Ecologically-Based Models To Assist The Burns Bog Ecosystem Review

Richard Sims, Jeff Matheson and Sergei Yazvenko

November 10, 1999

Introduction

This document provides a set of frameworking tools or "models" for the Burns Bog Ecosystem Review, to help set the stage for the four Technical Review Meetings (TRM). This is a working document, so it is anticipated that these models may be revised or replaced, either through the meetings or while collating other review / feedback. The overall intent is to help provide an initial base to apply background documents, evaluations and other data / information / knowledge to the Environmental Assessment Office's (EAO) decision-making phase of the Burns Bog Ecosystem Review.

A set of four frameworks are presented here, including:

1) an overview process model of wetland ecosystems;
2) an edatopic grid model for wetlands;
3) a process for relating ecosystem attributes to decision-making; and,
4) an environmental decision-making framework.

Models 1) and 2) are based in "purer" ecology and deal with biological / abiotic components and those ecological processes that are key "drivers" within wetland ecosystems. Model 3) depicts how ecological features can be linked to human-derived means of evaluating the significance and risk associated with ecosystem change and impact, and it also shows how the subject areas of the meetings fall within this overall framework. Model 4) then identifies the mechanisms that are needed in the human-directed process of ecological assessment.

Model 1: Wetland Ecosystem Processes

The overall process model of wetland ecosystems (Fig. 1) is adapted from overview models and concepts previously provided by Wells (1996), Holling (1986), Banner *et al.* (1988), Glaser (1992), Vitt (1994), Damman (1995), Zoltai and Vitt (1995), Parkyn *et al.* 1997, Warner 1996 and others. The current model identifies three core sets of wetland processes: ecological, hydrological / physical, and hydrochemical / geochemical. Within each of these three central spheres (Fig. 1), there are many processes and cycles that are critical to the maintenance and well-being of wetland ecosystems. For example, energetics, productivity, decomposition, biogeochemical cycling and others are important components of "ecological processes".

There is considerable interdependence among these three sets of wetland processes, hence the areas of overlap among the three central spheres. Two over-arching effects upon these sets of processes are climate and geomorphology. Climate directly affects all three processes, especially ecological processes, whereas geomorphology is more directly associated with hydrological / physical and hydrogeochemical / geochemical processes.

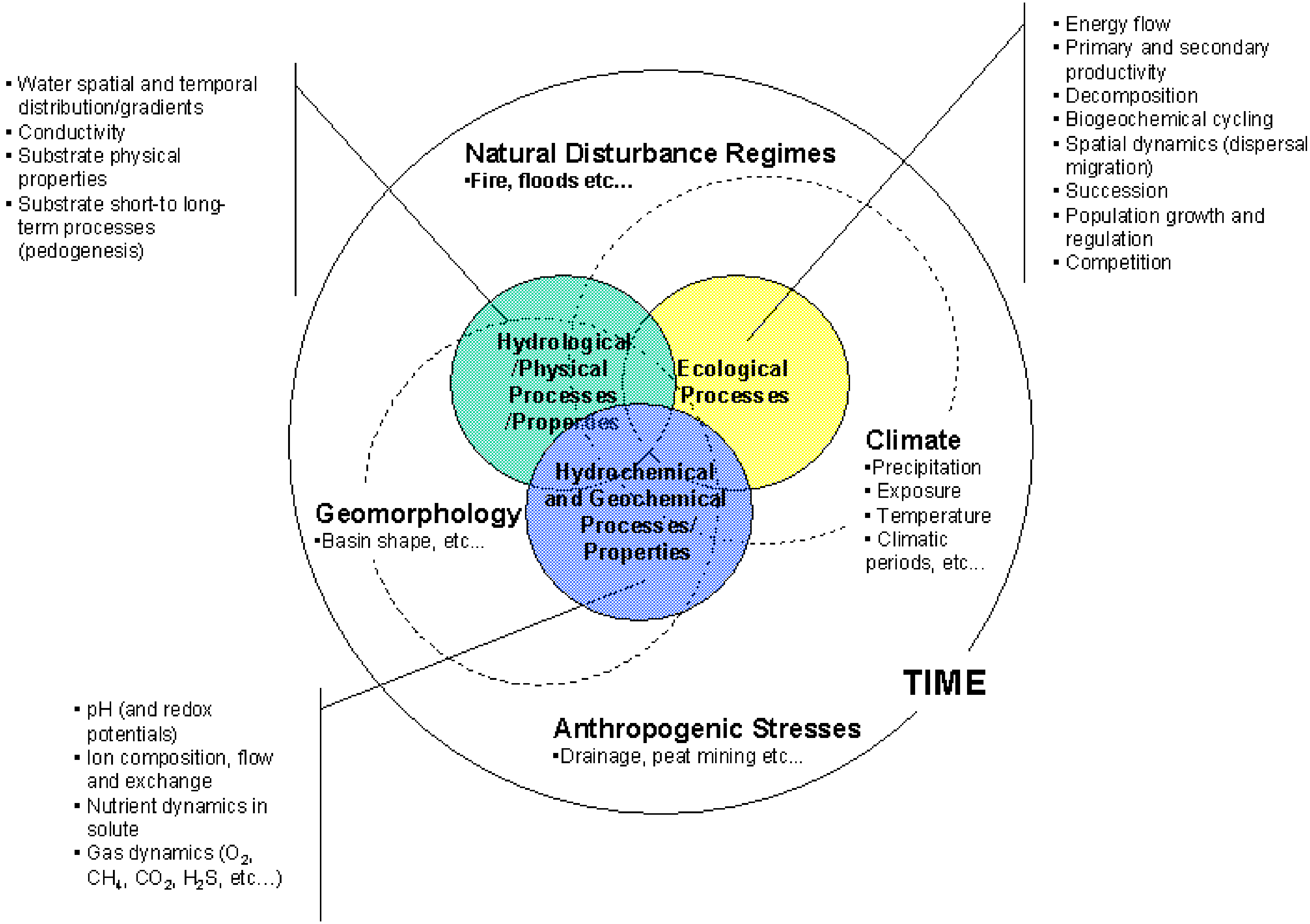


Figure 1. Factors of peatland development.

Natural and human-related stressors influence all three sets of processes to varying degrees, and at different times, depending upon such factors as the type, frequency, intensity and duration of the disturbance. Natural disturbance regimes may include fires, flooding, drought, disease, pest outbreaks, etc… Human related stressors include drainage, intentional flooding, peat extraction, farming, habitat alteration and fragmentation, eutrophication, the introduction of exotic species, etc… Cumulative effects may result from a combination of natural and human-induced stressors upon wetland ecosystems.

The wetland process model (Fig. 1) provides a generalized framework for integrating ecological processes and functions into the Burns Bog Ecosystem Review. It helps identify and represent biological / physical attributes and the sets of processes / dynamics involved within wetlands, and places them within a relative framework.

Model 2: Edatopic Grid for Wetlands

Within BC’s Biogeoclimatic Ecosystem Classification system (Meidinger and Pojar 1991), widespread use is made of the "edatopic grid" approach to describing ecosystems in terms of gradients of soil moisture regime / soil nutrient regime; "ecosites" are characterized in terms of their position and extents within a two-dimensional grid. The edatopic grid is well accepted as a tool by ecologists working within BC, and it provides a simplistic non-specific type of ecosystem model that is based upon fundamental ecosystem characteristics of terrestrial sites.

Mackenzie and Banner (1999) have noted that these factors alone are unsuitable for accurately portraying the important site characteristics of wetland ecosystems. Drawing upon an earlier model proposed by Vitt (1994), they have incorporated two additional variables to the edatopic grid to express major driving factors in wetlands: acidity / alkalinity and the hydrodynamic index. The resulting model (Fig. 2) is a useful framework for use in the Burns Bog Ecosystem Review because it provides linkages to the currently-evolving provincial wetland classification system, and to the "bigger picture" of ecological classification and mapping in BC Mackenzie and Banner (1999).

The acidity / alkalinity of the water table relates directly to base cation content, and indirectly to nutrient availability in wetland ecosystems. Major floristic shifts occur over this gradient, particularly in peatlands (Hebda 1977, Glaser 1992, Vitt 1994). For example, ombrotrophic sites receive surface water from precipitation only and have few available base-cations, high acidity, very poor-nutrient regimes, and are dominated by Sphagnum mosses.

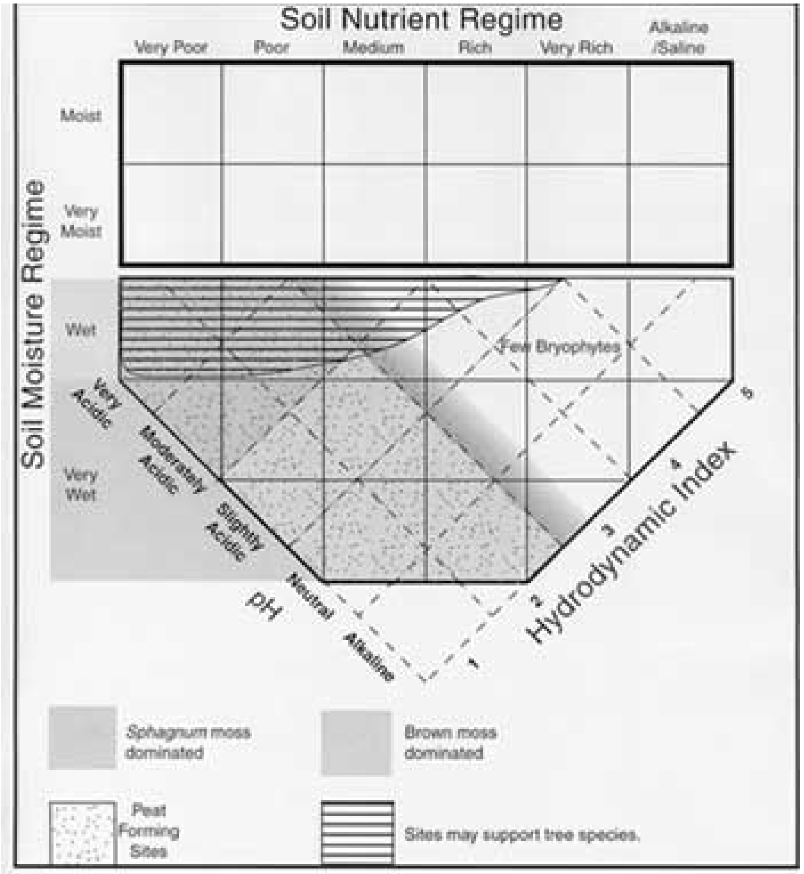


Figure 2. An edatopic grid model for wetlands in BC (from Mackenzie and Banner, 1999).

Water movement and seasonal water level fluctuation (hydrodynamics) in wetland ecosystems are as important as site factors as is soil moisture regime (e.g., Glaser 1992, Banner *et al.* 1995, Zoltai and Vitt 1995, Parkyn *et al.* 1997). Since the water table can

fluctuate significantly through the growing season, soil moisture regime may be hard to assess in many wetlands. Wetland sites with more stable hydrodynamic regimes (i.e., bogs, fens and some swamps) tend to promote deeper peat accumulations and have higher ground cover by bryophytes.

Model 3: Linking Ecological Features and Ecological Risk Assessment

The process for linking ecosystem attributes to decision-making (see Fig. 3) helps bring the data, concepts and models of science into the human domain of ecological risk assessment. Specifically, it helps identify key ecological features required to sustain an ecosystem and also to assess whether these features are at a sustainable level or are within a sustainable configuration (Schaeffer *et al.* 1988, Anon. 1998).

Figure 3 brings forward concepts introduced in the two previous diagrams, and provides a linkage (right-hand of Fig. 3) to the decision-making framework for ecological risk assessment that is presented in Figure 4. Also indicated in Figure 3 is how the themes of the four meetings (Wildlife & Fisheries, Hydrology, Ecosystem Processes, Global & Regional Significance) tie in with this overall concept.

Model 4: Environmental Decision-Making

The environmental decision-making framework (Fig. 4) describes a set of steps and feedback loops that may be used to assess and evaluate ecological risk / ecological integrity. The approach outlined here is based upon procedures developed over years of testing and evaluation by the US Environmental Protection Agency (IRP 1999), and prototyped by scientists and environmental decision-makers in the South Florida region (Everglades), as they sought ways to mitigate the long-term and cumulative impacts of developments (e.g., see Harwell *et al.* 1996, Harwell 1997).

The framework (Fig. 4) is appropriate for assessing potential or anticipated environmental risks (e.g., for comparing the environmental risks from alternate management policies) as well as existing environmental problems. Since there is no intrinsic ecological threshold for establishing ecological significance (Kaputska and Landis 1998), what is significant and what is acceptable needs to be determined through a decision-making process that is founded on sound scientific principles and process-based knowledge about ecosystems. Eventually the process must take place within the context of "human values" (Harwell *et al.* 1996, Harwell 1997, Gentile and Harwell 1998).

Figure 4 is adapted from the EPA's peer-review draft (IRP 1999) describing their formal procedure for integrated environmental decision-making and risk assessment. The overall approach involves an initial stage of problem formulation, with information and value assignments coming in from a range of sources, and the integrative consideration of risks and options. Analysis and decision-making is then undertaken as a second stage, and involves the integrated activity of risk comparison, options analysis and a process of screening / selection. Expert judgment may play a critical role in this phase of the process, as the biological bases for "ecosystem process modeling" typically includes insufficient knowledge and data gaps that are impossible to otherwise address. Another key component of the analysis and decision-making phase is the identification of performance measures which are used in the third stage (implementation and performance measures) to prepare formal report cards (Harwell *et al.* 1999) on the overall process via feedback loops.

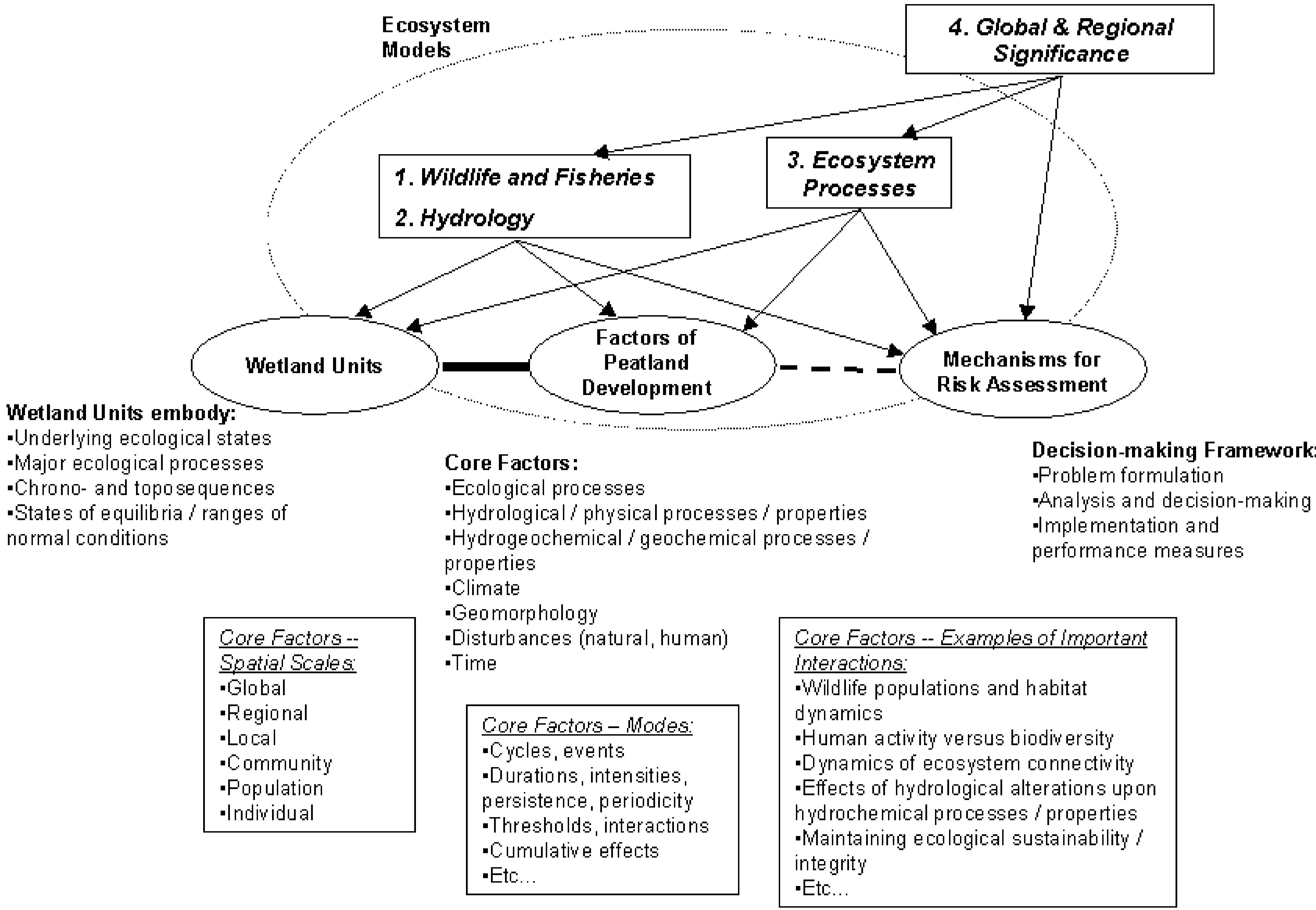
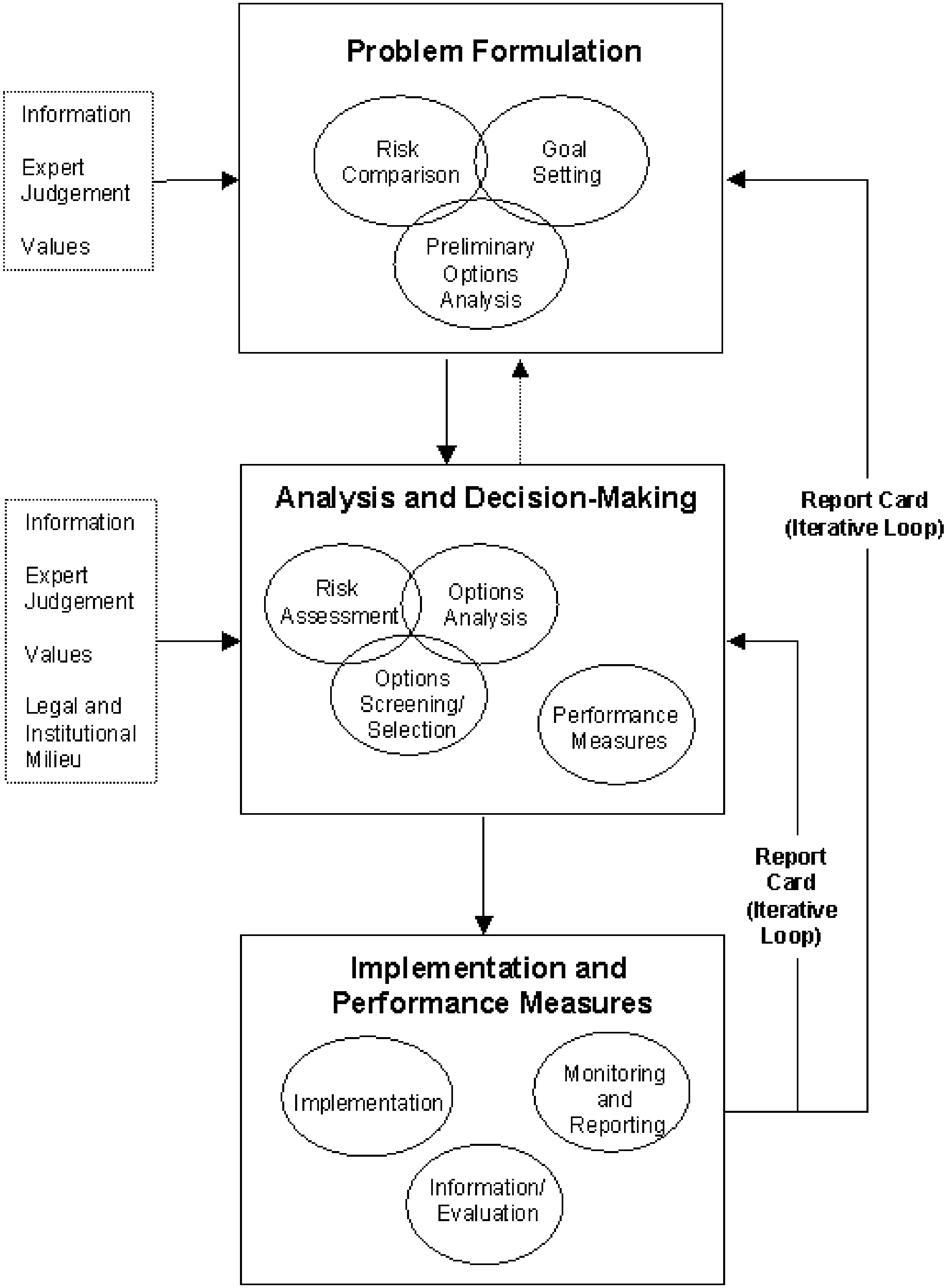


Figure 3. A process for relating ecosystem attributes to environmental decision-making.


Problem Formulation
Risk Comparison
Goal Setting
Preliminary Options Analysis
Information
Expert Judgement
Values
Analysis and Decision-Making
Risk Assessment
Options Analysis
Options Screening/ Selection
Performance Measures
Information
Expert Judgement
Values
Legal and Institutional Milieu
Report Card (Iterative Loop)
Report Card (Iterative Loop)
Implementation and Performance Measures
Implementation
Monitoring and Reporting
Information/ Evaluation

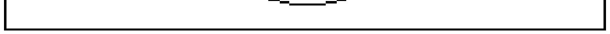


Figure 4. Environmental decision-making framework (from IRP 1999).

The process summarized above has considerable parallel to that being undertaken within Burns Bog. Similar steps have been followed, and the meetings represent part of the requirements for problem formulation, and help in the process of leading to analysis and decision-making. Other similarities to the EPA process that have been adopted in the Burns Bog Ecosystem Review include:

- Collation and interpretation of all available background information, and presentation of this in the most current scientific context;
- Creation of an interdisciplinary group of experts to provide important input, and the development of some integrated group perspectives;
- Emphasis on multifaceted affiliations, and the development of a shared scientific vision through workshops / charettes;
- Flexibility (throughout the process); and,
- The use of technological tools (especially GIS).

Discussion

The four models provided here can be used as an initial set of frameworking tools for the Burns Bog Ecosystem Review. They include two models that help to show relationships among basic ecological dynamics and processes that occur within wetland ecosystems. Also presented is a model that helps to "bridge" between the first two frameworks and the final one, which describes a generalized process for environmental decision-making.

The Burns Bog Ecosystem Review must deal with several conditions and situations for which data and information are limiting. Some of the difficult questions that need to be addressed are:

- What is the historical range of variation associated with the Bog’s hydrological regime?
- What are the historical ranges of variation associated with key ecosystem processes?
- What spatial extent is sufficient within Burns Bog so as to maintain a dynamic storage capacity that is sufficiently resilient against stresses (e.g., a series of dry years, etc…)?
- What are critical attributes of sustainability for the Burns Bog ecosystem?

Addressing the issue of sustainability is the most difficult chore. Using the models and concepts outlined in this document as a backdrop, the following five-step approach may provide a starting-point for this activity:

1. The "sustainable condition" and critical elements of it are developed using:

   a. direct reference to ecological models;
   b. comparison with data from other similar systems, or systems with similar processes;

c. compilation of measures or standards regarding sustainable conditions; and/or,
d. analysis / opinion by experts.

2. The current state / condition of the ecosystem is compared to the sustainable state.

3. The difference / divergence (if any) between the states are assessed, for example, by using a cumulative modeling approach. If the difference is small, the ecosystem may be deemed to be sustainable. The process also helps to spatially define critical functions within the landscape (e.g., see Suter 1990, Harwell *et al.* 1996).

4. As required, actions are developed by bringing current conditions (by attribute or function) into line with the sustainable condition (or some desired "ecological endpoint" (Gentile and Harwell 1998)).

5. Performance measures (i.e., means of monitoring progression towards the desired end-point(s)) must be carefully defined and then closely tracked (Harwell *et al.* 1999).

References Cited

Anon. 1998. *Compendium of Ecosystem Health Goals, Objectives, and Indicators. Indicators Quick Reference Guide.* Science Policy and Environmental Quality Branch, Environment Canada, Ottawa, Ont. (in partnership with the Inter-Agency Steering Committee). 18 pp. + appendices.

Banner, A., R.J. Hebda, E.T. Oswald, J. Pojar and R. Trowbridge. 1988. Wetlands of Pacific Canada. *In:* National Wetlands Working Group Canada Committee on Ecological Land Classification. *Wetlands of Canada.* Ecological Land Classification Series, No. 24. Polyscience Publications Inc., Montreal, Quebec.

Damman, A.W.H. 1995. Boreal peatlands in Norway and eastern North America: a comparison. *Gunneria* 70: 43-66.

Gentile, J.H. and M.A. Harwell. 1998. The issue of significance in ecological risk assessments. *Human & Ecol. Risk Assessm.* 4(4): 815-828.

Glaser, P.H. 1992. Raised bogs in eastern North America -regional controls for species richness and floristic assemblages. *Journal of Ecology* 80: 535-554.

Harwell, M.A., Long, J.F., Bartuska, A., Gentile, J.H., Harwell, C.C., Myers, V. and Ogden, J.C. 1996. Ecosystem management to achieve ecological sustainability: the case of South Florida. *Environ. Manage*. 20: 497-521.

Harwell, M.A. 1997. Ecosystem Management of South Florida… *BioScience* 47: 499-512.

Harwell, M.A., V. Myers, T. Young, A. Bartuska, N. Gassman, J.H. Gentile, C.C. Harwell, S. Appelbaum, J. Barko, B. Causey, C. Johnson, A. McLean,

R. Smola, P. Templet and S. Tosini. 1999. A framework for an ecosystem integrity report card. *Bioscience* 49(7): 543-556.

Hebda, R.J. 1977. *The Paleoecology of a Raised Bog and Associated Deltaic Sediments of the Fraser River Delta*. Ph.D. dissertation. University of British Columbia, Vancouver, B.C.

Holling, C.S. 1986. The resilience of terrestrial ecosystems: local surprise and global change. pp. 297-317 in Clark, W.C. and Munn, R.E. (ed.). *Sustainable Development of the Biosphere.* Cambridge Univ. Press, Cambridge, UK.

Integrated Risk Project (IRP). 1999. Integrated Environmental Decision-Making in the 21st Century Peer Review Draft - May 3, 1999. Science Advisory Board, Environmental Protection Agency.

Mackenzie, W. and A. Banner. 1999. Classification of Wetlands and Related Ecosystems in British Columbia. Wetland classification. Draft. Ministry of Forests Research Program.

Meidinger, D and J. Pojar. 1991. Ecosystems of British Columbia. Research Branch, BC Ministry of Forests.

Parkyn, L., R.E. Stoneman and H.A.P. Ingram (eds.). 1997. *Conserving Peatlands*. CAB International, New York.

Schaeffer, D.I., Herricks, E.E., and Kerster, H.W. 1988. Ecosystem health: I. Measuring ecosystem health. *Environ. Manage.* 12: 445-455.

Suter, G.W. 1990. Endpoints for regional ecological risk assessments. *Environ. Manage.* 14: 19-23.

Vitt, D.H. 1994. An overview of factors that influence the development of Canadian peatlands. *Memoirs of the Entomological Society of Canada* 169: 7-20.

Warner, B.G. 1996. Vertical gradients in peatlands. In: J. Mulamoottil,
B.G. Warner and E.A. McBean (Eds.), "Wetlands: Environmental Gradients,
Boundaries and Buffers: Proc. of an International Symposium, April 22-23,
1994. Lewis Publishers, Boca Raton etc. pp. 45-65.

Wells, E.D. 1996. Classification of peatland vegetation in Atlantic Canada. *Journal of Vegetation Science* 7: 847-878.

Zoltai, S.C., and D.H. Vitt. 1995. Canadian wetlands: environmental gradients and classification. *Vegetatio* 118(1-2): 131-137.