Land Stewardship Centre

Report on the Bow River Phosphorus Management Plan INFFER Analysis

Final Project Report

November 2013

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1. Executive Summary

Land Stewardship Centre (LSC) is working to bring awareness and knowledge of the Investment Framework for Environmental Resources (INFFER, www.inffer.com.au) to Alberta, and in particular, to key decision makers, land-use planners and program developers, in an effort to grow the capacity for implementing an asset-based, outcome-focused approach to natural resource management. LSC utilized the INFFER framework as a decision support mechanism to assist the Bow River Phosphorous Management Plan (BRPMP) Steering Committee in developing a phosphorus management plan. Included in the analysis was a need for clearly identifying the targeted asset, an assessment of the potential impacts of specific programs, estimating the adoption of programs by landowners and land managers, short and long-term costs for each proposed scenario, and risk estimates.

The general INFFER seven-step process begins with the identification of valuable assets (step #1), followed by assessing (filtering) their suitability for detailed assessment (step #2), project assessment (step#3), project selection and finally monitoring, evaluation and adaptive management. The BRPMP identified the Bow River from Bearspaw dam to Bassano Dam as the target asset for analysis. An on-line electronic Project Assessment Form (ePAF) allows users to capture information about the asset, the threats it faces, the goals that the project will try to achieve, and the actions needed to achieve those goals. Judgements about the likelihood of success in terms of technical feasibility and community and government support are also recorded, as well as the proposed project budget.

The INFFER analysis for the BRPMP completed steps #1- #3, with recommendations about which project activities are more cost-effective than others, including the calculation of a benefit: cost ratio (BCR) for each activity. If a BCR exceeds 1 then the benefits are judged to exceed the costs and the project is deemed to be cost-effective. Calculation of BCRs enables ready comparison between management actions or projects. Equally as important and valuable is that poor BCR values can facilitate further discussion about whether cost-effectiveness can be achieved if some of the risks, adoption rates or costs could be modified under different scenarios.

LSC and INFFER were brought into the BRPMP after the Steering Committee and Task Teams had already been working on existing process lead by the Government of Alberta. Task Teams for each of the urban point source (UPS), urban non-point source (UNPS) and rural non-point source (RNPS) had already been set up and had begun the process of identifying activities. Retrofitting Task Team activities and outcomes to support and enable the INFFER analysis took a significant amount of time and would have been streamlined had the INFFER process been utilized from the onset.

A prioritized list of actions produced by the Task Teams was provided to LSC and a further filter was applied to ensure that the identified actions could be meaningfully assessed with INFFER. The filter criteria for the BRPMP INFFER process were:

I. The likelihood of the proposed action, by itself, to directly reduce or manage the amount of phosphorus entering the mainstem or tributaries of the Bow River within the project area (high, medium, low). This filter was needed because Task Teams had focussed much of their effort on supporting activities, such as education and awareness raising activities, rather than direct actions.
II. An estimate of the magnitude of impact of the proposed action, assessed as the amount of phosphorus that would be removed or prevented from entering the mainstem or tributaries of the Bow River within the project area (high, medium, low).

The BRPMP INFFER analysis report includes:

- An explanation of how technical feasibility, practice change and adoption rates, and cost assumptions were calculated or determined.
- An assessment of proposed actions and program delivery scenarios with summary results of all modelled ePAF scenarios: RNPS scenario, UPS scenario, and combined scenario.
- A discussion of the assumptions included in the scenario analyses, and an overview of knowledge gaps and potential future directions.
- A discussion of lessons learned and the value added to the project through incorporation of INFFER as a decision support process.

INFFER ePAF scenarios were developed for the proposed actions developed by the RNPS Task Team and the UPS Task Team. The action list developed by the UNPS Task Team was not able to be translated into specific on-the-ground actions and so analysis on their impacts could not be assessed. A combined scenario, including actions from both the RNPS and UPS Task Teams was also developed.

The goal statement agreed upon for the BRPMP project is to maintain water quality in the Bow River between Bearspaw and Bassano dams over the next 20 years not to exceed a Median Annual Total Phosphorus (TP) Load of 230,324 kg/year (based on 2004 - 2010 levels). A total of 11 proposed actions were assessed. Actions were assessed individually in terms of their BCRs. In addition whole project assessments were developed for 3 scenarios - using all UPS actions, using all RNPS actions, and combining all UPS and RNPS activities.

The UPS actions are:

1. Upgrade the City of Calgary Bonnybrook waste water treatment plant.
2. Implement floating treatment wetland technology in lagoons within the project area.
3. Implement alum dosing technology in lagoons within the project area.

The RNPS actions are:

1. Manure management.
2. Cropland conversion adjacent to riparian areas.
3. Cropland conversion of waterways.
4. Restrict grazing access to riparian areas within the cultivated area.
5. Restrict grazing access to riparian areas within perennial cover areas.
6. Application of provisions within the Wetland Policy and mitigation.
7. Wetland protection.
8. Wetland restoration.

Overall, the goal of maintaining water quality could not be met through the activities identified. The RNPS scenario had an estimated phosphorus load reduction of 1461 kg/year (against a projected load increase of 45,737 kg P/yr), a total cost of $370,571,164 over 20 years with an extremely low BCR of 0.001. The UPS scenario had an estimated phosphorus reduction of 33,446 kg/year, a total cost of $69,198,054 over 20 years and a BCR of 0.400. The combined RNPS/UPS scenario had an estimated phosphorus reduction of 34,907 kg/year, a total cost of $439,769,218 over 20 years and a BCR of 0.010.

Given that both the water quality goal could not be met and that none of the scenarios had a favorable BCR (BCR<1), none of the assessed scenarios would be judged as a good investment for the benefits expected. The phosphorus reduction achieved with the combined RNPS/UPS scenario still fails to address the projected 20-year phosphorus loading increase by 10,830 kg/year and at significant cost.

Although the results do not predict a favorable BCR, they do serve as a basis for a number of important discussions including:

- Overall, the control of UPS appears much more cost-effective than RNPS, however much of that impact is a result of regulated improvement for UPS and is not voluntary in nature. Additional non-regulated UPS projects could be made more cost-effective by focusing only on the higher value activities or by reducing some of the project risks.
- The importance of obtaining finer scale information and modelling to enable targeting of 'hotspots' may have considerable potential to increase effectiveness of actions.
- The quality of available information on which to conduct the analysis was very limited and while a lack of information should not preclude active decision-making in the meantime, it will be important to develop a stronger evidence-base than currently exists.
- Some of the activities are very expensive and so focusing on activities that deliver best outcomes for the cost in the short-term should be a focus.

Of course, any analysis is only as good as the assumptions made. This applies not only to INFFER but to any other integrated analysis that might be done. Some of the major assumptions used as part of the BRPMP INFFER analysis include:

- Phosphorus attributed to RNPS in the goal statement was calculated from the portion entering the Bow River from tributaries. This portion of the phosphorus load was attributed to RNPS in lieu of more specific data.
- In BCR calculations, it was assumed that each unit area of rural land contributed equally to the phosphorus load.
- Effectiveness of action was calculated at 10% effectiveness for low impact, 20% effectiveness for medium impact, and 30% effectiveness for high impact actions. More specific data was generally not available for BMP effectiveness. The only source of more specific data was either from a report by Simpson and Weammert (2010) done for the Mid-Atlantic region of the United States or where Task Team contacts had specific information on effectiveness.
- Effectiveness of proposed rural non-point actions was calculated equally across the landscape. This may not be an accurate reflection of how BMPs would work on-the-ground, where it would be possible to target the implementation of BMPs to those areas where they would be more effective.
- The amount of phosphorus reduced by RNPS proposed actions was calculated by multiplying the estimated percent effectiveness by the land area to which that action could be applied.
- It is assumed that the GIS data used to characterize rural non-point land use represents actual conditions on the ground. No calibration was conducted as part of the BRPMP INFFER project, although some calibration may have been done as part of the Government of Alberta GIS data collection and calibration.
- Cost estimates for land acquisition are based on average values provided by Ducks Unlimited Canada and expert opinion. These estimates may not accurately reflect higher land values near urban centres and other variations in land value.
- Budgets and impacts are factored over the 20 year span of the BRPMP project and a 5% discount rate is used for calculations.

Limitations and knowledge gaps identified as part of the current BRPMP INFFER analysis include:

- Many of the proposed actions listed by Task Teams were categorized as planning, research, policy, or extension. These activities are a necessary part of developing a meaningful and effective plan. However, they do not directly contribute to the management of phosphorus and so were not assessed as part of the INFFER analysis. These preliminary planning stages are critical to develop a science-based, outcomes-focused implementation plan.
- BCR values for specific BMPs are presented in the report as relative rankings because of the lack of specific information available and the number of assumptions that went into the calculations.
- Factors related to generation, transport, and dynamics of phosphorus entering the Bow River remain an ongoing topic for investigation. Considerable effort has been made to manage phosphorus loading by municipalities (particularly the City of Calgary) from a point source perspective. The gap continues to widen, however, from a non-point perspective for both urban and rural. Many of the identified knowledge gaps have a particularly high impact for non-point phosphorus management, requiring immediate prioritization and resource allocation at a sufficient level to allow for completion of many of the tasks.
- Sources and the magnitude of urban non-point sources of phosphorus are not well characterized. More investigation is required to determine long-term development patterns and effects on non-point phosphorus loading.
- Although some water quality modeling data does exist, it is sparse and does not include much, if any, direct connection between on-farm and land management activities and resultant phosphorus loading into the system. More water quality modeling effort at a broad scale, or sub-basin level, is required to better predict environmental performance as a result of management action implementation.
- BMP effectiveness data was generally not available and assumptions and expert opinion had to be used. Further investigation into local, organizational, or unpublished information that provides information on BMP effectiveness may be a direction to investigate.
- Some investigation into the effectiveness of wetland protection and restoration has been done, however, given the large costs associated with wetland activities further refinement of this research is warranted to ensure accurate figures are available for phosphorus reduction.
- Enhanced coordination amongst partners is required to better align programs and initiatives that can have a direct impact on phosphorus management within the project area.
- More information may be required on in-stream flow needs to maintain ecological function of the portion of the Bow River within the project area.

Regardless of the supporting tools used, the BRPMP project cannot be successful without a clear vision of what is required to meet identified objectives. It will be important to build on the learnings from this project for the future.

In conclusion, although the results in terms of cost-effectiveness were disappointing, the process of INFFER worked very well. The time taken to do another analysis either on the Bow River or elsewhere could be markedly reduced with the learnings gained through this project. INFFER provides a useful integrating framework to address complex environmental problems which require evidence-based decisions by public institutions. We believe it has strong potential to improve decision-making in Alberta and in Canada more generally.

2. Overview of INFFER

The Investment Framework for Environmental Resources (INFFER™) is a decision support tool used to assess and prioritize projects to address diverse environmental issues such as reduced water quality, biodiversity, environmental pests and land degradation. It is designed to help environmental managers achieve the highest value environmental and natural resource outcomes possible with the available resources. INFFER gives priority to projects with a high likelihood of technical success, and high likelihood of adoption of the required actions at the scale required to achieve desired outcomes. INFFER helps develop projects that align delivery mechanisms with on-the-ground actions that will achieve the goal of the project. INFFER also provides insight into which policy response, such as extension, incentives, regulation, research, or no action, is the most appropriate for the given project based on the relative public and private benefits of the project.

INFFER is a valuable tool that can be used to address emerging environmental challenges, streamline program delivery, enhance accountability of public funds invested into environmental initiatives and help ensure the responsible investment of these funds for a greater return on investment. INFFER helps to address the persistent challenges associated with maximizing environmental benefits, within the constraint of limited budgets, and accounting for social and economic values in addition to environmental considerations.

2.1 Reason for Development

The development of INFFER in Australia was motivated by the desire to achieve better environmental outcomes through the appropriate allocation of the available resources. It stemmed from the recognition that the issues of environmental management are complex and stakeholders involved in protecting the environment may have different definitions of what the "best" outcome would be. The INFFER process has been developed to help determine whether the environmental or natural resource projects being considered for investment will deliver tangible results within budget, whether the tools and technical capacity needed to attain those results will be available to the project, and whether the stakeholders who will undertake the on-the-ground actions are committed to the project (Strang et al., 2010). INFFER assessments have been used by state governments in Western Australia, Victoria and New South Wales, and 19 of 56 regional groups in Australia have used INFFER or are in the process of trialling it (Roberts et al., 2009). Canada faces the same sets of problems as Australia and so it is likely INFFER would be useful here as well.

INFFER was developed from the need to allocate resources across a large area to derive the greatest benefits in the most cost effective way. The process utilizes a comprehensive, rigorous approach to evaluate and select environmental program options. It allows for multiple Beneficial Management Practices (BMPs) and program options to be examined simultaneously, data to be modified to assess a variety of scenarios for a particular project, and a realistic evaluation of which options provide the most effective on-the-ground social, environmental and economic results for a particular objective.

2.2 Context of Use

In recent years, more emphasis has been placed on environmental sustainability and conservation of natural resources. However, the means and funding to address environmental issues and to implement projects and programs have not followed this trend. With limited available financial and human resources, it has become more important to be able to prioritize issues and allocation of available resources.

Land Stewardship Centre (LSC) is working to bring awareness and knowledge of INFFER to Alberta, and in particular, to key decision makers, land-use planners and program developers, in an effort to grow the capacity for implementing an asset-based, outcome-focused approach to natural resource management. LSC utilized the INFFER framework as a decision support mechanism to assist the Bow River Phosphorus Management Plan (BRPMP) Steering Committee in developing a phosphorous management plan. LSC has used several components of this framework, including a clearly identified targeted asset, an assessment of the potential impact of specific programs, an estimate of the adoption of programming by landowners and land managers, short and long-term costs for each proposed scenario, and risk estimates.

The primary outcome of this detailed assessment is the development of a baseline Benefit: Cost Ratio that can be used to compare a variety of program options to assist the Steering Committee, and ultimately policy makers, to prioritize and allocate limited financial and human resources in a cost effective manner to achieve desired outcomes. The scenario analysis also provides the Steering Committee with the ability to assess public and private net benefits in a structured and consistent fashion, offering choices for policy responses that include either positive or negative incentives, extension-based programs or the decision to take no action based on the structured analysis.

2.3 Overview of INFFER Process

The general INFFER seven-step process begins with the identification of valuable assets, followed by project development, project assessment, project selection and finally monitoring, evaluation and adaptive management. An on-line electronic Project Assessment Form (ePAF) allows users to capture information about the asset, the threats it faces, the goals that the project will try to achieve, and the actions needed to achieve those goals. Judgements about the likelihood of success in terms of technical feasibility and community and government support are also recorded, as well as the proposed project budget. The information is used to calculate a Benefit: Cost Ratio (BCR) to assess the value for money that the proposed project will deliver. The INFFER developers also provide a Quality Assurance process to ensure projects are of high quality and have defensible BCRs (Strang et al., 2010). INFFER complements, rather than replaces, existing available technical and local knowledge, data and modelling tools.

LSC utilized a modified version of the first 3 steps of the general INFFER process. The asset was predefined by the BRPMP project team as the mainstem and tributaries of the Bow River between Bearspaw and Bassano dams (“the planning area”). Water quality objectives for the planning area were established by the BRPMP project team and refined by LSC to establish a suitable goal statement. A Government of Alberta (GoA) modelling team was established to better understand current and projected future phosphorus loading based on pre-existing modelling information that was reasonably coarse-scale, and estimated reductions to phosphorus loading attributable to specific BMPs were calculated by LSC based on best available data. Task Teams of topic experts and stakeholders for each of the Urban Point Source (UPS), Urban Non-Point Source (UNPS), and Rural Non-Point Source (RNPS) areas of concern defined the BMPs to be considered for implementation and provided input for the INFFER process. Monitoring and evaluation will be ongoing tasks to be undertaken subsequent to implementation of the defined actions.

Table 1 below provides a summary overview of the original INFFER process and the modified INFFER process utilized by LSC for the BRPMP project. See Appendix 8.10 and 8.11 for a detailed overview of the LSC INFFER process.

Table 1. A detailed overview of the original INFFER process and the modified INFFER process utilized by LSC for the BRPMP project.

	Description of Original INFFER Process	Description of Modified INFFER Process
1.	Develop a list of significant natural assets in the relevant region(s)	Develop a list of actions for each Task Team
2.	Apply an initial filter to the asset list, using a simplified set of criteria	Apply an initial filter to the action list, using a simplified set of criteria
3.	Define projects and conduct detailed assessments of them	Define actions and conduct detailed assessments of them
4.	Select priority projects	Select priority actions
5.	Develop investment plans or funding proposals	Develop investment plans or funding proposals
6.	Implement funded projects	Implement funded projects
7.	Monitor, evaluate and adaptively manage projects	Monitor, evaluate and adaptively manage projects

3. Background and Overview of BRPMP Prioritization Process

Prior to commencing the INFFER assessment, a checklist of questions (Pannell et al., 2009) designed to determine the suitability of the BRPMP project for a complete INFFER assessment was completed.

The first question asks whether the asset can be clearly defined and spatially identified. The BRPMP project team defined the asset as the mainstem and tributaries of the Bow River between Bearspaw and Bassano dams and included maps of the project area in the preliminary material provided to LSC.

Next, is it possible to define a SMART (specific, measurable, achievable, relevant and time-bound) goal for the project? The initial goal defined by the project team was to maintain the existing water quality measures using values defined by the Bow Basin Watershed Management Plan – 2012 (Bow River Basin Council). As the project progressed, and with LSC input, the initial goal statement was refined to fit within the SMART goal requirements. See further discussion of the Goal Statement below in Section 4.

Once a SMART goal has been defined, it must be determined if there is evidence that management actions can achieve the goal of the project. Based on the availability of several phosphorus management plans from other jurisdictions and the widespread endorsement of BMPs in Alberta to manage many aspects of water quality, it was judged that there was sufficient evidence that management actions had the ability to achieve the goals of the project, i.e. it is technically possible to prevent further degradation of the asset.

Question four asks if there is support for the adoption of recommended actions that must be implemented on private land and at the scale needed to achieve the goals of the project. Based on the voluntary activity of community and stewardship groups, and enrolment in incentive payment schemes through provincial and federal government agencies, it was determined that sufficient support for private adoption of actions exists within the project area.

Finally, is there generally support for the project from other organizations that must be involved in the implementation of recommended actions. The stakeholders engaged in the UPS, UNPS, and RNPS Task Teams include representatives from municipalities within the planning area, provincial government departments, and federal agencies therefore it was determined that there is generally support for the project from other agencies that may be involved in the implementation of recommended actions. Table 2 summarizes the pre-evaluation checklist and responses for the BRPMP project.

Table 2. Pre-evaluation checklist to determine the suitability of the BRPMP project for INFFER assessment.

Pre-Evaluation BRPMP Project Suitability Checklist		
1	Can you clearly identify the environmental or natural resource asset?	☑
2	Will it be possible to define a "SMART" goal for the asset (specific, measurable, achievable, relevant and time-bound)?	☑
3	Is there evidence to indicate that management actions can make a real difference, sufficient to achieve a worthwhile "SMART" goal for the asset?	☑
4	If the desired management actions are mainly on private land, is it likely that those actions would be reasonably attractive to fully informed land managers when adopted over the required scale?	☑
5	If the project requires change by other institutions (e.g. local government, other provincial government departments) is there a good chance that this will occur?	☑

3.1 Transition from the Bowtie Risk Assessment Tool

The Bowtie Risk Assessment tool was initially used to try to identify key sources of phosphorus and the existing procedures and structures in place that prevent phosphorus from entering the river. Using the Bowtie method of risk identification and assessment, each Task Team identified an extensive list of actions to be considered for investment and implementation. However, the outcomes from the Bowtie process were unclear and required additional refinement by LSC and the task teams in order to identify on-the-ground actions for INFFER assessment.

In addition, it is time consuming to apply the full INFFER assessment process using the electronic Project Assessment Form (ePAF) for every action identified, especially to those recognized as being less likely to meet one or more of the key criteria. An early filtering process, based on a simplified set of criteria, provides a transparent and efficient method for clarifying which of the identified actions consists of relatively good investment prospects. It can also help target the effort of conducting a detailed assessment to specified actions.

3.2 Process Utilized by Task Teams to Prioritize Proposed Actions List

In order to more clearly identify action, LSC worked with each Task Team and undertook a prioritization process to filter the initial list developed through the Bowtie process. Each Task Team undertook the development of strategies and actions from their own perspective using risk analysis, watershed mapping, and expert knowledge to assess and recommend a suite of strategies and actions that would best manage the amount of phosphorus entering the Bow River.

The RNPS Task Team, with support from ESRD GIS personnel, created several maps and map layers to understand which rural areas may contribute more phosphorus to the river than others. Factors considered included land use, land cover, topography and hydrology. The RNPS Task Team compiled nine priority strategies with associated proposed actions. A risk matrix approach was used to organize strategies in descending order of importance, with those strategies and actions deemed the most critical to address first at the top of the list.

The UNPS Task Team approached the prioritization of proposed actions from a systematic approach, beginning with a rooftop and moving along the path storm water runoff takes into the river. Source control and reduction was identified as the most important strategy to manage phosphorus, followed by immobilization of phosphorus and sequestration or removal.

The UPS Task Team addressed phosphorus management in the operations of wastewater treatment plants and wastewater lagoons. This team identified population growth as the most important threat to point source management of phosphorus. Strategies to maximize the efficiency of wastewater treatment plants and lagoons were included as well. It should be noted that wastewater treatment plants are regulated and must comply with total loading objectives, which include phosphorus levels.

3.3 LSC Prioritization

The prioritized lists of actions produced by the Task Teams were provided to LSC and a further filter was applied to ensure that the identified actions could be meaningfully assessed with INFFER. The suggested INFFER step-by-step process from Pannell et al., 2009 is:

1. For each asset, provide scores against the two criteria, using the following scales.
    a. How significant is the asset (in the sense of being valuable or important)?
        i. Exceptional (E)
        ii. Very high (VH)
        iii. High (H)

    b. Without a major new project for this asset, how damaged will the asset be in 20 years' time?
        i. Very high 76-100% loss of asset value (VH)
        ii. High 51-75% (H)
        iii. Medium 26-50% (M)
        iv. Low 0-25% loss of asset value (L)

Since the asset was the same (section of the Bow River) and the risk of damage was also the same, a modified filter criteria were developed for the BRPMP INFFER process:

1. The likelihood of the proposed action, by itself, estimated to directly reduce or manage the amount of phosphorus entering the mainstem or tributaries of the Bow River within the project area (high, medium, low).
2. The magnitude of impact of the proposed action, measured by the amount of phosphorus that will be removed or prevented from entering the mainstem or tributaries of the Bow River within the project area (high, medium, low).

Tables 3, 4 and 5 below detail the full list of proposed actions recommended by the Task Teams, the filter questions applied by LSC, and the final list of actions that were assessed using the ePAF process.

Table 3. Initial filter questions applied to rural non-point source Task Team proposed actions and final actions to be assessed with INFFER.

Rural Non-Point Source

Proposed Actions	Likelihood of Impact (H,M,L)	Magnitude of Impact (H,M,L)	Strategies to Assess with INFFER
Strategy 1:Map critical source areas, wetlands and riparian areas within the planning area			1. Ensure developers and land owners adhere to current Alberta Wetland Policy and Wetland Mitigation Process 2. Conservation Easement Implementation (wetland protection) 3. Conservation Easement Implementation (wetland restoration) 4. Increase the adoption of livestock grazing and offsite watering 5. Manure Spreading 6. Riparian Conversion 7. Grassed Waterways 8. Riparian Grazing
Identify areas contributing the most runoff and phosphorus	L	L	
Complete an inventory as well as health assessments of wetlands and riparian areas	L	L	
Integrate and update mapping inventories into GIS	L	L	
Conduct research on the effectiveness of wetlands in the planning area to manage P	L	L	
Strategy 2: No further net loss of wetlands in the Bow River Phosphorus Management Plan area			
Ensure developers and land owners adhere to current Alberta Wetland Policy and Wetland Mitigation Process	H	M	
Promote wetland preservation in CSAs	L	L	
Conservation Easement Implementation (wetland protection)	H	H	
Support current programs and possibly develop new conservation tools (Ecosystem Services – ES)	M	M	
Strategy 3: Work toward achieving wetland restoration objectives for the planning area.			
Promote wetland restoration in CSAs	M	M	
Conservation Easement Implementation (wetland restoration)	H	H	
Support current incentive programming	M	M	
Develop new conservation and restoration tools (ES)	M	L	
Strategy 4: Maintain and improve riparian area function.			
Utilize extension programs and policy, codes of practice and conservation tools targeted for protection and restoration in CSAs.	M	M	
Increase the adoption of livestock grazing and offsite watering	H	H	
Strategy 5: Minimize erosion and sediment loss.			
Promote the adoption of ESC BMPs during construction and repair activities	L	M	

Require Erosion and Sediment Control (ESC) designers and inspectors to obtain professional certification	L	L
Coordinate compliance enforcement of ESC	M	L
Enhance enforcement of responsible recreation trail use	L	L
Identify and reclaim unused and unofficial trails	M	L
Strategy 6: Evaluate and align policies governing small acreage development and management.		
Conduct a regulatory review to evaluate Municipal legislative and policy options to address issues related to small acreage development, land and livestock management	L	L
Create consistency between Municipalities within the planning area.	L	L
Strategy 7: Facilitate the adoption of livestock manure nutrient BMPs to reduce P buildup and runoff loss potential in CSAs.		
Complete risk assessments for commercial livestock operations and encourage adoption of practices to mitigate risk associated with: manure application, CFO livestock feeding and seasonal feeding and bedding sites	L	L
Manure Spreading	H	H
Strategy 8: Reduce sediment loading from regional drainage channels.		
Create inventory of erosion risk in natural channels and prioritize areas to be addressed	L	L
Implement erosion control measures to reduce sediment transport.	H	L
Encourage BMPs to address priority areas	L	L
Riparian Conversion	H	H
Grassed Waterways	H	M
Riparian Grazing	H	H
Convert canals to pipelines where possible to reduce return flow	M	L
Strategy 9: Develop and coordinate education programs within the planning area.		
Ecosystem service values for riparian areas and wetlands	L	L
Value and benefits of 4-R nutrient stewardship	L	L
Septic system management and risks	L	M
Responsible recreation	L	L
Livestock grazing and watering BMPs	L	L
Manure application BMPs to reduce P runoff losses	L	L

Table 4. Initial filter questions applied to urban non-point source Task Team proposed actions and final actions to be assessed with INFFER.

Urban Non-Point Source

Proposed Actions	Likelihood of Impact (H,M,L)	Magnitude of Impact (H,M,L)	Strategies to Assess with INFFER
Strategy 1: Don't add Phosphorus			
Investigate the feasibility and desirability of a Phosphorus fertilizer restriction for both private and public realms for various urban contexts.	M	L	
Strategy 2: Don't move / mobilize phosphorus			
Establish and enforce runoff volume targets for development in all watersheds in the planning area	M	M	
Strategy 3: Sequester / spread out / remove Phosphorus			
Investigate storm water BMPs for their ability and efficiency to treat Phosphorus	L	L	
Review and revise and develop regulations to enable rainwater and storm water reuse	L	L	
Set Phosphorus Loading objectives for all watersheds in the planning area	L	L	

Table 5. Initial filter questions applied to urban point source Task Team proposed actions and final actions to be assessed with INFFER.

Urban Point Source

Proposed Actions	Likelihood of Impact (H,M,L)	Magnitude of Impact (H,M,L)	Strategies to Assess with INFFER
Strategy 1: Reduce amount of phosphorus per capita entering the Bow River planning area from Mechanical Wastewater Treatment Plants and Lagoons			1. Construct wetlands downstream from lagoons and harvest vegetation to remove phosphorus 2. Floating Treatment Wetlands (Islands) 3. Upgrade Bonnybrook wastewater treatment plant 4. Alum dosing in waste water lagoons
Require all Wastewater Treatment Plants to develop Action Plans when 5 year forecasting brings P levels to total loading management plan targets or limits	L	L	
Coordinate a meeting amongst all Environmental Performance Plans (EPP) holders and ESRD to share learnings and practices	L	L	
Construct wetlands downstream from lagoons and harvest vegetation to remove phosphorus	H	M	
Look for ways to pilot other technologies to remove P from lagoons, such as Poo Gloo and Floating Islands	L	L	
Floating Treatment Wetlands (Islands)	H	H	
Strategy 2: Establish regional watershed targets for Phosphorus loading			
Base the Total Loading Objectives for wastewater (and storm water) on the receiving water's cumulative effects assessments. Currently, this is only done in the reach going through Calgary, and this is required for their approval. Consider the thresholds for phosphorus in the South Saskatchewan Regional Plan surface water quality management framework	L	L	
Strategy 3: Maximize the effectiveness of Wastewater Treatment Plants and Lagoons to reduce outputs of phosphorus into the Bow River planning area			
Seek opportunities to implement upstream phosphorus management actions to reduce phosphorus inputs into the planning area	L	L	
Address infiltration issues by rehabilitating existing, older sewage lines; replace and repair manholes	M	L	
Work with industries to control loadings to WWT plants from large industrial plants. This may require large industrial plants to pre-treat and test their effluent.	M	L	
Evaluate potential wastewater effluent re-use practices, and promote changes in the Water Act to allow for them	L	L	

Educate the public about sources of phosphorus, and encourage practice change such as eliminating the use of garburators	L	L
Work with industries to control loadings to lagoons	M	M
Examine the feasibility and best timing to introduce new strategies for removing P from wastewater (e.g., Ostara)	L	L
Continue to look for and share innovative solutions and best practices among water treatment personnel	L	L
Upgrade Bonnybrook WWTP	H	H
Strategy 4: Review lagoon Codes of Practice and regulations to allow for maximum phosphorus removal.		
Work with lagoon operators to review current codes of practice for lagoons and revise them to allow lagoons to upgrade to allow for phosphorus removal.	L	L
Develop or clarify guidelines to allow lagoons to make upgrades that will improve phosphorus removal, without becoming mechanical treatment plants	L	L
Clarify Municipal Policies and Procedures Manual with respect to guidelines for piloting unproven or innovative and alternative technologies for lagoons	L	L
Investigate treatment techniques that enable Phosphorus to settle out into lagoon sludge	L	L
Include long term planning requirements in the Code of Practice for lagoons	L	L
Evaluate potential wastewater effluent re-use practices for lagoons	L	L
Strategy 5: Ensure Quality Assurance of Current Practices for Lagoon Operations		
Determine optimal times for releasing phosphorus from lagoons and coordinate lagoon releases so not done at same time, or are done during high flow periods	L	L
Require lagoon operators to inspect lagoon facilities regularly	L	L
Require regular monitoring of phosphorus in lagoons as a measure of the effectiveness of a lagoon	L	L
Strategy 6 Research?		

None of the proposed actions that were not assessed with INFFER were removed from the BRPMP project plan. All Task Team recommendations have been captured and are included either within the body of the plan or in associated appendices. As the table shows, many of the proposed actions do not directly, *by themselves*, reduce or manage the amount of phosphorus entering the main stem or tributaries of the Bow River within the project area. On their own, extension and awareness programs have a limited ability to reduce or manage phosphorus. Many of the proposed actions, such as regular monitoring of lagoons, facility inspections, knowledge sharing and critical source area identification, support informed decision making but do not, by themselves, control phosphorus. However, the value of collecting and analysing data to determine sources and loading of phosphorus, as well as critical areas within which to target beneficial management practices, cannot be overstated. For this reason, an extension component has been included in the ePAF assessments. Many of these data gaps are identified in the prepared ePAFs and recommendations to address these gaps are included in the analysis. See more details below.

4. Overview of INFFER Analysis

The BRPMP project afforded the opportunity to conduct an INFFER analysis on a large, complex asset with many different stakeholder groups and land uses within the project area. The project is proactive, place-based and adaptive. The BRPMP INFFER analysis was conducted as a collaborative planning partnership between the LSC INFFER team, the Australian INFFER team which provided review and quality assurance support, and the BRPMP project team.

4.1 Scope of the Analysis

The BRPMP INFFER analysis report includes:

- An explanation of how technical feasibility, practice change and adoption rates, and cost assumptions were calculated or determined.
- An assessment of proposed actions and program delivery scenarios with summary results of all modelled ePAF scenarios: RNPS scenario, UPS scenario, and combined scenario.
- A discussion of the assumptions included in the scenario analyses, and an overview of knowledge gaps and potential future directions.
- A discussion of lessons learned and the value added to the project through incorporation of INFFER as a decision support process.

4.2 Overview of Methods and Assumptions

INFFER ePAF scenarios were developed for the proposed actions developed by the RNPS Task Team and the UPS Task Team. The action list developed by the UNPS Task Team was not able to be translated into specific on-the-ground actions and so analysis on their impacts could not be assessed. A combined scenario, including actions from both the RNPS and UPS Task Teams was also developed. The LSC INFFER team was the principal author of the ePAF scenarios developed with specific data and information provided by content experts from the relevant Task Team. The Australian INFFER team was consulted to ensure appropriate application of the INFFER process, as well as quality assurance for the ePAF scenarios developed.

Over the course of several project meetings attended by the stakeholders represented on the Task Teams and ESRD staff, preliminary work established the definition of the asset, an asset value score representing the current condition of the asset, and a tentative goal for the project. Continuing work helped establish the scenarios to be assessed with the INFFER ePAF process. A meeting was also held to establish the regulatory context within which the current plan was developed.

Interim calculations and findings were presented and further refined with input from the project team. Assumptions and identified knowledge gaps were outlined with follow-up from the LSC INFFER team with specific individuals from Task Teams for additional information. For detailed information on the process undertaken, see Appendices 8.8, 8.11, 8.13, and 8.14.

4.2.1 Asset, Threats and Goal Statement

The Bow River extends from its alpine headwaters of the west through a variety of ecosystems to its confluence with the Oldman River and forming the South Saskatchewan River in the prairies of eastern Alberta. The portion of the Bow River (the target asset) included within the INFFER analysis is the section that extends from the Bearspaw Dam upstream from the City of Calgary to the Bassano Dam downstream. It includes the watersheds of the Elbow River, Nose Creek, Fish Creek, the Sheep and Highwood Rivers, Crowfoot Creek and West Arrowwood Creek. It also includes area Irrigation Districts' lands and canals that are both within and outside of the natural watershed boundary. The BRPMP planning area is approximately 12,481 square kilometres in size, or almost 2% of the total area of Alberta. This is the most populated portion of the entire watershed. In 2012 the population was estimated at 1.3 million and is projected to grow to more than 2.28 million by 2041.

The main issue to be addressed by the BRPMP project is excess aquatic plant and algae growth within the Bow River, caused by high concentrations of phosphorus, and associated water quality indicators. The BRPMP project was undertaken to maintain or reduce the amount of phosphorus within the Bow River with the expectation that doing so would reduce the incidence and severity of aquatic plant and algae growth. The main threat to the asset is from population increase in the project area. Population increases lead to increased urban and peri-urban development, higher development density, and intensification of agricultural and industrial activities. Development and construction also directly contribute to increased phosphorus loading through erosion and mobilization of sediment containing phosphorus.

The initial goal for the BRPMP project was described as a voluntary agreement between stakeholders to maintain the current state of water quality indicators within the project area. The specific water quality indicators to measure and a numerical value describing the current state were not defined; without this an INFFER analysis was not possible and in fact, we would argue that any sound analysis without a clear goal is also problematic. A time frame for the project also was not defined. LSC recommended defining a SMART goal for the project and as a requirement of completing the INFFER analysis. The final goal statement agreed upon for the BRPMP project is to maintain water quality in the Bow River between Bearspaw and Bassano dams over the next 20 years not to exceed a Median Annual Total Phosphorus (TP) Load of 230,324 kg/yr (based on 2004 - 2010 levels) as attributed to:

Upstream Source	= 18,682 kg/yr (8%)
Urban Point Source	= 85,902 kg/yr (37%)
Urban Non-Point Source	= 16,439 kg/yr (11%)
Rural Non-Point Source	= 26,353 kg/yr (11%)
Unaccounted Source	= 72,949 kg/yr (32%)

The P loads came from the available modelling and data acquisition by the Government of Alberta. The goal is further described in Draft Bow River Phosphorus Management Plan Steering Committee Review

Version, August 9, 2013 pp18 – 19. It is recognized that large episodic events, such as fire or flood, have the potential to significantly impact the asset, however, the additional data and modelling required to characterize the impact on the asset are outside the scope of the current assessment.

4.2.2 Technical Feasibility

INFFER assesses technical feasibility through an evaluation of the work needed to achieve the outcomes defined by the goal. It also considers the time lag before benefits of the work are realized, how effective the actions are and the risk that the work will fail to achieve expected benefits (Roberts et al., 2009).

The analysis of technical feasibility for the BRPMP INFFER assessment was based on a combination of professional judgement provided by the individuals participating as content experts on the Task Teams and a review of the existing literature. The extant literature evaluating the effectiveness of proposed BMPs within an Alberta context was limited, therefore alternative sources of scientific data had to be consulted. In the absence of readily available Canadian information, Simpson and Weammert (2009), developed for the Mid - Atlantic region of the United States, was the main source consulted for BMP effectiveness. It is recognized that the Simpson and Weammert analysis may have differing results to a Canadian setting, nevertheless it provided an information base on which to begin. For a further discussion of knowledge gaps and assumptions in the INFFER analysis see the appropriate section below. Land cover remote sensing data from ESRD for the BRPMP project area was evaluated for the RNPS Task Team (see Appendix 8.5). Land cover was differentiated into the following categories:

- Water
- Exposed Land
- Developed
- Shrub land
- Wetland
- Grassland
- Annual Cropland
- Perennial Forage
- Coniferous Forest
- Deciduous Forest
- Mixed Forest
- Nursery
- Agriculture (Undifferentiated)

Specific RNPS land cover categories used for BMP effectiveness calculations were:

- Shrub land, Coniferous, Deciduous, Mixed and Nursery Forests
- Wetlands
- Grassland and Perennial Forage
- Annual Cropland and Agriculture (undifferentiated)

4.2.3 Practice Change

INFFER specifically considers the expected levels of adoption of recommended actions, as well as whether or not those levels of adoption will be sufficient to achieve the goals of the project. If the proposed actions occur on private land, there must be an assessment of how attractive the proposed actions will be to private landowners and any associated incentives required to ensure adoption. The levels of adoption for the RNPS BMPs were estimated in consultation with the content experts on the

RNPS Task Team. UPS BMPs were evaluated in the same way, except where the proposed action was required by regulations governing waste water treatment plant operations in which case an adoption rate of 100% was used. See the appropriate section below for more details.

The major limitation with respect to adoption rates and practice change is that rates are based on the best estimate of content experts but in most cases lack direct scientific data to validate those estimates. In general, it has been noted that adoption rates tend to be overestimated (Roberts, 2013), therefore, realistic estimates were used as much as possible.

4.2.4 Delivery Mechanisms and Costs

Delivery mechanisms for the proposed action are considered as part of the INFFER analysis. In the case of actions on private land, proposed actions can be implemented using a payment scheme, a legal agreement, a voluntary program, or a regulatory approach. Each method will have associated program requirements and program costs that are accounted for in the ePAF. The proposed actions can be categorized as on-the-ground actions, data collection, research actions and management plans. In INFFER the on-the-ground actions are critical (these being the only ones to have a direct impact on load reductions), however, the inclusion of important research activities, supporting extension and management plans should be included as part of the overall project if they are important to the success of the project as a whole. Actions that need to be implemented by other organizations are also included as part of the ePAF scenarios.

The socio-political risk of the project is also calculated within INFFER. Socio-political risk estimates the risk that the project will fail to achieve its goals due to one or more of the following factors:

I. Non-cooperation by other organisations responsible for natural resource management.
II. Social, administrative or political constraints.

Program costs are calculated for up-front costs, those costs associated with the initial implementation of an action, and on-going maintenance costs, the costs associated with the on-going maintenance of the program. Maintenance costs are calculated on an annual basis. Each prepared ePAF includes cash committed, cash required, and in-kind contributions. Compliance costs estimate the annual compliance costs for private citizens who have to comply with the regulations that are enforced as part of a project. The inclusion of these three categories of costs represents a comprehensive accounting of the likely costs associated with the assessed project. Program costs were calculated based on the best available data and in consultation with context experts from the Task Teams.

As new or more accurate data is made available, costs can be recalculated for each prepared ePAF. Further information on cost assumptions can be found in the relevant section below. Costs are discounted over the 20 year timeframe of the BRPMP project at a rate of 5% (Roberts et al., 2009). Limitations that must be accounted for when considering the cost estimates include the preliminary nature of some of the estimates. Costs are calculated on a single average figure basis. During actual program implementation, targeted application of specific BMPs would be possible. Costs are calculated to account for the majority of identified program costs but may not be exhaustive. EPAF scenarios can be recalculated as more data becomes available.

5. Results and Discussion

The outputs of the INFFER analysis included a Benefit : Cost Ratio (BCR) table that ranks the relative merit of proposed individual actions and five scenarios assessing a combination of actions, three ePAF assessments, and a discussion of assumptions, knowledge gaps, and possible future directions.

As part of the INFFER analysis, the current condition of the asset was defined and projected phosphorus loading was estimated based on information about historical and projected population growth and development.

- Benchmark conditions: Median Annual TP Load (2004 – 2010) = 230,324 kg/yr
  - Upstream Source = 18,682 kg/yr (8%)
  - Urban Point Source = 85,902 kg/yr (37%)
  - Urban NP Source = 26,439 kg/yr (11%)
  - Rural NP Source = 26,353 kg/yr (11%)
  - Unaccounted Source = 72,949 kg/yr (32%)

- Projected conditions: Median Annual TP Load (2033) = 276,061 kg/yr
  - Upstream Source (Projected 10% increase) = 20,550 kg/yr (8%)
  - Urban Point Source (based on City of Calgary) = 118,453 kg/yr (43%)
  - UNP Source (based on City of Calgary) = 32,485 kg/yr (12%)
  - RNP Source (Projected 20% increase) = 31,624 kg/yr (12%)
  - Unaccounted (Project to remain constant) = 72,949 kg/yr (26%)

- Projected total phosphorus loading increase (2033) = 276,061 - 230,324 = 45,737 kg/yr
- Projected asset value decreases by approximately 16% with no action over the 20 year project span.

5.1 Benefit : Cost Ratios

The BCR table includes information on the three UPS actions and eight RNPS actions assessed using the INFFER process. The UPS actions are:

1. Upgrade the City of Calgary Bonnybrook waste water treatment plant.
2. Implement floating treatment wetland technology in lagoons within the project area.
3. Implement alum dosing technology in lagoons within the project area.

The RNPS actions are:

1. Manure management
2. Cropland conversion adjacent to riparian areas
3. Cropland conversion of waterways
4. Restrict grazing access to riparian areas within the cultivated area
5. Restrict grazing access to riparian areas within perennial cover areas
6. Application of provisions within the Wetland Policy and mitigation
7. Wetland protection
8. Wetland restoration

The five project scenarios are:

1. UPS scenario 1: an assessment of the three UPS actions
2. RNPS scenario 1: an assessment of the eight RNPS actions
3. RNPS scenario 2: an assessment of six RNPS actions (without wetland protection and restoration as these are expensive options and may not be required if effective Wetland Policy implementation was to occur)
4. Combined scenario 1: an assessment of all UPS and RNPS actions together
5. Combined scenario 2: an assessment of all UPS and RNPS actions together, without wetland protection and restoration.

The BCR table includes all the quantitative values required for an ePAF analysis.

A relative BCR ranking table was also developed for all proposed actions to rank the merits of proposed actions against each other, rather than a numerical ratio value. See Appendix 8.4 for the complete BCR table.

Estimated phosphorus reduction was calculated based on the agreed to assumptions about land cover, land use, adoption rates and BMP effectiveness. RNPS actions were calculated to reduce phosphorus loading by 1461 kg/year. UPS actions were calculated to reduce phosphorus loading by 33,446 kg/year. Given the projected P load increases due to increased urban expansion (an additional 45,737 kg P/yr), neither set of activities is sufficient to meet the goal of maintaining water quality. See Appendix 8.6 for full calculations.

5.2 Results of ePAF Assessments

Three ePAF scenarios were completed for the BRPMP INFFER analysis: a RNPS scenario with all proposed RNPS actions, an UPS scenario with all proposed UPS actions, and a combined scenario with all proposed RNPS and UPS actions. Outputs of the ePAF analysis include a benefit: cost ratio (BCR) and a public: private benefit framework. A BCR value greater than one indicates that benefits exceed costs. Full ePAF outputs are included in Appendix 8.16.

The RNPS scenario had an estimated phosphorus load reduction of 1461 kg/year, a total cost of $370,571,164 over 20 years and a BCR of 0.001. The UPS scenario had an estimated phosphorus reduction of 33,446 kg/year, a total cost of $69,198,054 over 20 years and a BCR of 0.400. The combined RNPS/UPS scenario had an estimated phosphorus reduction of 34,907 kg/year, a total cost of $439,769,218 over 20 years and a BCR of 0.010.

None of the assessed scenarios had a BCR >1, therefore, none of the assessed scenarios would be judged as a good investment for the benefits expected. The phosphorus reduction achieved with the combined RNPS/UPS scenario still fails to address the projected 20-year phosphorus loading increase by 10,830 kg/year and at significant cost. The relatively low BCR calculated for the RNPS scenario was due to the costs associated with wetland protection and restoration. These costs included land securement costs, provided by Ducks Unlimited Canada which undertakes land securement activities, and the large land area that is needed to achieve benefits from wetland protection and restoration.

Based on Simpson and Weammert, 2009, four percent of the land area (watershed) must be wetlands to achieve appreciable benefits. When calculated over the entire BRPMP project area, this amounts to a significant area. For this reason, a BCR was calculated for RNPS actions without wetland protection and restoration. While the BCR score improved, it was still relatively low (the BCR score went from 0.001 to 0.014). Each Task Team identified education and awareness programming as a priority so an education, outreach and program administration cost component was included with each scenario. This component adds to the overall project delivery costs but does not significantly affect effectiveness.

The factors most likely to affect BCR values are effectiveness of proposed actions, time lags before benefits can be expected, socio-political risks and cost. These results, and an examination of the underlying assumptions, provide the basis upon which a systematic analysis of available options can be undertaken. It should be noted that no optimization analysis was undertaken. One of the guiding principles of the BRPMP INFFER project is that each sector would contribute voluntarily to meet the overall goal of the project, however it appears that voluntary actions alone are likely to be insufficient to have a substantial impact and will not meet the goal as stated. See below for a full discussion of the assumptions made for the ePAF analysis and the existing knowledge gaps.

The suite of programs proposed for the Combined RNPS/UPS Scenario has benefits much greater than those targeted specifically towards phosphorus management. These include:

1. Provides a venue for trialing and evaluation of floating treatment wetland (FTW) technology in Alberta. FTWs also enhance biodiversity, provide recreational opportunities and enhance the overall knowledge of the technology for various other applications apart from phosphorus management.
2. Implementation of alum dosing will precipitate phosphorus into the lagoon sludge which can then be removed under standard lagoon maintenance.
3. Implementation of the Bonnybrook enhancements will allow for the City of Calgary to treat an additional 100ML/day of waste water, providing enhanced services to a growing metropolitan center without having to construct another separate wastewater treatment plant.
4. Protection and restoration of wetlands will enhance biodiversity, promote source and ground water recharge, reduce risks associated with flooding, provide forage for livestock, provide recreational opportunities and enhance the quality of surface and ground water.
5. Protection and restoration of riparian areas will enhance biodiversity, reduce sedimentation, enhance surface water quality, and reduce pollutants entering the system (including nitrogen and fecal coliform).
6. Implementing a risk-based manure management system will reduce the risk of pollutants (including fecal coliform and other pathogens) entering the system and contaminating source water used for livestock and human consumption.
7. Conversion of marginal cropland into perennial forages will reduce sedimentation, pollutants (including fecal coliform and other pathogens) and chemicals (including nitrogen) from entering the system.

5.3 Assumptions

Some assumptions must be made as part of any INFFER analysis. However, assumptions made as part of the BRPMP analysis are made explicit and can be critiqued and refined.

Assumptions general to all INFFER analyses include (Pannell, 2013):

- Environmental benefits are linearly related to the adoption rate of proposed actions;
- One time lag is used for all the benefits of a scenario, although benefits may accrue at different rates for different actions; and

- Treating project costs, maintenance costs, and compliance costs as if there is one combined constraint on their availability.

Further assumptions made as part of the BRPMP INFFER analysis include:

- Phosphorus attributed to RNPS in the goal statement was calculated from the portion entering the Bow River from tributaries. This portion of the phosphorus load was attributed to RNPS in lieu of more specific data.
- In BCR calculations, it was assumed that each unit area of rural land contributed equally to the phosphorus load.
- Effectiveness of action was calculated at 10% effectiveness for low impact, 20% effectiveness for medium impact, and 30% effectiveness for high impact actions. More specific data was generally not available for BMP effectiveness. The only source of more specific data was either from a report by Simpson and Weammert (2010) done for the Mid-Atlantic region of the United States or where Task Team contacts had specific information on effectiveness.
- Effectiveness of proposed rural non-point actions was calculated equally across the landscape. This may not be an accurate reflection of how BMPs would work on-the-ground, where it would be possible to target the implementation of BMPs to those areas where they would be most effective.
- The amount of phosphorus reduced by RNPS proposed actions was calculated by multiplying the estimated percent effectiveness by the land area to which that action could be applied.
- It is assumed that the GIS data used to characterize rural non-point land use represents actual conditions on the ground. No calibration was conducted as part of the BRPMP INFFER project, although some calibration may have been done as part of the Government of Alberta GIS data collection and calibration.
- Cost estimates for land acquisition are based on average values provided by Ducks Unlimited Canada and expert opinion. These estimates may not accurately reflect higher land values near urban centres and other variations in land value.
- Budgets and impacts are factored over the 20 year span of the BRPMP project and a 5% discount rate is used for calculations.

5.4 Limitations and Knowledge Gaps

One of the strengths of the INFFER process is that it allows for the identification of knowledge gaps as part of the ePAF preparation. Identified limitations of the analysis and knowledge gaps may have potential implications for decision making. Once identified, knowledge gaps can be addressed for future analyses.

Limitations and knowledge gaps identified as part of the current BRPMP INFFER analysis are listed below. Note that these knowledge gaps and limitations apply regardless of whether INFFER or another process was used; INFFER simply makes the limitations of current knowledge more transparent than other processes. Limitations and knowledge gaps include:

- Assessment activities on their own typically do not provide any direct protection function, but are a necessary step in determining which protection activities may be best to implement.
- Optimization of proposed actions can only occur within sectors. BCRs cannot be used to compare the actions of the RNPS with actions from the UPS Task Teams.

- Many of the proposed actions listed by Task Teams were categorized as planning, research, policy, or extension (see Appendix 8.7 for the full list of proposed actions and categorization). These activities are a necessary part of developing a meaningful and effective plan. However, they do not directly contribute to the management of phosphorus and so were not assessed as part of the INFFER analysis. These preliminary planning stages are critical to develop a science-based, outcomes-focused implementation plan.
- BCR values are presented as relative rankings because of the lack of specific information available and the number of assumptions that went into the calculations.
- No modelling data was available detailing phosphorus origin, transport and fate. Factors related to generation, transport, and dynamics of phosphorus entering the Bow River remain an ongoing topic for investigation. Considerable effort has been made to manage phosphorus loading by municipalities (particularly the City of Calgary) from a point source perspective. The gap continues to widen, however, from a non-point perspective for both urban and rural. Many of the identified knowledge gaps have a particularly high impact for non-point phosphorus management, requiring immediate prioritization and resource allocation at a sufficient level to allow for completion of many of the tasks.
- Sources and magnitude of urban non-point sources of phosphorus are not well characterized. More investigation is required to determine long-term development patterns and effects on non-point phosphorus loading.
- No information was available on phosphorus loading by land use and land cover type, particularly important for the RNPS team. There is significant room to improve the understanding of how phosphorus sources are related to surface waters.
- Detailed mapping and risk assessment to target actions is required to better focus programs into high risk phosphorus loading areas.
- Although some water quality modeling data does exist it is sparse and does not include much (if any) direct connection between on-farm and land management activities and resultant phosphorus loading into the system. More water quality modeling effort at a broad scale, or sub-basin level, is required to better predict environmental performance as a result of management action implementation.
- BMP effectiveness data was generally not available and assumptions and expert opinion had to be used. Further investigation into local, organizational, or unpublished information that provides information on BMP effectiveness may be a direction to investigate.
- Some investigation into the effectiveness of wetland protection and restoration has been done, however, given the large costs associated with wetland activities further refinement of this research is warranted to ensure accurate figures are available for phosphorus reduction.
- The impacts of large episodic events such as flood and fire, and climate change on environmental outcomes are not accounted for in the current analysis. There is not enough data available on these events to incorporate into the analysis.
- Enhanced coordination amongst partners is required to better align programs and initiatives that can have a direct impact on phosphorus management within the project area.
- More information may be required on in-stream flow needs to maintain ecological function of the portion of the Bow River within the project area.

The Urban Point Source task team identified several high priority knowledge gaps to assist with implementation, including:

1. Complete modeling for the BRPMP project area to determine clear outcomes and connections between proposed programs and net phosphorus reduction.

2. Base the Total Loading Objectives for wastewater (and storm water) on the receiving water's cumulative effects assessments.
3. Seek opportunities to implement upstream phosphorus management actions to reduce phosphorus inputs into the planning area.
4. Evaluate potential wastewater effluent re-use practices, and promote changes in the Water Act to allow for them.
5. Clarify Municipal Policies and Procedures Manual with respect to guidelines for piloting unproven or innovative and alternative technologies for lagoons.

As a result of the RNPS Task Team consultations, several data and research needs were identified. After reviewing all of the proposed research needs, the following has been developed as priority knowledge gaps that will assist with the planning and delivery of programs:

1. Complete a water quality model of the BRPMP project area to determine clear outcomes and connections between proposed programs and net phosphorus reduction within the watershed.
2. Map critical source areas, wetlands and riparian areas within the planning area which will be used to identify those areas contributing the highest levels of runoff and phosphorus to the system.
3. A detailed upland cover inventory is required and should be combined with the wetland inventory into a GIS database.
4. Conduct research on the effectiveness of wetlands in the planning area to manage phosphorus.
5. Complete an inventory of trails, roadways and other linear features to determine current state and to identify priority reclamation projects or areas.
6. Conduct a regulatory review to evaluate municipal legislative and policy options to address issues related to small acreage development, land and livestock management.
7. Complete risk assessments for commercial livestock operations and encourage adoption of practices to mitigate risk associated with: manure application, confined feeding operation (CFO) livestock feeding and seasonal feeding and bedding sites.
8. Create an inventory of erosion risk in natural channels to determine current state and to identify priority reclamation projects or areas.

6. Conclusion

Overall for the very large scale of the asset, the results suggest that more work needs to be done before a whole-scale adoption of proposed BMPs can be expected to achieve the desired benefits. Some of this work is ongoing, such as Soil and Water Assessment Tool (SWAT) modelling and BMP effectiveness studies currently being undertaken in the Crowfoot Creek sub-watershed. This information should be incorporated as it becomes available into the BRPMP project to ensure decisions are based on the best available information. Conducting the analysis on a smaller scale, such as at the sub-watershed scale, would increase the accuracy of future INFFER analyses if better and more complete data was available to characterise phosphorus loadings, adoption rates, and expected phosphorus reductions.

The focus of the current assessment was on phosphorus management. However, many of the proposed actions have additional benefits for other variables such as biodiversity enhancement, management of other nutrients and total suspended solids. Future work could also focus on defining alternative BMPs not considered as part of the current analysis. Alternatively, investment in technology to improve phosphorus management outcomes may be another route to investigate but requires further analysis.

The implementation of proposed actions in the RNPS/UPS combined scenario will require significant financial and human resources. It will be critical for all partners to carefully explore the opportunity to align current programming efforts with those identified within this scenario.

The UPS and RNPS actions proposed are insufficient to maintain water quality for the Bow River. The projected phosphorus increases are more than the expected load reductions from the identified activities and, due to the very high costs, no project was assessed as cost-effective on its own or in combination with other options.

The testing of FTWs is seen as an experimental approach to managing waste water in a climate like Alberta. It is important that there are stringent design and evaluation measures put in place to ensure the efficacy of FTW technology can be accurately assessed and reported to partners.

It is evident that a RNPS only approach will not achieve the goal as stated and will require additional planning and input from other sectors.

Owing to the current high level of commodity prices within the agriculture sector generally, there is a risk that landowners and land managers will be unwilling to enter into any long term agreements that could increase their opportunity costs.

Although there are several programmatic actions identified, the BRPMP project area is an extremely large and diverse watershed with many local and/or sub-watershed issues that are the responsibility of municipal governments. There is a need to further explore implementation of programs targeting land conversion to rural residential and/or industrial development. A major risk is the lack of awareness or adoption of the proposed programs by municipal governments during deliberations surrounding land use planning. Potentially difficult phosphorus management decisions need to be made that could increase costs for developers and reduce revenue for municipalities.

As the new Alberta Wetland Policy and associated Implementation phase rolls out, it is important to align and refine program objectives associated with the BRPMP. As the South Saskatchewan Regional Plan (SSRP) and the Surface Water Quality Objectives are approved and implemented, it is critical to align and refine program objectives associated with the Bow River PMP.

6.1 Project and Implementation Recommendations

Further project and implementation recommendations include:

- Compare relative BCR rankings for RNPS actions to Crowfoot Creek SWAT outcomes. Preliminary analysis suggests that conversion, rather than protection, BMPs will be more effective and should be considered for pilot scenarios.
- It may be that one of the outcomes of the BRPMP INFFER analysis is that there is insufficient evidence to fully support the assumptions made, however, this is important information in itself.
- The BRPMP INFFER analysis suggests that implementation of the proposed BMPs within the project area will not achieve the goal of the project, therefore, strategic discussion of the direction and scope of future investment is required.
- Calculated BCRs are based on specific information and assumptions. Changes to program design and delivery should be re-evaluated through the INFFER process to ensure that expected benefits will be achieved.
- Any decisions made to adopt recommended BMPs based on the INFFER analysis should take knowledge gaps and quality of information used for the assessment into account.

6.2 Lessons Learned

LSC is testing the utilization of INFFER in an Alberta context. The BRPMP project area is highly varied and has multiple, competing land uses. The project is large and complex, with many sectors and stakeholders with a diversity of interests represented on the Task Teams.

INFFER adds value to the decision support process by:

- Providing a structured process for diverse interests to work towards a common goal.
- Supporting the choice of appropriate delivery mechanisms.
- Providing a transparent approach to discuss future directions for research and implementation.
- Integrating scientific, social and economic information with risk factors and quality of knowledge to assess actions.
- Identifying and prioritizing knowledge gaps and limitations.
- Reducing any bias that may exist in the decision-making process by making the information used, assumptions made, existing knowledge gaps and calculations transparent and available for critique and refinement (Strang et al., 2010).

Lessons learned through using the INFFER process for the BRPMP project include:

- Many of the proposed actions were at a strategic level, rather than an operational or tactical level that would have real impact on the problem as stated. Although the BRPMP project was initially conceived as an action oriented plan, many of the recommendations need to be re-framed into more specific actions that can be implemented in a targeted, science-based, outcome-focused way.
- The prioritization process with the Task Teams took much longer than expected, most likely because Task Teams were unused to defining specific on-the-ground actions rather than general strategic objectives and they were not familiar enough with the INFFER process to understand that the prioritization process was preliminary and further information would be collected during the actual ePAF preparation. Although several presentations were made to Task Teams outlining the INFFER process, a workshop-style presentation on INFFER may help increase familiarity and comfort with the INFFER process.

- Owing to the magnitude and time commitments to a project of this size, Task Team representation often varied and continuity of discussions were lost. Draft content provided to members for comment would have ensured continuity and allowed for better use of team meeting time.
- INFFER provides a factual basis for analysis and decision support and allows for re-evaluation of widely held beliefs that may not be supported by the evidence.

The INFFER analysis is the product of running data through a formula whose parameters are clear, transparent, and open for discussion, criticism, and possible testing with data by others. The factors in the formula are clearly defined, data used to generate results is provided, and the rationale for using the INFFER process in the BRPMP project context is clearly provided. INFFER allows identification of critical data essential for analysis that may be missing or unknown. If these knowledge gaps are found to be central, the analysis provides the basis upon which other analyses can be done.

Any decision support tool is dependent on the quality of information input into the process to generate a useful and accurate analysis. Regardless of the supporting tools used, the BRPMP project cannot be successful without a clear vision of what is required to meet identified objectives. It will be important to build on the learnings from this project so that future INFFER analyses can achieve more from the outset.

In conclusion, although the results in terms of cost-effectiveness were disappointing, the process of INFFER worked very well. The time taken to do another analysis either on the Bow River or elsewhere could be markedly reduced with the learnings gained through this project. INFFER provides a useful integrating framework to address complex environmental problems which require evidence-based decisions by public institutions. We believe it has strong potential to improve decision-making in Alberta and in Canada more generally.

7. References

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8. Appendices

8.1 Presentations

1. Investment Framework for Environmental Resources An Overview – Bow River Phosphorus Management Plan Task Team Workshop – September 21, 2012
2. Bow River Phosphorus Management Plan – A Proposed Prioritization Process For Task Teams – October 19, 2012
3. INFFER Overview and Water Quality Application – Dr. Anna Roberts Department of Primary Industries Victoria, Adjunct Professor, La Trobe University
4. Bow River Phosphorus Management Plan – Steering Committee Update – March 2013
5. Bow River Phosphorus Management Plan – Steering Committee Update – April 11, 2013
6. Bow River Phosphorus Management Plan – Steering Committee Update – June 18, 2013
7. Bow River Phosphorus Management Plan – AESRD Update – October 3, 2013
8. Bow River Phosphorus Management Plan – Steering Committee Update – October 24, 2013

8.2 Assumptions

8.3 Developing Best Management Practice Definitions and Effectiveness Estimates for Nitrogen, Phosphorous and Sediment in the Chesapeake Bay Watershed – Executive Summary

8.4 Program Summary

8.5 Data and Assumptions

8.6 Phosphorous Load Estimates

8.7 Task Team Actions

8.8 Task Team Actions Tracking Table

8.9 Project Backgrounder

8.10 INFFER Key Information Requirements

8.11 Process Overview

8.12 Process Flow Diagram

8.13 Program Plan Outline

8.14 Implementation Critical Next Steps

8.15 Filter Questions

8.16 INFFER ePAFs

1. Bow River PMP-RNP-Scenario #1
2. Bow River PMP-UPS-Scenario #1
3. Bow River PMP-Combined Sources-Scenario #1