et al. 2006). Fourth, a regional database would ameliorate the proponent's burdens of defining current baseline conditions and accounting for projects planned by others (Grzybowsky & Associates 2001, Creasey & Ross 2005, Bérubé 2007, Antoniuk 2008). Fifth, the science of CEA and EIA could be enhanced through use of a regional database (Dubé 2003, Kilgour et al. 2006). Sixth, assuming that adequate governing capacity is provided, regional CEA would support improved monitoring and follow-up, which have been identified as persistent weaknesses within EIA (Sadler 1996, Baxter et al. 2001, Duinker & Greig 2006). In recognition of the value of a regional perspective for CEA, section 16.2 of the CEAA was amended in 2003 to allow that the results of "regional studies" may be used to inform CEA within project-based EIA.

2.2.3. Watershed Based and Regional Assessments

One of the earliest environmental assessments conducted in Canada, the *ad hoc* Churchill River Study, was conducted using a multidisciplinary approach within watershed boundaries, and considered a wide range of aquatic VECs, including climate, water quantity (flow and levels), aquatic ecology, plankton, primary production, fisheries, sediments, and water quality (CRSB, 1975). The watershed framework has more recently come back in favour in the provinces of Saskatchewan and Alberta where there is increasing momentum toward assessment and management of aquatic impacts within watershed boundaries. Watershed-based source water protection planning is one such initiative in Saskatchewan, under the direction of the Saskatchewan Watershed Authority (see SWA 2008). The SWA is also developing state-of-the-watershed indicators used to identify trends on a watershed scale (SWA 2006). The Water for Life strategy in Alberta supports the development of integrated watershed management plans that address cumulative effects (see NSWA 2011). Further, cumulative effects were also recognized by a collaboration of 40 rural and urban municipalities and one First Nation in the South Saskatchewan River watershed in the development of the regional Waterwolf Growth Management Plan (2008). See Sheelanere (2010) for additional reading on governance and the roles of different agencies engaged in watershed scale assessment and river system management in Alberta and Saskatchewan.

In response to public concerns over the environmental impacts of development, a number of regional CEAs have been conducted in Canada outside of project-based EIA and the regulatory environment. In southwest Saskatchewan, for example, a regional cumulative assessment of land use activities, including natural gas development, roads and trails, recreation, and cattle grazing, was conducted in Great Sand Hills of Saskatchewan (see Noble 2008). Similarly, proponents in the bitumen sands region of Alberta also have driven the formation of a regional framework for managing the cumulative effects of energy development (Spaling et al. 2000).

There have also been several formal CEA-based initiatives conducted within the context of watersheds, and using watersheds as boundaries. The Moose River Basin study (Munkittrick et al. 2000, cited in Dubé et al. 2006), the Northern Rivers Basin Study (Culp et al. 2000) and the Northern Rivers Ecosystem Initiative (Dubé et al. 2006) were *ad hoc* assessments that together have created a foundation for watershed-based CEA. Subsequent studies have advanced the scientific capacity for conducting WCEA (Kilgour et al. 2006, Squires et al. 2010, Seitz et al. 2011) and new research is emerging to addresses institutional requirements for WCEA (Dubé 2007, Sheelanere 2010).

There is now a convergence of thought in academia, government, and business that CEA must go regional, and there is some momentum for the adoption of watersheds as regional boundaries when the focus of concern is on cumulative effects to aquatic systems. A watershed framework will allow a more proactive approach to CEA than what can be accomplished through project-based EIA alone. It will provide the opportunity to capture direct and indirect effects from activities in the watershed, and can be used to inform subsequent project-based impact assessment and development decisions.

2.2.4. Sharing Information between Assessment Scales

The assessment of cumulative effects must be conducted beyond the scope and scale of the individual project to be effective, and it must, under federal and provincial regulatory requirements, also be conducted at the scale of individual projects. It follows, therefore, that it would be desirable to exchange information between the regional and project scales of assessment (Boulden et al. 2000, Noble 2003). From the perspective of CEA science, this means connecting the stressor-based assessment approach used in project-scale EIA with the effects-based assessment approach used in watershed-based CEA science initiatives (Beanlands & Duinker 1983, Culp et al. 2000, Seitz et al. 2011). There is potential to leverage the complementary natures of stressor-based science and effects-based science to advance CEA science and our understanding of ecological cause-effect mechanisms (Dubé 2003).

Stressor-based science quantifies known environmental stresses, such as chemical loadings to the aquatic environment, and predicts consequent impacts on VECs (Beanlands & Duinker 1983). Effects-based science measures the condition of VECs, such as benthic invertebrates and fish in the aquatic environment, using condition indicators like community diversity and fish liver size and then works backwards to try to identify related sources of stress impacting those VECs (Kilgour et al. 2006). If WCEA can support the flow of information between the two approaches in science, then there will be increased opportunity to identify cause-effect relationships or associations that will in turn support improved prediction of impacts from projects and improved identification of stressors affecting watersheds (Dubé 2003). The identification of cause-effect mechanisms is considered essential for the advancement of CEA generally (Bérubé 2007, O'Riordon et al. 1988) and for WCEA (Reid 1993). In particular, if information can be exchanged in a quantitative capacity between the effects-based science currently used in watershed-based CEA and the stressor-based science used in project EIA, through the use of standard indicators, then relationships can be more easily identified (Kilgour et al. 2006). Thus, advancing watershed CEA will require the development of a shared and standard set of stressor-based and effects-based indicators.

As noted above, one of the challenges to CEA is identifying the VECs and indicators that should be considered in each assessment and at each scale of assessment (Hegmann et al. 1999). We should expect that WCEA will establish a set of regional VECs and indicators that will apply across the watershed and at the same time be responsive to the individual project scale (see Seitz et al. 2011). It is not clear, however, whether the VECs and indicators currently used in project-based EIA could be ‘scaled up’ to the watershed-scale. One of the challenges is that no studies have been conducted that look at the aquatic VECs and indicators used in project-based EIA or to consider their usefulness for watershed-based CEA.

2.3. Summary

The practice of CEA is intended to address environmental impacts that are often overlooked, or inadequately assessed, in project-based EIA. In the context of Canada’s watersheds, there is momentum building toward the establishment of a regional framework for CEA using watershed boundaries and with a focus on aquatic ecosystems. Watershed CEA will be tasked with sharing information between assessments at both the project scale and the regional scale, as well as between stressor-based and effects-based science. A standard set of VECs and common indicators are needed to facilitate information flow within a WCEA framework. Such VECs and indicators may already be in use within EIA practice, but no studies have examined the common assessment components and aquatic indicators used in EIA for the aquatic environment, nor the possibility that they may be useful if scaled up to the watershed scale.

CHAPTER 3

METHODS

The results presented in this thesis are based on a review of 35 environmental impact statements (EISs), selected to represent the geographical, jurisdictional, and developmental scope of the South Saskatchewan River watershed. The research methods generally followed the semi-quantitative approach employed by Burris and Canter (1997) and adapted by Atkinson et al. (2000) in their respective reviews of EISs, conducted in different contexts. An iterative series of qualitative readings of the documents provided a framework for identifying and categorizing data, and was interspersed by iterations of quantitative analysis. The research combined an inductive process used to establish a conceptual basis for comparison of content across EISs, a quantitative review of content across assessments, and an analysis of the quantitative findings.

3.1. Study Area

The headwaters of the South Saskatchewan River begin at the continental divide that separates the provinces of British Columbia and Alberta in Canada, and run through the eastern slopes and foothills of the Rocky Mountains (Figure 3.1). The river is fed mainly from the annual snow pack, although depleting glaciers in the headwaters, and a small groundwater component in the prairie lowlands augment the late summer flow (Halliday 2009). The watershed includes most of southern Alberta below the city of Red Deer, a small piece of northern Montana, and a swatch of central Saskatchewan running from the southwest of that province, up through the city of Saskatoon to the junction with the North Saskatchewan River near St. Louis. There is a large urban population in the watershed that includes the cities of Calgary and Saskatoon.

Land use in the watershed is primarily agricultural: cropland, grassland and forage (Martz et al. 2007). Intensive livestock operations and crop irrigation, mostly located in the southern Alberta portion of the watershed, consume more water than municipal, industrial, and power generation uses combined. Electrical power is generated in two coal-fired facilities at Hanna and Medicine Hat, and at a number of hydro generating stations, the largest of which is located on Lake Diefenbaker. Industry includes mining of metals, non-metals, coal and minerals, as well as oil and gas production, forestry, and manufacturing. The manufacturing sector produces packaged food and drink, chemicals, primary metals, rubber, plastic, equipment, paper, wood, and fabricated metal. Municipal sewage is introduced to the river systems from Calgary, Saskatoon, Lethbridge, Red Deer, Medicine Hat, Swift Current and several smaller communities.

The watershed has a complex jurisdictional structure that includes the federal, two provincial, and several regional quasi-governmental organizations, such as watershed advisory committees, with different regulatory roles. Water use is substantial, with irrigation allotments on the Alberta side making heaviest demand. Under the Prairie Provinces Water Board Master Agreement on Apportionment, 50% of flow must be passed on from Alberta to Saskatchewan. In dry years this is a management challenge (Schindler & Donahue, 2006). Summer flow is augmented by dams on the headwaters in Alberta. In Saskatchewan, the river provides water for irrigation, industry, and domestic use for a significant proportion of the province's population (Martz et al. 2007). Activities in the watershed have contributed to a history of screening-level EIA applied to many different types of development.

3.2. EIS Selection

The governments of Canada, Alberta and Saskatchewan all conduct environmental assessments in the South Saskatchewan River watershed. Projects with federal funding or other regulatory triggers, that are not excluded from assessment, must be assessed under the CEAA; in Alberta, the Ministry of Environment and other provincial agencies assess projects that trigger the *Environmental Assessment (Mandatory and Exempted Activities) Regulation*, or that draw the interest of the Environment Ministry (Alberta Environment 2010); and the Environmental Assessment Branch in Saskatchewan conducts assessments as required upon review of proposed projects under the *Saskatchewan Environmental Assessment Act* (Government of Saskatchewan 2009). In Saskatchewan, projects are routinely screened out from the formal assessment process through the submission of environmental protection plans (EPPs) along with development proposals (see Government of Saskatchewan 2009). While it could be argued that the Saskatchewan EPPs may be considered equivalent in nature to the federal screening assessments, they have not been included in this study; only formal EISs from Saskatchewan were reviewed. In Alberta, only large development projects have typically been assessed and relatively few EISs have been produced within the South Saskatchewan River watershed (see Alberta Environment undated).

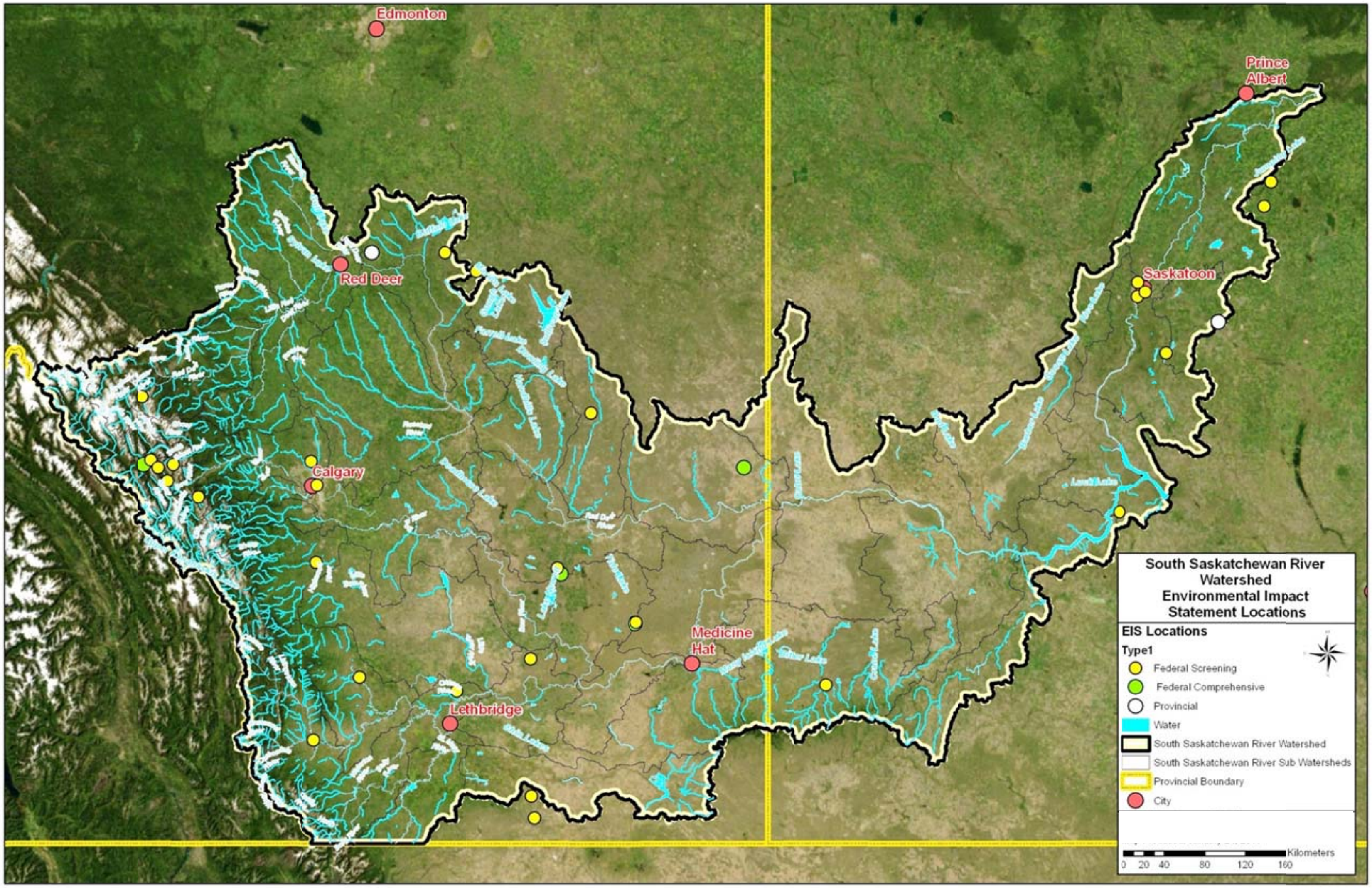

Figure 3.1: Study area showing the South Saskatchewan River Watershed with Provincial and international borders and sample environmental impact assessment locations

Overall, only a limited number of EISs have been produced in the watershed under provincial authority[1]. Most of the EISs identified within the watershed were federal assessments and the preponderance of federal assessments is reflected in the EIS selection.

Nearly 100 times more federal screening assessments have been completed in the watershed than the more rigorous comprehensive study or panel review assessments. Federal screening assessments are defined as a systematic approach to identifying the environmental effects of a proposed project and to determining the need to mitigate adverse effects (CEAA 2005). Federal screening assessments are used for routine undertakings that are not expected to generate significant adverse effects. The results of a screening assessment may lead to further assessment through mediation or a review panel. Federal comprehensive study assessments are more stringent than screening assessments and are typically used for large scale or complex projects likely to have significant adverse effects (CEAA 2005). Federal mediation and review panel assessments differ from comprehensive assessments in being advisory rather than decision-making processes and are conducted by an authority independent of government. Recognizing the nature of cumulative effects, described by Noble (2003) as the consequence of a tyranny of small decisions, this study concentrated primarily on screenings - the most numerous, and least rigorous, form of federal assessment. Representative numbers of provincial, harmonized provincial/federal and federal comprehensive studies were also included (see Table 3.1).

A judgemental sampling approach was used to select impact statements with an apparent connection to the aquatic environment; to represent the geographic diversity of the watershed; and to represent the range of project categories listed in the Canadian Environmental Assessment Registry (CEAR). Most of the EISs included in the study were completed between 2003 and 2007, although it was necessary to collect comprehensive studies from as early as 1998 to provide a sufficient sample size, and an Alberta provincial assessment from 1996, the most recent year available. The EISs were organized into two categories: ‘screening type assessments’ that

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[1] See the Alberta Environment List of Completed EIAs http://environment.alberta.ca/1274.html, the Saskatchewan Environmental Assessment Mapping Application http://www.environment.gov.sk.ca/Default.aspx?DN=41b56f8e-b563-4457-91ae-02a984317ee6, and the Canadian Environmental Assessment Registry http://www.ceaa-acee.gc.ca/050/index_e.cfm.

included both provincial assessments and federal screening assessments; and ‘comprehensive type assessments’ that included federal comprehensive study and panel review assessments (see Table 3.1).

Table 3.1: Study sample of environmental impact statements from the South Saskatchewan River watershed

EIS #	Title	CEAR Category*	Authority**	Year	Type
1	Rancher’s Beef Abattoir	Agriculture	AAFC	2005	screening
2	Fuel Tank Installation	Product and Waste Management	AAFC	2005	screening
3	Manure Storage and Handling	Product and Waste Management	AAFC	2007	screening
4	WEB Watershed Evaluation of BMPs	Water Management	AAFC	2004	screening
5	Wakaw Lake Water Distribution System	Water Management	WD	2004	screening
6	Maple Creek Dam Rehabilitation	Water Management	AAFC	2005	screening
7	Riverhurst Irrigation Expansion	Water Management	AAFC	2006	screening
8	Barrier Lake flow Manipulation	Water Management	DFO	2006	screening
9	Tipple Mine Site Remediation	Remediation Contaminated Land	DFO	2007	screening
11	Dormer Prescribed Burn	Forestry	PCA	2005	screening
12	Fairholme Range MPB Control	Forestry	PCA	2006	screening
13	Berry Creek Dam Rehabilitation	Dams, Weirs, Reservoirs	TC	2007	screening
14	Wakaw Lake Water Control Structure	Dams, Weirs, Reservoirs	DFO	2004	screening
16	Nose Creek Realignment	Aquaculture	DFO	2005	screening
20	Remediation Former Fire Training Area	Contaminated Sites	TC	2004	screening
22	City of Saskatoon Raw Water Intake	Dredging, filling, etc.	DFO	2007	screening
23	Bridge Replacement Over Crowsnest River	Bridges and Culverts	TC	2006	screening
25	Overhaul of Cascade Generating Unit	Hydroelectric Energy	PCA	2007	screening
26	IPS Factory Licence	Industrial	NRC	2005	screening
27	Western Bio-Diesel	Industrial	AAFC	2007	screening
28	Enchant Arcs CO_2 Enhanced Oil Recovery	Industrial	NRC	2004	screening
29	Improved Manure Storage and Handling	Agriculture	AAFC	2006	screening
32	Irrigation Management	Agriculture	AAFC	2006	screening
33	Fine Tailings Management Area	n/a	SK	2006	screening
34	Proposed Joffre Expansion Project	n/a	AB	1996	screening
35	Carrot Creek Prescribed Burn	Alteration of Flora, Fauna or Soil	PCA	2006	screening
36	Proposed Backshore Marina	Alteration of Flora, Fauna or Soil	DFO	2006	screening
37	Carwash Facility at Ralston	Building and Property Development	DND	2004	screening
42	Saskatoon Regional Waste Management Center Upgrade	Solid Waste, Provincial	WD and SK	2003	screening

45	230 kilovolt International Power Line	Industrial	NEB	2006	screening
47	Brooks Power Project	n/a	CEAA and EUB	2002	comprehensive
48	Encana Shallow Gas Infill Development	n/a	CEAA and DND	2007	comprehensive
49	Alliance Pipeline	n/a	CEAA	1998	comprehensive
50	Valley South Water	n/a	CEAA	1999	comprehensive
51	Banff Airstrip Decommissioning	n/a	CEAA	2005	comprehensive

* CEAR category refers to the 'project descriptor' used in the Canadian Environmental Assessment Registry to identify projects of similar natures. Only Screening type assessments are assigned project descriptors in the registry.

** Authority means responsible authority and refers to the federal or provincial government ministry or agency charged with overseeing the assessment process and ultimately approving the assessment.

AAFC - Agriculture and Agri-Food Canada
AB – Province of Alberta (Ministry of Environment)
CEAA – Canadian Environmental Assessment Agency
DFO – Department of Fisheries and Oceans
DND – Department of National Defence
EUB - Alberta Energy and Utilities Board
NEB – National Energy Board
NRC – Natural Resources Canada
PCA – Parks Canada Agency
SK – Province of Saskatchewan (Ministry of Environment)
TC – Transport Canada
WD – Western Economic Diversification Canada

3.3. EIS Procurement

Even though all impact statements were made available to the public during their respective assessment processes, they were not easily accessed afterward. A number of approaches were employed in this review to secure the selected EISs, with mixed success. Approximately 25% of the EISs targeted for review were not made available, mainly due to proponent reluctance to share documents combined with limited support and effectiveness of some responsible authorities. Another 6% were collected but not included in the review due to limited content, duplication of similar projects not linked to the aquatic environment, or because they were received after the document analysis process was initiated.

Direct appeals to obtain EISs from proponents were generally successful for larger industrial projects, and generally unsuccessful for municipal and small scale private developments. The projects where the proponent was forthcoming were generally ones completed by a third party consultant for a corporate client. Two private developers who had conducted their own assessments under the guidance of a federal responsible authority explained that they would not object if a copy of the EIS could be secured through another party, but that it was not a sound business decision to share the document directly. The responsible authority is the (usually federal) government department or agency responsible for ensuring that an EIA is conducted and that the results are considered when deciding whether the government will provide support to the project (CEAA 2005).

Provincial assessments conducted in Saskatchewan were available online, and in Alberta were available at the government library in Edmonton, although assessments conducted before the establishment of the province’s publicly available electronic directory were not listed. A contact in Alberta Environment was able to share an internal departmental list of older EISs that were physically available in the government library though they were not listed in the online catalogue. For federal assessments, the Canadian Environmental Assessment Agency indicated that it did not maintain an archive of completed EISs and that each federal department had its own retention policy for completed EISs (Pasqual 2009 pers. com.).

Most of the EISs sampled were eventually secured through the federal government departments and agencies that were identified as the responsible authority for the respective assessments. The National Energy Board (NEB) was the one federal authority that maintained an archive of completed EISs, available online with full sets of supporting documents. Inquiries with the Department of Fisheries and Oceans (DFO) were eventually directed to the regional CEAR coordinator who managed to secure most of EISs requested even though they were not part of the central archive and the documents had to be collected from local offices. Similarly Agriculture and Agri-Food Canada (AAFC) delegated a staff member to review scattered files in support of this project and most of the requested EISs were eventually located and forwarded. It required three months of active soliciting to collect the sample of EISs used in this study.

3.4. Document Content Analysis

Consistent with the scope of ‘environment’ under CEAA (1992), this study is limited in scope to biophysical VECs. Section 2.(1) of CEAA defines an environmental effect as:

> *(a) any change that the project may cause in the environment, including any change it may cause to a listed wildlife species, its critical habitat or the*

> *residences of individuals of that species, as those terms are defined in subsection 2(1) of the Species at Risk Act,*
>
> *(b) any effect of any change referred to in paragraph (a) on*
>
> > *(i) health and socio-economic conditions,*
> >
> > *(ii) physical and cultural heritage,*
> >
> > *(iii) the current use of lands and resources for traditional purposes by aboriginal persons, or*
> >
> > *(iv) any structure, site or thing that is of historical, archaeological, paleontological or architectural significance, or*
>
> *(c) any change to the project that may be caused by the environment,*

Environment effects in CEAA are understood first as changes in biophysical environmental components and second as consequent changes in social and economic environmental components. This study is limited to the first step in understanding environmental effects and focuses only on biophysical VECs.

Both qualitative and quantitative methods were used in the EIS document analysis. A number of thematic analyses identified and categorized the aquatic ecosystem components that were assessed and their respective indicators, as well as the sources of stress to water quality and their respective indicators. The thematic analysis was conducted by examining all EISs in an iterative review process, with the conceptual findings of each round of analysis informing subsequent rounds. Objectives (i) and (iii), the identification of VECs and aquatic VECs, were pursued through a thematic analysis that supported the adoption of a standard hierarchical framework for identifying and comparing assessment components and measurable parameters across projects. Empirical analysis was then used to examine how frequently individual aquatic ecosystem components were assessed (objective (ii)); how frequently indicators were used for aquatic ecosystem components and water quality stressors; and to rate EIS capacity to satisfy quantitative watershed CEA measurement requirements.

The first part of objective (iv), considering whether the aquatic VECs used in EIA should be used in WCEA, was addressed by examining factors affecting the selection of aquatic VECs in EIA practice in the South Saskatchewan River watershed. The second part of objective (iv), considering whether the indicators used in EIA for aquatic VECs may be useful for WCEA, was addressed by first identifying and categorizing the indicators used for the four water VECs (surface water quality and quantity and groundwater quality and quantity), then comparing the measurable parameters used for assessing surface water quality and surface water quantity across project classes, and finally considering the effectiveness of the quantitative assessment of those parameters. The impact statement thematic review was an inductive and iterative process where observations made in each round of review were used to inform and frame subsequent rounds of review until the study objectives were addressed. The themes identified and frameworks adopted through the document review process are presented with the results in Chapter 4.

CHAPTER 4
RESULTS

Conventions, definitions and organizational frameworks adopted through the document review process are described in this chapter along with the quantitative and analytical results for each study objective, beginning with objective (i), the identification of biophysical VECs, proceeding through objectives (ii) and (iii), combined as the frequency of aquatic VECs, then addressing objective (iv) with an analysis of the use and selection of aquatic VECs and indicators. The results conclude with an analysis of how indicator parameters were measured.

4.1. Identifying Biophysical VECs

The impact statements were first reviewed for their frequency of use of the term ‘valued ecosystem component’ or ‘VEC’ (Table 4.1). Three comprehensive type assessments conducted after 1999, the year that the Canadian Environmental Assessment Agency adopted the Cumulative Effects Assessment Guide (Hegmann et al. 1999), used the term VEC, but two earlier comprehensive assessments, from 1998 and 1999, did not. Only 10% of the screening assessments reviewed used the term ‘VEC’ even though 97% were conducted after 1999: Agriculture and Agri-Food Canada (AAFC) used ‘VEC’ in the Rancher’s Beef Abattoir project (Table 3.1, EIS # 1) and it was incorporated into the checklists used in two other federal screening assessments, one conducted by Transport Canada (TC) and the other by the Department of National Defence (DND) (see Table 3.1, EIS # 20 and EIS # 37 respectively). The term VEC was used in only 17% of the EISs reviewed overall.

Impact statements were next reviewed for terms similar in meaning to VEC. VEC-equivalent terms, often identified in the baseline sections of the EISs reviewed or used as headings in the impact analysis sections, were found in approximately 40% of assessments as follows: ‘environmental component’ (14%); ‘relevant environmental factor’ (14%); ‘environmental factors’ (5%); ‘environmental features’ (3%); and ‘biophysical elements’ (3%). Some responsible authorities were generally consistent in the VEC-equivalent terminology used, for example AAFC used the term ‘relevant environmental factor’ in all but one assessment. Screening assessments by the Department of Fisheries and Oceans (DFO), on the other hand, often did not explicitly identify VECs or use VEC-equivalent terminology.

Table 4.1: Screening and comprehensive type assessments that used the term 'VEC' as identified in a review of 35 EISs completed between 1996 and 2007 in the South Saskatchewan River watershed

Year EIS Submitted	Screening Type Assessments																														Comprehensive Type				
1996																							x												
1998																															x				
1999																																x			
2002																																	✓	✓	
2003																										x									
2004			x	x								x							x										✓	✓					
2005	x				x				x				x				x											✓							✓
2006						x	x			x				x	x					x	x	x		x	x		x								
2007		x						x			x					x		x																	
Responsible Authority	AAFC	AAFC	AAFC	WEDC	AAFC	AAFC	DFO	DFO	PCA	PCA	TC	DFO	DFO	DFO	TC	PCA	NRC	AAFC	NRC	AAFC	AAFC	SK	AB	PCA	DFO	SK/WD	NEB	AAFC	TC	DND	NEB	AAFC	AB/DFO	DND	PCA
EIS number	2	3	4	5	6	7	8	9	11	12	13	14	16	22	23	25	26	27	28	29	32	33	34	35	36	42	45	1	20	37	49	50	47	48	51

Natural Resources Canada	NRC	Province of Saskatchewan	SK
Agriculture and Agri-Food Canada	AAFC	Western Economic Diversification	WD
Department of Fisheries and Oceans	DFO	Department of National Defence	DND
Transport Canada	TC	National Energy Board	NEB
Parks Canada Agency	PCA	EIS did not use the term 'VEC'	x
Province of Alberta	AB	EIS did use the term 'VEC'	✓

The remaining 43% of EISs, including two comprehensive assessments, did not use the term 'VEC' or its equivalents. The comprehensive study report for the Valley South Co-op Ltd. Water Pipeline project (see Table 3.1, EIS # 50), for example, discussed impacts to terrestrial wildlife and habitat, but neither wildlife nor habitat was labelled as a VEC or as a VEC-equivalent. It was not possible to compare the environmental components that were the focus of investigation across projects by looking only at VECs and VEC-equivalents.

4.1.1. Impact Analysis Components

Disregarding what were labelled as VECs or VEC-equivalents, the biophysical environmental components that were actually identified and discussed within the impact analysis, mitigation and monitoring sections of the EISs reviewed were consolidated and are referred to in this study as 'impact analysis components'. The impact analysis components were generally more consistent across assessments than VECs or VEC equivalent terms. For example, 'surface water' was used as a VEC-equivalent in the Improved Manure Storage and Handling Project (Table 3.1, EIS # 29), but it was impacts to ‘surface water quality’ and ‘surface water quantity’ that were actually discussed in the analysis section of the EIS. Similarly, in the Rancher’s Beef Abbatoir EIS (Table 3.1, EIS # 1), ‘water’ was identified as a VEC, but ‘surface water quality’, ‘surface water quantity’, and ‘groundwater quality’ were the terms used in discussing potential impacts to water. Even though many terms were identified as VECs and VEC-equivalents for water, all EISs assessing water ultimately discussed impacts to four impact analysis components: surface water quality, groundwater quality, surface water quantity, and groundwater quantity. Only one EIS explicitly identified surface water quality as a VEC, but 30 of 35 EISs used surface water quality as an impact analysis component (see Table 4.2).

Table 4.2: Frequency of occurrence of the terms used to describe the water-related environmental components assessed in 35 EISs from the South Saskatchewan River watershed

Water Components		
VEC	**VEC-Equivalent**	**Impact Analysis Component**
Water (1)*	Water Resources (1)	
Hydrological Resources (1)	Groundwater Resources (2)	
Groundwater (2)	Groundwater (1)	
	Surface Water (3)	
	Small, Un-Named Streams (1)	
	South Saskatchewan River (2)	
	Hydrology (3)	
	Hydrogeology (2)	
	Surface Hydrology	
Surface Water Quality (1)	Water Quality (2)	Surface Water Quality (30)
Groundwater Quality (1)		Groundwater Quality (16)
Surface Water Quantity (1)	Water Quantity (1)	Surface Water Quantity (15)
Groundwater Quantity (1)		Groundwater Quantity (8)
* Indicates actual number of EISs using component		

4.1.2. VEC Hierarchy and Inconsistency

Across EISs, the VECs or VEC-equivalents used for similar environmental components varied in the level of detail used to describe the components. The broad term *water* was used as a VEC (Table 4.2) in one EIS (the Rancher’s Beef Abattoir project, Table 3.1, EIS # 1), for example, whereas the more specific term *groundwater* was used as a VEC in two EISs (Table 3.1, EIS # 20 and EIS # 37) and the even more specific and detailed terms *groundwater quality* and *groundwater quantity* were VECs in another single EIS (the Encana Shallow Gas Infill

Development Project, Table 3.1, EIS # 48). Water, groundwater, and groundwater quality can be understood as a hierarchy of increasingly more detailed descriptions of a single environmental component. The broadest term ‘water’ is at the apex of the hierarchy, and is at a level of detail that is too general to convey useful information across projects. Groundwater quality, on the other hand is sufficiently detailed and focused to support a useful comparison of similar impacts across projects. The use of components from different levels of the hierarchy contributed to mixed terminology and was another obstacle to comparing content across assessments.

Some of the VECs and VEC-equivalents identified in the EISs can be considered ‘frames of reference’ rather than actual ecosystem components. For example, terms like hydrology and hydrogeology (see Table 4.2) are scientific disciplines that frame water as an object of study. The study of water, however, may also involve other environmental components, such as soil texture and terrain slope. Ambiguity regarding the intended assessment components was created when disciplines were used as VECs. VEC terminology was also unnecessarily varied and inconsistent between assessments because indirect terms (hydrology) were used for ecosystem components referred to directly in other assessments (surface water quantity).

4.1.3. A Normative Hierarchy for Environmental Components

The variety, inconsistency and variation in the level of detail of VECs and VEC-equivalents were obstacles for the comparison of content between EISs. Accordingly, a normative hierarchy and standard nomenclature was adopted to facilitate further analysis (Figure 4.1). Ecosystem components were categorized by a hierarchy of specificity with ‘environment elements’, such as air, water and land at the top, embracing the most general level of components, and ‘VECs’, ‘VEC factors’ and ‘condition parameters’ constituting, in turn, progressively more detailed and specific sub-components. VECs are defined in the hierarchy as the impact analysis components described at the level of detail most suitable for sharing general information across assessments, following the Cumulative Effects Assessment Practitioners Guide observation that “VECs represent the investigative focal point of any EIA or CEA.” (Hegmann et al. 1999: 12). VEC factors are sub-components of VECs that are not specific enough to be measured directly. Condition parameters, the ecosystem components at the most detailed level, are components that can actually be measured. VECs and VEC factors and condition parameters are all biophysical environmental components in this framework. Condition parameters are defined here as things that can be measured to provide direct information about the condition or state of biophysical environmental components.

Secondary condition parameters represent the condition of a second VEC impacted by changes in a first VEC. In the Joffre Ethylene Expansion Project (Table 3.1, EIS # 34), for example, the condition of the VEC *aquatic life*, as represented by the condition parameter *algal abundance*, was predicted to be impacted by changes in the VEC *surface water quality*, specifically by changes in the surface water VEC factor *nutrients* (see Figure 4.2). The addition of nutrients was predicted to change surface water quality, which in turn was predicted to affect algal abundance. The relationship between the two VECs (surface water quality and aquatic life) was leveraged as an assessment tool, and algal abundance was used as a surrogate for nutrient concentrations to indirectly represent the condition of surface water quality. Algal abundance was used both as a secondary condition parameter for surface water quality and as a condition parameter for aquatic life.

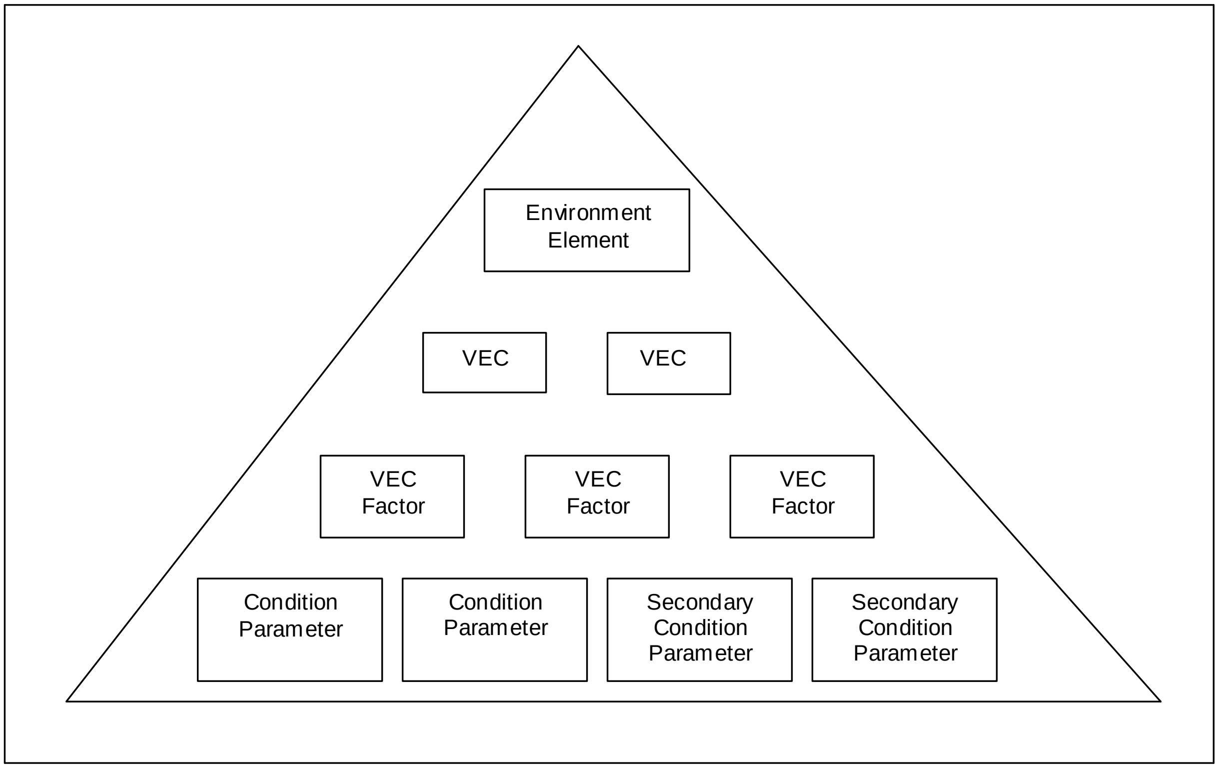

Figure 4.1: A normative hierarchy for biophysical environmental assessment components

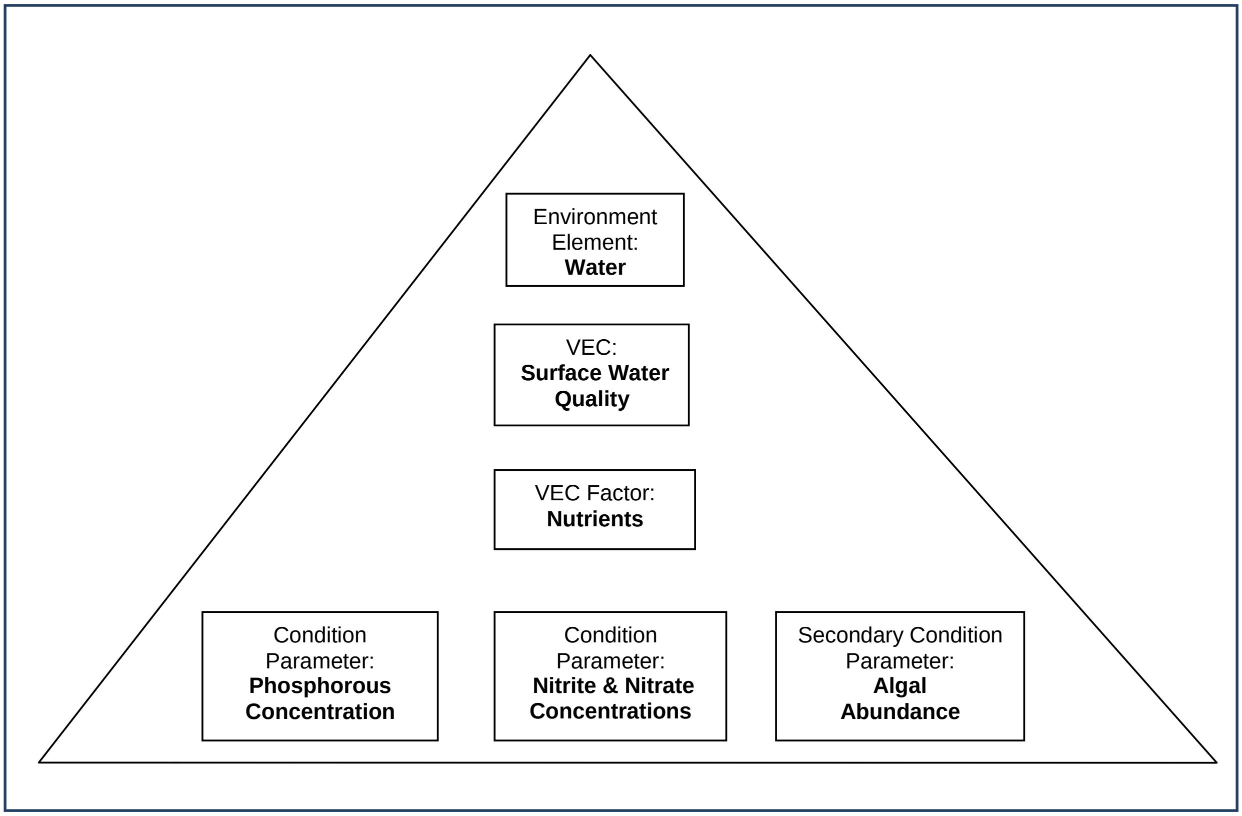

Figure 4.2: Application of normative hierarchy showing condition and secondary condition parameters for the surface water quality VEC factor *nutrients*

Using the environment element ‘water’ as an example, the EIS review identified condition parameters for all VECs and for most VEC factors (see Table 4.3). The few exceptions were the VEC factors ‘surface water volume’, ‘surface water levels’, ‘groundwater nutrients’, and ‘surface water toxicity’. Regarding toxicity, it could be argued that many of the condition parameters for surface water quality, such as metal and organics concentrations, were also condition parameters of surface water toxicity, particularly since toxicity is generally the basis for establishing water quality criteria for metals and organics. Secondary condition parameters were mainly identified for surface water quality, the water VEC most often cited, and to a limited extent for surface water quantity. No secondary condition parameters were identified for groundwater.

4.2. Aquatic VECs

For the remainder of the results presented below the VECs referred to are those that were drawn from the impact analysis components identified in the EIS review, rather than from the environmental components termed ‘VECs’ per se. Aquatic VECs were identified as the impact analysis components potentially either directly affecting or directly affected by changes in water quality or quantity. Similarly aquatic VEC factors were identified as the impact analysis VEC factors potentially either directly affecting or directly affected by changes in water quality or quantity. Water VECs were identified as the aquatic VECs that are sub-components of the element water: surface water quality, surface water quantity, groundwater quality, and groundwater quantity.

The range of aquatic VECs identified in this review covered the full spectrum of environmental elements found in a standard, regulatory-based screening EIA checklist – such as that used by Transport Canada, a federal government authority. All of the VECs included in the Transport Canada standard checklist were identified as aquatic VECs in this review, with the exception of climate. Climate was identified in the checklist and as a VEC linked to green house gas production in the Brooks Power Project EIS (Table 3.1, EIS # 47), but no connection was made in the latter between climate and changes in water. Arguably there is a connection between climate and surface water quantity that is a consequence of green house gas production, and all VECs used in the standard checklist could therefore be considered aquatic VECs.

Table 4.3: Breakdown of *water* into a normative hierarchy of VECs, VEC factors, condition parameters and secondary condition parameters as identified in a review of EISs from the South Saskatchewan River watershed

Element	VEC	VEC Factor	Condition Parameter	Secondary Condition Parameter
Water (33)*	Surface Water Quality (30)	Nutrients (7)	nitrite, nitrate concentrations (5)	aquatic ecosystem health (include water chemistry, benthic invertebrate community structure and benthic algal abundance) (1)
			ammonia (1)	
			phosphorous (5)	
		Metals (4)	chromium (2)	sediment metal concentration (1)
			arsenic (3)	metal concentrations in fish tissue (2)
			lead (2)	
			boron (1)	
			aluminum (2)	
			copper (1)	
			zinc (1)	
			mercury (4)	
			cadmium (1)	
			selenium (2)	

		Suspended Solids (23)	turbidity (4)	fish behaviour & physiology (3)
			total suspended solids (23)	fish mortality (1)
				fish populations (4)
				spawning bed porosity (4)
				over-wintering habitat (1)
				benthic invertebrate populations (1)
		Oxygen (2)	dissolved oxygen (2)	
		Thermal Regime (5)	water temperature (5)	total gas pressure (1)
				over-inflation of fish swim bladder (1)
				fish health and tissue quality (1)
				fish mortality (1)
				fish populations (1)
				spawning bed porosity (1)
				invertebrate productivity, species abundance and diversity (1)
		Acidity (4)	pH; field pH (4)	
		Salinity (3)	potassium & sodium & chloride (3)	soil sodium adsorption ratio (1)
		Pathogens (2)	fish pathogen presence (1)	
			fecal coliforms (1)	
		Organics (19)	polycyclic aromatic hydrocarbons (1)	
			fuels, lubricants, hydraulic fluids & ethanol (15)	
			pesticides (1)	
			total phenolics (2)	
			pentachlorophenol (1)	
		Toxicity (2)		fish abundance (1)
				fish spawning and rearing activities (1)
				fish mortality (1)
				fish health and tissue quality (1)
				benthic invertebrate mean taxonomic richness, density, community structure (1)
	Surface Water Quantity (15)	Surface Water Level (8)		amount of nearshore fish habitat (1)
		Surface Water Volume (11)		
		Surface Water Flow (13)	stream flow rate (11)	fish mortality (2)
			stream flow velocity (1)	
			stream flow timing (1)	
			run-off volume (3)	
			run-off timing (1)	
	Groundwater Quality (16)	General Chemistry (2)	pH, conductivity, major ions, alkalinity, hardness (2)	
		Salinity (4)	sulphate (2)	
			chloride (3)	
			potassium (1)	
			sodium (2)	
		Metals (3)	mercury (1)	
			aluminum (1)	
			arsenic (1)	
			boron (1)	
			selenium (1)	

			iron (1)	
		Hydrocarbons (10)	benzene (1)	
		Nutrients (3)		
		Organics (1)	total organic carbon (1)	
			dissolved organic carbon (1)	
			pesticides (1)	
			phenols (1)	
	Groundwater Quantity (8)	Groundwater Level (3)	levels in specific aquifers (1)	
		Groundwater Volume (5)	pump test drawdown and recovery (1)	
			depth of aquifer compared to depth of drawdown (1)	
			size and location of the aquifer recharge zone (1)	
			water level trends in area wells during pump test (1)	
			aquifer extent (1)	
		Groundwater Flow (6)	vertical flow rate (1)	
			horizontal flow rate (1)	
* Indicates actual number of EISs using each component				

A wide variation was found in the frequency of aquatic VEC use. A number of aquatic VECs were linked to project activities in only one or two EISs: aquatic, community and landscape biodiversity; aquatic invertebrates; wildlife; and sediment quality (Figure 4.3). This raised the possibility that review of a larger sample size may have identified additional aquatic VECs.

The four aquatic VECs that were identified most frequently in the EISs reviewed (Figure 4.2), namely surface water quality, soil stability, fish, and fish habitat, were cited together in 15 assessments in the context of surface disturbance leading to soil erosion and the introduction of deleterious substances to surface waters, which is an indictable offence under section 36 (3) of the *Fisheries Act* (Canada 1985). Similarly, the most frequently used biodiversity aquatic VEC (species diversity) was cited in the context of the *Species at Risk Act* (Canada 2002) in all 10 EISs where it was used. VECs with the potential to expose a proponent to penalties under federal legislation were used at least twice as frequently as any other aquatic VEC for five of the six environment elements identified in the review.

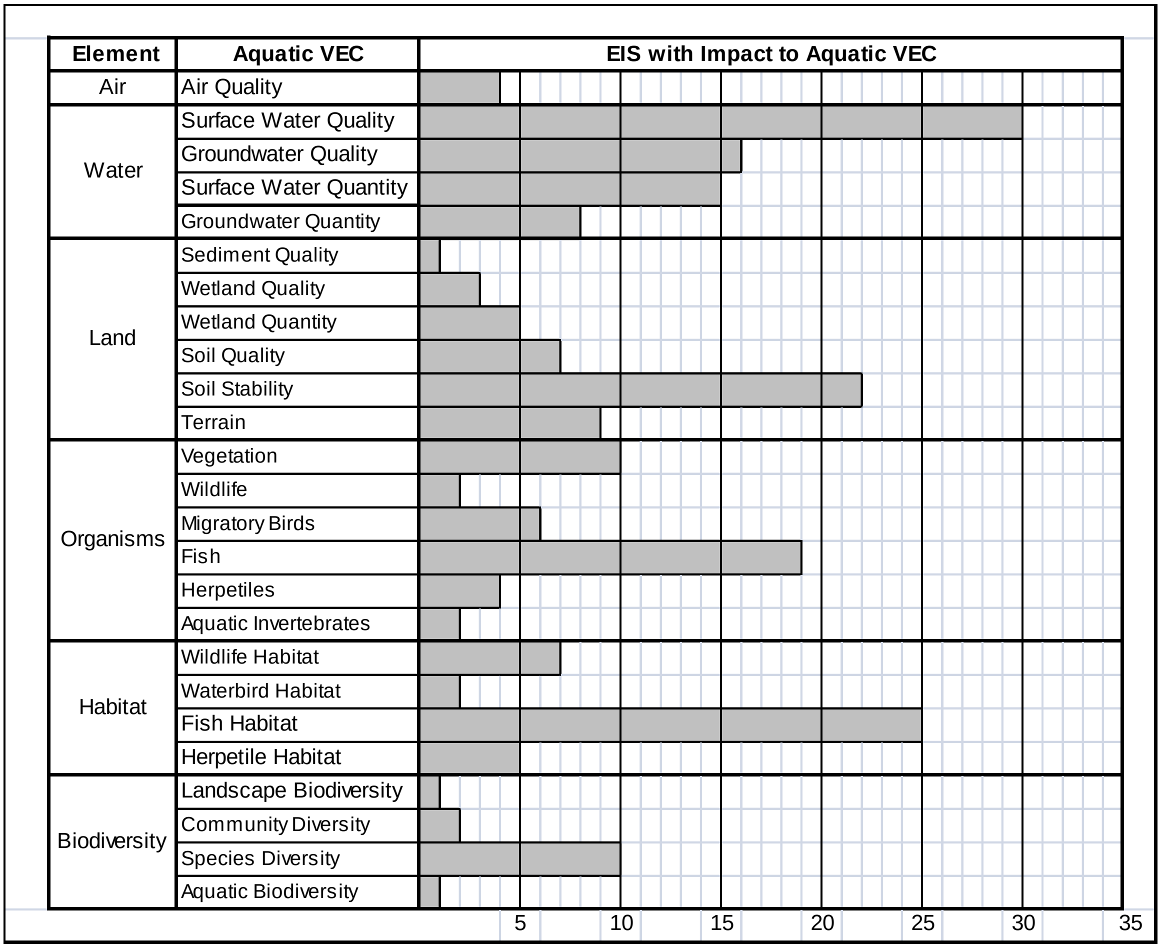

Figure 4.3: Frequency of project impacts to aquatic VECs as identified in a review of 35 EISs from the South Saskatchewan River Watershed

4.3. Analysis of the Use and Selection of Aquatic VECs

The first part of objective (iv), considering whether the aquatic VECs and aquatic VEC indicators used in EIA may be useful for WCEA, was addressed first through an examination of five factors that may have affected the selection and use of aquatic VECs: 1) type of assessment (screening or comprehensive), 2) whether public consultation may have contributed to VEC selection, 3) level of governing authority (provincial, federal or harmonized), 4) particular responsible authority (province or federal agency), and 5) class of project. The results of the examinations were then analyzed for implications of scaling up aquatic VECs and indicators used in EIA to WCEA.

4.3.1. Aquatic VEC Use by Assessment Type

There were differences in the aquatic VECs used between screening and comprehensive type assessments, and between provincial, federal, and harmonized provincial-federal assessments (Table 4.4). The range of VECs selected for consideration by screening assessments was more limited than that of comprehensive assessments. Only comprehensive assessments addressed impacts to wildlife, waterfowl and shorebird habitats and landscape-scale, community-scale and aquatic biodiversity; and not to groundwater quantity, sediment quality and wetlands at least ten times more frequently than screening assessments. Comprehensive assessments contained 2.7 times as many water VECs as screening assessments, on average.

Provincial assessments differed from both federal screening and comprehensive assessments. In contrast to federal assessments, provincial assessments consistently included groundwater quantity and excluded biodiversity, vegetation, sediments, and wetlands. Only provincial assessments from Alberta included aquatic invertebrates. The single project (Table 3.1, EIS # 47) that included over 90% of the aquatic VECs identified in the review (see Table 4.4) was a harmonized comprehensive assessment initially under the authority of Alberta Environment, later co-ordinated by the federal DFO: a proposed strip mine and coal-burning power plant situated on an irrigation reservoir and managed wetland.

4.3.2. Aquatic VEC Use by Public Consultation Category

All comprehensive assessments and 23% of screening assessments reviewed in this study engaged some degree of public consultation in the scoping phase of the assessment where the potential project impacts and VECs were determined (Table 4.5). The role of public consultation in VEC selection was divided into three categories for analysis in this review: 1) the 66% of the EISs that had no form of public consultation, 2) the 17% of EISs with public consultation that claimed it did not affect EIS content, 3) the 17% of EISs that indicated public consultation did or may have affected VEC selection. The ‘may have’ category included 60% of comprehensive assessments and 9% of screening assessments. Screening, provincial, harmonized and comprehensive type assessments were nearly evenly represented in the two categories of EISs that engaged public participation. Overall, assessments with some form of public consultation used nine aquatic VECs that were not used in assessments without public consultation.

Table 4.4: Frequency of aquatic VEC use by assessment type and by government authority

Element	Aquatic VEC	Screening																														Comprehensive				
Air	Air Quality										S														S				S			C				
Water	Surface Water Quality	S	S	S	S	S	S	S	S	S	S	S	S	S	S		S	S			S	S	S	S	S	S		S	S	S	S	C	C	C	C	
	Groundwater Quality	S	S	S		S	S									S					S		S				S		S	S	S	C	C		C	C
	Surface Water Quantity	S					S		S				S	S			S	S	S			S			S				S	S		C	C		C	
	Groundwater Quantity																								S		S		S	S	S	C	C		C	
Land	Sediment Quality																															C				
	Wetland Quality																								S								C	C		
	Wetland Quantity																											S				C	C	C	C	
	Soil Quality	S				S										S						S							S				C		C	
	Soil Stability	S		S	S		S		S	S	S		S		S		S	S					S	S	S	S			S			C	C		C	
	Terrain					S																			S		S		S		S	C	C	C	C	
Organisms	Vegetation				S								S	S			S	S							S							C	C	C	C	
	Wildlife																															C			C	
	Migratory Birds	S																S										S				C		C	C	
	Fish	S			S				S		S	S	S	S			S	S	S			S		S	S					S	S	C	C	C	C	
	Herpetiles						S																		S							C		C		
	Aquatic Invertebrates																													S		C				
Habitat	Wildlife Habitat										S																	S				C	C	C		C
	Migratory Bird Habitat																															C			C	
	Fish Habitat	S			S	S	S		S	S	S	S	S	S	S		S	S	S			S		S	S	S		S		S	S	C	C	C	C	
	Herpetile Habitat																		S			S			S							C		C		
Biodiversity	Landscape Biodiversity																															C				
	Community Biodiversity																															C		C		
	Species Biodiversity		S	S			S											S	S					S	S							C		C	C	
	Aquatic Biodiversity																															C				
	EIS number	1*	2*	3*	4*	5*	6*	7*	8*	9*	11*	12*	13*	14*	16*	20*	22*	23*	25*	26*	27*	28*	29*	32*	35*	36*	37*	45*	33**	34**	42***	47***	48*	49*	50*	51*

* Assessment by federal authority	Screening type assessment with aquatic VEC	S
** Assessment by provincial authority	Comprehensive type assessment with aquatic VEC	C
*** Harmonized provincial and federal authority		

The number and diversity of aquatic VECs used in both screening and comprehensive assessments increased with successively higher categories of input from public consultation (Table 4.5). Screening assessments that claimed public consultation affected VEC selection used 1.4 times as many aquatic VECs as screening assessments that claimed public consultation did not affect VEC selection, and twice as many aquatic VECs as screening assessments with no public consultation. Comprehensive assessments that claimed public consultation affected VEC selection used four aquatic VECs that were not used in any other assessments (sediment quality, landscape, community and aquatic biodiversity). Public consultation appears to have increased the number and range of aquatic VECs used in both assessment types when it was employed, most particularly in assessments that claimed public consultation may have affected VEC selection.

4.3.3. Aquatic VEC Use by Responsible Authority

Differences were found across responsible authorities in the aquatic VECs used (Table 4.6). The only authority to consistently include wetlands, the NEB, was also the only authority not to consider aquatic impacts related to soil. In all but one EIS, AAFC was similarly consistent in aquatic VEC selection: strong on surface water quality, groundwater quality and species diversity, but weak on wetlands, vegetation, herpetiles and water quantity. Biodiversity, soil quality, air quality and groundwater were consistently not selected for use by DFO, but were selected by most other authorities. Within screening type assessments, DFO always selected surface water quality and fish habitat, selected soil stability in more than 80% of EISs and selected fish in 50% of EISs. Some water-related ecosystem components, such as landscape biodiversity and wetland quality, were seldom considered by any responsible authority.

Table 4.5: Frequency of EISs with public consultation that did not or that may have affected VEC selection and those with no public consultation by responsible authority and assessment type

Element	VEC	Public Consultation Did Not Affect VEC Selection						Public Consultation May Have Affected VEC Selection						No Public Consultation																						
Air	Air Quality			S					S		C											S														
Water	Surface Water Quality	S	S	S	S	C		S	S	S	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S		S	S			S	S	S	S	
	Groundwater Quality	S	S	S	S	C	C	S			C	C		S	S	S		S									S						S			S
	Surface Water Quantity	S		S		C		S	S		C	C		S						S				S	S			S	S	S		S				
	Groundwater Quantity			S	S	C		S	S		C	C																								S
Land	Sediment Quality										C																									
	Wetland Quality								S			C	C																							
	Wetland Quantity					C				S	C	C	C																							
	Soil Quality			S		C						C		S				S									S					S				
	Soil Stability	S		S		C			S		C	C		S		S	S			S	S	S		S		S		S	S				S	S	S	
	Terrain			S	S	C			S		C	C	C					S																		S
Organisms	Vegetation					C			S		C	C	C				S							S	S			S	S							
	Wildlife					C					C																									
	Migratory Birds					C				S	C		C	S															S							
	Fish				S	C		S	S		C	C	C	S			S			S		S	S	S	S			S	S	S		S		S		
	Herpetiles	S							S		C		C																							
	Aquatic Invertebrates							S			C																									
Habitat	Wildlife Habitat						C			S	C	C	C									S														
	Migratory Bird Habitat					C					C																									
	Fish Habitat	S			S	C		S	S	S	C	C	C	S			S	S		S	S	S	S	S	S	S		S	S	S		S		S	S	
	Herpetile Habitat								S		C		C																	S		S				
Biodiversity	Landscape Biodiversity										C																									
	Community Biodiversity										C		C																							
	Species Biodiversity	S				C			S		C		C		S	S													S	S				S		
	Aquatic Biodiversity										C																									
	Responsible Authority	AAFC	AAFC	SK	SK/WD	AAFC	PCA	AB	PCA	NEB	AB/DFO	DND	NEB	AAFC	AAFC	AAFC	AAFC	WEDC	AAFC	DFO	DFO	PCA	PCA	TC	DFO	DFO	TC	DFO	TC	PCA	NRC	NRC	AAFC	AAFC	DFO	DND
	EIS number	6*	27*	33**	42***	50*	51*	34**	35*	45*	47***	48*	49*	1*	2*	3*	4*	5*	7*	8*	9*	11*	12*	13*	14*	16*	20*	22*	23*	25*	26*	28*	29*	32*	36*	37*

Natural Resouces Canada	NRC
Agriculture and Agri-Food Canada	AAFC
Department of Fisheries and Oceans	DFO
Transport Canada	TC
Province of Alberta	AB
Province of Saskatchewan	SK
Western Economic Diversification Canada	WD
Department of National Defence	DND
National Energy Board	NEB
Parks Canada Agency	PCA

Screening Assessment	S
Comprehensive Assessment	C
* Federal Assessment	
** Provincial Assessment	
*** Harmonized Assessment	

The Riverhurst Irrigation Expansion project (Table 3.1, EIS # 7) has been included in the linear corridor class in this review because it was limited in scope to the laying of pipeline for irrigation expansion, but like most of the other assessments under the authority of AAFC, including all of those in the agriculture class, it did not address surface water quantity or the impact of additional water withdrawal on the ecology of the South Saskatchewan River system. Two EISs by AAFC did discuss surface water quantity without examining environmental impacts: the Rancher`s Beef Abattoir project (Table 3.1, EIS # 1) discussed impacts to surface water quantity only in the context of municipal water licensing; and the Maple Creek Dam Rehabilitation project (Table 3.1, EIS # 6) foresaw that there would be no changes to surface water availability during the construction of the project. Ecological impacts from water withdrawal were also not assessed by the Encana Shallow Gas Infill Development Project (Table 3.1, EIS # 48) that cited the Master Agreement on Apportionment, a political agreement that allows a 50% flow reduction in the South Saskatchewan River in each province, as the rationale. It was argued that the additional withdrawal of water for the project would not result in a violation of the agreement, so therefore the impacts of water withdrawal need not be considered in the assessment.

4.3.4. Aquatic VEC Use by Project Class

Differences were also found between project classes in terms of the aquatic VECs selected, and within project classes in terms of the consistency of VECs used (Table 4.7). Agriculture and in-stream construction, for example, were more consistent in VEC use than were urban enterprises and contaminated sites. Surface water quality, surface water quantity, fish, and fish habitat were used quite consistently by all responsible authorities within the in-stream construction class, while groundwater quality, vegetation, migratory birds, herpetiles and species biodiversity were used inconsistently within the class. Contaminated sites were consistent only in selecting groundwater quality, and urban enterprises had no consistency across projects. Agriculture projects were the only projects not to consider impacts to water quantity; were less likely than most other project classes to consider habitat impacts; less likely than linear corridors, oil and gas, mines and prescribed burn projects to consider wetlands; and less likely than linear corridors to consider impacts to migratory birds.

Table 4.6: Frequency of aquatic VEC use displayed by responsible authority with assessment type and governing authority

Element	VEC	NRC		AAFC										DFO							AB	SK	TC			DND		WD		PCA					NEB	
Air	Air Quality																			C		S									S		S			
Water	Surface Water Quality	S		S	S	S	S	S	S	S	S	S	C	S	S	S	S	S	S	C	S	S		S	S		C	S	S		S	S	S		S	C
	Groundwater Quality			S	S	S		S	S		S		C							C	S	S	S			S	C	S	S					C		
	Surface Water Quantity								S		S							S		C	S						C									
	Groundwater Quantity												C							C		S					C						S			
Land	Sediment Quality																			C																
	Wetland Quality																										C						S			C
	Wetland Quantity												C							C							C								S	C
	Soil Quality	S							S				C									S	S				C	S								
	Soil Stability				S	S	S		S		S	S	C	S	S		S	S	S	C		S		S	S		C				S		S			
	Terrain												C							C		S				S	C	S	S				S			C
Organisms	Vegetation						S						C			S		S		C				S	S		C						S			C
	Wildlife												C							C																
	Migratory Birds								S				C							C					S										S	C
	Fish	S					S		S			S	C	S		S		S		C	S			S	S		C		S	S	S	S	S			C
	Herpetiles										S									C													S			C
	Aquatic Invertebrates																			C	S															
Habitat	Wildlife Habitat																			C							C				S		S	C	S	C
	Migratory Bird Habitat												C							C																
	Fish Habitat	S					S		S		S	S	C	S	S	S	S	S	S	C	S			S	S		C	S	S	S	S	S	S		S	C
	Herpetile Habitat	S																		C										S			S			C
Biodiversity	Landscape Biodiversity																			C																
	Community Biodiversity																			C																C
	Species Biodiversity			S	S						S	S	C							C					S					S			S			C
	Aquatic Biodiversity																			C																
	EIS number	28*	26*	2*	3*	29*	4*	27*	1*	7*	6*	32*	50*	8*	9*	14*	16*	22*	36*	47***	34**	33**	20*	13*	23*	37*	48*	5*	42***	25*	11*	12*	35*	51*	45*	49*

Natural Resouces Canada	NRC
Agriculture and Agri-Food Canada	AAFC
Department of Fisheries and Oceans	DFO
Province of Alberta	AB
Province of Saskatchewan	SK
Western Economic Diversification Canada	WD
Department of National Defence	DND
National Energy Board	NEB
Parks Canada Agency	PCA
Transport Canada	TC

* Assessment by Federal Authority	
** Assessment by Provincial Authority	
*** Harmonized Provincial/Federal Authority	
Screening type assessment	S
Comprehensive type assessment	C

Perhaps the most notable result in Table 4.7 is that there were differences in VEC selection across responsible authorities within the same project class. For in-stream construction projects, for example, only DFO did not link water impacts to biodiversity; only AAFC linked impacts to herpetiles and groundwater quality; only PCA considered herpetile habitat; only DFO and TC considered vegetation; only TC considered migratory birds. Results indicated varied VEC selection preferences by different responsible authorities assessing similar projects. It is also apparent that within each of the linear corridor, in-stream construction and mines project classes, comprehensive type assessments generally used more aquatic VECs than screening type assessments.

Table 4.7: Frequency of aquatic VEC use displayed by project class with assessment type, governing authority and responsible authority

Element	VEC	Agriculture				Linear Corridors						Petrochemical		Oil and Gas	Contaminated Sites			In-Stream Construction											Mines		Prescribed Burns			Urban Enterprise		
Air	Air Quality																												S	C	S		S			
Water	Surface Water Quality	S	S	S	S	S	S	S	C	C	S	S	S	C		S		S	S	S	S	S	S	S	S		S	S	S	C	S	S	S		S	
	Groundwater Quality	S	S	S		S				C		S	S	C	S	S	C	S											S	C					S	S
	Surface Water Quantity							S		C			S	C				S	S		S	S		S	S	S			S	C			S		S	
	Groundwater Quantity									C			S	C		S													S	C			S			S
Land	Sediment Quality																													C						
	Wetland Quality								C					C																			S			
	Wetland Quantity								C	C	S			C																C						
	Soil Quality					S		S		C				C	S														S						S	
	Soil Stability		S	S	S					C				C				S	S	S	S		S	S	S		S	S	S	C	S		S		S	
	Terrain					S			C	C				C		S													S	C			S			S
Organisms	Vegetation				S				C	C				C							S	S		S	S					C			S			
	Wildlife									C																				C						
	Migratory Birds								C	C	S														S					C					S	
	Fish				S			S	C	C			S	C		S			S		S	S		S	S	S	S			C	S	S	S		S	
	Herpetiles								C									S												C			S			
	Aquatic Invertebrates												S																	C						
Habitat	Wildlife Habitat								C		S			C			C													C	S					
	Migratory Bird Habitat									C																				C						
	Fish Habitat				S	S		S	C	C	S		S	C		S		S	S	S	S	S	S	S	S	S	S	S		C	S	S	S		S	
	Herpetile Habitat							S	C																	S				C			S			
Biodiversity	Landscape Biodiversity																													C						
	Community Biodiversity								C																					C						
	Species Biodiversity	S	S						C	C								S							S	S	S			C			S			
	Aquatic Biodiversity																													C						
	Responsible Authority	AAFC	AAFC	AAFC	AAFC	WEDC	AAFC	NRC	NEB	AAFC	NEB	AAFC	AB	DND	TC	SK/WD	PCA	AAFC	DFO	DFO	TC	DFO	DFO	DFO	TC	PCA	AAFC	DFO	SK	AB/DFO	PCA	PCA	PCA	NRC	AAFC	DND
	EIS number	2*	3*	29*	4*	5*	7*	28*	49*	50*	45*	27*	34**	48*	20*	42***	51*	6*	8*	9*	13*	14*	16*	22*	23*	25*	32*	36*	33**	47***	11*	12*	35*	26*	1*	37*

Natural Resouces Canada	NRC
Agriculture and Agri-Food Canada	AAFC
Department of Fisheries and Oceans	DFO
Transport Canada	TC
Province of Alberta	AB
Province of Saskatchewan	SK
Western Economic Diversification Canada	WD
Department of National Defence	DND
National Energy Board	NEB
Parks Canada	PCA

Screening Assessment	S
Comprehensive Assessment	C

* Federal Assessment

** Provincial Assessment

*** Harmonized Assessment

4.3.5. Factors Affecting Aquatic VEC Selection

The analysis of aquatic VEC use revealed four factors affecting VEC selection. First, VEC selection was significantly affected by regulatory mechanisms such as indictable offences, licensing, and inter-provincial agreements. Aquatic VECs protected by punitive federal legislation were selected more than twice as frequently as other aquatic VECs; an irrigation expansion project, an abattoir and a biofuel production facility, all under the authority of AAFC, cited water licensing as justification for not assessing impacts of water withdrawal on surface water quantity (with the consequence that impacts on other aquatic VECs from changes in surface water quantity were overlooked); the impacts to surface water quality from the abattoir and biofuel facility were overlooked because wastewater was directed to a licensed municipal system; and an oil and gas development did not consider cumulative impacts to surface water quantity because withdrawals did not breach an inter-provincial agreement on flow allocations. There were biases in aquatic VEC selection driven by adherence to regulatory mechanisms.

Second, there were differences between responsible authorities in the aquatic VECs selected even within the same project class and assessment type. The NEB was the only authority to consistently included wetlands, and the only authority not to consider aquatic impacts to soil; AAFC was uniquely consistent in aquatic VEC selection across different project classes, strong on surface water quality, groundwater quality and species diversity, but weak on wetlands, vegetation, herpetiles and water quantity; within screening assessments DFO consistently selected surface water quality and fish habitat, and soil stability, and consistently did not select biodiversity, soil quality, air quality or groundwater. For in-stream construction projects, only DFO did not include biodiversity, only AAFC used herpetiles and groundwater quality, only PCA considered herpetile habitat, and only TC considered migratory birds. There were biases in aquatic VEC selection driven by the preferences of different responsible authorities.

Third, there were differences in the number of aquatic VECs used by each assessment type within project classes. Comprehensive type assessments consistently used more aquatic VECs than screening type assessments in the linear corridor, in-stream construction and mines project classes. This is an indication that impacts to some aquatic VECs may have been overlooked in the less stringent screening type of assessment.

Fourth, both the number and diversity of aquatic VECs selected for assessment was higher in assessments that engaged some form of public consultation. This was observed even in assessments with public consultation that claimed the consultation did not affect VEC selection, but most particularly in those assessments that indicated public consultation did or may have affected VEC selection. Public consultation increased the number and diversity of aquatic VECs selected.

4.4. Analysis of the Use and Selection of Indicators for Water VECs

In support of the second part of objective (iv), considering whether the indicators used for aquatic VECs in EIA could be scaled up for use in WCEA, the use and selection of indicators for water VECs was examined. Both indicators explicitly labelled as ‘indicators’, and the measurable parameters actually used to assess potential impacts to surface water quality, were identified and examined. The sub-sections that follow present the findings with a hierarchical structure used to facilitate the comparison of measurable parameters across projects.

4.4.1. Indicators Used for Water Quality and Quantity VECs

Indicators used for predicting, assessing, or monitoring changes in aquatic VECs due to project activities were explicitly identified in 100% of comprehensive type assessments, and in only 7% of screening type assessments. Indicators for water VECs (surface and groundwater quality and quantity) were used in 60% of comprehensive and 7% of screening assessments. Two categories of indicators were identified as indicators in the review: effects-based indicators used to assess the condition of aquatic VECs potentially affected by project activities, and stressor-based indicators used to assess the project stresses potentially affecting aquatic VECs.

Effects-based indicators were explicitly identified as indicators for each of the four water VECs in the EISs reviewed (Table 4.8). For example, suspended solids concentration was labelled as an indicator for surface water quality in the Rancher’s Beef Abattoir project (Table 3.1, EIS # 1). Stressor-based indicators were also explicitly identified as indicators for two of the water VECs: surface water quality and groundwater quality. Groundwater quality of overburden aquifers, for example, was labelled as an indicator for surface water quality in the Brooks Power Project (Table 3.1, EIS # 47). Groundwater quality was identified as an indicator of stress to surface water quality, and surface water quality was also identified as an indicator of stress to groundwater quality. In both cases there was a perceived relationship between groundwater and surface water that allows contaminants from one to affect the other, and each was therefore a stressor-based indicator for the other. Air potential acidifying input, sediment metal and polycyclic aromatic hydrocarbon (PAH) concentrations and slope vegetation were also used as indicators of stress to surface water quality in the EISs reviewed.

Indicators were drawn from each of the lower three levels of the normative component hierarchy: VECs, VEC factors, and condition parameters were all identified as indicators (see Table 4.8). In some cases indicators at the level of VECs have been broken down into indicators at the more detailed and measurable level of parameters within the same EIS. Groundwater quality, for example, was used as a VEC-level stressor-based indicator for surface water quality in the Brooks Power Project (Table 3.1, EIS # 47), and condition parameters of groundwater quality, such as pH and aluminum concentration were also used as stressor-based indicators for surface water quality in the same EIS. Condition parameters from a second VEC used as stressor-based indicators for the VEC under consideration are referred to as stress parameters in this study. Stress parameters are described more fully in section 4.4.2.

4.4.2. Adopting a Normative Hierarchy for Stresses to Water VECs

Relationships between condition parameters and project stressors, and relationships between stress parameters and water VECs were frequently identified in the EIS review and used to assess impacts, even though the parameters were not always referred to as indicators. In order to compare the use of indicators across assessments, therefore, a review was conducted to identify all condition and stress parameters used in relation to water VECs. The condition and stress parameters identified, rather than the few parameters labelled as indicators, were then used as a basis for comparison.

Stress parameters for water VECs were identified in the review using a normative hierarchy for water stressors (see Figure 4.4). In the hierarchy, stress parameters are at the detailed lower level where stress can be measured directly and quantitatively, and projects are at the broad upper level where stressors are general in nature. Stress parameters measure the project stressors that directly affect a particular VEC, and indirect stress parameters measure changes in other VECs that in turn affect the VEC under consideration. In the case of atmospheric deposition of mercury in the Brooks Power Project (Table 3.1, EIS # 47), for example, the quantity of mercury that was expected to be deposited directly into the Kitsim Reservoir was a stress parameter for surface water quality, and the quantity of mercury expected to settle into the reservoir sediment, where it could be re-activated through methylation, was an indirect stress parameter for surface water quality. Only five assessments used an explicit indicator for a water VEC, and no individual water VEC indicator was used in more than a single assessment. Three assessments used explicit and quantifiable indicators for impacts to surface water quality.

Independent stress parameters were also identified in the review. Independent stress parameters are environmental factors not affected by human activities that contribute to natural variability and affect the magnitude of the project stress impacts. For example, terrain slope and extreme run-off events are two environmental components that may determine the intensity of soil erosion and therefore the magnitude of the suspended solids concentration in surface water following upslope ground disturbance by a project. Terrain slope and run-off intensity are environmental condition parameters that qualify the relationship between the VEC surface water quality and the project activity of ground disturbance, even though they are not directly affected by the project.

Stress parameters were used more frequently than either indirect stress parameters or independent stress parameters for assessing surface water quality (Table 4.9). Stress parameters were used for 85% of surface water quality stress factors; indirect stress parameters for 15% and independent stress parameters for 23%. Only one surface water quality stress factor, erosion from ground disturbance, was served by all three types of stress parameter.

4.4.3. Surface Water Condition and Stress Parameter Use by Category

This study analyzed the use of condition parameters (including secondary condition parameters) and stress parameters (including indirect and independent stress parameters) for surface water quality, the most frequently-cited VEC, and surface water quantity using the same approach applied to aquatic VECs. The frequency of parameter use was examined using four categories: project class, assessment type, governing authority and responsible authority (Table 4.10 and Figure 4.11). Patterns of parameter use were then examined within and across categories.

In general, the number of surface water quality parameters examined in individual projects appeared to be linked to the magnitude of the project's impact on water, regardless of assessment type or responsible authority. The Brooks Power Project (EIS # 47, see Table 3.1), a harmonized comprehensive assessment, with the largest footprint and widest scope of impact to the aquatic environment of all the projects examined in this review, identified both stress and condition parameters for 80% of surface water quality factors.

Table 4.8: Indicators for water VECs as identified in a review of 35 EISs from the South Saskatchewan River watershed, displayed by corresponding position in the normative component hierarchy

Indicator Position in Component Hierarchy	Indicators Used for Surface Water Quality	Indicators Used for Surface Water Quantity	Indicators Used for Groundwater Quality	Indicators Used for Groundwater Quantity
VEC	groundwater quality of overburden aquifers* (1)*** surface water quality at other specific locations** (1)		surface water quality* (1) groundwater quality at other locations** (1)	
VEC Factor	suspended sediment concentrations** (1)	flow regime on the Bow River** (1) flow regime in Antelope Coulee Spillway** (1) site runoff [volume]** (1)		groundwater levels in aquifers** (1)
Condition Parameter			pH, Eh, conductivity, Ca, Mg, TDS, Al, As, B, Se, Fe** (1)	pump test drawdown and recovery** (1) water level trends in area wells during pump test** (1) depth of aquifer compared to depth of drawdown during pump test** (1) size and location of the aquifer recharge zone** (1) well yields in aquifers** (1) extent of aquifers** (1)
Stress Parameter	modelled potential acidifying input from air emissions* (1) sediment concentrations of metals and PAH* (1) revegetation of exposed slopes* (1) groundwater pH, Eh, conductivity, Ca, Mg, TDS, Al, As, B, Se, Fe* (1)			

* Stressor-based indicator

** Effects-based indicator

*** Actual number of EISs using indicator

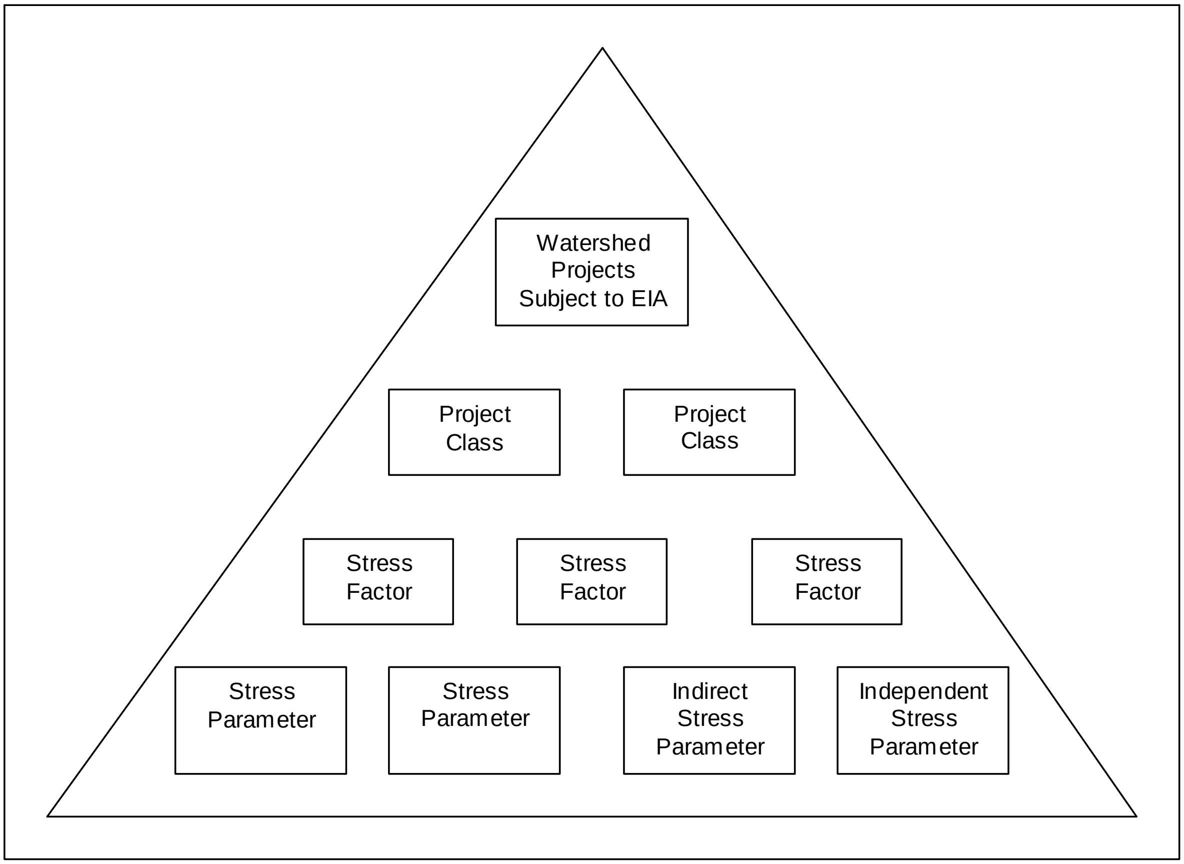

Figure 4.4: A normative hierarchy for categorizing stresses to water VECs based on an increasing level of detail from projects to parameters

Three smaller in-stream construction projects (EISs # 6, # 8 & # 23, Table 3.1), which were screening assessments conducted by different responsible authorities, had condition parameters for 50% or more of surface water quality VEC Factors, and stress parameters for between 10% and 30% of VEC factors. All other projects, with arguably less impact on water, and including four comprehensive assessments, had a mix of stress and condition parameters for 40% or fewer of the surface water quality factors.

Differences were found between responsible authorities in which surface water quality factors had condition or stress parameters, however, there were no clear patterns in parameter selection by different responsible authorities within any project class. Stress and condition parameters for nutrients, for example, were common in projects conducted by AAFC, and absent in projects conducted by DFO, TC, DND, PCA and NEB. However AAFC could not be compared to other responsible authorities within distinct project classes because AAFC was the sole responsible authority with projects in the agriculture class, and in the in-stream construction class where other authorities also had projects, AAFC was inconsistent in the use of nutrient parameters. Similarly, DFO consistently used condition parameters for organics (related to spills of automotive fluids), while PCA consistently did not use parameters for organics; however, the two authorities generally conducted projects in different classes, so there was no robust comparison available to confirm the pattern within a single class. While bias in parameter selection by responsible authority could not be ruled out, there was no clear evidence to support a finding of bias independent of project class.

Toxicity was the one surface water factor more often assessed by stress parameters than by condition parameters. This may be related to the above observation that while toxicity is used as the basis for establishing surface water quality criteria for many water quality factors, such as particular metal and organic concentration, the condition of a metal or organic concentration in water is not itself labelled as a toxicity factor. For example, mercury concentration in effluent (a stress parameter) may be identified as a toxicity factor, when mercury concentration in the receiving stream (a condition parameter), is identified as a metal factor. Condition parameters were cited slightly more frequently than stress parameters for most other surface water quality factors when both impact analysis and monitoring requirements were considered. There were two exceptions: organics concentrations in receiving water (generally related to potential spills of automotive fluids) were cited four times as often as organics stress parameters, and the magnitude of surface water flow was cited three times as often as stress parameters affecting flow. In general, however, when both the impact analysis and monitoring aspects of the EISs were taken into account, condition parameters were used marginally more frequently than stress parameters to assess impacts to surface water quality factors.

Multiple linkage cause-effect mechanisms may be discerned from the 40% of surface water quality factors (nutrients, metals, suspended solids and salinity) that had both indirect stress parameters (that affected surface water quality), and secondary condition parameters (that were affected by changes in surface water quality).

Table 4.9: Project classes, stress factors and stress parameters affecting surface water quality as identified in a review of 35 EISs from the South Saskatchewan River watershed

Stress Factor	Stress Parameter	Indirect Stress Parameter	Independent Stress Parameter
water withdrawal (1)			
erosion from ground disturbance (23)	amount and distribution of bare ground (12)	upslope vegetation loss (3)	extreme run-off events (1)
	discharge disturbed area (1)	quality of bank vegetation (3)	terrain slope (4)
	amount of channelization and bank armourment (1)	amount of organic material covering the mineral soil (1)	creek size (1)
		vegetative community diversity (1)	soil resistance to water erosion (1)
channel alteration (9)	amount of streambed disturbance (3)		
use of toxic material (2)	number of power poles in water (1)		
effluent discharge (6)	wasteload allocation screening (1)		
	effluent metal concentration (arsenic, chromium, mercury, zinc,) (1)		
	effluent fecal coliforms (1)		
	effluent total phenolics (1)		
	effluent TDS (1)		
	effluent total phosphorous (1)		
	acute whole effluent toxicity (1)		
contamination from groundwater (6)	groundwater AL, As, B, Se, Pb, Hg (1)		
	groundwater transport pattern (2)		
	groundwater flow pattern (1)		
	groundwater phenols, pesticides, DOC, nutrients (1)		
	groundwater pH, conductivity, major ions, alkalinity, hardness, chloride, sodium, sulphate, (1)		
contamination from soil (1)			
contamination from surface water (not suspended solids) (7)	run-off flow rate (1)		terrain slope (1)
	stream flow rate (1)		extreme run-off events (1)
	stormwater oil and grease, phenols, total suspended solids, pH (1)		
atmospheric deposition (3)	surface water evaporative concentration (1)	sediment heavy metal & PAH concentrations (1)	
	surface area and volume of water bodies		
	alkalinity of water body		
	air emission potential acidifying input (1)		
	air suspended saline dust (1)		
spills and leaks (18)			
cooling water discharge (1)	industrial heat transfer (1)		
change in bathymetry (1)	change to area/volume ratio (1)		
nutrient loading (4)	cattle access to shoreline (2)		extreme run-off events (2)
	effluent phosphorous (1)		
	groundwater nutrients (1)		
riparian vegetation disturbance (3)	quality of bank vegetation (2)		

* Indicates actual number of EISs with stress factor or stress parameter

With regard to the surface water quality factor suspended solids, for example, disturbance of upland vegetation affected surface water suspended solids concentration that in turn affected spawning bed porosity. Independent stress parameters, the environmental components that affect project stress magnitude even though they are not themselves affected by project activities, were used for 60% of surface water quality VEC factors, but not for any surface water quantity VEC factors. Independent stress parameters were used about half as frequently as stress parameters and indirect stress parameters combined.

4.5. Quality of Parameter Measurement

The use of criteria and baselines was examined for surface water quality parameters (stress and condition) identified in the impact analysis, mitigation and monitoring sections of the EISs reviewed. Only eight screening assessments and two comprehensive assessments (29% of EISs reviewed overall) indicated a commitment to measure at least one stress or condition parameter for surface water quality. Of those, five screening and one comprehensive assessment (17% of EISs reviewed) identified some sort of criteria to measure against, and three screening and one comprehensive assessment (11% of EISs reviewed) used a baseline trend in measuring a parameter. All of the assessments that used baseline trends were conducted initially under provincial authority: the Proposed Fine Tailings Management Area (EIS # 33, see Table 3.1) under the authority of the Province of Saskatchewan, the Saskatoon Regional Waste Management Upgrade (EIS # 42, see Table 3.1) harmonized with the Province of Saskatchewan and Western Economic Diversification Canada, the Proposed Joffre Expansion Project (EIS # 34, see Table 3.1) under the Province of Alberta, and the Brooks Power Project (EIS # 47, see Table 3.1) harmonized with Alberta and the Department of Fisheries and Oceans.

Baseline trends were mainly used for surface water quality stress parameters rather than condition parameters, and only the Proposed Joffre Expansion Project used a baseline in measuring a condition parameter, where upstream point sources were considered in establishing phosphorous concentration baseline trends in the Red Deer River. The Potash Corporation of Saskatchewan Proposed Fine Tailings Management Area project, concerned about contamination of surface water by saline groundwater, used a baseline of groundwater changes in salinity, from historical data collected under provincial licensing requirements.

Table 4.10: Use of condition and stress parameters for surface water quality displayed by project class and assessment type

VEC	VEC Factor	Agriculture				Linear Corridors						Petrochemical		Oil and Gas	Contaminated Sites			In-Stream Construction											Mines		Prescribed Burns			Urban Enterprise		
Surface Water Quality	Nutrients				●								●					●																		
				■												■																				
			▲																																	
			○	○	○							○	○			○		○																		
													△																							
	Metals												●																		●					
																■														■						
													▲																	▲						
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																														△	△					
	Suspended Solids			●	●			●	●										●	●	●	●	●	●	●			●		●				●	●	
									■													■			■						■		■			
			▲			▲								▲													▲						▲		▲	
			○	○	○	○	○	○	○	○		○		○				○	○	○	○	○	○	○	○		○			○	○		○		○	
									△															△	△					△			△		△	
	Oxygen																																			
																		○	○																	
	Thermal Regime																													●						
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	Acidity																													●					●	
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	Salinity													●															●							
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											△																									
	Pathogens																													●						
																									○					○						
	Organics												●																						●	
																■														■						
		○				○				○	○	○	○			○		○	○	○	○	○	○	○	○		○	○		○					○	
	Toxicity												●																							
																■														■						
														▲		▲														▲					▲	
													△	△		△														△						
	EIS number	2	3	29	4	5	7	28	49*	50*	45	27	34	48*	20	42	51*	6	8	9	13	14	16	22	23	25	32	36	33	47	11	12	35	26	1	37

Stress Parameter	●	Condition Parameter	○
Indirect Stress Parameter	■	Secondary Condition Parameter	△
Independent Stress Parameter	▲	* Comprehensive Assessment	

Table 4.11: Use of condition and stress parameters for surface water quantity displayed by project class, assessment type and responsible authority

VEC	VEC Factor	Agriculture				Linear Corridors						Petrochemical		Oil and Gas	Contaminated Sites			In-Stream Construction											Mines		Prescribed Burns			Urban Enterprise		
Surface Water Quantity	Surface Water Level																																			
																					○	○														
																						△														
	Surface Water																																			
														△																						
	Surface Water Flow																		●																	
																								■	■					■						
														○											○					○			○			
									△				△	△					△					△	△	△				△						
	Responsible Authority	AAFC	AAFC	AAFC	AAFC	WEDC	AAFC	NRC	NEB	AAFC	NEB	AAFC	AB	DND	TC	SK/WD	PCA	AAFC	DFO	DFO	TC	DFO	DFO	DFO	TC	PCA	AAFC	DFO	SK	AB/DFO	PCA	PCA	PCA	NRC	AAFC	DND
	EIS number	2	3	29	4	5	7	28	49*	50*	45	27	34	48*	20	42	51*	6	8	9	13	14	16	22	23	25	32	36	33	47	11	12	35	26	1	37

Natural Resouces Canada	NRC	National Energy Board	NEB
Agriculture and Agri-Food Canada	AAFC	Parks Canada Agency	PCA
Department of Fisheries and Oceans	DFO	* Comprehensive Assessment	
Transport Canada	TC	Stress Parameter	●
Province of Alberta	AB	Indirect Stress Parameter	■
Province of Saskatchew an	SK	Independent Stress Parameter	▲
Western Economic Diversification Canada	WD	Condition Parameter	○
Department of National Defence	DND	Secondary Condition Parameter	△

The Saskatoon Regional Waste Management Upgrade, concerned about contamination of surface water by landfill leachate in groundwater used a baseline of groundwater monitoring data collected through a contaminated site monitoring program. The Brooks Power Project drew on the air quality monitoring database in Alberta for a baseline used to predict potential acid deposition into surface water. The Proposed Joffre Expansion Project, a petrochemical facility expansion concerned about effluent impacts on the Red Deer River, was the only assessment to use a baseline for the condition of surface water quality. The assessment used a database of surface water quality testing to establish a condition parameter baseline, and a database of effluent concentrations to establish a stress parameter baseline. Cumulative impacts to water VECs were generally not assessed using a quantitative approach with criteria and baseline trends in the South Saskatchewan River watershed.

CHAPTER 5

DISCUSSION

Results of this research confirm the observation that “practitioners use a considerable number of definitions and applications for VECs” (Hegmann et al. 1999: 12), and it is therefore very difficult to compare content across EISs. The sections that follow offer some discussion of how, by avoiding the terminology used for VECs and adopting a standard hierarchical structure, the aquatic impact analysis components (*de facto* VECs) can be identified, how such VECs have been used in EIA practice, and how they are supported by stressor-based and effects-based indicators and related measurable parameters. Implications for scaling-up VECs and indicators from project-based EIA to regional WCEA are explored, along with the implications for the development of regional WCEA, for EIA practice, and for the current trend in Canadian environmental assessment policy to streamline EIA.

5.1. Standard Aquatic Biophysical VECs

Though the term VEC is identified in the academic literature as common terminology for EIA (Beanlands & Duinker 1983, Hegmann et al. 1999), this research demonstrates that it is rarely used in practice. The VEC *concept* was applied in more than half of the EISs reviewed for the use of VEC-equivalent terms, but the terminology was confusing because it varied considerably, was inconsistent both within and across assessments, and described ecosystem components at varying levels of hierarchy and detail. In the case of the South Saskatchewan River watershed, there is no standard terminology or framework of understanding of VECs and hierarchies of VEC components and indicators within EIA that could be scaled-up from the project to the watershed.

It is feasible to identify a set of *de facto* VECs used in practice, however, by applying a standard hierarchical framework. Beanlands and Duinker (1983) suggested that it is useful to think in terms of a nested hierarchy of environmental components ranging from detailed physical/chemical constituents through individual organisms, then VECs (characterized mainly as biotic populations), to the broader levels of communities and finally whole ecosystems. In shifting the organization of the hierarchy from ecosystems to environmental elements (including biodiversity and habitat as elements), and the idea of VECs from biotic populations to a range of biophysical components representing all environmental elements, as observed in practice and presented in this thesis, the components can be organized to better match a complementary hierarchy of stressors and therefore facilitate the exchange of quantitative information between stressor-based and effects-based assessment strategies.

The hierarchical architecture of environmental elements identified in this review differs from the ecological indicator hierarchy proposed by Dale and Beyeler (2001) who eschew VECs as a foundation for a component or ecological indicator hierarchy in favour of ‘structure’, ‘function’ and ‘composition’. The elements of air, water and land used in this review would be included under ‘structure’ in the Dale and Beyeler model; organisms under ‘function’; biodiversity under ‘composition’; and habitat under all of structure, function and composition. The category of ‘function’ includes factors such as rate of nutrient cycling, erosion and disturbance that are identified as stressors in EIA. Dale and Beyeler have adopted a holistic hierarchy that includes stressors as part of the ecosystem, but that is problematic for the assessment of cumulative effects that must focus on the mitigation of human impacts and where a separation of anthropogenic stresses and VECs is therefore required.

A subset of aquatic VECs used in EIA can be identified by analyzing the environmental components directly affected by or affecting water due to project activities. Perhaps it should not be surprising that the set of aquatic VECs identified through such a process in the South Saskatchewan River watershed is virtually indistinguishable from a standard set of VECs identified for use in a federal government checklist used in EIA practice. This indicates two things: first, either the assessments reviewed all relied on the same checklist, or the practice of EIA has developed a fairly good understanding of what in the environment needs to be assessed; second, all environmental components at the level of VECs are directly affected by or have the potential to directly affect changes in water.

VEC factors and condition parameters, at lower and more specific levels of the component hierarchy, are used less consistently across projects, but certainly also could be organized in a standard format to allow a greater degree of consistency among assessments. Though all VECs appear to be connected to water, not all VEC factors or condition parameters are connected to water. Water is connected to the VEC *species biodiversity*, for example, through impacts on fish, but water may not necessarily be connected to the related VEC factor *invasive species*, if the invasive species is terrestrial. At the lower levels of the component hierarchy, fewer components are connected to water. Likely only a small percentage of wildlife condition parameters would have an aquatic connection, for example, but it may be very important to wildlife that those connections are recognized when managing impacts to water. Therival and Ross (2007) highlighted the risk of losing critical local scale information in moving assessment to a broader scale. Perhaps in watershed CEA the loss of priority information could be avoided by sharing information at several levels of the component hierarchy, something recommended by Dale and Beyeler (2001: 5) in their review of the use of ecological indicators: "Indicators should be selected from multiple levels in the ecological hierarchy in order to effectively monitor the multiple levels of complexity within an ecological system." In creating a standard set of aquatic assessment components, therefore, it may be necessary to look beyond the level of VECs, to embrace greater complexity and include aquatic VEC factors and aquatic condition parameters as well.

On the other hand, through interdisciplinary review, it may be feasible to simplify the set of aquatic VECs, VEC factors and condition parameters required for assessment. The Great Sand Hills regional environmental study (SAC 2007), for example, focused the assessment of biodiversity and habitat on species guilds (communities of species with similar habitat). In that case the presence/absence of Baird's sparrow was used as a single indicator (an effects-based indicator or a condition parameter using the component hierarchy structure presented above) that represented the state or condition of four VECs associated with a particular grassland community: community biodiversity, wildlife habitat, migratory birds and migratory bird habitat. The guilds were identified through statistical correlation of species presence in similar habitats using surveys and established databases. There may be an opportunity to identify similar focal assessment parameters for the aquatic environment, but there is no evidence that such work has been undertaken within EIA in the South Saskatchewan River watershed.

While the analysis of EIA practice may help define the range of aquatic biophysical VECs applicable to a watershed, it will not establish the aquatic VEC assessment priorities. The aquatic

VECs used in impact assessments in the South Saskatchewan River watershed were often selected without regard to watershed priorities but were chosen due to various other factors, if included at all. First, aquatic VECs were most often selected to address proponent exposure to liability under the Fisheries Act and the Species at Risk Act. Second, aquatic VECs were omitted where proponents relied on regulatory alternatives, such as citing water withdrawal licensing in place of assessing impacts related to changes in surface water quantity and flow. Water quantity in the South Saskatchewan River ought to be a watershed scale priority for assessment considering that the in-stream flow requirement of the South Saskatchewan River within Alberta is estimated at 85% of naturalized flow (Clipperton et al. 2003), but the naturalized flow at the Alberta/Saskatchewan border is only 78% on average and much lower in some years mainly due to water withdrawals for irrigation (Johnson & Gerhardt 2005, cited in Halliday 2009). Licensing arrangements were used to justify the omission of surface water quantity as an aquatic VEC even though it is an issue of regional significance for aquatic life. Third, VEC selection was affected by agency mandate, so that different aquatic VECs were selected by different responsible authorities even when assessing similar projects. The DFO almost exclusively assessed impacts to water quality, fish and fish habitat while AAFC assessed impacts to water quality and species diversity but not to wetlands or water quantity. Finally, assessments with some sort of public consultation used a greater range of aquatic VECs than assessments without public consultation, suggesting the possibility that assessments conducted without public input may have been conservative in the aquatic VECs selected for assessment. The value of public participation was highlighted by Sinclair and Diduck (2005) who criticized the CEAA for not requiring public input into the scoping phase of federal screening and comprehensive assessments, where VEC selection occurs. Considering the biases, omissions and inconsistencies in aquatic VEC selection, there can be no confidence that the frequency of aquatic VECs used across assessments is an indication of the priorities for aquatic assessment in the watershed. As a corollary, neither can there be confidence that the range of aquatic VECs selected for use in individual assessments is based on watershed scale aquatic assessment priorities.

5.2. Standard WCEA Indicators

This study offers little to support the identification of a standard set of indicators suitable for conducting WCEA in the South Saskatchewan River watershed. The term ‘indicator’ was not frequently used in the EISs reviewed, and although both (stressor-based) stress parameters and (effects-based) condition parameters were identified in this study, the scope of analysis was limited to impacts on surface water quality. It is likely that a review of the parameters used for all aquatic VEC factors identified in this study would be useful in establishing a standard set of assessment components and indicators for WCEA, but the priority regional VECs must be established for the watershed before indicator requirements can be fully understood (Harriman & Noble 2009). The work of identifying standard stress and condition indicators for aquatic cumulative effects assessment of the watershed must be part of a larger interdisciplinary initiative that draws on lessons learned from related initiatives conducted outside of EIA, such as the federal environmental effects monitoring program and regional cumulative effects assessments.

Indicators explicitly labelled as indicators in the EISs reviewed were used very rarely for water VECs, and few of those were quantifiable. Only a portion of the explicit effects-based indicators were drawn from the condition parameter level of the component hierarchy and explicit stressor-based indicators included VECs, stress parameters and indirect stress parameters, but only the latter two were quantifiable. Few assessments used explicit and quantifiable indicators for water VECs and then for only a limited number of the water VEC factors. In EIA practice, impacts to water VECs and VEC factors were most often assessed without identifying indicators, and particularly without identifying quantifiable indicators.

Some types of measurable parameters, not labelled as ‘indicators’, were used to assess impacts to aquatic VECs in the impact analysis, mitigation and monitoring sections of EISs. Parameters used to directly measure the strength of known stressors, which may be considered, *de facto,* stressor-based indicators, and parameters used to measure condition parameters, which may be considered, *de facto,* effects-based indicators, were found in the EISs reviewed and both may be useful for WCEA for a number of reasons. First, the stress and condition parameters were identified through observed or perceived relationships between stressors and environmental components, or between two different environmental components, and relationships represent cause-effect mechanisms that are useful for science-based assessment at both the project and the watershed scales (Reid 1998, Dubé 2003). Second, both stressor-based and effects-based parameters were used, creating the opportunity to identify previously unknown relationships or correlations between the two. Third, the independent (non-anthropogenic) stress parameters used in EIA, such as the compounding effect of terrain slope to soil erosion and surface water quality, could be useful in developing models for WCEA. Perhaps because stress and condition parameters were used in the context of relationships, no discernable biases were identified in their selection by responsible authority or assessment type. Stress and condition parameters were examined in this review for only two aquatic VECs, surface water quality and surface water quantity. It is likely that additional aquatic measurable parameters would be identified through a review of the other aquatic VECs and VEC factors, and that an examination of the stress and condition parameters used for all aquatic VECs and VEC factors may establish a useful database that would support the establishment of quantitative models as well as further identification of cause-effect mechanisms required for aquatic cumulative effect assessment for a watershed.

Effects-based indicators, in the form of condition and secondary condition parameters, were used, *de facto,* slightly more frequently than stressor-based indicators when the impact analysis, mitigation and monitoring aspects of the EISs were considered. This is somewhat unexpected because condition parameters were generally found within the monitoring commitments for mitigation and follow-up and the literature highlights a general inadequacy of monitoring within EIA (Baxter et al. 2001, Duinker & Greig 2006). This suggests that monitoring is not the only weakness in aquatic EIA; that the identification and use of stressor indicators also remains a challenge, at least for surface water quality and surface water quantity factors. The overall frequency-of-use of both condition parameters and stress parameters for surface water factors remains low (see Tables 4.10 and 4.11).

5.3. Complementary Nature of EIA and WCEA

Petersen et al. argued that it is necessary to “integrate and build upon the relative strengths of both a top-down and a bottom-upwards approach to cumulative effects management” (1987:41), and that continual input from the project level of assessment is required to inform the development of standards to serve the regional scale. That argument is supported by the findings of this research, and it presents a challenge to recent initiatives to reduce the number of screening level assessments federally, by providing for project exemptions, and to streamline EIA more generally by restricting the frequency and breadth of its application. This research supports the notion that EIA could be made more effective through the implementation of complementary regional cumulative effect assessment initiatives such as WCEA, and that federal comprehensive and provincial assessments in particular could become both more effective and more efficient by using the information developed and shared at the regional scale.

There are a number of services that project based EIA can provide to WCEA, including the identification of VECs that may need to be understood at a regional scale. The range of aquatic VECs used in practice in the South Saskatchewan context, for example, is related to the degree of public consultation used in VEC selection, and some aquatic VECs, such as *wetlands* and *community* and *landscape biodiversity*, were only selected for consideration in EIAs where public consultation was noted to have affected VEC selection. The public may be leading EIA practice by introducing new aquatic VECs that have not otherwise been used in practice. In losing public input at the project scale, therefore, one of the mechanisms for improving assessment practice for impacts to the aquatic environment would be jeopardized.

A related mechanism provided by project based EIA is the identification of local values that may need to be protected at a regional scale, such as the preservation of species important for cultural use, like sturgeon. Lake sturgeon was identified as a VEC in only one of the EISs reviewed, the Encana Shallow Gas Infill Development project (EIS # 48, Table 3.1), whereas fish in general were identified as an assessment component in 18 of the EISs reviewed. While the habitat requirements for lake sturgeon are not fully understood (Haxton et al. 2008), evidence in the South Saskatchewan River indicate that spawning and over-wintering sites are located hundreds of kilometres apart (Smith 2003), suggesting that lake sturgeon can only be protected through a regional strategy. The regional strategy, however, must be applied at the local level to protect key sturgeon habitat that can be very localized in nature. Managing cumulative impacts such as the potential effects on sturgeon habitat within a watershed framework will require coming to terms with the issues of scale raised for CEA generally: more harm may be done by a small developments in sensitive sites than by a larger developments in a more robust sites (Wood 2007), and multiple scales of assessment are required to ensure that local priorities are not lost (Therival & Ross 2007). Project based EIA can complement WCEA by offering continual identification of assessment components of local significance as well as the opportunity to affect development decisions at key locales at the time they are made.

Some problems in the practice of EIA could also be overcome in adopting a combination of EIA with WCEA. One is that there is currently no easy way of transferring information from one project EIA to another, something essential for predicting future cumulative impacts (required under CEAA) but difficult to achieve when other proponents or government agencies are not forthcoming (see Creasy & Ross 2005, Therival & Ross 2007, Harriman & Noble 2008). In the case of the Cheviot Mine Project, for example, difficulties in obtaining information about future plans of other industries and regional actors contributed to a three year delay in completing the EIA that ultimately led to the suspension of the project (Creasey & Ross 2005). Information about future developments could be shared between EIAs through a regional database as part of a cumulative effects framework (Dubé 2003, Harriman & Noble 2009), as could information about priority aquatic VECs, emerging priority aquatic VECs, and sensitive sites. Regarding priorities, this research identified a tendency of responsible authorities to focus only on aquatic VECs that pertain to their own mandate without considering the full range of aquatic VECs that may be impacted by the project under consideration. Fisheries and Oceans Canada, for example focused almost exclusively on water quality, fish and fish habitat for in-stream construction projects without considering impacts to riparian vegetation, migratory birds or invasive species that were considered by other responsible authorities doing similar projects. The bias in aquatic VEC selection may be seen as a failure to share information about priorities both between responsible authorities and across assessments. There is no mechanism within project-based EIA to share information between assessments within a region. The healthy river ecosystem assessment system (THREATS), currently under development in Canada, will have the capacity to support the sharing of aquatic assessment information between projects in a watershed, and could play a key role in the establishment of WCEA.

A second problem is the near absence of a quantitative, combined stressor-based and effects-based approach in assessing water VECs. While it is argued that precision in quantifying cumulative impacts is of less importance than understanding the big picture and mechanisms underlying the effects (Reid 1998, Therival & Ross 1997, Harriman & Noble 2009), it is also argued that a quantitative approach applied at the functional level of ecosystems (Beanlands & Duinker 1983) and in both stressor-based prediction and effects-based monitoring (Dubé 2003, Kilgour et al. 2006) can improve the science of impact assessment and our understanding of the mechanisms underlying effects. The single project that did establish a quantitative baseline trend for surface water quality, the Proposed Joffre Expansion Project (EIS # 34, Table 3.1), recognized that phosphorous concentrations in the Red Deer River already exceeded provincial guidelines before their project was considered. In this case the proponent took the initiative to launch a regional cumulative effect management collaborative as a mitigation mechanism to offset additional phosphorous loading. The 29 other projects that examined impacts to surface water quality, however, ultimately acted without a regional perspective. Some used water quality guidelines as assessment criteria, but most relied on 'expert' judgement to determine whether impacts were or were not likely to be significant. Unfortunately, the use of 'expert judgment' for assessing potential impacts identified in project-based EIA can easily overlook subtle but cumulatively significant effects when the underlying mechanisms are not understood (Therival & Ross 1997). For practical reasons expert judgment may nonetheless be a preferred option in assessing some stressors with cumulative significance for small projects, such as increased suspended sediment concentrations from ground disturbance causing soil erosion, where standard precautionary mitigation measures may be more appropriate than a quantitative monitoring process. For factors such as phosphorous loading, however, regional data management, trend analysis, target thresholds, effects-based modeling, and stress predictions, all quantitative in nature, could provide the information necessary to effectively manage cumulative impacts at the project level (Dubé 2003, Harriman & Noble 2008). In keeping with the expectations of the literature (Duinker & Grieg 2006), only 1 of 35 assessments reviewed in the South Saskatchewan River watershed attempted to take this approach for a surface water quality factor.

A combination of EIA and WCEA would provide a mechanism for information about sensitive sites to move from the local to the regional scale, and information about priorities to move from the regional to the local decision-making scale. Assessments at both scales are necessary to ensure that CEA is responsive to local conditions, effective in establishing assessment priorities, and effective in influencing development (Therival & Ross 2007, Harriman & Noble 2009). Unfortunately, the requirement to conduct EIAs is being eroded at the federal and provincial levels in Canada. The Budget Implementation Act (Canada 2009) included a reform package for CEAA that exempted a number of infrastructure projects receiving federal funding from the requirement to conduct federal environmental assessments (see Noble et al. 2011) and amendments to the Navigable Waters Protection Act (Canada 1985) eliminated the requirement for environmental assessments for ‘minor works’ (Transport Canada 2010). Similarly the province of Saskatchewan is currently developing a code-of-practice approach to environmental regulation that will effectively bypass the EIA screening process for many small and medium size projects (Saskatchewan 2010). The adoption of codes of practice in place of EIA may significantly reduce the burden of assessment costs and delays that are seen as obstacles to economic development, but the alternative of establishing a regional assessment framework such as WCEA, where a regional database, such as THREATS (2011) may be used to provide baseline information, establish regional assessment priorities, archive knowledge of other developments, and continually improve assessment science (Dubé 2003), would arguably also reduce the proponent burden while at the same time better serve the environment through improved management of aquatic cumulative effects. A combination of WCEA and project-based EIA would provide assessment efficiency, better understanding of cumulative effects at a watershed scale, VEC and indicator priorities identified regionally, and an analytical assessment and decision-making process for individual projects. The burden of conducting cumulative effects assessments within individual project assessments could be significantly reduced through the establishment of WCEA, but the role of project-based EIA, where the particular impacts of individual projects can be identified, understood, and deferred if necessary, should not be eliminated.

5.4. Establishing Priority VECs and Priority Parameters

The above section highlights the importance of being able to transfer knowledge produced at the local scale through project based EIA up to the regional scale where priority VECs can be established, and then back down again to other assessments at the local scale. It is important to consider that while the VECs and condition parameters identified in project based EIA can be applied at any scale, priority regional VECs will not necessarily be the same as project scale VECs (Hegmann et al. 1999) because they must also account for stresses that occur at the landscape level outside of EIA (Dubé 2003); they must account for social and economic factors in addition to aquatic ecosystem factors (Noble 2008); and they must be oriented to regional planning needs (Harriman & Noble 2008). Regional priorities will also need to be established for VEC factors and condition and stress parameters as well as for VECs. Where quantitative regional models are established for effects-based assessment, the stress and condition parameters that are essential to the models will become regional priorities for inclusion in project EIA.

Harriman and Noble (2009: 285) observed that regional cumulative effects assessment can take many forms and must be “fit for purpose” to be effective. As the emerging practice and science of WCEA unfolds, the competing purposes that complicate VEC and indicator selection may become clearer. It is apparent that WCEA must come to terms with issues of scale to interpret and communicate both local and regional information, identify reference conditions and baseline trends, provide information to establish loading limits and thresholds for acceptable levels of change, and identify priority stressors and sensitive sites to serve EIA (see Noble 2010). It might also be anticipated that WCEA should help develop an understanding of the broad geomorphological and ecological functions of the river system, and help develop quantitative modeling tools that can enhance our ability to predict impacts to the aquatic environment (see Reid 1993, Seitz 2011). It seems likely that many of these purposes could share a core set of VECs and indicators broadly applicable within a watershed and responsive to different scales of assessment.

5.5 Information Management Deficiency in EIA

One of the shortcomings of EIA practice, from a cumulative effects perspective, is the “shifting baseline syndrome” where successive assessments look only as far back as the most recent study to establish a reference or baseline condition and, as a result, longer-term and underlying trends are often overlooked (see Pauly 1995:430). Baselines must identify changing conditions over space and time so as to avoid the serial degradation of the environment through cumulative impacts (see Dubé 2003, Noble 2006). We have the science to capture baseline trends, but data availability is an issue (Kilgour et al. 2006, Seitz 2011). Temporally and spatially explicit data, such as the baseline studies frequently conducted historically within EIA, is required to establish baseline trends that in turn can be used to establish thresholds for VECs (see Dubé 2003, Kilgour et al. 2006, Seitz 2011). Recognizing which VECs are approaching thresholds is necessary for selecting priority VECs for CEA and WCEA. Unfortunately this research demonstrates that, with one or two exceptions, such data is generally not available. Even with the investment of countless hours of active solicitation over a three month period, combined with the additional support of government agency personnel, 25% of the EISs targeted for this review (all federal screening assessments) could not be located or accessed. CEAA does not keep an archive of completed EISs and proponents are difficult to identify and frequently not forthcoming. Among the EISs that were reviewed, many referred to technical studies and to data that were not included in the actual report. This research supports the observation by made by Dubé (2003) that it is necessary to provide better management of the spatially and temporally explicit data and analysis that is produced within a watershed, including within EIA. EIA data can contribute to the establishment of reference conditions and baseline trends and variability, and use that information to help establish loading limits and thresholds to guide future development and land use decisions (see also Noble 2010), and to help identify priority VECs for CEA.

The province of Saskatchewan, Canada is currently developing a regional airshed framework for long-term monitoring of air quality and atmospheric depositions where independent management boards for each airshed will oversee and coordinate monitoring with adjacent provinces (McCullum 2011 pers. com). It could be argued that a parallel structure for watersheds would provide a sound basis for producing and managing the data required for WCEA (and to support aquatic CEA within EIA), and could utilize related monitoring data from government agencies and industry as well as the aquatic baseline data produced within project based EIA, if it were available. There is a serious deficiency in information management within EIA that needs to be overcome to help prevent baseline shift, support effective CEA, and identify priority CEA VECs. The NEB, with on-line postings of EISs, complete with background studies and related documentation, has demonstrated how the information management deficiency within EIA could be easily overcome.

CHAPTER 6
CONCLUSION

This thesis set out to determine whether the VECs and indicators used for the aquatic environment in the practice of project-based EIA can be scaled up for use in regional, watershed-based aquatic cumulative effects assessment. Watershed cumulative effect assessment aims to combine stressor-based and effects-based assessment practices used in EIA and regional assessments conducted outside of EIA, respectively, to improve the modelling and strengthen the science available for effective CEA, and to develop a regional database and resource that can support a range of environmental management and planning processes in a watershed in an ongoing capacity. One of the challenges in developing a framework for WCEA is to establish a set of assessment components and indicators that reflect the assessment needs of the watershed at both the project and regional scales. This research examined the quality and use of aquatic VECs and indicators in EIA practice and determined that they are not suitable for direct application at the watershed scale. The implications of that finding are addressed here.

The environmental components identified as VECs in EIA practice are too few and too inconsistent to be useful in comparing content from EISs across a watershed, although a standard set of aquatic biophysical VECs, VEC factors and condition parameters could be developed from EIS content analysis by employing a standard hierarchical framework. Such a set of aquatic assessment components could be used to standardize terminology and facilitate information exchange between assessments and assessment scales, but would be of limited use in establishing priority assessment foci for WCEA. Priorities for regional aquatic assessment cannot be identified by scaling up the VECs and indicators used in project based EIA because the selection and frequency of VEC use is affected by regulatory biases, responsible authority mandates and preferences, omissions and inconsistencies, and because indicators are used infrequently and generally not oriented to a quantitative approach. The aquatic VECs and indicators that are priorities for assessment across the South Saskatchewan River watershed will therefore need to be determined through a regional assessment that accounts for mesoscale and local scale sensitivities (see Noble 2010, Seitz 2011).

The biases and omissions influencing aquatic VEC selection for individual projects indicate that guidance is required for project based EIA if it is to deal effectively with cumulative effects at the project level or contribute to regional cumulative effect assessment. The selection of VECs and indicators for EIA must be influenced by priorities established through a regional assessment and it will therefore be necessary to apply aquatic cumulative assessment tools at the regional or watershed scale. The range of aquatic VECs identified in this review indicates that an interdisciplinary approach to science will be essential, but at the same time WCEA must be influenced by the public consultation that is part of EIA if it is to respond to emerging aquatic VECs that are not yet commonly used in EIA practice and to benefit from local knowledge and local scrutiny. Both WCEA and EIA are required to ensure that regional and local aquatic assessment priorities are properly identified and taken into consideration when development decisions are made, and a mechanism is required to ensure the aquatic assessment priorities identified in WCEA subsequently influence the terms of reference for project based environmental impact assessment.

Valued socioeconomic components (VSCs) were not examined in this review, even though they are linked to many biophysical components that are ultimately part of impact assessment. The VSCs included economic, aesthetic, human health, and cultural factors such as First Nation culturally significant sites and traditional-use resources that may also be interpreted as biophysical VECs. A recent ruling by the Supreme Court of Canada, in Mikisew Cree First Nation v. Canada, recognized the requirement for First Nation consultation on developments affecting traditional-use areas. We can therefore expect that traditional ecological knowledge (TEK) is becoming a necessary contribution rather than an optional extra to inform the EIA and CEA processes, for the identification of sensitive sites and important ecological relationships and for the selection of biophysical VECs and indicators. None of the 35 EISs reviewed in the South Saskatchewan River watershed utilized TEK, and there appears to be a deficit of understanding with respect to how such work can be incorporated into EIA and CEA.

Aquatic cumulative effects, such as inadequate instream flow related to excessive water withdrawals, identified as an issue in the South Saskatchewan River basin, are often a consequence of incremental impacts and it is therefore necessary to assess the impacts of even small changes to aquatic VECs such as surface water quantity and flow. That can only be accomplished through broad application of CEA, through project-based EIA, to proposed projects with the potential to affect priority regional and locally significant aquatic VECs. If a VEC is omitted from assessment due to licensing arrangements or the application of a code of practice, the cumulative impact to the VEC, and indirect cumulative impacts to related VECs, will not be accounted for. On the South Saskatchewan River, EIAs for irrigation expansion and consumptive use of water for industrial processes failed to consider direct impacts to surface water quantity and stream flow or indirect impacts to sturgeon habitat or the downstream Saskatchewan River Delta resulting from reduced flow.

The selection of VECs for aquatic CEA requires the development of thresholds for priority stressors identified through application of a regional assessment supported by long-term monitoring and the sharing of existing data produced within the region. Aquatic CEA therefore will not be effective in Canada until we institutionalize regional approaches such as WCEA. It will also be necessary to update CEA guidelines for EIA practice to ensure that regional priorities and sensitivities are accounted for in individual development projects; that information such as baselines and monitoring data are made easily available to support other assessments and VEC identification; that TEK is incorporated; and that licensing and codes of practice do not limit the scope of assessment so that cumulative impacts to priority VECs are overlooked.

6.1. Limitations

In accordance with the state of practice in the South Saskatchewan River watershed, and the likeliest source of unidentified cumulative impacts, the EISs selected for review were mainly drawn from (federal) screening assessments. As a consequence, the sample size of both comprehensive type assessments, and provincial or harmonized federal/provincial assessments was quite limited. Observations of differences between assessment types and governing authorities are therefore of limited power from an analytical perspective and should be taken more as indications than as proofs of differences. The same caveat applies to observations regarding some responsible authorities; although DFO and AAFC were well represented in the study, DND, TC and WD were less so. Sample size limitations may have affected some particular observations, but the overall trends such as selection bias by responsible authorities would be difficult to refute on that basis.

The organization of environmental components was not an interdisciplinary exercise, but rather an inductive exercise by a sole researcher, and therefore may be somewhat limited in its capacity to represent essential ecosystem components. A number of assumptions underlie the component organization and identification, such as categorizing species at risk and invasive species as species-level biodiversity issues or components, and assuming that when the introduction of deleterious substances to fish bearing waters from ground disturbance was identified as an assessment issue, that suspended solids concentrations in surface water was implicated as a VEC factor. The environmental element hierarchy presented should be taken as an example of a VEC hierarchy oriented to aquatic assessment, and not be considered definitive.

6.2. Recommendations for Further Research

While cumulative effects are the consequence of a myriad of small changes in the environment, cumulative effects assessment must be focused on changes to the environment that are judged significant, such as when VECs are beginning to approach some kind of threshold. Ecosystems are far too complex for us to model everything that may occur, and resources need to be directed to those environmental changes that we know or suspect are significant. VECs therefore need to be carefully scoped in support of CEA (see Noble 2010). That scoping depends on analysis of long-term data, and must consider regional, mesoscale, and local issues (see Seitz et al. 2011). Scoping must focus on biophysical VECs but must also account for value placed on different biophysical VECs in a socioeconomic context. It is necessary to understand how First Nation cultures, for example, interpret acceptable limits of environmental change, and what biophysical components and thresholds can be used to assess such change. Research that will support the establishment of VECs for WCEA needs to move forward on several fronts. We need to develop data management systems that can make existing and future temporally and spatially explicit baseline and monitoring data readily available for review and analysis. We need to develop long term monitoring regimes for river systems that can support CEA requirements within the watershed, including the identification of priority VECs at different scales. We need to understand how best to amend out-dated guidelines for conducting CEA and for incorporating

CEA into EIA. We need to examine how to ensure that cumulative impacts obscured by licensing and codes-of-practice are accounted for. We need to understand the implications of a bi-cultural approach to resource management, and how that may affect VEC and indicator selection. We need to understand how to incorporate WCEA itself into our policy and institutional structures.

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