Muskeg River Diversion Reassessment
Shell Jackpine Mine Expansion

Hydrology & Geomorphology Review

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EXECUTIVE SUMMARY

Shell Canada Energy has proposed major modifications to the Mine Plan associated with its proposed Jackpine Mine Expansion. The changes involve an alternative approach to diverting the Muskeg River and changes to tailings management. Shell has provided a reassessment of its Environmental Impact Assessment information (as amended) in support of this new direction. The present review examines the reassessment information for the quality, accuracy and sufficiency of the hydrologic and geomorphological science provided and for the validity and effectiveness of interpretations and communications of the scientific findings. The review focuses on Chapters 1, 3, 4 and 6 of the May-2011 "Muskeg River Diversion Assessment" (Golder 2011) and Chapter 2 of the May-2011 "Submission of Information to the Joint Review Panel" (Shell 2011) which are here collectively referred to as the reassessment. In addition, the 2007 EIA submission and subsequent amendment and supplemental-information submissions were reviewed, as necessary.

The reassessment information is found to suffer from serious deficiencies in science and its communication and, as a result, its validity and reliability are in question. In general, the information provided is insufficient to reach independent conclusions about the consequences of the revised plan on First Nation Treaty and aboriginal rights and/or traditional uses. From gaps in methods and data gathering, to unsuitable presentation of findings, to subjective evaluation and communication, the reassessment does not provide what regulators such as the Energy Resources Conservation Board, the Joint Review Panel, the Canadian Environmental Assessment Agency, Alberta Environment, and the Department of Fisheries and Oceans should need to determine whether Shell's science and planning will adequately protect First Nation Treaty and aboriginal rights and/or traditional use and safeguard the environment. Information is not provided that assesses implications for traditional use as a result of the revised plan. The information that is provided is generally non-scientific and subjective and as a result is unreliable in determining impact significance. This unreliability is exacerbated by ambiguity in presentation and a lack of consideration of scientific uncertainty. Results are not communicated effectively to decision makers and others affected by the findings. Nine recommendations are provided that, if implemented, would assist in remedying the shortcomings of the reassessment.

1.0 INTRODUCTION

Shell Canada ("Shell") is developing its plans for the Jackpine Mine Expansion (JME) in the oilsands region of northern Alberta. As part of the proposed mine, Shell plans to remove a large part of the Muskeg River. The 1480-km^2 Muskeg River watershed drains an extensive area of boreal forest wetlands and is tributary to the Athabasca River, about 55 km north of Fort McMurray, Canada (CEMA 2008). The Muskeg River has several major tributaries including Jackpine Creek, Wapasu Creek, and Muskeg Creek. Originally, Shell planned to divert the river into a pipe during future decades of mining but have recently altered plans and now propose to reroute the Muskeg River into a diversion channel to the north of the mine site. Shell has provided a reassessment of the environmental implications of this proposal because it differs from what was originally put forth in its JME Environmental Impact Assessment submission and subsequent amendment ("as amended"). The present review examines the reassessment information for the quality, accuracy and sufficiency of the hydrologic and geomorphological science provided and for the validity and effectiveness of interpretations and communications of the scientific findings.

Shell submitted its original application for the proposed Jackpine Mine Expansion and Pierre River Mine (PRM) in December 2007. An update to this EIA was submitted in May 2008 for the JME/PRM (Shell 2008) addressing: (1) the separation of the environmental impacts associated with the two projects, ie, Jackpine Mine Expansion and Pierre River Mine; (2) removal of impacts associated with mining the Fort McKay First Nations lands since these lands are not included in the development plan; and (3) provision of an updated SEIA to include 2007 census data for the region and Government of Alberta infrastructure funding. Three Supplemental Information Rounds have subsequently been published: the December-2009 SIR Round 1 for JME and the April-2010 SIR Round 1 for PRM (Shell 2009); the June-2010 SIR Round 2 (Shell 2010a), and the August-2010 SIR Round 3 (Shell 2010b). In October 2010, the applications were deemed to be complete and awaited consideration by the JRP.

As introduced above, Shell has chosen to submit additional information supporting changes to its EIA application. It is modifying its planning with respect to the Muskeg River in two significant ways. It originally proposed to route the Muskeg River into a gravity pipeline. It is now proposing a modification to this arrangement so that the river is diverted into a long-term temporary open channel at the north end of the mine site. The second modification involves removing contaminated tailings from the northern end-pit lakes. These two major changes in approach require significant modifications to the Mine Plan such that the EIA information that has been submitted is no longer complete. Shell has provided updated information elaborating the changes to the Mine Plan associated with this new direction and any changes to the EIA findings as already submitted to the JRP. Shell (2011) provides this update and contains an appendix, here called Golder (2011), which provides the supporting data and analysis for the reassessment. The present review focuses on the information provided in Golder (2011), supplemented by Shell (2011) and other relevant publications.

The Muskeg River Mine sits on the Albian sands, a deposit of bitumen that is of interest to a number of mining operations. There are various major existing, approved, and proposed mines in the Muskeg River drainage. These are Aurora North, Aurora South (Syncrude), Muskeg River Mine, Muskeg River Mine Expansion (Albian Oilsands), Jackpine Mine Phase 1, Jackpine Mine Expansion (Shell), Kearl Oil Sands (Imperial Oil Sands), Husky Sunrise (SAGD), in addition to two major limestone quarries (AENV 2008). Based on 2008 oil prices, and building on current approved and application mines, it is estimated that up to 60% of the area of the Muskeg River drainage may be subject to surface mining with much of the remaining areas suitable for in situ methods which involve additional surface disturbance (CEMA 2008, p13), with most of this disturbance resulting from open-pit bitumen mining. Prior to developing the proposal contained in Shell (2011), Shell intended to route the Muskeg River into a gravity pipeline during mine operations. Under this former plan, there were four end-pit lakes – two in the northern section of the lease and two in its southern section. The northern lakes were planned to receive Mature Fine Tailings (MFT) and their contaminants, with these waters proposed to be routed into the Muskeg River upon closure. Shell has opted to modify this proposal to improve the environmental performance of its Mine Plan. Under Shell's new proposal described in Shell (2011), it is proposing to route the Muskeg River through a new channel it will build at the northern limit of the Mine Plan area and to modify its approach to dealing with MFT so that water flowing into the Muskeg River upon closure is expected by Shell to be uncontaminated. Under the new configuration, the Northeast Pit Lake flows into the Northwest Pit Lake which in turn discharges into the Muskeg River. Additionally, the Jackpine South Pit Lake flows into the Jackpine South Central Pit Lake which in turn discharges into the Muskeg River. At closure, the open channel used to divert the Muskeg River will be closed and reclaimed and the river directed through the Northeast Pit lake then through the Northwest Pit Lake to rejoin the existing Muskeg River on the west side of the JME mine area.

Shell notes that the Energy Resources Conservation Board (ERCB) Directive 074 has influenced its decision to make these changes. Given that the new directive raises the environmental standards for tailings management, it appears that the proposed changes are offered partly to address these new requirements. However, Shell also suggests that this revised plan and its reassessment are a result of extensive input from First Nations arising from four years of consultation. While there has been input concerning the nature and type of disturbance in the Muskeg River watershed, First Nations have requested repeatedly, in consultations, that the Muskeg River be left intact, in place. In addition, First Nations have requested that Shell provide an analysis of the impacts of its proposal on First Nation Treaty and aboriginal rights and/or traditional uses. To date, Shell has not addressed these central requirements of First Nations, as provided through consultations. In fact, in its reassessment in support of the revised proposal, it continues to avoid mentioning this outcome from its First Nations consultations.

In its revised proposal submitted to the Joint Review Panel for consideration (Shell 2011; Golder 2011), Shell has provided its view of an alternative mine plan within the larger Jackpine Mine Expansion proposal. Fine tailings will be eliminated from the aquatic landscape through a variety of means. Fines will be dried in Dedicated Disposal Area 2 (DDA2), sequestered in Non-Segregating Tailings (NST) at a higher rate than originally anticipated, and the remaining inventory thickened in centrifuges using emerging technology. As a result, the pit lakes will contain no MFT (Golder 2011, p15). The pit-lake volume formerly filled with MFT will be filled, instead, with water from the lower Athabasca River. Other changes include removal of a surge pond, increase in the Project Development Area (PDA) with a decrease in the mine footprint, revisions to the mine development area and mine pit cell locations, new water balances for the process water and tailings, modifications to drainage and closure plans including the size and character of pit lakes and locations of littoral zones, extension of mine life by one year, and changes to the Fort Hills Overburden Disposal Area (OBDA). The new proposal also modifies some procedural details associated with the EIA approach such as adjustment in snapshot years.

1.1 Objectives

Aqua Environmental Associates has been retained by the Athabasca Chipewyan First Nation (ACFN) and the Mikisew Cree First Nation (MCFN) to carry out a targeted review of Shell's May-2011 submission to the Joint Review Panel that will review Shell's application for the Jackpine Mine expansion. This review holds two central objectives:

1. *To assess the quality, accuracy and sufficiency of the hydrologic and geomorphological science provided by Shell in support of its revised Muskeg River Diversion Alternative plan.*
2. *To assess the validity and effectiveness of interpretations and communications of the scientific findings to the Joint Review Panel.*

The review focuses on Chapters 1, 3, 4 and 6 of (Golder 2011) and Chapter 2 of (Shell 2011) which are here collectively referred to as the "reassessment". The review draws on other relevant publications as necessary such as Shell (2007, 2008, 2009, 2010a, and 2010b). The focus of the review is on *differences* between the revised proposal and the EIA, as amended; it is beyond the scope of this limited review to provide an examination of the merits of the original EIA nor the EIA as amended. Unless otherwise indicated, all references to "regulators" refer to one or more of the Energy Resources Conservation Board, the Joint Review Panel, the Canadian Environmental Assessment Agency, Alberta Environment, and the Department of Fisheries and Oceans.

The ACFN and MCFN have advised Aqua Environmental Associates that if First Nation Treaty and aboriginal rights and/or traditional uses are to be sustained in the context of the Muskeg River, at least two criteria must be met. First, healthy ecosystems must be maintained. The health of the Muskeg River and its drainage is defined, in part, in terms of the function and structure of the riverine environment;

a healthy ecosystem supports healthy populations of fish living in the rivers, as well as healthy populations of waterfowl and wildlife species living in or near the river. Second, First Nations' ability to continue use of the Muskeg River, and the traditional resources associated with it, must be sustained, in terms of quantity, quality and access. The review has been conducted in such a way to inform the evaluation by decision-makers and First Nations as to whether these two criteria are met in the context of the Muskeg River Diversion Alternative Plan. It is also important to note that the ACFN and MCFN have informed Aqua Environmental Associates that the First Nations have been expressing concerns to Shell about any further disturbance to the Muskeg River and have been requesting that the Muskeg River be left intact.

2.0 FINDINGS

Review findings are provided according to five topics in planning and science that are foundational to safeguarding the Treaty and aboriginal rights and/or traditional uses of the ACFN and the MCFN.

2.1 Regional Planning and Cumulative Effects

As reviewed in section 1, there are various major mine proposals either planned or operational within the Muskeg River drainage. These adjacent and nearby activities have the potential to prevent the success of Shell's plans for the future condition of the Muskeg River. Potential interactions include groundwater interception, changes in contaminant transport, and changes in soils and surface characteristics with potential to influence runoff patterns. Golder (2011) and Shell (2011) make little mention of regional-scale interactions which implies that they have not taken them into account or have insufficiently taken them into account. What steps have been taken to take these watershed scale issues into account in the reassessment? In some cases, the adjacency issues of concern involve other Shell mines; it is also unclear whether Shell has coordinated its reassessment with its *own* nearby industrial development.

In addition to the direct influences from adjacent and nearby development, there is also the potential for indirect influences resulting from changes in hydrologic behavior of the drainage as its surface is mined and altered. For example, pit lakes can attenuate the hydrograph in comparison with the pre-development case and many of these changes may take place off Shell's lease but still within the Muskeg River drainage. Similarly, to what extent have the approvals of other existing and proposed mines located elsewhere in the Muskeg River watershed depended on an intact Muskeg River? Are other mines removing inflow to the Muskeg River at other locations along its length? It is beyond the scope of the present review to examine the EIA and approval history of the other existing and proposed mines within this drainage however it is important that Shell and regulators examine this information to determine whether there are interactions with other developments that could invalidate elements of its reassessment. It is suggested that Shell begin with its other leases in the area then move on to other existing and proposed projects.

2.2 Hydrology

The revised proposal involves significant revisions to the hydrologic characterization of the Muskeg River through time. Also, as wetlands on a large scale are destroyed and reclaimed as non-wetlands, changes will come about in the basic hydrologic behaviour of the drainage and its runoff dynamics. These considerations are addressed in this section.

2.2.1 Hydrologic Modelling

Golder (2011, p9) states that the aquatic resources snapshots for the years prior to 2050 will not change as a result of the revised proposal and the reason for this is that the flow results "are expected to be comparable to the Application Case" in the EIA update. No evidence is apparent for this statement. Although the text refers to "reasoning," in fact reasoning is not provided for this statement except to say that the revised proposal won't affect the pre-2050 snapshots thus only the 2050 and 2065 snapshots are reassessed. This is not "reasoning" because neither explanation nor evidence is provided to justify why this statement is made. The rationale with evidence needs to be provided for consideration. In the absence of such evidence, it must be assumed that the pre-2050 period will be affected by the revised proposal and that the reassessment is, thus, incomplete.

Hydrologic modeling has been undertaken in support of the reassessment information. Details are not provided in Golder (2011) about the model that has been used, the scenarios that have been considered, and the model parameterization and assumptions that were used to run the model. Without this information it cannot be determined whether the model runs have considered the appropriate information. For example, there are other mines elsewhere in the Muskeg River drainage which will have additional effects on the surface water and groundwater hydrology in the drainage and thus have the potential to impact the hydrograph beyond the changes that Shell is considering as part of its revised proposal. In addition, climate change (see next section) will affect the future Muskeg River hydrograph however because of the lack of information provided, it is unclear the extent to which such emerging issues have been addressed appropriately in the modeling.

Golder (2011, p9) states:

> "The Application Case assessment evaluates the effects of the JME, and the existing and approved developments, including effects due to integration of operational water management and closure drainage plans, on the surface water hydrology within the Local Study Area (LSA) and Regional Study Area (RSA). The Project will include design features and mitigation measures to reduce the effects on hydrology. The design features and mitigation measures, included in the operational water management and closure drainage plans, follow the same management principles, objectives and design criteria, as outlined in the EIA."

This appears to be saying that regional concerns are addressed and that standard mitigation measures already in the EIA, as amended, will be sufficient to cover incremental risk issues that may arise from the revised proposal. This is insufficient to address issues associated with the revised proposal's major changes to the EIA, as amended. For the ACFN and MCFN to be confident that their Treaty and aboriginal rights and/or traditional uses will not be jeopardized by Shell's change of plans, the detailed information describing the new environmental effects that will ensue under the revised proposal needs to be described and a linked and transparent explanation provided as to how the specific mitigative measures described in the EIA, as amended, will be sufficient to address the additional issues.

The hydrologic modeling undertaken to assess effects of the revised proposal on Muskeg River flows is summarized in Golder (2011) in terms of characteristics of the projected hydrograph of the Muskeg River for 2050 and 2065/Far-Future (herein simply called 2065) at four points along the river. The parameters are the same as those originally calculated from the EIA, as amended, namely mean annual discharge, mean open-water discharge, mean ice-cover discharge, 7Q10 low flow discharge, and 10-year flood peak discharge in addition to the average and maximum flow depths corresponding to each of these metrics. The impact assessment nodes are M0 (downstream of Stanley Creek), M1 (downstream of Muskeg Creek), M2 (downstream of Jackpine Creek), and M3 (at the mouth with the lower Athabasca River). The results are given in terms of the absolute amount of change (ie, with original units) and are compared with the projections provided in the EIA, as amended.

Golder (2011) provides a qualitative and subjective discussion of these new projections in comparison with the previous EIA projections, as amended. It is unclear from this presentation what is the relative degree of the various changes. To assist in understanding these changes, Tables 1 and 2 provide an alternative presentation of the change in terms of the percentage change at each node for each of the five hydrograph parameters (and contributing area). The percentage change relative to the EIA as amended ranges between 0 and about 8% for most parameters at most nodes with some changes ranging up to over 100%.

Table 1. Incremental change to 2050 from EIA-Update as percentage of EIA-Update.

Parameter	**Units**	**Muskeg River Node**			
		M0	**M1**	**M2**	**M3**
area contributing to runoff	km^2	7.5	3.8	1.9	1.8
mean annual discharge	m^3/s	6.3	3.4	2.1	2.1
mean open-water discharge	m^3/s	7.6	4.7	2.5	2.2
mean ice-cover discharge	m^3/s	-3.1	-1.1	-0.3	0.8
7Q10 low flow discharge	m^3/s	1.7	7.9	6.3	5.0
10-year flood peak discharge	m^3/s	122.3	63.0	29.0	27.4

Table 2. Incremental change to 2065 (and far future) from EIA-Update as percentage of EIA-Update.

Parameter	**Units**	**Muskeg River Node**			
		M0	**M1**	**M2**	**M3**
area contributing to runoff	km^2	0	0	0	0
mean annual discharge	m^3/s	2.8	1.5	1.2	0.9
mean open-water discharge	m^3/s	2.2	1.2	0.7	0.1
mean ice-cover discharge	m^3/s	5.1	3.5	3.0	2.8
7Q10 low flow discharge	m^3/s	31.2	0.8	4.8	5.3
10-year flood peak discharge	m^3/s	-1.6	-2.2	-3.0	-0.7

The discussion of these changes provided in Golder (2011) is a subjective and ambiguous evaluation of the relative significance of the degree of change with terms used such as "comparable", "similar", "slightly higher", "slightly lower", and "practically the same". There is no reference made to the significance to the riverine aquatic ecosystem of a particular level of change of a specific parameter. For example, in DFO's June-2010 CSAS workshop for the Athabasca River, the group agreed that any water removed from the Athabasca River would be significant if the river were at its 100-year 7-day low flow (7Q100). So, in this instance, if a water license were for only a few percent of the river flow, that level of removal at the 7Q100 was deemed significant and detrimental to the aquatic ecosystem. Put another way, some system functions are sensitive to change in specific hydrograph parameters while others are relatively insensitive. Unfortunately, in addition to the ambiguous comparative assessment of these amounts of change, there is also no indication provided on the level of significance for the aquatic ecosystem that the incremental proportional change in each of these parameters implies due to Shell's revised proposal. And in other cases, the level of change is much larger, at times over 100% from the EIA, as amended. While these ambiguities remain unaddressed, regulators will be unable to interpret the environmental implications of these departures from the EIA, as amended.

To help understand its definition of qualitative terms used, Table 3 provides the quantitative percentage change for each of the comparisons provided in Golder (2011). It is clear from this table that there is no reliable pattern associated with the terms that are used, suggesting not only subjectivity but also inconsistency and thus implying a troubling ambiguity for those such as regulators and First Nations who have to rely on this reassessment to verify that Treaty and aboriginal rights and/or traditional uses are being safeguarded. In examples 1 and 2, revised values that are on average 14.9% and 3.5% larger are considered "comparable" to the existing EIA as amended whereas in example 8, the overall change is deemed "practically the same" as the EIA, as amended for change that is on average 14.9% higher (2050) and 3.7% higher (2065). In example 3, parameters that are 3.5, 4.2, and 60.4% higher are considered "similar" to the original EIA values, as amended. The terms introduce a bizarre level of subjectivity and inconsistency into what is supposed to be an objective science-based discussion. It is suggested that this discussion be revised to remove the subjectivity, quantitative measures be used to describe change (preferably using clearly expressed operational definitions), and these measures be linked to our best understanding of how that level of change affects key functions of the aquatic ecosystem. Until that is done, this reassessment of the modeling results is of no value to regulators in reaching a determination as to whether the revised proposal will protect the aquatic ecosystem and safeguard First Nation Treaty and aboriginal rights and/or traditional uses.

2.2.2 Climate Change

There is a global scientific consensus that climate change is real and is being driven by the burning of fossil fuels by humans (ACS 2010; GSA 2010; AGU 2007; AMS 2007; APS 2007; AAAS 2006). As discussed in detail in Carver (2010), emissions are outpacing even the most severe scenario presented by the Intergovernmental

Table 3. Implied quantitative meaning of subjective comparative terms as used in the Golder (2011) reassessment.

Page	Excerpt from Golder (2011)	Comparative Term	Actual % Change[1]
1)12	For the 2050 snapshot, the predicted changes in flow parameters from pre-development case are comparable to those presented in the May 2008 update at various nodes (M0,M1,M2,M3) on the Muskeg River. [2050]	comparable	M0: 28.2 M1: 16.0 M2: 8.1 M3: 7.5 All: 14.9
2)13	The combined effect would be increase [sic] in mean annual flow at all four nodes on the Muskeg compared to the pre-development value. The expected changes for the MRDA Mine Plan assessment are comparable to the results presented in the May 2008 EIA Update.	comparable	M0:6.3 M1:3.4 M2:2.1 M3:2.1 All: 3.5
3)12	The expected mean annual flow, mean open-water flow, and 10-year flood flow are lower than the pre-development case due to the JME closed-circuit operations, but similar to the May 2008 EIA update. [2050]	similar	annual:3.5 open:4.2 10flood:60.4
4)12	The expected mean ice-cover flow and 7Q10 low flow are higher than pre-development case due to overburden dewatering flows during operation but similar to the results presented in the May 2008 EIA update. [2050]	higher	ice-cover:2.4 7Q10:114. (note: this is a pre-dev comparison)
5)12	The expected mean ice-cover flow and 7Q10 low flow are higher than pre-development case due to overburden dewatering flows during operation but similar to the results presented in the May 2008 EIA update. [2050]	similar	ice-cover:1.3 7Q10:5.2
6)12	The changes to the annual average flow depth and annual maximum flow depth for the MRDA Mine Plan are similar to those presented in the May 2008 IEA Update. [2050]	similar	Annual: 2.7 maximum: 2.9
7)15	The incremental increases to the annual average and maximum flow depths at closure are similar to the results presented in the May 2008 EIA Update. [2065]	similar	Annual: 0.2 maximum: 0.2
8)15	This assessment shows that the predicted effects on the surface hydrologic conditions in the Jackpine Creek, Kearl Lake, Muskeg River and the Athabasca River for the MRDA Mine Plan are practically the same as those presented in the EIA as updated. [overall]	practically the same	2050 mean: 14.9 2065 mean:3.7
9)12	For the assessment, the flow statistics for the mean annual, mean open-water, mean ice-cover and 7Q10 low flow parameters are slightly higher than the May 2008 EIA update at all nodes, except for the mean ice-cover flow at Nodes M0 and M1, which is slightly lower than the values in 2008 EIA update. [2050]	slightly higher slightly lower	Annual:3.5 open:4.2 Ice-cover:1.3 7Q10:5.2 Ice-cover: 3.1/-1.1/-0.3/0.8 (M0/M1/M2/M3)
10) 12	The 10-year flood flow statistics are much higher than the 2008 EIA Update due to removal of the surge pond in the MRDA Mine Plan. [2050]	much higher	10flood:60.4

[1] Items 1-3, 5-12 are relative to the EIA as amended and item 4 is relative to the pre-development case: these follow the nature of each excerpted comparison.

Panel on Climate Change. The Muskeg River Diversion reassessment makes no reference to the potential for future flows to depart from expected patterns as a result of climate change. The lack of assessment information provided by Shell suggests that Shell may be unaware of key developments in climate change science and its importance in examining the potential to significantly modify future water dynamics in the Muskeg River. Analysis of the effects of climate change on surface hydrology is a dynamic area of science. Shell's possible lack of scientific concern and awareness on this central issue is surprising given the huge investments that are being based on the promise of returning the Muskeg River's function in the post-mine landscape. Without scientifically understanding the potential for climate change to interfere with achieving projected flows, Shell may be jeopardizing the future viability of the ACFN and MCFN to continue to secure its Treaty and aboriginal rights and/or traditional land uses. Any possible shortcomings of Shell's technical work can be addressed by applying the appropriate climate projections to suitable hydrologic models and presenting the outcomes with their corresponding confidence limits. Until this is done and made available, regulators will be unable to make an informed decision on the merits of the revised proposal for evaluating environmental effects and its utility in safeguarding the ACFN's and MCFN's Treaty and aboriginal rights and/or traditional uses.

In the scientific work undertaken through the Phase Two Framework Committee (P2FC; Ohlson et al 2010), AENV and DFO recognize that climate change will have a significant negative effect on mean annual flow and long-term low flow of the Lower Athabasca River (Lebel *et al.* 2009). For example, the P2FC provides modelling results that show that low flows in the Athabasca are expected to decline by an average of 32.2% by the 2050s and may decline by as much as 54.1% according to some Global Climate Modelling data (Carver 2010.) Similar processes are at work in the Muskeg River drainage and are likely to modify hydrologic projections away from the projections provided in the reassessment particularly given the long times of interest in the planning associated with the Jackpine Mine Expansion (to 2065). It is suggested that more information about the modeling details be provided so that these concerns can be investigated. If scenarios of climate change have not been meaningfully incorporated into the modeling projections, the results may be inappropriate and misleading.

It is suggested that Shell review Carver (2010, section 3.1) for a critical review of the P2FC climate change science. The guidance therein on addressing climate change implications is applicable in the present situation and, if followed, would enable Shell to scientifically incorporate the potential effects of climate change on future Muskeg River flows, thereby supporting its present planning and approval stage. In addition, a collection of significant deficiencies in the technical approach followed by Lebel *et al* (2009) is identified in Carver (2010) indicating that the quantitative conclusions of the P2FC are inappropriate. It is beyond the scope of this review to repeat that assessment, however most of the statements made within that context are applicable to the Muskeg River drainage (a notable exception is the discussion on glaciers).

2.2.3 Waterbodies

The 5.6-km^2 Kearl Lake is the largest natural lake in the watershed, draining 85.6 km^2. Four mines surround Kearl Lake. Golder (2011, p10) states that there will be no change in the water levels of Kearl Lake due to the revised proposal. Unfortunately, no method of analysis is provided, no data are presented, nor is any explanation tendered to explain why the revised proposal would have no effect on Kearl Lake. It is beyond the scope of this review to do this analysis. It is suggested that this explanatory information be provided so that the ACFN and MCFN may determine whether the revised proposal will have an effect on Kearl Lake, in light of the various disturbances already present in its catchment.

2.2.4 Integration

Golder (2011, p13) concludes: "Based on the analysis, the MRDA Mine Plan, employing the mitigation measures identified in the Hydrology Assessment in the EIA, does not alter the results presented in the Hydrology Assessment in the EIA." That is, the conclusion in the EIA, as amended, of no effect on the aquatic ecosystem is reinforced. However, as noted above, Golder's analysis is based on revised (EIA) projections that are subjectively evaluated, differences that are dismissed without reference to their physical significance to the aquatic ecosystems, and mitigation of recognized significant differences that is based on generic assurances of standard operating practices.

It is unclear why Shell has provided a non-scientific evaluation of its revised proposal in a process that is required to be scientific (Hegmann 1999). A scientific evaluation would present relevant forms of relative differences such as percentage change and potentially other non-dimensional comparisons, discuss these measures of change in terms of their threshold levels of effect, and generally provide the outcomes in terms of defined risk classes. Instead, Shell has provided new information to regulators that is not sufficient for reaching a determination of "no incremental effect". To the contrary, some of the revised model projections point to 2.1 to 28.2% average change in hydrograph parameters (at different nodes) that might be significant to the aquatic ecosystem, particularly in light of the fact that at the elevated risk levels that the watershed will be subjected to regionally during 2050 and 2065 snapshots, incremental risk becomes of greater concern in comparison with the same increment of change imposed on a pristine ecosystem.

2.3 Hydrogeology

Golder (2011, p8) indicates that Shell's new Muskeg River Diversion proposal will potentially affect the quality of groundwater, depressurization of the Basal Aquifer, dewatering of the Pleistocene Channel Aquifer, dewatering of the overburden, seepage rates, and outflows to surface water. Few additional details are provided as to the extent of these potential additional and modified impacts. It appears from Golder (2011) that Shell will be using existing standard measures to address these new projected impacts. For example, Shell will reactively capture contaminated surface runoff and seepage, returning it for reuse. Also, Shell will determine whether additional contaminated seeping is occurring by referring to data from its groundwater monitoring program and then capturing seepage through active piping or ditching.

The scope of potential impacts to groundwater due to Shell's new proposal is significant. Yet, Golder (2011, p8) concludes that predicted changes to groundwater outflows and groundwater quality "are similar to or lower than those predicted in the EIA." Unfortunately, data are not provided to support this subjective conclusion. The spread of contaminated seepage into surrounding surface water and groundwater is a serious concern throughout the oilsands region. It is inappropriate to conclude that the additional impacts will be essentially zero without a corresponding analysis to support this conclusion. The assertion that existing reactive measures already specified in the EIA, as amended, will be sufficient to address incremental concerns is inadequate unless details are provided indicating that equipment, staffing, surveillance intensity, etc will be sufficient. Additionally, details must be provided about the groundwater monitoring program and how it will be adapted in scope and intensity to detect the incremental changes that may arise under Shell's new proposal. Again, with none of these details given in Golder (2011), it is impossible to conclude that there will be no increase in environment impact.

2.4 Geomorphology and Water Quality

Golder (2011) does not provide information on the characteristics of the new channel proposed for the northern limit of the PDA. Will the channel be a flume with riprap or will it be engineered to develop natural riverine structure and function? If the planned channel has few characteristics of ecological value, then it is unclear the extent to which this proposal will provide "mitigative" benefit over the earlier EIA plan, as amended.

Given the proximity of pit lakes maintained in place using engineered dikes, and potentially at elevations higher than the future Muskeg River, there may be the potential for instability and avulsion hazards. What is the likelihood of these and other flood-related events jeopardizing the integrity of the future channel? This is not discussed in Golder (2011) nor in Shell (2011).

Golder (2011) maintains that there will be no decline in water quality as a result of the revised proposal. From the information provided, however, it is not possible to verify the accuracy of this claim. On the one hand, the removal of MFT from the pit lakes should improve the water quality in the pit lakes and the water flowing into the future Muskeg River. However, there are tradeoffs in the revised proposal that may jeopardize water quality. For example, Golder (2011, p14) states "During the post-construction "conditioning" period, some erosion of the new channels are [sic] anticipated, potentially with total suspended solids concentrations in excess of regulatory guidelines. The duration of the conditioning period could range from several days to several weeks. Sediment generation in the channel will be minimized by revegetation of stream banks, overbank areas and berms as soon as possible after construction and by the use of channel armour (riprap), where required. Relevant regulatory guidelines and standards of best-management practices will be followed during construction activities. These mitigation measures will reduce the risk of increased sediment loadings to the receiving stream." There is very little detail provided to evaluate these performance claims, however, it is possible that the conditioning period that Golder (2011) states may be optimistic, given the magnitude of what is being attempted and the challenges inherent in recreating a stable channel environment. A detailed plan for the operation and post-construction periods regarding the new river reaches needs to be provided. The measures indicated amount to saying that using best-management practices and following regulations will address all possible problems and yet little detail and evidence is provided to assess whether this is likely.

Golder (2011, p15) lists two other changes associated with the revised proposal that may threaten water quality. First, DDA2 will be created and operated to remove process-affected water from fine tailings. Second, deeper pit lakes will be created and these have the potential for a loss of suitable mixing and aeration. Unfortunately, assessment of these implications is not given and thus cannot be evaluated. Instead, Golder (2011, p16) makes a vague reference to the value of "design features and mitigation measures to reduce the Project effects on water quality." Although it is a little unclear, it appears that the mitigation measures intended to address contamination due to DDA2 are the same existing standard measures that will already be in place to limit the potential for contamination from industrial activities. For example, Shell will reactively capture contaminated surface runoff and seepage, returning it for reuse. Also, Shell will capture contaminated seepage through active piping or ditching. Based on this generic performance promise, Golder (2011) states that "effects on water quality due [sic] the construction and operation of DDA2 are expected to be negligible." This statement is unreliable: there is no basis provided for the claim of no effect. Nor is there empirical evidence presented from the Alberta oilsands region to support the claim.

These generic management promises do not provide the scientific assessment that the regulators, the ACFN and the MCFN need to assure themselves that First Nation Treaty and aboriginal rights and/or traditional uses will be protected under the revised proposal.

2.5 Reclamation

A collection of changes has been made to address ERCB Directive 074 and many of these changes may have implications for the Muskeg River at closure. However, few quantitative details are provided hence it is not possible to evaluate the implications for the Muskeg River. For example, the size and volume of the pit lakes has been changed but not provided. How long will it take for these lakes to fill and overflow to feed the Muskeg River? How will the open channel used to divert the Muskeg River be closed and reclaimed? How will the Muskeg River be directed through the northern pit lakes before returning to its original channel? The development of effective pit lakes is an area of ongoing research and as such it is unclear the reliability of the techniques that Shell intends to follow. What is the percentage likelihood that there will be contamination to the lakes and, as a result, to the Muskeg River at closure? Water to fill the pit lakes will also come from the Athabasca River (Golder 2011, p15) under the revised proposal. Have these new withdrawals already been factored into the Phase 2 Framework Committee (P2FC) non-consensus Option H (Ohlson et al 2010)? If not, then do these additional withdrawals jeopardize the P2FC's outcome? With these questions unanswered by the revised proposal, it remains unclear to regulators and to First Nations whether the revised proposal will meet its objectives and safeguard First Nation Treaty and aboriginal rights and/or traditional uses.

3.0 DISCUSSION

3.1 Scope

Shell maintains that the proposal to put the Muskeg River into an open channel at the north end of the PDA is a mitigation to accommodate First Nations consultation input regarding Shell's EIA application, as amended, to put the river into a pipe. Putting a river into a pipe is a terminal action and as such, almost anything would improve upon it. That said, the diversion and open channel are inconsistent with the First Nations' request: namely, that the river be left in place. If the revised plan is deemed by Shell to be a way to address this consultation input from First Nations, then Shell should provide additional information about how its proposal for rerouting the Muskeg River will maintain in place the traditional-use opportunities currently associated with the Muskeg River. Such information has not been provided in the reassessment. For example, what will be the characteristics of the new river and how will those characteristics be maintained in the new location? How will the characteristics of the new channel reflect preferences in the exercise of traditional activities and cultural connections to the Muskeg River? Until this additional information is made available, and the scope clarified of what is intended to be achieved under this revised plan to address consultation input, then the proposal should be considered simply an alternate plan, not a mitigation.

3.2 Subjectivity

Golder (2011) and Shell (2011) are notable for their extensive use of subjective evaluations. A selective listing of subjective commentary used in Golder (2011) with reference to hydrologic modeling is provided in section 2.2. This practice continues in other parts of the reassessment such as on page 7 where Golder (2011) states that the shift in timing of the mining activities "is not anticipated to affect the findings of the Aquatics Resource Assessment…" Objective, evidence-based statements are needed, not generic reassurances of no effect. Shell has a responsibility to look ahead and identify where its choices may cause impacts not foreseen in the EIA, as amended. There are many other examples distributed throughout the reassessment. Shell (2011) continues this practice as it reaches conclusions about the implications of the (subjective) reassessment on the EIA, as amended. For example, Shell (2011, p31) repeatedly uses evaluations such as "are expected to be comparable", "are practically the same", "are essentially the same", and "are the same or similar to" and uses these subjective comparisons to conclude that the Alternative Mine Plan does not change any of the assessments presented in the EIA, as amended.

It is difficult to understand how Shell (2011) can conclude that the flows are "practically the same" when there are departures of up to and over 60% for some parameters in comparison with the results from the EIA, as amended. This speaks to the drawbacks of subjective evaluation – unintended and intended bias can arise and find its way into the proponent's conclusions. This practice highlights a central deficiency of the reassessment and its interpretation: a majority of its conclusions are founded upon subjective statements unsubstantiated by evidence and sound reasoning. The reassessment and its interpretations are non-scientific which is inappropriate in the present context. To avoid the potential for bias, the reassessment should be redone using clear operational definitions of terms used to describe significance of impact. For example, if the term “practically the same” is going to be used, then it should be defined and in reference to empirical data from the Alberta oilsands region. Quantitative presentation of the changes is needed and using methods that are described and repeatable. These outcomes can then be clearly communicated to decision makers and others interested in the outcome. The problem of subjective analysis and communication is present in almost every aspect of the reassessment. Until this information is presented in a scientific manner, its reliability will remain in question, and regulators will not be in a position to determine whether Shell’s plans can safeguard the environment and the Treaty and aboriginal rights and/or traditional uses of the ACFN and the MCFN and neither will the ACFN and the MCFN be in a position to decide for themselves whether their interests are being protected.

Subjectivity is also intermixed with ambiguity making it impossible to engage meaningfully with the related content. In addition to the subjective evaluations, Golder (2011) and Shell (2011) make reference to standard management practices, and what may be best-management practices, without describing them and without linking their implementation to the particular details of what they say these practices will address. (see section 3.4 for more details). This aspect of the reassessment should be redone to provide clarity about the issues and how they are being addressed. It is beyond the scope of the present review to inventory the many subjective evaluations and examine each one in detail; here, we can only indicate the deficiencies and describe what is needed in general to correct them.

Note that Golder (2011, p30) makes reference to Shell (2009b) yet there is no reference description provided, adding additional ambiguity to the discussion.

3.3 Uncertainty

Golder (2011) and Shell (2011) read as if there is certainty that there will be no impacts from the revised proposal (incremental to the EIA, as amended) and in those unusual instances where some new or modified impact is possible, then it is standard practices already laid out in the EIA, as amended, that will effectively address anything that will arise. Throughout Golder (2011) and Shell (2011), there is essentially no acknowledgement of the uncertainty associated with claims of performance, for example, around seepage management. Where it is acknowledged that something new will come about, rather than providing insight into the new outcomes and their uncertainty, the reassessment and its interpretation dismiss further concern by referring ambiguously to measures that are already in the EIA, as amended. In addition, there is a lack of detail provided about how these performance standards will be achieved.

Hydrologic modeling results are provided in Golder (2011) without any indication of the scientific confidence in these outputs. All models involve assumptions and data limitations that lead to a range in confidence of their outputs. The reliability of the model outputs is not discussed by Golder (2011). For these models to be of value in the reassessment, the confidence limits on the model outputs need to be provided.

In addition, the details of how climate change influences have been considered should also be provided. If climate change concerns have not been addressed, then an assessment of the uncertainty introduced therein should be provided.

3.4 Practices

There are many instances in which Shell acknowledges that additional environmental impacts will occur with the revised proposal. Rather than providing a specific discussion of these impacts and what is needed to address them, Shell chooses to refer to measures that are already generically in place under the existing EIA, as amended, to say that there will be no additional impact. Instead, what is needed is a clear presentation of the new outcome that is anticipated and the specific measures that will be undertaken to address the outcomes. The responses need to be clearly linked to expected environmental outcomes and provide sufficient information so that the reader can be assured that the resources and measures will be in place to address the need.

This level of detail also applies to monitoring programs that will be relied upon for Shell to become aware of the environmental consequences and its need to respond. It is inadequate to refer to "monitoring" in general based on an overall promise. Instead, the monitoring design needs to be provided so that regulators and First Nations can assure themselves that the incremental environmental impacts associated with the revised plan will be detected in time and resources made available to address them. Criteria, indicators, interpretive thresholds etc should all be provided and be based on empirical data from the Alberta oilsands region.

3.5 Communication

There is considerable uncertainty in the new assessment information provided. Unclear outcomes are implied that involve probabilities of occurrence that are neither determined nor estimated. The presentation typically begins with a subjective comparison with information that was provided in the EIA, as amended, followed by, in most instances, claims of no significant change and that the EIA, as amended, remains an accurate statement of environmental impact. Where differences are acknowledged to be significant, reference is made to an existing part of the EIA, as amended, (generally either standard practices or routine monitoring) to justify concluding that no new consequences will be present for the environment and by implication for First Nation Treaty and aboriginal rights and/or traditional uses.

This approach is inappropriate as a basis for carrying out a science-based assessment of potential impact and sharing the results with interested parties. As detailed elsewhere in this review, appropriate objective measures should be used for comparing former assessment information with new results. Where changes are found, significance should be discussed in reference to what is meaningful to the ecosystem. And where changes of significance are determined to be present, a risk-based presentation of the change should be provided that links the various response options to the level of risk. Instead, ambiguous statements are difference are provided with vague performance promises to address the change and relating to measures that are already in place (eg, BMPs and monitoring programs) or are based on unproven technologies.

4.0 RECOMMENDATIONS

The reassessment information provided by Shell in support of its Muskeg River diversion proposal falls well short of necessary standards in scientific analysis and communication. From inappropriate measurement, to subjective evaluation and communication, to unsuitable presentation of findings, the reassessment does not enable regulators to determine whether Shell's science and planning will adequately protect First Nation Treaty and aboriginal rights and/or traditional uses and safeguard the environment. These scientific and communication deficiencies compound with a lack of analysis of traditional land-use to make this reassessment of little value to First Nations in assuring them that the reassessment is protecting their Treaty and aboriginal rights and/or traditional uses.

The reassessment is deficient in two broad areas. First, in being scientific – objective, repeatable, quantitative, etc. Second, in communicating outcomes and change so that decision-makers and other interested and affected parties can meaningfully make use of the results. As it stands, Shell's May-2011 submission does not do this. The following recommendations, if implemented fully, would assist in addressing these significant gaps in the reassessment. Until all of these recommendations are properly implemented in a revised reassessment, the reassessment does not assist regulators in reaching a determination as to whether the revised proposal will protect the aquatic ecosystem nor whether the revised proposal will have impacts on First Nation Treaty and aboriginal rights and/or traditional uses. This outcome results because, for the reasons cited above, there will remain unacceptable doubt as to the validity of the reassessment.

To complete the reassessment of the EIA update information, it is recommended that the ACFN and MCFN request that the development proponent provide the following additional information and technical analyses:

A) Assessment

1. **Carry out a traditional-use study to identify potential impacts from the revised proposal.** Impacts to the environment are significant and have implied consequences for traditional use opportunities. Shell should consider and address the consultation input that it has already received from First Nations.
2. **Assess the proposed changes to the EIA within a regional and watershed context**. Consider surface water changes due to other development activities within the Muskeg River watershed and groundwater changes from other development activities with the potential to affect regional groundwater affecting the future Muskeg River. Examine cumulative effects from multiple leases.
3. **Incorporate climate change projections into the hydrologic modeling and communicate the methods and results transparently.** Provide methods and scenarios used in the hydrologic modeling to incorporate credible consideration of future climates.

B) Analysis

4. **Avoid subjectivity in evaluating change and communicating results.** Be objective in how change is described, evaluated and communicated to decision makers and others who may be affected by Shell's activities. Provide additional information particularly around those items for which subjective reasoning is used to justify omitting certain rework and analyses (e.g., the pre-2050 hydrologic modeling). Use percentages and other appropriate relative values, explain (and justify) the portrayal of the significance of these percentage changes with reference to best knowledge of system behavior and thresholds.

5. **Use appropriate measures to describe change from the EIA, as amended.** Absolute measures can be inappropriate and may need to be replaced by appropriate proportional change and linked to understanding of system behavior (e.g., thresholds). Engage services of individuals with skills and experience in communicating environmental change to decision makers.

6. **Provide scientific confidence using quantitative or qualitative measures.** Communicate the degree of confidence in quantitative and qualitative measures. Where quantitative confidence limits can be determined, provide them (eg, outputs of hydrologic models). Where future success depends on unproven technology and yet-to-be undertaken research, communicate the level of uncertainty, at least qualitatively.

C) Communication

7. **Describe the characteristics of the new channel that will replace sections of the Muskeg River and the restoration methodology that will be followed.** Describe how the fluvial behavior of the new channel will be managed to yield a naturalised river with suitable structure and function.

8. **Describe the scope and details of any monitoring programs being relied upon to reduce incremental EIA risks.** Provide the design of monitoring programs that are in place to address incremental environmental impact.

9. **Provide technical information about the hydrologic modeling.** Provide a technical rationale for why the pre-2050 snapshots will be unaffected by the revised proposal.

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Shell Jackpine Mine Expansion
No Net Loss Plan

Hydrology & Geomorphology Review

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EXECUTIVE SUMMARY

As part of its proposed Jackpine Mine Expansion (JME) in the oilsands region of northern Alberta, Shell plans to remove a part of the Muskeg River and parts of other nearby waterbodies. To compensate for the fish habitat losses associated with these landscape changes, Shell intends to create lake habitat to meet its requirements under the federal Fisheries Act. Shell has provided the preliminary design concept of a proposed compensation reservoir, to be located in a paleochannel of the lower Athabasca River. The present review examines this July-2011 Draft No Net Loss Plan (NNLP - main report; Appendix C; Appendix E) for the quality, accuracy and sufficiency of the hydrologic and geomorphological science provided and for the validity and effectiveness of interpretations and communications of the associated scientific findings.

The NNLP information is found to suffer from significant deficiencies in science and its communication and, as a result, its validity and reliability are in question. In general, the information provided is insufficient to reach independent conclusions about the consequences of the NNLP on First Nations Treaty and aboriginal rights and traditional uses. Weak study design, methodological shortcomings, data deficiencies, and inappropriate presentation of findings make it difficult for regulators to determine whether Shell's science and planning will create sufficient compensatory fish habitat and adequately protect First Nations' Treaty and aboriginal rights and traditional uses. Information is not provided that assesses implications for traditional use as a result of the NNLP. There is extensive and unquantified uncertainty arising from the models and methods that is not recognized in the NNLP. The implications of climate change on the habitat compensation exercise have not been considered. Statistical work is descriptive and lacking tests to determine representativeness and significance. Many of the assessments rely heavily on untested professional opinion. Methodological flaws in the surrogate streams assessment and geomorphic assessment invalidate the conclusions reached. Reliance is placed on monitoring and adaptive management to overcome scientific uncertainties yet there is limited information provided directly within the NNLP explaining how this will be achieved.

The collective unreliability of Shell's NNLP science is exacerbated by its lack of evaluation of scientific uncertainty. Confidence limits are not provided on any quantitative results nor is evaluation provided on the overall reliability of the output numbers. It appears that Shell is pursuing an approach to uncertainty whereby scientific omissions and shortcomings are being compensated for by "conservative" calculations in the accounting of fish habitat, however the degree to which this tradeoff is realized is completely unstudied and unrecognized. Overall, results and their limitations are not communicated effectively to decision makers and others affected by the findings of the NNLP and unfounded conclusions are reached. Nine recommendations are provided that, if implemented, would assist in addressing the significant gaps identified here. These recommendations address assessment, information and analysis, and communication deficiencies in the draft NNLP.

1.0 INTRODUCTION

Shell Canada ("Shell") is developing its plans for the Jackpine Mine Expansion (JME) in the oilsands region of northern Alberta. As part of the proposed mine, Shell plans to remove a large part of the Muskeg River and parts of other nearby waterbodies. To compensate for the habitat losses associated with these landscape changes, Shell intends to create lake habitat west of the lower Athabasca River (LAR) on top of a LAR paleochannel that will be dammed and bermed to create a reservoir with fish habitat values. This approach follows that of the Department of Fisheries and Oceans (DFO) that mandates no net loss of fish habitat in those situations where a HADD (Harmful Alteration Disruption or Destruction of fish habitat) has happened under the federal Fisheries Act.

Shell has provided the preliminary design concept of the proposed preferred compensation reservoir (Golder 2011, p44), located west of and parallel to the LAR. At closure, the Redclay reservoir lake will have a water surface elevation of 237 masl. The reservoir lake will be contained within Reaches 1 and 2 of Redclay Creek and within the Redclay paleochannel through the use of dykes located at the northern extent of the paleochannel, in the southern portion of the paleochannel at the Big Creek raw water storage pond, and at three locations along the eastern side of the lake, separating the reservoir from the LAR. The Redclay reservoir lake will actually be two reservoirs – North Redclay reservoir and South Redclay reservoir – and will have a combined area of 5.82 km^2, a length of 18 km, a maximum depth of 13 m, and a width ranging from 150 m to 850 m. The South Redclay Lake is being put forth as compensation for the JME/PRM project and will have a length of 9.8 km, a maximum depth of 13 m, a width ranging from 220 m to 390 m, and a surface area of 3.52 km^2. The North Redclay reservoir acts as compensation for the Muskeg River Mine Expansion. An outlet channel will be created on the east side of the lake to discharge reservoir outflows to the LAR.

1.1 Objectives

Aqua Environmental Associates has been retained by the Athabasca Chipewyan First Nation (ACFN) to carry out a review of Shell's July-2011 Draft No Net Loss Plan for the Jackpine Mine Expansion (Golder 2011). This review focuses on understanding the plan's objectives and key elements to ascertain whether the ACFN's concerns have been addressed from hydrologic and geomorphological perspectives. Specifically, the review holds two central objectives:

1. *To assess the quality, accuracy and sufficiency of the hydrologic and geomorphological science provided by Shell in support of its Draft No Net Loss Plan for the Jackpine Mine Expansion.*
2. *To assess the validity and effectiveness of interpretations and communications of the scientific findings to the Department of Fisheries and Oceans and, ultimately, to the Joint Review Panel.*

This report provides a brief review of these hydrology and geomorphology concerns coming out of Shell's July-2011 Draft No Net Loss Plan (NNLP) and offers recommendations to address concerns identified. The review focuses on the draft plan and draws on other relevant publications as necessary. Specifically, the main report and Appendices C and E of Golder (2011) were reviewed and here are collectively referred to as the (draft) NNLP.

The ACFN has advised Aqua Environmental Associates that if First Nation Treaty and aboriginal rights and/or traditional uses are to be sustained in the context of the aquatic ecosystems that are affected and/or modified in the draft NNLP*,* at least two criteria must be met. First, healthy ecosystems must be maintained. The health of the Muskeg River, its drainage, and other waterbodies affected by the JME proposal, is defined in part, in terms of the function and structure of the riverine and lacustrine environments; a healthy ecosystem supports healthy populations of fish living in rivers and lakes, as well as healthy populations of waterfowl and wildlife species living in or near these waterbodies. Second, First Nations' ability to continue use of existing waterbodies, and the traditional resources associated with them, must be sustained, in terms of quantity, quality and access. The review has been conducted in such a way as to inform the evaluation by decision-makers and First Nations as to whether these two criteria are met in the context of the JME NNLP. ACFN has also advised that there are other considerations for Treaty and aboriginal rights and/or traditional uses in the context of No Net Loss Planning that go beyond aquatic ecosystems; however, these are beyond the scope of this review.

Unless otherwise indicated, all references to "regulators" refer to one or more of the Energy Resources Conservation Board, the Joint Review Panel, the Canadian Environmental Assessment Agency, Alberta Environment, and the Department of Fisheries and Oceans.

Hatfield (2010), Golder (2008) and Golder (2003) are referred to in Golder (2011) and upon brief review, they appear to contain information that is relevant to and should inform the decision by regulators on the NNLP. Due to constraints of time and budget, it is not possible to provide detailed review of these reports at this point. Shell does not appear to have incorporated the relevant information from these reports directly into Golder (2011). Will DFO review and integrate that information into their decision-making process?

Note that whereas water quality and fish habitat issues are, in general, out of scope for this review, there are overlapping aspects of these topic areas that are touched on in this review.

2.0 FINDINGS

The review of Shell's Draft NNLP (Golder 2011) is provided in four areas: modeling, climate change, geomorphology, and uncertainty and monitoring. The integration of these findings is discussed in section 3.

2.1 Hydrologic Modelling

The NNLP is built on the results of several modeling exercises including a hydrologic model, habitat quantity assumptions, and various empirical relations linking habitat value by species to river characteristics. Each modeling component involves extensive simplifications and unknowns only some of which are acknowledged in the draft NNLP. The uncertainties lead to serious concerns about the accuracy and precision of Shell's habitat calculations and possibly overconfident assurances of projected fish habitat under the compensation regime. The habitat modeling embodies extensive simplifications and data shortages and is not reviewed further here because it is addressed in a separate review (MSES 2011).

The hydrologic behavior of the future landscape is simulated using a hydrologic model created by the USA Environmental Protection Agency and called HSPF (Hydrologic Simulation Program Fortran). Unfortunately, information on its assumptions and inherent errors is not provided directly in Golder (2011) and hence the implications of these limitations for the habitat projections are difficult to evaluate. Despite the inherent complexity of the HSPF model, only one calibration attempt has been carried out as part of Shell's initial EIA application (Shell 2007). The effectiveness of this calibration is unclear and potentially in question given the profound landscape changes that would be part of any future hydrologic simulations (due to consequences of widespread open-pit mining) and which may imply the need for additional calibration.

There is little or no indication of how the future landscape is characterized in the HSPF simulation runs supporting the habitat-compensation calculations. For example, it is not specified in Golder (2011) whether the modeling simulations include the subsequent EIA update information nor the more recent changes associated with the revised Muskeg River Diversion Plan. Are the recent revisions to end-pit reservoirs incorporated into the hydrologic projections? Is the wetland loss and change included in the modeling simulations? Impacts to regional groundwater have the potential to impact surface water. Have the simulations incorporated potential changes to regional groundwater resulting from present and future cumulative oilsands developments over the period of modeling? It seems unlikely given that Worley Parsons (2008) and AENV (2010) have identified considerable uncertainty in understanding the interactions between groundwater and surface water in the oilsands area. In fact, the Interim Groundwater Management Framework (AENV 2010) goes on to point out that it will "take up to two years to properly characterize the baseline conditions in the key regional aquifers and much longer to establish the natural range of variability or seasonality." Unfortunately, Golder (2011) is silent on the limitations that this lack of regional groundwater knowledge holds for the draft NNLP.

Golder (2011) does not mention climate change yet the models project flows many decades out when northern climates are expected to be very different to what they are today. Have the hydrologic simulations considered scenarios of future climate change? If not, how can Shell be confident that its NNLP will deliver the quantities of replacement habitat that the NNLP puts forth? With enhanced evaporation rates and with markedly changed annual runoff patterns, the shift from riverine to lacustrine fish habitat may be unreliable as a compensation approach. The next section provides details on climate change and its importance in developing the NNLP.

Given the lack of information outlined above, it is not possible to determine the reliability of the HSPF model projections nor the suitability of the model simulations. And given the implied lack of consideration of other factors in the simulations – notably climate change – there is concern that the simulations may be not only imprecise, but inaccurate, particularly given that many of the landscape changes are expected to result in reduced water availability. This scientific uncertainty casts doubt on the validity of the projected habitat estimates. It is suggested that Shell present the above requested information directly in the report so that an informed assessment can be made of the uncertainty and reliability associated with its model projections.

2.2 Climate Change

There is a global scientific consensus that climate change is real and is being driven by the burning of fossil fuels by humans (ACS 2010; GSA 2010; AGU 2007; AMS 2007; APS 2007; AAAS 2006). As discussed in detail in Carver (2010), emissions are outpacing even the most severe scenario presented by the Intergovernmental Panel on Climate Change. The Draft NNLP (Golder 2011) makes no reference to the potential for future hydrologic conditions to depart from past patterns as a result of climate change. The lack of recognition of this dynamic situation in Shell's assessment information and NNLP suggests that Shell may be unaware of key developments in climate change science and its importance in examining the potential to significantly modify future water dynamics in planning for its compensation action. Analysis of the effects of climate change on surface hydrology is a dynamic area of science. Without scientifically understanding and estimating the potential for climate change to interfere with achieving habitat projections, Shell may be jeopardizing the future viability of projected compensatory habitats. Any actual shortcomings of Shell's technical work can be addressed by examining a plausible range of projected future climates and applying the hydrologic parameters to the HSPF modeling. Results should be provided with corresponding confidence limits. Until this is done and made available, DFO will be unable to make an informed decision on the validity of forecasted habitat compensation and thus will be unable to safeguard the ACFN's Treaty and aboriginal rights and/or traditional uses in its decision-making.

In the scientific work undertaken through the Phase Two Framework Committee (P2FC; Ohlson *et al* 2010), regulators recognize that climate change will have a significant negative effect on mean annual flow and long-term low flow of the LAR (Lebel *et al.* 2009). For example, the P2FC provides modelling results that show that low flows in the LAR are expected to decline by an average of 32.2% by the 2050s and may decline by as much as 54.1% according to data from Global Climate Models (Carver 2010.) Similar processes are at work in the Muskeg River drainage and are likely to modify hydrologic behaviour sufficiently that the HSPF modeling outputs may be optimistic (*i.e.*, not conservative) particularly given the long times of interest in the planning associated with the Jackpine Mine Expansion (to 2065). It is suggested that more information about the modeling details be provided so that these concerns can be investigated. If scenarios of climate change have not been meaningfully incorporated into the modeling projections, the results may be inappropriate and misleading.

It is suggested that Shell review Carver (2010, section 3.1) for a critical review of the P2FC climate change science. The guidance therein on addressing climate change implications is applicable in the present situation and, if followed, would enable Shell to scientifically incorporate the potential effects of climate change on future inflows to the Redclay reservoirs, thereby supporting its present planning and application stage. In addition, a collection of significant deficiencies in the technical approach followed by Lebel *et al* (2009) is identified in Carver (2010) indicating that the quantitative conclusions of the P2FC are inappropriate. It is beyond the scope of this review to repeat that assessment, however most of the statements made within that context are applicable in the present context (a notable exception is the discussion on glaciers).

2.3 Geomorphology

The landscape changes Shell proposes to make to the Muskeg River and its drainage area are predicted by Golder (2011) to decrease the Muskeg River's peak flows and augment its low flows due to increased water storage in end-pit reservoirs (an overall process called "flow attenuation"). Upon mine closure, the two-year peak flow is predicted to decline from its current 22.9 m^3/s to 12.2 m^3/s at the mouth with the LAR (Golder 2011, appendix E, p2). Such hydrograph changes have the potential to modify river structure and, as a result, fish habitat. To address concerns that flow attenuation of the Muskeg River may negatively affect its fish habitat, Shell provides two assessments intended to examine concerns for possible channel change. The Surrogate Streams Assessment (Golder 2011, appendix C) describes three regional streams with upstream lakes to infer expected habitat changes in the Muskeg River once its drainage contains mining-related reservoirs. According to Golder (2011, p34), the "purpose of the surrogate stream assessment was to identify candidate streams that have a similar hydrologic regime as to that predicted for the Muskeg River after closure as a means of understanding what the channel morphology, habitat conditions, water quality and fish community of the far future Muskeg River might resemble." The Geomorphic Assessment (Golder 2011, appendix E) examines channel morphology on a regional basis to predict potential channel responses to the flow alterations from mining.

According to Golder (2011, p35): "An additional mechanism in which the reduction in peak flows may affect fish habitat is through a change in the channel morphology in response to a different flow regime. The possibility of the Muskeg River channel changing from its current configuration was evaluated through a geomorphic assessment…" Shell undertook a number of studies "To evaluate the net change in habitat (ie, to balance to potential [sic] gains and losses" (Golder 2011, p34) including the Surrogate Streams Assessment and the Geomorphic Assessment. Through these assessments, Shell appears to be inferring that the channel morphology and habitat characteristics of the far future Muskeg River, under flow attenuation, will be relatively unchanged thereby providing its current level of fish habitat into the far future time period. Unfortunately, each assessment includes methodological weaknesses, discussed below in this section, that compromise the validity of the conclusions reached. As a result, these assessments do not support the conclusion that the far future Muskeg River will possess equivalent fish habitat as it does today and consequently, additional compensation habitat may be required of which Shell is not taking account in its draft NNLP.

2.3.1 Surrogate Streams Assessment

In the surrogate streams assessment, streams with major lakes in their drainages are selected for comparison with the far future Muskeg River drainage (which will contain a regionally anomalous percentage of large lakes (due to the creation of pit-lake reservoirs). The principle behind the study is that potential flow-attenuation changes to the Muskeg River can be better understood by looking at the characteristics of natural streams with lake-dominated hydrographs and comparing them with those of the present and future Muskeg River. Golder (2011) searched Water Survey of Canada data for streams sites in northeastern Alberta and northwestern Saskatchewan (and only within the boreal forest) with a mean annual flow and a 2-year peak flow within 50% of that of the predicted far future Muskeg River. Only one site fit this criterion (Jackfish River) while another (La Biche) was added that was considered "slightly outside" the 50% tolerance (62.3%) and so was included due to the lack of target data. A third site (Winefred River) with a lake in its drainage but lacking hydrometric data was added due to anecdotal accounts that it was similar in characteristics to the Muskeg River. For the three streams chosen, and for reaches of the Muskeg River, physical, chemical, and biological measurements were recorded.

The study reaches a number of conclusions that, for the most part, focus on a descriptive comparison of the surrogate streams and the Muskeg River. The study's strengths lie in its focus on channel-forming flows (mean annual flow and two-year peak flow) and the objective of studying channels dominated by lakes. Also, it reaches a conclusion that "large changes in flow primarily result in changes to depth with minimal changes to wetted width" (p21) which is plausible based on first principles. However, given the severe data limitations that they faced in carrying out the assessment, it is unclear why Golder continued with the assessment because their conclusions are weak without sufficient target data. In addition, its weaker descriptive inferences are also difficult to verify given the lack of information presented. Specifically, the assessment suffers from the following methodological shortcomings:

- The sample size of the surrogate streams (three) is too small to enable a useful statistical analysis able to address the stated objectives.
- The flow regimes of two of the surrogate streams are significantly different than that of the far future Muskeg River (one more so than the other). The flow regime of the third surrogate stream is unknown due to a lack of a flow record. Implications of these differences are not evaluated.
- The key distinguishing metric of interest for the three surrogate streams (percentage lake area within the drainage) is actually quite different than for the far future Muskeg River drainage (about 50% of the value).
- The relative location of the lakes within the drainages is a formative factor in determining the degree of flow attenuation that the lakes cause in the stream hydrograph. This factor is not considered in selecting the surrogate stream sites. This characteristic is also not reported in the assessment.
- The assessment compares the far future Muskeg River and the surrogate streams (Figure C9) using flow duration curves (Golder 2011, p11): "…the general shape of the duration curves for the Muskeg River is comparable to the longer period of record available. It can be seen that the flows of the surrogate streams do fall within the bounds of the Muskeg River below Jackpine Creek (Node M2) and below Muskeg Creek (Node M1). Based on the hydrology data, the surrogate stream sites would appear to be suitable for comparison with Reach 2 through Reach 5." ACFN explained to Shell at the Feb-2011 consultation meeting that such exceedance curves are *designed* to show similarity not difference because of the compression of the distributions. Use of these curves to support the hypothesis that the candidate streams are suitable for this comparison is inappropriate because it masks differences, rather than highlighting them. Furthermore, there is no statistical test of difference or similarity carried out, just subjective appearance of suitability for comparison.
- Land use, wetland, soils, geology, topography, bank cohesion, and other factors influence the hydrograph and/or the nature of the streams and their hydraulic geometry. This information is not reported in the assessment and appears to have been largely disregarded in selecting the candidate streams and in analyzing the field data. This is inappropriate given the significance of these stream controls. It would be helpful in evaluating the work that has been done if an inventory of the watershed characteristics for each of the surrogate streams were made available. This was requested at the February-2011 consultation meeting but was unfortunately not included in the published assessment.
- In the analysis, a comparison of the *current* hydrograph of the Muskeg River is not made with the hydrographs of the surrogate streams. Nor does the analysis include recognition of the dramatic changes in land use and surface condition (infiltration, etc) that will take place in the far future Muskeg river drainage.
- It is concluded (p31) that because the beaver dam activity in the three surrogate streams was at a "slightly lower frequency" than in the comparable

section of the Muskeg River that "more stable flow regimes in the far future Muskeg River will not result in increased density of beaver dams." This conclusion is bizarre because it implies that beaver dam frequency is the only factor affecting the peak flow regime and that this severely limited comparison, with no consideration of other ecological influences on beaver dam frequency, and combined with the many study limitations listed above, can justify such a conclusion. This conclusion is baseless given the information provided.

Unfortunately, the study's field observations, while descriptively interesting, provide little utility in meeting the study objectives because the underlying scientific design is faulty and the data sets used are severely inadequate. Conclusions are based on a very small and statistically biased sample ignoring the many landscape variables potentially influencing the characteristics of interest. Given the paucity of major streams with flow data and containing large lakes, it is doubtful that this assessment can be amended to ever address its stated objectives. Therefore, Golder (2011) is in error when it claims: "The surrogate streams supported the findings of the models that the far future Muskeg River will provide comparable fish habitat to the current Muskeg River and watershed integrity will be maintained."

2.3.2 Geomorphic Assessment

The Geomorphic Assessment (Golder 2011, appendix E) examines the flow regime and channel morphology of the Muskeg River (past and future) along with patterns in regional streams to reach quantitative predictions of channel change under the future Muskeg River flow regimes. A 52-year history of channel morphology is examined qualitatively using remote sensing data and shows little change overall in the five reaches studied. Reaches 2 through 6 of the Muskeg River exhibit sinuous low-gradient behaviour controlled to a great extent by cohesive vegetated banks. The stream reaches of interest and the three streams from Golder (2011, appendix C) are compared to stream data from a regional oilsands study of alluvial channels (Golder 2008) to infer expected changes in channel width as a result of the new flow regime. The assessment concludes with a series of quantitative estimates of reduction in Muskeg River channel width (by reach) based on this data comparison and attributing the majority of this overall reduction to previously approved projects. The expected trend in width reduction is supported by the results of a hydraulic analysis that includes consideration of stream velocities.

Overall, the study concludes that a width reduction will occur under the far future Muskeg River scenario essentially due to a decline in annual peak flow. The assessment does not make mention of climate change and its effect on the future flow regime and on potential future bank cohesion (via vegetation changes). If climate change implications have not been incorporated, then the future flow regime may be different than expected and future bank cohesion may also be different. For example, if flows decline and if vegetation changes, then this could lead to additional channel narrowing and simplification leading to a further loss of fish habitat. The study also discounts the potential of sedimentation issues causing a widening of stream width because it holds that upstream sedimentation ponds during operation and end-pit reservoirs in the closure landscape will fully avoid enhanced sedimentation (p38). If this is untrue, then the conclusion of channel narrowing could be invalidated by sediment inundation leading to channel widening. Highly sinuous streams with cutoff meanders can be very sensitive to increases in sediment transport. In theory, however, this potential is avoidable if the upstream sediment management is effectively designed and implemented.

The assessment relies on a comparison of data sets between a regional study (Golder 2008) and those of the NNLP assessments. The channels characterized in the regional study are smaller (bankfull discharge of 0.2-10 m^3/s) than the NNLP streams (10-25 m^3/s) indicating that the streams of interest drain watersheds that are larger in size than the streams of interest and raising the concern for unaddressed scale-related effects. Although some attempt is made to reconcile this difference, Golder (2011, appendix E, p21,39) does stress caution in making this comparison due to the almost-one-order-of-magnitude scatter in the relationship, reflecting the wide range of channel and watershed characteristics. Yet, it is not clear what caution was used because the study continues with the analysis and reaching conclusions without qualification (p42). The regime data themselves exhibit scatter of almost an order of magnitude in bankfull width. Although the controls on this variability are mentioned in broad terms (p21), there is no analysis provided that attempts to explain this scatter. This is significant because a main control of interest in this analysis is the percentage of lakes in the drainage and the location of these lakes relative to each gauge location yet this characteristic is not evaluated for either data set. Why not? This is the key independent variable of interest in the analysis and without investigating it, the analysis may mask important information about the behaviour of these streams when making comparative inferences.

On page 40, Golder (2011, appendix E) states: "However, there is considerable uncertainty associated with the magnitude of the reduction in channel width." Despite this, and regardless of the factors that were not incorporated nor analysed in detail, the assessment concludes with quantitative estimates of channel narrowing though "actual width reductions cannot be reliably quantified but are expected to be smaller." (p41). The analysis gives contradictory messages about uncertainty. On the one hand, specific percentage reductions in width are provided by reach in response to the new (far future) flow regime. On the other hand, the analysis recognizes how uncertain and even unreliable quantitative predictions are. In addition, there are methodological concerns and assumptions that may alter these unreliable quantitative results. The predicted decreases in channel width are apportioned to the JME versus "previously approved projects. It would be helpful if additional following information were provided as part of this quantitative analysis of channel narrowing (p41). For example, how was this relative attribution done? Which other projects were considered? How is the proportional role of each project reflected in the composite hydrograph?

Lastly, the assessment notes the proposed changes to the Jackpine Mine Expansion EIA (Shell 2008) due to the Muskeg River Diversion alternative mine plan (Shell 2011b), however, it also dismisses the significance of those changes based on a subjective comparison ("very similar" – p41) of the difference between the MRDA and the EIA, as amended (Shell 2008). Without a quantitative reckoning of the differences and indication of the physical meaning of this difference to the ecosystem, it is difficult to know whether this statement's conclusion is accurate.

2.4 Uncertainty and Monitoring

Inherent in any scientific measure, whether stated or not, is a range around the value which indicates how big or small the value could be (to a certain degree of statistical confidence, e.g. 90%) – this range is often called the "variance" of the measure. As estimates are generated and then used in subsequent stages of analysis, the associated uncertainty grows. For example, the output from one stage of the NNLP analysis is an input into the next stage. From basic principles of error propagation, the product or sum of two values each with a certain level of error has a larger error associated with it than the inputs. The NNLP is notable for its absence of variance for the numbers it provides. The findings in Section 2 provide a basis to infer that the quantitative habitat calculations generated at the various stages of Shell's analysis contain a high degree of uncertainty. Inappropriate scientific design, methodological errors, inadequate data, fundamental shortcomings in scientific understanding, and random variation lead to what is referred to here as simply "uncertainty". There is even greater uncertainty associated with the changes in traditional-use opportunities associated with the proposed changes in fish habitat because Shell has not provided for the appropriate assessment to be undertaken to extend the implications of its quantitative habitat projections.

Shell does not explicitly recognize the many sources of uncertainty in its NNLP. Instead, Shell makes what it calls "conservative" choices in its habitat calculations which decrease its estimate of compensation habitat thereby, presumably, improving the likelihood that a lower amount will be delivered in practice given the many unknowns. Conservative choices are in contrast to what could be called "liberal" choices that would tend to inflate estimates beyond what is likely. Consider, for example, Golder (2011, p78):

> It should also be noted that although the same factors would affect stream populations in existing habitat that will be affected by the Application Case, no such correction was made to those habitat unit predictions. This provides another level of conservatism to the analysis. The purpose of the draft NNLP is to demonstrate that Shell has a feasible plan to provide fish habitat compensation. This very conservative approach of reducing the predicted compensation lake habitat units by 36% while not reducing predicted impacts accomplishes that goal."

There are numerous other instances of "conservative" computations in the NNLP (Golder 2011, p3,8,11,27,36,54,80) and the geomorphic assessment (appendix E, p41).

While Shell is very clear about its conservative assumptions, it is less clear about its liberal assumptions and shortcomings in methodology. Rather than inventorying them, it appears that Shell is including conservative choices in its computation and accounting of fish habitat so as to *arbitrarily adjust* for other concerns that may tend to inflate estimates of compensation habitat:

> "As an additional level of conservatism to account for model uncertainty in the output values in applying the results to the HIS models, if the modeled DO value was less than 1 mg/l above an HIS model threshold, the immediately lower suitability category was applied to both Base Case and Application Case (but not Pre-Development Case)." (Golder 2011, p36)

This tradeoff approach is methodologically inappropriate in a quantitative scientific environment with environmental and First Nations consequences hanging in the balance. While it is positive to be making calculation choices that will underestimate rather than overestimate the habitat projections, it is of concern that these benefits to habitat calculations are being incorporated to make up for unquantified liberal assumptions and issues with the entire approach. How can Shell and the regulators be assured of the balance of conservatism and liberalism embodied in the estimates of habitat compensation? The gaps in methodology are significant and may easily overwhelm the computational conservatism. Until Shell addresses these gaps and shortcomings and provides key additional information about its projected habitat values, it will be difficult for regulators to be confident that the NNLP will meet legal requirements.

The concern about unquantified and unrecognized uncertainty is not unknown to Shell. For example, in the February-2011 presentation meeting in Fort McMurray, Habitat Unit values were presented that involved eight significant figures. The ACFN pointed out openly at that meeting (and again at the July-2011 meeting) that this could mislead decision makers into concluding with a great deal of certainty that the projected habitat would be realised. Later in the published draft NNLP for review the same degree of significance is provided in the habitat projections (Golder 2011, p74,77). In its August-29-2011 letter to Lisa King, Shell states:

> "The DFO-accepted HSI [Habitat Suitability Index] models for the Oilsands Region do not have confidence limits. … Confidence limits were not applied, and the issue had never been raised before. However any express confidence limits would also be based on professional judgment and would also be developed in a multi-stakeholder workshop setting, and not on any quantitative analysis. Such confidence limits would also have to be accepted by DFO."

Instead of an uncertainty assessment, Shell has indicated that it intends to rely on its monitoring program to be sure that the habitat projections are realized in practice. This was stated at the February-2011 and July-2011 consultation meetings and in Golder (2011, p80):

> "Shell also has a detailed monitoring program designed to address all of its fish and fish habitat monitoring that will track the progress of the compensation habitat, identify any intervention that is required, and evaluate the success of the habitat (Hatfield 2010)."

According to Rick Courtney (personal communication, February-2011 consultation meeting), the computer models enable Shell to “get something within the realm of reality” and it is the monitoring that counts in determining whether the appropriate extent of compensatory fish habitat has been created. By its own admission, Shell lacks confidence in its habitat projections to such a degree that it relies on monitoring and adaptive management to deliver on its legal obligations. This approach is consistent with the fact that the practice of creating compensatory fish habitat on this scale is relatively new in Canada and in the oilsands region. Monitoring refers to a wide range in parameters and associated analysis and includes fish presence, hydrometric data, water quality parameters, among other metrics. Monitoring scope and intensity and its ongoing associated data analysis form a complex design that needs to be effectively linked to monitoring objectives. Sampling intensity needs to be spatially and temporally sufficient to provide statistical power able to reach conclusions confidently about performance promises. In the present situation, it is also recognized by Shell and DFO that there needs to be an effective feed from the monitoring program into an adaptive management response, if the appropriate amount of compensatory habitat is to be created. Golder (2011, p70) states: “the monitoring program will be used to inform future decisions regarding lake management requirements”.

An additional concern with the approach to monitoring being followed by Shell and endorsed by DFO lies in how the monitoring contractor will be chosen. Shell chooses its preferred contractors and DFO selects from Shell’s list. To assure independence and no question of bias, DFO should instead determine who is eligible to conduct the monitoring with Shell then potentially determining from the list provided by DFO. This is easily accomplished through the creation of an eligibility list by the regulator. With the approach that DFO is currently following, the monitoring exercise is vulnerable to bias. Even a suspicion of bias, particularly given the extent to which Shell and DFO intend to rely on monitoring results to assure that the legal responsibilities have been met, mean that the decision-maker cannot be assured that the compensatory habitat has been met. This fact was raised by the ACFN directly with DFO at the February-2011 meeting and although it was recognized to be worthwhile, DFO is not applying the procedure in this situation.

3.0 DISCUSSION

Successful application of DFO's no-net-loss approach on the scale required for the Jackpine Mine Expansion is a difficult undertaking. This review has uncovered a range of concerns associated with Shell's draft NNLP including its scope, the sufficiency of information presented, methodological errors, unrecognized and uncalculated uncertainty, and overall shortcomings in scientific reliability for decision making. These concerns are discussed below and recommendations provided in Section 4 to address them.

The scope of the NNLP focuses on fish habitat creation and does not address traditional land use (TLU). The plan does not include an evaluation of the TLU implications of the draft NNLP.

Shell provides a list of compensation site options that it considered in choosing its proposed Redclay option (Golder 2011, p24). Shell's preference to choose an option from which it can "walk away" and which is situated on its lease appears to rule out other options that may be preferable to First Nations and may be more effective in providing compensation habitat. A tradeoff analysis is not provided in Golder (2011) that includes consideration of First Nations needs in maintaining the traditional-use values currently associated with the configuration and condition of existing waterbodies. In addition, there is a flood risk and leakage potential associated with Shell's preferred site. The flood risk is assumed low by Shell based on extrapolated mapping elsewhere along the channel but Shell has not tested the validity of this assumption provided nor discussion of the implications of this assumption if it is in error. It is not clear from the review of options provided the value Shell has placed on the Treaty and aboriginal rights and/or traditional uses of First Nations in relation to its own priorities. It is suggested that the selection of location for habitat compensation should accommodate, not over-rule, the recommendations from First Nations. If the NNLP is considered by Shell to incorporate consultation input from First Nations, then Shell should provide additional information about how its NNLP will reflect First Nation preferences in the exercise of traditional activities and cultural connections currently associated with the habitats proposed for modification or removal, including existing waterbodies such as the Muskeg River and terrestrial habitats in the Redclay Creek area.

There are various major mine proposals either planned or operational within the vicinity of the Muskeg River and the drainages supplying the (proposed) Redclay reservoir. These adjacent and nearby activities must be incorporated into Shell's planning and assessments because they have the potential to influence the design intent of the proposed compensation habitat, for example due to changes in hydrologic behaviour of the drainage as the area is mined and altered. Golder (2011) is silent on regional-scale interactions which implies that these have not been taken into account however this remains unclear. What steps have been taken to take these watershed-scale issues into account in the draft NNLP? Have approved or proposed mining activities within drainages relevant to the draft NNLP been considered in Shell's analyses? It is beyond the scope of the present review to examine the EIA and approval history of the other existing and proposed mines within relevant drainages however it is important that Shell and regulators examine this information to confirm that there are no interactions with other developments that could invalidate elements of the calculations.

Assessment information is missing in Golder (2011) that is required in order to evaluate the strength of the scientific work carried out. Key inputs to the hydrologic model are not provided such as future surface condition and consideration of climate change. Watershed information for the surrogate stream watersheds is not provided yet is key to reaching conclusions from the study. Lake percentage and location (relative to stream gauge location) within the regime data analysis should be provided. A section is needed summarizing the integrated assumptions and limitations involved in the fish habitat modeling and the hydrologic modeling in addition to the inputs and configuration of the hydrologic model and scenarios.

The NNLP displays methodological weaknesses with implications for the conclusions reached. A changing climate does not appear to have been recognized in the NNLP component assessments. Given the expected changes in snow accumulation, runoff timing, and evaporation rates, this omission has serious implications for the accuracy of the predicted amount and quality of fish habitat compensation. The drainages and streams sampled in the surrogate streams assessment are not representative of the study drainages (eg, lake percentage is about half that of the study drainage) nor are they sufficient in number to yield the types of conclusions reached in that assessment (Golder 2011, appendix C, p31). The geomorphic assessment (Golder 2011, appendix E) lacks content around important elements concerning the many controls/factors on stream regime sets. There may be other areas of deficiency identified when the information gaps noted previously have been remedied.

Conservative habitat calculations do not correct for significant shortcomings in approach (such as not addressing climate change) nor do they address limiting scientific data and assumptions. Rather than determining the degree of uncertainty associated with its NNLP habitat projections, Shell instead makes arbitrary conservative choices in how habitat is calculated to address overestimates in other aspects of the assessment. Shell states many times in its NNLP that it is being conservative in calculating the balance of estimated and simulated fish habitat but it does not appear to be conservative in how it deals with assumptions and limitations of the tools it uses, of the knowledge base and the overall modeling approach. With the information provided, it is impossible for a decision maker and other interested parties to ascertain how likely the habitat ratio of 2.9:1 is to come about. Do the non-conservative assumptions overwhelm the conservative ones? If Shell itself cannot quantify the confidence of its own outputs with all its attendant information and data in hand, how will a regulator or a First Nation be able to do this? At the February-2011 consultation meeting, Shell said that it would not undertake an analysis of scientific confidence because it would be very expensive (Rick Courtney, personal communication). However, it is also costly to First Nations and to the wider public if Shell's assurances are not realized in practice.

If Shell will not directly address the question of uncertainty, then it should provide a complete inventory of the sources of uncertainty and their relative significance. Ideally, this would involve quantitative measures from objective sources such as model outputs, however where that is not possible, then quantitative estimates derived from professional opinion may be suitable (with rationale).

Until this issue of uncertainty has been addressed adequately, there will be substantial doubt that Shell's habitat compensation projections are valid and will be achievable. In addition, the arbitrary nature of Shell's attempts to make conservative calculations to balance out other liberal shortcomings in the assessment leave the scientific exercise vulnerable to questions of bias which will be difficult for regulators. It is unfortunate that Shell is unwilling to do this science (Shell 2011a) because without knowledge of the confidence associated with these habitat estimates, it is difficult for regulators to reach defensible determinations. For example, DFO will be challenged to know whether no net loss will be achieved if it approves the NNLP. The possibility of a biased result may be problematic for decision-makers because it jeopardizes their confidence in reporting that they are protecting the range of values within their mandate. For example, an uncertain projection of compensation habitat combined with a monitoring program lacking independent verification or sufficient effort could result in shortcomings, possibly unreported, in compensation habitat. To enable informed decision-making, it is important that there be thorough monitoring independence/oversight and transparency and analysis of the many assumptions, simplifications, and potential errors of the quantitative approach in addition to explicit clarification in the NNLP pointing out how elements of the monitoring plan and adaptive-management approach will expose and address specific vulnerabilities in habitat creation. However, it is only in the conclusion of the draft NNLP where the one reference to adaptive management is given: the "monitoring program and adaptive management response will further ensure that Shell meets its fish habitat compensation regulatory requirements." This lack of specificity suggests that bias, if present, may not be exposed in the adaptive-management process. As long as the NNLP is vulnerable to bias, it will be difficult for regulators to move forward.

Rather than addressing the uncertainty concerns, Shell intends to rely on its monitoring and adaptive management program to instead demonstrate that the required compensation habitat is created. It is unclear why Shell would not complete the scientific process to improve the reliability of the habitat estimates and improve the ability of regulators to reach timely and effective decisions. Of course, it is appropriate to monitor and adaptively manage however it is inappropriate to do this as a compensation for inadequate science. Instead, regulators should require that the methodological and data issues be addressed first so that issues of scope are addressed, reliable defensible conclusions are reached, the range of opportunities are given adequate consideration, and the degree of uncertainty in this approach is clearly presented to decision-makers and affected parties.

Monitoring and adaptive management in complex systems need time to be effective. Under an adaptive management approach, management activities become dynamic experiments with ongoing learning about cause and effect in achieving objectives. The greater the pace of change, the more difficult it becomes to gain useful knowledge about system behaviours resulting from resource development and other management interventions. If the planned heavy reliance on monitoring and adaptive management (Rick Courtney, personal communication) is pursued instead of a sound basic assessment, then there is a need to slow down mining development so that the adaptive management approach can function properly. As the pace of change increases, the ability to learn from adaptive management generally declines, for example due to the confounding effects of multiple new mines able to affect the dependent variables of interest. At the current pace of mine approval, it may not be possible to rely on the monitoring-and-adaptive-management approach to make up for the high level of uncertainty that is present in the Shell's NNLP science. A slower pace of development would also allow the TLU opportunities on the landscape to be changed in stages so that they could be evaluated for verification as to their effectiveness and whether or not First Nations communities are making use of those opportunities. As it stands, there is not only no assessment of the change and needs, there is no possibility of course correcting if Shell's developments fail to meet legal requirements. Regulators cannot approve this NNLP with confidence that the projected compensation habitat will be created and that First Nation Treaty and aboriginal rights and/or traditional uses will be protected.

4.0 RECOMMENDATIONS

The assessment information provided by Shell in support of its NNLP proposal falls short of necessary standards in scientific analysis and communication. The assessment does not enable regulators to determine whether Shell's science and planning will adequately protect First Nations' Treaty and aboriginal rights and/or traditional uses and achieve the promised levels of habitat compensation. These scientific and communication shortcomings compound with a lack of analysis of TLU to make the draft NNLP inadequate for First Nations in assuring them that the NNLP is protecting their Treaty and aboriginal rights and/or traditional uses.

The following recommendations, if implemented fully, would assist in addressing the significant gaps identified in this review. Until these steps are undertaken, regulators will not be in a position to be able to render a decision on this application and unacceptable doubt will remain as to the validity of the NNLP itself and the sufficiency of measures taken to protect First Nations Treaty and aboriginal rights and/or traditional use. To complete the NNLP, it is recommended that the ACFN request that Shell provide the following additional information and technical analyses:

A) Assessment

1. **Support the completion of a traditional-use study to identify the expected balance in TLU opportunities with the NNLP and in the decades of mine operation prior to full NNLP implementation.** Impacts to the environment are significant and have implied consequences for traditional-use opportunities.
2. **Incorporate climate change projections into the hydrologic, geomorphic and fish habitat modeling and communicate the methods and results.** Provide methods (including scenarios used) in the hydrologic modeling to incorporate credible consideration of future climates into the fish habitat accounting. Incorporate implications of future climates into related calculations and modeling.

B) Information and Analysis

3. **Provide the selection criteria/weightings for the NNLP candidate compensation lake sites.** A variety of relevant site attribute information is provided in draft NNLP without clear indication as to how the various factors have been traded off against each other, notably the needs of First Nations and the potential of sites that are not located on Shell's leases.

4. **Provide information about the inputs and outputs associated with the hydrologic modeling and all steps taken in calibration.** Information is needed about the hydrologic model simulations including land-use, surface condition, groundwater, calibration efforts, etc.

5. **Provide additional information for the surrogate streams and geomorphic assessments.** Important information is not reported within these assessments and should be included therein.

6. **Conduct an assessment to estimate the uncertainty associated with key components of the draft NNLP and in particular the hydrologic projections and fish habitat estimates.** Confidence intervals can be generated quantitatively in some situations (eg, hydrologic model outputs) and in others situations (eg, habitat suitability curves) estimates may be more appropriate via professional opinion with rationale.

C) Communication

7. **Present uncertainty in compensation habitat estimates to regulators and explain the implications of aggregate uncertainty for the goals of the draft NNLP.**

8. **Slow down the pace of mine development to enable the monitoring and adaptive management approach to function successfully.**

9. **Choose monitoring contractors from an independent DFO-created eligibility list of approved monitoring contractors for application in the roll-out of the NNLP.**

5.0 REFERENCES

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July 24, 2012

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Ms. Melody Lepine
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Dear Lisa and Melody,

Re: Review of Shell Canada response (May-15-2012) to Joint Review Panel (JRP) Supplemental Information Request (SIR; Jan-30-2012) in reference to the Jackpine Mine Expansion (JME) EIA

Following your request, I have prepared a targeted review of Shell Canada's responses to the JRP's SIR dated January 30, 2012. Specifically, this letter provides a review of the responses to Supplemental Information Requests 5a, 5b, 5c, 5d, 5e, 27d, 27e, 27f, and 34. My focus for this review is in the areas of hydrology, geomorphology, and climate change.

Yours sincerely,

<signature removed>

Martin Carver, PhD, PEng/PGeo, PAg

General – SIR 5a

Jackpine Mine Expansion and Pierre River Mine Project Base Case Report – Hydrogeology, Section 3.3.1, Pages 13-14. Shell discusses the hydrogeology of Devonian-aged formations and states that "The D2 unit (of the Waterways Formation) is expected to act as an effective barrier to vertical flow, except in areas where prominent fracturing has occurred." Incidents have occurred in the minable oil sands area demonstrating that the Devonian formations do not provide an effective hydrogeologic barrier in all areas, and can allow substantial volumes of saline water to be released to mine pits if the natural covering material is removed.

a. Discuss how Shell will identify areas near the base of the McMurray Formation that may potentially act as conduits for Devonian-sourced groundwater to be released into the mine pit if exposed during mining. What types of features (other than areas of "prominent fracturing") may allow such upward flows?

Shell Response

As outlined in its letter to the JRP on January 18, 2012 (page 12), Shell will indentify [sic] areas that may potentially act as conduits for Devonian-sourced groundwater by refining its Devonian Geo-Science Program and implementing a geohazard protocol developed in consultation with the ERCB, Alberta Environment and Water (AEW) and Alberta Energy. While the focus of this program is currently the active mine areas of the Muskeg River Mine (MRM) and Jackpine Mine (JPM) it will be expanded to include the JPME, prior to development, if approval is received. The protocol identifies and characterizes hydraulic pathways in the Devonian rock layer beneath the bitumen-bearing McMurray formation. This protocol builds on Shell's existing geological knowledge of the Devonian formation under its leases and specifically helps to inform mine and tailings planning departments to:

- avoid exchanges of Devonian aquifer waters with other aquifers via pathways to and from Devonian saline aquifers;
- identify areas affected by the Devonian that may contribute to mine wall or floor instability; and
- identify areas affected by the Devonian that may contribute to fracture instabilities related to in-pit dyke structures.

The geohazard protocol is based on geological, geophysical, geotechnical and hydrogeologic investigations using a combination of investigative methods. These methods include; the review of existing data, airborne geophysics, drilling, seismic and other techniques to acquire the following: stratigraphy, structure(s), history of disturbance (structural and karst-induced), hydro-stratigraphy, hydro-chemistry data, and geomechanical characteristics, all of which may affect the Devonian.

The features that could lead to an upward vertical flow from the Devonian units into the mine may include any one or combination of possible vertical pathways through the cap rock; sinkholes, collapse chimneys, fractures or faults (of tectonic or solution origin). The present focus is on identifying and characterizing these vertical pathways in parallel with developing an improved understanding of their origin and distribution.

Review Comments

Shell responds that it will identify areas that may act as conduits through refining its Devonian geosciences program, developing a geohazard protocol in conjunction with regulators, then implementing the protocol. The protocol will identify and characterize hydraulic pathways in the pertinent Devonian rock layer to enable mine and tailings planning departments to locate areas of concern then act to avoid detrimental water exchanges. Shell outlines the general types of approaches that it will use to gather data.

Shell's response to SIR 5a describes very general steps of an approach to *determine* how to address the geo-hazard, rather than describing what will actually be done to address the concern. Shell indicates that a collection of investigative methods will be used but unfortunately does not explain what each method will accomplish, how the methods complement each other, what data sets the methods must yield to resolve the problem, and how the acquired data will be interpreted to identify the various hazard features within the Devonian limestone. In summary, Shell does not explain how the generalized methods and approach will address the objectives presented.

It is notable that although Shell refers to its response program currently active within the Muskeg River Mine and the Jackpine Mines (both approved), it is unclear from its response whether there is a detailed procedure already available from those mines, or whether a procedure is under development. If a procedure is in place, then Shell should provide the details of that procedure because that procedure will guide what is done in the proposed JME mine. If it is under development in those existing mines, then Shell should provide the status of its development and clarify any uncertainties present in that initiative to assist the Panel's review and assessment of the sufficiency of Shell's capabilities and preparedness.

To complete its response to the Panel's SIR 5a, Shell is requested to do the following:

1. Provide details on the status of geo-hazard management (karst) in the Muskeg River and Jackpine Mines and explain what specific knowledge gained in those mines Shell intends to transfer to geo-hazard management in the proposed JME.
2. Describe the specific data sets that each investigative method will generate and how these data sets and methods complement each other to yield mapping of Devonian features.
3. Explain how the mapped features will be assessed for hazard and what the hazard levels mean in the context of mine operations and environmental risk.

General – SIR 5b

Jackpine Mine Expansion and Pierre River Mine Project Base Case Report – Hydrogeology, Section 3.3.1, Pages 13-14. Shell discusses the hydrogeology of Devonian-aged formations and states that "The D2 unit (of the Waterways Formation) is expected to act as an effective barrier to vertical flow, except in areas where prominent fracturing has occurred." Incidents have occurred in the minable oil sands area demonstrating that the Devonian formations do not provide an effective hydrogeologic barrier in all areas, and can allow substantial volumes of saline water to be released to mine pits if the natural covering material is removed.

b. How will Shell adjust mining practices to prevent or mitigate the risk of an influx of Devonian-source groundwater?

Shell Response

A site-specific risk assessment will be carried out at the JPME through the application of geo-hazard protocols to identify high, medium and low risk areas. The risk management process will focus on four areas:

- absolute elevation of pit floor (a lower elevation limit has been imposed on mine pit depths;
- changes in elevation of the Devonian surface, determined as gradient;
- thickness of cover between the Devonian surface and lowest mine surface; and
- any anomalies observed while mining in the area.

A combination of these factors contributes to the overall mine plan that is to be selected for a particular area. Other oil sands companies have also agreed to share data on regional aquifer flows and the geology of rock structures underlying oil sands deposits. Coordination now exists amongst operating companies to expand and develop the knowledge of regional subsurface conditions of the Devonian succession which includes its aquifers.

The protocols manage risk by identifying the elevation below which no mining is allowed without detailed study and approval from the Chief Geologist and Chief Tailings Geotechnical Engineer. This elevation will be selected considering the hydraulic head in the Prairie Evaporite Aquifers and the subcrop elevation of the Devonian limestone.

Above this elevation, areas of elevated risk can be properly addressed through the protocol utilizing geo-hazard maps for the mine. Currently, the protocol followed when medium risk areas are mined include sampling of any observed water flows, observation of anomalies by pit-geologists and increased awareness of the risk area by shovel operators. Identified areas of high risk are not immediately mined but rather the base of feed is adjusted to leave sufficient material in place to ensure a buffer remains on top of any potential vertical pathway. A risk assessment is then conducted on this area to determine whether mining at a later date is possible.

Review Comments

The first part of Shell's response to SIR 5b provides some additional details on the protocol introduced in its SIR 5a response. Shell states that it will establish elevation limits to mining based on areas identified by geo-hazard protocols as low, medium, and high risk. Shell's response provides general information on factors that will be considered in setting these risk levels, however Shell does not indicate how this information will be used to establish the risk levels spatially. When mining an area mapped as medium risk, the protocol provides for increased observation and awareness during mining. In high risk areas, the protocol requires that a material buffer be left intact however the response is again vague in that it does not indicate how the depth of this buffer is determined.

In summary, while Shell provides a response to SIR 5b, it is highly generalized, lacking in sufficient details for the Panel. To complete its response to the Panel's SIR 5b, Shell is requested to do the following:

1. How are Shell's four identified hazard factors combined to shape its overall mining plan?
2. Which oilsands companies have agreed to share related data (and for which locations) and will those data be made available for independent review?
3. How is the elevation limit for mining determined from the hazard factors?
4. What depth of buffer is left in place in high risk areas?

<u>General – SIR 5c</u>

Jackpine Mine Expansion and Pierre River Mine Project Base Case Report – Hydrogeology, Section 3.3.1, Pages 13-14. Shell discusses the hydrogeology of Devonian-aged formations and states that "The D2 unit (of the Waterways Formation) is expected to act as an effective barrier to vertical flow, except in areas where prominent fracturing has occurred." Incidents have occurred in the minable oil sands area demonstrating that the Devonian formations do not provide an effective hydrogeologic barrier in all areas, and can allow substantial volumes of saline water to be released to mine pits if the natural covering material is removed.

c. Explain how Shell would handle such a release event if it were to occur. Describe the potential response for large volume releases and small volume releases.

Shell Response

For very small releases, such as seeps, the water will be sampled and directly analyzed to understand its origin. If there is a possibility that it originated from the deeper saline aquifers, mining will immediately cease, and a cap will be placed over the inflow location and a more detailed investigation initiated.

For larger volume releases, mining will immediately be redirected to other areas and samples will be taken. Depending on the size and volume of the release, the water will either be contained by placing material on top of the ingress, or contained by building dykes.

Based on Shell's current experience with Cell 2A at MRM, a design and methodology for sealing uncontrolled inflows has been developed. An Execution Plan for engineering, constructing and operating a plant capable of injecting cement, acrylamide/polyurethane and hot bitumen grouts is nearing completion. This execution plan will serve as a template for the development of a response plan for potential future events greatly reducing the response time.

Shell has engaged world leading experts on subsurface feature grouting to develop and execute plans to seal the Cell 2A fracture.

- A series of directional delineation holes will be drilled around the fracture perimeter. It is intended that this step will help to determine the length, width and depth of the fracture.
- A series of vertical characterisation holes will be drilled into the fracture zone to quantify the fracture shape and volume.
- High pressure pumping of grout materials will take place through the characterisation holes into the fracture. Additional drilling may be required to ensure adequate flow of grout materials.
- A final series of holes will be drilled into the sealed fracture zone to verify that the sealing activities have returned the permeability of the fracture zone to general mine flaw permeability levels.

Review Comments

Shell provides a response to SIR 5c, however it is general and lacking in essential details. For example, with respect to small releases:

- It does not explain how it will determine whether seeps may have originated from deeper saline aquifers.
- It does not specify the size over which mining will cease if a seep of concern is identified.

For larger releases:

- How will a re-deposit overtop the release area serve to plug the ingress?
- When will the Execution Plan be completed and made available?
- What will the response time actually be when the Execution Plan is in place?
- Who are the world's leading experts Shell has engaged to address the Cell 2A ingress?

Overall, Shell has provided a response to SIR 5c, however it is lacking key details needed for regulators to have confidence in Shell's preparedness for small and large releases.

In summary, while Shell has provided a response to SIR 5b, it is highly generalized, lacking in sufficient details for the Panel to have confidence in Shell's preparedness for small and large releases. To complete its response to the Panel's SIR 5b, Shell is requested to do the following:

1. Discuss the relative effectiveness of intact native *in situ* material versus placed capping deposits in inhibiting water releases through the Devonian layer.

2. Specify the size over which mining will cease when a seep or release of concern is identified.
3. Indicate when the Execution Plan will be completed and made available.
4. When will the Execution Plan be implemented at MRM and when can the Panel expect an update as to its effectiveness?
5. Provide evidence that demonstrates that Shell's approach in addressing the Cell 2A rupture has been successful elsewhere around the world.
6. Provide the names and contact information of the "world leading experts on subsurface feature grouting" who have been contributed in addressing the rupture associated with MRM Cell 2A.

General – SIR 5d

Jackpine Mine Expansion and Pierre River Mine Project Base Case Report – Hydrogeology, Section 3.3.1, Pages 13-14. Shell discusses the hydrogeology of Devonian-aged formations and states that "The D2 unit (of the Waterways Formation) is expected to act as an effective barrier to vertical flow, except in areas where prominent fracturing has occurred." Incidents have occurred in the minable oil sands area demonstrating that the Devonian formations do not provide an effective hydrogeologic barrier in all areas, and can allow substantial volumes of saline water to be released to mine pits if the natural covering material is removed.

d. If such an event were to occur, discuss the impact would it have to mining operations and the environment.

Shell Response

Shell is confident that, given the safeguards that have been put in place, the ingress of Devonian-sourced groundwater at JPME is unlikely. In the event that these safeguards fail, the following potential impacts could occur.

Impact to Mine Operations:

An influx of water into the mine pit is a safety concern. The recent MRM Cell 2A is an example of this type of incident and has provided Shell with valuable experience in preparing for and managing future incidents in the unlikely event they should occur. Specific impacts to mine operations would be highly dependent on the volume of water and the location of the ingress, however, in general terms, an ingress incident similar to Cell 2A could:

- reduce the amount of recoverable ore (sterilization);
- result in modified mine plans to avoid the area of ingress;
- result in modified tailings plans to account for changes to in-pit storage availability; and
- require mitigation plans to seal the ingress.

Effects to local freshwater supplies and vegetation:

Environmental effects to local freshwater supplies and vegetation are not anticipated should saline water ingress into the JPME pits.

The baseline hydrogeology work for MRM and JPME coupled with the findings from the ingress incident at MRM indicate the following:

- Prior to the ingress at MRM, Methy Formation baseline water levels were anticipated to range from 256 to 268 masl based on data from seven monitoring wells completed in the Muskeg River Mine area.

- Monitoring of Methy Formation ingress at MRM over 18 months indicates water levels in Cell 2A have stabilized near 245 masl since January 2012.
- Piezometers completed into the Methy Formation and monitored over the same period show that Methy Formation piezometric levels have risen following the ingress incident and are asymptotically approaching equilibrium; all observed levels to date are lower than 255 masl.
- At JPME, the range of elevations for the top of the McMurray Formation is consistently higher than the new equilibrium water level of 245 masl and is higher than 270 masl for the vast majority of the mine footprint area. It is only in portions of the west boundary of the JPME mine footprint that the elevations of the top of the McMurray Formation are lower than 270 masl, but higher than 255 masl.

Accordingly, environmental effects to local freshwater supplies and vegetation due to saline water ingress in the JPME pits are considered negligible, as the expected stabilized water level in the pit (approximately 245 to 255 masl) would be lower than the top of the McMurray Formation.

In the unlikely event that water levels at JPME were to stabilize at elevations greater than 255 masl such that there was a potential for interaction of the ingress water and freshwater Quaternary aquifers, Shell could mitigate environmental impacts by installing a barrier between the ingress water and the aquifer at points of potential contact. The slow rate of elevation increase above 245 masl would allow time for such mitigation.

Review Comments

Shell response to SIR 5d does not provide sufficient information to answer the Panel's request because it is too general and lacks details essential for understanding the implications for mine operations and the environment. To complete its response to the Panel's SIR 5d, Shell is requested to provide responses to the following:

With respect to the impact to mine operations:

1. What amount of recoverable ore is vulnerable?
2. To what extent are tailings plans (and reclamation plans) subject to change due to managing this hazard?
3. How will existing commitments, particularly to First Nations and environmental protection, be delivered when significant changes to mine planning and design need to be made *after* approval?

With respect to effects on local freshwater supplies and vegetation:

4. What is the equilibrium asymptote (masl) which the Methy formation piezometric levels are expected to reach?
5. What percentage of the mine footprint area in the west boundary of the JPME mine footprint is below 270 masl but higher than 255 masl?
6. What does "negligible" environmental effects mean in practice? How was this subjective assessment determined?
7. What is the likelihood that water levels at JPME could stabilize at elevations greater than 255 masl?
8. What types of barrier technology are proposed in those instances where potential exists for environmental contamination of a freshwater aquifer? What is the long-term effectiveness of these technologies in terms of field-level performance data?

9. In situations such as MRM Cell 2A where saline Devonian water is "entombed" in a mining cell, discuss the long-term implications for environmental protection of holding contaminated water in place indefinitely by mine walls and constructed dykes.
10. Discuss the potential for rupture contamination from the Methy aquifer to affect the water quality of pit lakes.

General – SIR 5e

Jackpine Mine Expansion and Pierre River Mine Project Base Case Report – Hydrogeology, Section 3.3.1, Pages 13-14. Shell discusses the hydrogeology of Devonian-aged formations and states that "The D2 unit (of the Waterways Formation) is expected to act as an effective barrier to vertical flow, except in areas where prominent fracturing has occurred." Incidents have occurred in the minable oil sands area demonstrating that the Devonian formations do not provide an effective hydrogeologic barrier in all areas, and can allow substantial volumes of saline water to be released to mine pits if the natural covering material is removed.

e. Provide a figure showing all areas that have been identified as having the potential to act as conduits for flow of Devonian-sourced groundwater into the mine pit. Provide a brief discussion on each of the identified areas including why they are considered a potential risk, and how such risk will be mitigated.

Shell Response

The requested figure is not available at this time. Should the JPME application be approved, further development work including mapping will be undertaken. Currently the focus has been on the active Lease 13 mine areas.

The recently completed 2011/2012 drilling program included 33 holes at JPME. These holes are currently in the lab for core description and analysis, and will provide additional data about the Devonian surface. These wells are located in the south portion of Lease 88 and 89, as well as on Lease A36.

Review Comments

Shell does not provide the information requested by the Panel in SIR 5e. The information requested by the Panel was and remains essential because it provides the foundation for quantifying the extent of the hazard, interpreting the significance of the features present, communicating the implications of the risk levels to regulators and other concerned and affected parties, identifying the adjustments needed to mining operations (mitigation), and overall demonstrating preparedness in addressing this complex and uncertain geo-hazard.

To complete its response to the Panel's SIR 5e, Shell is requested to respond to the Panel's SIR 5e:
1. Provide a figure showing all areas that have been identified as having the potential to act as conduits for flow of Devonian-sourced groundwater into the mine pit.
2. Provide a brief discussion on each of the identified areas including why they are considered a potential risk, and how such risk will be mitigated.

Navigation - SIR27d

In its 2010 Muskeg River Navigability Assessment (p. 94-96) Golder and Assoc. identified specific activities affecting navigability. The Panel requests Shell:

d. describe effects of proposed fish habitat compensation and reclamation works on navigation, how these effects will be mitigated, and the significance of residual effects on navigation

Shell Response:

The Redclay Compensation Lake will be developed in a valley parallel to the Athabasca River and will receive flows from Big Creek and Redclay Creek. Outflows from the Redclay Compensation Lake to Athabasca River will be similar to the existing flows. As Redclay Creek is not classified as navigable, the only potential effects on navigability will be on the Athabasca River (Letter from Transport Canada to Shell, February 23, 2010, Navigability Assessment Results for the Proposed Pierre River Mine (PRM) and Jackpine Mine Expansion (JPME) Projects). Since the outflows from the Redclay Compensation Lake will be similar to existing combined outflows from Big Creek and Redclay Creek into the Athabasca River, there is no expected effect on the navigation within the Athabasca River. Further details of the Redclay Compensation Lake can be found in the August 2010, Jackpine Mine Expansion Project & Pierre River Mine Project, Federal Information Requests, Appendices, Navigability Assessment Information Request – PRM.

The only reclamation work for JPME anticipated to potentially affect navigability is the diversion of flows from the upper Muskeg River through the JPME pit lakes in the final closure channels. Once this diversion is complete, navigation would be wholly through the newly established closure channels and pit lakes. It is anticipated that this transition period will be of short duration (i.e. days to weeks).

Review Comments

This SIR has two main parts. The first part concerns the impacts of fish habitat compensation lakes on downstream navigability. The second part involves the impacts of reclamation works on downstream navigability. They are discussed separately below.

Fish Habitat Compensation Lakes

Shell's response to this SIR is incomplete in two respects.

First, Shell base its comments on Redclay Creek being classified as non-navigable. The reviewer is unaware of an official TC determination stating that Redclay Creek is non-navigable. In addition, Teck Resources (2009) assessed the navigability of Redclay creek in support of its EIA for the Frontier Mine. That assessment provided information about two sites on Redclay Creek but was inadequate to determine whether Redclay Creek is considered "navigable" according to the criteria and standards set by Transport Canada (TC). Further, ACFN has reported that Redclay Creek is navigable and used for traditional purposes (Candler 2011, Figure 16, p 88). Therefore, at least a portion of Redclay Creek below the proposed Redclay fish habitat compensation lake may be considered navigable and as such remains subject to this SIR 27c.

Second, Shell's response asserts that "Outflows from the Redclay Compensation Lake to Athabasca River will be similar to the existing flows." This is unsupported by the response. These outflows would be influenced by the activities of the proposed Frontier Mine should it be approved (it is currently in the EIA review stage). The associated Frontier Mine EIA information provided by Teck Resources does not support Shell's assertion that the Redclay Compensation Lake outflows will be similar to the existing flows. This aspect of the proposed Frontier Mine was reviewed by ACFN & MCFN (2012). That review stated:

> "Teck proposes that in 2041, a new combined diversion channel will begin to divert the headwaters of Redclay Creek and Unnamed Creek 17 around the northern boundary of the MDA [Main Development Area]. It further proposes the creation of a flow splitting structure located where this diversion channel crosses a natural reach of Unnamed Creek 17. The IA [Integrated Assessment] states (V1, p 7-15) that the device will direct sufficient flow from the diversion channel back into the natural Unnamed Creek 17 'to ensure minimum flows are

maintained close to the existing regime', maintaining the flows to Ronald Lake, and ultimately to Lake Claire. The remaining flow will stay in the Redclay Creek diversion channel, destined for the Redclay Compensation Lake. In addition, the monitoring of the present Redclay Creek provides inadequate information about its flows for Teck Resources to confidently manage the flow splitting device to maintain the present flow regime within Redclay Creek. Teck gathered data during a few years and during this time, there were extensive data gaps within the monitoring resulting in a spotty data record over a short timeframe. Teck's IA does not provide an indication of the implications of these extensive data uncertainties. It is baseline data that lay the foundation for a meaningful comparison of projected impacts and evaluation of proposed mitigations. While hydrologic models are helpful in simulating past conditions where data may be sparse, they remain unable to simulate real environments unless they have access to calibration data specifically from the environments of interest. From Teck Resource's EIA data and interpretations, it is clear that the future outflows from the Redclay Compensation Lake remain uncertain."

The flow uncertainties associated with the proposed Frontier Mine apply to any navigable sections of Redclay Creek situated downstream of the Redclay Compensation Lake (and the flow splitting device) and the Athabasca River downstream of its confluence with Redclay Creek. Shell cannot claim that there will be no effect on navigability downstream associated with the hydrology of the Redclay fish habitat compensation lake. As a result, it is suggested that Shell engage with Teck Resources to assure that sufficient data have been gathered pre-disturbance so that the current flow regime is known so that it can then be re-established. In addition, it is suggested that Shell collaborate with Teck to also confirm the design of the flow splitting approach so that the Redclay Creek hydrograph reasonably approximates that of the natural flow regime.

As a result of these omissions, Shell concludes a lack of effect on downstream navigability hence also does not provide a discussion of any associated mitigation and post-mitigation residual impacts to navigation.

It is notable that in Shell's own statement of concern about Teck Resources' proposed Frontier oilsands mine, it states under #5) Seepage of Process-Effected [sic] Water:

> "During mine operations the Frontier project will be closed-circuited with respect to water with the potential to materially decrease flows into Shell's proposed South Redclay compensation lake. At closure, Teck Resources proposes to limit seepage of process-affected waters from their project area in perpetuity by constructing low-permeability barriers in proximity to South Redclay fish compensation lake. Shell is concerned that these changes to water inflows and new groundwater barriers may impact its regulatory commitment to the Department of Fisheries and Oceans to maintain fish habitat."

Thus although Shell has recognized the potential for the Frontier Mine to reduce flows associated with the Redclay Compensation Lake, it does not take this into account in its response to the SIR 27d.

To complete its response to SIR 27d, and to ensure that sufficient information is before the Panel, Shell is requested to do the following:

1. Work directly with Teck Resources to assure that sufficient monitoring data is gathered and used in designing the operation of the device proposed to partition the flow between Redclay Creek and Unnamed Creek 17.
2. Describe effects of the proposed Redclay Compensation Lake (including related impacts from the proposed Frontier Mine) on the navigability of Redclay Creek, how these effects will be mitigated, and the significance of residual effects on navigation.

Reclamation Works

In its Muskeg River Diversion Alternative Assessment (Golder 2011), Shell describes the reclamation landscape associated with its revised plans of directing the Muskeg River into an open channel rather than into a pipeline. Whereas Shell's above response to SIR 27d indicates that the only potential affect on navigability associated with the reclaimed landscape concerns "the diversion of flows from the upper Muskeg River through the JPME pit lakes in the final closure channels," its own assessment information does not support this interpretation. Golder (2011) has been reviewed by Carver (2011, p 16/17) and found to be inadequate to reach such a conclusion:

> "...few quantitative details are provided hence it is not possible to evaluate the implications for the Muskeg River. For example, the size and volume of the pit lakes has been changed but not provided. How long will it take for these lakes to fill and overflow to feed the Muskeg River? How will the open channel used to divert the Muskeg River be closed and reclaimed? How will the Muskeg River be directed through the northern pit lakes before returning to its original channel? The development of effective pit lakes is an area of ongoing research and as such it is unclear the reliability of the techniques that Shell intends to follow. ... Water to fill the pit lakes will also come from the Athabasca River (Golder 2011, p15) under the revised proposal. Have these new withdrawals already been factored into the Phase 2 Framework Committee (P2FC) non-consensus Option H (Ohlson et al 2010)? If not, then do these additional withdrawals jeopardize the P2FC's outcome? With these questions unanswered by the revised proposal, it remains unclear to regulators and to First Nations whether the revised proposal will meet its objectives and safeguard First Nation Treaty and aboriginal rights and/or traditional uses."

Some of these concerns relate to navigability potential. There are potential temporary (decadal) effects and permanent post-closure effects on navigation potential within the Muskeg River system. Only temporary effects are acknowledge by Shell in its SIR response with inadequate details provided to justify this limited interpretation. Until further details on the closure landscape are provided by Shell, it is inappropriate for Shell to conclude as it does about the limited potential for its proposed reclamation design to affect the downstream navigability of the Muskeg River.

Note that in its response to the SIR 27d, Shell does not provide discussion of "any associated mitigation and post-mitigation residual impacts to navigation" as requested by the JRP.

To complete its response to SIR 27d, and to ensure that sufficient information is before the Panel, Shell is requested to do the following:

3. Provide sufficient details associated with Shell's latest Muskeg River Diversion alternative plan. ("Muskeg River Diversion Reassessment") such that the combined implications of the reclamation plan on navigability of the Muskeg and Athabasca Rivers can be quantified. See Carver (2011) for further details. Quantify the downstream navigability implications.

4. Describe the mitigation and post-mitigation residual impacts to navigation associated with the navigability implications documented above.

References

ACFN & MCFN 2012. *Technical Sufficiency Review of Teck Resources Ltd. Integrated Application for the Frontier Oil Sands Project.* Report submitted to the CEAA Frontier Review Panel Manager, June 4, 2012, 98 p.

Candler C 2011. *Integrated Knowledge and Land Use Report and Assessment for Shell Canada's Proposed Jackpine Mine Expansion and Pierre River Mine*. Report prepared for the Athabasca Chipewyan First Nation, 163 p.

Carver, M 2011. *Muskeg River Diversion Reassessment – Hydrology and Geomorphology Review.* Report prepared by Aqua Environmental Associates for the Athabasca-Chipewyan and Mikisew Cree First Nations, October 2011, 23 p

Golder Associates 2011. *Muskeg River Diversion Alternative Assessment*. Prepared for Shell Canada Energy in support of its Jackpine Mine Expansion EIA, 54 p.

Shell Canada Energy Ltd. 2012. *Shell Canada Energy's Statement of Concern for the Teck Resources Ltd, Frontier Oilsands Mine Project*. Letter from District Approvals Manager, Alberta Environment and Sustainable Resource Development, from Don Crowe, 3 p. Available at: http://www.ceaa.gc.ca/050/document-eng.cfm?document=57009

Teck Resources 2009. *Appendix E – Navigation Determination*. Prepared by Stantec in support of the Frontier Mine EIA, 29 p.

Navigation - SIR27e

In its 2010 Muskeg River Navigability Assessment (p. 94-96) Golder and Assoc. identified specific activities affecting navigability. The Panel requests Shell:

e. discuss whether proposed changes to the Muskeg River diversion from pipeline to channel and potential changes to associated bridge works will affect navigation.

Shell Response

The proposed change from a pipeline to the Muskeg River diversion channel and the proposed bridge works on the Muskeg River are anticipated to maintain navigation. Proposed changes to the Muskeg River diversion from pipeline to channel will eliminate a previously proposed barrier to navigation (i.e., the pipeline) maintaining flows of the river through the JPME development area. Proposed erection of a single-span bridge over the Muskeg River Bridge will be undertaken in consultation with Transport Canada to ensure navigation meets the requirements of the Navigable Waters Protection Act as further discussed in the response to JRP SIR 28.

Review Comments

Shell states that its revised plan to avoid a pipeline option in favour of an open channel will result in the maintenance of navigation and hence it does not provide further information on this aspect of its SIR response. This is, however, an incomplete response because there are hydrologic changes (from the Pre-Industrial Case) associated with the revised plan that have been inadequately assessed, interpreted, and communicated. Carver (2011) has reviewed the revised plan (Golder 2011) and states:

> "The reassessment information is found to suffer from serious deficiencies in science and its communication and, as a result, its validity and reliability are in question. In general, the information provided is insufficient to reach independent conclusions about the consequences of the revised plan on First Nation Treaty and aboriginal rights and/or traditional uses. From gaps in methods and data gathering, to unsuitable presentation of findings, to subjective evaluation and communication, the reassessment does not provide what regulators such as the Energy Resources Conservation Board, the Joint Review Panel, the Canadian Environmental Assessment Agency, Alberta Environment, and the Department of Fisheries and Oceans should

need to determine whether Shell's science and planning will adequately protect First Nation Treaty and aboriginal rights and/or traditional use and safeguard the environment. Information is not provided that assesses implications for traditional use as a result of the revised plan. The information that is provided is generally non-scientific and subjective and as a result is unreliable in determining impact significance. This unreliability is exacerbated by ambiguity in presentation and a lack of consideration of scientific uncertainty. Results are not communicated effectively to decision makers and others affected by the findings. Nine recommendations are provided that, if implemented, would assist in remedying the shortcomings of the reassessment."

Given the deficiencies in science and its communication evident in Golder (2011), it is inappropriate for Shell to conclude in its SIR response that the revised plan will maintain navigability. To respond adequately to the JRP's SIR 27e, a revised assessment should be prepared that addresses the deficiencies of Golder (2011).

To complete its response to SIR 27e, Shell is requested to do the following:

1. Address the nine recommendations found in Carver (2011) to complete Shell's reassessment of its EIA update information. Reproduced here, these are:
   - Carry out a traditional-use study to identify potential impacts from the revised proposal.
   - Assess the proposed changes to the EIA within a regional and watershed context.
   - Incorporate climate change projections into the hydrologic modeling and communicate the methods and results transparently.
   - Avoid subjectivity in evaluating change and communicating results.
   - Use appropriate measures to describe change from the EIA, as amended.
   - Provide scientific confidence using quantitative or qualitative measures.
   - Describe the characteristics of the new channel that will replace sections of the Muskeg River and the restoration methodology that will be followed.
   - Describe the scope and details of any monitoring programs being relied upon to reduce incremental EIA risks.
   - Provide technical information about the hydrologic modeling.

   See Carver (2011) for further details.

<u>References</u>

Carver, M 2011. *Muskeg River Diversion Reassessment – Hydrology and Geomorphology Review.* Report prepared by Aqua Environmental Associates for the Athabasca-Chipewyan and Mikisew Cree First Nations, October 2011, 23 p

Golder Associates 2011. *Muskeg River Diversion Alternative Assessment.* Prepared for Shell Canada Energy in support of its Jackpine Mine Expansion EIA, 54 p.

<u>Navigation - SIR27f</u>

In its 2010 Muskeg River Navigability Assessment (p. 94-96) Golder and Assoc. identified specific activities affecting navigability. The Panel requests Shell:

f. ensure that, in its updated cumulative effects assessment, it takes into account influences such as: overall water withdrawals, climate trends, water diversion, natural river fluctuation, sand movement, and dredging.

Shell Response

In the updated cumulative effects assessment, influences of overall water withdrawals, climate change, water diversion, and natural river fluctuations have been taken into consideration. This information is included in Appendix 2, Section 3.3.

Review Comments

Shell's response to SIR 27f refers to section 3.3 of Appendix 2 of its supporting submission. This new analysis incorporates additional foreseeable development that has come to light subsequent to its initial EIA submission. While this partially addresses the SIR 27f, it does not address the other components requested by the JRP in several respects. First, "overall water withdrawals" include direct withdrawals from the Athabasca River and indirect withdrawals through groundwater changes and any tributary withdrawals. Only the direct withdrawals have been summarized. Declines due to indirect pathways have been disregarded. Second, the supporting appendix does not update the assessment with respect to impacts due to climate change. Third, water diversions and natural river fluctuations are not mentioned in the supporting appendix to which Shell makes reference in its response. Hence, Shell's response to SIR 27f must be considered incomplete.

To complete its response to SIR 27f, Shell is requested to do the following:

1. Include in Shell's navigability assessment updated cumulative effects analyses including consideration of a) both direct and indirect water withdrawals from the Athabasca (i.e., including withdrawals through groundwater and tributaries), b) climate change projections and their implications for hydrograph changes, and c) any other water diversions and natural fluctuations (as referred to by the Joint Review Panel.)

Accidents & Malfunctions - SIR34 (Karst Response aspect)

Submission of Information to the Joint Review Panel, May 2011, Section 3.2.1.1, Page 37.

Shell stated that "In making this likelihood determination [of potential accidents and malfunctions] Shell considers the relevant historical (i.e. Shell and industry) frequency of such an event and the corrective actions that may or may not be taken". The Panel requests that Shell provide a discussion on the history of accidents and malfunctions in the Oil Sands including:

a. information on recently reported accidents from Shell operated mines including, but not limited to, the rupture of the Methyl Aquifer below the Muskeg River Mine in October 2010 and any reported tailings leaks;

b. lessons learned from recent reported accidents and how these lessons would be applied to the Project. Describe any proposed mitigation measures that would be put in place at the proposed mine site to avoid the recurrence of previously reported accidents.

Shell Response (sections noted here are the ones related to the Ingress of the Methy Aquifer into Cell 2A):

The following is a combined response to SIR 34(a) and 34(b).

In preparing the Accidents and Malfunctions (A&M) information contained in the May 2011, Submission of Information to the Joint Review Panel, Section 3.2, Shell was guided by previous submissions prepared for oil sands projects. In selecting these scenarios, Shell looked at accidents that had the potential to produce environmental effects outside the project area. The selection of these scenarios was based on Shell's understanding of oil sands mining in the region and the technology platform proposed for the Jackpine Mine Expansion (JPME).

Historical Shell Accidents and Malfunctions

Shell Albian Sands is a large operation consisting of two integrated mines which has grown in size and complexity since start-up in 2003. During this 10 year operating period, Shell has experienced a number of incidents that have provided opportunities to learn and improve the performance of Shell's operation. A short description of these reported incidents and the follow up actions taken is outlined below. It should be noted that, while these incidents were reported to the appropriate regulator, in all cases the environmental effects were limited to the immediate project area.

MRM Ingress of Methy Saline Water into Cell 2A – October 2010

In October 2010, a flow of water into Muskeg River Mine Cell 2A occurred which was subsequently confirmed to be originating from the Methy aquifer. This incident is not considered an accident or malfunction but more appropriately classified as an uncommon and unanticipated natural feature Due to the uniqueness of this feature and the operational incident which it triggered, this ingress has been the subject of review by the ERCB, AEW and other stakeholders, including adjacent mine operators. While this incident represented a potential mine safety issue, it should be noted that no environmental effects have been observed nor are anticipated outside or within Cell 2A. Details of the incident and the progress of remedial actions underway have been, and will continue to be shared with the ERCB, AEW and industry neighbours with the goal of avoiding future events. A summary of the incident and the preventative actions proposed for Shell's mining operations, including JPME, is outlined in the response to SIR 5.

Review Comments

In general, Shell's response to SIR 34 provides very limited information about the environmental ramifications of accidents, malfunctions, and related/unexpected incidents associated with its mining activities. Shell indicates that, in preparing its response to SIR 34, it focused on accidents with the "potential to produce environmental effects outside the project area." It is unclear what is meant by "project area." Is this the mine footprint? When introducing its Tables 34-1 and 34-2, Shell explains that only "publicly reported major incidents" with "the potential to produce environmental effects outside the project area" have been included. This differs from the SIR which asks for information on "recently reported" incidents. Shell provides limited or no information of the environmental consequences associated with the incidents it presents. For example, in discussing the MRM Basal Water Pipeline Release (March 2008), Shell provides no information on the environmental consequences of the pipeline failure associated with this incident. Later in its response, Shell refers to its own "incident management system" that tracks events and its response performance yet this information source is not referenced in Shell's inventory of incidents. With these various limitations placed on its response, it is unclear whether there are additional events - of interest to regulators, other stakeholders, and First Nations - that are not discussed by Shell in its response.

In responding to the specific concern about the Methy aquifer ingress into Cell 2A, Shell does not provide that there have not been environmental effects as a result of the incident. Instead, Shell indicates that it has not *observed* any environmental effects from the incident. This is inadequate information because the lack of observation of effects may be a direct outcome of monitoring being insufficient to discern the effects. To understand the implications of this incident, Shell should describe the monitoring that was functioning in place to identify effects. In addition, it appears that Shell does not consider its plan to permanently retain in Cell 2A the escaped saline water to include environmental effects. Before the incident, this cell formed part of a reclaimed landscape. Subsequent to the incident, it appears that this cell will be a permanent isolated saline reservoir, excluded from the reclamation plan. Shell does not provide any details in its SIR 34 response to indicate how reliable this containment will be in the decades to come. It closes by noting that "details of the incident and the progress of remedial actions underway... will continue to be shared with the ERCB, AEW, and industry neighbours"; it is unclear why First Nations and other potentially affected groups are excluded from this list of information recipients.

SIR 34 also asks for information on any reported tailings leaks. Shell does not provide this information and instead, opts to refer to summary reports provided to ERCB in September 2011 with respect to "on-site loss of tailings". Again, it is unclear whether this is a complete response to the SIR. Are there additional tailings-related incidents beyond those referred to? In addition, has Shell's noted summary report been made publicly available?

To complete its response to SIR 34, Shell is asked to do the following:

1. Provide the detailed environmental monitoring results, including a description of the monitoring system in place, for each incident described in the SIR 34 response so that the environmental consequences of each incident can be understood. Include in this incident list the Methy rupture into MRM Cell 2A.
2. Provide a list of Shell's Muskeg River Mine and Jackpine Mine reported incidents that are not included in Shell's response to SIR 34.
3. Make publicly available the September-2011 summary reports concerning on-site tailings losses.
4. Identify any additional tailings-related incidents at Muskeg River Mine and Jackpine Mine that are not included in Shell's September-2011 summary reports.

Review of the Phase Two Framework Committee Non-Consensus Recommendation for the Lower Athabasca River

Hydrology, Geomorphology, Basin Issues, Decision Framework

Final Report

Prepared for:

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EXECUTIVE SUMMARY

This report provides a technical review of the Phase 2 Framework Committee's (P2FC's) non-consensus Option H recommendation with respect to the hydrology, geomorphology, basin issues, and decision framework. Whereas the P2FC was tasked with coming up with an IFN to protect the aquatic ecosystem of the Lower Athabasca River and to maintain the ability of First Nations to fulfill their Treaty and aboriginal rights, the Option H recommendations falls well short of this goal as detailed in this technical review. This review forms part of a larger review that includes fish and fish habitat (Boag and Vander Meulen 2010) and traditional use (Candler 2010.) A synthesis of the reviews is provided in ACFN-MCFN *et al.* (2010.)

A range of science shortcomings is identified in the areas of climate change analysis, geomorphology, and hydrology. The climate change analysis suffers from an inappropriate timeframe under consideration, analytical biases, and major errors of fact acknowledged and, as yet, unaddressed by Alberta Environment. The full implications of climate change have not been duly considered by the various P2FC models resulting in considerable uncertainty surrounding the consequences of proposed water withdrawals under future climates. The consequences of water withdrawals for the Peace-Athabasca Delta (PAD) are evaluated by the P2FC process using a scientific design that is simplistic and does not incorporate current knowledge of the PAD. The corresponding analysis of the Lower Athabasca River (LAR) is misleading as it focuses on effects that are the least likely to occur while neglecting more sensitive issues such as changes to off-channel connectivity, fish passage under ice, loss of tributary access for navigation, and changes in the sediment regime. Appropriate expertise in LAR and PAD behaviour needs to be assembled in an independent science panel to guide future assessment of impacts to the LAR and the PAD.

The P2FC science and policy work has been undertaken out of context in both physical and policy respects. The proposed water withdrawals should be examined within the context of the regional hydrology, groundwater/surface-water interactions, upstream changes such as glacier decline, cumulative effects from land-use pressures throughout the entire drainage, and ultimately evaluated within the context of a basin water budget and in consideration of the effects of future climates. Similarly, this policy decision needs to be integrated explicitly within the provincial policy context that includes the current development of the Lower Athabasca Regional Plan (and its own climate change analysis), the Water for Life Strategy, and in keeping with climate change adaptation protocols under development within Alberta (*e.g.* from the Prairie Adaptation Research Centre).

The decision framework guiding the P2FC process includes key deficiencies that undermine the potential for a robust outcome able to protect the interests of potentially affected parties. Indefensible risk thresholds, simplistic risk measures, a lack of confidence limits on the science outcomes, and unquantified uncertainty combine to cast doubt on the legitimacy of the Option H recommendation. And when these shortcomings in the decision process combine with the errors and gaps

in the P2FC science, it is clear that the P2FC is not ready to recommend a set of Phase 2 water management rules.

It is recommended here that scientists with greater independence and more appropriate expertise be assembled to complete the science work required to support an informed decision. Individuals with expertise in hydrology, climate change analysis, and fluvial geomorphology need to be engaged to design and oversee the science required to support the P2FC decision goal. Key gaps needing attention include a credible unbiased climate change analysis, modeling impacts of water withdrawals on the Peace-Athabasca Delta now and under climate change, and a more thoughtful analysis of vulnerabilities in river morphology vis-à-vis navigation and fish passage in response to water withdrawals and under projected climate futures. In addition, improvements are needed in the decision framework particularly in terms of how science outcomes are communicated to the P2FC (or equivalent) and the process followed by the P2FC in considering the consequences of water withdrawals on potentially affected parties with long established rights. **Until the results of this additional work become available, short term measures are needed to supplement the Phase 1 rules to provide low flow protection. These measures should include a cut-off (LAR) flow below which withdrawals from the LAR are completely disallowed.**

1.0 INTRODUCTION

This report describes the findings and implications of a technical review of the January-2010 Phase 2 Water Management Framework (P2WMF) for the lower Athabasca River (Ohlson *et al* 2010) with a focus on hydrology, geomorphology, basin issues, and the decision framework. Fish habitat modeling was also reviewed and is included where it is within scope of this review. Based on the findings, a collection of recommendations is provided that, if implemented, would help assure that First Nations Treaty and aboriginal rights are adequately addressed from the perspective of sound science and informed decision-making.

1.1 Instream-Flow Need for the Lower Athabasca River

With increasing oilsands demands for industrial water withdrawals from the LAR, there is a need to understand the flows the river requires throughout the year to support rights of established river users. Specifically of concerns are the First Nations Treaty and aboriginal rights to hunting, fishing and trapping along with the incidental rights that support these primary rights (*e.g.,* navigation and tributary access). The Phase 2 Framework Committee (P2FC) has set in place a process of modelling and other scientific analysis (Ohlson *et al* 2010) to determine what this IFN should be to maintain its obligations to First Nations Treaty and aboriginal rights.

The work required to establish the instream flow need (IFN) has two parts. The first is to determine the flow needed to maintain a healthy aquatic ecosystem (*e.g.,* Clipperton *et al.* 2000). This approach is often focused on the fishes present in the river and, in this case, includes recognition that an Ecosystem Base Flow (EBF) is required: a flow level below which all withdrawals cease (DFO 2006.) The other part involves the incidental rights of First Nations to use the river effectively to fulfill their direct Treaty and aboriginal rights. Two independent reviews have been carried out to address these parts directly (Boag and Vander Meulen 2010; Candler 2010). The present work complements these two reviews by assessing how well the P2FC work has considered the hydrology and geomorphology of the Lower Athabasca River (LAR) in its science work and how appropriately the science has been interpreted for and by decision-makers. Together, the three studies provide an assessment of the P2FC non-consensus "Option H" IFN recommendation.

The P2FC is a multi-stakeholder committee set up in 2008 to develop recommendations for a new P2WMF to prescribe when, and how much, water can be withdrawn from the LAR for cumulative oilsands mining water use. Its work concluded in January 2010 with the publication of Ohlson *et al*. (2010) which included a recommendation supported by a subset of the committee and known as "Option H" that identifies, for each calendar week of the year, how much water can be taken directly from the LAR (see Table 19 of Ohlson *et al.*, 2010.) The recommendation would allow instantaneous withdrawals of up to 29 m^3/s, excludes consideration of tributary and regional groundwater withdrawals, and includes a 4.4

m^3/s exemption at any time regardless the severity of low flows in the LAR. It was not reached by consensus nor is it publicly documented which members of the P2FC were in support of this option.

Determination of an appropriate IFN, particularly for a river the size of the LAR, is a highly complex scientific undertaking. Despite there being myriad approaches (see instreamflowcouncil.org), there are increasing calls to move away from habitat provisions for target species toward preserving the viability of the broader river aquatic environment (Anderson *et al*. 2006.) The P2FC acknowledges at least 28 impact hypotheses in five riverine components (hydrology; geomorphology; water quality; connectivity; biology) and four other factors (tributary land-use; upstream land-use; climate change; fish harvest) all of which have the potential to affect the IFN (Dan Ohlson, Pers. Comm.) Due to lack of data, insufficient available science, assumed lack of significance, redundancy between ECs, and budget, only a small subset of these (~9) are evaluated with detailed quantitative modelling. In so doing, the P2FC has left out of its investigation many of the process dynamics that state-of-the-art IFN practitioners recognise as necessary. Potentially important impact mechanisms remain unstudied. Further, the EC work is focused on the needs of largely the aquatic ecosystem rather than on the complexity of river use by the First Nations. While the science focus of the present review is on examining the hydrology and geomorphology work that *has* been carried out and how this science has been made available to decision makers, key omissions are raised where they are significant.

1.2 From Phase One to Two: Setting the Water Management Rules

In 2006-2007, Alberta Environment (AENV) introduced the Phase 1 Management Framework for water withdrawal for the LAR (AENV 2007.) This P1 framework was established to provide limits to industrial LAR water withdrawals in relation to LAR discharge and up to a maximum of 34 m^3/s in any season. Under "green" conditions, industry is permitted a total of 15% of instantaneous flow with no maximum. Under yellow and red conditions, this percentage is reduced and reaches a *minimum withdrawal* of 8 m^3/s under red conditions and 11 m^3/s under yellow conditions. The more restrictive values are based on averages (of weekly Q90, Q95, and HDA80 values) determined from historic flow records (1957-2004, Ernst Kerkhoven, Pers. Comm.) and do not incorporate any influence of climate change in modifying the hydrograph, nor are they kept up to date by incorporating flow data from recent years (2005-2009). And because the thresholds between conditions are based on weekly exceedances, not annual exceedances, these limits change weekly with the historic mean hydrograph. While this may be appropriate for the yellow condition, using this approach under the red condition is dangerous for the river as it assumes that the unusual low flow will always occur in the same narrow window of time as in the past. Under climate change, the red condition should be based on annual exceedances so that a minimum protection is provided year round as the timing of the hydrograph shifts away from the historic norm due to various effects including climate change. Hence, while the conceptual basis for the P1 rules may be sound, they are applied to a flow frequency distribution that no longer applies and, as a result, permit excessive withdrawals during sensitive (*i.e.,* low flow) periods. In addition, the P1 rules do not include a cut-off flow below which no withdrawals are permitted. Overall, it appears that the P1 rules have been configured to provide certainty to industry rather than protection of the riverine ecosystem.

It is also unclear how the P1 rules are being applied for spawning periods. According to Tom Boag (Pers. Comm.), the following are the relevant spawning periods for fishes known to spawn in the LAR:

- Early-to-mid May - northern pike, walleye
- Mid-May through early June - suckers, Arctic grayling
- Late May to late June - forage fishes
- Early October through third week in October - lake whitefish
- Late January through mid-February - burbot

AENV confirms that the spawning restrictions indicated for all spawning periods occurring during red and yellow conditions (see Table 1 of AENV 2007) are not being applied to fall or winter spawners. Due to the lower flows present in fall and winter, the 5% spawning restriction would imply a reduced withdrawal limit than is currently in place (as indicated in Table 5 of ANEV 2007.) Further discussions are warranted to clarify that the appropriate limit is in place during spawning periods.

Refinement to the P1 approach for management of withdrawals led to creation of the Phase 2 Water Management Framework (P2WMF) and proposed IFN released in January 2010. This non-consensus Option H outcome provides for a reduced withdrawal limit and at a lower minimum flow. So, while the scheme is more complex, it has the same emphasis as the P1: it is minimum industry withdrawals that are guaranteed, not minimum LAR flows. In establishing this approach, AENV argues that the formula recommended (1/100 year event based on historic data and ignoring the future effects of climate change on the hydrograph) will protect the aquatic ecosystem and by inference, Treaty and aboriginal rights in the Lower Athabasca River (LAR) and Peace-Athabasca Delta (PAD.)

2.0 REVIEW APPROACH

The overall technical review has three components emphasising physical (this report), biological (Boag and Vander Meulen 2010), and First Nations elements (Candler 2010). A synthesis of the three components has been provided in ACFN-MCFN *et al*. (2010). The present review reports on the physical aspects with a focus on climate change, the PAD, channel geomorphology, and various cross-cutting issues. Some themes such as monitoring and scientific uncertainty overlap and are taken up in each review, as appropriate.

This review holds two central objectives within its subject areas and with respect to the work carried out under the auspices of the P2FC:

1. *To assess the adequacy of the scientific work for supporting the interpretations and conclusions reached, and in particular for supporting the Option H non-consensus P2FC recommendation. This includes three key questions:*

   (a) has the best science been available and was it employed?;

   (b) where gaps are identified, what further work is required to resolve them; and

   (c) has the science recognized and quantified uncertainty sufficiently to support informed decision making?

2. *To identify important gaps in process associated with putting the work into a basin context, addressing uncertainty, and enabling informed and transparent decision-making.*

Key source documents and information relied upon in preparing this technical review include:

- Ohlson *et al* (2010) - *Phase 2 Framework Committee Report January 2010*;
- Technical appendices included as part of Ohlson *et al* (2010):
  - Bothe and Franzin (2009): *Evaluation Criteria for Flow Alterations in the Lower Athabasca River – Channel Maintenance Flows*
  - Ghamray *et al* (2009a): *Evaluation Criteria for Connectivity of Distributaries in the Lower Athabasca River (Fletcher Channel) – Segment 1*
  - Ghamray *et al* (2009b): *Evaluation Criteria for Connectivity of Perched Basins in the Lower Athabasca River – Segment 1*
  - Lebel *et al* (2009): *Climate Change Sensitivity Analysis;*
- A collection of background reports that led to the establishment of the P2FC;

- Attendance and technical feedback at the Department of Fisheries and Oceans (DFO) Canadian Science Advisory Secretariat (CSAS) meeting May 31-June 4 2010 held to prepare science advice for DFO's review of the proposed Option H rules;
- Peer-reviewed literature, industry reports, and government reports; and
- Personal communications including email correspondence with Alberta Environment (AENV), DFO, Athabasca-Chipewyan First Nation (ACFN), Mikisew Cree First Nation (MCFN), science experts, and others.

The synthesis report (ACFN-MCFN *et al* 2010) brings together the findings from the three technical reviews with a focus on projected impacts to the river's aquatic ecosystem and their implications for traditional use. Substantive issues with the P2FC process and proposal are presented along with the additional science needed to address gaps. Possible mitigation measures are provided. The report concludes with a series of recommendations that, if followed, would help assure that First Nations Treaty and aboriginal rights can be maintained.

3.0 PHYSICAL COMPONENTS

Physical implications of the P2FC proposals are investigated through an examination of the hydrology and geomorphology of the LAR in three major areas. Within the context of climate change, patterns of flow within the river are reviewed both in terms of the documented past and the projected future and including a summary of trends in projected water demand. A review is provided of the physical dynamics of the Peace-Athabasca Delta (PAD) and an assessment given of the P2FC attempts to model impacts to the PAD from proposed water withdrawals. Lastly, the geomorphology of the river is reviewed in relation to the modelling work that has been carried out for the P2FC. Section 3.1 has been prepared with a contribution from Gregory Utzig.

3.1 Climate Change and Its Hydrologic Implications

Under a program entitled "America's Climate Choices," the prestigious USA National Academy of Sciences (2010) has recently published "Advancing the Science of Climate Change" in which it states (page 17):

> "Some scientific conclusions or theories have been so thoroughly examined and tested, and supported by so many independent observations and results, that their likelihood of subsequently being found to be wrong is vanishingly small. Such conclusions and theories are then regarded as settled facts. This is the case for the conclusions that the Earth system is warming and that much of this warming is very likely due to human activities."

As the National Academy emphasises, the debate is over as to whether accelerated climate change is happening and what its cause is. Other leading global science organisations have issued communiqués to this effect (*e.g.,* AAAS 2006; AGU 2007; AMS 2007; ACS 2007; IPCC 2007a; NA 2005) not to mention a host of major international disciplinary science organisations (*e.g.,* ACS 2010; INQUA 2007; GSA 2010; AGU 2007; APS 2007). The scientific debate has moved to defining how fast climate will change in relation to potential emissions scenarios. The fourth report of the Intergovernmental Panel on Climate Change (IPCC 2007b) presents a range of possible emissions scenarios based largely on socioeconomic factors and the take up of technology. Although it is impossible to know what will happen decades out, it is clear already that we are exceeding the worst case (A1Fi) scenario considered by the IPCC and emphasises the urgency in taking seriously adaptation needs around potential future climates.

Northern climates are expected to be one of the most affected of the world's climates. The scientific literature examining changing climates around the world has become voluminous. There is a growing body of scientific literature describing what has already happened to northern climes and providing projections on what is expected to come about as a result of anthropogenic climate change. It is accepted that globally we are not in an equilibrium climate (*e.g.,* AGU 2007) and that the recent changes are generally detectable back several decades.

3.1.1 The Changing Hydrograph of the Lower Athabasca River

While total precipitation is generally increasing modestly with climate change throughout the Canadian prairies and western Cordillera, the proportion of precipitation falling as snow is declining (Akinremi 1999) and as a result mountain snowpacks are in decline (Mote 2004; Mote *et al.* 2005). With less snow, there is less storage of precipitation to provide runoff during low flow periods. Experience elsewhere has shown that although the increased precipitation counteracts some of the effect on low flows of reduced snow, increased temperatures and their effects on melt rates and on evapotranspiration overwhelm the precipitation effect so that overall, we see lower low flows from climate change (Barnett et al 2005). In addition, runoff from the Athabasca drainage is significantly influenced by melt from Rocky Mountain glaciers which are known to be melting at accelerated rates (Parks Canada 2010). Furthermore, flow in the Athabasca River below Fort McMurray is dominated by runoff from these glaciated mountainous headwaters. For example, the Athabasca River basin upstream of Hinton makes up only 13% of the drainage area above the town of Athabasca but provides on average 40% of the flow volume (AENV 2004). This combination of reduced snowfall, increased glacial melt, and increased evapotranspiration, despite an increase in total precipitation, is already leading to decreased low flows throughout the prairies (Schindler and Donahue 2006).

To what extent have these effects already shown up in the hydrograph of the Athabasca at Fort McMurray? Burn *et al.* (2004) evaluate hydrometric records throughout the Athabasca drainage and find that the spring freshet is beginning earlier due to the earlier onset of higher spring temperatures. It is not always easy to see the signature of these changes in the short and medium term because initially, the enhanced glacial melt serves to *increase* the low flows and counteract the long-term impacts to low flows. However, once the enhanced glacial melt potential is exhausted, a strong decline is expected thereafter. This could be assessed through water budget analyses linked to glacier studies, however such work is beyond the scope of the present review. Such work should be carried out as part of a climate change analysis. With a better grasp on the underlying contemporary flow regime at Fort McMurray, the P2FC would be in a better position to apply appropriate climate change projections from Global Climate Models.

3.1.2 Choice of GCMs and Emission Scenarios in the Climate Change Analysis

The use of Global Climate Model (GCM) results for modeling future hydrologic flow regimes requires careful selection of GCMs and emission scenarios. In a recent paper on methods for assessing climate change impacts on hydrology of US pacific northwest, Salathe *et al.* (2007) emphasize the need to compare the GCM outputs for historic periods (e.g. 1961-1990) with empirical data for the same period to assess the various models for their ability to accurately model local conditions. The assumption is that a model that most accurately models the past for an area, is more likely to accurately predict the future. This comparison does not appear to have been done for the GCM models used in the analysis for the Athabasca watershed. This can easily be accomplished with the Regional Analysis Tool available on the Pacific Climate Impacts Consortium website: http://pacificclimate.org/tools/regionalanalysis/ . Figure 1 provides an example for another study area in British Columbia.

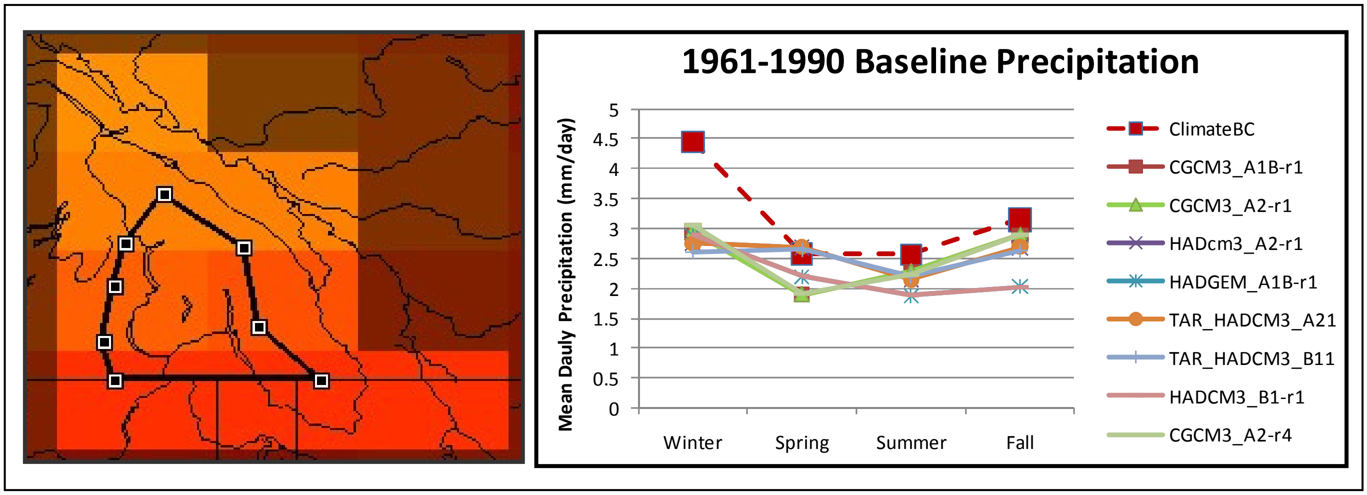

Figure 1. Comparison of mean seasonal precipitation for a southeastern British Columbian study area as summarised from historic climate data by ClimateBC and projected by various GCMs for the baseline reference period (adapted from Utzig 2010).

This is particularly important where the time period of interest is the near-future (e.g. 2010-2039), because the climate change that will occur over the that period is mainly a result of past emissions, and the variation between GCM outputs over that period reflect mainly the differences between models rather than assumptions regarding emission scenarios.

Where the comparison identifies consistent bias in a set of model results (*e.g.* insufficient resolution to recognize local topographic effects), statistical corrections can be applied to make the GCM more applicable to local conditions (Salathe *et al.* 2007). For example the data in Figure 1 indicate that all of the GCMs consistently underestimate winter precipitation for the Kootenay area, likely due it inadequate representation of orographic effects.

Alternatively, where such analysis is not readily available, or is beyond the scope of a project, Spittlehouse and Murdoch (2010), in their recommendations for selecting emissions scenarios in BC, have suggested selecting a limited number of GCM scenario combinations that represent a range of possible outcomes (*e.g.*, hot dry, warm wet, cool moist). This is consistent with the IPCC comments that there is insufficient certainty to say that any of the model outcomes are more likely than others (IPCC 2007a). All authors strongly recommend against utilizing a single mid-range outcome, as it would imply a level of certainty that does not exist.

For medium- and long-term climate change projections, emission scenario selection becomes more important, as the future levels of emissions begin to exert greater influence on climate change. Given that our recent past and present emissions are exceeding all scenarios previously run by previous IPCC modeling, more emphasis should be placed on the higher emission scenarios (see Figure 2.) More emphasis should likely be placed on the A2 and A1Fi scenarios where there is an assumption of continued dependence on fossil fuels, and continuing high emissions. These scenarios are also more consistent with the assumptions about future oil sands development, where continued oil sands development implicitly implies a continued dependence on fossil fuels and high emissions. The A1 scenario, which assumes a rapid increase in low carbon energy use, could be considered a moderate probability lower limit. The B2 scenario, which assumes we make drastic cuts in emissions in the near future, should be considered as a very low probability lower limit.

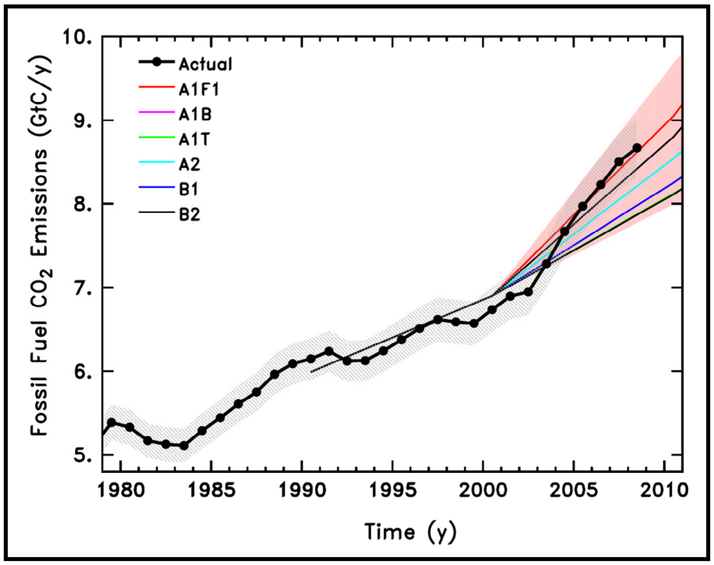

Figure 2. Actual fossil fuel emissions since 1980 compared to emission projections for various IPCC scenarios (from Allison *et al*. 2009, p.9).

3.1.3 Future Time Periods for the Assessment

Available information on the water demands for oil sands development indicate that demand will likely peak sometime in the 2040s (Golder 2005 - CEMA Surface Water Working Group, p28-29, Figure 12). This report indicates that some pit-lake infilling water demands will extend into the 2060s (p.22, Table 12). In addition, Golder (2009) reports on water requirements for oil sands mining operations and indicates a sustained water demand beyond the end of the period for that study (2030), and it does not take into account water demands for pond filling or pit-lake filling at the end of operations (p.9, Figure 4, note). Golder (2009, p2) also comments that there are start-up delays for some development projects, and therefore the timelines will likely be extended further.

It is clear from both of these reports, that any consideration of climate change impacts should include potential impacts into at least the 2040s and 2050s. In contrast, the Climate Change Sensitivity Analysis report (Lebel *et al.* 2009, App. 2, Table 1, p 24-25) considers only the period prior to 2040. A review of the results of the second time period (2040-2069), in Appendix 2 of Lebel *et al.* (2009, App. 2, Table 1, p 24-25) shows virtually all the models project a reduction in flow in the second time period compared to results in the first period.

In addition, with a decreasing trend in flow, utilization of the average flow values for period 1 (2010-2039) over-estimates potential impacts for the first half of the period (2010-2025), and under-estimates potential conditions for the second half of period 1 (2025-2039). If it is preferred to use just one time period, it would be more representative to utilize 2030 to 2059, assuming a maximum demand in the 2040s. Although averages for this period were not made available in the Lebel *et al.* (2009) report, they can be easily produced from the data (see Table 1, in section 3.1.6).

Alternatively, given the data available from Lebel *et al.* (2009), it would at least be preferable to utilize the projected flow data for their period 2 (2040-2069) to err on the side of caution, rather than under-representing the potential climate change impacts for the primary period of interest.

The argument that regulations based on period 1 data could eventually be adjusted to fit period 2 in the future, as more information is available, shifts significant risk to potential oil sands developers. The lead times for development are significant, and once the investments are made, it would be very costly to downscale or delay projects because water availability has decreased.

3.1.4 Present and Future Trends in Oilsands Water Demand

Golder and Associates (2009) provide a report on future oilsands water requirements. They base their annual water requirements on the demands that would occur in the driest of years – defined by the 100-year drought conditions (to simulate worst case for evaporative losses and minimal availability of on-site water sources). This may or may not be reasonable under a climate change scenario. The IPCC and other climate change reports forecast an increase in the magnitude and frequency of extreme events, including drought (although the IPCC 2007b does not predict a large increase in droughts for the Athabasca region (Meehl *et al.* 2007, p 785). Climate change adaptation studies typically (Meehl *et al*. 2007) recommend against assuming that past frequencies and magnitudes of extreme events will continue to be valid under a changing climate.

Golder (2005, CEMA Surface Water Working Group, p 23-24, Table 13) assumes that all other water use on the Athabasca will be constant into the future. This seems unreasonable given the industrial growth in the area, and the possibility that climate change may affect the water needs of other users (e.g. irrigation). The analysis should include a more reasonable assessment of future water use on the Athabasca by other users. At the very least, a complete and up-to-date assembly of all licensed LAR water withdrawal volumes, existing and approved, for oilsands and other uses, should be prepared and made available. Such a compilation can then be used in forecasts gaming economic growth scenarios, climate change scenarios, proposed rules and other significant factors (see for example, Mannix *et al.* (2010), Table 2).

It is also unclear why the sensitivity report (Lebel *et al.* 2009) emphasizes summer and winter flows, to the exclusion of fall flows. Golder (2005, p 24, Table 13) indicates that fall and winter are the key seasons with respect to the percentage of the flow that is expected to be diverted (5.8% and 12.8% respectively), while summer is only 2%. Modeling of fall flows might also be warranted however this would depend on the relative importance of elevated summer-versus-fall stream temperatures and heavy ice-cover interacting with the reduced flow rates.

3.1.5 Sources of Uncertainty in Projecting Future Athabasca River Flow Regimes

As mentioned above, there is significant uncertainty attached to the modeling of future climate. There is significant uncertainty regarding future greenhouse gas emissions, as represented by the various IPCC scenarios. As with all models, there is also uncertainty associated with the GCMs and their application. Contributing factors include an incomplete understanding of atmospheric physics and climate sensitivity, and the limited resolution of global models. There is also a problem calibrating the models due to an incomplete understanding of the interactions between the atmosphere and marine/terrestrial domains (e.g. changes to ocean currents, vegetation shifts). Due to insufficient data, IPCC climate modeling to date has also not fully incorporated various feedbacks such as methane releases from arctic oceans and permafrost zones, melting of the Greenland ice sheet and shifts in ocean currents. Some of these feedback mechanisms are associated with potential tipping points that could lead to amplified climate change that has not been accounted for in present modeling (Allison *et al.* 2009). In fact, there are recent signs that climate warming has been underestimated by the IPCC: accelerated sea level rise (Rohling *et al.* 2009), greater insect damage and higher incidence of forest fire (Kurz *et al.* 2008), longer periods of high atmospheric carbon dioxide (Archer *et al.* 2009), accelerated melting of permafrost (Tarnocai *et al.* 2009) and greater ocean acidification.

There is also additional uncertainty associated with the hydrologic model used to project future Athabasca River flows based on the modeled climatic changes. These are discussed in Chapters 6 and 7 of Kerkhoven (2008), and include factors such as model calibration under a warmer climate, inventory of soil properties, predictions of vegetation changes under modified climates, incomplete understanding of local interactions between the atmosphere and the land surface and statistical sampling. Other potential uncertainties are changes in flow associated with the loss of glaciers (e.g. Barnett et al. 2005) as discussed in section 3.1.1 and potential changes in infiltration properties. None of these is recognised nor discussed in Lebel *et al.* (2009.)

The significance of the glaciers in the headwaters of the Athabasca drainage to summer/fall low flows and to mean annual flows has not been examined by the P2FC science resulting in further uncertainty around the reliability of its projections for these important parameters. The modeling of Kerkhoven (2008), on which the projected summer/winter low flows and MAF are based, does not include glacial processes nor does it stratify the recent accelerated glacial melt from the contribution expected due to changes in snow melt and accumulation. As a result, because the model is calibrated to existing discharge records (that do not resolve glacial melt), it is possible that the model has overestimated the projected flows (including the summer low flows) due to not recognizing that there has been an embedded enhanced component within the discharge record. That component is expected to begin to sharply decline by about 2030 (Garry Clarke, Pers. Comm.) as these glaciers pass their maximum rate of disappearance. This "mixed signal" can lead to overestimates of future water availability. Demuth and Pietroniro (2001) looked at this situation in the North Saskatchewan River basin and found the minimum and mean streamflows in the North Saskatchewan River basin to already be in decline in its glaciated headwater basins.

As discussed earlier, there are also uncertainties regarding non-oilsands water diversions, and the future magnitude and timing of oil sands development and associated water requirements.

3.1.6 Magnitude of Athabasca Flow Changes Relevant to Planning and Regulation

The potential future changes in Athabasca River flows considered for setting future regulations should include potential changes over the full period of planned oilsands water diversions. According to data in Golder (2005), water withdrawals for operational and reclamation requirements will extend into at least the 2060s.

Kerkhoven (2008) has completed hydrologic modeling for the Athabasca River below Fort McMurray based on GCM outputs for various GCM/emission scenario combinations for three time periods 2010 to 2039, 2040-2069 and 2070-2099. His results are summarised in Lebel *et al.* (2009). In an email dated July 26, 2010, Kerkhoven indicates that the projections given in Lebel *et al.* (2009) are mistakenly presented. The minimum flow projections were portrayed as the mean annual flow projections and vice versa. Following up on his email erratum, results for the first time period (2010-2039) project changes for mean annual flow ranging from an increase of 9.3% to a decrease of 21.7% (mean -5.8%), and changes in minimum flow ranging from a 5.3% increase to a 40.2% decrease (mean –16.3%), in relation to baseline flows (1957-2007 means). Results for the second time period (2040-2069) project changes in mean annual flow ranging from an increase of 9.4% to a decrease of 28.3% (mean -12.2%), and decreases in minimum flow from 8.0% to 54.1% (mean -32.2%).

The errors in Lebel *et al.* (2009) have far reaching consequences. It is the projections of minimum flow that have been used to investigate the climate change sensitivity in other P2FC models. It is evident from the above paragraph that the estimated changes in low flow are about two to three times more severe and will deepen concerns raised in these models. This new information should also affect the outcome of DFO's CSAS process (Roger Wysocki, Pers. Comm.)

Two P2FC-commissioned reports on trends in flow based on data from the past 50 years of flow records both indicate a trend of decreasing flows over time. Gill and Rood (2009) have calculated a decreasing trend of about 0.4% per year in winter flows (~minimum flows) and a decreasing trend of 0.5% for mean annual discharge. They indicate that in the past this trend may be a result of shifting phases of PDO, but state that is unclear how the PDO will react in the future with a changing climate.

The other trend analysis (Burn 2009) shows similar trend results when the full 50-year stream flow records are taken into account. Burn (2009) also computed trends for the last 30-year period and found that when the analysis is restricted to this more recent period, the trend in decreasing flows is much steeper. The 30-year trend for annual flow is decreasing at 1.1% per year, and winter flows at 1.3% per year.

Although both authors emphasize that there is no certainty that these trends will continue into the future, if these trends are projected out to period 1 of the climate change projections, Burns (2009) indicates that they would correspond to decreases in mean annual discharge of 21.3% to 35.4% at 2022, and 29.4% to 51.1% at 2037. The decreases for winter flows, based on continuing trends, would be 15.9% to 40.3% at 2022, and 21.9% to 58.6% at 2037.

Taken in aggregate, all of the available data point to significant decreases in mean annual discharge and minimum flows over the coming decades. However, there is significant uncertainty regarding the magnitude and timing of the decreases. Given this uncertainty, it is prudent to consider a range of potential outcomes. Secondly, given that available information indicates that water demand is likely to peak sometime in the 2040s, and continue into the 2060s, it is also necessary to consider projections that are relevant into at least the 2050s or 2060s.

A logical approach might be to take the Kerkhoven (2008) flow modeling results based on climate change projections for period 2 (2050s) and use a range of one standard deviation from the mean to provide a reasonable indication of the uncertainty (see Table 1). This would mean that taking into account projections of climate change impacts would be interpreted as a 17.0% to 47.4% reduction on annual minimum flow and a 0.7% to 23.7% reduction in mean annual flow over the coming few decades. Emphasis however, should likely be placed on the larger decreases in flows to be consistent with a precautionary approach, and to be consistent with the trend analysis results.

In contrast to the above unbiased procedure, the climate change projections considered in the modelling were selected via subjective assessments and policy-biased intervention. The mean was "eyeballed" subjectively by one of the authors (Ernst Kerkhoven, Pers. Comm.) rather than calculated based on the projections available. The range of projections (variance, or standard deviation) was not provided to decision makers in a systematic manner nor was it applied appropriately to the other models in the sensitivity analyses. Instead, a subjective collection of outcomes was applied which may or may not be representative of the range as indicated by the Global Climate Models and the surface hydrology model. In addition, the Climate Change subgroup was told to not consider scenarios that were "immediately recognised as extreme hydrological changes" because they "would have significant Provincial-scale policy and management implications that would far dominate the potential implications of water withdrawals" (Ohlson *et al* 2010, p104). The P2FC essentially holds that climate change will be assessed as long as the assessment excludes extreme possibilities, no matter their likelihood. This is a policy bias inserted into what should be an objective scientific summation of climate change projections prepared to inform policy makers not modified by *a priori* policy choices.

Table 1. Projected flow changes for the 2050s as reported in Lebel *et al*. (2009) and corrected following the email by Kerkoven of July 26, 2010.

Variable	Mean	Mean+1 std devn	Mean-1 std devn	Minimum	Maximum
Minimum flow	-32.2[1]	-17.0	-47.4	-54.1	-8.0
Mean annual flow	-12.2[1]	-0.7	-23.7	-28.3	9.4

[1] For comparison, the (corrected) modeled change in mean annual flow for period 1 was -5.8% and for minimum flow, it was -16.3%.

3.1.7 Requirements for Further Analysis

The following work needs to be completed so that climate change is appropriately considered in the P2FC science:

- The climate change scenarios-GCM combinations need to be averaged in a suitable unbiased way and the mean and range of future climates and future hydrograph changes presented. An example has been provided in section 3.1.6.

- The climate change sensitivity analyses need to be re-applied to all the other models and correcting for the AENV error in Lebel *et al.* (2009.)

- Further analysis is needed to understand the significance of the Athabasca's headwater glaciers on projected LAR streamflow. To date, 20-25% of glacial ice has been lost due to melt during 1985-2005 in the central Rocky Mountains (Bolch *et al.* 2010). Shawn Marshall has recently calculated that these glaciers will be all gone in 83 years (Bob Sandford Pers. Comm.). To improve on estimates of longevity, Parks Canada is sponsoring a major study to determine, using Light Detection Radar (LiDAR), the volume of actual ice remaining within the Columbia Icefield system, the largest glacial system in the Canadian

Rockies. Led by Mike Demuth, the results of this work will be available to be coupled to GCM projections to more reliably estimate the expected lifespan of these glaciers in relation to carbon emission scenarios. Establishing long-term water commitments to the oilsands industry in advance of receiving and applying the results of this research may result in a high level of risk to oilsands investments because additional water beyond that required for exercising Treaty and aboriginal rights may, when it is needed in the future, be unavailable.

- Lastly, ideally, the climate change projections provided would distinguish seasonal changes or justify why this aspect of climate change is not being considered.

3.2 The Peace-Athabasca Delta

The Peace-Athabasca Delta in northern Alberta is a Ramsar Wetland of international significance and a UNESCO world heritage site. It is one of the world's largest inland freshwater deltas and a wetland of international importance. It is home to some of the largest undisturbed grass and sedge meadows in North America, and provides habitat for large populations of waterfowl, muskrat, beaver and free-ranging wood bison (Beltaos *et al.* 2006a.) In recent decades, several prolonged dry periods have turned some basins in the PAD from aquatic into terrestrial ecosystems due to lack of flooding. The first came after the construction and initial filling of the W.A.C. Bennett hydroelectric dam at the headwaters of the Peace River, between 1968 and 1971, and the second after the retreat of a major spring flood in 1974. Without an abundant supply of water in areas dependent on overflow, it is difficult for wetlands to regenerate. It is flooding in the PAD that spurs the high biological productivity for which the PAD is famous and as a result, proposals to dam or divert water from the sources which create the PAD need to be carefully studied to identify their potential effects on the future of the PAD.

The PAD is a complex geomorphic feature that provides extensive habitat in response to the seasonal rhythms of the Athabasca, Peace, and Fond du Lac Rivers, as well as a collection of smaller inflows, that are collectively largely responsible for its annual recharge. Regional hydrologic regimes interact with a host of geomorphologic and anthropogenic influences to maintain the PAD’s integrity. These dynamics are complex and far from fully understood. Climate change is further changing the PAD by modifying when and where key processes are available. For example, it is projected that under future climates, the ice-jam process that brings about recharge of otherwise isolated PAD lakes (perched basins), will decline (Beltaos *et al.* 2006a) thereby increasing the reliance on periods of high open water for recharging perched basins.

Ghamray *et al.* (2009a and 2009b) provide two Evaluation Criteria assessments to assess the potential impact of P2 water withdrawals on the PAD. They are essentially anecdotal case studies of one particular site, rather than an assessment of connectivity of the Athabasca River to the PAD lakes. They include an uncomfortable list of significant unquantified assumptions and simplifications perhaps the most concerning of all is the lack of an assessment as to the representativeness of this single site for connectivity and recharge to all sites. While the models are interesting, they are insufficient for understanding the potential hydrologic disconnection that is likely to result in the coming decades as industrial water withdrawals and climate change intensify, in tandem.

The first Evaluation Criterion (Ghamry *et al.* 2009a) describes a model constructed to investigate the extent to which Phase 2 water withdrawals would be expected to limit the connectivity to side channels and major distributaries thereby jeopardizing the maintenance of the quantity and quality of available habitat in the associated floodplains. They measured the relative change in connectivity at a single bifurcation of the Athabasca River in the delta, Fletcher Channel. "This bifurcation is but one of dozens of bifurcations in the delta each with its own particular flow regime. The Fletcher Channel represents only a limited view of the potential impacts of water withdrawals on the distributaries that may or may not be connected to Lake Athabasca in the winter." (Ghamray *et al* 2009a.) They make no attempt to assess how representative of the PAD is this one bifurcation that they analyzed in relation to many that exist elsewhere around the delta. And as mentioned above, nor was there an attempt to consider this incremental effect under the different projected climate regimes. Furthermore, the results are interpreted in terms of a low, medium and high risk levels and yet the thresholds between these classes of risk were drawn up arbitrarily and with "there being no known data for impact thresholds" (Ghamray *et al* 2009a.)

The second Evaluation Criterion (Ghamry *et al* 2009b) describes a model constructed to investigate the extent to which P2 water withdrawals would be expected to limit the connectivity of LAR perched basins to recharge, thereby affecting the quantity and quality of those available habitats. They use the connection to one perched basin, Big Egg Lake, as a surrogate for all the perched basins. However, the PAD can be stratified into zones in which different recharge processes are dominant (ice-jam flooding vs. high-open-water recharge) (Peters *et al.* 2006). These differences correspond, along with various other factors, to variations in the elevation of the perched basins and more specifically, to sills that limit the entry of water into any given lake. Ghamray *et al.* (2009b) do not gather information on lake elevations and hence are unable to link their anecdotal work to these zones of interest. While the modeling work is interesting, it is relevant to the specific spatial makeup of the site that they examined in detail; unfortunately it is not possible to generalize their [sic] results across the delta. As Ghamray *et al.* (2009b) say: "The current work focuses on a single perched basin that is in close proximity to the main channels of the Athabasca where the river's influence is expected to be maximized. Big Egg Lake is but one of hundreds of basins spread throughout the delta each with their own particular flood regime and thus represents only a limited view of the potential impacts of water withdrawals on floodplain dynamics."

Despite a listing of many serious uncertainties and an overall rating of "high" uncertainty, confidence limits are not provided on the model outputs. Also, there is no attempt made in these two Evaluation Criteria to consider this incremental effect under different projected climate regimes. Given the list of deficiencies and inadequacies of the modeling applied to this situation, as it stands, these models cannot be considered suitable to support informed decision-making.

While it appears from Ghamray *et al.* (2009a, 2009b) that the research literature on the PAD has been reviewed, there is little evidence of this understanding in the design of the corresponding modeling work. The research literature is rich in insights about the hydrologic dynamics of the PAD in relation to its sources, climate change, diversions, topography, and other controls. Some examples of research findings include:

- Prowse *et al.* (1996) carried out an early study under the Northern Region Basins Study. They examined the hydrometeorological conditions controlling ice jams floods associated with the Peace River. Peters *et al.* (2006) conducted a systematic followup examination of the flood hydrology of the PAD. They identify three zones of floodwater origin within the PAD and two mechanisms – ice-jam induced and open-water floods. Both types were found to recharge perched basins in the Athabasca Delta. Ice jamming is the most effective mechanism for producing extremely high backwaters capable of recharging perched basins. The lateral expansion of the central delta lake into inland areas is found to be a notable mechanism for replenishing the low-to-medium elevation contiguous wetlands.

- Beltaos *et al.* (2006a) examine the detailed requirements for ice jams to occur in the Peace River portion of the Delta. Ice jams are known to cause much higher water levels than open water floods and are particularly effective in replenishing the higher elevation, or perched, basins of the PAD.

- Wolfe et al. (2008) use water-isotope tracers and multi-proxy paleolimnological records to characterize connectivity controls on water balances of floodplain lakes in the Athabasca Delta within the context of its hydroecological evolution over the twentieth century. They conclude that the hydroecology of the Athabasca sector of the PAD is far more sensitive to changes in Athabasca River flow than the Peace sector which is resilient to changes in Peace River flows. They conclude that recent drying of some PAD lakes in the Athabasca sector and the surrounding landscape may represent the leading edge of rapidly evolving hydroecological conditions in the Athabasca Delta. Implications include reduction in aquatic habitats, loss of navigation access, and complete loss due to lake desiccation.

- Neill and Evans (1981) examine sediment transport through the Athabasca Delta and find that the delta front, thirty years ago, was advancing at about 0.8 km^2/yr. How will the progress of this delta be affected by reduced mean annual flows brought on by climate change and exacerbated by water withdrawals? How will this change navigation and biodiversity? It is not clear that the P2FC has considered the influence of a changing sediment regime on the values of concern.

These and many other research studies in hydrology and geomorphology (*e.g.,* Peters and Buttle 2009; Beltaos *et al.* 2006b; Peters and Prowse 2006; Toth *et al.*

2006; Wolfe *et al.* 2005; Prowse and Conly 1998) need to be brought together to form a state-of-the-art understanding of the PAD in relation to proposed water withdrawals. With this in hand, an appropriate scientific examination can be undertaken to address the uncertainty. It would be preferred that this work be led by a team of researchers with experience in the PAD, and with affiliations that are independent of AENV, DFO, and the oilsands industry.

In summary, Ghamray et al (2009a and 2009b) provide two Evaluation Criteria assessments that are essentially anecdotal case studies of one particular site, rather than an assessment of connectivity of the Athabasca River to the delta lakes. They include an uncomfortable list of significant unquantified assumptions and simplifications perhaps the most concerning of all is the lack of any assessment as to the representativeness of this single site for connectivity and recharge to all sites. In addition, in Ghamray et al (2009a), there is little reference to nor an understanding demonstrated of the peer-reviewed literature which is extensive and provides good stratification of this extensive deltaic landscape according to the processes that are hydrologically regenerative. Further industrialization of the Peace River (e.g., Site C) along with water withdrawals in the Athabasca River and other anthropogenic changes create uncertainty as to whether the PAD habitats and the navigability of its river systems (and therefore First Nations' access to traditional harvesting areas in the PAD) will be sustained into the future. While the models are interesting, they cannot be considered sufficient for meeting the need for understanding the potential hydrologic disconnection that is likely to result in the coming decades as industrial water withdrawals and climate change intensify.

3.3 Channel Geomorphology

The LAR is a sand-bed river that hosts populations of fishes and other organisms with life cycle needs that vary in relation to the river's seasonal rhythms. It is also the waterbody, along with the PAD, that is at the centre of life for the ACFN and MCFN, allowing these Nations access to their traditional lands to fulfill Treaty and aboriginal rights. From the high-flow freshet to the low flows of the summer and fall to the almost six months of ice cover over winter low flows, the annual cycle of the river depends on fluctuations in flow rates to maintain the structure of the river itself and the integrity of the aquatic ecosystem and to sustain the many goods and services it provides (aquatic organisms, resources, navigability, etc.). As climate change alters, most likely reduces, expected seasonal water availability, and as industrial demand for water increases, it will become more difficult to meet these industrial demands without compromising the LAR's ability to maintain its ecological goods and services, including the delivery of Treaty and aboriginal rights.

Doyle (1977) provides a summary account of the geomorphological behaviour of the LAR and Kellerhals *et al.* (1972) provide further detailed descriptive geomorphological information about various Albertan rivers including the LAR. These studies, though decades old, provide insights into the basic behaviour of the LAR. At the time of these studies, below Fort McMurray, the channel was relatively straight and supply limited in its sediment dynamics. Below these upper reaches, the channel changes to an unconfined meandering river toward Embarras with transport-limited sediment dynamics. Since these observations were made, the discontinuation of dredging and possibly other disturbance factors may be creating causing a tendency for the river to aggrade in general. The interplay of sediment regime with hydrologic behaviour is how habitat and navigation opportunities evolve throughout the river. Habitat is generally best in peripheral zones and in side-channel areas. Navigation is generally the most limiting where sediment accumulates due to gradient declines, tributary interactions, and a host of other site-specific controls. In some instances, the decline in navigability is affecting First Nations' ability to access their reserve lands.

It is these kinds of dynamics that need to be identified and described so that a program of scientific study can be designed to assess how they are expected to change under water withdrawals and future climates. What particular types of local river structures are most vital to maintaining fish habitat for the various species of interest and for the seasonal needs of their individual life cycles? Which are most vulnerable to diminished flows? How do these vulnerabilities change seasonally? For example, is fish passage/access to winter rearing habitats threatened by reduced flows? Similarly, the key seasonal vulnerabilities to navigation need to be identified so that a targeted research program can be designed. For example, tributary access is a fundamental element in securing the navigation capabilities that are an essential part of the incidental rights of the ACFN and MCFN. How are these navigational opportunities affected by water withdrawals and what sorts of interactions are of concern when there are also simultaneous water withdrawals from important tributaries? These and other questions need to be answered to mount a credible analysis of the direct effects of water withdrawals on fish habitat and navigation.

What is the role of ice thickness in whether water will access side channels? According to Preston McEachern (Pers. Comm, DFO CSAS workshop), a change in ice thickness of only 5-10 cm can affect whether water will get into the side channels and highlights the significance of water depth in relation to local channel geomorphology.

In contrast, the P2FC science focuses on changes to the macrostructure of the LAR in relation to water withdrawals and does not give attention to these site-specific, more limiting possibilities. Bothe *et al.* (2009) examine the effects of water withdrawals on channel maintenance based on data from the Fort McMurray Water Survey Canada (WSC) hydrometric gauge. Rivers need periodic high flow to maintain their structure and sediment regime. These higher flows also regenerate fish habitat and mobilize and reorganize sediment deposits. Given that channel maintenance flows are generally considered the one-year or two-year flows (Wolman and Miller 1960), the approach taken in Bothe *et al.* (2009) is to use the flow frequency distribution from 1957-2007 and investigate the extent to which the river would be outside the range of such channel maintenance flows due to the proposed withdrawals. They define channel maintenance flows as 60% to 160% of bankfull. Because this range of these flows is relatively high in comparison with the proposed water withdrawals, they conclude that the P2 rules would have no significant effect on channel maintenance. There are four elements of concern specific to this methodology:

1. Using the 50-year flow record as an accurate representation of today's frequency distribution is inappropriate. As discussed earlier, the hydrologic regime is in transition to a new state and as such it is scientifically incomplete to use this historic record without applying a correction factor reflecting the pace of climate change to date on the flow regime of the LAR.

2. Allowance is not made for further changes in the hydrograph over the lifecycle of the oilsands. As discussed and summarized earlier in this section, Lebel *et al.* (2009) indicate, using a variety of analyses, that the mean annual flow (MAF) is expected to decline by 12% (range 1-24% - see Table 2) by the 2050s. While changes in spring peak flows are unavailable, these are expected to decline with the MAF. Thus, a decline in spring freshet is expected and this has not been considered in Bothe *et al.* (2009).

3. Confidence limits have not been provided on the results (for example due to the above points) nor have the assumptions been listed and the implications of these discussed for the P2FC and others to consider.

4. The risk thresholds used, though set with reference to observations of the Peace River, are grossly subjective and would benefit from an interdisciplinary examination that includes expertise in fluvial geomorphology and, in particular, experience with large sandbed rivers. According to the lead author of the EC, the risk thresholds are set high and have a very limited basis (Ron Bothe Pers. Comm., DFO CSAS Workshop, May 31- June 4 2010). In his view, the 25% limit used should be reduced to "10-15%," but that it doesn't matter because the effect is still well below the risk threshold. This level of subjectivity is unacceptable in science, particularly given the unknowns about the present and future flow regimes.

While it is clear that the macrostructure of the river is of great importance, changes to it as a result of water withdrawals are expected to be less likely, at least in the coming years, than the more sensitive vulnerabilities to fish habitat and navigation such as changes to side-channel connectivity, fish passage under ice, loss of tributary access for navigation, and changes in the sediment regime. Some of these limitations may actually already be occurring seasonally in response to *current* water withdrawals (Candler 2010.) As long as these dynamics remain unstudied, there will be additional uncertainty present in how water withdrawals are interacting with aquatic ecosystem maintenance and with the upholding of Treaty and aboriginal rights.

Another area of concern with respect to the geomorphology of the LAR is the uncertainty associated with the River 2D model because this model forms the backbone to the habitat-suitability-curve analyses. The River2D model is one of a number of two-dimensional depth-averaged models available. They enable study of rivers where velocities and slopes change (Chris Katopodis Pers. Comm.) The complex bedforms and ice-cverered conditions of the LAR present computational challenges for simulating hydrodynamics. As a result of these challenges, there is a lengthy list of significant assumptions and uncertainties associated with the application of the River2D model. The model does not address the ice formation period and the ice-breakup period. The models were based on sites that were chosen to be representative of the segment with respect to fish, not for navigation, so they don't mirror navigation needs. It is a fixed-bed model without any sediment transport component. The lack of validation data is likely the greatest concern, particularly for the winter low flows where there have been insufficient observations to calibrate the model (Chris Katopodis Pers. Comm.) While assumptions are provided, they are accepted with little indication of their quantitative implications for the habitat suitability curves. And the sites with the highest River2D model error are generally where the habitat is the most desirable (the side channels). Ice freezes more at the edges so tubular cross-sections are expected rather than rectangular cross-sections that are assumed by the model. Unfortunately, it is difficult to evaluate the model results because of the lack of validation data.

Consideration is not given in the P2FC science to changes in potential riparian vegetation that may occur under projected climates (Rood *et al.* 2008.) These changes are of concern in relation to riparian habitats and implications for the practice of Treaty and aboriginal rights, however they may also have effect here by changing the competence of bank stability and thus have further effects on channel morphology.

In summary, while it is recognized and acknowledged that channel maintenance flows are less vulnerable to water withdrawals than other channel flows (e.g., low flows), the analysis provided is incomplete in several respects. At a minimum, subjectivity should be removed, attention should be given to the actual present and potential future flow regimes, and this understanding should be used in this EC and outcome confidence limits generated. In addition, the analysis needs to be redone, with guidance by a fluvial geomorphologist, recognizing a broader understanding of the controls on navigation and fish habitat in this sandbed river and incorporating field experience of the LAR. Current understanding of ice dynamics (*e.g.* Wojtowicz 2010) needs to be incorporated into the analysis. Extensive site-specific river surveys have been conducted and would be available to add local information –for example, Trillium Engineering and Hydrographics (2002.)

4.0 CROSS-CUTTING CONCERNS

Placing the LAR within its basin and provincial context and informing decision-makers appropriately about the scientific findings are analytical needs that cut across disciplines and can result in far-reaching problematic implications if underimplemented.

4.1 Regional and Basin-Level Considerations

4.1.1 Water Budget and Basin Assessment of the LAR

The P2FC discounted as negligible the complete loss of LAR tributaries due to oilsands developments and declines in LAR tributary flows due to water withdrawals (Brian Makowecki and Ernst Kerkhoven, DFO CSAS workshop, Pers. Comm.). Yet, these basin-level changes increase further the effective withdrawal above and beyond the Option H withdrawals being considered by the P2FC. Rather than disregard these non-zero increments, they should be inventoried and summed, so that interested parties can reach their own conclusions about the implications. Otherwise, it casts doubt on the validity of the assumption that they are negligible.

While significant withdrawals from tributaries need to be evaluated in light of their impact on the LAR, smaller levels of tributary withdrawals are of serious concern at the scale of the tributaries themselves. Discounting the complete loss of tributaries as "negligible" to the LAR does not take into account that even a small percentage of water taken from a tributary can have an effect on the tributary itself. Furthermore, it does not consider the impacts to the use of LAR tributaries for harvesting and access by ACFN and MCFN members and the impacts of these losses on the Treaty and aboriginal rights of the First Nations. With respect to tributary navigation, the meaningful practice of rights would be breached long before a "complete" loss came about.

Based on historic reviews of hydrometric data from the WSC stations on the LAR and on tributaries to the LAR, while winter low flows in the LAR are dominated by water originating upstream of Fort McMurray, historic spring freshet flows show strong increases in the proportion derived from the LAR tributaries and can exceed 50% (Doyle 1977). This observation highlights the need to fully inventory the pattern of withdrawals from these LAR tributaries and understand their implications.

The P2FC has not considered the potential effects of regional groundwater withdrawals on LAR flows, casting additional unrecognized and unquantified uncertainty on the P2FC outcome. Worley Parsons (2008) has described that the "Athabasca River valley exists as the dominant discharge area with flow occurring towards that low-lying feature." In particular, based on WSC gauging data, Alberta Environment (2010) identifies that in 2008 there was an increase of 38 m^3/s in the lowest ~100 km of the Athabasca River and concluded that there is a "notable contribution" from the various formations to the natural flow of the river. It is also notable that the Kearl Channel (a groundwater feature) is situated in this area, is by far the most heavily licensed aquifer (0.82 m^3/s – AENV 2010, p 27), is identified as being potentially connected to the Athabasca River (Worley Parsons 2008, p 67), and is also identified as the groundwater body of "highest potential risk," in the entire Alberta oilsands area, to contamination from surface activities (Worley Parsons 2008, p 67). These observations supported by AENV highlight the troubling significance to the P2FC outcome of the absence of consideration of groundwater interaction with surface water.

It is clear from Worley Parsons (2008) and AENV (2010) that there is considerable uncertainty present in understanding the interactions between groundwater and surface water. As a result, the objectives of the groundwater monitoring program include gaining "further understanding of aquifer interactions and how the system is connected to surface environments" (AENV 2010.) The Interim Groundwater Management Framework (AENV 2010) goes on to point out that it will "take up to two years to properly characterize the baseline conditions in the key regional aquifers and much longer to establish the natural range of variability or seasonality." It is unclear how the Phase 2 rules could be set at this time when a couple of years of further work appear to be needed to gain confidence in understanding how the regional groundwater withdrawals may effect the LAR discharge.

The LAR drainage system is far from pristine. With extensive development alongside the LAR and in tributary drainages upstream and downstream of Fort McMurray, this system is a partially degraded system with weakened resilience. For example, Burn *et al.* (2004) look at hydrometric records from throughout the Athabasca drainage. They report mixed signals indicating the variable effect of land-use and highlighting the need to look more closely at the flow records in light of the land-use history. The water withdrawals being considered by the P2FC need to be put in the context of a basin assessment that inventories the full range of effects present in the drainage including, but not limited to, other water withdrawals. (See also section 3.1.4.)

The above hydrologic information can be assembled into a first-order water budget for the drainage. It is within the context of such a budget, that the proposed water withdrawals would be best interpreted and linked to projected changes due to climate change and loss of glaciers.

4.1.2 Cumulative Effects

Existing pressures on the LAR and PAD systems include petro-chemical contamination, dams and diversions, forest removal, groundwater mining, transportation and resource corridors, and climate change, among others. The P2FC does not address these combined pressures on the LAR and PAD; new and possibly significant declines in ecosystem structure and function may be taking place which will affect First Nations' ability to exercise Treaty and aboriginal rights. The examination of the LAR should be set in the context of the entire drainage, and include the present and future contributions of the glaciers that provide a significant percentage of the summer base flow. The common approach to cumulative effects assessment (CEA) in Alberta is a project-specific impacts approach, rather than a planning/regional approach. Further, a lack of defined thresholds and lack of shared data limit the ability to conduct CEA. Notwithstanding these challenges of conducting CEA in Alberta, the issue of cumulative effects remains unacknowledged by the modelers to the P2FC and by the P2FC for decision makers.

Decision makers have raised this issue in public forums. Former Chairman of the Energy Resources Conservation Board (ERCB), Neil McCrank, spoke to the need for regional assessments in his farewell speech at the University of Calgary (March 2007). The following month, Acting ERCB Chairman Brad McManus raised the same issue at a Canadian Energy Research Institute conference (also in Calgary). Subsequently, the Canadian Council of Ministers and Environment 2009 commissioned a report entitled "Regional Strategic Environmental Assessment in Canada: Principles and Guidance." Given that regional effects are fully within the federal and provincial government's mandate, they should be addressed by the P2FC. These issues are summarized by Schindler and Donahue (2006): "We predict that in the near future climate warming, via its effects on glaciers, snowpacks, and evaporation, will combine with cyclic drought and rapidly increasing human activity in the WPP [Western Prairie Provinces] to cause a crisis in water quantity and quality with far-reaching implications."

4.1.3 Provincial and Watershed Planning Initiatives

The P2FC Option H recommendation should be examined against and aligned explicitly with other provincial land-use and watershed-planning initiatives. The Lower Athabasca Regional Plan (LARP) is being developed under Alberta's Land-Use Framework (LUF). Given the size of the water withdrawals being considered by the P2FC, information flowing from the LARP undertaking should be directed to the P2FC to improve the robustness of its recommendation. As part of this initiative, Golder and Associates is preparing a climate change analysis to inform development of the LARP (Ernst Kerkhoven Pers. Comm.). The P2 WMF should not be finalized until that relevant information is reviewed by the P2FC and affected parties and incorporated into the water withdrawal rules.

The P2FC recommendation should also be aligned explicitly with Provincial commitments under the renewed Water For Life (WFL) strategy. In its WFL renewal statement, endorsed by the Government of Alberta, the Alberta Water Council recognizes the need to be proactive and to accelerate its actions "to protect our water sources now rather than waiting until later." In addition, a new principle has been added – WFL will be integrated into other policies and plans, such as LUF planning, to help ensure better resource management integration. The Alberta Water Council indicates that "success will depend on… a growing appreciation of the value of water as a scarce resource." In this regard, the Council recommends renewing the strategy around safeguarding Alberta's water sources, including "addressing aquatic ecosystem degradation." These course corrections are being implemented to reach the goal of assuring that Alberta's aquatic ecosystems are maintained and protected and that priorities for sustaining aquatic ecosystems are implemented through watershed plans.

Finally, the Prairie Adaptation Research Centre (PARC) provides climate change adaptation research services to the prairie provinces (Sauchyn and Kulshreshtha 2008). Despite PARC reports detailing the need for climate change adaptation throughout Alberta in response to climate change projections, it is not clear that the Province of Alberta uses these products in guiding its policy development.

It appears that the P2FC work is not unfolding in step with these very significant provincial initiatives and commitments. The P2FC's mandate on setting water withdrawals needs to be integrated within this broader collection of provincial land, water and climate initiatives already underway. And in general, greater transparency would be useful with respect to how the Province integrates the various procedures, commitments, and initiatives that are underway, particularly with respect to climate change.

4.2 Decision Making Framework

The Phase 2 Framework Committee has followed a Structured Decision-Making process. While in general it is a strength of the P2FC work, there are some major gaps in the process and in how the science is provided to the P2FC that render the SDM approach ineffective in grappling appropriately with pivotal issues present in this decision-making challenge. While the decision-making structure possesses a defined structure, its implementation reflects a blindness to serious gaps in knowledge brought about by deficiencies in how the science has been provided to the P2FC.

4.2.1 P2FC Principles

The P2FC principles include some valuable items that if implemented in their full spirit could support an effective decision-making process. Unfortunately, some of the most important principles have not been implemented while others suffer from being incomplete and thus ineffective. Four specific gaps in the SDM process are highlighted below.

1) The Principle "Be Explicit About Uncertainty" is not met. Modeling results need to include a quantitative understanding of the level of confidence with the model outputs.

Uncertainty in modeling outcomes needs to be quantitatively presented to decision-makers. The principle as stated creates an expectation that the decision maker will be clear on the level of confidence that accompanies a model output yet, in reality, model outputs are provided to decision makers without a quantitative understanding of their reliability. Section 4.3 expands on concerns about scientific uncertainty in the P2FC process.

2) The principle "The best available information from all sources would be used" is not met. Significant improvements are required on some models and analyses before they can be considered the best available information (notably the climate change analysis provided in Lebel et al*. 2009).*

As evident in the discussions at the DFO CSAS workshop (May 31-June 4, 2010), and Chapter 3 of this report, there are significant improvements needed on some of the models before they could be considered "best information." Note that the Regional Aquatic Monitoring Program (RAMP) possesses field data that would be very useful to the P2FC work, is not included in the P2FC work, and yet would be part of what one would consider the best information.

3) The fourth principle in the P2FC Process Guidelines states that "the process would strive for consensus but not require a consensus recommendation among participants. Areas of consensus and non-consensus (if necessary) would be clearly documented along with the perspectives of each participating party." Striving for consensus but not requiring it will always be problematic because decision-making discretion and accommodation remain unclear.

Consensus cannot be operationalised successfully in this way. Any valid consensus process requires that a clear alternative process be in place should the consensus one fail. In practice, not only did consensus fail in the final outcome of the P2FC (non-consensus Option H), the perspectives of each participating party have not been recorded and made available. Without these components, the decision-making process is most likely driven by the most influential stakeholders. From a decision-making perspective, this offers little to indicate what a minority view can expect in terms of due process. There are no minimum timelines provided, no conflict resolution policies indicated, no clarification provided as to what would constitute consensus and what would not, no explanation of when efforts would cease in the discussions to accommodate each party's concerns, and lastly and most importantly, the manner in which one party's interests can be favoured over another's when those interests cannot be mutually met. In practice, this puts certain stakeholders at an implicit disadvantage over others and means that the process does not meet the spirit of what the principles portray. And when the deliberations are established explicitly to "balance" (Ohlson et al 2010, p2) various stakeholder interests, the lack of procedure on how this will be done coupled with the ambiguity and lack of commitment to consensus means that the balancing will be reflective of the most powerful stakeholders as in conventional exploitative decision-making.

While the principles and structure of the P2FC process give the impression that science is guiding policy development, in practice, policy preferences are also, at times, infused into the science work in the P2FC process resulting in a scientific bias in favour of industrial development. Examples include the climate change analysis (section 3.1), the Option H bias toward oilsands water licenses rather than First Nations Treaty and aboriginal rights, and the modeling focus on a handful of species of management interest rather than an ecosystem focus. While it is difficult to correct this at this point in the process, it still remains possible to make clear to decision-makers this leakage of policy bias into science so that this information can be duly considered.

It is understood that AENV has acted as neutral facilitator for the P2FC process and has opted not to have representatives involved in the discussion. While it is appropriate for the provincial regulator to provide facilitation, the role of AENV does not end at this point. Neither AENV nor any other department of the Alberta Government can simply play a role akin to a "referee" or facilitator given the importance of the issue at hand. AENV must take a positive role in this process including, among other things, carrying out the legal responsibility of the Crown before making any decisions, including supporting any recommendations.

4) The Precautionary Principle, though implied at times, is not met. The use of the term precautionary in the P2FC discussions could give the impression to those outside these processes, especially decision-makers and the public, that the Precautionary Principle is being applied. Yet there is no clear evidence of its application in the P2FC results nor in its final report.

The essence of the Precautionary Principle is as follows:

> "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context, the proponent of an activity, rather than the public, should bear the burden of proof. If an action poses a risk of causing harm to the environment, in the absence of scientific consensus that the action is harmful, the burden of proof that it is not harmful falls on those who advocate implementing the action." (http://www.sehn.org/wing.html)

While the Canadian government does not consider the Precautionary Principle to be a rule of customary international law (GoA 2003), it holds more importance in other jurisdictions. For example, the 1992 Maastricht Treaty adopted the principle as a fundamental element of environmental policy. Still, the Government of Canada does hold that "[T]he application of precaution is a legitimate and distinctive decision-making approach within risk management." Members of the P2FC committee appear not to understand the concepts of precaution given that Ohlson *et al.* (2010, p 111) state "Option H's 4.4m^3/s EBF exemption is a precautionary approach to managing low flow events (being significantly below the assumed 16 m^3/s) demand requirement." There is nothing precautionary about taking water from the river at discharges down to zero; the willingness of water license holders to reduce their withdrawal voluntary may be a *concession*, but it is not a *precaution* and it cannot be regulated because it depends on voluntary measures. How can AENV ensure a precautionary approach if it cannot enforce so-called precautionary measures?

Regardless of the lack of take up of the Precautionary Principle, it is well recognized that a modern decision-making process must be informed by an appropriate assessment of "consequent risks" (GoC 2003). Furthermore, during the DFO CSAS workshop in Calgary, scientific discussions were at times misdirected by policy directives. For example, rather than focus on what the fish populations require, the modelers generally fell back to considering a policy option (Option H). This muddling of policy and science contributes to a loss of effectiveness in the science work, particularly given the extreme level of uncertainty present.

4.2.2 Risk Assessment

Rather than follow the precautionary principle in making its tradeoffs, the P2FC has chosen to incorporate risk assessment. Whereas precaution asks how much harm can be avoided, risk assessment tries to determine how much harm will be tolerated (Raffensperger and Schettler 2000). For each Evaluation Criterion, a single metric is determined for evaluation and expressed as a "percentage change relative to natural." Embedded in this risk assessment are the ubiquitous problems associated with the P2FC's assumption that the historic flow regime is equivalent to the present or "natural" flow regime (section 3.1). Setting aside this significant concern, the change in each metric is compared against two thresholds that separate three zones of response: undetectable, detectable, and potentially irreversible (Ohlson *et al.* 2010, p 29-30). While this is conceptually sound, the identification of the thresholds for each EC is, at best, weakly scientific and, in some cases, subjective or essentially arbitrary (depending on the EC).

Stronger alternatives are conceivable to the rather simplistic risk assessment scheme pursued by the P2FC science. While single metrics may in some instances be reasonable proxies of key aspects of ecosystem maintenance, in other instances, blended indices or other constructions based on multiple indicators may be more effective in representing the overall result of interest. Such expert system ratings can be supported by informed viewpoints of independent science experts able to interpret, say, a suite of indicators in relation to larger measure of interest (*e.g.,* navigability). Other possibilities exist.

The P2FC approach to risk assessment is misleading to decision makers. With weakly defensible risk thresholds and with option uncertainties that are not prioritized, quantified, nor otherwise interpreted for the decision-maker, how can a decision-maker know how best to trade off proposed options? In the simplest of decision-making situations, Hammond *et al.,* (1999) stress the need to build a risk profile of the options and for each, identify the key uncertainties that might significantly influence the consequences associated with each option. Ecological/environmental risk assessment (ERA - *e.g.,* Salasan Consulting 1999) is a more comprehensive organized approach that estimates the likelihood of adverse outcomes from various hazards under consideration. It is a vibrant area of study and development and the P2FC's present decision challenge would benefit from improving how ERA is incorporated into its Structured Decision-Making process.

While there is a broad spectrum of ERA approaches in use around the world (Power and McCarty 2002), there are fundamental principles of transparency, inclusiveness, communication of uncertainty, and clarity of separation between science and policy that underpin all approaches and relate to basic communication and group process rather than decision theory *per se*. It is in these fundamentals that the P2FC process needs important adjustments before it will be able to reach a sound science-based decision equitable to all affected parties.

The P2FC states (Ohlson *et al.*, p 2) that there will be a "balancing" of environmental, social, and economic interests and that trade-offs will be needed as part of the decision-making process. Given the interests at stake, it seems likely that it will be difficult, or at least very costly, to meet all rights simultaneously. Yet, this is at the heart of the balance that the P2FC identifies. Gregory et al (2006) point out the pitfalls of overemphasizing science when there are social choices being made. In the P2FC instance, it appears that, while a significant amount of scientific effort has been expended, a social choice is preventing science from being more fully heard because recent water licenses are upheld in the Option H at the expense of upholding Treaty and aboriginal rights. The process would be more efficient if this social choice were clearly stated because then the debate could move toward the social realm rather than the scientific work being confused with the social choice (*i.e.,* Option H). Preferred would be to provide a transparent procedure for making social choices. How will one party's interests be favoured ("balanced") over another's when those interests cannot be mutually met? In practice, underneath the SDM and science that are the focus of attention, lies a social tradeoff that is not being given sufficient recognition – preferred would be to document how "losing" parties will be compensated in those situations where each party's needs cannot be simultaneously met.

Ohlson et al (2010, p4) state "SDM helps people deal clearly and consistently with uncertainty, explore risk tolerance, make judgments about acceptable levels of risk and precaution, and find creative ways to manage residual risk." Given the lack of measure of uncertainty (see next section), the almost arbitrary nature of the risk thresholds used in some of the models, the lack of a transparent consensus process, it is not clear how SDM in this case has assisted decision-makers with 'dealing with uncertainty" nor has it helped individuals "explore risk tolerance."

4.3 Uncertainty

Ragas *et al.* (2009) distinguish between three types of uncertainty in risk assessment. First, "problem definition uncertainty" arises when the definition of the management problem differs from that of the scientific risk assessment problem. This is not unusual as surrogates or indicators are frequently used, as they are in the P2FC process, to represent the management issue of concern – for example, the protection of an aquatic ecosystem. Second, "true uncertainty" results from a lack of knowledge. Given climate change and the unknown behavior and needs of many fishes particularly under a changing hydrograph, the scope for this type of uncertainty is very high in the P2FC situation. While it is not always possible to quantify true uncertainty, it can be broken down and described to highlight its scope. Vercelli (1995, in Ragas *et al.* 2009) use the terms hard and soft (true) uncertainty to distinguish between uncertainty that can be quantified and that which can be expressed only qualitatively. Other stratifications of uncertainty are plausible. Third, "variability" is inherent in natural systems such as the LAR and the PAD and describes the distribution of a system characteristic around a mean.

As introduced in section 4.2, the many uncertainties associated with the P2FC decision problem have been inadequately presented to the P2FC. In some of the ECs, there is a reasonable effort made at listing the sources of uncertainty (and including some of the modeling errors), however this information is rarely converted into quantitative expressions of confidence around the modeled outcomes. It is recognized that quantification of uncertainty is not always feasible and to that end, it is useful to distinguish between different types of uncertainty. Despite mandating its subcommittees to "be explicit about uncertainty," the model outputs as provided to decision-makers for consideration do not include confidence limits, nor an accounting of the combined implications of uncertainty for the outputs. There is apparently no attempt made to propagate error in data inputs through to the model outputs nor effort given to examining compounded and interacting errors. In the P2FC's analysis of the LAR, as with many northern rivers, there is a lack of basic data on fluvial geomorphology and fish biology data and along with extensive assumptions, other data gaps, and modeling simplifications, the confidence of modeling outputs is generally low yet this is not communicated. Decision makers are not able to make an informed choice when they are not informed about the unstated and unquantified implications of data gaps and scientific simplifications/assumptions. Unless uncertainty is made clear, then the science is not ready to be considered in decision making.

According to the Government of Canada (2000), "scientists and science advisors should ensure that scientific uncertainty is explicitly identified in scientific results and is communicated directly in plain language to decision makers." The P2FC report does not do this. Instead, there is a complex suite of models each with its own limitations. Error analyses sufficient to inform decision makers of the implications of uncertainty within the models are required to remedy this. Completing these error analyses will require the participation of all the modelers to propagate the errors through the models and to devise estimates that represent interactions and non-linearities within and between the models. It will also require the modelers' professional judgments as to the implications for uncertainty of the many simplifying assumptions upon which the models have been built. This is a complex undertaking requiring the input of the entire modeling team. The Minimum Significant Increment of Change (MSIC – Ohlson *et al.* 2010, p 27) is not a replacement for an error analysis and communication of uncertainty largely because it is a subjective simplification that tends to reduce the potential for identifying uncertainty and error. No effort was given to this important step in interpreting the science that is intended to underpin this decision. Do the modelers and other applied scientists understand how projected changes translate into risk for important water values such as navigability and ecosystem maintenance? And where this is understood, have these uncertainties been effectively communicated to the P2FC and/or to decision makers?

In designing a scientific problem-solving effort like the P2FC one, resources need to be allocated carefully to assure that the information base for the decision will be complete. Extensive detail in one area at the expense of a basic level of interpretation or communication in another may result in the entire decision process being disabled. Ohlson et al (2010) state: "Within the constraints of time and resources, every attempt was [be] made to: be explicit about uncertainty." If time and resources indeed prevented the appropriate presentation of uncertainty and risk to the P2FC, then the combined science and decision process of the P2FC may be interpreted as a failure in the allocation of resources. In the balance of resource allocation to this decision problem, some of the resources given to modeling studies would have been better allocated to quantifying the uncertainty (in various ways) while more resources are needed to gather basic physical and biological data to calibrate and validate the models and ultimately better describe how the system functions. Any situation is constrained by time and resources and this cannot be held as a justification for making a decision based on inadequate and poorly interpreted science.

5.0 DISCUSSION

5.1 Progress Toward an IFN

Based on this review and that of Boag and Candler (2010) and Vander Meulen (2010), it can be concluded that the P2FC science and its decision-making process are incomplete and inadequate for establishing the P2 water management rules at this time. A science program that can address the existing data and analytical deficiencies needs to be put in place along with improvements to the decision-making process including how the science is provided to decision-makers for their consideration. These adjustments will take time and resources and in the meantime, it is important that safeguards be put in place to protect the LAR while this further work is undertaken, by filling gaps in protection currently existing under the P1 rules.

As discussed in section 1.1, establishing a sound IFN for the LAR requires understanding, amid a changing hydrologic regime, the measures needed into the future both to protect the aquatic ecosystem and to honour earlier legal commitments to First Nations Treaty and aboriginal rights for using the river. The P2FC has reduced the scope of its IFN efforts to emphasizing selected fish species and giving less emphasis to both the broader aquatic ecosystem and to First Nations use of the LAR. Within this narrowed scope, the P2FC outcome excludes an EBF and instead allows withdrawals of 4.4 m^3/s at any river discharge, this despite previous processes recommending the inclusion of an EBF. The intent of an EBF is to halt withdrawals below a defined cut-off flow to protect essential and sensitive ecosystem processes: this has not been achieved by the P2FC outcome. The IFN should also protect Treaty and aboriginal rights: in addition to requiring a healthy ecosystem, these rights imply incidental rights to navigate the river and access tributaries. Candler (2010) identifies preliminary Aboriginal Base Flow (ABF) and Aboriginal Extreme Flow (AXF) levels to be incorporated into the IFN to provide this protection. He defines the ABF as the open-water LAR flow level below which water withdrawals result in varying degrees of direct and cumulative impacts to Treaty and aboriginal rights. Similar to the ABF, the AXF is the open-water LAR flow below which extreme disruption of Treaty and aboriginal rights occurs along the LAR, the PAD and tributaries. Unfortunately, the P2FC work does not adequately recognize these open-water needs and instead focuses on the winter low flows to protect selected fish species. As the effects of climate change increasingly show up in a changing hydrograph, the incremental hydrologic adjustments are expected to cause new “hotspots” in declining ecosystem integrity and opportunities for navigation. For example, excessive late summer stream temperatures may also become limiting and inadequate fall flows may arise for maintaining connectivity to off-channel habitats. Given the lead times and depth of investment involved in the oilsands sector, it would present increased risk to the industry to encourage this investment when there is a deep but unquantified level of uncertainty as to whether that water will be available after the obligations to Treaty and aboriginal rights and to ecosystem maintenance have been met.

Achieving a robust science-based IFN outcome has been made difficult due to the P2FC's scientific design and its own process. Notably, the P2FC has caused a bias in the scientific work by infusing it with inappropriate policy direction. For example, its instructions to the Climate Change subgroup to not consider certain scenarios that were "immediately recognized as extreme hydrological changes" has caused a bias in the science associated with one of the most compelling scientific questions and uncertainties in the entire P2FC science analysis (section 3.1). A lopsided outcome has resulted from its emphasis on modeling fish habitat (despite significant model-input data gaps) while other key areas have gone understudied (First Nations river use – see Candler 2010) or just haven't been allocated the appropriate scientific expertise (climate change and the PAD). This has "shown up" in its emphasis on conducting work to set up an EBF while not carrying out equivalent work to set an ABF or AXF (or equivalent.) And while the P2FC's principles include being "explicit about uncertainty," it has apparently not insisted that the "explicitness" include quantitative measures with confidence limits.

As reviewed in chapters 3 and 4, the science itself further obfuscates the decision-making process by not being upfront and clear about the extreme level of uncertainty that is present in the scientific outcomes. Lists of assumptions and uncertainties are generally provided in qualitative terms and rarely, if ever, translated into quantitative measures interpreted for the P2FC to understand. Instead, they are converted into coarse generic qualitative classes of risk that are defined by, at times, essentially arbitrary class boundaries and embody a vast level of simplication, error, and overall uncertainty that is not communicated sufficiently. While the P2FC modeling and analytical work varies in its quality, components related to hydrology and geomorphology are notably weak due to the absence of sufficient expertise being assembled to conduct the work in these areas.

5.2 Getting Back on Track

The various scientific gaps can be addressed with additional time and resources. In addressing scientific shortcomings, the LAR and PAD knowledge base existing in peer-reviewed publications, consulting reports, and independent experts should be assembled to address this management question. Whereas literature reviews are carried out in the P2FC science, it is unclear why the hydrology and geomorphology insights from these reviews are not well reflected in the subsequent P2FC modeling. For example, the complex behavior and changing nature of the PAD is unreflected in the P2FC modeling work. The absence of efforts to evaluate how climate change may affect river development and connectivity to side-channels and tributaries, and the absence of consideration of changing sediment transport dynamics as the hydrograph changes, all suggest a need to have appropriate independent experts examine the status of the LAR in relation to proposed water withdrawals.

The science work and the decision-making process exist within a context which has not been examined in Ohlson *et al.* (2010.) The LAR exists at the downstream end of a much larger basin and it is within the context of a state-of-the-basin analysis that the P2 rules should be developed. The Athabasca drainage, as with the LAR and PAD, is not in pristine condition. It is being subjected to various anthropogenic pressures (Schindler and Smol 2006) including extensive forest removal, wetland conversion, agricultural development, water withdrawals not considered by the P2FC, climate change, among others and these together contribute to cumulative effects. Reductions associated with water withdrawals will be superimposed upon aquatic systems already under stress from other factors. The implications of these added pressures and potential cumulative effects need to be understood as the P2 rules are developed. In addition to the physical setting, the rules development exists within an existing and emerging Provincial policy framework that includes the renewed Water for Life Strategy and the Land-Use Framework. Their implications for and interactions with the P2 rules have not been transparently communicated to the P2FC. To proceed with the P2FC decision in the absence of understanding these basin contexts would, again, pose undue risks to investors and to those holding earlier river-based rights.

The PAD is a Ramsar wetland and a UNESCO world heritage site. As such, Canada and Alberta have commitments under an international agreement that oblige them to manage these PAD areas to protect their values. The decision-making objectives should be adjusted to reflect these commitments.

Climate change has an over-riding importance in setting the P2 rules due to the potentially deep changes in hydrograph behaviour that are expected through time (Lebel *et al.* 2009.). It is essential that the methodological errors and bias be fully corrected in how climate change has been addressed. In particular, the implications of the error in Lebel *et al.* (2009) recently acknowledged by AENV (Ernst Kerkhoven Pers. Comm.) be addressed in all the Evaluation Criteria. This review has offered one plausible presentation of climate change projections. Given the demonstrated vulnerability of this work to the influence of policy makers, it should be carried out by independent experts with experience in linking climate change projections to surface hydrology and land use.

Steps need to be taken immediately to fill data gaps critical to reducing scientific uncertainty. With respect to hydrology, existing data should be assembled to better understand the regional hydrology and construct a first-order water budget. These data include RAMP and Water Survey of Canada (WSC) flow measurements, records of water withdrawals, groundwater information, among others. Use insights from an examination of these data to improve understanding of groundwater interactions with the LAR flow and the seasonal significance of tributaries and tributary water withdrawals. With improved hydrologic data, and using all of the data that currently exist, a first order water budget for the drainage can then be developed. The present work can be put in context of the water budget. Similar efforts should be made to synthesise information in various consulting reports and peer-reviewed literature looking at the geomorphology of the LAR.

How science is communicated to decision-makers can be as essential in resolving a complex management question as how well the science is designed and conducted. The P2FC decision-making system can be amended and strengthened with real consensus decision making, defensible risk thresholds, and quantified modeling error and system uncertainty otherwise its outcome will remain ineffective and misleading. With further work, non-linearities and modeling interactions and compounding effects can be examined in the P2FC models to ultimately propagate the modeling uncertainties through to the modeled outcomes. Only when the outcomes are provided to decision-makers with defensible confidence limits will they be suitable for supporting informed decisions. With improved data sets in hand, and quantified uncertainties, the P2FC can address the serious gaps in data and knowledge that currently prevent it from reaching an informed decision.

5.3 Monitoring and Adaptive Management

The above discussion casts light on data and monitoring requirements needed to inform the current deliberation for a strong P2FC decision. While Appendix E of Ohlson *et al.* (2010) describes several valuable hydrologic monitoring proposals for the future, more can first be done with existing hydrologic data to support the P2 decision as indicated above. With respect to new future-oriented data, at a minimum, there is a need for a year-round hydrometric station to be put in place immediately upstream and near where the Athabasca empties into the PAD. Both WSC and the United States Geological Survey have manuals describing winter hydrometry. It is important to retain the services of someone experienced in ice-based flow measurements to get accurate measurements and avoid the pitfalls associated with hydrometric measurements under ice. The other proposals in Appendix E should also be supported (*e.g.,* a monitoring network in the LAR and PAD and improved records of water withdrawals.) Candler (2010) and Boag and Vander Meulen (2010) suggest other important data requirements in related themes.

According to Brian Makowecki (Pers. Comm., DFO CSAS workshop), once the P2 rules are established, they won't be opened again for revision for another ten years. Should the proposed non-consensus Option H outcome be endorsed by regulators despite its many scientific and decision-process shortcomings, it would be unjustified scientifically to not evaluate it on an ongoing basis. The lack of an EBF, the degree of uncertainty present, and the many other weaknesses in the science and the decision process all highlight the need to move slowly forward with any decision at this time. Instead, seasonal and annual adaptive management programs, with independent expert oversight, are needed that establish and evaluate performance measures directly related to navigation and ecosystem integrity.

If the Option H is adopted without a credible, independent and corrected climate change analysis being completed and applied to the P2FC models, then an annual review of the hydrograph should be carried out to assess the direction of change of peak flows and low flows. The annual observations would be used to ascertain whether unusual and more frequent low flows are occurring. If unusual extremes are suspected, this would provide further justification for implementing a temporary precautionary (cut-off) flow to protect river and navigation values. Consideration could be given to the staged-in construction of off-channel storage to prevent excessive repeated low-flow withdrawals. In such a staged storage regime, storage would be tied to annual observations of low flows following a formula; should annual flows stay low and/or decline, increased storage would be built.

The current day-to-day river situation offers an opportunity to integrate understanding of the effects of changing river dynamics and water withdrawals on emerging challenges to First Nations in exercising their Treaty and aboriginal rights. The P1 rules have been in place for a few years. Current and recent experience of river users can be explored within the context of the dynamic of each year's hydrograph and in relation to the weekly flux in industry water withdrawals. As the new hydrograph unfolds, at times with unexpected behaviour, it offers the opportunity to identify empirical thresholds in access to navigation for fulfilling Treaty and aboriginal rights, in addition to accessing reserve lands. Candler (2010) has used such information to develop preliminary indications of an ABF and AXF. More field research is needed in this regard.

6.0 RECOMMENDATIONS

As a result of this review, the following recommendations are provided to guide the development of the appropriate science and its interpretations to support informed decision-making.

Science

1. Create an independent scientific oversight and review body.

Establish a scientific panel of independent researchers, practioners and river users with no connection to AENV, DFO, and the oilsands industry to oversee the scientific work carried out in support of this decision.

2. Conduct a credible climate change analysis.

Building on the guidance provided in this report, revise the climate change analysis to provide plausible projections that extend through the likely duration of the oilsands development and which provide projected means and standard errors of future climates based on plausible emissions scenarios and on unbiased methods. Integrate findings from the LARP climate change analysis. (Be sure to correct known errors in Lebel *et al.* (2009) and apply these corrections to all P2FC models.) Use these climate change projections, complete with corresponding confidence limits, to develop/confirm projections for the changes in hydrograph behavior (at least winter and summer low flows, annual peak flow, and mean annual flow) for the LAR and make these model outputs available to the other science work.

3. Apply meaningful climate change projections to all P2FC models.

As existing biophysical models are refined and new models are developed to assess the impacts of water withdrawals on ecosystem health and on Treaty and aboriginal rights, apply the future climates to the model outputs for a range of plausible water withdrawal scenarios.

4. Place the LAR scientific work in the context of its regional hydrology and of the entire Athabasca drainage.

Assemble basic information and conduct preliminary analysis of groundwater-surface interactions, the significance of LAR tributary inflows, extent of LAR tributary water diversions, regional and upstream land-use pressures, and cumulative effects. Acquire the flow data for all gauges on the LAR and use these data to improve knowledge of the basin water budget.

5. Assemble an independent expert team with direct knowledge and experience of the Lower Athabasca River to lead future modeling and interpretation of the effects of water withdrawals.

Led by an independent expert team, bring together existing data, industry reports, and peer-reviewed publications on the structure and function of the LAR, its tributaries and its riparian areas to build a complete picture of its status and behaviour. Use this state-of-the-art understanding to guide the development of future LAR modeling under a range of water withdrawal scenarios, and coupled to climate change projections.

6. Assemble an independent expert team with direct knowledge and experience of the Peace-Athabasca Delta to lead future modeling and interpretation of the effects of water withdrawals.

Led by an independent expert team, bring together existing data, industry reports, and peer-reviewed publications on the structure and function of the PAD and its tributaries to build a complete picture of its status and behavior and including consideration of the climate change projections and the flow regulation on the Peace River. Use this state-of-the-art understanding to guide the development of future PAD modeling under a range of water withdrawal scenarios. Explicitly identify how provincial and federal commitments under the Ramsar treaty are being met to protect this Unesco World Heritage site.

7. Establish confidence limits on P2FC model outputs and interpret the science outcomes for the P2FC (or successor) along with any significant accompanying assumptions.

Require that uncertainty be clearly described, explicitly quantified, and the implications of uncertainty for model outputs be provided by the relevant science group for consideration by (non-science) decision-makers.

8. Interpret findings from the PAD and LAR expert groups in light of direct field experience from First Nations and other informed LAR and PAD users.

Examine past and ongoing river-use dynamics in the context of associated water withdrawals and discharge measurements for the LAR and its tributaries. Identify vulnerabilities in navigation, emerging patterns in downstream flow changes, and possible options for optimizing the interaction between water withdrawals and navigation/access needs. Interpret findings in the context of model outputs to develop improved water withdrawal proposals reflecting the needs of all affected parties.

Decision-making

9. Put in place short term measures to protect river values.

Implement temporary measures to protect river values until the needed science can be completed and the provincial/regional policy development becomes available.

10. Address deficiencies in process and decision-making of the P2FC (or its successor).

Re-establish the P2FC (or successor) process based on consensus decision-making and a requirement that uncertainty be substantially quantified and interpreted for decision-making.

11. Require that the P2FC (or its successor) follow the Precautionary Principle in designing the scientific program and in considering the scientific outcomes. If this is not implemented, then improve the communication of risk to decision-makers.

Examine this problem-solving setting for opportunities to apply the Precautionary Principle. Where risk assessment is used in place of the Precautionary Principle, improve how risk is calculated and interpreted for decision-making. Provide the modeled outputs, complete with quantitative confidence limits and the additional qualitative assumptions that accompany each metric. Assure that there is transparency around the defensibility and reliability of risk thresholds.

12. Link the findings and policy needs of the P2FC work transparently to existing provincial policy initiatives and commitments.

Put the P2FC work explicitly in the context of existing provincial policy initiatives and commitments: the Lower Athabasca Regional Plan, the Water for Life Strategy, and guidance from the Prairie Adaptation Research Council.

13. Establish an appropriate monitoring and adaptive management program.

Develop and implement a monitoring and adaptive management program focused on 1) hydrologic changes due to climate change and regional water withdrawals and 2) adjustments in the fluvial geomorphology of the LAR and PAD. Immediately install a hydrometric station near the mouth of the Athabasca River. Use monitoring results to better quantify the uncertainty. Secure use of beneficial RAMP data.

14. Request that federal agencies such as the Department of Fisheries and Oceans, Indian and Northern Affairs Canada, Transport Canada, and Health Canada intervene on behalf of the First Nations of the Lower Athabasca River.

The Department of Fisheries and Oceans needs to intervene to protect fish habitat. Indian and Northern Affairs Canada needs to intervene to preserve access to protected lands by First Nation peoples. Transport Canada needs to intervene to ensure navigability of the Athabasca River. Health Canada needs to intervene to safeguard the health of the Fort Chipewyan community and its peoples. Environment Canada needs to intervene and protect species that are threatened or endangered, such as the caribou.

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Trillium Engineering and Hydrographics 2002. *Winter Survey of Athabasca River Below Peter Lougheed Bridge*. Report prepared for the Cumulative Environmental Management Association, contract number 2001-0011, 3 p plus figures.

Utzig G 2010. *Climate change projections for the West Kootenays*. Unpl. Rpt. Kutenai Nature Investigations Ltd. Nelson, BC. 7 p.

Vercelli A 1995. From soft uncertainty to hard environmental uncertainty. *Economie.*

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Wojtowicz AM 2010. *Two-D Modeling of Freeze-up Processes on the Athabasca*. Master of Science in Water Resources Engineering, Department of Civil and Environmental Engineering, University of Alberta, 157 p.

Worley Parsons 2010. *Regional groundwater quality study and monitoring network design in the Athabasca Oil Sands. Phase 1, Technical Summary.* Prepared for the Cumulative Environmental Management Association, 97 p plus appendices.

Martin Carver

<personal information removed>

I am a hydrologist and geomorphologist drawing on over 20 years of experience in water resources. I provide a bridge between science and policy in guiding sustainable land management for the protection of water values such as drinking water and aquatic habitats. Land-use planning through environmental risk assessment and other technical knowledge provides the basis for applying sustainability principles, in the development and implementation of strategies and policies for sustainable communities and biodiversity conservation, particularly in response to climate change. I have worked in Canada, Nepal and Ecuador.

PERSONAL INFORMATION

Citizenship:	Canada, United Kingdom
Languages:	English, Spanish, French, some Nepali

EDUCATION

Ph.D. 1990-1997	University of British Columbia (Resource Management Science, Interdisciplinary Studies), Vancouver, BC; thesis entitled *Diagnosis of Headwater Sediment Dynamics in Nepal's Middle Mountains: Implications for Land Management*.
M.A.Sc. 1985-1988	University of Waterloo (Mechanical Engineering), Waterloo, Ontario; thesis in Environmental Fluid Mechanics (atmospheric dynamics) entitled *An Experimental Investigation of the Behaviour of Plumes Merging in a Cross-flow*.
B.Sc. 1980-1984	University of Manitoba (Mechanical Engineering), Winnipeg, Manitoba; Degree with Distinction, Dean's Honour List. A focus in energy and fluid mechanics.

PROFESSIONAL POSITIONS

2009-present	**Principal** *Aqua Environmental Associates*, Nelson, BC
2008 – 2009	**A/Director of Source Water Protection** *BC Ministry of Healthy Living and Sport, Victoria, BC.* Built new group within the Health Protection Branch responsible for setting new provincial policy directions to protect water source areas affecting human health. Worked closely with other ministries/partners. Led MHLS implementation of commitments under Living Water Smart, BC's new provincial water strategy.
2005 – 2008	**Watershed Hydrologist and Aquatic Risk Assessment Modeller** *BC Ministry of Environment, Water Stewardship Division, Victoria, BC.* Led the creation of a program of provincial aquatic risk assessment modelling focused on the water and aquatic-related consequences of climate change for communities, biodiversity, agencies, and industry with initial emphasis on the effects of the mountain pine beetle and associated salvage.
1998 - 2005	**Principal** *Aqua Environmental Associates*, Nelson, BC
1996 –1998	**Hydrology and Terrain Specialist** *BC Environment*, Nelson, BC
1984 –1985	**Energy Consultant** *E.J. Faraci and Associates Ltd.*, Winnipeg, MB
1984	**Researcher** *Solar Energy Program, National Research Council*, Ottawa, ON

PROFESSIONAL REGISTRATIONS

- Registered as a *Professional Geoscientist* (P.Geo.) in the Province of British Columbia with the Association of Professional Engineers and Geoscientists of British Columbia (since 2003).
- Registered as a *Professional Engineer* (P.Eng.) in the Province of British Columbia with the Association of Professional Engineers and Geoscientists of British Columbia (since 1997).
- Registered as a *Professional Agrologist* (P.Ag.) in the Province of British Columbia with the British Columbia Institute of Agrologists (since 1997).

AQUATIC RISK ASSESSMENT AND LAND-USE PLANNING

- Development & application of aquatic environmental/ecological risk assessment (ERA) frameworks & risk mgmt
- Analysis and integration of implications of global climate change in ERA
- Creation of expert systems and physically-based models including linkages to habitat-supply modelling
- Application of scenario development and decision systems for risk management in decision analysis
- Environmental stressor/threat classification and aintegration of environmental values affected by stressors
- Review and analysis of Environmental Impact Assessments in resource sector with focus on water and land values

Selected Publications

Dubé, M, P Duinker, L Greig, M Carver, M Servos, M McMaster, B Noble, H Schreier, L Jackson, K Munkittrick 2012 (submitted). *A Framework for Assessing Cumulative Effects in Watersheds*. Journal of Integrated Environmental Assessment and Management

Athabasca-Chipewyan First Nation, Mikisew Cree First Nation, M Carver, C Candler and T Boag 2010. *Athabasca-Chipewyan First Nation, Mikisew Cree First Nation Review of the Phase 2 Framework Committee Recommendations: Synthesis Report*. Submitted to Alberta Environment and Canada Department of Fisheries and Oceans, July 2010, 63 p plus appendices.

Pike R, M Feller, J Stednick, K Rieberger and M Carver 2010. Water quality and forest management. Chapter 12 in: *Compendium of Forest Hydrology and Geomorphology in British Columbia*, p 401-440.

Carver, M and M Gray 2010. BC Assessment Watersheds for Regional Level Applications *Streamline*, 13(2) Spring 2010.

Carver M, M Weiler, C Scheffler, K Rosin 2010. *Development and Application of a Peak Flow Hazard Model for the Fraser Basin, British Columbia*. Report to Natural Resources Canada, MPBI Project #7.29, 39 p.

Carver M, M Weiler, K Stahl, C Scheffler, J Schneider, JAB Naranjo 2010. *Development of a Low Flow Hazard Model for the Fraser Basin, British Columbia*. Report to Natural Resources Canada, MPBI Project #7.29, 30 p.

Carver M, M Weiler, et al. 2007. *Hydrologic Risk Assessment: Preliminary Modelling Results*. Paper presented at Mountain Pine Beetle and Watershed Hydrology Workshop: Preliminary Results of Research from BC, Alberta and Colorado, Kelowna, BC, Canada, 4 p.

OPERATIONAL ANALYSIS IN SUPPORT OF SUSTAINABLE RESOURCE DEVELOPMENT

- Watershed, channel, wetland, & riparian assessments particularly associated with forestry and mining activities
- Regional hydrologic analysis and water quality monitoring design, assessment, and analysis
- Site hydrologic assessment for protection of water supplies, aquatic habitats, infrastructure, & other values

Selected Publications

B Carson, D Maloney, S Chatwin, M Carver and P Beaudry 2009. Protocol for Evaluating the Potential Impact of Forestry and Range Use on Water Quality (Water Quality Routine Effectiveness Evaluation). Forest and Range Evaluation Program, BC MFR & MoE Victoria, BC http://www.for.gov.bc.ca/ftp/hfp/external/!publish/frep/indicators/Indicators-WaterQuality-Protocol-2009.pdf

Carver M. 2006. Watershed Assessment – Sullivan Creek. Report prepared for the Creston Valley Forest Corporation, Creston BC. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=8764

Carver M. 2003. *Watershed Assessments for the Buffer Zone of Podocarpus National Park (Ecuador).* Report prepared for Fundacion Ecologica Arcoiris, Loja, Ecuador.

Carver M. 2003. *Hydrologic Opportunities for Enhancing Environmental Condition – Connor Creek and Vicinity*. Report prepared for Aquila Networks Canada, 24 p. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=8762

Carver M., G. Utzig, and D. Putt 2001. *Watershed Assessment & Reconnaissance Stability Assessment of Structure Locations – Glade Creek*. Prepared for KRM Associates Inc. (for West Kootenay Power Ltd.) Nelson, BC, February, 46 p. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=8767

Carver M. and G. Utzig 1999. *Hydrologic Assessments – Arrow Creek, Arrow Mountain, and Adjacent Areas*. Report prepared for Creston Valley Forest Corporation, Creston, B.C,. 60 p plus maps and appendices. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=9248

POLICY DEVELOPMENT AND SUSTAINABILITY ANALYSES

- Facilitation, consultation, and public education in pursuit of consensus around environmental issues
- Evaluation of ecological goods & services, drought & water supply planning, watershed planning techniques
- Water strategy development, precautionary management, leadership/coaching, vision development
- Hydrology and geomorphology assessment and analysis for watershed health diagnosis
- Forest certification, stewardship initiatives, biodiversity conservation, wetland policy development

Selected Publications, Presentations, and Initiatives

Howard SG & M Carver 2011. *Central Interior Ecoregional Assessment: Freshwater Analysis.* BC J. of Ecosystems and Mgmt 12(1): 72-87. http://jem.forrex.org/index.php/jem/article/viewFile/30/61

Carver M. 2010. *Incorporating Water into Food Security by Expanding on the Concept of Virtual Water.* Draft report prepared for the University of Saskatchewan (Saskatoon) for UNEP/GEMS (Nairobi), p 33.

Created new policy group (2008-2009) within the Health Protection Branch of the BC Ministry of Healthy Living and Sport responsible for setting new provincial policy directions to protect water source areas affecting human health. Scope included hiring and training personnel, setting provincial source water protection policy priorities, and application of health stewardship principles

Member (2001-2012) of the BC Wetland Stewardship Partnership, a multi-agency group improving policies and tools for BC wetlands.

Carver, M. 2006. *Changes to British Columbia's Aquatic Environments from Global Climate Change*. Paper presented at annual conference of Association of Professional Engineers and Geoscientists of BC, Victoria, BC, Oct 12-14, 2006.

Carver, M. 2004. *Wetland Stewardship in British Columbia*. Paper presented at the INTECOL 7th International Wetlands Conference, Utrecht, Netherlands, July 25-30, 2004.

Carver M. 2001. *Riparian Management for Protection of Aquatic Values – Literature Review and Synthesis.* Prepared for Forest Stewardship Council British Columbia Regional Standards Team (Riparian Sub-Committee), 48 p.

Schreier, H., S. Brown, and M. Carver 1998. Linking land degradation to nutrient and sediment transport in a Middle Mountain watershed in Nepal. In: *Headwater Control IV: Hydrology, Water Resources and Ecology in Headwaters*. Headwater'98 Conf, Apr 20-23, Italy.

Bruce David Maclean

B.Sc.

<personal information removed>

Education:

Bachelor of Science, Environmental Science, University of Manitoba (1997)

Professional Experience:

Maclean Environmental Consulting
May 2011 – Present

Research co-ordination for the Athabasca Chipewyan First Nation
Training and establishment of Community-Based Monitoring programs

Project Manager
Centre for Indigenous Environmental Resources
Winnipeg, MB (2006-May 2011)

Managed staff to build the capacity of First Nations to deal directly with their environmental concerns through a multifaceted approach that includes education and training, targeted environmental research, restoration activities and facilitated workshops between rights holders.

- designed environmental monitoring programs to observe impacts from oil sands development as well as for sewage lagoon and landfill site inspections
- advised Chief and Councils in sustainable cattle development and on nutrient management options for their sewage lagoons.
- reviewed federal and provincial Environmental Assessments on behalf of First Nations to determine if they met provincial and federal regulations.
- reviewed current provincial and federal waste site regulations for the Manitoba region
- Interpreted elements of the Indian Act for research done for report to CEAA on the meaningful involvement of Aboriginal people in environmental assessment.
- developed and implemented workshops to ensure that a strong Traditional Knowledge foundation is used to inform conservation decision making by Environment Canada and Fisheries and Oceans Canada for Species At Risk in the designation of critical habitat
- developed and delivered monitoring programs using Traditional Knowledge for Mikisew Cree First Nation
- designed and led training programs in:
    - strategic planning
    - environmental monitoring
    - environmental assessment
- facilitated consultation workshops between First Nations and federal government
- provided fuel tank inventories in Quebec nursing stations to Health Canada
- delivered fish habitat assessment expertise to First Nations in Manitoba
- liaised, consulted and negotiated with First Nations, federal governments, provincial agencies, agricultural associations and producers on nutrient sustainability issues

- provided expert scientific advice to Chief and Council on the environmental impact of community infrastructure projects
- managed and supervised a project team consisting of 4 research associates for the delivery of the First Nations Fish Habitat program.
- Managed large multi-year budgets, developed agendas, briefing notes and position papers, generated communications products and reported on accomplishments

Aquatic Biologist
North/South Consultants Inc
Winnipeg, MB (2003-2006)

- planned, executed and delivered impact studies for proposed generating stations
- educated First Nation technicians in the application of field study methodologies
- sampled for lake sturgeon along the Nelson and Hayes rivers in northern Manitoba in conjunction with the environmental assessments for the proposed Conawapa and Keeyask generating stations
- coordinated fish community scientific investigation in Angling Lake, Manitoba, including acoustic tagging, mercury sampling and water chemistry analysis
- monitored the disturbance on fish and fish spawning areas and provided compliance monitoring of water quality in rivers and tributaries due to linear developments, including:
    - turbidity monitoring at Lake Manitoba Narrows for a Manitoba Hydro fibre optics line
    - turbidity monitoring and fish habitat monitoring on the Athabasca River open cut pipeline crossing by ATCO in Fort Assiniboine, Alberta
    - turbidity monitoring for Encana pipeline's directional drilling in Fort Nelson, Alberta
- delivered a creel study on Athapapuskow and Kississing lakes in northern Manitoba
- managed fly in research camps of 20 staff or more for research activities and day to day operations

Education Coordinator
City of Winnipeg
Winnipeg, MB (2001-2003)

- engaged youth and volunteers in riverbank restoration projects
- managed budgets and staff to maintain natural areas
- promoted the adoption of diverse beneficial management practices to improve the environmental performance of agricultural operations
- prepared briefing materials, managed budgets and supervised consultant contracts

Fisheries Biologist
Mexican National Government Department of Environment
Isla Contoy, Mexico (2000-2001)

- provided advice to Mexican government about the state of barrier reef ecosystem health
- completed a sustainable lobster fishing study and instigated sustainable lobster fishing programs
- devised a reef protection plan and monitoring study

Pipeline Integrity Consultant
J.E. Marr and Associates - Calgary, AB
Calgary, AB (1997 – 1999)

- investigated pipeline integrity for Transcanada Pipelines
- provided expert risk assessment on stress corrosion data to WestCoast Energy

Selected Publications:

Meaningful Involvement of Aboriginal Peoples in Environmental Assessment, Centre for Indigenous Environmental Resources, Series 2006.

Computer skills:

I am proficient in using email and all Microsoft programs.

Languages:

Fluent in English, French and Spanish.

Communications:

- strong technical report writing skills and am effective at communicating in briefing notes, emails and letters.
- experience delivering presentations to large audiences and am comfortable communicating orally in English, French and Spanish.
- Presentations to the Manitoba Conservation District Association Annual meeting, the Lake Winnipeg Research Consortium, and to Mikisew Cree First Nation.

Interpersonal skills:

I have strong interpersonal skills through project work at CIER and through work on the Mining Watch Canada, Board of Directors. One of these skills is showing initiative, by developing strategic plans to anticipate and formulate project goals. I am dependable with sound judgment as a team player and am relied on to lead project teams, with a style based on action management.

Training:

Water Quality Sampling and Design (2011)		Vancouver Island University
Fundamental of Successful Project Management(2009)	-	SkillPath
Practical Workshop Facilitation Skills (2008)	-	University of Winnipeg
Participatory Action Research (2008)	-	Natural Resources Institute
Environmental Assessment Awareness and Referral Training (2008)	-	Department of Fisheries and Oceans
Culture and Conflict (2008)	-	Mediation Services
Strategic Planning - Advanced (2007)	-	Aboriginal Leadership Institute
Pangnirtung, Nunavut - Inuit Traditional Knowledge6 week field study (2002)		-University of Manitoba

Certificates:

CRITI CARE EMS Advanced First Aid (2006)
Marine Emergency Duties - Level A3 commercial boating certification (2005)
Advanced SCUBA diver certification (1999)

Boards:

Mining Watch Canada – Board of Directors (2009-present)

Athabasca Chipewyan First Nation – Industry Relations Corporation

Community Based Monitoring Program

Final Report on the 2011 Water Quantity Monitoring

September 2012

Table of Contents

1.0 EXECUTIVE SUMMARY

The Athabasca Chipewyan First Nation (ACFN) began their Community Based Monitoring CBM in the summer of 2011. They recorded water quantity at 8 sites for water depth.

At 6 of the 8 sites, in 2011, quantity levels were recorded as below the established Aboriginal Base Flow level of 4 feet, with 3 sites being below this threshold continuously.

2.0 INTRODUCTION

The purpose of this report is to describe the activities of, and provide results for, the Athabasca Chipewyan First Nation – IRC Community Based Monitoring (CBM) Program. The report will describe tasks for the project from spring 2011 to winter 2012. The report will give results for the 2011-2012 sampling season.

The report will focus on the following specific aspects of the program:

- Program development and review;
- Training;
- Water quantity results;
    - Depth profiles; and,
    - IK interviews.

3.0 PROGRAM DEVELOPMENT

3.1 TRAINING

3.1.1 Water quantity training

Training was given on September 7-9, 2011 in Fort Chipewyan. Sites were chosen to be sampled based on the report by the Firelight Group, As Long As the Rivers Flow, (Firelight Group, 2010) to support the protection of Aboriginal and Treaty rights. Training participants included Jonathan Bruno and John Cardinal. Participants learned to measure water depth and staff gauge height and take appropriate meteorological measurements.

3.1.2 Water quantity TEK interview training

Jonathan Bruno was trained in September to interview ACFN land users about their ability to access traditional areas. This work involved one-on-one initial interviews about land use followed by weekly phone interviews. The interview questions are designed to accompany the water quantity measurements, in order to combine the western science with the Traditional Knowledge to strengthen results. For example, a recorded water level of below 122 cm (four feet) at an ACFN sample might limit access for ACFN members to traditional use areas, which would be captured in their stories during interviews. This training was continued in October to look at Cybertracker database use and expanded to look at winter travel conditions.

4.0 METHODS

4.1 SAMPLE LOCATIONS

The sampling site selection for all aspects of the CBM has been a combination of Traditional Knowledge and western science. Figures 1 and 2 display the CBM water depth sites. The sampling specific site locations are described below.

4.1.1 Water Quantity

Sampling sites were chosen with the assistance of Lionel Lepine (ACFN), Johnathan Bruno (ACFN), Nicole Nicholls (ACFN), Craig Candler (Firelight Group) and Steven DeRoy (Firelight Group). Sites reflect both local knowledge from frequent lake and river users, as well as Traditional Knowledge from ACFN members, as summarized in the report “As Long as the Rivers Flow” (Firelight Group, 2010). Sites were selected that were known ‘pinch points’, (areas that when water levels reached lower than four feet limited access to traditional hunting, fishing and trapping spots). Martin Carver also reviewed the site selection based on a hydrology perspective to determine if the water quantity is reflective of Peace River flows or Athabasca River flows.

Figure 1. All CBM water quantity sampling sites.

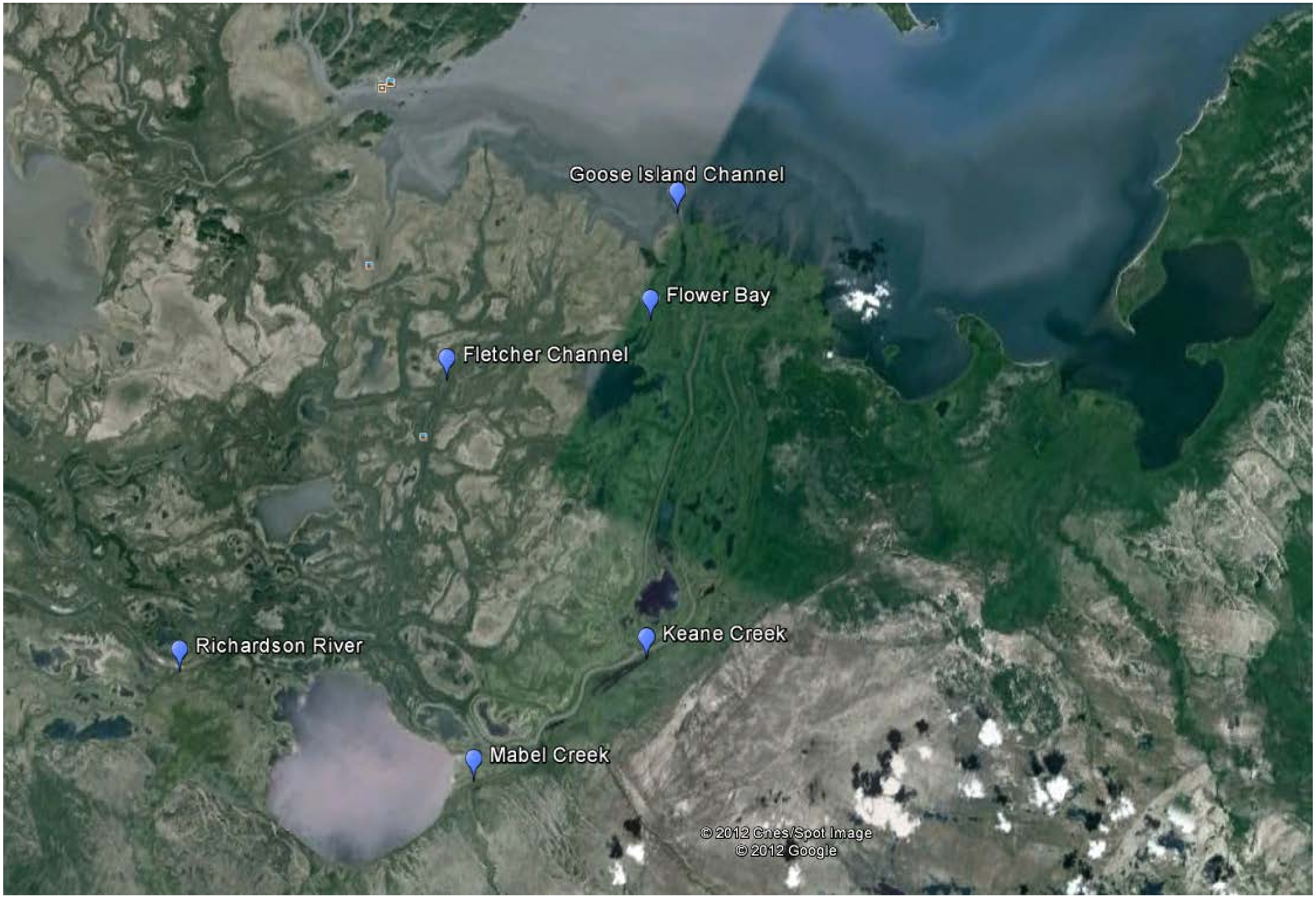

Figure 2. CBM water quantity sites in the Delta

5.0 TEK MONITORING RESULTS

5.1 WATER QUANTITY AND WINTER SAMPLING

Water quantity interviews began late in the open water season and therefore the interview questions were modified to include all travel (summer and winter). This allowed for the collection of information about the safety of ice conditions and for the ability of ACFN members to reach their traditional areas by snowmobile. A total of 5 ACFN members were interviewed over the course of five months. They were:

ACFN

- Alan Adam
- Archie Cyprien
- Conrad Bruno
- Morgan Voyageur
- Raymond Cardinal

The interviews collected information on the following areas:

- Fletcher Channel
- Flower Bay
- Goose Island Channel
- Jackfish Creek
- Jackfish Lake
- Embarass River
- Freezie Lake
- Big Snye
- Rotten Snye
- Poplar Point
- Richardson River

Overall, 41 interviews were recorded. Of those, 40 interviews were winter readings, 1 was a summer reading. Nine interviews identified a problem with travel (8 winter and 1 summer).

6.0 WESTERN SCIENCE RESULTS

6.1 WATER QUANTITY

Water quantity was measured at 8 sites in the Athabasca Delta and Athabasca River for changes in depth, using five physical depth measurements along the entire stream/river channel. The deepest reading was used in the following graphs to display the access by channels.

There was limited data collected at some sites because sampling teams became stuck on sandbars or mudflats in trying to reach sample sites due to very low water levels. Travel to the southernmost sites became impossible due to low water, even in jet boats, by mid October.

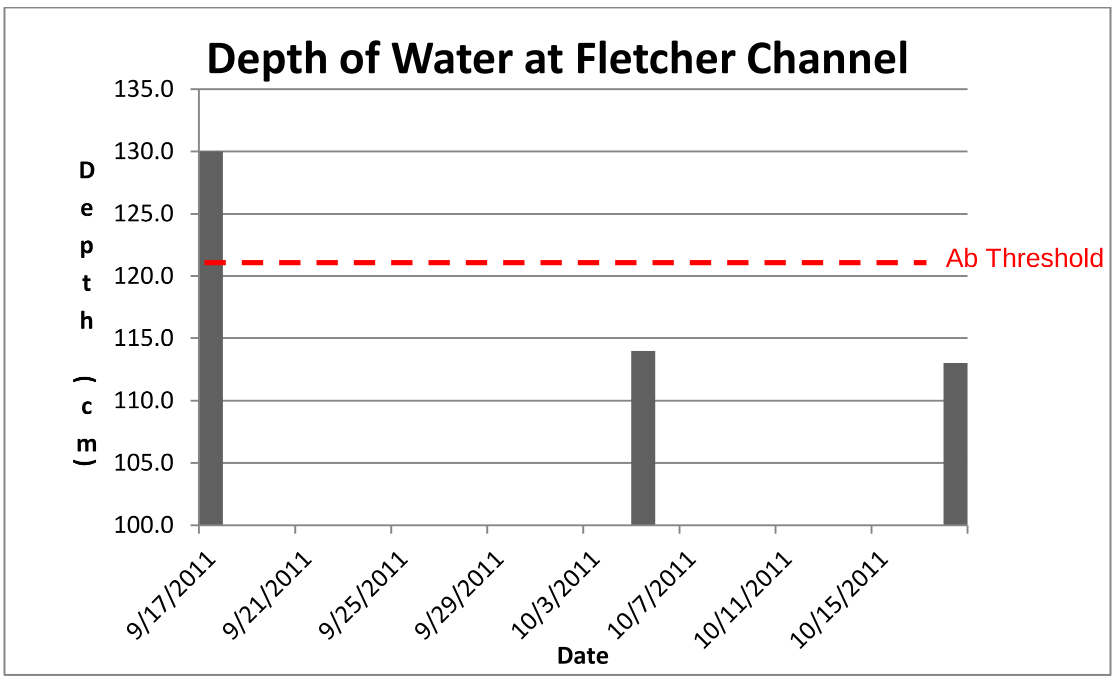

Figure 3. Deepest Recorded Water Depth at Fletcher Channel (red line is Aboriginal base flow).

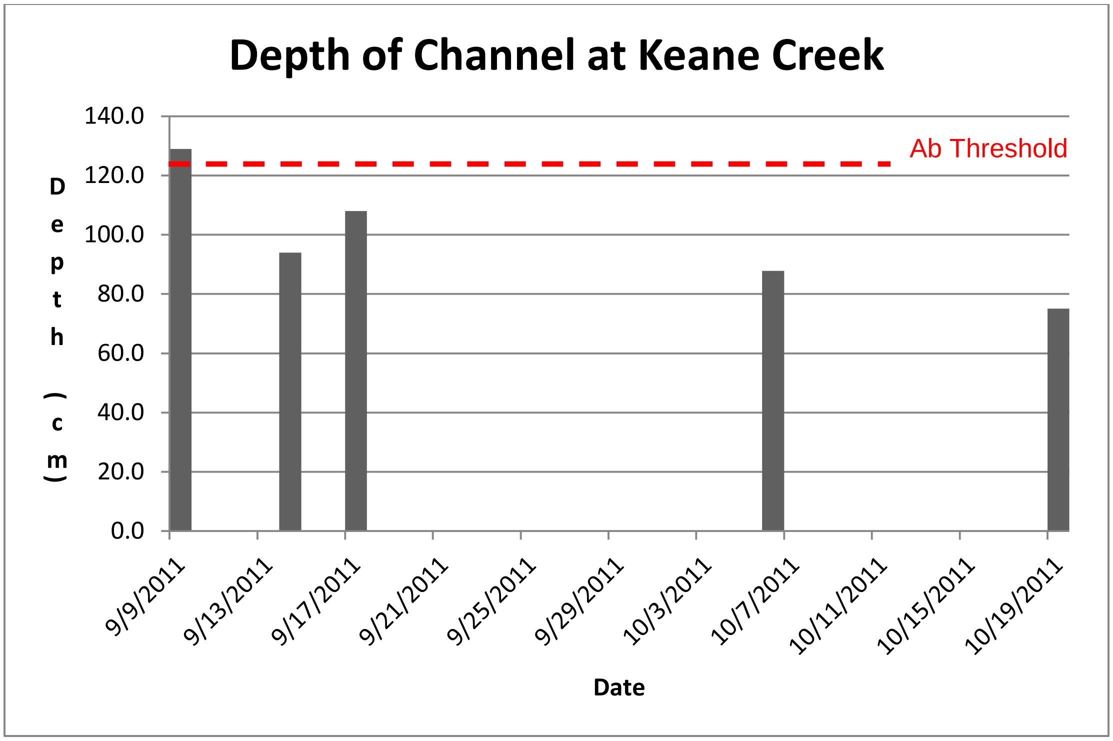

Figure 4. Deepest Recorded Water Depth at Keane Creek (red line is Aboriginal base flow).

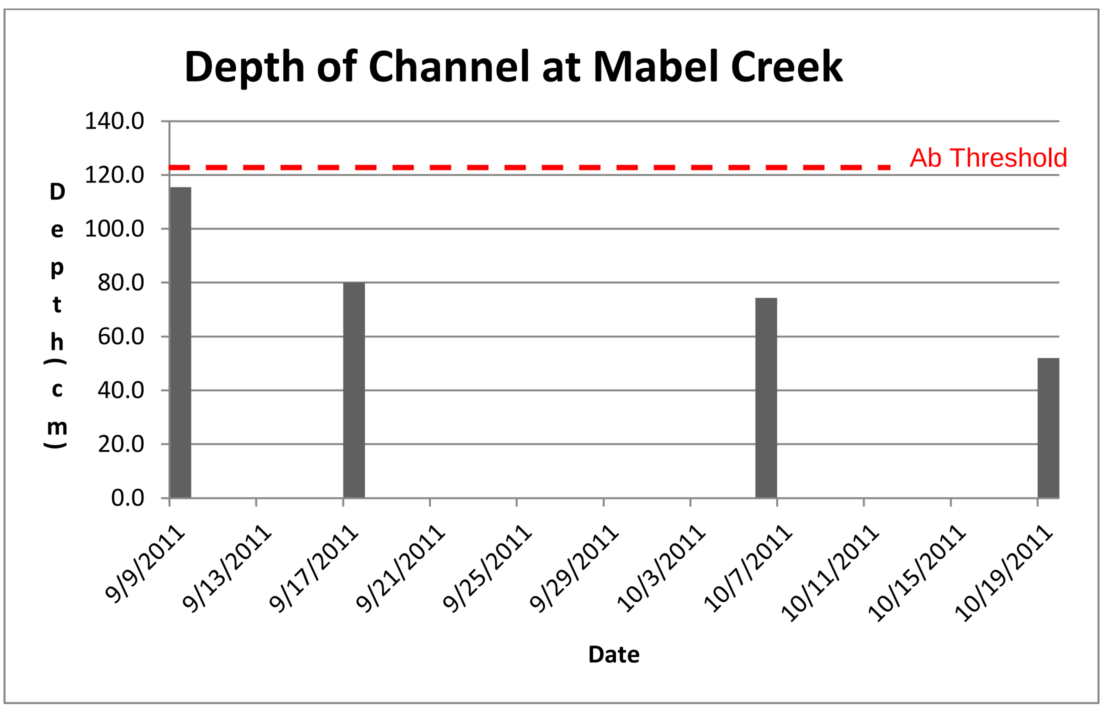

Figure 5. Deepest Recorded Water Depth at Mabel Creek (red line is Aboriginal base flow).

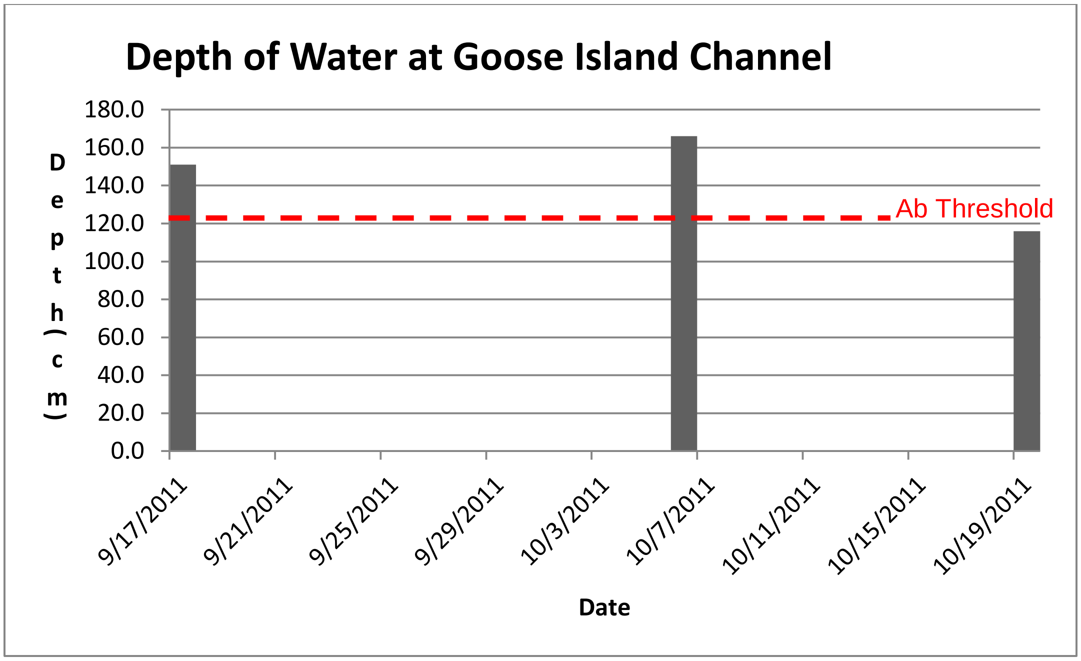

Figure 6. Deepest Recorded Water Depth at Goose Island Channel (red line is Aboriginal base flow).

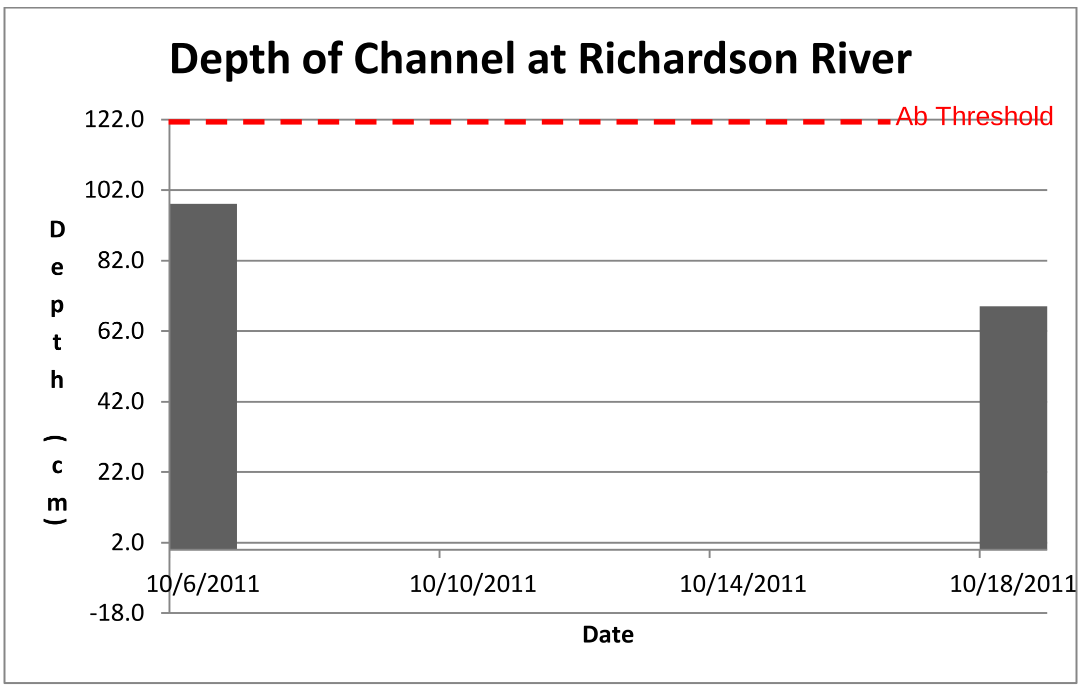

Figure 7. Deepest Recorded Water Depth at Richardson River (red line is Aboriginal base flow).

Although sampling was infrequent at some sites, it was clear that water levels were well below the four foot level (base Aboriginal flow) at six sites (Figure 8) with 3 sites being below this threshold continuously (Table 1).

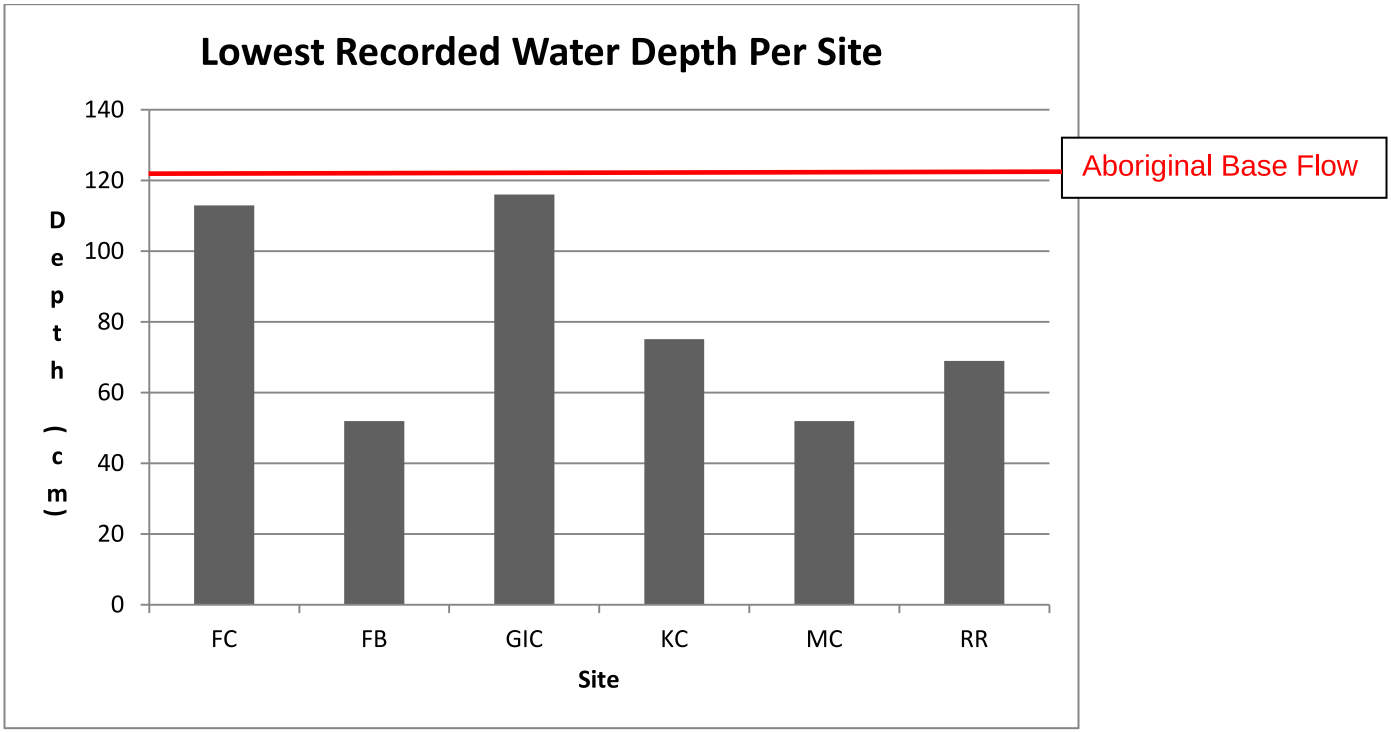

Figure 8. Lowest Recorded Water Depth at six sites (red line is Aboriginal base flow).

Table 1. Maximum recorded water depths per site and date.

Date	Aboriginal Threshold (cm)	Depth in cm per location							
		FR	FC	FB	GIC	KC	MC	PP	RR
9/8/2011	122.0	179.0	-	-	-	-	-	500.0	-
9/9/2011	122.0	-	-	106.5	-	129.0	115.5	-	-
9/14/2011	122.0	-		-	-	94.0	-	-	-
9/17/2011	122.0	-	130.0	96.0	151.0	108.0	80.0	-	-
10/5/2011	122.0	-	114.0	-	-	-	-	-	-
10/6/2011	122.0	-	-	54.2	166.0	87.8	74.4	-	98.1
10/18/2011	122.0	-	113.0	-	-	-	-	181.1	69.0
10/19/2011	122.0	-	-	52.0	116.0	75.1	52.0	-	-

(red) below threshold

FR	Firebag River	GIC	Goose Island Channel	PP	Polar Point
FC	Fletcher Channel	KC	Keane Creek	RR	Richardson River
FB	Flower Bay	MC	Mabel Creek		

Preliminary Analysis of Health and Contaminant Status of Fish Collected from the Slave and Athabasca Rivers, 2011-2012

Paul D Jones

Associate Professor

School of Environment and Sustainability

University of Saskatchewan.

27 September 2012

Executive Summary

1. 1498 fish were collected from the Athabasca and Slave rivers during 2011-2012. Of these fish 286 were collected at or near Fort Chipewyan AB.

2. This study was designed to address concerns based on current observations and traditional knowledge that have identified changes over time in the health and quality of fish in the Athabasca/Slave river system. This study provides a brief snapshot in time of the condition of fish down the length of the river system. It cannot address the temporal changes observed based on traditional knowledge.

3. This report provides preliminary data concerning the health and contaminant status of all fish with particular reference to those from the Ft Chipewyan area. These data are preliminary as statistical analysis of the data set has not yet been completed.

4. Data on the incidence of lesions and other ``abnormalities`` in the collected fish is still being analyzed.

5. There is no statistical evidence, from the morphometric data, of consistent health impacts on a species, site or seasonal basis. While some differences were observed they were for only one species at one time point or location.

6. Concentrations of two metals, vanadium and thallium, appear to be greater in the Slave river than in the Athabasca river. Data for other metals is still being analyzed.

7. PAH concentrations in fish bile are not a direct measure of human health risk based on my understanding that little or no bile is consumed by humans. The flesh of the fish is concumed in much greater quantities and the relationship between bile and muscle concentrations of PAHs is not fully understood. Human health risk can only be estimated from PAH concentrations in tissue consumed by humans. These analyses are currently underway.

8. The concentrations of PAHs measured in fish bile decrease from the upper to the lower sampling sites on the river system. Larger 5 ring PAHs are only common in fish bile from sites in proximity to oilsands operations.

9. Concentrations of PAHs in fish bile from Ft Chipewyan are more similar to those in the Slave river than to those in the upper Athabasca sites.

10. In general this data supports the hypothesis that contaminants from oilsands operations are reaching the aquatic food webs of the Slave and Athabasca rivers. While this is the case there do not, at this time, appear to be any frank health effects on the fish exposed to these contaminants.

11. These conclusions may alter as additional statistical analysis is conducted and as data from additional tests on these fish becomes available.

Purpose

This report provides a **preliminary** analysis of results from a survey of fish collected from the Athabasca/Slave river system. These data and interpretations are considered draft on are provided to the First Nations of Fort Chipewyan in consideration of the collaboration we received from First Nations in the collection of the fish. I emphasize that this is a preliminary analysis and that the observations and conclusions indicated here may change as the dataset is finalized. Metal concentrations in fish muscle from the Spring collection are currently being determined. Data for the occurrence of lesions and other anomalies in fish are not reported as the dataset needs to be updated with information from the spring collection and all anomalies need to be re-verified from photographic records, this analysis is currently underway and should be complete by December 2012.

Collection

In 2011-2012 a team from the University of Saskatchewan collected fish from the Slave and Athabasca river systems. The aim of the study was to determine the health status of fish in the river system and to assess the potential for human health impacts from consumption of those fish. The focus of the collection was therefore on those species most frequently caught and consumed. These are the large body species; Jackfish (*Esox Lucius*), Whitefish (*Coreogonus clupeaformis),* Walleye (*Sander vitreus),* Goldeye (*Hiodon alosoides*), and the Loche Mariah or Burbot (*Lota lota*). Collections were carried over 4-6 week periods in the summer and fall of 2011 and in the spring of 2012. In total 1498 were collected and examined with assistance in collections from First Nations bands in five major locations; Ft McMurray AB, Ft. Mackay AB, Ft Chipewyan AB, Ft Smith NWT and Ft Resolution NWT. In the spring of 2012 three additional sites (Upstream of Ft McMurray AB, Peace Point AB and Fort Fitzgerald AB) were sampled.

Data for the summer and fall collections are presented here. Data for the spring collection is still being processed and tabulated. Data for burbot collected in the Slave river in the winter of 2011 are also not reported as sample numbers for this species were limited in locations other than the Slave river.

Methods

Fish were collected from 5 sites along the Athabasca and Slave rivers in the summer and fall of 2011 in cooperation with First Nations fishers, and regional and federal agencies. A total of 1498 fish of 5 species were collected. Each fish was subjected to detailed external and internal health examinations. Blood plasma and bile were collected and tissues were preserved for enzyme analyses, contaminant measurements, and for future nucleic acid analysis. Aging structures were also collected and preserved. Analysis of metals was conducted by ICP-MS using standard laboratory protocols. Briefly, samples were prepared as follows: approximately 0.1 g of dry, ground tissue was added to a 15 ml Teflon vial. Samples were digested in concentrated nitric acid (69%) and hydrogen peroxide (30%) and evaporated to dryness (approximately 70^{o}C). Once dry, 5 ml of 2% HNO_3 was added to the digested sample which was then filtered (0.45 micrometers nominal pore size) and transferred to an 8-ml HDPE bottle for storage.

Bile total PAH concentrations were estimate using synchronous fluorescence spectroscopy (SFS) in a Thermo Scientific Lumina spectrofluorometer. A 1000-fold dilution of each sample was prepared with

50% methanol. The solution was centrifuged for 15 min to remove particulates. Samples were analyzed by Synchronous Fluorescence Scanning (SFS) with a wavelength differential of 42nm for PAHs.

Statistical Analysis

To ensure the comparability of the statistical methods used with current Canadian Environmental Effects Monitoring (EEM) methods the full data analysis has been contracted to Prof. Kelly Munkittrick of the University of New Brunswick. Prof. Munkittrick's laboratory developed many of the methods currently used in Canadian EEM programmes and are experts in the data evaluation of such projects. As an example of the data analysis provided Table 1 of this report provides the statistical analysis of the health assessment data. The statistical analysis of such a large and complicated dataset requires an intense analysis which produces large amounts of output (see Appendix 2 as an example). In this report I will try to summarize this output.

Funding

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Results

A summary of all fish collected in Fort Chipewyan by species and season is provided (Table 1).

Table 1 Summary of fish collected in Fort Chipewyan AB, by species and season 2011-2012. Species are: JF = Jackfish (*Esox Lucius*), WF = Whitefish (*Coreogonus clupeaformis),* WE = Walleye (*Sander vitreus),* GE = Goldeye (*Hiodon alosoides*), and BB = Burbot (*Lota lota*).

Species	Season	Total	Female	Male	Juvenile/Resting
BB	Fall	3	1	2	0
GE	Fall	15	13	2	0
JF	Fall	14	13	1	0
WE	Fall	5	4	1	0
WF	Fall	23	12	11	0
GE	Spring	30	28	2	0
JF	Spring	29	18	11	0
WE	Spring	31	18	13	0
WF	Spring	30	14	16	0
BB	Spring	0	0	0	0
BB	Summer	2	1	1	0
GE	Summer	29	23	5	1
JF	Summer	14	7	6	1
WE	Summer	30	15	14	1
WF	Summer	31	15	16	0

Fish Health Measures

The health of a fish can be measured in a variety of ways. While external lesions and sores may be useful these indicators tend to be relatively rare and so very large numbers of fish are required to obtain a sound understanding of the rates of occurrence. More general measures of health include length, weight and the relative weights of key internal organs such as the liver and spleen. These measurements are called morphometrics. These morphometric measurements are more readily obtained on a population basis and provide information on the health and nutritional state of the fish.

The statistical analysis of the morphometric fish health data is provided in Appendix 2. In general the analysis did not point to any major differences in the health status of fish at Ft Chipewyan compared to any of the other sites. Ft Chipewyan is the mid-point of the sampling down the length of the river system. Since some of the indicators show steady trends down the river system we find that for some measures Ft Chipewyan is more similar to the upstream sites while for others it is more similar to the downstream locations. There are also no morphometric differences that are consistent across different species and seasons. For example while the analysis indicates a slight decrease in the Liver somatic index of both male and female Jackfish in the summer, this difference is not shown by other species nor is it shown by jackfish during other seasons.

It should be remembered that Ft Chipewyan and Ft Resolution are slightly different from the other locations since fish were collected from both lakes and river in the respective areas. All fish from the other locations were collected only from the rivers in question.

Data for the occurrence of external lesions or abnormalities on the fish is still being compiled and analyzed statistically. The nature of this kind of data makes the statistical analysis more complicated.

Metals in Fish Muscle

A variety of metals were analyzed in fish muscle samples. Full statistical analysis of all metal data is still being carried out. Of interest among this data were increases in the concentrations of vanadium (V) and thallium (Tl) in some species collected in the Slave river (Figure 1). Thallium and vanadium are of interest as they are commonly observed in environments impacted by petroleum based activities. It is unclear why these metals do not increase in the river system until the Slave river sites are reached. Possible explanations would be local sources of these metals in the Slave river system, contributions from the Peace river or alterations in metal availability in the lower Slave river. Additional sampling sites at Peace Point and Fort Fitzgerald were sampled in 2012 to investigate this phenomenon further.

Samples from Ft Chipewyan show metal concentrations more similar to the upstream sites than to those on the Slave river, that is, samples from Ft Chipewyan appear to have lower levels of vanadium and thalium

PAHs in Fish Bile

Fish bile was analyzed as an indicator of recent exposure of fish to polycyclic aromatic hydrocarbons (PAHs). These compounds have many natural and industrial sources but are particularly prevalent in petroleum products and are often emitted from petroleum product mining and refining operations. Once taken up by the fish these compounds are metabolized and eliminated in the bile. This efficient metabolic elimination means that while PAHs may be present in the bile they are not necessarily present in the flesh or other tissues consumed by humans. Therefore, while bile analysis indicates the degree to which fish have been exposed it is not an indicator of human health risks. Human health risks can only be addressed by PAH analysis of the muscle and tissues consumed by humans. These analyses are currently underway.

Bile PAH analysis indicates that fish in the upper Athabasca sites (Ft McMurray and Ft Mackay) are exposed to greater concentrations of PAHs than fish from the lower Athabasca and Slave river sites (Figure 2). PAHs can be broken into several groups depending on the structure of the chemical which is made up of a series of carbon rings. PAHs with 2-3 rings are most common in the environment and are produced by a variety of natural as well as human activities. Most notably these 2-3 ring PAHs are produced in combustion processes such as forest fires, automobile engines, grilling food and indeed an uncontrolled burning process. In contrast PAHs with a larger number of rings are often used as markers of contamination with petroleum based products. In the Athabasca/Slave systems this can be from natural bitumen seeps as well as from oilsands operations.

Fish show a generally decreasing trend in PAH exposure going down the river system (Figure 2). For 2-3 ring PAHs this is indicative of the general decrease in human population density and activities moving down the river system. The drop off is most dramatic for the larger 5 ring PAHs which are present mainly in the upper Athabasca river sites. I feel this data supports my opinion that the greater concentrations of larger PAHs are related to oilsands operations in the vicinity of the sampling sites. The lower concentrations of 5 ring PAHs in the Slave river despite the presence of natural bitumen seeps on the river banks would suggest that fish are not exposed to significant levels of these larger PAHs from natural sources. Further sampling and analysis would be required to confirm these hypotheses.

Further statistical analysis of this PAH data is currently underway.

Conclusions

At this point in the data analysis I am comfortable in saying that fish from the Athabasca and Slave rivers are exposed to contaminants associated with bitumen. The relative levels of some contaminants decrease with distance from the main oilsands operations. This would suggest that at least some portion of the contaminant load is due to those oilsands operations. Increases in petroleum associated metals in the Slave river are unusual in that the rise in concentrations is not observed until the Fort Smith sampling site is reached. Additional sampling was undertaken in the spring of 2012 to assess these increases further. Metal analyses are currently underway.

The morphometric health indicators assessed to date do not appear to indicate any large impacts of contaminants on fish health. This suggests that at this time and under the current loading conditions fish are able to cope with the contaminant loads. Data for lesion and abnormality incidence rates are being statistically analyzed now.

It needs to be remembered that this study is only one snapshot in time and that development of the oilsands is expanding dramatically. Future monitoring should continue to examine these markers of fish health in the face of increasing loads from oilsands operations.

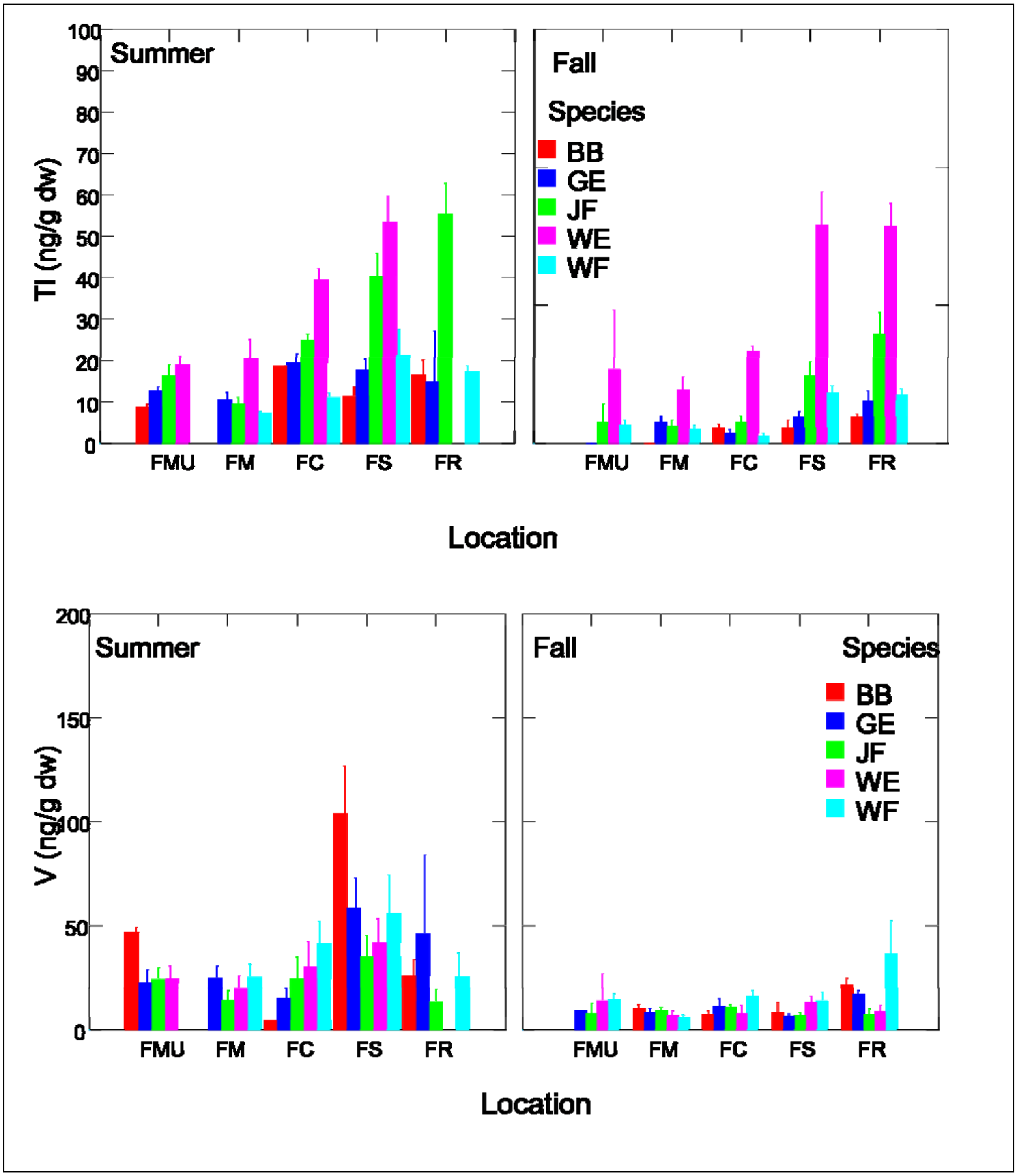

Figure 1 Concentrations of Thallium and Vanadium in fish muscle from the Athabasca/Slave river system 2011-2012. Species are: JF = Jackfish (*Esox Lucius*), WF = Whitefish (*Coreogonus clupeaformis),* WE = Walleye (*Sander vitreus),* GE = Goldeye (*Hiodon alosoides*), and BB = Burbot (*Lota lota*). Sites are FMU = Fort McMurray, FM = Fort Mackay, FC = Fort Chipewyan, FS = Fort Smith, FR = Fort Resolution. Bars represent mean ± s.e.

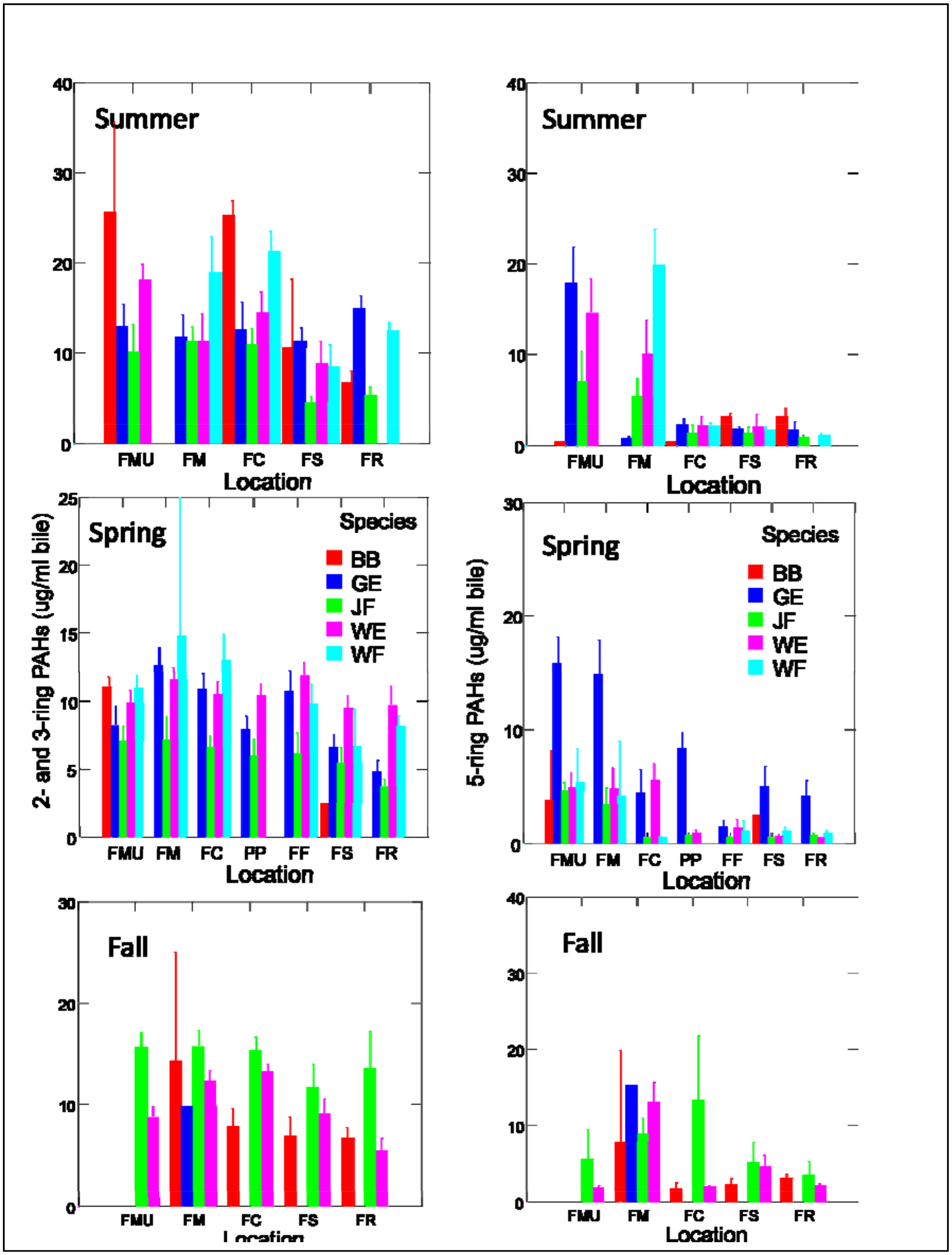

Figure 2 Concentrations of 2+3- and 5 ring PAHs in fish collected from the Slave and Athabasca rivers in 2011-2012 (see text for details). Species are: JF = Jackfish (*Esox Lucius*), WF = Whitefish (*Coreogonus clupeaformis),* WE = Walleye (*Sander vitreus),* GE = Goldeye (*Hiodon alosoides*), and BB = Burbot (*Lota lota*). Sites are FMU = Fort McMurray, FM = Fort Mackay, FC = Fort Chipewyan, FS = Fort Smith, FR = Fort Resolution. Bars, mean ± s.e.

Appendix 1.

Summary of fish samples collected

Summary of fish collected in 2011-2012. Species are JF = Jackfish (*Esox Lucius*), WF = Whitefish (*Coreogonus clupeaformis),* WE = Walleye (*Sander vitreus),* GE = Goldeye (*Hiodon alosoides*), and BB = Burbot (*Lota lota*). Sampling locations were: FMU = Fort McMurray, FM = Fort Mackay, PP = Peace Point, FC = Fort Chipewyan, FF = Fort Fitzgerald, FS = Fort Smith, and FR = Fort Resolution and US = Upstream of Fort McMurray.

Species	Location	Season	Total	Females	Males	Juvenile/Resting
BB	FC	Fall	3	1	2	0
GE	FC	Fall	15	13	2	0
JF	FC	Fall	14	13	1	0
WE	FC	Fall	5	4	1	0
WF	FC	Fall	23	12	11	0
BB	FM	Fall	2	1	1	0
GE	FM	Fall	30	16	14	0
JF	FM	Fall	9	6	3	0
WE	FM	Fall	15	6	9	0
WF	FM	Fall	31	20	11	0
GE	FMU	Fall	1	1	0	0
JF	FMU	Fall	3	3	0	0
WE	FMU	Fall	3	2	0	1
WF	FMU	Fall	29	23	6	0
BB	FMU	Fall	0	0	0	0
BB	FR	Fall	11	8	3	0
GE	FR	Fall	20	20	0	0
JF	FR	Fall	22	15	6	1
WE	FR	Fall	10	1	9	0
WF	FR	Fall	25	10	15	0
BB	FS	Fall	3	1	2	0
GE	FS	Fall	27	21	6	0
JF	FS	Fall	24	23	1	0
WE	FS	Fall	24	10	14	0
WF	FS	Fall	30	11	19	0
GE	FC	Spring	30	28	2	0
JF	FC	Spring	29	18	11	0
WE	FC	Spring	31	18	13	0
WF	FC	Spring	30	14	16	0
BB	FC	Spring	0	0	0	0
GE	FF	Spring	21	2	2	17
JF	FF	Spring	29	21	8	0
WE	FF	Spring	30	24	5	1
WF	FF	Spring	8	5	3	0
BB	FF	Spring	0	0	0	0
GE	FM	Spring	30	20	2	8

Species	Location	Season	Total	Females	Males	Juvenile/Resting
JF	FM	Spring	5	5	0	0
WE	FM	Spring	31	14	14	3
WF	FM	Spring	2	2	0	0
BB	FM	Spring	0	0	0	0
BB	FMU	Spring	3	0	1	2
GE	FMU	Spring	30	23	3	4
JF	FMU	Spring	19	17	2	0
WE	FMU	Spring	29	24	4	1
WF	FMU	Spring	4	2	2	0
BB	FR	Spring	6	3	3	0
GE	FR	Spring	26	21	3	2
JF	FR	Spring	31	25	6	0
WE	FR	Spring	14	11	3	0
WF	FR	Spring	22	13	9	0
BB	FS	Spring	1	0	1	0
GE	FS	Spring	31	24	5	2
JF	FS	Spring	18	17	1	0
WE	FS	Spring	31	23	7	1
WF	FS	Spring	5	2	3	0
GE	PP	Spring	29	25	2	2
JF	PP	Spring	15	11	4	0
WE	PP	Spring	31	23	5	3
WF	PP	Spring	0	0	0	0
BB	PP	Spring	0	0	0	0
GE	US	Spring	13	9	2	2
WE	US	Spring	0	0	0	0
WF	US	Spring	0	0	0	0
JF	US	Spring	0	0	0	0
BB	US	Spring	0	0	0	0
BB	FC	Summer	2	1	1	0
GE	FC	Summer	29	23	5	1
JF	FC	Summer	14	7	6	1
WE	FC	Summer	30	15	14	1
WF	FC	Summer	31	15	16	0
GE	FM	Summer	29	24	5	0
JF	FM	Summer	15	4	11	0
WE	FM	Summer	20	2	13	5
WF	FM	Summer	30	22	8	0
BB	FM	Summer	0	0	0	0
BB	FMU	Summer	3	2	1	0
GE	FMU	Summer	31	22	8	1
JF	FMU	Summer	17	3	11	3

Species	Location	Season	Total	Females	Males	Juvenile/Resting
WE	FMU	Summer	26	13	12	1
WF	FMU	Summer	0	0	0	0
BB	FR	Summer	17	15	2	0
GE	FR	Summer	2	2	0	0
JF	FR	Summer	30	8	22	0
WF	FR	Summer	27	16	11	0
WE	FR	Summer	0	0	0	0
BB	FS	Summer	3	1	0	2
GE	FS	Summer	30	17	5	8
JF	FS	Summer	28	21	6	1
WE	FS	Summer	29	6	10	13
WF	FS	Summer	7	2	5	0
BB	FR	Winter	34	33	1	0
BB	FS	Winter	1	1	0	0

Appendix 2

Statistical summary of Morphometric Fish Health Indicators

Mean weight, length, condition factor (K), liversomatic index (LSI), gonadosomatic (GSI), spleen somatic index (SSI), and proportion immature/resting for species collected during the mid-spawning reproductive phase. Species include GE = goldeye (*Hiodon alosoides*), JF = Northern pike (jackfish) (*Esox lucius*), WE = walleye (*Sander vitreus*) and WF = whitefish (*Coregonus clupeaformis*). Summary statistics (means, SE = standard error of the mean; n = sample size) and analyses separated by sex (M = male; F = female) and season (FA = fall, SU = summer; SP = spring). Summary statistics and analysis for GSI is separated for females by developing females and spent females. The proportion of immature, resting, or spent females (Prop I/R/S) and total sample size are listed for data sets that contained such females. The number of immature, resting, or spent females was compared to the number of developing females using a Chi-square test of independence. Sig? = Y means chi-square statistic was significant at α = 0.05 or that the magnitude of the differences in the proportions is large (Chi-square test not performed for all comparisons due to low sample sizes).

Species	Sex	Season	Site	Mean Weight(g) ±SE (n) *	Mean Length(cm) ±SE (n) *	Mean K±SE (n)	Mean LSI±SE (n) *	Mean GSI±SE (n) * (developing only)	Mean SSI±SE (n) *	Prop I/R/S (n)	Sig?
GE	F	SP	FMU	540±29 (23) B	33.5±0.7 (23) B	1.42±0.03 (23) A	1.20±0.04 (23) AB	(0)	0.055±0.007 (23) ABC	0.52 (23)	Y
			FM	379±42 (20) C	29.9±1.4 (20) C	1.33±0.04 (20) BC	1.37±0.05 (20) A	(0)	0.099±0.037 (20) C	0.45 (20)	
			FC	534±18 (28) B	36.4±0.5 (28) A	1.11±0.03 (28) C	1.43±0.09 (28) A	(0)	0.074±0.007 (28) AB	0.07 (28)	
			FS	568±18 (24) AB	36.6±0.5 (24) A	1.18±0.02 (23) BC	1.20±0.09 (24) A	11.68±0.59 (18) A	0.066±0.015 (24) ABC	0.25 (24)	
			FF	518±288 (2)	35.1±7.6 (2)	1.07±0.04 (2)	1.81±0.09 (2)	7.30 (1)	0.077±0.030 (2)	0.50 (2)	
			FR	619±34 (21) AB	37.0±0.7 (21) A	1.19±0.03 (21) B	1.28±0.04 (21) A	11.01±0.54 (15) A	0.076±0.008 (21) A	0.29 (21)	
			PP	671±21 (25) A	38.9±0.4 (25) A	1.14±0.02 (25) BC	1.04±0.06 (25) B	12.37±0.51 (24) A	0.038±0.004 (25) BC	0.04 (25)	
			US	664±29 (9) AB	36.0±0.8 (9) AB	1.44±0.09 (9)	1.01±0.09 (9)	12.77±2.16 (4)	0.121±0.065 (9)	0.56 (9)	
GE	M	SP	FMU	527±35 (3)	34.5±0.6 (3)	1.28±0.02 (3)	1.17±0.22 (3)	0.25±0.04 (3)	0.145±0.059 (3)		
			FM	360±170 (2)	30.5±6.4 (2)	1.21±0.15 (2)	1.25±0.03 (2)	0.18±0.10 (2)	0.336±0.164 (2)		
			FC	525±95 (2)	34.6±1.0 (2)	1.25±0.13 (2)	1.18±0.08 (2)	0.26±0.02 (2)	0.101±0.019 (2)		
			FS	338±31 (5)	31.6±1.0 (5)	1.06±0.02 (5)	1.22±0.09 (5)	0.71±0.02 (5)	0.075±0.032 (5)		
			FF	681±601 (2)	33.4±11.8 (2)	1.09±0.30 (2)	1.65±0.43 (2)	0.74±0.53 (2)	0.126±0.015 (2)		
			FR	460±72 (3)	33.4±1.9 (3)	1.23±0.14 (3)	1.03±0.13 (3)	0.70±0.11 (3)	0.070±0.018 (3)		
			PP	548±21 (2)	36.9±0.9 (2)	1.09±0.04 (2)	0.87±0.05 (2)	0.40±0.06 (2)	0.094±0.018 (2)		
			US	595±15 (2)	36.8±1.3 (2)	1.20±0.15 (2)	0.76±0.09 (2)	0.29±0.01 (2)	0.083±0.023 (2)		
JF	F	SP	FMU	3050±309 (17) ABC	70.5±2.8 (17) ABC	0.82±0.03 (16) A	1.67±0.12 (17) A	5.91±1.06 (8)	0.103±0.010 (17) A	0.53 (17)	
			FM	2460±637 (5)	66.9±7.3 (5)	0.79±0.07 (5)	1.38±0.20 (5)	3.71±0.57 (2)	0.084±0.008 (5)	0.60 (5)	
			FC	1994±224 (18) C	65.4±2.1 (18) C	0.68±0.02 (18) D	1.44±0.10 (18) A	6.42±0.20 (3)	0.147±0.012 (18) A	0.83 (18)	
			FS	3572±321 (17) AB	76.0±2.4 (17) AB	0.76±0.01 (16) ABC	1.66±0.18 (17) A	10.89±0.88 (16) A	0.128±0.010 (17) A	0.06 (17)	
			FF	4294±505 (21) A	79.9±3.2 (21) A	0.77±0.02 (21) AB	1.73±0.14 (21) A	6.07±1.19 (3)	0.151±0.016 (21) A	0.86 (21)	
			FR	2299±142 (24) BC	68.6±1.5 (24) BC	0.70±0.02 (24) CD	1.34±0.12 (23) A	11.07±1.40 (11) A	0.124±0.011 (24) A	0.54 (24)	
			PP	2520±451 (11) BC	69.3±3.7 (11) ABC	0.70±0.03 (11) BCD	1.15±0.15 (11) A	10.61±0.75 (5)	0.143±0.021 (11) A	0.55 (11)	
JF	M	SP	FMU	1895±15 (2)	55.9±2.5 (2)	1.10±0.14 (2)	1.97±0.38 (2)	0.17±0.04 (2)	0.062±0.011 (2)		
			FC	1561±106 (11)	61.4±1.4 (11)	0.67±0.02 (11) A	1.14±0.11 (11) A	0.46±0.09 (11)	0.214±0.019 (11) A		
			FF	2695±225 (8)	70.6±1.8 (8)	0.76±0.04 (8) A	1.36±0.17 (8) A	0.52±0.14 (8)	0.191±0.030 (8) A		
			FR	2411±248 (6)	69.4±2.6 (6)	0.71±0.02 (6) A	1.22±0.20 (6) A	0.61±0.24 (6)	0.165±0.015 (6) A		
			PP	1190±193 (4)	54.8±2.4 (4)	0.72±0.09 (4)	1.04±0.22 (4)	0.50±0.02 (4)	0.108±0.026 (4)		

Species	Sex	Season	Site	Mean Weight(g) ±SE (n) *	Mean Length(cm) ±SE (n) *	Mean K±SE (n)	Mean LSI±SE (n) *	Mean GSI±SE (n) * (developing only)	Mean SSI±SE (n) *	Prop I/R/S (n)	Sig?
WE	F	SP	FMU	1491±152 (24) BC	46.0±1.4 (24) C	1.43±0.03 (24) A	1.09±0.08 (24) D	(0)	0.217±0.017 (24) B	1.00 (23)	Y
			FM	1126±83 (14) C	44.1±1.2 (14) C	1.28±0.03 (14) B	1.09±0.06 (14) D	(0)	0.378±0.041 (13) A	1.00 (13)	
			FC	1534±102 (18) ABC	53.1±1.3 (18) AB	1.00±0.02 (18) E	1.28±0.06 (18) BCD	(0)	0.327±0.024 (18) A	1.00 (18)	
			FS	2067±66 (23) A	55.9±0.6 (23) A	1.18±0.02 (23) BCD	1.69±0.08 (23) ABC	14.53±0.51 (21)	0.230±0.014 (21) B	0.09 (23)	
			FF	2100±176 (24) AB	56.8±1.3 (24) A	1.10±0.02 (24) CDE	1.73±0.12 (24) A	15.92 (1)	0.247±0.02 (24) B	0.96 (23)	
			FR	1448±126 (11) ABC	48.6±1.7 (11) BC	1.26±0.08 (11) BC	1.65±0.14 (11) AB	(0)	0.360±0.030 (11) A	1.00 (10)	
			PP	1672±178 (23) ABC	52.2±1.6 (23) AB	1.09±0.02 (23) DE	1.29±0.07 (23) CD	(0)	0.214±0.014 (23) B	1.00 (23)	
WE	M	SP	FMU	1205±112 (4)	45.2±1.1 (4)	1.29±0.07 (4)	1.19±0.12 (4)	0.30±0.09 (4)	0.179±0.040 (4)		
			FM	1194±78 (14) A	46.1±1.3 (14) A	1.21±0.05 (14) A	1.02±0.09 (14) B	0.38±0.03 (14) B	0.404±0.034 (13) X		
			FC	1288±107 (13) A	48.8±1.6 (13) A	1.09±0.03 (13) A	1.45±0.08 (13) A	0.61±0.10 (13) A	0.312±0.017 (13) X		
			FS	913±133 (7)	43.8±2.0 (7)	1.04±0.02 (7)	1.47±0.25 (7)	1.66±0.39 (7)	0.158±0.018 (7)		
			FF	1607±183 (5)	52.8±1.8 (5)	1.08±0.03 (5)	1.64±0.28 (5)	0.56±0.07 (5)	0.413±0.067 (5)		
			FR	1020±160 (2)	41.9±3.8 (2)	1.40±0.16 (2)	1.63±0.32 (2)	1.04±0.73 (2)	0.207±0.008 (2)		
			PP	1034±94 (5)	47.2±1.6 (5)	0.97±0.02 (5)	1.16±0.10 (5)	0.62±0.16 (5)	0.449±0.210 (5)		
WF	F	FA	FMU	1039±40 (24) A	41.4±0.4 (24) AB	1.45±0.04 (24) C	0.89±0.04 (24) BC	10.82±3.55 (4) A	0.088±0.009 (24) A	0.83 (24)	Y
			FM	1109±39 (18) A	40.5±0.4 (18) B	1.67±0.05 (18) AB	0.82±0.04 (18) BC	11.2±1.11 (16) A	0.078±0.019 (18) A	0.11 (18)	
			FC	1144±61 (12) A	39.7±0.6 (12) B	1.82±0.06 (12) A	1.50±0.08 (12) A	12.63±1.47 (6) A	0.182±0.065 (12) A	0.50 (12)	
			FS	1053±86 (11) A	41.0±0.8 (11) AB	1.50±0.05 (11) BC	1.02±0.06 (11) B	12.37±0.85(11) A	0.085±0.012 (11) A	0.00 (11)	
			FR	1258±95 (10) A	43.4±0.8 (10) A	1.52±0.07 (10) BC	1.02±0.06 (10) BC	(0)	0.112±0.017 (10) A	1.00 (10)	
WF	M	FA	FMU	980±120 (6) B	41.3±1.9 (6) AB	1.37±0.05 (6) B	0.74±0.05 (6) B	0.86±0.15 (6) A	0.159±0.021 (6) AB		
			FM	1004±56 (10) B	40.0±0.8 (10) B	1.56±0.04 (10) AB	0.77±0.04 (10) AB	1.14±0.21 (10) A	0.084±0.025 (10) C		
			FC	895±46 (11) B	37.6±0.8 (11) B	1.60±0.03 (10) A	1.24±0.12 (10) A	0.91±0.16 (11) A	0.090±0.011 (11) BC		
			FS	936±33 (19) B	40.2±0.4 (19) B	1.43±0.03 (19) B	0.60±0.04 (19) B	1.21±0.11 (19) A	0.175±0.022 (19) A		
			FR	1280±83 (17) A	44.0±0.8 (14) A	1.48±0.04 (14) AB	0.72±0.03 (14) AB	1.06±0.09 (14) A	0.162±0.015 (14) A		

* Sites sharing a capital letter (A,B,C), within an endpoint and within a sex/season grouping are not significantly different (ANOVA for length and weight; ANCOVA for other analyses) at $\alpha = 0.05$ (Tukey family-wise error rate for multiple comparisons). X = significant interaction ($p = 0.05$).

Mean weight, length, condition factor (K), liversomatic index (LSI), gonadosomatic (GSI), spleen somatic index (SSI), and proportion immature/resting for species collected during the early developing reproductive phase. Species include GE = goldeye (*Hiodon alosoides*), Northern pike (jackfish) (*Esox lucius*), WE = walleye (*Sander vitreus*) and WF = whitefish (*Coreogonus clupeaformis*). Summary statistics (means, SE = standard error of the mean; n = sample size) and analyses separated by sex (M = male; F = female) and season (FA = fall, SU = summer; SP = spring). Summary statistics and analysis for GSI for females is based on developing females only (immature and resting females were removed). The proportion of immature and resting females (Prop Im/Res) and total sample size are listed for data sets that contained immature and resting females. The number of immature and resting females was compared to the number of developing females using a Chi-square test of independence. Sig? = Y means chi-square statistic was significant at α = 0.05 or that the magnitude of the differences in the proportions is large (Chi-square test not performed for all comparisons due to low sample sizes).

Species	Sex	Season	Site	Mean Weight(g) ±SE (n) *	Mean Length(cm) ±SE (n) *	Mean K±SE (n)	Mean LSI±SE (n) *	Mean GSI±SE (n) * (developing only)	Mean SSI±SE (n) *	Prop Im/Res (n)	Sig?
GE	F	FA	FM	651±34 (16) A	37.7±0.6 (16) A	1.20±0.02 (16) AB	1.14±0.01 (16) B	10.39±0.89 (14) A	0.035±0.005 (16) A	0.13 (16)	Y
			FC	633±24 (13) AB	37.3±0.6 (13) AB	1.22±0.02 (13) A	1.34±0.10 (11) A	9.80±0.04 (12) A	0.028±0.004 (13) A	0.08 (13)	
			FS	568±13 (20) BC	35.5±0.4 (20) C	1.27±0.03 (20) X	1.17±0.04 (20) B	8.23±0.38 (16) A	0.039±0.005 (16) A	0.20 (20)	
			FR	547±12 (19) C	36.1±0.2 (19) BC	1.17±0.02 (20) B	1.33±0.04 (20) AB	7.44±0.37 (11) A	0.028±0.003 (18) A	0.45 (20)	
GE	M	FA	FM	540±13 (14) A	36.0±0.4 (14) A	1.16±0.02 (14) A	1.28±0.05 (14) A	0.46±0.03 (14) A	0.051±0.008 (14) A		
			FS	459±40 (6) B	33.3±0.9 (6) B	1.22±0.05 (6) A	1.13±0.03 (6) B	0.34±0.06 (6) B	0.066±0.020 (6) A		
JF	F	FA	FMU	3287±840 (3)	71.5±7.8 (3)	0.87±0.11 (3)	1.91±0.22 (3)	3.95±0.87 (3)	0.093±0.011 (3)		
			FM	3030±616 (6) AB	66.7±5.0 (4)	0.70±0.05 (4)	1.92±0.18 (5)	2.80±0.25 (6)	0.101±0.013 (6)		
			FC	4295±376 (13) A	74.6±1.9 (10) A	0.91±0.08 (9)	1.70±0.11 (12) A	2.33±0.22 (13) A	0.110±0.009 (13) X		
			FS	2701±287 (22) B	66.8±1.7 (18) B	0.71±0.03 (18) A	1.09±0.08 (21) B	1.40±0.21 (22) X	0.123±0.011 (21) A		
			FR	3060±507 (15) AB	69.0±2.7 (14) AB	0.76±0.04 (14) A	1.54±0.16 (15) A	2.33±0.20 (17) A	0.120±0.009 (15) A		
JF	M	FA	FM	1533±164 (3) A	58.0±2.2 (3) A	0.78±0.01 (3) A	1.98±0.11 (3) A	2.29±1.32 (3) A	0.098±0.006 (3) A		
			FR	2507±458 (6) A	67.2±2.7 (6) A	0.78±0.06 (6) A	1.14±0.09 (5) B	1.58±0.16 (6) A	0.156±0.012 (6) A		
WE	F	FA	FMU	1275±85 (2)	48.9±0.6 (2)	1.09±0.04 (2)	1.85±0.07 (2)	5.46±1.98 (2)	0.214±0.082 (2)		
			FM	1375±190 (6) A	48.7±2.0 (6) A	1.15±0.05 (6) A	1.90±0.13 (6) A	5.38±1.06 (6) A	0.196±0.042 (6) A		
			FC	1420±211 (4) A	50.8±1.8 (4) A	1.06±0.05 (4)	2.14±0.38 (4)	4.50±0.41 (4)	0.306±0.018 (4)		
			FS	1587±145 (10) A	51.1±1.7 (10) A	1.17±0.04 (10) A	2.05±0.18 (10) A	4.43±0.33 (10) B	0.279±0.030 (10) A		
WE	M	FA	FM	1093±89 (8) A	46.0±1.3 (8) A	1.11±0.02 (8) A	1.10±0.06 (8) B	1.78±0.23 (8) A	0.19±0.018 (8) B		
			FS	1080±41 (14) A	46.1±0.8 (14) A	1.10±0.03 (14) A	1.30±0.12 (14) B	2.35±0.09 (14) A	0.231±0.017 (14) B		
			FR	1176±161 (9) A	46.5±2.3 (9) A	1.11±0.06 (9) A	2.34±0.41 (9) A	2.00±0.42 (9) A	0.301±0.020 (8) A		
WF	F	SU	FM	1319±72 (22) A	42.9±0.8 (22) A	1.64±0.04 (22) A	1.06±0.05 (21) B	4.17±0.48 (13) A	0.198±0.022 (21) A	0.41 (22)	Y
			FC	1093±86 (15) A	40.2±0.9 (15) AB	1.64±0.05 (15) A	1.20±0.08 (15) A	2.20±0.27 (14) A	0.179±0.026 (15) A	0.07 (15)	
			FS	974±169 (2)	41.1±3.1 (3)	1.14±0.12 (2)	0.72±0.08 (2)	2.40±0.64 (2)	0.150±0.050 (2)	0.50 (4)	
			FR	814±47 (16) B	38.8±0.8 (16) B	1.38±0.03 (16) B	1.03±0.04 (16) A	1.75±0.28 (16) A	0.213±0.038 (16) A	0.00 (16)	
WF	M	SU	FM	1398±174 (8) A	44.4±1.8 (8) A	1.55±0.03 (8) A	0.85±0.07 (8) B	1.26±0.19 (8) A	0.142±0.030 (7) A		
			FC	1085±103 (16) AB	39.8±1.0 (16) B	1.66±0.04 (16) A	1.02±0.08 (16) A	0.44±0.06 (16) B	0.199±0.027 (16) A		
			FS	799±28 (5) B	40.9±1.3 (5) AB	1.19±0.10 (5)	0.82±0.14 (5)	0.15±0.02 (5)	0.243±0.028 (5)		
			FR	834±43 (11) B	39.7±0.7 (11) AB	1.33±0.03 (11) B	0.82±0.05 (11) AB	0.43±0.11 (11) B	0.305±0.078 (11) A		

* Sites sharing a capital letter (A,B,C), within an endpoint and within a sex/season grouping are not significantly different (ANOVA for length and weight; ANCOVA for other analyses) at α = 0.05 (Tukey family-wise error rate for multiple comparisons). X = significant interaction (p = 0.05).

Mean weight, length, condition factor (K), liversomatic index (LSI), gonadosomatic (GSI), spleen somatic index (SSI), and proportion immature/resting for species collected during the post spawning reproductive phase. Species include GE = goldeye (*Hiodon alosoides*), Northern pike (jackfish) (*Esox lucius*), WE = walleye (*Sander vitreus*) and WF = whitefish (*Coreogonus clupeaformis*). Summary statistics (means, SE = standard error of the mean; n = sample size) and analyses separated by sex (M = male; F = female) and season (FA = fall, SU = summer; SP = spring). Summary statistics and analysis for GSI for females is based on developing females only (immature and resting females were removed). The proportion of immature and resting females (Prop Im/Res) and total sample size are listed for data sets that contained immature and resting females. The number of immature and resting females was compared to the number of developing females using a Chi-square test of independence. Sig? = Y means chi-square statistic was significant at α = 0.05 or that the magnitude of the differences in the proportions is large (Chi-square test not performed for all comparisons due to low sample sizes).

Species	Sex	Season	Site	Mean Weight(g) ±SE (n) *	Mean Length(cm) ±SE (n) *	Mean K±SE (n)	Mean LSI±SE (n) *	Mean GSI±SE (n) * (developing only)	Mean SSI±SE (n) *	Prop Im/Res (n)	Sig?
GE	F	SU	FMU	564±27 (22) B	36.3±0.7 (22) A	1.16±0.02 (22) A	1.12±0.05 (22) B	4.23±0.29 (15) A	0.040±0.004 (22) B	0.32 (22)	Y
			FM	678±23 (24) A	38.1±0.4 (24) A	1.22±0.02 (24) A	1.41±0.05 (24) AB	5.30±0.31 (21) A	0.056±0.004 (23) A	0.13 (24)	
			FC	582±18 (21) B	36.9±0.4 (21) A	1.15±0.02 (21) A	1.27±0.05 (21) AB	2.46±0.17 (7) B	0.031±0.003 (21) BC	0.70 (23)	
			FS	358±30 (16) C	32.8±0.9 (16) B	0.98±0.02 (16) B	0.80±0.03 (16) C	7.28 (1)	0.048±0.010 (16) C	0.94 (17)	
GE	M	SU	FMU	555±23 (7) A	36.4±0.5 (7) A	1.14±0.04 (8) A	1.20±0.11 (8) A	0.20±0.03 (8) A	0.088±0.032 (8) A		
			FM	620±20 (5) A	37.1±0.6 (5) A	1.22±0.04 (5) A	1.39±0.11 (5) A	0.30±0.04 (5) A	0.092±0.024 (5) A		
			FC	506±42 (5) A	36.1±0.8 (5) A	1.07±0.04 (5) A	0.93±0.10 (5) AB	0.15±0.03 (5) A	0.058±0.004 (5) A		
			FS	228±29 (5) B	29.2±1.1 (5) B	0.89±0.03 (5) B	0.65±0.14 (4) B	0.26±0.11 (5) A	0.034±0.010 (5) B		
JF	F	SU	FMU	2859±913 (3) A	70.5±5.8 (3) A	0.75±0.10 (3)	1.26±0.27 (3)	(0)	0.126±0.033 (3)	1.00 (3)	Y
			FM	2275±657 (4) A	69.2±5.2 (4) A	0.65±0.08 (4)	1.64±0.32 (4)	(0)	0.153±0.036 (4)	1.00 (4)	
			FC	2426±444 (7) A	68.6±2.5 (6) A	0.61±0.01 (6) B	0.91±0.11 (7) B	(0)	0.111±0.012 (7) AB	1.00 (7)	
			FS	2082±176 (21) A	65.9±1.5 (21) A	0.70±0.02 (21) A	1.35±0.12 (21) A	8.64±1.14 (10)	0.110±0.011 (21) B	0.52 (21)	
			FR	2044±229 (8) A	66.7±2.2 (8) A	0.67±0.02 (8) AB	1.45±0.12 (8) A	6.73±0.74 (3)	0.161±0.023 (8) A	0.63 (8)	
JF	M	SU	FMU	1909±404 (11) A	63.6±6.3 (11) A	0.69±0.03 (10) AB	1.55±0.2 (11) A	0.27±0.10 (11) B	0.140±0.027 (9) A		
			FM	2508±509 (11) A	66.0±4.2 (11) A	0.77±0.03 (11) A	1.57±0.15 (11) A	0.33±0.10 (11) B	0.140±0.016 (11) A		
			FC	1557±118 (6) A	62.1±2.2 (6) A	0.65±0.04 (6) B	0.80±0.08 (6) B	0.20±0.03 (6) AB	0.125±0.042 (6) A		
			FS	2113±285 (6) A	67.3±2.7 (6) A	0.67±0.02 (6) AB	1.30±0.11 (6) A	0.44±0.09 (6) AB	0.142±0.017 (6) A		
			FR	2313±198 (22) A	67.3±1.7 (22) A	0.73±0.02 (22) AB	1.73±0.08 (22) A	0.57±0.07 (21) A	0.185±0.015 (22) A		
WE	F	SU	FMU	1350±93 (11) A	52.4±1.5 (11) A	0.94±0.06 (11) A	0.97±0.10 (11) A	0.86±0.10 (11) A	0.289±0.030 (11) B		
			FM	1293±76 (5) A	48.9±1.2 (5) A	1.10±0.03 (5)	1.18±0.13 (5)	0.85±0.07 (5)	0.412±0.085 (5)		
			FC	1254±81 (15) A	49.6±1.3 (15) A	1.01±0.02 (15) A	1.1±0.08 (15) A	0.60±0.08 (15) A	0.398±0.023 (15) A		
			FS	1088±129 (6) A	47.7±2.4 (6) A	0.98±0.04 (6)	1.21±0.17 (6)	0.74±0.09 (6)	0.313±0.054 (6)		
WE	M	SU	FMU	1102±82 (12) AB	17.8±1.1 (12) AB	1.00±0.06 (12) A	1.27±0.18 (12) A	0.46±0.09 (12) A	0.306±0.051 (12) A		
			FM	977±97 (13) B	45.1±1.4 (11) B	1.03±0.04 (13) A	1.08±0.07 (13) A	0.44±0.07 (13) A	0.291±0.041 (11) A		
			FC	1372±59 (14) A	51.0±0.8 (14) A	1.03±0.03 (14) A	1.19±0.11 (14) A	0.49±0.10 (13) A	0.444±0.031 (14) A		
			FS	1073±62 (10) AB	47.2±0.8 (10) AB	1.01±0.03 (10) A	1.03±0.11 (10) A	0.45±0.09 (8) A	0.359±0.055 (10) A		

Species	Sex	Season	Site	Mean Weight(g) ±SE (n) *	Mean Length(cm) ±SE (n) *	Mean K±SE (n)	Mean LSI±SE (n) *	Mean GSI±SE (n) * (developing only)	Mean SSI±SE (n) *	Prop Im/Res (n)	Sig?
WF	F	SP	FMU	1380±350 (2)	41.6±2.2 (2)	1.87±0.18 (2)	1.24±0.07 (2)	1.81±1.10 (2)	0.197±0.024 (2)		
			FC	1248±100 (14) A	42.5±1.1 (14) A	1.58±0.05 (14) X	1.38±0.07 (12)	1.10±0.13 (13)	0.232±0.036 (13) A		
			FS	940±40 (2)	39.7±0.3 (2)	1.50±0.03 (2)	0.96±0.04 (2)	1.60±0.84 (2)	0.104±0.047 (2)		
			FF	1293±301 (5)	43.5±3.7 (5)	1.49±0.08 (5)	1.12±0.25 (5)	0.78±0.29 (5)	0.235±0.070 (5)		
			FR	805±33 (13) B	39.4±1.0 (13) A	1.34±0.07 (13) X	1.06±0.06 (13)	1.13±0.12 (13)	0.299±0.096 (13) A		
WF	M	SP	FMU	1175±75 (2)	41.7±1.0 (2)	1.64±0.22 (2)	1.15±0.11 (2)	0.24±0.02 (2)	0.143±0.06 (2)		
			FM	1025±25 (2)	38.1±1.3 (2)	1.86±0.14 (2)	0.98±0.01 (2)	0.17±0.06 (2)	0.098±0.037 (2)		
			FC	1405±116 (16) A	44.3±1.2 (16) A	1.57±0.03 (16) A	1.17±0.11 (15) A	0.38±0.04 (16) A	0.309±0.057 (16) B		
			FS	1000±60 (3)	41.1±0.4 (3)	1.44±0.04 (3)	0.87±0.13 (3)	0.32±0.02 (3)	0.256±0.090 (3)		
			FF	2086±551 (3)	48.0±3.6 (3)	1.79±0.09 (3)	1.28±0.45 (3)	0.38±0.11 (3)	0.254±0.045 (3)		
			FR	838±66 (9) B	38.9±0.9 (9) B	1.40±0.06 (9) B	0.96±0.06 (9) A	0.36±0.06 (9) A	0.305±0.037 (9) A		

* Sites sharing a capital letter (A,B,C), within an endpoint and within a sex/season grouping are not significantly different (ANOVA for length and weight; ANCOVA for other analyses) at $\alpha = 0.05$ (Tukey family-wise error rate for multiple comparisons). X = significant interaction ($p = 0.05$)

August 2011

CURRICULUM VITAE

Paul D. Jones, PhD

Associate Professor

School of Environment and Sustainability

1. PERSONAL:

<personal information removed>

2. ACADEMIC CREDITIONALS:

B.Sc. (First Class Honours) University of Otago, 1982, Zoology
Ph.D. University of Otago, 1987, Biochemistry

3. OTHER CREDITIONALS:

APPOINTMENT(S)/PROMOTION(S) (UNIVERSITY OF SASKATCHEWAN):

Research Scientist, Appointment without term, (Oct. 2006-Oct. 2009) Toxicology Centre

Northern Ecosystems Toxicology Initiative (NETI) Chair, Associate Professor, Without Tenure, October 2009, School of Environment and Sustainability with 50% appointment in the Toxicology Graduate Programme.

Northern Ecosystems Toxicology Initiative (NETI) Chair Associate Professor, With Tenure, July 12012, School of Environment and Sustainability with 50% appointment in the Toxicology Graduate Programme.

5.0 ASSOCIATE MEMBERSHIPS

5.1 In other Departments or Colleges at U of S

Toxicology Center, 50% appointment, October 2009-present

5.2 Associate or Adjunct Appointments at other Institutions while employed at U of S.

Not Applicable

6. LEAVES

Not Applicable

7. HONOURS (MEDALS, FELLOWSHIPS, PRIZES)

"Premiers Award for Collaboration – Team Category" – Awarded by Premier of the Northwest Territories

Post Graduate Scholarship, Medical Research Council of New Zealand Post, 1984

Award in Science, University of Otago 1981

8. PREVIOUS POSITIONS RELEVANT TO U OF S EMPLOYMENT

Research Associate, Microbiology and Public Health, Michigan State University, East Lansing, Michigan, United States, 1988-1989

Research Associate, Pesticide Research Center, Michigan State University, East Lansing, Michigan, United States, 1989-1990

Research Fellow, Department of Scientific and Industrial Research (DSIR), Chemistry Division, Wellington, New Zealand, 1991-1992

Scientist, Institute of Environmental Science and Research (ESR), Wellington New Zealand, 1992-1997

Science Leader Ecotoxicology, Institute for Environmental Science and Research (ESR), Wellington, New Zealand, 1997-1998

Senior Research Associate, National Food Safety and Toxicology Center, Michigan State University, East Lansing, Michigan, United States, 1999-2000

Visiting Associate Professor, National Food Safety and Toxicology Center, Michigan State University, East Lansing, Michigan, United States, 2001-2003

Visiting Professor, National Food Safety and Toxicology Center, Michigan State University, East Lansing, Michigan, United States, 2003-2006

9.0 TEACHING RECORD

9.1 SCHEDULED INSTRUCTIONAL ACTIVITY

University of Saskatchewan

Year	Course	Type	Enrl.	YIH	YCSH
2011-2012	Environmental Issues and Negotiations (Team Taught with Markus Hecker)	Lec	15	39	585
	ENVS 898 Chemicals in the Environment	Lec	9	39	351
	TOX 844 Toxicology Techniques	L/P	6	15	90
2010-2011	ENVS 898 Chemicals in the Environment	Lec	12	39	468
	TOX 843 Environmental Chemodynamics	Lec	6	39	234
2009-2010	TOX 898 Toxicology Techniques (Term 1)	L/P	9	15	135
	TOX 843 Envionmental Chemodynamics	L	4	39	156
2008-2009	TOX 898 Toxicology Techniques (Term 1)	L/P	7	13	91
2006-2007	TOX 843 Envionmental Chemodynamics	L	8	39	312

Michigan State University

Year	Course	Type	Enrl.	YIH	YCSH
2006	ZOOL 446 Environmental Negotiation	L	av. 59	45	2250
	ZOOL 814 Environmental Chemodynamics	L	av. 10	45	450
2005	ZOOL 446 Environmental Negotiation	L	av. 59	45	2250
2004	ZOOL 446 Environmental Negotiation	L	av. 59	45	2250
	ZOOL 814 Environmental Chemodynamics	L	av. 10	45	450
2003	ZOOL 446 Environmental Negotiation	L	av. 59	45	2250
2002	ZOOL 446 Environmental Negotiation	L	av. 59	45	2250

9.2 UNSCHEDULED INSTRUCTIONAL ACTIVITY

Year	Activity	Course		Type	Enrl	YIH	YCSH
2010	Guest Lecture	TOX 898 Inhalation Toxicology		L	15	2	30
	Guest Lecture	Janz	Toxicology of Industrial Pollutants	L	35	2	70
	Guest Lecture	Dube	Sustainable Water	L	10	2	20
	Guest Lecture	Wickstrom	Wildlife Toxicology	L	6	2	12

9.3 POSTGRADUATE STUDENTS SUPERVISED OR ON THEIR COMMITTEE

<u>Supervised</u>

Aniekan Udofia (PhD University of Saskatchewan 2011-) Thesis: TBD

Timothy Tse (MSc University of Saskatchewan 2011-) Thesis: TBD

Hongda Yuan (MSc University of Saskatchewan 2011-) Thesis: TBD

Ehimai Ohiozebau (PhD University of Saskatchewan 2010-) **Thesis:** Contamination of "country foods" by emissions from Alberta tar sands industries.

Peter J. Day (MSc, Victoria University, 1993-1996). **Thesis:** The Bioaccumulation of Persistent Organochlorine Contaminants in a New Zealand Marine Food Chain.

Caren Schröder (MSc, Victoria University, 1994-1996). **Thesis:** Accumulation of Polychlorinated biphenyls in Pilot Whales (*Globicephala melas*).

Liu Cao (SENS) MSEM Faculty advisor – 2011-2012.

Ana Isobel Melgarajo (SENS) MSEM Faculty advisor – 2012.

Co-Supervised

Jonathan Naile (PhD., Toxicology, University of Saskatchewan, 2007-2011**). Thesis:** Perfluorinated Compounds in the Environment.

Yinfei Yang (MSc, Toxicology, University of Saskatchewan, completed December 2009). 2,3,7,8-TCDF and 2,3,4,7,8-PeCDF species-specific relative sensitivities: AhR binding affinity, in vitro functional bioassays.

Patrick Bradley (MSc, Michigan State University, Completed 2009). PBDEs in two Michigan Lakes.

Tannia Gracia (PhD., Zoology, Michigan State University, March 2008). **Thesis:** Evaluation , Validation and Application of the H295R System for the Analysis of Endocrine Disrupting Effects.

Wenyue Hu (PhD., Zoology, Michigan, State University, December 2005). **Thesis:** Use of Genomic Screening Methods to Assess the Effects of PFOS on gene expression.

Katherine Coady-Kemler (MSc., Zoology, Michigan State University 2003). **Thesis:** 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin Equivalents (TCDD-EQs) in Tissue Samples from the Denver Metropolitan Area.

Wenyue Hu (MSc., Zoology, Michigan State University, December 2002). **Thesis:** In Vitro studies of the biochemical toxicity of perfluorooctane sulfonic acid and its possible interaction with 2,3,7,8 – tetrachlorodibenzo-p-dioxin.

Committee Member

Brett Lucas (MSc, Toxicology, University of Saskatchewan 2011-) **Thesis**: Paleolimnological studies of Lake Diefenbaker, Saskatchewan.

Leanne Flahr (MSc, Biology) MSc candidate. Committee member/Lab supervision – 2011-present. **Thesis**: TBD

Sarah Crawford (MSc., University of Saskatchewan, 2010-present) **Thesis:** TBD

Nav Toor (PhD, Toxicology, University of Saskatchewan 2008-present) **Thesis:** Degradation and Aquatic Toxicity of Oil Sands Naphthenic Acids Using Simulated Wetlands.

Jordan Marritt (MSc., University of Saskatchewan, 2008-2010) Thesis: Swim Performance as an Effective, Environmentally Relevant Measure of Sublethal Toxicity in Zebrafish (*Danio rerio*)

Mohammed Mohammed (PhD, Department of Chemistry, University of Saskatchewan. Completed September 2010) Thesis Title: "Sorption of Naphthenic Acids using β-Cylodextrin-based Polyurethanes"

Melissa Driessnack (MSc, Toxicology) - ex officio committee member – 2008-present

9.4 NEW OR REVISED TEACHING MATERIALS

ENVS 823 . Chemicals in the Environment. (New Course Fall 2010)

9.5 SUBSTATIONALLY REVISED OR NEW COURSES DEVELOPED AND APPROVED

9.6 PUBLICATIONS IN JOURNALS OR BOOKS RELATED TO TEACHING METHODS

9.7 ATTENDANCE AT TEACHING IMPROVEMENT WORKSHOPS AND CONFERENCES

"Transforming Teaching" Gwenna Moss Centre for Teaching Effectiveness (Sept-Dec 2010).

9.8 TEACHING AWARDS OR RECOGNITIONS RECIVED

9.9 OTHER TEACHING RELATED ACTIVITIES (GIVE NARRATIVE DESCRIPTION)

Biology demonstrator (1st year), University Otago, 1981-1986

Biochemistry demonstrator (1st, 2nd and 3rd year), University of Otago, 1983-1988

10. THESES SUPERVISED (Completed only)

Supervised:	P.J. Day	MSc	The Bioaccumulation of Persistent Organochlorine Contaminants in a New Zealand Marine Food Chain	1995-1998
	C. Schröder	MSc	Accumulation of Polychlorinated biphenyls in Pilot Whales (*Globicephala melas*)	May 1996
Co-Supervised:	J. Naile	PhD	Perfluorinated Chemicals in the Environment	2007-present
	Y. Yang	MSc	2,3,7,8-TCDF and 2,3,4,7,8-PeCDF species-specific relative sensitivities: AhR binding affinity, in vitro functional bioassays	December 2009
	P. Bradley	MSc	PBDEs in two Michigan Lakes	December 2009
	Tannia Gracia	PhD	Evaluation , Validation and Application of the H295R System for the Analysis of Endocrine Disrupting Effects	March 2008
	W. Hu	PhD	Use of Genomic Screening Methods to Assess the Effects of PFOS on gene expression	December 2005
	W. Hu	MSc	In Vitro studies of the biochemical toxicity of perfluorooctane sulfonic acid and its possible interaction with 2,3,7,8 – tetrachlorodibenzo-p-dioxin	December 2002
	K. Coady-Kemler	MSc	2,3,7,8-Tetrachlorodibenzo-*p*-dioxin Equivalents (TCDD-EQs) in Tissue Samples from the Denver Metropolitan Area	1999-2001

11. BOOKS, CHAPTERS IN BOOKS, EXPOSITORY AND REVIEW ARTICLES

BOOKS
Not Applicable

CHAPTERS IN BOOKS

ACCEPTED:
Jones, Paul D. Markus Hecker, Steve Wiseman and John P. Giesy (2011) Chapter 10. Birds. In: Methods of Measuring the Hazards and Predicting the Risks of Endocrine Disrupters for Wildlife, P. Matthiessen Ed. IN PRESS.

PUBLISHED:
J.P. Giesy, S.A. Mabury, J.W. Martin, K. Kannan, **P.D. Jones**, J.L. Newsted, and K. Coady (2006). Perfluorinated compounds in the Great Lakes. *Hdb. Env. Chem. Vol. 5, Part N*:391-438.

Paul D. Jones, Kurunthachalam Kannan, Alan L. Blankenship and John P. Giesy (2001): The use of TRVs to assess the risks persistent organochlorines pose to marine mammals. *In:* Coastal and Estuarine Ecological Risk Assessment Ed. M.C. Newman M.H. Roberts, Jr. and R.C. Hale. M. Newman. Lewis Publishers, Boca Raton, FL.

Tillitt, D., Gilbertson,M., **Jones, P.D.**, Stromborg, K., Clark, J., Van den Berg, M., Giesy, J., and Olsson, M. (1998): Hazard assessment of organochlorine chemicals for terrestrial and aquatic animals. *IN: Ecotoxicological Risk Assessment of the Chlorinated Organic Chemicals*. Carey, J., Cook, P., Giesy, J., Hodson, P., Muir, D., Owens, W., Solomon, K. (Eds). SETAC Press, Pensacola FL, USA.

Giesy, J.P., R. Crawford, **P.D. Jones**, D.E. Tillitt, G.T. Ankley, J.L. Newsted, L.L. Williams, G. Walter and D.A. Verbrugge (1994): Uptake, disposition and effects of dietary 2,3,7,8-tetrachlorodibenzo-p-dioxin on the survival, growth, reproduction, histology, biochemistry and haematology of rainbow trout. pp 64-68 in L. Norrgren (Ed.). *Report from the Uppsala Workshop on Reproduction Disturbances in Fish*, October 20-22, 1993, Uppsala Sweden.

Giesy, J.P., R. Crawford, **P.D. Jones**, D.E. Tillitt, G.T. Ankley, J.L. Newsted, L.L. Williams, G. Walther and D.A. Verbrugge (1993): Uptake, Disposition and Effects of Dietary 2,3,7,8-Tetrachlorodibenzo-p-dioxin on the Survival, Growth, Reproduction, Histology, Biochemistry and Haematology of Rainbow Trout. pp. 235-238 in H. Fiedler, H. Frank, O. Hutzinger, W. Parzfall, A. Riss and S. Safe (Eds). *Organohalogen Compounds; Emission Control, Transport and Fate and Environmental Levels and Ecotoxicology*. Federal Environmental Agency, Austria.

Giesy, J.P., R. Crawford, **P.D. Jones**, D.E. Tillitt, G.T. Ankley, J.L. Newsted, L.L. Williams, G. Walther and D.A. Verbrugge (1993): Uptake, Disposition and Effects of Dietary 2,3,7,8-Tetrachlorodibenzo-p-dioxin on the Survival, Growth, Reproduction, Histology, Biochemistry and Haematology of Rainbow Trout. pp. 235-238 in H. Fiedler, H. Frank, O. Hutzinger, W. Parzfall, A. Riss and S. Safe (Eds). *Organohalogen Compounds; Emission Control, Transport and Fate and Environmental Levels and Ecotoxicology*. Federal Environmental Agency, Austria.

Ludwig, J. P., M. E. Ludwig, H. J. Auman, **P. D. Jones**, J. P. Giesy, D. Verbrugge, B. Chisholm and W. Swain (1992). The uptake of toxic contaminants by double-crested cormorants, Caspian terns and herring gulls from forage fish in the upper Great Lakes: The Basis of a Model for Great Lakes Fish-eating Warm-blooded Wildlife Species. ***Proceedings of Cause-Effects Linkages in the Great Lakes.*** Lewis Press, Chelsea, MI.

Bowerman, W.W., D.A. Best, E.D. Evans, S. Postupalsky, M.S. Martel, K. Kozie, R.L. Welch, R.H. Schell, D.F. Darling, J.C.Rogers, T.J. Kubiak, D.E. Tillitt, T.R. Schwartz, **P.D. Jones** and J.P. Giesy (1990): PCB Concentration in Plasma of Nestling Bald Eagles from the Great Lakes Basin, North America. pp. 203-206 in O. Hutzinger and H. Fiedler (Eds.). *Toxicology- Environment, Food, and Exposure Risk for Halogenated Hydrocarbons*. ECO-INFORMA Press, Bayreuth, Germany.

EXPOSITORY AND REVIEW ARTICLES
ACCEPTED:
Not Applicable

PUBLISHED:
Not Applicable

12. PAPERS IN REFERRED JOURNALS (Students co/supervised are underlined)
ACCEPTED:
Not Applicable

PUBLISHED:
E. Higley, S. Grund, **P. D. Jones**, T. Schulze, T. B. Seiler, U. L. V. Varel, W. Brack, J. W+Âlz, H. Zielke, J. P. Giesy, H. Hollert, and M. Hecker. Endocrine disrupting, mutagenic, and teratogenic effects of upper Danube River sediments using effect-directed analysis. Environmental Toxicology and Chemistry 31 (5):1053-1062, 2012.

K. Zhang, Y. Wan, **P. D. Jones**, S. Wiseman, J. P. Giesy, and J. Hu. Occurrences and fates of hydroxylated polybrominated diphenyl ethers in marine sediments in relation to trophodynamics. Environmental Science and Technology 46 (4):2148-2155, 2012.

J. E. Naile, S. Wiseman, K. Bachtold, **P. D. Jones**, and J. P. Giesy. Transcriptional effects of perfluorinated compounds in rat hepatoma cells. Chemosphere 86 (3):270-277, 2012.

P. W. Bradley, Y. Wan, **P. D. Jones**, S. Wiseman, H. Chang, M. H. Lam, D. T. Long, and J. P. Giesy. PBDEs and methoxylated analogues in sediment cores from two Michigan, USA, inland lakes. Environ.Toxicol.Chem. 30 (6):1236-1242, 2011.

J. E. Naile, J. S. Khim, T. Wang, Y. Wan, W. Luo, W. Hu, W. Jiao, J. Park, J. Ryu, S. Hong**, P. D. Jones**, Y. Lu, and J. P. Giesy. Sources and distribution of polychlorinated-dibenzo-p-dioxins and -dibenzofurans in soil and sediment from the Yellow Sea region of China and Korea. Environ.Pollut. 159 (4):907-917, 2011.

A. M. Cohen-Barnhouse, M. J. Zwiernik, J. E. Link, S. D. Fitzgerald, S. W. Kennedy, J. P. Giesy, S. Wiseman**, P. D. Jones**, J. L. Newsted, D. Kay, and S. J. Bursian. Developmental and posthatch effects of in ovo exposure to 2,3,7,8-TCDD, 2,3,4,7,8-PECDF, and 2,3,7,8-TCDF in Japanese quail (Coturnix japonica), common pheasant (Phasianus colchicus), and white leghorn chicken (Gallus gallus domesticus) embryos. Environ.Toxicol.Chem. 30 (7):1659-1668, 2011.

Cohen-Barnhouse, A. M., M. J. Zwiernik, J. E. Link, S. D. Fitzgerald, S. W. Kennedy, J. C. Hervé**, P.D. Jones**, J. P. Giesy, et al. 2011. Sensitivity of japanese quail (coturnix japonica), common pheasant (phasianus colchicus), and white leghorn chicken (gallus gallus domesticus) embryos to in ovo exposure to TCDD, PeCDF, and TCDF. Toxicological Sciences 119, (1): 93-103.

Driessnack, M. K., M. G. Dubé, L. D. Rozon-Ramilo**, P. D. Jones**, C. I. E. Wiramanaden, and I. J. Pickering. 2011. The use of field-based mesocosm systems to assess the effects of uranium milling effluent on fathead minnow (pimephales promelas) reproduction. Ecotoxicology: 1-16.

Wiseman, S. B., Y. Wan, H. Chang, X. Zhang, M. Hecker**, P. D. Jones**, and J. P. Giesy. 2011. Polybrominated diphenyl ethers and their hydroxylated/methoxylated analogs: Environmental sources, metabolic relationships, and relative toxicities. Marine pollution bulletin.

C. Liu, X. Zhang, H. Chang, **P.D. Jones**, S. Wiseman, J. Naile, M. Hecker, J. P. Giesy, and B. Zhou (2010). Effects of fluorotelomer alcohol 8:2 FTOH on steroidogenesis in H295R cells: Targeting the cAMP signalling cascade. *Toxicology and Applied Pharmacology* 247 (3):222-228.

Y. Wan, F. Liu, S. Wiseman, X. Zhang, H. Chang, M. Hecker, **P. D. Jones**, M. H. W. Lam, and J. P. Giesy (2010). Interconversion of hydroxylated and methoxylated polybrominated diphenyl ethers in Japanese medaka. *Environmental Science and Technology* 44 (22):8729-8735, 2010.

Y. Wan, **P. D. Jones**, S. Wiseman, H. Cha, D. Chorney, K. Kannan, K. Zhang, J. Y. Hu, J. S. Khim, S. Tanabe, M. H. W. Lam, and J. P. Giesy (2010). Contribution of synthetic and naturally occurring organobromine compounds to bromine mass in marine organisms. *Environmental Science and Technology* 44 (16):6068-6073.

Y. He, S.B. Wiseman, X. Zhang, M. Hecker, **P.D. Jones**, M.G. El-Din, J.W. Martin, and J.P. Giesy (2010). Ozonation attenuates the steroidogenic disruptive effects of sediment free oil sands process water in the H295R cell line. *Chemosphere* 80:578-584

Yang, Y., S. Wiseman, A. M. Cohen-Barnhouse, Y. Wan, **P. D. Jones**, J. L. Newsted, D. P. Kay, et al. 2010. Effects of in OVO exposure of white leghorn chicken, common pheasant, and japanese quail to 2,3,7,8-tetrachlorodibenzo-p-dioxin and two chlorinated dibenzofurans on cyp1a induction. Environmental Toxicology and Chemistry 29, (7): 1490-1502.

Zhang, K., Y. Wan, J. P. Giesy, M. H. W. Lam, S. Wiseman, **P. D. Jones**, and J. Hu. 2010. Tissue concentrations of polybrominated compounds in Chinese sturgeon (Acipenser sinensis): Origin, hepatic sequestration, and maternal transfer. Environmental Science and Technology 44, (15): 5781-5786.

He, Y., S. B. Wiseman, X. Zhang, M. Hecker, **P. D. Jones**, M. G. El-Din, J. W. Martin, and J. P. Giesy. 2010. Ozonation attenuates the steroidogenic disruptive effects of sediment free oil sands process water in the H295R cell line. Chemosphere 80, (5): 578-584.

Liu, C., X. Zhang, H. Chang, **P. Jones**, S. Wiseman, J. Naile, M. Hecker, J. P. Giesy, and B. Zhou. 2010. Effects of fluorotelomer alcohol 8:2 FTOH on steroidogenesis in H295R cells: Targeting the cAMP signalling cascade. Toxicology and applied pharmacology 247, (3): 222-228.

Naile, J. E., J. S. Khim, J. N. House, **P. D. Jones**, and J. P. Giesy. 2010. Standard purity and response factors of perfluorinated compounds. Toxicological and Environmental Chemistry 92, (7): 1219-1232.

Naile, J. E., J. S. Khim, T. Wang, Y. Wan, W. Luo, W. Hu, W. Jiao, **P.D. Jones**, et al. 2011. Sources and distribution of polychlorinated-dibenzo-p-dioxins and -dibenzofurans in soil and sediment from the yellow sea region of china and korea. Environmental Pollution 159, (4): 907-917.

Wan, Y., K. Choi, S. Kim, K. Ji, H. Chang, S. Wiseman, **P. D. Jones**, et al. 2010. Hydroxylated polybrominated diphenyl ethers and bisphenol a in pregnant women and their matching fetuses: Placental transfer and potential risks. Environmental Science and Technology 44, (13): 5233-5239.

Wan, Y., **P. D. Jones**, S. Wiseman, H. Cha, D. Chorney, K. Kannan, K. Zhang, et al. 2010. Contribution of synthetic and naturally occurring organobromine compounds to bromine mass in marine organisms. Environmental Science and Technology 44, (16): 6068-6073.

J.P. Giesy, J.E. Naile, J.S. Khim, **P.D. Jones**, and J.L. Newsted (2010). Aquatic toxicology of perfluorinated chemicals. *Reviews of Environmental Contamination and Toxicology* 202:1-52.

J.E. Naile, J.S. Khim, T. Wang, C. Chen, W. Luo, B.O. Kwon, J. Park, C.H. Koh, **P.D. Jones**, Y. Lu, and J.P. Giesy (2010). Perfluorinated compounds in water, sediment, soil and biota from estuarine and coastal areas of Korea. *Environmental Pollution* 158(5):1237-1244.

H. Chang, Y. Wan, J. Naile, X. Zhang, S. Wiseman, M. Hecker, M.H.W. Lam, J.P. Giesy, and **P.D. Jones** (2010). Simultaneous quantification of multiple classes of phenolic compounds in blood plasma by liquid chromatography-electrospray tandem mass spectrometry. *Journal of Chromatography A* 1217 (4):506-513.

J.C. Herve, D. Crump, S.P. Jones, L.J. Mundy, J.P. Giesy, M.J. Zwiernik, S.J. Bursian, **P.D. Jones**, S.B. Wiseman, Y. Wan, and S. W. Kennedy (2010). Cytochrome P4501A induction by 2,3,7,8-tetrachlorodibenzo-p-dioxin and two chlorinated dibenzofurans in primary hepatocyte cultures of three avian species. *Toxicological Sciences* 113 (2):380-391.

Y. Wan, **P.D. Jones**, R.R. Holem, J.S. Khim, H. Chang, D.P. Kay, S.A. Roark, J.L. Newsted, W.P. Patterson, and J.P. Giesy (2010). Bioaccumulation of polychlorinated dibenzo-p-dioxins, dibenzofurans, and dioxin-like polychlorinated biphenyls in fishes from the Tittabawassee and Saginaw Rivers, Michigan, USA. *Science of the Total Environment* 408 (11):2394-2401.

X. Zhang, J.N. Moore, J.L. Newsted, M. Hecker, M.J. Zwiernik, **P.D. Jones**, S.J. Bursian, and J.P. Giesy (2009). Sequencing and characterization of mixed function monooxygenase genes CYP1A1 and CYP1A2 of Mink (*Mustela vison*) to facilitate study of dioxin-like compounds. *Toxicology and Applied Pharmacology* 234 (3):306-313.

J.W. Park, A.R. Tompsett, X. Zhang, J.L. Newsted, **P.D. Jones**, W.T.A. Doris, R. Kong, S.S.W. Rudolf, J.P. Giesy, and M. Hecker (2009). Advanced fluorescence in situ hybridization to localize and quantify gene expression in japanese medaka (*Oryzias latipes*) exposed to endocrine-disrupting compounds. *Environmental Toxicology and Chemistry* 28 (9):1951-1962.

H. Yoo, N. Yamashita, S. Taniyasu, K.T. Lee, **P.D. Jones**, J.L. Newsted, J.S. Khim, and J.P. Giesy (2009). Perfluoroalkyl Acids in Marine Organisms from Lake Shihwa, Korea. *Archives of Environmental Contamination and Toxicology* 57:552-560.

Y. Wan, S. Wiseman, H. Chang, X. Zhang, **P.D. Jones**, M. Hecker, K. Kannan, S. Tanabe, J. Hu, M. H. W. Lam, and J. P. Giesy (2009). Origin of hydroxylated brominated diphenyl ethers: Natural compounds or man-made flame retardants? *Environmental Science and Technology* 43 (19):7536-7542.

A.R. Tompsett, J.W. Park, X. Zhang, **P.D. Jones**, J.L. Newsted, D.W.T. Au, E.X.H. Chen, R. Yu, R.S.S. Wu, R.Y.C. Kong, J.P. Giesy, and M. Hecker (2009). In situ hybridization to detect spatial gene expression in medaka. *Ecotoxicology and Environmental Safety* 72 (4):1257-1264.

Yang, Y., S.B., Wiseman, J.C., Hervé, R., Farmahin, T.B., Fredricks, P.W., Bradley, A., Cohen-Barnhouse, Y., Wan, **P.D., Jones**, J.L., Newsted, S.W. Kennedy, M.J., Zwernick, S.J., Bursian, J.P., Giesy (2009). Impact of chlorinated dioxins and furans on Japanese quail, ring-necked pheasant, and domestic chicken: insights from in *ovo studies*. *Organohalogen Compounds*, 71: 703.

T. Gracia, **P.D. Jones**, E.B. Higley, K. Hilscherova, J.L. Newsted, M.B. Murphy, A.K.Y. Chan, X. Zhang, M. Hecker, P.K.S. Lam, R.S.S. Wu, and J.P. Giesy (2008). Modulation of steroidogenesis by coastal waters and sewage effluents of Hong Kong, China, using the H295R assay. *Environmental Science and Pollution Research* 15 (4):332-343.

J.W. Park, A. Tompsett, X. Zhang, J.L. Newsted, **P.D. Jones**, D. Au, R. Kong, R.S.S. Wu, J.P. Giesy, and M. Hecker (2008). Fluorescence in situ hybridization techniques (FISH) to detect changes in CYP19a gene expression of Japanese medaka (*Oryzias latipes*). *Toxicology and Applied Pharmacology* 232:226-235.

K.D. Strause, M.J. Zwiernik, J.L. Newsted, A.M. Neigh, S.D. Millsap, C.S. Park, P.P. Moseley, D.P. Kay, P.W. Bradley, **P.D. Jones**, A.L. Blankenship, J.G. Sikarskie, and J.P. Giesy (2008). Risk assessment methodologies for exposure of great horned owls (*Bubo virginianus*) to PCBs on the Kalamazoo River, Michigan. *Integrated Environmental Assessment and Management* 4 (1):24-40.

X. Zhang, M. Hecker, **P.D. Jones**, J. Newsted, D. Au, R. Kong, R.S.S. Wu, and J.P. Giesy (2008). Responses of the medaka HPG axis PCR array and reproduction to prochloraz and ketoconazole. *Environmental Science and Technology* 42 (17):6762-6769.

X. Zhang, M. Hecker, J.W. Park, A.R. Tompsett, J. Newsted, K. Nakayama, **P.D. Jones**, D. Au, R. Kong, R.S.S. Wu, and J.P. Giesy (2008). Real-time PCR array to study effects of chemicals on the Hypothalamic-Pituitary-Gonadal axis of the Japanese medaka. *Aquatic Toxicology* 88 (3):173-182.

X. Zhang, M. Hecker, J.W. Park, A.R. Tompsett, **P.D. Jones**, J. Newsted, D.W.T. Au, R. Kong, R.S.S. Wu, and J.P. Giesy (2008). Time-dependent transcriptional profiles of genes of the hypothalamic-pituitary-gonadal axis in medaka (*Oryzias latipes*) exposed to fadrozole and 17+¦-trenbolone. *Environmental Toxicology and Chemistry* 27 (12):2504-2511.

T. Gracia, K. Hilscherova, **P.D. Jones**, J.L. Newsted, E.B. Higley, X. Zhang, M. Hecker, M.B. Murphy, R.M.K. Yu, P.K.S. Lam, R.S.S. Wu, and J.P. Giesy (2007). Modulation of steroidogenic gene expression and hormone production of H295R cells by pharmaceuticals and other environmentally active compounds. *Toxicology and Applied Pharmacology* 225 (2):142-153.

K.D. Strause, M.J. Zwiernik, I.H. Sook, P.W. Bradley, P.P. Moseley, D.P. Kay, C.S. Park, **P.D. Jones**, A.L. Blankenship, J.L. Newsted, and J.P. Giesy (2007). Risk assessment of great horned owls (Bubo virginianus) exposed to polychlorinated biphenyls and DDT along the Kalamazoo River, Michigan, USA. *Environmental Toxicology and Chemistry* 26 (7):1386-1398.

T. Puzyn, J. Falandysz, **P.D. Jones**, and J.P. Giesy (2007). Quantitative structure - Activity relationships for the prediction of relative in vitro potencies (REPs) for chloronaphthalenes. *Journal of Environmental Science and Health - Part A* 42 (5):573-590.

S. Jernbro, P.S. Rocha, S. Keiter, D. Skutlarek, H. Farber, **P.D. Jones**, J.P. Giesy, H. Hollert, and M. Engwall (2007). Perfluorooctane sulfonate increases the genotoxicity of cyclophosphamide in the micronucleus assay with V79 cells. Further proof of alterations in cell membrane properties caused by PFOS. *Environmental Science and Pollution Research* 14 (2):85-87.

I. Jordaan, R. Pieters, L.P. Quinn, J.P. Giesy, **P.D. Jones**, M.B. Murphy, and H. Bouwman (2007). The contribution of dioxin-like compounds from platinum mining and processing samples. *Minerals Engineering* 20 (2):191-193, 2007.

M.B. Murphy, M. Hecker, K.K. Coady, A.R. Tompsett, E.B. Higley, **P.D. Jones**, L. H. Du Preez, K.R. Solomon, J.A. Carr, and E.E. Smith (2006). Plasma steroid hormone concentrations, aromatase activities and GSI in ranid frogs collected from agricultural and non-agricultural sites in Michigan (USA). *Aquatic Toxicology* 77 (2):153-166.

A.M. Neigh, M.J. Zwiernik, P.W. Bradley, C.S. Park, A.L. Blankenship, J.P. Giesy, D.P. Kay, **P.D. Jones**, and J.L. Newsted (2006). Tree swallow (*Tachycineta bicolor*) exposure to polychlorinated biphenyls at the Kalamazoo River Superfund site, Michigan, USA. *Environmental Toxicology and Chemistry* 25 (2):428-437.

A.M. Neigh, M.J. Zwiernik, M.A. MacCarroll, J.L. Newsted, A.L. Blankenship, **P.D. Jones**, J.P. Giesy, and D.P. Kay (2006). Productivity of tree swallows (*Tachycineta bicolor*) exposed to PCBs at the Kalamazoo River Superfund site. *Journal of Toxicology and Environmental Health - Part A* 69 (5):395-415.

A.M. Neigh, M.J. Zwiernik, A.L. Blankenship, P.W. Bradley, D.P. Kay, M.A. MacCarroll, C.S. Park, **P.D. Jones**, S.D. Millsap, J.W. Newsted, and J.P. Giesy (2006). Exposure and multiple lines of evidence assessment of risk for PCBs found in the diets of passerine birds at the Kalamazoo River Superfund site, Michigan. *Human and Ecological Risk Assessment* 12 (5):924-946.

M.B. Murphy, M. Hecker, K.K. Coady, A.R. Tompsett, **P.D. Jones**, L.H. Du Preez, G.J. Everson, K.R. Solomon, J.A. Carr, and E.E. Smith (2006). Atrazine concentrations, gonadal gross morphology and histology in ranid frogs collected in Michigan agricultural areas. *Aquatic Toxicology* 76 (3-4):230-245.

M. Hecker, J.L. Newsted, M.B. Murphy, E.B. Higley, **P.D. Jones**, R. Wu, and J.P. Giesy (2006). Human adrenocarcinoma (H295R) cells for rapid in vitro determination of effects on steroidogenesis: Hormone production. *Toxicology and Applied Pharmacology* 217 (1):114-124.

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13. PAPERS IN NON-REFEREED JOURNALS

ACCEPTED:
I do not list non-refereed publications among my credentials

PUBLISHED:
I do not list non-refereed publications among my credentials

14. INVITED PAPERS/ABSTRACTS IN PUBLISHED CONFERENCE PROCEEDINGS

15. CONTRIBUTED (NON-INVITED) PAPERS/ABSTRACTS IN PUBLISHED CONFERENCE PROCEEDINGS

16. TECHNICAL REPORTS RELEVANT TO ACADEMIC FIELD

Paul D. Jones, John L. Newsted, John Slocomb (2003) Principal Components Analysis of Soil Samples Collected During the Denver Front Range Survey. by:, ENTRIX Inc. Prepared for US-EPA Region VIII, Denver, CO, USA.

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17. BOOK REVIEWS

Jones, P.D. (1997): Book Reviews: "Proceedings of the Exxon Valdez Oil Spill Symposium." *N.Z. J. Marine Freshwater Res*. (31) 2, 281-285.

18. INVITED LECTURES (OUTSIDE OF U OF S) AND INVITED CONFERENCE PRESENTATIONS

"Anthropogenic and Naturally Occurring Bromine Compounds in the Marine Environment. With: Y. Wan, S. Wiseman, H. Chang, M. Hecker and P.D. Jones, and J.P. Giesy. To: 6th International Conference on Marine Pollution, May 31 – June 3, 2010, Hong Kong. ***Invited Plenary Keynote***

"Development of Fluorescence in situ Hybridization Techniques to Detect and Quantify Gene Expression Profiles. With P.D. Jones, and J.P. Giesy. To: 17th International Conference on Bioindicators, Moscow, Russia May 18-22nd 2009. ***Invited, Plenary Keynote***

"Biochemistry and Toxicology of Perfluorinated Compounds". Paul D. Jones. To: Division of Analytical and Environmental Toxicology, Department of Laboratory Medicine and Pathology, Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Alberta, May 3, 2007.

"Quantification of Perfluorinated Compounds in Food and Tissues: Analytical Challenges of a Novel Class of Compounds". With Paul D. Jones, Jonathan E. Naile and Jong Seong

Khim, and J.P. Giesy. To: Saskatoon International Validation Workshop for Regulatory Analysis of Residues in Foods (SaskVal Workshop). June 10 - 14, 2007, Saskatoon, Saskatchewan, Canada. ***Invited Plenary Keynote***

"Monitoring For Novel Compounds In The Environment And Status And Trends Of Emerging Pollutants". With P.D Jones, P.K.S. Lam and R. S. S. Wu, and J.P. Giesy. Beijing Conference and Exhibition on Instrumental Analysis (BCEIA) 2007, Beijing, China, Oct 17-21 2007. ***Invited, Plenary Keynote.***

"Uptake of PCDD/DF and Potential Effects on Wildlife of the Tittabawassee River, Michigan, USA.". With P. D. Jones, M. J. Zwiernik, D. L. Tazelaar, J. N. Moore, T. B. Fredricks, S. J. Coefield, R. Seston, P. W. Bradley and D. P. Kay, and J.P. Giesy. To 3^{rd} International Symposium on Persistent Toxic Substances. October, 22-25, 2006 Beijing, China. ***Invited, Plenary Keynote.***

"Monitoring of Poly-fluorinated Compounds in the Environment". With P. D. Jones, J. L. Newsted, W.-Y. Hu, K. Kannan and D. Villeneuve, and J.P. Giesy. To: Workshop to Identify Emerging Contaminants of Concern and Their Implications for the Estuaring/Marine Environment and Human Health. May 11-12, 2005, Charleston, South Carolina. ***Invited Keynote***

"Results of the Ecological Risk Assessment of Organochlorines in the New Zealand Environment." P. D. Jones and S. Scobie, and J.P. Giesy. To: Pollution Effects-Biomarkers in Environmental Toxicology, July 14-16, 1999, Christchurch, New Zealand. ***Invited***

"A Competitive Polyclonal ELISA for Determination of Vitellogenin in Cyprinids". P. D. Jones and J.P. Giesy. To: Pollution Effects-Biomarkers in Environmental Toxicology, July 14-16, 1999, Christchurch, New Zealand. ***Invited***

19. CONTRIBUTED (NON-INVITED) PAPERS/ABSTRACTS AT CONFERENCES

American Chemical Society

"Polychlorinated Diaromatic Hydrocarbons in North Pacific Albatrosses: Contamination Exceeds Thresholds for Effects". To: Pacific Chapter Annual Meeting, Dec. 1995. J.P. Giesy, J.P. Ludwig, C.L. Summer, and **P.D. Jones**

American Chemical Society-Great Lakes Regional Chapter

"An Historic Perspective on Contaminants in the Great Lakes". **P.D. Jones** and J.P. Giesy. To: 33^{rd} Regional Meeting of the Great Lakes Chapter of the American Chemical Society, June 11-13, 2001, Grand Rapids, MI.

American Fisheries Society:

"Effects of Estrogenic Substances on Laboratory and Feral Fishes". P. D. Jones, S. A. Villalobos and D. L. Villeneuve, and J.P. Giesy. To: 129th Annual meeting, August 29-September 2, 1999, Charlotte, North Carolina. ***Invited***

American Society for Testing Materials (Section E.47):
"The H4IIE Rat Hepatoma Cell Bioassay as a Tool for the Assessment of Bioaccumulation". D. E. Tillitt, P. D. Jones, J. L. Newsted, D. A. Verbrugge, and J.P. Giesy. 14th Symposium on Aquatic Toxicity and Hazard Assessment, San Francisco, CA. April, 1990.

International Association for Great Lakes Research:
"Toxicological perspectives of perfluorooctane sulfonate (PFOS) to aquatic organisms in the Great Lakes." J.L. Newsted, P.D. Jones, and J.P. Giesy. To: 49th Conference on Great Lakes Research, Windsor, Ontario, May 22-26, 2006.

"Developmental deformities in double-crested cormorant and Caspian Tern chicks and embryos from the Upper Great Lakes". J.P. Ludwig, C.L. Summer, D. E. Tillitt, P.D. Jones, H. Kurita-Matsuba, H. Auman, M.E. Ludwig, and J.P. Giesy. To: 38th annual meeting, East Lansing, Michigan, May 28- June 1, 1995.

"Development of Toxic Equivalency Factors for Planar, Halogenated Hydrocarbons in Rainbow Trout (*Oncorhynchus mykiss*). J. L. Newsted, P. D. Jones, R. Crawford, J. Gooch, and J.P. Giesy. 34th Annual Meeting, Buffalo, NY. June 2-6, 1991.

"2,3,7,8-TCDD Equivalents in Multiple Trophic Levels at Thunder Bay, Lake Huron, Determined by H-4-IIE Rat Hepatoma Cell Bioassay." P. D. Jones, D. E. Tillitt, J. L. Newsted, D. A. Verbrugge, N. DeGalan, G. T. Ankley, T. J. Kubiak, D. A. Best, J. P. Ludwig, and J.P. Giesy. 33rd Annual Conference, Windsor, Ontario, May 1990.

"Uptake of Toxic Substances by Newly-hatched Double-crested Cormorant and Herring Gull Chicks at Eight Upper Great Lakes Sites in 1989". J. P. Ludwig, M. E. Ludwig, H. Kurita, H. J. Auman, P. D. Jones, D. E. Tillitt, J. L. Newsted D. A. Verbrugge, and J.P. Giesy. 33rd Annual Conference, Windsor, Ontario, May 1990.

"Bioassessment of Complex Mixtures of Polyhalogenated Hydrocarbons in Fish, Fish-eating Birds and Furbearers of the Great Lakes." P. D. Jones, J. L. Newsted, D. E. Tillitt, J. P. Ludwig, M. E. Ludwig, T. Kubiak, D. Best, G. T. Ankley, and J.P. Giesy. 33rd Annual Conference, Windsor Ontario, May 1990. ***Invited***.

"Toxicity in Eggs of Great Lakes Colonial Waterbirds 1986-1989." J. P. Ludwig, M. E. Ludwig, H. J. Auman, P. D. Jones, D. E. Tillitt, J. L. Newsted, D. A. Verbrugge, and J.P. Giesy. 33rd Annual Conference, Windsor, Ontario, May 1990.

Society of Environmental Toxicology and Chemistry (SETAC):
"Origin of Hydroxylated Brominated Diphenyl Ethers: Natural Compounds or Man-made Flame Retardants?" Y. Wan, S.B. Wiseman, H. Chang, X. Zhang, P. Jones, M. Hecker, K. Kannan, J. Hu, and M. Lam, and J.P. Giesy. To: 30th annual meeting, November 19-23, 2009, New Orleans, LA.

"Effects of PFCs on Gene Expression of the H4IIE Rat Hepatoma Cell Line." J.E. Naile, S.B. Wiseman, and P. Jones, and J.P. Giesy.. o: 30th annual meeting, November 19-23, 2009, New Orleans, LA.

"Effects of Ozone-Treated and Untreated Sediment-Free Oil Sand Processed Water on In Vitro Steroidogenesis." Y. He, S.B. Wiseman, M. Hecker, P. Jones, M. Gamel El-Din, and J.W. Martin, and J.P. Giesy. To: 30th annual meeting, November 19-23, 2009, New Orleans, LA.

"Mechanism of Biotransformation of Methylated-PBDE's to Hydroxylated-PBDE's." S.B. Wiseman, Y. Wan, X. Zhang, H. Chang, M. Hecker, P. Jones, and M. Lam, and J.P. Giesy. To: 30th annual meeting, November 19-23, 2009, New Orleans, LA.

"Perfluorinated Compounds in Environmental Samples Collected from the Estuarine and Coastal Areas of Korea." J.E. Naile, J. Khim, T. Wang, C. Chen, B. Kwon, C. Koh, P. Jones, and Y. Lu, and J.P. Giesy. To: 30th annual meeting, November 19-23, 2009, New Orleans, LA.

"Effects of Chlorinated Dioxins and Furans on Japanese Quail, Common Pheasant, and Domestic Chicken: Insights from in ovo Studies." Y. Yang, S.B. Wiseman, J. Herve, R. Farmahin, T.B. Fredricks, P.W. Bradley, A. Cohen-Barnhouse, Y. Wan, P. Jones, J. Newsted, S.W. Kennedy, M. Zwiernik, andS. Bursian, and J.P. Giesy. To: 30th annual meeting, November 19-23, 2009, New Orleans, LA.

"Sensitivity of White Leghorn Chicken (*Gallus gallus domesticus*) Embryos to in ovo Exposure to 2,3,7,8-TCDD, 2,3,4,7,8-PeCDF and 2,3,7,8-TCDF." A. Cohen-Barnhouse, S. Bursian, J. Link, P. Jones, Y. Wan, S.B. Wiseman, Y. Yang, S.W. Kennedy, J. Newsted, B. Collins, and M. Zwiernik, and J.P. Giesy. To: 30th annual meeting, November 19-23, 2009, New Orleans, LA.

"Sensitivity of Common Pheasant (*Phasianus colchicus*) Embryos to in ovo Exposure to 2,3,7,8-TCDD, 2,3,4,7,8-PeCDF and 2,3,7,8-TCDF." A. Cohen-Barnhouse, S. Bursian,

J. Link, and P. Jones, and J.P. Giesy. To: 30th annual meeting, November 19-23, 2009, New Orleans, LA.

"Characterization of Mixed Function Monooxygenase Genes *CYP1A1* and *CYP1A2* of Mink (*Mustela vison*) to Facilitate Study of Dioxin-like Compounds." X. Zhang, M. Hecker, S. Wiseman, P.D. Jones, J.N. Moore, S.J. Bursian, M.J. Zwiernik, M. Hecker, and J. Newsted, and J.P. Giesy. To: 29th annual meeting, November 16-21, 2008, Tampa, FL.

"Aquatic Toxicology of Perfluorinated Chemicals." J. Naile, J. Khim, P.D. Jones and J.L. Newsted, and J.P. Giesy. To: 29th annual meeting, November 16-21, 2008, Tampa, FL.

"Sensitivity of Chicken and Japanese Quail Embryo Hepatocyte Cultures to Cytochrome *P4501A* Induction Upon Exposure to TCDD, PeCDF, and TCDF." J.C. Herve, S.W. Kennedy, S.P. Jones, L.J. Mundy, S.J. Bursian, M.J. Zwiernik and P.D. Jones, and J.P. Giesy. To: 29th annual meeting, November 16-21, 2008, Tampa, FL.

"Application of a Medaka HPG Axis Real Time PCR Array Method to Environmental Chemical Screening." X. Zhang, M. Hecker, A. Tompsett, and P.D. Jones, and J.P. Giesy. To: 29th annual meeting, November 16-21, 2008, Tampa, FL.

"Species-specific Accumulation of Polychlorinated Dibenzo-*p*-dioxins (PCDDs), Dibenzofurans (PCDFs), and Coplanar Polychlorinated Diphenyls (PCBs) in Fishes from the Tittabawassee and Saginaw Rivers (Michigan, USA)." Y. Wan, P.D. Jones, J. Khim, R.R. Holem, D.P. Kay, S.A. Roark, and J.L. Newsted, and J.P. Giesy. To: 29th annual meeting, November 16-21, 2008, Tampa, FL.

"Perfluorinated Compounds in Environmental Samples Collected from Inner-Mongolia, China." J. Naile, J. Khim, P.D. Jones, T. Wang, W. Jiao, C. Chen, Y. Lu, and K. Kannan, and J.P. Giesy. To: 29th annual meeting, November 16-21, 2008, Tampa, FL.

"Perfluorinated Compounds in Sediment and Water from Bohai Bay and its Vicinity, China." J. Khim, J.E. Naile, Y. Wan, P.D. Jones T. Wang, W. Jiao, J. Geng, C. Chen, and Y. Lu, and J.P. Giesy. To: 29th annual meeting, November 16-21, 2008, Tampa, FL.

"Perfluorooctane Sulfonate and other Fluorochemicals in Soils from Bohai Bay, China." T. Wang, W. Jiao, C. Chen, Y. Lu, L. Wei, W. Guang, L. Jing, J. Khim, J.E. Naile, Y. Wan, and P.D. Jones, and J.P. Giesy. To: 29th annual meeting, November 16-21, 2008, Tampa, FL.

"Effects of TCDD, TCDF, and PeCDF Injected into the Air Cell of Japanese Quail (*Coturnix japonica*) Prior to Incubation." A. Cohen-Barnhouse, S. Bursian, J. Link, P.D. Jones, Y. Wan, S. Wiseman, S. Kennedy, J. Newsted, and M. Zwiernik, and J.P. Giesy. To: 29th annual meeting, November 16-21, 2008, Tampa, FL.

"Effects of TCDD, 2,3,7,8-TCDF and 2,3,4,7,8-PeCDF Exposure on *CYP1A4* and *CYP1A5* mRNA Abundance in Japanese Quail (*Coturnix japonica*), Ring-necked Pheasant (*Phasianus colchicus*), and Chicken (*Gallus gallus*) in Ovo." S. Wiseman, Y. Yang, P. Jones, Y. Wan, M. Zwiernik, S. Bursian, J. Herve, S. Kennedy, and J. Newsted, and J.P. Giesy. To: 29th annual meeting, November 16-21, 2008, Tampa, FL.

"Determination of Relative Response factors and Matrix Effects on Quantification of Perfluorinated Compounds." J. Naile, J.-S. Khim, and P.D. Jones, and J.P. Giesy. To: 28th Annual Meeting, November 11-15, 2007, Milwaukee, WS.

"Testing of Five Model Endocrine Disrupting Chemicals using Medaka Hypothalamic-pituitary-Gonadal (BHG) Axis Model and RT-PCR Array Methods". X. Zhang, A. Tompsett, J. Park, M. Hecker, J.L. Newsted and P.D. Jones, and J.P. Giesy. To: 28th Annual Meeting, November 11-15, 2007, Milwaukee, WS.

"Gene Expression and Histological Structure as Biomarkers of Chemical Exposure in Japanese Medaka." AR. Tompsett, J. Park, X. Zhang, M. Hecker, P.D. Jones, J.L. Newsted and D. Au, and J.P. Giesy. To: 28th Annual Meeting, November 11-15, 2007, Milwaukee, WS.

"Development of Fluorescence in situ Hybridization (ISH) Techniques to Detect and Quantify Expression Profiles of Genes Along the HPG-Axis in Japanese Medaka". . AR. Tompsett, J. Park, X. Zhang, M. Hecker, P.D. Jones, J.L. Newsted and D. Au, and J.P. Giesy. To: 28th Annual Meeting, November 11-15, 2007, Milwaukee, WS.

"Productivity of American Robins (*Turdus migratorius*) in the Tittabawassee River Floodplain". D.L. Tazelaar, M.J. Zwiernik, R.M. Seston, D.P. Kay, S.A. Roarck, S.C. Plautz, T.B. Fredricks, M.S. Shotwell and S.J. Coefield, and J.P. Giesy. To: 28th Annual Meeting, November 11-15, 2007, Milwaukee, WS.

"Elucidating Changes in Aromatase (CYP19) Gene Expression in Japanese Medaka (*Oryzias latipes*) Exposed to Fadrozole: Q RT-PCR and its comparison with ISH methods". J. Park, A.Tompsett, X. Zhang, M. Hecker, P.D. Jones, J.L. Newsted, and J.P. Giesy. To: 27th Annual Meeting, November 5-9, 2006, Montreal, Quebec, Canada.

"Data Analysis Approaches for Interpreting Complex Toxicogenomic Data Sets." **P.D. Jones**, X. Zhang, J.L. Newsted, T. Gracia, J.T Sanderson, and K. Hilscherova, and J.P. Giesy. To: 27th Annual Meeting, November 5-9, 2006, Montreal, Quebec, Canada.

"A Mixture Model for Chemical Clustering —- An Application Using Data from H295R Cell Assays." X. Zhang, P.D. Jones, Y. Zuo, J.L. Newsted, and M. Hecker, and J.P. Giesy. To: 27th Annual Meeting, November 5-9, 2006, Montreal, Quebec, Canada.

"Toxicological Perspectives of Perfluorooctane Sulfonate (PFOS) to Aquatic Organisms." J.L. Newsted, P.D. Jones, and S.A. Beach, and J.P. Giesy. To: 27th Annual Meeting, November 5-9, 2006, Montreal, Quebec, Canada.

"Human Adrenocarcinoma (H295R) Cells for Rapid In vitro Determination of Effects on Steroidogenesis: Sex Steroid Concentrations and Aromatase Activity." E.B. Higley, M. Hecker,M. J.L. Newsted, M.B. Murphy, P.D. Jones, and R. Wu, and J.P. Giesy. To: 27th Annual Meeting, November 5-9, 2006, Montreal, Quebec, Canada.

"Multiplex in situ Hybridization to Detect CYP19a and b Gene Expression Patterns Along the HPG-axis of the Japanese Medaka (*Oryzias latipes*)." J. Park, A.R. Tompsett, X. Zhang, M. Hecker, P.D Jones, and J.L. Newsted, and J.P. Giesy. To: 27th Annual Meeting, November 5-9, 2006, Montreal, Quebec, Canada.

"Elucidating Changes in Aromatase (CYP19) Gene Expression in Japanese Medaka (*Oryzias latipes*) Exposed to Fadrozole: In Situ Hybridization in a Whole Animal Model." A.R. Tompsett, J.W. Park, M. Hecker, P.D. Jones, J.L. Newsted, D. Au, and Chen, and J.P. Giesy. To: 27th Annual Meeting, November 5-9, 2006, Montreal, Quebec, Canada.

"Effects of Pharmaceuticals on Gene Expression and Hormone Production in H295R Cell Line Using Q-RT-PCR/ELISA". T. Gracia, P.D. Jones, K. Hilscherova, K. Higley, and J.L. Newsted, and J.P. Giesy. To: 26th Annual Meeting, November 13-17, 2005, Baltimore MD.

"A Comparison of H295R, R2C and JEG-3 Cells as Screening Tools for Effects on Steroidogenesis". X. Zhang, R.M.K. Yu, P.D Jones, J.L. Newsted, T. Gracia, M. Hecker and R.S.S Wu, and J.P. Giesy. To: 26th Annual Meeting, November 13-17, 2005, Baltimore MD.

"Avian Toxicity Reference Values (TRVs) for Perfluorooctane Sulfonate (PFOS)". J.L Newsted, P.D. Jones and K. Coady, and J.P. Giesy. To: 26th Annual Meeting, November 13-17, 2005, Baltimore MD.

"PCDDs and PCDFs in Small Mammals Foraging in the Tittabawassee River Floodplain, Michigan". S.J. Coefield, M.J. Zwiernik, R.M. Seston, T.B. Fredricks, J.N. Moore, D. Tazelaar, D.L. Kay, P.D. Jones and P. Bradley, and J.P. Giesy. To: 26th Annual Meeting, November 13-17, 2005, Baltimore MD.

"Separation and Characterization pf Structural Isomers of Perfluorinated Compounds". H. Yoo, P.D. Jones, P.W. Bradley, M. Gužviae, B.L. Upham, J.E. Trosko, and J.L. Newsted, and J.P. Giesy. To: 26th Annual Meeting, November 13-17, 2005, Baltimore MD.

"Assessment of Belted Kingfisher (*Ceryle alcyon*) Dietary Exposure to PCDDs and PCDFs in the Tittabawassee River, MI". R.M. Seston, M.J. Zwiernik, J.N. Moore, D.L. Tazelaar, H.L. Wong, P.W. Bradley, T.B. Fredricks, J.J. Coefield and P.D. Jones, and J.P. Giesy. To: 26th Annual Meeting, November 13-17, 2005, Baltimore MD.

"Application of *In situ* Hybridization to Detect CYP19-A1 and –A2 Gene Expression Patterns Along the HPG-Axis at Different Organizational Levels using Japanese Medaka (*Oryzias latipes*)". J-W. Park, A. Tompsett, M. Hecker, P.D. Jones and J.L. Newsted, and J.P. Giesy. To: 26th Annual Meeting, November 13-17, 2005, Baltimore MD.

"Quantitative Assessment of Chemical Effects on Steroidigenic Enzymes in H295R Cells Line Using Q-RT-PCR". T. Gracia, K. Hilscherova, X. Zhang, P. D. Jones, J. T. Sanderson and J. L. Newsted, and J.P. Giesy. To: 25th Annual Meeting, November 14-18, 2004, Portland, Oregon.

"A Cell Culture Based Assay for the Measurement of Xenobiotic Effects on Steroid Production". P. D. Jones, M. Heckeer, T. Gracia, X. Zhang, J. T. Sanderson and J. L. Newsted, and J.P. Giesy. To: 25th Annual Meeting, November 14-18, 2004, Portland, Oregon.

"Reduction in Estrogenic Activity by Membrane-Based and Conventional Waste Water Treatment". A. Coors, P. D. Jones and H. T. Ratte, and J.P. Giesy. To: 25th Annual Meeting, November 14-18, 2004, Portland, Oregon.

"Effects of Atrazine Exposure on Aromatase Activity and CYP19 Gene Expression in Male Adult Xenopus laevis". J.-W. Park, M. Hecker, M. R. Murphy, P. D. Jones, K. R.

Solomon, G. van der Kraak, and R. J. Kendall, and J.P. Giesy. To: 25th Annual Meeting, November 14-18, 2004, Portland, Oregon.

"Gross Morphology and Gonadal Histology of Ranid Frog Species Collected from Atrazine-exposed Sites in Michigan". A. RT. Tompsett, M. B. Murphy, K. K. Coady, M. Hecker, L. DuPreez, P. D. Jones, E.E. Smith, G. van der Kraak, K. R. Solomon and R. J. Kendell, and J.P. Giesy. To: 25th Annual Meeting, November 14-18, 2004, Portland, Oregon.

"Estradiol and Testosterone Levels in Juvenile and Adult Frogs from Atrazine-exposed Sites in Michigan". A. R. Tompsett, M. B. Murphy, K. K. Coady, M. Hecker, P. D. Jones, E. E. Smith, G. van der Kraak, K. R. Solomon and R. J. Kendall, and J.P. Giesy. To: 25th Annual Meeting, November 14-18, 2004, Portland, Oregon.

"Mixed Function Oxygenase Enzymes in Juvenile and Adult Frogs from Atrazine-Exposed Sites in Michigan". M. B. Murphy, A. R. Tompsett, K.K. Coady, M.Hecker, P. D. Jones, J. A. Carr, E. E. Smith, G. van der Kraak and R. J. Kendall, and J.P. Giesy. To: 25th Annual Meeting, November 14-18, 2004, Portland, Oregon.

"Effects of Atrazine and Estradiol on Plasma Sex Steroid Concentrations in Male Adult Xenopus laevis". M. Hecker, M. B. Murphy, P. D. Jones, K. R. Solomon, G. van der Kraak and R. J. Kendall, and J.P. Giesy. To: 25th Annual Meeting, November 14-18, 2004, Portland, Oregon.

"Seasonal Changes and Natural Variability of Plasma Sex Steroid Concentrations in Xenopus laevis from South Africa". L. Du Preez, M. B. Murphy, P. D. Jones, K. S. Solomon, G. van der Kraak, E. E. Smith, R. Kendall and M. Hecker, and J.P. Giesy. To: 25th Annual Meeting, November 14-18, 2004, Portland, Oregon.

"Effects of Atrazine on Mixed Function Oxygenases in *Xenopus laevis*". J.-W. Park, M. Hecker, M. B. Murphy, P. D. Jones, K. R. Solomon, G. van der Kraak and R. J. Kendall, and J.P. Giesy. To: 25th Annual Meeting, November 14-18, 2004, Portland, Oregon.

"Induction of EROD by TCDD and Selected PCBs in Primary Hepatocytes of Brown House Snakes (Lamprophis fuliginosus". P. D. Jones, M. Hecker, M. B. Murphy, and W. Hopkins, and J.P. Giesy. To: 25th Annual Meeting, November 14-18, 2004, Portland, Oregon.

"Plasma Testosterone and Estradiol Concentrations, Aromatase Activities and Gonadal Histology of Ranids in Michigan". M.B. Murphy, K.K. Coady, M. Hecker, P.D. Jones, J.P. Carr, J.A. Smith, G. Van der Kraak, K.R. Solomon and R. Kendall, and J.P. Giesy. To: 24th Annual Meeting, November 9-13, 2003, Austin, Texas.

"Identification and Characterization of Genes Responsive to Perfluorinated Sulfonic Acid Exposure using Gene Expression Profiling". W.-Y. Hu, P.D. Jones, J.L. Newsted, and C. Lau, and J.P. Giesy. To: 24th Annual Meeting, November 9-13, 2003, Austin, Texas.

"An Examination of Bald Eagles PCB Exposure on the Kalamazoo River, MI based on site-specific and regional-specific exposure profiles". M.J. Zwiernik, K.D. Strause, P.W. Bradley, P.D. Jones, D.P. Kay, and C.S. Park, and J.P. Giesy. To: 24th Annual Meeting, November 9-13, 2003, Austin, Texas.

"Binding of Perfluorinated Chemicals to Serum Proteins". P.D. Jones, W.Y. Hu, W. De Coen and J.L. Newsted, and J.P. Giesy. To: 24th Annual Meeting, November 9-13, 2003, Austin, Texas.

"Effects of Atrazine on Adult Xenopus laevis in the Wild and the Laboratory: No Evidence for an Aromatase Based Mechanism". M. Hecker, D.L. Villeneuve, L. Du Preez, K.K. Coady, M.B. Murphy, P.D. Jones and K.R. Solomon, and J.P. Giesy. To: 24th Annual Meeting, November 9-13, 2003, Austin, Texas.

"PCB Congener Pattern Differences and Biomagnification Factors in Mink (Mustela vison) and Select Prey Items Collected from tje Kalamazoo River, Michigan". S.D. Pastva, A.L. Blankenship, P.W. Bradley, P.D. Jones, D.P. Kay, A.M. Neigh, C.S. Park, K.D. Strause, and M.J. Zwiernik, and J.P. Giesy. To: 24th Annual Meeting, November 9-13, 2003, Austin, Texas.

"Assessment of Risks of PCBs to Mink (*Mustela vison*) at the Kalamazoo River, Michigan". S. D. Pastva, A. L. Blankenship, P. W. Bradley, P. D. Jones, K. Kannan, A. Neigh, C. S. Park, K. D. Strause and M. J. Zwiernik, and J.P. Giesy. To: 23rd Annual Meeting, November 16-20, 2002, Salt Lake City, Utah.

"Aromatase Activity in Tissues of Adult *Xenopus laevis* Exposed to Atrazine". D. L. Villeneuve, K. K. Coady, M. M. Murphy, M. van der Zee, M. Hecker, P. D. Jones, J. J. Carr, E. E. Smith and G. van der Kraak, and J.P. Giesy. To: 23rd Annual Meeting, November 16-20, 2002, Salt Lake City, Utah.

"Effects of Atrazine on Developing Xenopus laevis: Potential Endocrine Disruption". K. K. Coady, D. L. Villeneuve, M. M. Murphy, M. van der Zee, M. Hecker, P. D. Jones, J.

A. Carr, E. E. Smith, G. van der Kraak, and J.P. Giesy. To: 23rd Annual Meeting, November 16-20, 2002, Salt Lake City, Utah.

"Effects of Atrazine on Developing *Rana clamitans*". K. K. Coady, D. L. Villeneuve, M. M. Murphy, M. van der Zee, M. Hecker, P. D. Jones, J. A. Carr, E. E. Smith and G. van der Kraak, and J.P. Giesy. To: 23rd Annual Meeting, November 16-20, 2002, Salt Lake City, Utah.

"Screening for Androgen and Glucuronide Receptor (ant)agonists using MDA-kb2 Cells". M. Murphy, D. L. Villeneuve, W. H. Lam and P. D. Jones, and J.P. Giesy. To: 23rd Annual Meeting, November 16-20, 2002, Salt Lake City, Utah.

"Principal Components Analysis of Dioxins from Rocky Mountain Arsenal and Denver, Colorado". P. D. Jones, J. L. Newsted, J. Slocum, G. Henningson, L. Williams and C. Bicher, and J.P. Giesy. To: 23rd Annual Meeting, November 16-20, 2002, Salt Lake City, Utah.

"Perfluorooctanesulfonate in the Environment". K. Kannan, P.D. Jones, and K. Hansen, and J.P. Giesy. To: 22th Annual Meeting, November 11-15, 2001, Baltimore, Maryland. ***Invited***

"A Global Survey of PFOS". K. Kannan, P.D. Jones, and K. Hansen, and J.P. Giesy. To: 22th Annual Meeting, November 11-15, 2001, Baltimore, Maryland. ***Invited***

"Effects of Environmentally Relevant Concentrations of TCDD on Rainbow Trout Reproduction". P.D. Jones, K. Kannan, J.L. Newsted, D.E. Tillitt, and L.L. Williams, and J.P. Giesy. To: 22th Annual Meeting, November 11-15, 2001, Baltimore, Maryland.

"A Country-Wide Risk Assessment of Organochlorines in New Zealand". P.D. Jones, S.J. Buckland, H.K. Ellis, and S.E. Scobie, and J.P. Giesy. To: 22th Annual Meeting, November 11-15, 2001, Baltimore, Maryland.

"Measurement of the Effects of Environmental Contaminants on Cell Membrane Fluidity by Flow Cytometry". W. Hu, L. King and P.D. Jones, and J.P. Giesy. To: 21th Annual Meeting, November 12-17, 2000, Nashville, Tennessee.

"Biological Monitoring of Planar PCDD/Fs and PCBs as Exposure Indicators of Potential Environmental Contamination". S. Kennedy, G. Henningsen, S. Skipper, R. Roy, M. Macrander, P.D. Jones, I. Nisbit and D. Regan, and J.P. Giesy. To: 21th Annual Meeting, November 12-17, 2000, Nashville, Tennessee.

“Tetrachlorodibenzo-*p*-dioxin Equivalents (TCDD-EQs) in Tissue Samples from Three Species in the Denver Metropolitin Area”. K. Kemler, K. Kannan, P.D. Jones and A.L. Blankenship, and J.P. Giesy. To: 21th Annual Meeting, November 12-17, 2000, Nashville, Tennessee.

“Aroclors, PCB Congeners, and TCDD-Equivalents: Considerations for Selecting PCB Quantification Approaches for Ecological Risk Assessment “. A.L. Blankenship, K. Kannan, P.D. Jones, M. Zwiernik and D. Kay, and J.P. Giesy. To: 21th Annual Meeting, November 12-17, 2000, Nashville, Tennessee.

“Screening for Endocrine Modulating Chemicals in Lake Mead, Nevada using Caged Adult Common Carp (*Cyprinus carpio*)”. E.M. Snyder, S.A. Snyder, K.L. Kelly, T.S. Gross, P.D. Jones, S.D. Fitzgerald, D.L. Villeneuve and S.A.Villalobos, and J.P. Giesy. To: 21th Annual Meeting, November 12-17, 2000, Nashville, Tennessee.

“The Use of a Vitelogenin ELISA to Measure the Effects of Estrogenic Substances on Laboratory Fishes”. P.D. Jones, S.L. Pierens, E.M. Snyder, S. Miles-Richardson, V.J. Kramer, S.A. Snyder, K.M. Nichols, S.A. Villalobos, and D.L. Villeneuve, and J.P. Giesy. To: 20th Annual Meeting, November 14-18, 1999, Philadelphia, Pennsylvania.

“Accumulation of PCBs in Southern Ocean Pilot Whales (*Globicephala melas)* from New Zealand Stranding Events”. C. Schröder, P.J. Day, and P.D. Jones, and J.P. Giesy. To: 20th Annual Meeting, November 14-18, 1999, Philadelphia, Pennsylvania.

“Toxicity Reference Values for the Toxic Effects of Polychlorinated Biphenyls to Aquatic Mammals”. K. Kannan, A.L. Blankenship and P.D. Jones, and J.P. Giesy. To: 20th Annual Meeting, November 14-18, 1999, Philadelphia, Pennsylvania.

“Accumulation of Persistent Organic Pollutants in the Eggs of Southern Ocean Migratory Albatrosses.” P.D. Jones, C.J.R. Robertson and K. Kannan, and J.P. Giesy. 19th Annual meeting, November 15-19, 1998, Charlotte, North Carolina.

“Total PCBs, TCDD-EQs in Eggs: Reproductive Hazards to North Pacific Albatrosses”. J.P. Ludwig, H.J. Auman, C.L. Summer, J.M. DeDoes, D.A. Verbruggee and P.D. Jones, and J.P. Giesy. 16th Annual Meeting, November 5-9, 1995, Vancouver, British Columbia, Canada.

"Accumulation and disposition of dietary 2,3,7,8-tetrachlorodibenzo-p-dioxin by rainbow trout." R. Crawford, P.D. Jones, D.E. Tillitt, G.T. Ankley, J.L. Newsted, L.L. Williams and D.A. Verbrugge, and J.P. Giesy. 14th Annual Meeting, November 14-18, 1993, Houston, TX.

“Uptake of Planar PCBs and 2,3,7,8-substituted PCDFs and PCDDs by Birds Nesting in the Lower Fox River/Green Bay, WI." G.T Ankley, G.J. Niemi, K.B. Lodge, H.J. Harris, K.L. Beaver, P.D. Jones and D.E. Tillitt, and J.P. Giesy. 13th Annual Meeting, Cincinnati, Ohio, Nov. 8-12, 1992.

“Planar, Chlorinated Hydrocarbons in the New Zealand Environment". P. D. Jones, T. J. Kubiak, D. A. Best and D. Scott, and J.P. Giesy. 12th Annual Meeting, Seattle, WA. November 3-7, 1991.

"Persistent Organochlorines and Embryonic Abnormalities in Three Species of Colonial Waterbirds From the Upper North American Great Lakes." N. Yamashita, S. Tanabe, T. Iida, R. Tatsukawa, J.P. Ludwig, H. Kuita, M.E. Ludwig, H.J. Auman, T.J. Kubiak, D.A. Best, P.D. Jones and D.E. Tillitt, and J.P. Giesy. 12th Annual Meeting, Seattle, WA. November 3-7, 1991.

"Alterations in the Biological Potency of Environmental Planar Chlorinated Hydrocarbons." P.D. Jones, J.L. Newsted, D.A. Verbrugge, D.E. Tillitt, G.T. Ankley, T.J. Kubiak, D.A. Best, J.P. Ludwig and M.E. Ludwig, and J.P. Giesy. 12th Annual Meeting, Seattle, WA. November 3-7, 1991.

"Bioaccumulation and Biomagnification of Bio-active Organochlorine Contaminants as Determined by Bioassay and Chemical Analysis." P. D. Jones, G. T. Ankley, T. J. Kubiak, D. A. Best, J. P. Ludwig, M. E. Ludwig, H. Auman, S. Tanabe and N. Yamashita, and J.P. Giesy. 11th Annual Meeting, Washington, D.C., November 9-15, 1990.

SETAC-Europe.
“Impact of Chlorinated Dioxins and Furans on Japanese Quail, Ring-Necked Pheasant, and Chicken: Insights from *in Ovo* Studies.” : S.B. Wiseman , Y. Yang , J. Herve , R. Farmahin , T. Fredricks , P. Bradley , A. Cohen-Barnhouse , Y. Wan , P. Jones , J. Newsted , S. Kennedy , M. Zwernick , S. Bursian, and J.P. Giesy. To: SETAC Europe 19th Annual Meeting, May 31 – June 4, 2009 Goteborg, Sweden.

“Development of a H295R Cell Line Test to Evaluate Toxicant-Induced Effects on Steroidogenesis”. M. Hecker, M. Murphy, T. Gracia, P. Jones, X. Zhang, T. Sanderson and J. Newsted, and J.P. Giesy. To: 15th Annual Meeting, May 22-26, 2005, Lille, France.

"Q-RT-PCR Methods for Evaluating Toxicant-Induced Effects of Steroidogenesis Using the H295R Cell Line". X. Zhang, R.M.K. Yu, T. Gracia, J.T. Sanderson, P.D. Jones, J.L. Newsted, and R.S.S. Wu, and J.P. Giesy. To: 14th Annual Meeting, April 18-22, 2004, Prague, Czech Republic.

"In Vitro Dioxin-like Potencies and Cytotoxicity of N-heterocyclic PAH Derivatives". I. Sovadinova, R. Vykonalova, J. Jaroslav and L.Blaha, and J.P. Giesy. To: 14th Annual Meeting, April 18-22, 2004, Prague, Czech Republic.

"Effects of Chemicals on Steroidogenesis in H295R Cells". T. R. Gracia, K. Hilscherova, P. D. Jones, J.T. Sanderson, X. Zhang and J.L. Newsted, and J.P. Giesy. To: 14th Annual Meeting, April 18-22, 2004, Prague, Czech Republic.

"Acute Toxicity and Estrogenic Potency of Individual Nonylphenol Isomers" T. G. Preuss, P. D. Jones and H.-T. Ratte, and J.P. Giesy. To: 14th Annual Meeting, April 18-22, 2004, Prague, Czech Republic.

"Structure-toxicity Relationships for N-heterocyclic PAHs: In vitro Cytotoxicity and Dioxin-like Effects". L. Blaha, I. Sovadinova, R. Vykonalova and J. Janosek, and J.P. Giesy. To: 14th Annual Meeting, April 18-22, 2004, Prague, Czech Republic.

"PCB Distribution and Accumulation Patterns in an Ecosystem-Wide Investigation of the Kalamazoo River Flood Plain, Michigan, USA". P. Bradley, P. D. Jones, M. Zwiernik, A. L. Blankenship and D. Kay, and J.P. Giesy. To: 14th Annual Meeting, April 18-22, 2004, Prague, Czech Republic.
"Binding of Perfluorinated Chemicals to Serum Proteins". P.D. Jones, W.Y. Hu, W. De Coen, and J.L. Newsted, and J.P. Giesy, To: 13th Annual Meeting, April 27-May1, 2003, Hamburg, Germany.

"Principal Components Analysis of Dioxins from Rocky Mountain Arsenal and Denver, Colorado.". P.D. Jones, J.L. Newsted, G. Henningson, L. Williams, C. Bicher, and J. Slocomb, and J.P. Giesy. To: 13th Annual Meeting, April 27-May1, 2003, Hamburg, Germany.

"Comparison of Genome-Wide Gene Expression Analysis Methods". W. Hu, and P.D. Jones, and J.P. Giesy. To: 13th Annual Meeting, April 27-May1, 2003, Hamburg, Germany.

“Identification of Genes Responsive to Perfluorooctane Sulfonate Acid Using Gene Expression Profiling ”. W. Hu, P.D. Jones, C. Lau, and J.L. Newsted, and J.P. Giesy. To: 13th Annual Meeting, April 27-May1, 2003, Hamburg, Germany.

“Estrogenic Activity in Waste Waters of Different Origins Before and After Treatment with Advanced Methods”. A. Coors, P.D. Jones and H.T. Ratte, and J.P. Giesy. To: 13th Annual Meeting, April 27-May1, 2003, Hamburg, Germany.

“Demonstration of a Substantial Reduction in Uncertainty after Application of Site-Specific Data - A Case study with Wildlife Exposure to PCBs via Plants in the Diet.” M. Zwiernik, A.L. Blankenship, P.D. Jones, K. Kannan, D. Kay, P. Bradley, K. Strause, S. Pastva and R. Holem, and J.P. Giesy. To: 12th Annual meeting, May 12-16, 2002, Vienna, Austria.

“Comparison of Two Common Treatment Processes of Municipal Landfill Leachate with Regard to the Elimination of Xenoestrogens.” A. Coors, P.D. Jones, and H.T. Ratte, and J.P. Giesy. To: 12th Annual Meeting, May 12-16, 2002, Vienna, Austria.

“Demonstration of a Substantial Reduction in Uncertainty after Application of Site-Specific Data–A case Study with Wildlife Exposure to PCBs via Plants in the Diet.” To: 12th Annual Meeting, May 12-16, 2002, Vienna, Austria. M. Zwiernik, A.L. Blankenship, P.D. Jones, D. Kay, P. Bradley, K. Strause, S. Pastva and R. Holem, and J.P. Giesy.

“The Effects of Perfluorinated Chemicals on the Steroid Binding Properties in the blood of Fish and Birds”. W.M. De Coen, W. Hu, P. Jones and K. Kannan, and J.P. Giesy. To: 11th Annual meeting, May 6-10, 2001, Madrid, Spain.

“Comparisons Among Peffluorinated Compounds of Effects on Gap Junction Intercellular Communication”. W. Hu, P.D. Jones, B.L. Upham and J.E. Trosko, and J.P. Giesy. To: 11th Annual meeting, May 6-10, 2001, Madrid, Spain.

“Tetrachlorodibenzo-p-dioxin Equivalents (TCDD-EQ) in Tissue Samples from Three Species in the Denver Metropolitan Area” K.K. Kemler, P.D. Jones and A.L. Blankenship, and J.P. Giesy. To: 11th Annual meeting, May 6-10, 2001, Madrid, Spain.

“The Use of Vitellogenin ELISA to Measure the Effects of Estrogenic Substances on Laboratory Fishes”. P. D. Jones, S. L. Pierens, E. M. Snyder, S. Miles-Richardson, V. J. Kramer, S. A. Snyder, K. M. Nichols, S. A. Villalobos and D. L. Villeneuve, and J.P.

Giesy. To: 3rd SETAC World Congress, May 21-24, 2000, Brighton, United Kingdom. Invited keynote

"Accumulation of PCBs in Southern Ocean Pilot Whales (Globicephala melas) From New Zealand Stranding Events" P. D. Jones, C. Schroder and P. J. Day, and J.P. Giesy. To: 3rd SETAC World Congress, May 21-24, 2000, Brighton, United Kingdom.

SETAC-Europe, German Language Division:

"Teratogenetic and genotoxic evaluation of several perfluorinated chemicals (PFCs)". S. Jernbro, P. Suares-Rocha, S. Keiter, D. Skutlarek, H. Färber, J. P. Giesy, P. D. Jones, H. Hollert & M. Engwall. To: Annual meeting, 3rd.-5th September in Landau, Germany.

SETAC-Asia-Pacific:

"OH-PBDE and MeO-PBDE's: Methods, Sources and Consequences". Y, Wan, S. B. Wiseman, X. W. Zhang, H. Chang, M. Hecker, P. D. Jones, M. H.W. Lam, K. Choi, S. Kim, K. Ji, J. S. Khim, S. Park, S. Park, J. Park, and J.P. Giesy. To: Society of Environmental Toxicology and Chemistry Asia Pacific, Annual Meeting, June 4-7, 2010, Guangzhou, China. ***Invited, Plenary Keynote***

"Trophodynamics of Polybrominated Diphenyl Ehters in the Marine Food Web of Bohai Bay, North China". Y. Wan, J. Hu, K. Zhang, L. An, P. Jones, and J.P. Giesy. To: Society of Environmental Toxicology and Chemistry (SETAC) 5th World Congress, August 3-7, 2008, Sydney, Australia.

"Binding of PFOS and Related Perfluorinated Chemicals to Serum Proteins". P.D. Jones, Wenyue Hu, Wim De Coen and J.L. Newsted, and J.P. Giesy. To: Annual meeting, September 28-October 1, 2003, Christchurch, New Zealand.

"Principal Components Analysis of Dioxins from Rocky Mountain Arsenal and Denver, Co.". P.D.Jones and J.P. Giesy To: Annual meeting, September 28-October 1, 2003, Christchurch, New Zealand.

SETAC Ohio Valley Regional Chapter

"Assessment of belted kingfisher (Ceryle alcyon) dietary exposure to PCDDs and PCDFs in the Tittabawassee River,". E.M. Koppell, R.M. Seston, M. J. Zwiernik, J.N. Moore, D.L. Tazelaar, H.L. Wong, P.W. Bradley, T.B. Fredricks, S.J. Coefield and P.D. Jones, and J.P. Giesy. To: 23rd Annual meeting, April 20-21, 2006, Fort Wayne, IN.

“Application of in situ hybridization to detect CYP19 A1 and A2 gene expression patterns along the HPG-axis at different organizational levels using Japanese Medaka (Oryzias latipes)”. J.W. Park, A.R. Tompsett, M. Hecker, P.D. Jones, J.L. Newsted, and J.P. Giesy. To: 23rd Annual meeting, April 20-21, 2006, Fort Wayne, IN.

“Human Adrenocarcinoma (H295R) Cells for Rapid In vitro Determination of Effects on Steroidogenesis: Hormone Production”. E.B. Higley, M. Hecker, J.L. Newsted, M.B. Murphy, P.D. Jones, R.Wu, and J.P. Giesy . To: 23rd Annual meeting, April 20-21, 2006, Fort Wayne, IN.

“Effects of Pharmaceuticals on gene expression and hormone production in H295R cell line using RTQ-PCR/ELISA”. T. Gracia, P.D. Jones, K. Hilscherova, EK.2, E.B. Higley, and J.L. Newsted, and J.P. Giesy. To: 23rd Annual meeting, April 20-21, 2006, Fort Wayne, IN.

“Comparison on the Toxicity Profile of PFOA and PFOS Using Genomic Data”. X. Zhang, L.W.Y. Yeung, K.S. Guruge, W.Y. Hu, P.K. S. Lam and P.D. Jones, , and J.P. Giesy. To: 23rd Annual meeting, April 20-21, 2006, Fort Wayne, IN.

SETAC-Prairy-Northern Regional Chapter
“Growth of Chironomus dilutes larvae exposed to ozone-treated and untreated oil sands process water”. J. Anderson, S. Wiseman, E. Franz , G.M. El-Din, J.W. Martin, P.D. Jones, and K. Liber, and J.P. Giesy. To: Annual meeting June 11, 2010, Saskatoon, SK.

Society of Toxicology:
“Profiling Gene Expression in Human H295R Adrenocortical Carcinoma Cells and Rat Testes to Identify Pathways of Toxicity for Conazole Fungicides”. H. Re, J. E. Schmid, J. Retief, Y. Turpaz, X. Zhang, P. D. Jones, J. L. Newsted, J. P. Giesy, D. C. Wolf, C. R. Wood, W. Bao and D. J. Dix. To: 44th Annual Meeting, March 6-10, 2005, New Orleans.

“Comparisons Among Perfluorinated Compounds of Effects on Gap-Junction Intercellular Communication.” W.-Y. Hu, P.D. Jones, B.L. Upham and J.E. Trosco, and J.P. Giesy. To: 41st Annual Meeting, March, 2002, Nashville, TN.

“Does Binding to Albumin Modulate The Biological Effects of Perfluorooctane Sulfonic Acid?”. P.D. Jones, W.-Y. Hu, and W. DeCoen, and J.P. Giesy. To: 41st Annual Meeting, March, 2002, Nashville, TN.

“Identification and Characterization of Genes Responsive to Perfluorooctane Sulfonic Acid Exposure During Exposure Using Differential Display and Gene Chips”. W.-Y.

Hu, P.D. Jones, C. Lau and R.G. Hanson, and J.P. Giesy. To: 41st Annual Meeting, March, 2002, Nashville, TN.

Wildlife Disease Association:
"Albatross As Sentinels of Organochlorine Pollution in the North Pacific Ocean". M Rolland, T. Colborn, P.D. Jones, C.L. Summer, H. Auman, D. Verbrugge and J.P. Ludwig. , and J.P. Giesy 43rd Annual Conf. 1995, East Lansing, Michigan.

SYMPOSIA AND WORKSHOPS:
"Toxicity pathway-based approaches to evaluate the impact of environmental chemicals". X. Zhang, S. Wiseman, M. Hecker, and P. Jones, and J.P. Giesy. With To: International Conference on Water Pollution and Management, May 23-27, 2009, Suzhou, China.

"Biological factors of importance in the bioaccumulation of dioxins in aquatic ecosystem". Y. Wan, P. Jones, and J.Y. Hu, and J.P. Giesy. To: International Conference on Water Pollution and Management, May 23-27, 2009, Suzhou, China.

"Impact of chlorinated dioxins and furans on Japanese quail, ring-necked pheasant, and domestic chicken: insights from *in ovo* studies." Y. Yang, S.B. Steve, J.C. Hervé, R. Farmahin, T.B. Fredricks, P.W. Bradley, A. Cohen-Barnhouse, Y. Wan, P.D. Jones, J.L. Newsted, S.W. Kennedy, M.J. Zwernick, S.J. Bursian, J.P. Giesy. To: Dioxin 2009: 29th International Symposium on Halogenated Persistent Organic Pollutants (POPs). August 23-28, 2009, Beijing, P.R.China.

"Evaluation of Environmental Endocrine Disrupting Chemicals Using the Medaka HPG Axis Model". X. Zhang, M. Hecker, J. L. Newsted, A. R. Tompsett, J-W. Park and P.D. Jones, and J.P. Giesy. To: 5th International Symposium on Persistent Toxic Substances"September 21-24, 2008, Beijing, China.

"Characterization of Mixed Function Monooxygenase Genes CYP1A1 and CYP1A2 in Mink (*Mustela Vison*) Exposed to Polychlorinated Dibenzofurans (PCDFs)." J.N. Moore, J.L. Newsted, M.J. Zwiernik, M. Hecker, P.D. Jones and S.J. Bursian, and J.P. Giesy. To: Dioxin 2008: 28th International Symposium on Halogenated Persistent Organic Pollutants (POPs). August 17-22, 2008, Birmingham, UK.

"Application of a medaka HPG axis real time PCR array method to chemical screening". X. Zhang, M. Hecker, A. Tompsett, J. Newsted, and P. Jones, and J.P. Giesy. To 35 Annual Aquatic Toxicity Workshop, October 5-8, 2008, Saskatoon, SK.

"In vitro evaluation of the toxic effects and endocrine disrupting potential of oil sands processed water and naphthenic acids. X. Zhang, S. Wiseman, E. Higley, P. D. Jones, M.

Hecker, M. Gamel El Din, and J. W. Martin, and J.P. Giesy. To 35 Annual Aquatic Toxicity Workshop, October 5-8, 2008, Saskatoon, SK.

"Aquatic toxicology of perfluoroctanesulfonate and related fluorochemicals J. Naile, J. Khim, J. Newsted, and P. Jones, and J.P. Giesy. To 35th Annual Aquatic Toxicity Workshop, October 5-8, 2008, Saskatoon, SK.

"Toxicity of perfluorooctane sulfonate (PFOS) to avian wildlife: ambient safe water value derivation and uncertainty analysis. J. Newsted, J. Naile, J. Khim, and P. Jones, and J.P. Giesy. To 35th Annual Aquatic Toxicity Workshop, October 5-8, 2008, Saskatoon, SK.

"Elucidating Changes in Aromatase (CYP19) Gene Expression in Japanese Medaka (Oryzias latapes) Exposed to Fadrazol: In Situ Hybridization in a Whole Animal Model". A.R. Tompsett, J.W. Park, M. Hecker, P.D. Jones, J.L. Newsted, D.W.T Au, E.X.H. Chen and R. S.S. Wu, and J.P. Giesy. To: Marine Environmental Research and Innovative Technology, 3rd Annual Symposium, January 4-5, 2007, Hong Kong, China.

"Human Adrenocarcinoma (H295R) Cells for the Rapid, *in vitro* Determination of Effects on Steroidogenesis: Gene Expression, Sex Steroid Concentrations and Aromatase Activity". J.L. Newsted, M. Hecker, P.D. Jones, J.P. Giesy, R. Yu and R.S.S. Wu, and J.P. Giesy. To: Intrnational Forum on Computational Toxicology, May 21-23, 2007, Research Triangle Park, North Carolina, USA. ***Invited***

"Mechanistic Classification of Environmental Endocrine Disrupting Chemicals". X. Zhang, M. Hecker, J.L. Newsted and P.D. Jones, and J.P. Giesy. To: To: 15th International Cnference on Environmental Bioindicators, June 7-9, 2007, Hong Kong, China.

"Total fluorine analysis of fish samples using a novel combustion ion chromatography approach." J. Naile, J. S. Khim and P.D. Jones, and J.P. Giesy. To: 34th Aquatic Toxicity Workshop, Halifax, Nova Scotia, October 1, 2007.

"Differential effects of environmental chemicals and selected pharmaceuticals on aromatase activity." E. Higley, J.L. Newsted and M. Hecker, P.D. Jones and X. Hang, and J.P. Giesy. To: 34th Aquatic Toxicity Workshop, Halifax, Nova Scotia, October 2, 2007. ***Best student poster presentation.***

"Chemical Induced Changes in Gene Expression Patterns Along the HPG Axis at Different Organizational Levels in the Japanese Medaka ". A. Tompsett, J.-W. Park, M. Hecker, P. D. Jones and J. W. Newsted, and J.P. Giesy. To: US EPA STAR

Computational Toxicology Progress Review Workshop, July 18-19, 2005, Research Triangle Park, North Carolina.

"Separation and Characterization of Structural Isomers of Perfluorinated Compounds." H. Yoo, P.D. Jones, P.W. Bradley, M… Guzvic, B.L. Uptam, J. E. Trosco and J.L. Newsted, and J.P. Giesy. To: FLUOROS: International Symposium on Fluorinated Alkyl Organics in the Environment, August 18-20, 2005, Toronto, Ontario, Canada.

"Panax Ginseng Extracts Accelerate TCDD Excretion in Rats". J. Moon, C. Lee, P. D. Jones, H. Lim, Y. Kim, D. Kang, K. Ha and Y. Cho, and J.P. Giesy. To: 25th International Symposium on Halogenated Environmental Organic Pollutants and POPs, August 21-26, 2005, Toronto, Ontario, Canada.

"PCDDs and PCDFs in Aquatic and Terrestrial Food Webs of the Tittabawassee River, Michigan, USA". D. Kay, A. Blankenship, M. Zwiernik, J.L. Newsted and P.D. Jones, and J.P. Giesy. To: 25th International Symposium on Halogenated Environmental Organic Pollutants and POPs, August 21-26, 2005, Toronto, Ontario, Canada.

"Eco-Toxicological Evaluation of Perfluorooctane Sulfonate (PFOS) in the Environment". P.D. Jones, J.L. Newsted, D. Kay and M. Shotwell, and J.P. Giesy. To: World SECOTOX Conference, September 5-7, 2005, Brno, Czech Republic. ***Invited Keynote***

"Development of a H295R Cell Screening Test to Evaluate Toxicant-Induced and Hypoxic Effects on Steroidogenesis". . M. Hecker, M. Murphy, T. Gracia, P.D. Jones, X. Zhang, J.L. Newsted, R. Yu and R.S.S. Wu, and J.P. Giesy. To: Symposium, Centre for Marine Pollution and Environmental Research and Innovative Technology, City University of Hong Kong, Kowloon, Hong Kong, China, November 30-December 1, 2005.

"Principal Components Aanalysis of Dioxins from the Rocky Mountain Arsenal and Denver, CO." P.D. Jones, J.L. Newsted, J. Slocum, G. Henningson, L. Williams and C. Bicher, and J.P. Giesy. To: 23rd International Symposium on Halogenated Environmental Organic Pollutants (POPs), August 24-29, 2003, Boston, Massachusetts.

"Determination of Fluoroquinolone Antibiotics in Wastewater Effluents by Liquid Chromatography-Mass Spectrometry and Fluorescence Detection". H. Nakata, K. Kannan and P.D. Jones, and J.P. Giesy. To: 23rd International Symposium on Halogenated Environmental Organic Pollutants (POPs), August 24-29, 2003, Boston, Massachusetts.

“Elimination of Estrogenic Activity in Advanced Waste Water Treatment”. A. Coors, P.D. Jones and H.T. Ratte, and J.P. Giesy. To: Ecohazard 2003, International Water Association, September 14-17, 2003, Aachen Germany.

“Eological Risk Assessments for Perfluorinated Fatty Acids in the Marine Environment”. P.D. Jones, J.L. Newsted, M.K. So, S. Taniyasu, N. Yamashita, P.K.S. Lam and R.S.S. Wu, and J.P. Giesy. To: 4th International Conference on Marine Pollution and Ecotoxicology, June 1-5, 2004, Hong Kong, SAR, China. ***Invited, Plenary Keynote***

“Toxicological Perspectives on Perfluorinated Compounds in Avian Species”. P. D. Jones, and J.P. Giesy To: 24th International Symposium on Halogenated Environmental Organic Pollutants and POPs, September 6-10, 2004, Berlin Germany. ***Invited Keynote***

“Effects to Marine Mammals”. P. D. Jones, K. Kannan and , A. L. Blankenship, and J.P. Giesy. To: Costal and Estuarine Risk Assessment Forum”. July 20-21, 2000, Williamsburg, VA.

“Dioxin-like and Non-dioxin-like Toxic Effects Polychlorinated Biphenyls: Implications for Risk Assessment.” K. Kannan, P. D. Jones and A.L. Blankenship, and J.P. Giesy. To: SECOTOX, 6th Annual meeting of the Eastern European Regional Section (In conjunction with the 3rd annual meeting of the Union of Hungarian Toxicologists, Sept. 13-19, 1999, nföldvár, Hungary. ***Invited Keynote***

“Dioxin-like and Non-dioxin-like Toxic Effects of Polychlorinated Biphenyls (PCBs): Implications for Risk Assessment”. K. Kannan, A.L. Blankenship and P.D. Jones, and J.P. Giesy. To: Dioxin >99, 19th International Symposium on Halogenated Environmental Organic Pollutants, September 12-17, 1999, Venice, Italy. ***Invited***

”Vitellogenin as a Biomarker for Environmental Estrogens”. P. D. Jones, W. De Coen and L. Tremblay, and J.P. Giesy. To: 3rd International Water Association (IWA) Specialized Conference on Hazard Assessment and Control of Environmental Contaminants (ECOHAZARD >99). December 5-8, 1999, Otsu, Japan. ***Invited, Keynote***.

“Effects of Estrogenic Substances on Laboratory and Feral Fishes”. P.D. Jones, S.A. Villalobos and D.L. Villeneuve, and J.P. Giesy. To: International Symposium on Environmental Endocrine Disruptors >99. December 9-11, 1999, Kobe, Japan. ***Invited, Plenary***.

"PCBs and 2,3,7,8-Substituted Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Albatross Tissues from Midway Island in the Central Pacific Ocean" P.D. Jones, D.J. Hannah, S.J. Buckland, P.J. Day, S.V. Leathem, L.J. Porter, H.J. Auman, J.P. Ludwig and C. Summer, and J.P. Giesy. To: Dioxin-'94, November 21-27, 1994 Kyoto, Japan.

"Uptake, Disposition and Effects of Dietary 2,3,7,8-Tetrachlorodibenzo-p-dioxin on the Survival, Growth, Reproduction, Histology, Biochemistry and Hematology of Rainbow Trout" R. Crawford, **P.D. Jones**, D.E. Tillitt, G.T. Ankley, J.L. Newsted, L.L. Williams, G. Walther and D.A. Verbrugge, and J.P. Giesy. To: DIOXIN '93, 13th International Symposium on Chlorinated Dioxins and Related Compounds, Vienna Austria, September 21-24, 1993.

"Congener-Specific PCB and H4IIE-EROD Bioassay Data on Fishes From Three Michigan Rivers: Relevance to Hydroelectric dam Relicensing and Inland Dwelling Piscivorous Wildlife". M. E. Ludwig, P. D. Jones and B. Chisholm, and J.P. Giesy. To: Cause-Effect Linkages II Conference and Biennial Meeting of the International Joint Commission, Traverse City, Michigan. September 29-October 2, 1991. ***Invited***.

"H4IIE Bioassay TCDD-EQ in Colonial Waterbird Eggs from the Great Lakes Colonies 1986-1990 as Measured by H4IIE EROD Assay". D. E. Tillitt and P. D. Jones, and J.P. Giesy. To: Cause-Effect Linkages II Conference and Biennial Meeting of the International Joint Commission, Traverse City, Michigan. September 29-October 2, 1991. ***Invited***.

"Uptake of Toxicity from Great Lakes Fish by Double-Crested Cormorants and Herring Gull Chicks Measured by H4IIE EROD Bioassay and PCB Congeners". J. P. Ludwig, M. E. Ludwig, H. J. Auman, P. D. Jones and D. A. Verbrugge, and J.P. Giesy. To: Cause-Effect Linkages II Conference and Biennial Meeting of the International Joint Commission, Traverse City, Michigan. September 29-October 2, 1991. ***Invited***.

"Relative Concentrations of Coplanar PCB, Chlorinated Dibenzo-Dioxin (PCDD) and Dibenzo-Furan (PCDF) Congeners in Fish and Wildlife of the North American Great Lakes and Their Relationships with Observed Effects". P. D. Jones, M. Mora, J. L. Newsted, D. A. Verbrugge, R. Aulerich, S. Bursian, C. Summer, J. P. Ludwig, M. J. Ludwig, T. J. Kubiak, D. A. Best, G. T. Ankley, K. B. Lodge, D. E. Tillitt, K. Stromberg and S. Tanabe, and J.P. Giesy. To: Dioxin' 91, Research Triangle Park, NC. Sept. 23-27, 1991. ***Invited***.

"The use of TEFS for Understanding the Toxicology of Complex Mixtures of Chlorinated Hydrocarbons in Fish and Wildlife of the Great Lakes". P. D. Jones, M. Mora, J. L.

Newsted, D. A. Verbrugge, R. Aulerich, S. Bursian, C. Summer, J. P. Ludwig, M. J. Ludwig, T. J. Kubiak, D. A. Best, G. T. Ankley, K. B. Lodge, D. E. Tillitt, K. Stromberg and S. Tanabe, and J.P. Giesy. To: Dioxin' 91, Research Triangle Park, NC. Sept. 23-27, 1991. ***Invited***.

"Utilization of an *in vitro* Assay to Investigate the Environmental Effects of Planar, Halogenated Hydrocarbons". P. D. Jones, D. E. Tillitt, J. L. Newsted, D. A. Verbrugge, N. DeGalan, G. T. Ankley, T. J. Kubiak, D. A. Best, M. E. Ludwig, and J. P. Ludwig, and J.P. Giesy. To: Physiological and Biochemical Approaches to the Toxicology and Assessment of Environmental Pollution. Utrecht, Netherlands. August, 1990.

"Use of an *in vitro* Biochemical Assay to Assess Environmental Contamination". P. D. Jones, D. Tillitt and G. Ankley, and J.P. Giesy. To: International Symposium on Aquatic Ecosystem Health,. Waterloo, Ont., Canada. July, 1990. ***Invited***.

20. PATENTS GRANTED

Not Applicable

21. RESEARCH GRANT AND CONTRACT INFORMATION

New Grants/Contract Received

2011-2012 Boreal SongBird Initiative
Contamination of Country Foods by oilsands activities.
$280,000

2011-2012 Health Canada
(National First Nations Environmental Contaminants Program)
"In Land And Life: Cadmium and Health Implications for Indigenous Communities in Central Alberta. $140,000

2011-2014 (Global Institute for Water Security)
'Exotic' Chemical Contaminants in the South Saskatchewan River Basin. Paul Jones, Alan Cessna, Marly Waiser, John Giesy, Markus Hecker, Gordon Putz, Jim Kells, David Janz and Steven Siciliano. (**Co-Principal Investigator)**
$590,000

2011-2014 (Global Institute for Water Security)
Paleolimnological Studies of Lake Diefenbaker. Lorne Doig, Karsten Liber, Paul D Jones and John P. Giesy (**Co-Principal Investigator)**
$375,117

Ongoing Grants/Contracts

University of Saskatchewan New Faculty Scholarship
$18,500

University of Saskatchewan NSERC Bridge Fund
2010 “Interactions between cold adaptation and Chemical Sensitivity $10,000

Alberta Water Resource Institute
2008-2011 Remediation of Oil Sands Process Water and Predicting
and Monitoring of Environmental Effects
(To J.P. Giesy P.D. Jones and S. Wiseman) $800,000

Western Economic Diversification Fund
2007 Analytical Tools for Industry (To K. Liber P.D. Jones
And others) $465,000

Completed Grants/Contracts

Funding Attracted (In New Zealand only PDJ sole PI)

ESR (Environmental Science and Research Ltd.) Capital Expenditure Program
1998-1999 Assessment of Endocrine Disrupters using Cell Culture
Methods $56,000

New Zealand Ministry for the Environment
1998 Preparation of Reports for the Organochlorines Program.
$19,820

New Zealand Ministry for the Environment (with Kingett Mitchel Ltd.)
1998 Review of Indicators for Toxic Contaminants in the
Environment $13,770

FRST Non Specific Output Funding (NSOF)
1997-1998: “Soil Microbial Diversity” $60,000

Foundation for Research Science and Technology (FRST)
1997-1998: Environmental Effects of Chemical Contaminants
on Cetaceans. $80,000

Environment Bay of Plenty (Formerly the Bay of Plenty Regional Council)
1997 Investigation of Chemical Accumulation and Biological
Responses of Rainbow trout (*Onchorhynchus mykiss)* in
the Tarawera River $20,350

FRST Non Specific Output Funding (NSOF)
1996-1997:- "Implementation of New Molecular Biology Techniques $74,000

Environment Waikato (Formerly Waikato Regional Council)
1995-1997 The Use of Fish Health Indicators for Environmental Monitoring of the Waikato River $67,570

Foundation for Research Science and Technology (FRST)
1993-1996: "Environmental Effects of Chemical Contaminants" $312,000

Directors Post Doctoral Research Fellowship (DSIR Chemistry Division) $80,000

In the USA (Only proposals on which PDJ was a significant (>50%) contributor)

US EPA Science to Achieve Results (STAR) Program on Computational Toxicology and Biology in Hazard Identification and Risk Assessment.
2004-2007 "Chemical Induced Changes in Gene Expression Patterns (GEPs) using a Small Fish Model: A Systems Approach". $750,000

US EPA.
2004-2005 "Optimization of an Assay using the H295R Cell Line to Identify Chemical Modulators of Steroidogenesis and Aromatase Activity". $602,871

Brown and Caldwell, Maui, Hawaii.
2003 "Analysis of Industrial Chemicals in Waste Waters from Honolulu". $19,020

Ciba Specialty Chemicals, Manchester, UK.
2003 "Assessment of the Estrogenic Potential of Fluorinated Compounds". $15,000

US EPA
2002-2004."Use of the H295R Human Adrenocortical Carcinoma Line for Screening for Effects of Compounds on Steroidogenesis" $341,000

Hercules, Inc.

2001-2002 “Assessment of Toxicity of perfluorinated Compounds” $75,000

3M Company

1999-2000 “Perfluorinated Chemicals in the Environment” $1,300,000

Michigan Audubon Society and McGregor Fund
1989-1990 "Biochemical Determination of Mixtures of Co-planar, Polychlorinated Hydrocarbon in Great Lakes, Fish-eating Colonial Waterbirds". $89,135

U.S. Fish and Wildlife Service
1989-1990 "Use of the H-4-II-E rat Hepatoma Cell/Environmental Extract Bioassay for Determination of 2,3,7,8-Tetrachlorodibenzo-p-dioxin equivalents in Environmental Samples". $22,500

U.S. EPA
1989-1991 "Effects of Mixtures of Toxic Chemicals to Colonial, Fish-eating Water Birds of Green Bay Wisconsin". $40,000

In the Canada (Only proposals on which PDJ was a significant (>50%) contributor)

Dow Chemical Company
2007-2008 Dibenzo-furans in fish of the Tittabawassee and Saginaw Rivers (To J.P. Giesy and P.D. Jones) $650,000

Dow Chemical Company
2007-2008 Dynamics of Polychlorinated Dibenzo Furans in Tissues of Japanese Quail, Chickens and Turkeys (To J.P. Giesy P.D. Jones and others) $658,000

Dow Chemical Company
2004-2008 Field Studies in Support of the Tittabawassee River Ecological Risk Assessment (To J.P Giesy P.D. Jones and others) $1,968,765

US-EPA Science to Achieve Results (STAR) program
2007-2007 Chemical Induced Changes in Gene Expression Patterns (To J.P. Giesy P.D. Jones and 2 others) $304,878

ENTRIX/US-EPA

2005-2007 Use of the H295R Human Adrenocortical Carcinoma Line
(To J.P. Giesy P.D. Jones and others) $162,200

22. ARTISTIC EXHIBITIONS OR PERFORMANCES

23. PROFESSIONAL PRACTICE

Society and Editorial Board Memberships

1994 - Elected regional representative of the Australasian Society for Ecotoxicology
1995 - Elected to the Editorial Board of "Environmental Toxicology and Chemistry"
2001 - Elected to the Editorial Board of "The Australasian Journal of Ecotoxicology"
2001 - Elected to the Editorial Board of "Environmental Toxicology and Chemistry"
2003-08 Associate Editor "Chemosphere".

Journals for which Papers have been Reviewed

Environmental Toxicology and Chemistry
Environmental Science and Technology
Environmental Health Perspectives
Australasian Journal of Ecotoxicology
Toxicological Sciences
Chemosphere
Marine Mammal Science
New Zealand Journal of Marine and Freshwater Research
Marine and Freshwater Research (Australia)
Aquatic Toxicology
Toxicological Sciences
Toxicology and Applied Pharmacology
Environmental Science and Pollution Research

24. CONSULTING WORK UNDERTAKEN

Senior Project Scientist, Giesy Ecotoxicology Inc., Williamston, Michigan. 1999-2006
Project Consultant, ENTRIX Inc., Houston, Texas. 1999-present

Preparation of a briefing document for the interagency working group in support of the UNEO Global POPs treaty. "Organochlorine Residues in and Their Effects on Fish and Wildlife of the North American Great Lakes", John P. Giesy, Paul D. Jones, Kurunthachalam Kannan and Alan L. Blankenship.

Data Quality Assurance for the assessment of PCB contamination in the Kalamazoo river Area of Concern, MI, USA. (2002-2004)

Pattern Recognition Techniques for Dioxins and PCBs on the Rocky Mountain Arsenal, CO, USA. For US-EPA. (2002-2003)

25. DEPARTMENTAL AND COLLEGE COMMITTEES

2011-present Teaching and Learning Committee, School of Environment and Sustainability.

2010-2011 Admissions and Awards Committee, School of Environment and Sustainability.

2009-present (Chair) Seminar and Special Presentations Committee, School of Environment and Sustainability. 2009-present.

2007-present Aquatic Toxicology Research Facility Management Committee, Toxicology Centre.

26. UNIVERSITY COMMITTEES

2011-2014 University of Saskatchewan Council – member at large.

2011-2014 Teaching and Learning Committee of Council (TLCC).

2009-Present University Committee on Laboratory Supplies and Small Equipment Purchasing.

2007-Present Local Safety Committee #21, OVPR.

27. PROFESSIONAL AND ASSOCIATION OFFICES AND COMMITTEE ACTIVITY OUTSIDE UNIVERSITY

Not Applicable

28. PUBLIC AND COMMUNITY CONTRIBUTIONS

UNIVERSITY RELATED

Not Applicable

NOT UNIVERSITY RELATED

Not Applicable

29. EXTENSION PUBLICATIONS AND ACTIVITIES

Not Applicable