Available online at www.sciencedirect.com
ScienceDirect
Environmental Impact Assessment Review 27 (2007) 770–788
Environmental Impact Assessment Review
www.elsevier.com/locate/eiar

Impact significance determination—Pushing the boundaries

David P. Lawrence *

P.O. Station A, Box 3475, Langley, B.C., Canada V3A 4R8

Received 28 December 2006; received in revised form 18 February 2007; accepted 20 February 2007
Available online 26 March 2007

Abstract

Impact significance determination practice tends to be highly variable. Too often insufficient consideration is given to good practice insights. Also, impact significance determinations are frequently narrowly defined addressing, for example, only individual, negative impacts, focusing on bio-physical impacts, and not seeking to integrate either the Precautionary Principle or sustainability.

This article seeks to extend the boundaries of impact significance determination practice by providing an overview of good general impact significance practices, together with stakeholder roles and potential methods for addressing significance determination challenges. Relevant thresholds, criteria, contextual considerations and support methods are also highlighted. The analysis is then extended to address how impact significance determination practices change for positive as compared with negative impacts, for cumulative as compared with individual impacts, for socio-economic as compared with bio-physical impacts, when the Precautionary Principle is integrated into the process, and when sustainability contributions drive the EIA process and related impact significance determinations. These refinements can assist EIA practitioners in ensuring that the scope and nature of impact significance determinations reflect the broadened scope of emerging EIA requirements and practices. Suggestions are included for further refining and testing of the proposed changes to impact significance determination practice.

Keywords: Impact significance determination; Good practices; Positive impacts; Cumulative effects; Socio-economic effects; Precautionary Principle; Sustainability

* Tel.: +1 604 532 9889; fax: +1 604 534 9889.
E-mail address: lawenv@telus.net.

0195-9255/$ - see front matter © 2007 Elsevier Inc. All rights reserved.
doi:10.1016/j.eiar.2007.02.010

1. Introduction

Impact significance determination practice tends to be highly variable. Too often insufficient consideration is given to good practice insights. As a result the "learning curve" associated with impact significance determination practice is more gradual than it needs to be. Also, impact significance determinations are frequently narrowly defined addressing, for example, only individual, negative impacts, focusing on bio-physical impacts, and not seeking to integrate either the Precautionary Principle or sustainability. Broadening the scope of impact significance determination to encompass positive impacts, to consider social and economic impacts, and to systematically address uncertainties facilitates the design and application of EIA approaches and methods directed toward substantive environmental goals such as sustainability. A broadened and reoriented impact significance approach, although necessary, is not sufficient. It also is necessary to understand the implications of such modifications for the ways in which impact significance determination procedures can and should be designed and applied.

This article seeks to extend the boundaries of impact significance determination practice. It begins by providing an overview of good general impact significance practices, together with stakeholder roles and potential methods for addressing significance determination challenges. Relevant thresholds, criteria, contextual considerations and support methods are also identified. The analysis is then extended to address how impact significance determination practices change for positive as compared with negative impacts, for cumulative as compared with individual impacts, for socio-economic as compared with bio-physical impacts, when the Precautionary Principle is integrated into the process, and when sustainability contributions drive the EIA process and related impact significance determinations. Overall conclusions also are presented.

The analysis integrates distinctions, frameworks and insights derived from a series of applied research studies and presentations undertaken on behalf of the Joint Review Panel for the Mackenzie Gas Project, the Mackenzie Valley Environmental Impact Review Board, the Yukon Environmental and Socio-economic Assessment Board and the Canadian Environmental Assessment Agency (Lawrence, 2002, 2004, 2005). The conceptual distinctions, frameworks and schemas presented are a limited form of EIA theory-building (Lawrence, 1997). It is hoped that the analysis will be further tested and refined in practice at both the regulatory and applied levels.

2. Good general practices and support methods

Good general impact significance determination practices can be integrated into individual or composite impact significance determination procedures, with appropriate contextual adjustments (see Table 1). The suggested practices, presented in Table 1, are structured using procedural objectives. In addition, a proposed impact significance determination approach can be assessed against substantive objectives, and reviewed against major significance determination properties.

Good practice also encompasses procedures for grappling with such significance determination challenges as how to design a significance determination approach, how to adapt an approach to context, how to evaluate documented significance determinations, how to address study area tradeoffs and conflicting perspectives, what to do when public perceptions are at odds with technical and scientific analyses, and how to incorporate significance interpretations into impact management (Table 2). In addition, good practice impact significance determination entails careful attention to individual and joint role definitions for EIA specialists, technical and scientific specialists, decision-makers, government agencies and the public (Fig. 1), and to the appropriate context selection and application of significance thresholds, significance criteria,

Table 1
Examples of general good practices — impact significance determination

Criteria	Examples of Practices
Focused/efficient	• Focus efforts and resources on matters critical and relevant to decision-making. • Focus on key sustainability requirements and cumulative effects. • Focus on major community issues and tradeoffs. • Consider insights and lessons from comparable projects and environments in focusing significance determinations.
Consistent/unbiased	• Guard against advocacy and bias. • EIA guidelines (generic and project-specific) should explicitly and consistently address impact significance. • Ensure that comparable situations are treated in a comparable manner. • Ensure that alternatives are treated consistently. • Apply thresholds, criteria and significance determination procedures consistently.
Clear/explicit/understandable	• Clearly describe all procedures. The explanation of the approach should be straight-forward and non-technical. • Distinguish among impact magnitude, impact likelihood, environmental significance and impact significance. • Address significance with and without mitigation and enhancement. • Address significance of positive and negative effects. • Address significance of individual and cumulative effects. • Explicitly integrate public and agency concerns and preferences. • Distinguish, where appropriate, significance of impacts for various project phases, for various study areas, and for various time horizons. • Use illustrative materials where can facilitate understanding. • Make use of explicit criteria and decision aids whenever practical and appropriate.
Comprehensive/systematic/traceable	• Ensure a coherent, transparent and orderly procedure for integrating impact characteristics, environmental characteristics, contextual factors, institutional requirements and objectives, and the perspectives and concerns of interested and affected parties. • Ensure that the significance of positive, cumulative, and socio-economic effects are addressed. • Ensure that other parties can independently reconstruct how judgments were derived from relevant inputs. • Address significance for each EIA activity, with appropriate adjustments to reflect character of each activity.
Logical/substantiated/reasoned	• Text should be concise and thoughtfully reasoned. • Substantiate all methods and assumptions. • Interpretations and conclusions should flow logically from support materials. • Fully substantiate all thresholds, criteria, scaling levels and indicators. • Ensure that judgments are supported by qualitative and quantitative data, clear evidence, logical deduction and reasoned arguments. • Ensure that the attribution of significance is made in a rational, defensible and problem-relevant way.
Integrates knowledge	• Build on knowledge base established through EIA quality and effectiveness analyses (e.g., good practice principles). • Ensure that full use is made of technical and scientific knowledge. • Ensure that full use is made community and traditional knowledge. • Integrate lessons and insights from good practice significance determination procedures.

Table 1 (*continued*)

Criteria	Examples of Practices
Manages uncertainties	• Be explicit regarding level of confidence in significance judgments. • Ensure that the significance determination process is conducive to identifying and managing uncertainties. • Identify significant knowledge gaps and relevance to significance determination. • Use, as appropriate, uncertainty as a significance criterion, as a rationale for elevating scaling levels or as a trigger for mitigation, enhancement, monitoring or project rejection. • Explicitly consider the implications of information loss as focus and summarize. • Recognize action limits and uncertainties, especially regarding mitigation and enhancement effectiveness. • Integrate, as appropriate the Precautionary Principle into significance determinations. • Where uncertain, seek to minimize the consequences of being wrong regarding both impact prediction and mitigation/enhancement effectiveness.
Effective/decision-making support	• Ensure consistent with EIA and environmental regulatory requirements. • Link to international standards, conventions and guidelines. • Link to national and territorial policies and standards. • Assess in terms of compliance with land claims agreements and treaty rights.
Open/inclusive/involves public	• Define significance broadly. Burden of proof should be on those seeking to define more narrowly. • Ensure the involvement of technical specialists. •Ensure the direct, early and ongoing involvement of interested and affected parties. • Ensure that consultation methods appropriate to the characteristics and needs of each interested and affected party. • Consider public and agency concerns and preferences. • Ensure that the approach facilitates the involvement of all interested and affected parties.
Collective/collaborative/facilitates learning/facilitates conflict resolution	• Address impact significance from multiple perspectives. • Collaboratively design and adapt impact significance approach. • Ensure that significance determination approach is conducive to collaboration with interested and affected parties. • Ensure early, effective and frequent links to the broader public. • Ensure that membership in interactive forums reflect the full range of interests and values associated with the proposed action. • Make effective use of alternative dispute resolution, where appropriate. • Provide procedural assistance and training to participants, as appropriate.
Democratic/empowering/facilitates public support	• Employ simple to use and widely supported criteria, thresholds and decision rules. • Intensity and extent of public controversy can be a useful significance criterion. • Focus on what people consider is significant, in either a positive or negative sense. • Make a concerted effort to support rather than inhibit local and regional democratic decision-making.
Appropriate to context/real/genuine	• Place within the context of local and regional issues, conditions and challenges. • Link judgments to local perceptions, and to local and regional ecological, social, economic and political problems and challenges. • Place within the context of historical, current and emerging conditions. • Ensure that the significance determination methods and procedures are appropriate to the culture and to the social, ecological, economic, legal and political setting. • Take into account regulatory framework including relevant historical decisions.

(continued on next page)

Table 1 (*continued*)

Criteria	Examples of Practices
Appropriate participant roles	• Ensure that the roles of all parties in the significance determination process are clear and substantiated. • Make effective use of fully qualified specialists, with adequate local and regional experience and knowledge.
Adaptive/innovative	• Focus on those environmental components most susceptible to change and on likelihood and ability to enhance capacity to adapt to and manage change. • Ensure that process for determining significance can adapt to varying roles in the process. • Immediately seek to correct and resolve misinformation and misunderstandings. • Ensure that the significance determination process can be adapted to changing circumstances. • Hedge away from large losses and give greater weight to vulnerability. • Adapt approach to characteristics and needs of each interested and affected party.
Value-full/ethical/favours most vulnerable	• Focus on major values and value tradeoffs. • Ensure that the value basis for all judgments can be readily understood. • Devote particular attention to the most vulnerable environmental components and segments of society. • Provide measures to offset procedural inequities. • Take into account the interests, values and concerns of each interested and affected party. • Make a particular effort to involve those most directly affected, most vulnerable to change and least likely to be able to participate in the process.
Substantive/facilitates environmental enhancements/sustainable	• Ensure that the approach is conducive to the realization of substantive objectives. • Distinguish between ecological and socio-economic importance. • Place within the context of corporate and institutional social and environmental sustainability policies and objectives. • Analyze and interpret impact significance for each valued socio-economic and ecological component. • Ensure that the significance determination approach culminates in a judgment about project acceptability from a sustainability perspective.

effectiveness criteria for evaluating significance determination procedures, and contextual adaptations (Table 3).

Effective impact significance determination relies upon numerous support methods. For example:

- A variety of technical qualitative and quantitative analysis, aggregation and evaluation techniques are available for applying and combining thresholds and criteria (McBride et al., 1993);
- A range of effective public consultation and communications methods can support collaborative impact significance determination approaches (Finsterbusch, 1995; Stamps, 1997);
- Many group interaction procedures (e.g., peer review, Delphi, task forces, workshops, alternative dispute resolution) can facilitate collaborative approaches to significance determination (Glasson, 1995);
- Effective use can be made of community and regional plans and community surveys/interviews for establishing local and regional perspectives, values, and aspirations (Barrow, 2000);
- A variety of methods (e.g., distributional analysis, environmental justice and gender analysis, ecological and human health assessments) can help identify potentially significant inequities in the distribution of impacts (Burdge and Robertson, 1990; Seebohm, 1997);

Table 2
Good practices — addressing significance determination challenges

How to select a significance determination approach or approach combination
- Select approach or approach combination best suited to context.
- Adapt to context jointly with interested and affected parties.
- Ensure approach consistent with procedural and substantive objectives.
- Ensure good general practices and approach—specific good practices.
- Adapt to changing circumstances and preferences.

How to adapt the approach to fit the context
- Determine relevant project characteristics (e.g., components, time horizons, study areas).
- Review documents, web sites, oral histories and newspapers to identify historical and current issues, concerns and perspectives.
- Review documents to provide a sense of historical, current and likely future physical, ecological, social, cultural, economic, political and legal–administrative conditions and interactions.
- Review available submissions from interested and affected parties to identify major perspectives, issues, concerns and preferences.
- Consider pertinent laws, policies, treaty rights, agreements, values and interests.
- Consider relationships to other past, present and reasonably foreseeable future actions.
- Hold scoping sessions with general public and with a cross-section of interested and affected parties.
- Interview community leaders and most directly affected groups and individuals.
- Attempt to derive approach or approach combination most consistent with context.
- Design, refine, apply and adapt approach jointly with interested and affected parties.

How to evaluate impact significance determinations in EIA documents and procedures
- Review whether explicit and broad procedural and substantive significance determination objectives.
- Assess whether appropriate to local and regional context.
- Determine if reflects perspectives and positions of all major parties.
- Review if clearly defined, substantiated and applied thresholds, criteria and procedures.
- Determine if consistent with good general practices.
- Determine if consistent with approach good practices.
- Determine if consistent with procedural and substantive objectives.
- Determine if consistent with good practices for determining significance of positive, cumulative effects, socio-economic effects, the application of the Precautionary Principle and sustainability.
- Review adequacy of explanations for differences in conclusions regarding impact significance between documents and interpretations of other parties.

How to deal with tradeoffs among study areas (e.g., local, regional, national) in impact significance determinations
- Aim to achieve net benefits at each scale.
- Identify impacts that are locally, regionally and nationally significant. Manage at each level.
- Distinguish significance of impacts for various study areas and time horizons without ranking study areas or time horizons.
- Recognize that many interactions of impacts across study areas and time horizons. Consider implications for impact significance determinations.
- Make particular effort to prevent and offset adverse impacts and to provide lasting benefits at local and regional scale because larger scales inherent in project purpose and more severe impacts tend to be concentrated at local and regional scales.

What to do when there are multiple conflicting perspectives regarding which impacts are more significant and why
- All parties should provide full and succinct substantiation for significance judgments.
- Identify and explore nature of and reasons for perspective differences.
- Identify and explore validity of significance judgments by each party.
- Explore potential use of forums (including alternative dispute resolution) to see if parties can reach consensus regarding impact significance and how best to manage.
- Consider use of independent peer review to evaluate impact significance procedures and arguments by various parties (could include recommendations for resolution).
- Explore overlaps and gaps to determine potential for identifying middle ground positions that could be acceptable to all parties.
- Make difficult decisions regarding impact significance and substantiate basis for judgments.

(continued on next page)

Table 2 (*continued*)

What to do when public perceptions regarding what is significant are inconsistent with technical and scientific predictions and interpretations of impact magnitude, likehood and significance

- Review basis for all predictions (with or without peer review).
- Review basis and scope of all significance determination thresholds, criteria and decision rules (with or without peer review).
- Explore with each party rationale for interpretations.
- Clear up any misunderstandings and misconceptions.
- Review against experience with comparable projects in comparable environments.
- Initiate forums for parties to attempt to resolve perspective differences (with or without alternative dispute resolution).
- Ensure adequate allowance for uncertainties and potential repercussions of uncertainties.
- Explore whether concerns can be addressed through additional impact management.
- Allow for monitoring and management of perception-related impacts.

How to integrate significance interpretations into impact management

- Use mitigation and enhancement potential and/or reversibility as significance criteria.
- Focus mitigation and enhancement measures on potentially significant impacts. Where practical, apply to all adverse impacts.
- Examine potential for significant effects from mitigation and enhancement.
- Address significance of impacts, with and without mitigation, for both individual and cumulative effects.
- Monitor potentially significant impacts. Test accuracy of impact predictions and reliability of impact management measures.
- Take into consideration uncertainties regarding likelihood of significant impacts and the effectiveness of mitigation and enhancement.
- Monitoring should include, where practical, explicit significance thresholds and criteria, and explicit procedures to be enacted when monitoring detects potentially significant impacts.
- Roles of each party in determining and managing potentially significant impacts should be clearly defined.

- Literature reviews, applied research, and case study analyses can assist in identifying the significant impacts and environmental components associated with comparable projects and environments (Interorganizational Committee, 2003; Larcombe and Winds and Voices Environmental Services Inc., 2000);
- Various methods are available for characterizing values (e.g., value trees) and stakeholders (e.g., stakeholder analysis) (Harrop and Nixon, 1999);
- A range of procedures are available for exploring the uncertainties associated with impact significance determinations (e.g., uncertainty analysis, scenario writing, sensitivity analyses, adaptive management, the Precautionary Principle, risk assessment, fuzzy set analysis) (Hildén, 1997; Marusich, 2001) and
- Tools, such as scenarios, models, system maps, network diagrams, schematic trees, life cycle analysis and matrices, can enhance understanding of significant system interactions.

The general good practices, the good practices for addressing significance determination challenges, and the example thresholds, criteria and contexts should be tested and refined further in varying situations. The quality and effectiveness criteria should be refined, adapted and applied to evaluate significance determination requirements, guidelines, processes, documents and methods. Additional attention should be devoted to delineating the roles and role interactions of interested and affected parties in determining the significance of impacts for various project types and in various settings. Good practices and pitfalls to avoid in the use of significance determination support methods also should be considered further.

3. The significance of positive effects

The general tendency in assessment documents is to present positive effects from a proposed project in terms of a combination of project rationale (e.g., benefits to proponent and to end users)

and economic benefits (especially jobs and sales). Adverse effects are then minimized. This approach has several flaws when interpreting impact significance including 1) positive effects are not compared to negative effects to determine if the project is, on balance, in the public interest; 2) no consideration is given to unacceptable impacts (i.e., impacts that warrant project rejection regardless of project benefits); 3) no consideration is given to the distribution of benefits over space, over time, among population groups and sectors of society, and among valued ecosystem components; and 4) there is no link to sustainability.

The determination of the significance of beneficial effects helps to address these flaws. By interpreting the significance of beneficial effects positive and negative effects can be compared to determine if the project is in the public interest and should proceed (Joyce and MacFarlane, 2001). The tendency with most projects is dispersed benefits and concentrated adverse effects (e.g., energy for consumers and potentially significant adverse effects in close proximity to the proposed facility). There also is the concern with "leakage" of benefits outside the local and regional study areas. One way of offsetting these imbalances is to seek to achieve net positive effects in each study area (e.g., local, regional). It is especially important to prevent and offset adverse effects, through mitigation,

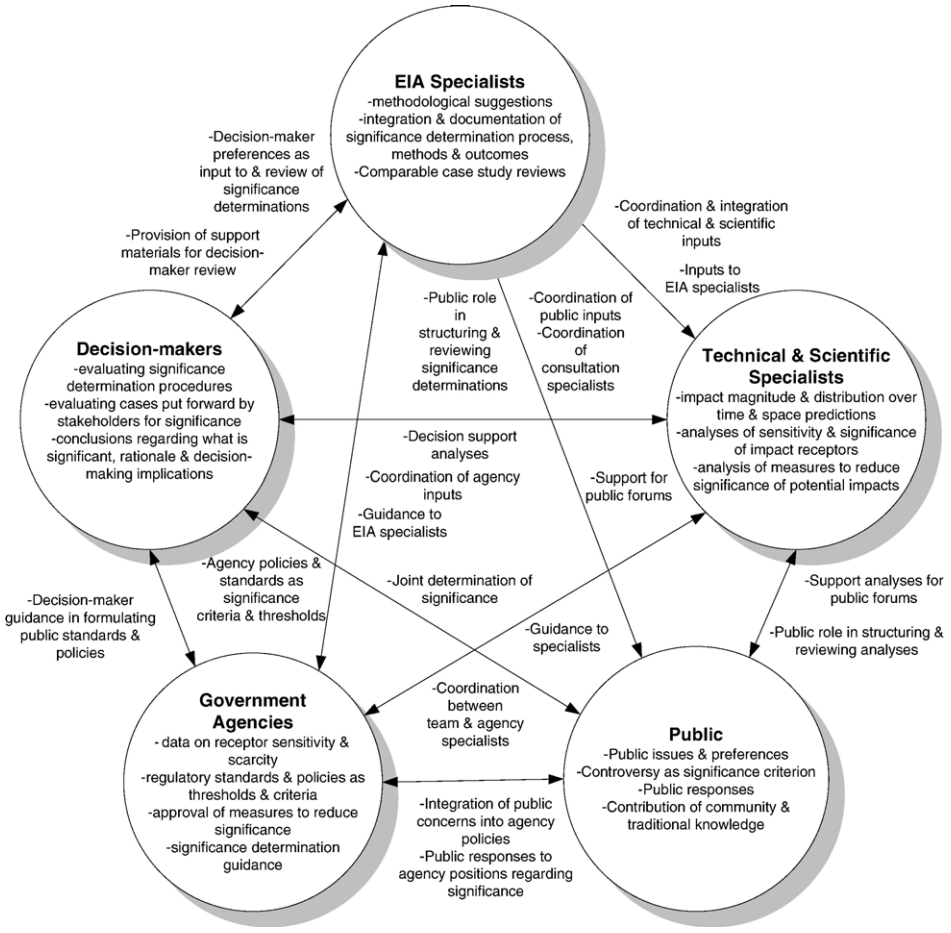

Fig. 1. Examples of significance determination roles.

enhancement, compensation and local benefits, in those areas where adverse effects are most concentrated.

In some cases natural or social features are so sensitive and important that no adverse effects can be tolerated. This may necessitate, for example, avoidance, compensation or enhanced benefits. An awareness of the desirability of optimizing beneficial effects, wherever practical, can lead to the modification and refinement of project benefits in a manner that facilitates the achievement of local and regional community and environmental aspirations (e.g., project as a catalyst for community sustainability, project as a means of facilitating community goals and plans).

Beneficial effects can be closely tied to community acceptance and support. Appreciating the dangers of "buying" support from vulnerable communities notwithstanding serious environmental consequences, it is still possible for a project to be designed and implemented such that project benefits are supportive of community needs and aspirations without necessitating environmental sacrifices. In such cases increased levels of community acceptance and support often result. Perceptions of positive and negative impacts affect behaviour even if based on misunderstandings. Also, perceptions vary among populations and sectors of society regarding which impacts are positive and negative, and to what degree. This suggests the need to consider how various populations and groups perceive which impacts are positive and negative, to what degree and why. This sensitivity is necessary not only because it is good practice but also because it can prevent and reduce adverse social and economic impacts.

Sometimes individuals, groups and communities are so vulnerable, often as a result of the impacts of historical activities that even small environmental changes can lead to severe consequences. Accordingly, particular attention should be given to the distribution of positive and negative effects among such individuals, groups and populations. Sometimes a special effort is required to ensure that the project is a net benefit in such cases. Community benefit agreements can be a useful tool in such cases.

The distribution of positive and negative effects over time also should be carefully considered. The classic concern is short-term benefits at the price of long-term costs. The dangers associated with this dilemma underscore the need for a concerted effort to avoid and minimize the "boom and bust phenomenon". A longer-term perspective regarding net benefits also facilitates the link to sustainability.

Significance determination practice would benefit from further analysis of the positive and negative implications of including positive effects in impact significance determinations. Consideration also should be given to the various ways in which positive effects can be integrated into significance determination procedures and the relative effectiveness of alternative approaches in a range of contexts.

4. Individual and cumulative effects

Cumulative effects assessment (CEA) explores whether individually insignificant impacts become significant when combined, at the project level, and in conjunction with other past, present or likely future activities affecting the same environment. The potential to induce cumulative effects can be a significance criterion when making judgments regarding the importance of individual impacts. Also, significance judgments occur as part of the CEA stage in the EIA process. Because of the nature of cumulative effects, significance thresholds and criteria tend to vary somewhat from those applied to individual impacts. CEA practitioners, for example, may interpret the significance of such impacts as:

- Amplifying and linear additive effects (Erickson, 1994);
- Compounding and synergistic effects;

Table 3
Examples of significance thresholds, criteria and context

Thresholds of significance	Generic criteria	Quality and effectiveness criteria	Context
–An effect is permanent or irreversible (can also occur when major options are precluded)	–Positive or negative	–The treatment of significance in EIA requirements and guidelines (e.g., explicitly addressed, linked to context, linked to EIA decisions, procedures for stakeholder involvement, specification of thresholds and criteria)	–Within different spatial contexts (e.g., global, national, regional, local)
–Receptors are highly sensitive or significant	–Degree of intensity or magnitude	–The significance determination process (e.g., explicit, traceable, procedures for threshold and criteria formulation and application, open, stakeholder role definition)	–Relative to other past, current and likely future actions likely to affect the same environment
–The intensity, magnitude, scale, duration or frequency is great as compared with ambient conditions	–Spatial extent	–Significance determination thresholds and criteria (e.g., explicit, consistent, relevant, addresses major impact dimensions, easy to apply, appropriate to context)	–Within a physical, ecological. social, economic, cultural, political or legal–administrative context
–Human health or ecological health and risks are potentially severe	–Frequency and duration	–The treatment of significance in EIA documents (e.g., criteria and thresholds defined and substantiated, explicit procedures for application of thresholds and criteria, interpretations substantiated, interpretations placed in context)	–From the perspective of various potentially affected interests
–There is a high degree of uncertainty	–Reversibility	–Significance determination methods (e.g., comprehensive, reliable, focused, explicit, readily applicable, readily understandable, accountable, unambiguous, facilitates review, facilitates public involvement)	–Relative to public objectives, policies, plans and programs
–Resources or features are very rare or unique	–Likelihood	–Data quality (e.g., utility, objectivity, integrity, reproducibility)	–Within a sustainability context
–Highly valued setting or setting type	–Uncertainty		
–There is a high level of public controversy	–Complexity		

(continued on next page)

Table 3 (*continued*)

Thresholds of significance	Generic criteria	Quality and effectiveness criteria	Context
–Substantial cumulative effects are likely	–Precedent setting		
–Regulatory standards are likely to be contravened	–Size of community affected		
–It is likely that the proposal will conflict with public policies, plans, programs, guidelines, criteria or objectives	–Sensitivity, stability and resilience of receptors		
–Transboundary effects are likely	–Rarity, scarcity and uniqueness		
–Community or ecological carrying capacity is jeopardized	–Direct or indirect		
–There is a high level of resource or energy consumption or waste generation	–Accidental or planned		
–Activity inherently causes significant effects	–Degree of controversy		
–Establishes a precedent for future actions with significant effects	–Mitigation potential		
–Major inequities in the distribution of effects	–Cumulative effects potential		
	–Inequity potential		
	–Relevance to current or potential government policies, plans or objectives		

- Discontinuous effects (e.g., cross boundary movements, time lags, spatial lags);
- Crowding effects (e.g., within a narrow time span, within a limited spatial area);
- Thresholds, triggers and structural surprises (e.g., exceeds ecological or community service capacity);
- Nibbling, habitat fragmentation, patchiness and incremental insults;
- Growth-inducing effects (e.g., spin-off activities);
- Precedent-setting actions or actions that represent a pre-condition to the implementation of another undertaking;
- Bio-magnification; and
- Feedback effects (Hegmann and Yarranton, 1995).

CEA tends to make greater use of holistic, interdisciplinary perspectives and methods (e.g., network diagrams and models) in seeking to better understand the importance of ecological and

socio-economic components and interactions, with and without individual and multiple interventions. The interpretation of impact significance, with and without mitigation, enhancement and local benefits also changes with an increased emphasis on positive impacts, and on goal setting and on impact management through regional planning, regional environmental and resource management, strategic environmental assessment, multi-project monitoring, public–private partnerships, and regional sustainability strategies. Particular emphasis is placed on the significance of cumulative impacts relative to the carrying and assimilative capacity of ecological and socio-economic systems, resources and communities.

The combination of complex regional ecological, social and economic systems, the difficulties in managing pervasive environmental problems, the ill-defined roles for the host of stakeholders, and the extended temporal and spatial horizons, tend to mean that uncertainty and uncertainty management assume an enhanced role when interpreting the significance of cumulative effects. Collaboration among interested and affected parties in data collection and analysis, and in impact interpretation and management is essential if meaningful, joint significance determinations are to be made. CEA can be an effective bridge between significance determination at the project or strategic levels, and significance determination as part of sustainability assessment.

Further analysis should be conducted of how significance determination practices change for cumulative effects. Methods generally effective for interpreting the significance of individual effects could be less or even inappropriate when applied to cumulative effects. Over time it should be possible to identify a suite of good practices for interpreting the significance of cumulative effects. Adaptations to context will be essential, as with all significance determination good practices.

5. Bio-physical and socio-economic effects

Scientific and/or the adaptive management models tend to be favoured when interpreting the significance of physical and biological impacts. With the scientific model, a high premium is placed on objectivity, on technically and scientifically sound databases, on quantification, and on the effective integration of consistent standards, objectives and protocols (Kirk, 2000; Lynch-Stewart and Associates, 2000, 2002). Adherents to this approach tend to favour technical impact significance methods. Supporters of adaptive management generally temper the scientific approach by stressing the need to adaptively manage uncertainty, and to periodically use collaborative procedures such as workshops. Workshops or similar forums provide the opportunity for government officials, specialists, environmental managers and other stakeholders to jointly decide what is important, integrate analyses and derive effective management strategies.

Differences between bio-physical and socio-economic impact assessment (SIA) have significance determination implications. Social and economic impacts, for example, commence with project announcement and planning (Erickson, 1994). People can and do alter their behaviour in anticipation of impacts (Finsterbusch, 1995). They adapt, to varying degrees, to change (Denq and Altenhofel, 1997). The EIA/SIA process and the public role in the process can alter the nature, magnitude and importance of social and economic impacts (Burdge and Vanclay, 1996). Sometimes perceptions, and resulting behavioural changes, are based on misconceptions. Interpretations of the significance of social and economic impacts vary greatly over time, and among groups, communities and sectors of society because of differences in values, beliefs, perceptions, interests and attitudes (Barrow, 2000; Kauppinen, 2002). Many types of social and economic impacts (e.g., empowerment concerns, gender issues, poverty concerns, community image, cultural and archaeological impacts) have no parallel among physical and biological impacts. Social phenomena tend to be complex, contentious, changeable, uncertain, and subject to

multiple interpretations (Barrow, 1997; Finsterbusch, 1995; Vanclay, 2002). Often they are difficult to predict or manage (Finsterbusch, 1995). Meaning and value are socially determined and are adjusted through social interactions.

Significance determinations are especially subjective for social and economic impacts because they are filtered through multiple values, beliefs and perspectives, and are highly dependent on context. Dialogue is central to social interactions (Lockie, 2001; Ortolano, 1997). Distortions in dialogue can exacerbate adverse social impacts. Effective public participation can be critical in reducing some social and economic impacts to acceptable levels and in identifying opportunities for mutual gains (Vanclay, 2002). The interpretation of social and economic impact significance is inhibited by SIA limitations (e.g., conflicts among technical, scientific, collaborative and political SIA approaches, highly variable practice, secondary status to bio-physical impact assessment, lack of a uniform set of criteria for evaluating SIAs) (Bronfman, 1991; Burdge, 2002). The interpretation of social and economic significance also is inhibited by social science constraints (e.g., multiple, overlapping and competing models, approaches that tend to be critical and discursive rather than predictive and explanatory, many concepts are not amenable to empirical measurement) (Finsterbusch and Freudenburg, 2002; Vanclay, 1999).

There is some potential for using legal and other pre-defined thresholds for interpreting such socio-economic impacts as health, noise, and heritage and resource displacement. Quantitative aggregation methods can help interpret the significance of the economic, population, housing, service and municipal financial impacts associated with projects with large workforces and purchasing requirements (Hildén, 1997; Walker, 2003). But for most other potentially significant social and economic impacts (e.g., displacement of people, composite impacts on people and communities, capacity to change, sustainability, vulnerability, inequity) public reasoned judgments, in combination with collaborative consultation (aided by generic criteria, qualitative and semi-quantitative assessment procedures and technical judgment), is the more common practice. Collaborative approaches to significance determination tend to be favoured by SIA practitioners.

Collaborative impact significance determination processes can facilitate dialogue, contribute to co-learning, minimize communications distortions, build consensus, ameliorate conflicts and explore and identify "win–win" opportunities (Taylor et al., 1998; UNEP, 2002). Such procedures not only facilitate decision-making about what is socially and economically significant, they can be instrumental in ameliorating and avoiding potentially significant adverse social and economic impacts, and in enhancing positive impacts and community benefits.

Social and economic impact assessment tends to be overshadowed by physical and biological impact assessment at the regulatory level, and in much of EIA practice (Burdge, 2002; Rickson et al., 1990b). Consequently, social and economic impact assessment significance interpretations must generally fit into technical, quantitative, natural scientific frameworks and procedures. The unequal status of bio-physical and socio-economic impact assessment, and the common failure to appreciate the implications of the differences between bio-physical and socio-economic impacts and impact assessment, can mean that the significance of impacts that interconnect and transcend disciplinary boundaries receives limited attention (Rickson et al., 1990a). Composite significance determination approaches that make suitable adjustments to allow for the differences between bio-physical and socio-economic impacts, and that systematically address the significance of interdisciplinary impacts can help ameliorate these potential problems.

Recognizing the differences between bio-physical and socio-economic effects and the associated implications for significance determination is a good point of departure. However, further analysis of the relative effectiveness of alternative significance determination methods when applied to various classes of physical, biological, social, cultural and economic impacts

would be helpful. The most difficult task methodologically is likely to be how best to integrate impact interpretations across disciplines into an overall evaluation of alternative and impact acceptability, with and without impact management.

6. Significance determination and the Precautionary Principle

The Precautionary Principle (PP) addresses the dilemma of what to do when scientific knowledge is incomplete but there is a threat of serious adverse consequences. In such cases the lack of full certainty should not be used as a reason to preclude or postpone actions to prevent harm (IAIA, 2003; WHOROE, 2001). Lack of certainty, also should not be used as a reason for approving a planned intervention or for not requiring the implementation of mitigation measures and stringent monitoring (IAIA, 2003).

There are numerous interpretations of the PP and concerning if, when and how it should be applied. Interpretations vary regarding the definitions of terms (e.g., harm, threat, serious), when action should be triggered (e.g., harm alone, irreversible harm, catastrophic potential), the applicable evidence standards, and the actions that should be taken (e.g., reject the project, ameliorate impacts, prove the project is safe, proceed only if a reasonably convincing case can be made that the project is safe, proceed with caution) (Gullett, 1997; Wiener and Rogers, 2002).

The PP also is controversial. It can reduce harm and address uncertainties (Gullett, 1997). It ensures that harm reduction options are fully explored, and project acceptability is seriously assessed (Tickner et al., 1998). It places more of the "burden of proof" on proponents (Australian Government, 2006). It contributes to environmentally prudent, democratic and substantive (advances environmental and social values) decision-making (Government of Canada, 2001; Tickner et al., 1998). But it is so open to interpretation that it has been used to justify everything from minimal change (i.e., slightly more cautious decision-making) to the rejection of any project because there is always some uncertainty. Potential decision-making considerations, other than uncertainty, can sometimes be ignored or oversimplified (Holm and Harris, 1999). The PP can be abused. It can stifle innovation, advance dubious agendas (e.g., trade protectionism), raise unwarranted fears, misallocate resources and discredit scientific knowledge (Appell, 2001; Holm and Harris, 1999).

Impact significance determination changes markedly when the PP is applied. Uncertainty becomes an explicit factor in significance determination. At a minimum significance judgments are more tentative and cautious. Harm potential, coupled with uncertainty, can provide a basis for project rejection during screening or at the end of the process (e.g., project benefits outweighed by the combination of adverse impacts, uncertainties and severe harm potential). Greater weight is given to uncertainty and harm avoidance in interpreting impact significance when selecting, screening and comparing alternatives, and when determining the need for mitigation and/or monitoring (Tickner, 1998). Uncertainty can elevate an impact significance rating (e.g., from minor to moderate).

The implications of uncertainties for decision-making (e.g., additional analysis, favouring alternatives that hedge away from large losses, additional monitoring and contingency measures, additional consultation) are explicitly considered. Sensitivity analyses test the implications of alternative interpretations of impact significance. Uncertainty may trigger the need for mitigation and/or monitoring. More stress is placed on assessing the vulnerability of potentially affected populations, on protecting the interests of future generations, and on hedging away from risks and harm (e.g., risk avoidance, least regrets, preventative anticipation).

Proponents have a greater responsibility (i.e., a reversed burden of proof) for demonstrating safety and harm avoidance. The shift in the "burden of proof" can mean that the balance of benefits over negatives has to be greater if there are considerable uncertainties regarding the magnitude of either

the benefits or the adverse effects. The public tends to have a greater say in deciding what is significant. Their fears about irreversible harm, the validity of impact predictions and the effectiveness of mitigation measures cannot be so easily dismissed. Greater methodological attention must be devoted to analyzing, interpreting and managing uncertainties. Significance determination procedures can become more open, transparent and accepting of public concerns, perceptions and positions. The significance determination process tends to be more iterative and adaptive.

Given its discretionary nature and its potential for misapplication, the integration of the PP into impact significance determinations should be approached with caution. An open and democratic decision-making process is essential. The significance of the risks and uncertainties of both action and inaction should be assessed (Wiener and Rogers, 2002). Terms should be defined. Methods, assumptions and decision rules should be explicit and substantiated. Good practice guidance can aid in realizing the benefits of applying the PP while still avoiding potential drawbacks (Gullett, 1997). Care should be taken to avoid the drawbacks and pitfalls associated with how the concept is sometimes applied. Particular care should be given to determining, explaining and justifying the appropriate "burden of proof". Regardless of the extent to which the PP is formally integrated into significance determination procedures, it is still necessary to identify and manage uncertainties, and to adaptively anticipate and respond to unforeseen circumstances.

Further consideration should be given to the relative effectiveness of different approaches for integrating the PP and alternatives to the PP into impact significance determination procedures. Such analyses should consider the implications for significance determination of how the PP is interpreted. More broadly the effectiveness of different treatments of uncertainty in significance determinations also should be assessed.

7. Significance determination and sustainability

The definition of sustainability most commonly used is that of the World Commission on Environmental Development (WCED): "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 8). There are debates surrounding the definitions of sustainability and sustainable development. The debates concern whether, for example, the definitions should be broadened and adapted to address intra-generational inequities, spatial inequities, human aspirations, other species needs, public participation in decision-making, ecological limits, relationships among sustainability forms, and sustainability instruments. Increasingly the general characteristics of sustainability are now evident. Common to most definitions is a desire to maintain, over an indefinite future, necessary and desired attributes of the socio-political systems and of the natural environment (Deakin et al., 2002).

Impact significance determinations can change dramatically when sustainability is a primary goal of EIA requirements, processes and documents (Vanclay, 1999). Alternatives, for example, are screened for sustainability and compared for their relative contribution to sustainability (IAIA, 2003). The focus shifts from minimizing damage (i.e., reducing the negative) to maximizing long-term gains and opportunities for multiple parties (Gibson, 2005). The significance of both positive and negative impacts is addressed. Time horizons are extended to consider significance for future generations. More attention is devoted to interdependencies within and among social, economic, physical and ecological systems (Goodland, 1998; Sadler, 1996). More attention is devoted to cumulative impacts (e.g., lasting, net environmental and human benefits), and to systems-level, collective impact significance (e.g., net contribution of social, economic, physical, and ecological changes to sustainability) (Barrow, 2000). Proposed actions are viewed as potential sustainability catalysts or as impediments to sustainability.

EIA processes and proposed actions are viewed as potential vehicles for advancing community aspirations, and for promoting community development and capacity (Gagnon, 1995; Goodland, 1998). Proposed actions are assessed against both likely and desired (sustainable) futures. An impact from a proposed action is considered negatively significant if it inhibits sustainability (Barrow, 2000). It is considered positively significant if it makes a durable contribution to achieving local and regional sustainability visions and strategies, and to furthering global and future generational interests (Barrow, 2000; Joyce and MacFarlane, 2001). A net positive contribution to sustainability, through the selection of alternatives and proposed actions, although generally necessary and desirable, is not sufficient. The overall aim should be to ensure the best overall contribution to sustainability.

Positive contribution to sustainability can be a significance threshold and/or a significance criterion (i.e., a factor for evaluating impact significance). Impact significance can be interpreted by applying specific quantifiable sustainability criteria (when impacts can be predicted with accuracy), and sustainability principles (when factual information is lacking) (Hildén, 1997; Howitt, 1995). Land and resource use impact significance interpretations focus on the resilience of the human environment, on the sustainability of land uses, and on optimizing resource use and management (ANZECC, 1991; IAIA, 2003). Greater stress is placed in significance determinations on identifying and protecting the most vulnerable, the poor and the disadvantaged (Joyce and MacFarlane, 2001). Significance interpretations, at the project level, operate within the context of and are explicitly linked to broader sustainability visions and aspirations.

Sustainability is not without its critics and potential drawbacks. The concept is, to some, albeit a diminishing number of commentators, vague and sometimes confusing (e.g., sustainable environment or sustainable development). Consequently, it can be used to justify minimal action, fundamental change, and/or multiple, often conflicting, actions. The theoretical base for sustainability is well developed. But many questions are still being raised regarding how best to determine what is sustainable, over what area, and for how long a period. There are many debates concerning who is to decide what is and is not sustainable. Apportionment procedures, how to consider uncertainties, and the treatment of compromises and tradeoffs are difficult issues requiring further attention (Gibson, 2005). The fragmentation of disciplines, sectors and institutions continues to hinder integration efforts. Sustainability indicator systems are sometimes borrowed uncritically from other settings and then misapplied. It is sometimes difficult to make broad sustainability concepts and principles operational in legal/administrative settings. Dilemmas abound (e.g., sustainable activities that supports an unsustainable development, unsustainable activities that are conducive to a sustainable environment).

On the positive side, a broad consensus regarding the common characteristics of sustainability assessment has emerged, the range of sustainability initiatives is enormous, the record of tangible improvements from these initiatives is considerable, and sufficient experience has been acquired to identify general properties and effectiveness factors. Effective impact significance determination, within the context of sustainability assessment, involves building on positive experiences, and acknowledging and confronting potential limitations and dilemmas.

8. Conclusions

Numerous general good impact significance determination practices and a range of support methods are identified. These practices and methods can assist in reducing the frequency of poor practice in determining impact significance, providing appropriate adjustments are made to fit the context.

EIA practice tends to address positive impacts by a combination of project rationale and economic benefits. This tendency makes it difficult to adequately consider the public interest, impact

acceptability, the distribution of impacts, and the links to sustainability. The systematic consideration of the significance of positive impacts can help further the public interest, reduce the "leakage" of benefits, ameliorate spatial, temporal and social group inequities, assess impact acceptability, optimize benefits and community aspirations, and facilitate sustainability.

Cumulative effects assessment (CEA) interprets the significance of the overall impacts from the proposed project, in combination with the effects of other past, present and likely future activities that affect the same environment. Both individual and CEA apply methods and procedures to interpret the importance of potential impacts. But the scope and range of considerations, the significance determination process, the methods used, and the areas of emphasis are all altered and broadened when the significance of potential cumulative impacts are determined.

A similar range of modifications to process, methods, scope and emphasis also occurs when interpreting the significance of bio-physical as compared with socio-economic effects, when applying the PP, and when integrating impact significance determination and sustainability. Appropriate allowance should be made for such differences. Due consideration should be given to the characteristics, strengths, limitations and potential for misapplication associated with different forms of impact assessment, and when applying such concepts as the PP and sustainability.

The proposed changes to the scope and orientation of impact significance determinations presented in this article can assist EIA practitioners in ensuring that impact significance determination approaches reflect the broadened and re-oriented scope of emerging EIA requirements and practices. The "learning curve" associated with impact significance determination practice can be further accelerated with additional conceptual and methodological refinements and testing, by more sharing of experiences, with further applied case studies, research and follow-up studies, by refining and adapting relevant EIA requirements and guidelines, by means of further good practice guidance, and with a concerted effort to better match contextual characteristics and significance determination methods and processes (Burdge, 2002). At the same time residual limitations, perspective divisions, and some intractable problems and dilemmas will remain and should be acknowledged, together with practice implications.

Acknowledgements

The research undertaken for this article was sponsored by the Joint Review Panel for the Mackenzie Gas Project (Joint Review Panel), the Mackenzie Valley Environmental Impact Review Board (MVEIRB), and the Yukon Environmental and Socio-economic Assessment Board (YESAB). Financial support was provided by the Canadian Environmental Assessment Agency. Helpful questions, comments and suggestions, provided by other presenters, MVEIRB board members and Joint Review staff, peer reviewers, and hearing and workshop attendees, are gratefully acknowledged.

References

Appell D. The uncertainty principle. Scientific American; 2001. January.

Australian and New Zealand Environment and Conservation Council (ANZECC). A national approach to environmental impact assessment in Australia, ANZECC secretariat, Canberra, Australia; 1991.

Australian Government. EPBC Act Policy Statement 1.1 Significance Impact Guidelines: matters of National Environmental Significance. Department of the Environment and Heritage, Commonwealth of Australia; 2006.

Barrow CJ. Environmental and social impact assessment — an introduction. London: Arnold; 1997.

Barrow CJ. Social impact assessment — an introduction. New York: Oxford University Press Inc.; 2000.

Bronfman LM. Setting the social impact agenda: an organizational perspective. Environmental Impact Assessment Review 1991;11:69–79.
Burdge RJ. Why is social impact assessment the orphan of the assessment process? Impact Assessment and Project Appraisal 2002;20:3–9.
Burdge RJ, Robertson RA. Social impact assessment and the public involvement process. Environmental Impact Assessment Review 1990;10:81–90.
Burdge RJ, Vanclay F. Social impact assessment: a contribution to the state of the art series. Impact Assessment 1996;14:59–86.
Deakin M, Curwell S, Lombari P. Sustainable urban development: the framework and directory of assessment methods. Journal of Environmental Assessment Policy and Management 2002;11:171–97.
Denq F, Altenhofel J. Social impact assessments conducted by Federal agencies: an evaluation. Impact Assessment 1997;15:209–31.
Erickson PA. A practical guide to environmental impact assessment. San Diego, California: Academic Press; 1994.
Finsterbusch K. In praise of SIA — a personal review of the field of social impact assessment: feasibility, justification, history, methods, issues. Impact Assessment 1995;13:229–52.
Finsterbusch K, Freudenburg WR. Social impact assessment and technology assessment. In: Riley RA, Michelson W, editors. Handbook of environmental sociology. Westport, Connecticut: Greenwood Press; 2002. p. 407–47.
Gagnon C. Social impact assessment in Québec: issues and perspectives for sustainable community development. Impact Assessment 1995;13:273–88.
Gibson RB. Sustainability assessment — criteria and processes. London, U.K.: Earthscan; 2005.
Glasson J. Socio-economic impacts 1: overview and economic impacts. In: Morris P, Thérivel R, editors. Methods of environmental impact assessment. Vancouver: UBC Press; 1995. p. 9–28.
Goodland R. The concept of environmental sustainability. In: Porter AL, Fittipaldi JJ, editors. Environmental methods review: retooling impact assessment for the new centuryArmy Environmental Policy Institute and International Association for Impact Assessment, Fargo, North Dakota; 1998. p. 69–76.
Government of Canada. A Canadian perspective on the precautionary approach/principle. Discussion paper. Ottawa, Canada: Government of Canada; 2001. September.
Gullett W. Environmental protection and the 'Precautionary Principle': a response to scientific uncertainty in environmental management. Environmental and Planning Law Journal 1997;14:52–69.
Harrop DO, Nixon JA. Environmental assessment in practice. London: Routledge; 1999.
Hegmann GH, Yarranton GA. Cumulative effects and the energy resources conservation board's review process. Working paper, vol. 1. Calgary, Alberta: Macleod Institute for Environmental Analysis; 1995. July.
Hildén M. Evaluation of the significance of environmental impacts. Canadian environmental assessment agency and international association for impact assessment, report of the EIA process strengthening workshop, Canberra 4–7 April 1995. Hull, Quebec: CEAA; 1997. p. 49–60. January.
Holm S, Harris J. The Precautionary Principle stifles discovery. Nature 1999:400.
Howitt R. SIA, sustainability, and developmentalist narratives of resource regions. Impact Assessment 1995;13:387–402.
International Association for Impact Assessment (IAIA). Social impact assessment international principles. Special publication seriesFargo, ND: IAIA; 2003. May.
Interorganizational Committee on Principles and Guidelines for Social Impact Assessment. Principles and guidelines for social impact assessment in the USA. Impact Assessment and Project Appraisal 2003;21:231–50.
Joyce SA, MacFarlane J. Social impact assessment in the mining industry: current situation and future directions. UK: International Institute for Environment and Development; 2001.
Kauppinen T. 2002. Human impact assessment (HuIA) in Finland. STAKES — Human Impact Assessment-Seminar., STAKES National Research and Development Centre for Welfare and Health Helsinki.
Kirk D. A decision support tool to aid in evaluating significance of adverse effects on birds for environmental assessment. Hull, Quebec: Canadian Environmental Assessment Agency; 2000.
Larcombe P, Winds and Voices Environmental Services Inc. Determining significance of environmental effects: an aboriginal perspective. Hull, Quebec: Canadian Environmental Assessment Agency; 2000.
Lawrence D. The need for EIA theory-building. Environmental Impact Assessment Review 1997;17:79–107.
Lawrence D. Significance in environmental assessment. Ottawa: Canadian Environmental Assessment Agency; 2002. http://www.ceaa-acee.gc.ca/015/001/011/index_e.htm.
Lawrence D. The significance of social and economic impacts in environmental assessment. Ottawa: Canadian Environmental Assessment Agency; 2004. http://www.ceaa-acee.gc.ca/015/001/023/index_e.htm.
Lawrence D. Significance criteria and determination in sustainability-based environmental impact assessment, Mackenzie Gas Project review panel; 2005. http://ngps.nt.ca/registryDetail_e.asp?CategoryID=265.

Lockie S. SIA in review: setting the agenda for impact assessment in the 21st century. Impact Assessment and Project Appraisal 2001;19:277–87.
Lynch-Stewart and Associates. Using ecological standards, guidelines and objectives for determining significance. Hull, Quebec: Canadian Environmental Assessment Agency; 2000.
Lynch-Stewart and Associates. Sharing good practice. Hull, Quebec: Canadian Environmental Assessment Agency; 2002.
Marusich S. The application of fuzzy logic analysis to assessing the significance of environmental impacts: case studies from Mexico and Canada. Ottawa: Canadian Environmental Assessment Agency; 2001.
McBride GB, Loftis JC, Adkins NC. What do significance tests really tell us about the environment? Environmental Management 1993;18:317.
Ortolano L. Environmental regulation and impact assessment. New York: Wiley; 1997.
Rickson RE, Burdge RJ, Hundloe T, McDonald GT. Institutional constraints to adoption of social impact assessment as a decision-making and planning tool. Environmental Impact Assessment Review 1990a;10:233–43.
Rickson RE, Western JS, Burdge RJ. Social impact assessment: knowledge and development. Environmental Impact Assessment Review 1990b;10:1–10.
Sadler B. Environmental assessment in a changing world: evaluating practice to improve performance, IAIA and Canadian Environmental Assessment Agency, Ministry of Supply and Services, Ottawa, Canada, 1996.
Seebohm K. Guiding principles for the practice of social assessment in the Australian water industry. Impact Assessment 1997;15:233–51.
Stamps III AE. A paradigm for distinguishing significant from non-significant visual impacts: theory, implementation, case histories. Environmental Impact Assessment Review 1997;17:249–94.
Taylor CN, Goodrich CG, Bryan CG. Social assessment. In: Porter AL, Fittipaldi JJ, editors. Environmental methods review: retooling impact assessment for the new centuryArmy Environmental Policy Institute and International Association for Impact Assessment, Fargo, North Dakota; 1998. p. 210–8.
Tickner J. A commonsense framework for operationalizing the Precautionary Principle. Paper presented at the Wingspread Conference, strategies for implementing the Precautionary Principle. Wisconsin: Racine; 1998.
Tickner J, Raffensperger C, Myers N. The Precautionary Principle in action: a handbook. Ames, Iowa: Science and Environmental Health Network; 1998.
United Nations Environment Program (UNEP). Environmental impact assessment training resource manual. second ed. 2002. Australian EIA Network. URL, http://www.unep.ch/etu/publications/EIAMan_2edition_toc.htm.
Vanclay F. Social impact assessment. In: Petts J, editor. Handbook of environmental impact assessment, vol. 1. Oxford: Blackwell Science; 1999. p. 301–26.
Vanclay F. Conceptualising social impacts. Environmental Impact Assessment Review 2002;22:183–211.
Walker A. Restoring flows on Australia's Snowy River: assessing the impacts on local amenity. Impact Assessment and Project Appraisal 2003;21:119–24.
Wiener JB, Rogers MD. Comparing precaution in the United States and Europe, WP 2001–02, Duke Center for Environmental Solutions. Durham, North Carolina: Duke University; 2002.
World Commission on Environment and Development (WCED). Our common future. Oxford: Oxford University Press; 1987.
World Health Organization Regional Office for Europe (WHOROE). Precautionary policies and health protection: principles and application. Report of a WHO Workshop, Rome, Italy; 2001.

David Lawrence is President of Lawrence Environmental, based in Langley, British Columbia, Canada. Dr. Lawrence has over 30 years of EIA experience as a project manager, and as a specialist advisor–peer reviewer in such areas as study design, impact prediction and interpretation methodology, cumulative effects assessment, alternatives evaluation and the integration of sustainability, social and land use concerns. He has undertaken a substantial amount of applied EIA research, taught EIA at the graduate and undergraduate levels, and published widely in the field.