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Reasearch

Evaluating the Effectiveness of a Practitioner Tool for Support Site-Specific Risk Management Planning: A Source Water Protection Implementation Case Study

Hugh C Simpson[1,2,3*] and John Fitzgibbon[2,4]

[1]*Ontario Ministry of Agriculture, Food and Rural Affairs, Guelph, Ontario, Canada*

[2*]*School of Environmental Design and Rural Development, University of Guelph, Guelph, Ontario, Canada*

[3]*Water Policy and Governance Group, University of Waterloo, Water, Ontario, Canada*

[4]*Ontario Farm Environmental Coalition, Guelph, Ontario, Canada*

Abstract

Source water protection is the first of a five-part multi-barrier approach for protecting municipal drinking water supplies. Source Protection Planning is an approach to source water protection being implemented in Ontario under the authority of the Clean Water Act, 2006. Central to this approach is the development of site-specific Risk Management Plans (RMPs) between regulators and landowners. A critical problem associated with this process is which approach should be used when developing RMP format and content. One option is the traditional expert-driven approach where the regulator determines unilaterally how risks will be managed. An alternative involves a collaborative approach where risk management outcomes are negotiated by regulators with landowners, integrating different types of expert science, local knowledge, and community beliefs and values. This approach can assist regulators who have little or no knowledge of the science associated with a specific land use, and the effectiveness, relative cost and operational considerations associated with risk management alternatives. This paper presents a case study concerning a risk management framework and workbook developed by the Ontario Farm Environmental Coalition. The framework provides a tool to help farmers to identify on-farm risk management measures, and lays a foundation for farmers and regulators to negotiate RMPs.

Keywords: Source Water Protection; Stakeholder Participation; Social Networks; Risk Management; Agriculture

Introduction

Source water protection (SWP) has been defined as a process for ensuring that the quality and quantity of human water supply sources are not diminished by land use activities [1-3]. Fundamentally, SWP is a form of problem-solving where alternative courses of action are evaluated [4] with a specific focus on land and water management practices. This problem-solving has typically been undertaken using a traditional risk analysis approach based on expert science [5]. Unfortunately, the traditional risk analysis approach is not well suited for emerging complex environmental problems with a high degree of indeterminacy (i.e., ambiguity, complexity, uncertainty), because these challenges have no clear end-point, and the risk of an adverse outcome, which requires ongoing societal involvement for their resolution [5-13]. There is emerging consensus that complex environmental problems require more than scientific knowledge to be solved. Specifically, problem-solving involving complex environmental problems needs to incorporate experiential knowledge and community beliefs and societal values [5,14].

Collaborative approaches have been proposed for addressing complex environmental problems. Collaborative problem-solving approaches are centred around the substantive contribution of different stakeholder groups. These stakeholders have a key role in creating a "vernacular knowledge" from expert science, and experiential knowledge in the context of community beliefs and values, which will form the basis for the deliberation and negotiation of solutions [15]. An important means for stakeholder involvement are social networks that can support the creation of vernacular knowledge across horizontal and vertical scales [16].

The purpose of this paper is three-fold. First, the characteristics

***Corresponding author:** Hugh C Simpson, Environmental Management Branch, Ontario Ministry of Agriculture and Food, Guelph, Ontario, Canada, E-mail: hugh@uoguelph.ca

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of complex environmental problems are presented, and the challenges they present for traditional risk analysis have are discussed. Second, collaborative approaches to problem-solving and their applicability for addressing complex environmental problems are presented. Finally, a case study involving an example of how a stakeholder group has contributed to the development of vernacular knowledge as part of Source Protection Planning in Ontario, and the development of a risk assessment tool that will support the implementation of Source Protection Plan requirements, is presented.

Challenges With Traditional Risk Analysis and Complex Environmental Problems

Problem-solving involving environmental problems has relied on traditional risk analysis to provide objective guidance concerning the 'tolerability' or acceptability of a risk, and the equity and fairness of the associated benefits and adverse effects, within society [5,14,17,18]. A tolerable risk has been defined as one where it is perceived that the benefits associated with a potential threat are greater than the adverse effects and where the potential impacts can be mitigated [5]. This guidance has been developed using a traditional risk analysis approach where experts evaluate objective and quantitative scientific knowledge acquired through research insulated from normative and subjective questions associated with the societal (i.e., moral, political and religious) concerns of society [19].

Unfortunately, challenges concerning risk and the environment are posing complex problems that are rooted in societal concerns. Such complex problems have proven to be a particular challenge because traditional risk analysis and objective science have difficulty comprehending and incorporating experiential knowledge and societal values - both of which tend to be qualitative and subjective in nature [20-22]. Complex problems are characterized by different forms of indeterminacy associated with risk analysis-complexity, uncertainty, or ambiguity [23]. Complex problems have no clear end point or obvious solution, involve the interests of many state and non-state actors, and have a risk of an adverse outcome [6-13]. Turner [10] classifies these problems-where the contributions of objective scientific knowledge alone is not enough because more than scientific knowledge is required to make competent decisions-as 'quasi-scientific'. As a consequence, there is growing consensus that such an expert-driven approach is not adequate for dealing with complex environmental problems [5,11].

The use of traditional risk analysis for addressing complex environmental problems is further complicated by subjectivity introduced unintentionally into the risk analysis process by risk experts when making simplifying assumptions that unconsciously incorporate policy objectives, personal values and technical perspectives without scrutiny [20-22,24]. Unfortunately, access to information for different threats can vary quite widely in terms of their availability, comparability, and quality. Consequently, assumptions often need to be made to extrapolate results from existing research populations to the specific complex problem under consideration [25]. Unfortunately the uncertainty associated with making these simplifying assumptions is typically not recognized and documented in the expert evaluation [20].

Together, indeterminacy and subjectivity can influence the risk analysis process in two ways. The first is by constraining the way a problem is 'framed' or delineated, potentially limiting the extent of 'possible scientific inquiry, political debate, and policy options' without the awareness of people involved in the process [20,26]. An example of this is the selection of 'bright lines'-a bright line is a 'specific threshold below which some risk is tolerable, when characterizing a complex problem or making regulatory decisions [27]. Such a threshold often operationalizes the level of a risk for a particular threat that will be used by a risk expert or regulator when determining what does and does not constitute a tolerable risk. The second involves the potential exclusion of important topics from the risk analysis, political debate, or evaluation of potential policy options for resolving a risk. For instance, a risk analysis that is framed using only a technical perspective will most likely exclude other concerns that may be extremely important to the broader community [17,20,24].

As a consequence, even apparently objective decisions are affected by subjective perceptions [20,22,24] and cannot be separated from the underlying subjective beliefs of the person(s) making the decisions, or the context within which the decisions are made. Therefore, excluding the concerns of the broader community because they are based on subjective risk perception is problematic when the objective positions of risk experts themselves have a subjective component.

Renn [5] observes that risk analysis should be guided by both scientific and experiential knowledge, provided by experts and stakeholders. However, this blend of expert and lay information does not always occur. There is a need for increased capacity of the expert science and stakeholder communities so that they can more effectively share and integrate expert science and experiential knowledge with community local beliefs and values. The development of capacity to participate in a problem-solving process that integrates scientific and experiential knowledge would help allay concerns that broader society may not understand or be able to discuss the underlying scientific assumptions in question [10,11]. This will also help build social capital, including trust, which will be necessary for different stakeholder groups to collaborate [24]. Increased social capacity and capital will better enable the risk analysis process to support problem-solving associated with complex problems [7,8,24,28].

Collaborative Approaches to Problem-Solving

Concerns with traditional risk analysis have led to recognition that a new approach is required for addressing complex environmental problems [7,8,29-32], one which incorporates expert science and experiential knowledge, with societal beliefs and values [11,33-35]. The outcome of this new approach, a vernacular knowledge, is the outcome of a process where complex environmental problems are deliberated and solutions are negotiated by stakeholders [11,36,37]. Vernacular knowledge is widely thought to be necessary for finding solutions to complex problems, and proponents suggest that its creation can help to reduce differences in power between actors, encourage discussion of value-based issues, build social capital [28,38] and provide a foundation for collaborative problem-solving [11].

Collective action through deliberative forums is critical because no single actor, public or private, has all the expertise or knowledge required for solving complex problems [11,39,40]. Cooperative efforts are also necessary to achieve the 'radical shift in thinking' [and practice] that will be critical to achieve the 'societal acceptance of trade-offs and limitations' that are necessary for good problem-solving involving complex problems [11,41]. Such collaborative approaches to environmental problem-solving are characterized by the broad involvement of state and non-state actors in the problem-solving process [42-45]. What is envisioned is an "institutionally embedded" form of stakeholder involvement that will promote problem-solving that is 'fairer, more environmentally sound and more broadly accepted', by 'harness[ing] the energy and creativity of those with the greatest stake in successful environmental management: the people who live in or depend on the affected ecosystems' [42,45].

There is a growing recognition that social networks can help stakeholders participate more effectively in collaborative forms of problem-solving in at least four important ways. First, networks help build social capital, by promoting 'bonding' through relatively close relationships and shared values in well integrated and cohesive networks, and by encouraging 'bridging' between diverse groups [46]. Second, networks can foster social learning both as a process and outcome, when people from different backgrounds work together to integrate expert science, experiential knowledge and community beliefs and values. Third, networks can encourage the creation of vernacular knowledge that provides a foundation of knowledge to support collaborative problem-solving concerning complex problems [13,28,47-50]. Fourth, networks promote communication and co-operation concerning issues that cross horizontal and vertical scales [16].

One example of a horizontally and vertically-integrated stakeholder network is the agricultural network, which is composed of representatives of farm organizations and agricultural government agencies at the national, provincial/state, and local scale [51-54]. The agricultural community has well-documented involvement with a key complex environmental problem, the sustainable management of water while also producing food for a steadily increasing global population [55]. The remainder of this paper will present and evaluate a case study concerning the initiative of a provincial scale agri-environmental network as part of the broader efforts to implement source water protection within the Province of Ontario. It will focus on the efforts of the network to develop a broader risk-based framework to assist farmers to negotiate mutually-agreeable risk mitigation outcomes.

Methods

Source water protection (SWP) has been defined as a process for ensuring that water resources that form the basis for human water supply are not degraded by land use activities [1-3,56-60]. Fundamentally, SWP is a form of environmental problem-solving where alternative courses of action are evaluated, with a specific focus on land and water management practices, often within a broader context of financial, institutional, political, social and technical considerations [2,3,61,62].

Source water protection has been identified as an inherently complex form of environmental problem-solving that involves [54]

- State and non-state actors with different and potentially conflicting interests concerning land and water management (e.g., municipal water supply versus economic activity)
- Information that is potentially conflicting due to complexity, uncertainty, and ambiguity (e.g., there is never enough hydro-geological information, and it can be interpreted in a number of ways)
- Scientific knowledge and societal values need to be considered (e.g., we need to protect the water supply, but how should this be achieved?)
- There is obvious or single solution to problems (e.g., each actor has a potentially different perspective)
- There is no clear end point (e.g., the collection and evaluation of information is part of an ongoing process)

Source Protection Planning in Ontario

The Walkerton Tragedy, which occurred in May 2000, is a stark reminder of how a complex environmental problem can result in a catastrophe. Seven persons died, and several thousand became ill, in the Town of Walkerton, Ontario, when a poorly sited municipal well was engulfed by runoff from an adjacent farm, and contaminated water was distributed throughout the community through a poorly maintained and operated municipal water system

[61]. Justice O'Connor investigated the causes of the tragedy, and published recommendations to ensure the safety of municipal water supply systems throughout Ontario. The recommendations were structured around a multi-barrier approach that included developing watershed-scale source protection plans (SPPs) [61,63]. The Province of Ontario responded by enacting the Clean Water Act, 2006, [64] which provides authority for regulation empowering multi-stakeholder Source Protection Committees (SPCs) to develop local SPPs. Each SPP includes requirements for mitigating risks associated with land use activities classified as threats to municipal drinking water supply sources.

The Source Protection Planning Risk Analysis

Approach

Ontario's Source Protection Planning (SPP) framework is a hybrid of the traditional risk analysis and collaborative problem-solving approaches [15,62], and is being implemented in three phases. The first phase involved a semi-quantitative assessment evaluation and classification of risks posed by land use activities located within or adjacent to wellhead protection areas (WHPAs) and surface water intake protection zones (IPZs) [65]. Specifically, 19 land use activities that have been classified as prescribed threats to water quality, and 2 land use activities prescribed as prescribed threats to water quantity, through Ontario Regulation 287/07 [66] under authority of the Clean Water Act, 2006, were identified (see Table 1). The results of this process have been summarized in an Assessment Report for each source protection area. This expert science forms the basis for the development of SPP requirements at a watershed scale [67].

The second phase of the SPP process concerns the development of local policies, and has involved a prescribed collaborative problem-solving process that has been structured around 19 SPCs composed of members representing municipalities, industry and the broader community, coordinated by watershed-based conservation authorities [67]. A number of risk mitigation tools were available to SPCs for mitigating prescribed threats, including education and outreach, management, and prohibition [68]. At the time of writing of this paper, all SPCs had submitted Plans to the MOECC for review, which have been subsequently approved and assigned a legally-binding effective date, and implementation of the approved

Table 1. Land Use Activities Classified as Prescribed Threats

Threat #	Prescribed Threat Description
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage
3	The application of agricultural source material to land
4	The storage of agricultural source material
5	The management of agricultural source material
6	The application of non-agricultural source material to land
7	The handling and storage of non-agricultural source material
8	The application of commercial fertilizer to land
9	The handling and storage of commercial fertilizer
10	The application of pesticide to land
11	The handling and storage of pesticide
12	The application of road salt
13	The handling and storage of salt
14	The storage of snow
15	The handling and storage of fuel
16	The handling and storage of a dense non-aqueous phase liquid
17	The handling and storage of an organic solvent
18	The management of runoff that contains chemicals used in the de-icing of aircraft
19	An activity that takes water from an aquifer or a surface water body without returning the water to the same aquifer or surface water body
20	An activity that reduces the recharge of an aquifer
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area of farm-animal yard.

plans had begun.

The third phase of the SPP process has involved the implementation of individual SPP requirements in accordance with timelines specified by the SPC. One risk mitigation tool is the negotiation of a site-specific Risk Management Plan between the local Risk Management Official, who represents the interests of the local municipality, and land owner on whose property a threat to the municipal water supply source is located. At the time of writing of this paper, Risk Management Officials had begun to prepare for negotiation of Risk Management Plans with the implementation of SPP policies requiring risk mitigation.

The Farm Source Water Protection Plan.

The farm sector has been a key stakeholder group in the development and implementation of the SPP process. Farmers own or manage approximately one-third of the land in southern Ontario [69] and municipal water systems are often located adjacent to or within easements on farm lands. To coordinate the farm sector's contribution to the SPP process, the Ontario Farm Environmental Coalition organized a SWP Task Team composed of representatives from major farm organizations and staff from the Ontario Ministry of Agriculture, Food and Rural Affairs, and included the authors of this paper.

A major initiative of the Task Team was to develop a Farm Source Water Protection Plan (FSWPP) framework and workbook that would help affected farmers to prepare to negotiate a Risk Management Plan with the local Risk Management Official. Task Team members all had extensive knowledge of regulatory standards and voluntary BMPs that had been used successfully as part of the Canada-Ontario Environmental Farm Plan program to mitigate on-farm source of groundwater and surface water contamination [54]. Based on this experience, it was anticipated that many of the risk mitigation measures that would be required as part of a Risk Management Plan had already been implemented on many farm operations, but that farmers required a structured process for identifying and creating an inventory of existing risk mitigation measures. The Task Team also realized that many of the Risk Management Officials would have little or no knowledge of agri-environmental science and its relationship to on-farm risk mitigation, and so an approach was needed to provide this knowledge in a standardized manner.

The Task Team drew on the model of the Environmental Farm Plan (EFP) which had been introduced in 1992 [70]. It has been estimated that 70% of the registered farms in Ontario have participated in the EFP program [71]. The connection to the EFP provided a process with which farmers were familiar and one that has shown itself to be an effective tool for identification and assessment of environmental risks related to agricultural activities. The EFP is delivered through two-day workshops during which participants complete a series of modules that address agri-environmental concerns using worksheets that serve as both an educational and risk assessment tool [72,73]. The design of the EFP worksheet was fairly straightforward, with the farmer evaluating questions related to key agri-environmental concerns associated with overall theme of each worksheet. The worksheet for each module has been prepared and updated regularly by EFP worksheet working groups that have included farmers, researchers, conservation authorities, regulatory agency staff, and professionals from other related groups such as environmental organizations [55]. Possible ratings for farm practices included: Level 1 which does not meet the applicable benchmark (i.e., regulatory standard or a consensus based equivalent negotiated by the working group); Level 2 which meets the applicable benchmark; and Levels 3 and 4 which exceed applicable benchmarks in an incremental fashion.

An assumption that was made by the Task Team during the development of the framework for assessment of agricultural risks for municipal drinking water sources was that regulators and the regulated would collaborate to implement a multi-barrier approach to risk mitigation. As a result, the framework incorporated characteristics of the multi-barrier approach to risk mitigation that were identified in the Walkerton Report [61]

- Adopting a preventative rather than a reactive approach
- Identifying different magnitudes of risk (i.e., greater vs. lesser)
- Addressing the greater risks first
- Allocating resources proportional to the risk posed

The task team adapted the model from the Environmental Farm Plan program, modifying it so that each of the agricultural land use activities prescribed as quality threats under the Clean Water Act, 2006, were addressed on a dedicated worksheet. The worksheet was designed as a matrix with applicable key standards and BMPs grouped vertically into one of three barriers-containment, spatial, and contingency. The rationale for each of these barriers is summarized in Table 2. Each of the key standards and BMPs were also rated according to the different magnitude of risk reduction (i.e., Level 1, Level 2 or Level 3). The relative risk reduction capacity for each benchmark had been determined as part of the EFP program process using a collaborative process involving stakeholders from farming, government and other interested parties such as conservation authorities and environmental groups [71]. For each prescribed threat that might be found on a farm operation, one worksheet was developed for groundwater resources and one worksheet was developed for surface water resources, because the applicable key standards and risk mitigation measures differed for these settings. The result was a draft set of worksheets that would provide a multi-barrier approach for protecting municipal groundwater and surface water sources from each of the threats prescribed under the Clean Water Act, 2006, that might be found on a farm operation. Together, the draft framework and worksheets provided a prototype FSWPP for further validation and reliability testing.

Table 2. Summary of the Rationale for FSWPP Barriers

Barriers	Rationale
Containment	Measures that control potential contamination by containment.
Spatial	Measures that control the impact of potential contamination by distance of separation.
Contingency	Measures that control the impact of potential contamination through training and preparation for potential situations.

Validation and Reliability Evaluation Process

The prototype FSWPP assembled by the Task Team was then put through a process to validate its use as a science-based risk mitigation tool, and its reliability for on-farm use by farmers and local Risk Management Officials. This process is described in the following section.

Delphi Method

The Delphi Method is a technique that provides a structured approach for collecting informed judgement complex problems by seeking knowledge from a purposively selected panel of experts who possess knowledge that is highly context and expertise-specific [74,75]. The Delphi Method is well suited for exploring solutions to complex environmental problems in at least three ways. First, it can incorporate knowledge from experts located in different locations without having to physically bring them together. Second, it helps promote consensus by encouraging participants to consider the opinions of others involved in the process. Finally, involving experts individually can help avoid the power differentials that may occur in other problem-solving forums where one individual or sector can dominate a discussion [74,75].

The expert Delphi was used to provide an independent expert review of both the structure and process of the Framework but also the content of specific measures employed in each of the sequential barriers. A total of ten experts in the field drawn from academic, professional and government organizations were asked to review the framework developed by the Task Team. All but one of the experts had no difficulty in recognizing the process and supporting the merit of the use of the multi-barrier approach. Once a more detailed explanation of the process had been provided, all of the experts agreed that the process was useful. There were also a number of suggestions with respect to both the language used to describe the measures in the framework and the method of communicating these measures. These suggestions were incorporated and the experts were asked to review and critique the framework a second time. As a result of the second review, two further suggestions were identified by participants and these were incorporated into the workbook. The prototype Framework was then ready for the next step for field testing on Pilot Farms in order to assess the effectiveness and ease of use of the framework and workbook in practice.

Field Testing

The FSWPP was field tested in two phases. The first phase involved the use of the prototype FSWPP by Soil and Resource Group (SRG) consulting staff on seven operations located across southern Ontario that had volunteered to act as pilot farms. These farms included cash crop, beef, hog, dairy and horticultural operations. The project provided up to $5,000 to cover the costs of using the prototype to guide the development of a report containing an inventory and risk rating of on-farm practices found in the FSWPP. Each report included comments from SRG staff and the volunteer farmer concerning the use of the FSWPP.

Overall, the reports indicated that the prototype was easy to use, and the sequence of barriers was seen to be easily applied to any pathway that might link a source of contamination to a source of municipal drinking water WHPA or IPZ. The consultant who assisted the farmers in use of the FSWPP reported that they found the FSWPP easy to use and a viable process for identifying and assessing both potential threats as well as risk mitigation measures to the threats. The farmers also reported that they found the FSWPP useful. However, two of the measures in the worksheets related to nutrient management planning were found to be in need of revision. The issue with the measures was related to the differences between nutrient management plans that had been prepared to meet the regulatory requirements of the Nutrient Management Act, 2002, and those that had been prepared on a voluntary basis under programs such as the EFP. Specifically, the issue was related to the 100 metre setback required under the Nutrient Management Act for farm operations located in the vicinity of municipal water supply wells, and the grazing density regarding seasonal use of pastures. The consultant and the farmers also indicated that they required specific information concerning local SPP requirements on affected farms. This included information concerning potential prescribed threats that were believed to be located on the farms, copies of maps and/ or aerial photos showing the portion of the farm property that was affected by the local SPP policy requirements, and specific requirements of the local SPP policies governing vulnerable areas and the mitigation of risks associated with potential threats that might exist on the farms.

Upon completion of the pilot farms an additional 28 farms operations were identified where the operator had volunteered to participate as a demonstration farm. Again, assistance was provided in identifying a consultant to assist the farmer in use of the framework and funding up to $5,000 was provided to support any costs associated with using the Framework. The final Framework assessment was completed on October 7, 2013. The results of the inventories completed as part of the field test are summarized in Table 3.

Table 3. Summary of On-Farm Evaluation of FSWPP

Prescribed Threat	**Barrier**	**Risk Mitigation Level**			
		1	**2**	**3**	**N\A**
Application of Agricultural Source Material	Containment	15	23	20	0
	Separation	2	4	10	10
	Contingency	11	7	16	10
Storage of Agricultural Source Material	Containment	2	6	2	0
	Separation	1	8	7	3
	Contingency	16	6	0	0
Handling of Agricultural Source Material	Containment	4	14	2	15
	Separation	1	2	8	7
	Contingency	13	8	0	6
Application of Commercial Fertilizer	Containment	9	53	18	5
	Separation	2	14	18	10
	Contingency	12	20	10	1
Application of Pesticides	Containment	1	32	25	1
	Separation	4	10	12	12
	Contingency	19	20	16	4
Handling and Storage of Pesticides	Containment	3	0	0	0
	Separation	0	1	1	0
	Contingency	1	2	1	0
Outdoor Confinement Areas and Animal Farm Yards (>1.0 NU/acre/year)	Containment	3	3	0	0
	Separation	4	0	0	2
	Contingency	9	8	2	0
Pasturing and Grazing (<1.0 NU/acre/year)	Containment	4	2	1	0
	Separation	0	1	4	3
	Contingency	8	3	4	0

A review of Table 3 demonstrates that 22% of the measures inventoried were classified as a Level 1, 38% were classified as Level 2, 27% were classified as Level 3, and 13% were classified as not applicable (not part of FSWPP risk mitigation measures). This indicates that 22% of the risk mitigation measures inventoried should be upgraded to meet at least a Level 2. However, it is worth noting that the majority of Level 1 risk ratings were due to a lack of contingency measures, namely a lack of a contingency plan and staff training, which are measures that can readily be addressed by the farmer in consultation with the local Risk Management Official. The Ontario Soil and Crop Improvement Association recently released an Emergency Plan document that would assist farmers and local Risk Management Official to develop a contingency plan [76]. Conversely, 62% of the risk mitigation measures inventoried were classified at a Level 2 or Level 3, indicating that a significant number of existing risk mitigation measures on the farm met or exceeded applicable benchmarks (e.g., standards or voluntary BMPs). Further, 13% of risk mitigation measures inventoried were not in the FSWPP, indicating that there are additional risk mitigation measures on the volunteer farms that are contributing to the mitigation of the associated prescribed threats, although the relative risk reduction capacity could be determined using the FSWPP worksheets.

The major issue that was encountered was related to what would be an acceptable set of measures that would constitute the equivalent of an appropriate nutrient management plan, for operations that were or were not phased-in under the authority of the Nutrient Management Act. These issues arose because farms that are not phased-in under the authority of the Nutrient Management Act are not required to implement all of the measures that are required for farms that are phased-in under the authority Nutrient Management Act. This difference between the regulatory and voluntary scenarios provided a challenge for developing a standardized risk mitigation framework for all farms affected by local SPP policies. The Task Team resolved this issue by concluding that an acceptable set of measures would include those that were equivalent to those included in the NMAN 2 nutrient management planning software [77]. The NMAN 2 software is provided by the Ontario Ministry of Agriculture, Food and Rural Affairs, and is used to support the development and approval of mandatory nutrient management plans under the authority of the Nutrient Management Act.

Workshops

A total of four training workshops were held in order to introduce practicing professional advisers to the FSWPP, including locations in Barrie (70 attendees), Kemptville (22 attendees), Guelph (31 attendees), and Cambridge (60 attendees). In addition to the professionals, the sessions were attended by farmers, staff from the Ministry of the Environment, the Ministry of Agriculture, Food and Rural Affairs, conservation authorities, and municipalities. The use of the FSWPP was reviewed with the consultants and a significant amount of explanation and discussion of the Framework process and content (i.e., Table 3 Summary of On-Farm Evaluation of FSWPP) occurred. Several inconsistencies were identified between terminology of the FSWPP and requirements for risk mitigation under the Clean Water Act, 2002.

Negotiation of Risk Management Plans

The Task Team had planned that the farmer would negotiate their Risk Management Plan as part of the validation and reliability testing, with the support of the consultant, with the local Risk Management Official. Unfortunately, the development and implementation of local SPPs took longer than anticipated and local Risk Management Officials were unable to negotiate Risk Management Plans under the authority of the Clean Water Act, 2002.

Uptake of FWSPP

Following the revision of the FSWPP framework and worksheets, the Task Team added a set of appendices to the workbook that summarized relevant information sources for each prescribed threat that provided more in-depth explanation concerning the theory and implementation about each of the risk mitigation measures. A report template was also included in the workbook to help a farmer summarize the results of the inventory and risk rating for the risk mitigation measures for each prescribed threat on the farm. Following finalization of the FSWPP in October 2013, 800 copies of the workbook were printed and distributed broadly. An additional 3000 copies of the workbook were made available for distribution through a second printing in March 2015.

Discussion and Conclusions

In this section the manner in which key concepts and concerns related to risk analysis and collaborative approaches to problem-solving are evaluated using the example of the OFEC Farm Water Source Water Protection Plan framework and workbook.

Selection of Bright lines

The selection of 'bright lines' is a key challenge related to the mitigation of risks when determining what is an appropriate threshold below which a specific risk can be considered tolerable as part of a risk analysis process [27]. The Province of Ontario has provided guidance for Source Protection Committees for classifying whether or a prescribed threat (see Table 1) constitutes a significant threat and must therefore undergo mandatory risk reduction so that that it no longer constitutes a significant drinking water threat [68]. However, a review of available materials indicates that the Province of Ontario has not provided any guidance on what level of risk reduction would be required to mitigate the risk associated with a prescribed threat so that it no longer constitutes a significant drinking water threat. This is problematic for the local RMO who has no access to provincial guidance on how or to what extent the risk associated with a specific significant drinking water threat should be mitigated, and may lack an adequate level of risk expertise in order to develop a local risk reduction framework and criteria. This situation is compounded by the diverse variety of sectors represented within the range of prescribed threats, each with its own unique operational characteristics and constraints. As a consequence, the RMO is presented with a significant challenge in how to develop a standardized approach that will operationalize the minimum level of a risk that is required for a for a particular threat for determining what constitutes an adequate level of risk mitigation for a specific significant drinking water threat.

An evaluation of the OFEC Farm Water Source Water Protection Plan (FSWPP) indicates that it provides a risk mitigation approach that includes three-parts: First, a definition of what provides an adequate level of risk mitigation – Level 2 (meets accepted benchmarks or design standards at the time of application or construction); Second, a definition of what constitutes an inadequate level of risk mitigation-Level 1 (does not meet accepted benchmarks or design standards at the time of application or construction); and, Third, a definition of what exceeds an adequate level of risk mitigation-Level 3 (exceeds accepted benchmarks or design standards at the time of application or construction). The framework is then used to highlight key risk reduction measures that can be implemented for on-farm risk reduction in a worksheet format, selected and summarized to each of the agricultural prescribed threats in either or both groundwater or surface water vulnerable areas. The level of risk mitigation assigned to each measure had been determined as part of a separate problem-solving process as part of the voluntary EFP worksheet development process using a collaborative process involving stakeholders from farming, government and other parties such as conservation authorities and environmental groups [55]. The validation and reliability testing process also enabled landowners and regulators to evaluate and provide comments concerning the format and content of prototype FSWPP. In this way, the risk assessment tool and associated benchmarks were developed using a risk analysis process guided in which both experts and stakeholders participated, and in which expert science and experiential knowledge was integrated with community beliefs and values [5].

Incorporation of Community Concerns

A significant concern during risk analysis is the potential during the framing process of excluding important topics. This concern is particularly prevalent in situations where the framing process is limited to what can be classified as technical considerations, and where other concerns and perspectives that are considered to be non-technical, and may be important to the broader community, are intentionally or unintentionally excluded from the risk analysis process [17,20,24]. One example of the topic that was overlooked during the risk analysis process, but was extremely important to the farm community, was the development and implementation of a standardized risk management process across the province.

This concern was raised by agricultural representatives during SPC meetings, and by farm organization representatives during discussions with MOE staff, but these efforts were unsuccessful largely because only the risk assessment portion of the SPP risk analysis process was prescribed.

A position of the agricultural community in Ontario is that the risk management component of the SPP program implemented by under the authority of the Clean Water Act, 2006, should be standardized so that farmers can expect to meet a common approach across the province [78]. Specifically, a desire for a standardized approach to regulation is rooted in farmers' promotion of an economically and environmentally sustainable farm sector [79]. An evaluation of the OFEC Farm Water Source Water Protection Plan (FSWPP) indicates that it supports this position by providing a standardized approach for creating an inventory of risk management measures using a three-level risk mitigation approach that includes a common set of key risk mitigation measures for each of the prescribed threats. Further, because the risk mitigation measures included in the FSWPP worksheets were drawn from EFP worksheets, an affected farmer can transfer information from portions of their EFP. The FSWPP also provides farmers with risk mitigation guidance through the numerous technical resources that are listed in the appendices for each FSWPP worksheet, many of which were developed to support the EFP. Overall, this approach has enabled the concerns that were important to the affected community to be considered as part of the risk analysis process [17,20,24].

Better Risk Mitigation by Creating Vernacular Knowledge

An important contributor to the success of risk mitigation efforts will be the development of capacity of all parties to participate in a problem-solving process that integrates scientific and experiential knowledge. This will help the parties to discuss, better understand and address each other's concerns [10,11]. A key part of this process involves working together to acknowledge and incorporate scientific and experiential knowledge, and societal beliefs and values [11,33-35]. The outcome of this new approach-the creation of vernacular knowledge-results from the deliberation of environmental problems and the negotiation of solutions [11,36,37]. This process of negotiating vernacular knowledge is widely thought necessary for finding solutions to complex problems, by building trust and social capital, and provide a foundation for collaborative problem-solving that is necessary with complex problems [11,54].

An evaluation of the FSWPP indicated that opportunities for the development of vernacular knowledge were provided on at least three different points. First, the Delphi process that was used helped the Task Team to interact with a variety of experts using a two-stage iterative approach. This provided the opportunity for the Task Team to explain the intent and refine the content of the FSWPP, and for experts engaged to develop a better understanding of the purpose and contribution of the FSWPP to risk analysis. Second, the pilot and demonstration studies using the FSWPP enable the Task Team to learn where the FSWPP could be modified to better suit on-farm application, and for farmers to learn more about on-farm risk mitigation in general and regarding their farm operations in particular. Finally, the workshops provided the Task Team with an opportunity to learn more about and incorporate the concerns and needs of the local Risk Management Official into the FSWPP, and for the local Risk Management Official to learn about a standardized framework that was accepted and endorsed by the farm community for on-farm risk mitigation. As a consequence, the process used has provided ongoing opportunities for the building of social capital and trust between the different parties [24]. Collectively, these opportunities have better enabled the risk analysis process to support collaborative problem-solving associated with complex problems [7,8,24,28].

The Contribution of the Agricultural Network

Stakeholder networks have been identified as a key contributor to collaborative forms of environmental problem-solving. In this context, stakeholder networks have a mutual understanding, shared vision, joint-working capacity, and economy of scale and scope that can foster collaboration [16,28,39,80].

There is a growing recognition that stakeholder networks can contribute to collaborative forms of problem-solving in at least four important ways. First, networks help build social capital, by promoting 'bonding' through relatively close relationships and shared values in well integrated and cohesive networks, and by encouraging 'bridging' between diverse groups [46]. Second, networks can foster social learning both as a process and outcome, when people from different backgrounds work together to integrate expert science, experiential knowledge and community beliefs and values. Third, networks can encourage the creation of vernacular knowledge that provides a foundation of knowledge to support collaborative problem-solving concerning complex problems [13,28,47,48-50]. Fourth, networks promote communication and co-operation concerning issues that cross horizontal and vertical scales [16].

The agricultural community worked as a horizontally and vertically-integrated stakeholder network, including representatives of farm organizations and agricultural government agencies at the provincial and local scale [51-54], during the development of the FSWPP [70]. The most visible part of the network-the Task Team-was composed of representatives working at the provincial scale, and had knowledge of and connections with local farm organizations, through which local farmers were recruited to volunteer as pilot and demonstration participants. The Task Team built social capital and created vernacular knowledge through its interactions with local farmers, and negotiations with government representatives with an interested or involvement in SPP implementation, during the development of the FSWPP. Finally, the Task Team promoted the sharing and discussion of issues between provincial and local interests across horizontal and vertical scales. The result was a movement towards an "institutionally embedded" form of stakeholder involvement that promoted problem-solving that is 'fairer, more environmentally sound and more broadly accepted', by 'harness[ing] the energy and creativity of those with the greatest stake in successful environmental management" [42,45] -those with an interest and involvement in the implementation of on-farm risk mitigation. It is anticipated that the Task Team will have an ongoing role in supporting the use of the FSWPP by both affected farmers and local RMOs as they negotiate mutually acceptable on-farm Risk Management Plans.

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