



FINAL REPORT

**Feasibility of integrated surface water management on agricultural land in
Manitoba**

***Tobacco Creek Model Watershed c/o Deerwood Soil and Water
Management Association Inc***

March 1 2012 – July 31 2012

Executive Summary

This project was a short feasibility study run between March and July 2012, to identify the potential for on-farm systems to store flood water, and to use the nutrients in the water for crops.

Topographical information (LiDAR) was used to identify potential areas to store water in three geographically and hydrologically distinct areas in Manitoba – South Tobacco Creek, the Red River Valley and the Icelandic River. A model was developed using MATLAB to predict the volume and duration of water stored, and another to predict the growth rate of cattails (*Typha* spp.) under different rainfall and temperature conditions. Producers helped to shape the project and the scenarios investigated.

The time available for this project limited what could be achieved, but the research team were able to thoroughly test new models that can be applied more widely across Manitoba (where LiDAR data are available), and that can be applied to other crops, and to other water storage designs such as back-flooding, modified ditches and small reservoirs.

The results were presented to producers, farm advisors and government representatives at a facilitated workshop in July. These showed that there are significant public and private benefits to be gained from storing water, harvesting cattails, and removing phosphorus from the environment.

1). SUMMARY

(a) Title; ***The feasibility of integrated surface water management on agricultural land in Manitoba***

(b) Name of Applicant(s); ***Tobacco Creek Model Watershed c/o Deerwood Soil and Water Management Association Inc***

(c) Name of Institution or Organization; ***Tobacco Creek Model Watershed c/o Deerwood Soil and Water Management Association Inc***

(d) Project duration (date of Project start up and completion); ***March 1 2012 – July 31 2012***

(e) Project Objectives;

- Identify the current research gaps in understanding farmland surface water management systems in Manitoba;
- Generate information on the factors to consider to construct effective water storage and management systems;
- Identify different potential uses for water storage systems in Manitoba and how they impact on design and management, such as retention of surface run-off on farmland in constructed multi-use wetlands or ponds, and re-use of the water for irrigation;
- Identify some candidate sites for trials of different drainage scenarios;
- Inform future research projects that deliver enhanced surface drainage on farmland;
- Establish the means to disseminate the research findings to the farming community.

(f) Activities carried out (a brief one or two page description of the accomplishments and a listing of project outputs, eg. business plan, thesis, conference paper, journal publication.); and,

This study involved a number of different activities to accomplish the objectives.

- Objective 1: Identify the current research gaps in understanding farmland surface water management systems in Manitoba;

Through discussions with researchers, farm advisors, producers, and government representatives, the gaps in knowledge were identified as falling into the following areas:

- 1) A lack of understanding of the farmland, and other areas (eg municipal or provincial drains) that have the potential to store water under a

surface water management system. This could be addressed if LiDAR was completed across the province.

- 2) A lack of collective knowledge of the surface water management systems in place currently. Throughout the project, schemes already underway were identified across the province. These include flood storage schemes in rural municipalities, wetland management and forage harvesting schemes supported by conservation districts, tile drainage and irrigation systems on farm. Some of the federal and provincial government staff were aware of schemes that had been big enough to require permits or licenses and researchers were aware of the schemes they were involved in researching. However, information about these schemes was not stored in a way that it could be retrieved, catalogued and factored into a Manitoba wide water management strategy.
- 3) The need for further research into i) the design and operation of surface water management structures; ii) the crops that would best utilize the nutrients and water either by growing in flooded areas or would benefit from the irrigation; and iii) the processing and end use potential of crops grown in flooded areas or irrigated.
- 4) The economic benefits to farm producers of surface water management systems and crop management.
- 5) The ecological goods and services that would be achieved through a surface water management strategy, and the social aspects of achieving such benefits (reduced flooding in Winnipeg, improved water quality in Lake Winnipeg).

- Generate information on the factors to consider to construct effective water storage and management systems;

Through workshop sessions with landowners, farm advisors, regulators and researchers the factors to consider in the design, construction and operation of water storage systems were captured. These are set out in detail in the workshop feedback in Appendix 1. The feedback covered the drainage factors, potential uses, design factors, maintenance issues, environmental goods and services, possible candidate sites and pre-existing examples.

- Identify different potential uses for water storage systems in Manitoba and how they impact on design and management, such as retention of surface run-off on farmland in constructed multi-use wetlands or ponds, and re-use of the water for irrigation;

This study explored the potential to store excess water on agricultural land, subsequently grow cattail on that same land, and estimate both private and public benefits from the stored water, harvested biomass, and the phosphorus contained within the harvested biomass at three agricultural locations in Manitoba. A simple cattail growth model and a two-dimensional hydrologic model were employed to simulate cattail growth and the water balance during a 90 day period at three physiographically distinct sites in Manitoba. Model simulations were performed under four different climatological scenarios (dry and hot, dry and cold, wet and hot, wet and cold) for hypothetical storage reservoirs identified from topographical analyses of LiDAR data.

Results indicate large private and public benefits from storing water, harvesting cattails, and removing phosphorus from the environment. The unavailability of LIDAR data eliminates the possibility of performing simulations throughout much of Manitoba, but the storage simulation model could be modified to deal with the three scenarios of interest - backflooding, using modified ditches and creating small reservoirs. The biomass production model can be changed to simulate growth of other plants.

Outputs from the study include a report on the scenario development and modelling (appendix 3); workshop reports (appendices 1 and 2); and presentations.

- (g) A copy of project outputs as per (f) are provided in the appendices to this report. Copies of the presentations are available on request.

2.) RESOURCES

(a) Summarize the project contributions for the entire project by source, as follows:

CAAP	Applicant/ Industry Cash	Applicant In kind	Provincial/ Municipal Cash	Federal Cash
\$16,500	\$3,500	\$1,850		

(b) If possible, provide an estimate of the potential financial impact on the sector (*e.g., amount of increased investment, sales, exports, cost savings*) if widely adopted or applied, or fully implemented.

This study was a feasibility study, which will lead to further research and analysis of the options before any on-farm investment can be made. Full economic analysis was beyond the scope of the project, but should be a significant part of the next phase.

3). REACH AND DISSEMINATION

Indicate who were the ultimate beneficiaries of the project and what level of contact was there with them (*eg. 150 producers, 70 representatives of government, 25 members of academia*).

The primary beneficiaries of this project are the agricultural producers in the Red River Valley and Tobacco Creek Watershed in particular.

The secondary beneficiary of this project would be *any* producers who have a need to manage water on their agricultural land, which includes cropland or improved pasture land experiencing in-season excess moisture, or overland flooding events

There are 44 farm producers within South Tobacco Creek, and about 500 within the Tobacco Creek Watershed, and many more throughout the lower Red River Valley who will be interested in the project.

Indicate vehicles used to disseminate the information to the ultimate beneficiaries and any feedback/uptake where applicable.

The main method of communication about this project was through workshops to which farmers in the interested areas were invited. This was done through producer groups, the conservation districts and through farm advisor contacts in MAFRI.

The workshops were designed to seek feedback from the producers. In the first workshop in March, soon after the project started, feedback was requested on the priorities for the project and this shaped the research. At this workshop we also requested input into the development of a communication strategy. At the second workshop, when results were provided, feedback was again requested through facilitated working groups, and attendees were invited to comment on the process as a whole. The outcomes from both of these workshops are included in appendices to this report.

The project team also gave presentations at a number of meetings that included:

Conservation Districts Managers meeting	Jan 2012
Red River Basin Commission South Chapter	Feb 2012
Red River Basin Commission North Chapter	Feb 2012
University of Manitoba Visionary Conversation	Feb 2012
Biomass workshop, Winnipeg	Mar 2012
Project workshop, Carman	Mar 2012
Water Management Strategy Workshop	Apr 2012
Water Security Summit, Winnipeg	May 2012
Living Lakes 2012 Gathering, Winnipeg	May 2012
Project workshop, Winnipeg	July 2012

4). RESULTS

- (a) Provide conclusions of the project including the significance of results and discussion of the project results including an explanation or interpretation of such results and indication of any unanticipated factors that affected the results of the project;

The project was carried out over short timescales and with a limited budget, which limited what could be achieved. However, the outcome is working water storage and biomass growth models that are transferable to different climate and physiographic areas.

The physiographic areas investigated were those of interest to the applicants and other partners, and the extension to other areas is limited by the availability of LiDAR data to develop digital elevation models.

The biomass model was limited to cattails for the purposes of this study. It showed that in the example scenarios an economic crop of cattails could be grown, and would provide a reasonable return for producers from marginal land. Further work is needed to incorporate other plant types and consider the application of water stored through irrigation to conventional crops.

- (b) What are the short-term outcome(s) expected at the end of the project (select one of the following):

- Improved knowledge of potential innovative products, processes or technologies
- Improved knowledge of solutions/strategies analyzed/tested to address issues/opportunities

Based on your selection above, describe the actual outcomes of the project.

The project has provided good background information to apply to the next phase of research which will cover in more detail: i) the design and operation of surface water management structures; ii) the crops that would best utilize the nutrients and water either by growing in flooded areas or would benefit from the irrigation; and iii) the processing and end use potential of crops grown in flooded areas or irrigated.

Where there any other planned outcome(s)? If yes, describe.

- (c) Next steps (if applicable);

The next steps are already underway. A proposal has been submitted to Manitoba Conservation and Water Stewardship to carry out a full

feasibility study which will consider i) the design and operation of surface water management structures; ii) the crops that would best utilize the nutrients and water either by growing in flooded areas or would benefit from the irrigation; and iii) the processing and end use potential of crops grown in flooded areas or irrigated.

The Watershed Systems Research Program is also proactively seeking partners for pilot projects to take designs forward to researching and testing on-farm. These include producer partners and research partners across Canada.

- (d) Include any publications, documents or materials for communications and all promotional activities as well as any and all other material for public distribution generated by the project, or which will be disseminated in the future.

Now that the project is nearing completion, and following the advice of workshop attendees on a communications strategy a series of communications are planned in addition to the presentations made and outlined in this report. These include the development of a simple factsheet to be available from the Watershed Systems Research Program website wsrp.ca and which can be handed out to producers and others at events. The Research Development Coordinator for the Research Program will coordinate writing of a press release and editorials for farm press. In consultation with the Communications Advisor in the Faculty of Agricultural and Food Sciences at University of Manitoba these will be targeted to the appropriate producer newspapers and magazines. The factsheet and editorials will be provided to MAFRI contacts in the provincial knowledge transfer offices, and to producer groups eg KAP.

Which of the following describe the potential long-term benefits from this project?

- reduced production of processing costs
- improved product quality
- improved market share
- preserving market share
- other (specify)

5). FOLLOW UP

- (a) Indicate any project follow-up that is planned (e.g., dissemination of results, full implementation of project, etc)

The outputs from the workshop held in July will be shared with those who attended the workshop, and made available to others through the Watershed Systems Research Program website wsrp.ca.

The results will form background information in a study to begin shortly funded by Manitoba Conservation and Water Stewardship at University of Manitoba titled 'Feasibility of innovative water and crop management practices to reduce nutrient loading from agricultural watersheds'.

- (b) Indicate questions on implementation/commercial impact that may be appropriate to include in a follow-up survey to your organization one year after project completion.

As this was a feasibility study, that was not expected to lead to implementation or immediate commercial impact it would be inappropriate to survey the organization in 1 year's time.

Appendix 1 Notes from Workshop 1 Carman, March 27, 2012

Integrated Surface Water Management Project Workshop held March 27 2012 at Ian Morrison Research Station in Carman, Manitoba 10am - 2pm

Background

This workshop was set up to provide those initiating the project (Tobacco Creek Model Watershed/Deerwood) an opportunity to invite input from other interested producers on the topic and to help the project team gauge the support for the ideas they were promoting and researching. The workshop was timed to run before producers became busy with their farming calendar (although the season started early this year). There was a lot of interest amongst producers and numbers were restricted to 30 attendees to make the session effective. The workshop was chaired by Selena Randall, Research Development Coordinator for the Watershed Systems Research Program at University of Manitoba.

Workshop Objectives:

- To use current knowledge and practical experience amongst farming community to inform the development of water management scenarios;
- Identify potential case study sites for in depth study;
- Develop communication strategy for project.

To start the session off, David Lobb from University of Manitoba gave some background to the project. This was followed by Hank Venema from International Institute for Sustainable Development (IISD) the contractor delivering the project who set out the way his team planned to deliver the development of the scenarios. The main purpose of the day was to introduce the project and the planned work and to get feedback from farm producers and their advisors to shape the way the proposed water management scenarios would be developed.

The biggest session of the day was the breakout sessions. Two groups facilitated by Selena Randall and David Lobb respectively covered the same set of questions:

- What are the drainage factors to consider in construction of water storage and management systems?
- What are the potential uses for water storage systems in Manitoba (irrigation, crop production)?
- Any design factors (siting, safety etc) to consider?
- Any maintenance issues?
- Any Environmental Goods and Services we can achieve?
- Candidate sites for trials of different drainage scenarios?
- Any pre-existing examples of these types of systems?

The feedback was recorded by the facilitators and consolidated after the meeting in the following pages.

A further breakout session was held after lunch to get input into the development of a communication strategy. The project team wanted to know the best ways and

times to communicate about the project to farm producers. The session was facilitated in two groups by Selena Randall and David Lobb respectively and each group was asked to consider the following questions:

- Who should our target audience be?
- What are the preferred methods for communications?
- When is the best time to communicate?
 - To tell producers this project is happening
 - To tell producers about the outcomes

The feedback and ideas were recorded by the facilitators and consolidated after the meeting in the following pages.

Integrated Surface Water Management on Farmland in Manitoba Breakout session 1

Objectives

- What are the drainage factors to consider in construction of effective water storage and management systems?
- What are the potential uses for water storage systems in Manitoba (irrigation, crop production)?
- Any design factors (siting, safety etc) to consider?
- Any maintenance issues?
- Any Environmental Goods and Services we can achieve?
- Candidate sites for trials of different drainage scenarios?
- Any pre-existing examples of these types of systems?

Guiding principles:

Technically feasible;
Agriculturally practical;
Economically feasible;
Environmentally acceptable.

General comments:

Need tax breaks or carbon credits or insurance credits
Need to find way to show system generates money back to provinces
How to get policy makers to table to discuss other options

Drainage Factors	
Example	Comments
Upstream and downstream benefit	Need both to be recognised
Ownership	May have multiple owners Need to go farm by farm Form a Co-op RM's, provincial drains and management will be factors in effectiveness
Move away from the idea of just conveying water away - its more about water transport	Look on it as a way to manage water
How to contain spring run-off but hold water for dry seasons	Use 'sacrificial land' Control the way water is discharged
Mindset needs to change	Need to get social scientists involved to get people to think differently
Natural Drainage	Identify land that has excess water management problems, old wetlands and consider for restoration
Enhanced drainage areas	Backflood - temporary storage Dug-outs Enhancing existing ditches/surface drains Enhance ditches for alternate uses Design and maintenance of RM and MB drains conveyance of water Isolation and independence pf drains
Need to manage soil erosion caused by runoff	

Potential water uses	
Example	Comments
Irrigation	Eg potatoes in RRV Water supply for spraying
Storing and pumping for grain production	Land application to offset aquifer use. Reduce the need to take surface water tanks to surface water drains
Native grasses, willows algae	These do well under water for 2 years - vegetation can be used for forage, spread to land, composted Can be scraped off ponds/tanks - used for fertilizer, biodiesel, pharmaceuticals Lots of research on uses of algae in USA
Watering livestock	Need to consider design. Can be used to intensively manage grass Can be used to wash barns and parlours
Recreation	All water uses
Aquaculture	fisheries
Wildlife	Eg Ducks Unlimited approach, restoration of wetlands
Hunting, fishing, ecotourism	
Maintenance Factors	
Example	Comments
Natural systems easier to maintain	Or not maintain - let nature do its thing?
Bank stability	
Siltation	Eventually a pond fills up
Salinity/ nutrient concentrations	Need management
Dry retention area	Culvert or gate operated - who maintains it and how do you protect it
Landowners change hands	How to manage and keep memory of reasons why things are managed this way
Decision making	Needs to be integrated between CDs/RMs and DFO etc
How to take account of off-site impact	What is the net benefit? Is benefit limited to on-farm?

Design Factors	
Example	Comments
Culverts have a finite life	Need something more passive, but this still has maintenance and security issues. 2-stage ditches? Can we use natural processes
Take advantage of the naturally wet areas	Willows, wet areas Tend to be distributed around farm area - minimal maintenance What about if you want to use the vegetation for biomass - view was it was better not to do anything large- scale that required much maintenance
Hold back water in one area improve drainage elsewhere	Overall benefit needs to be clear and demonstrable
Needs to be upstream of urban areas and reap multiple benefits	Eg. water uses, recreational benefits around urban areas Natural retention ponds
How does money become available to design and build?	
Water table	How to manage sub-surface flow
Rainfall and snowmelt	
Topography	
Existing drainage	
Water quality and quantity	
Environmental Goods and Services	
Example	Comments
Need comprehensive strategy	Integrated - assess net benefits
Managing soils	Reducing soil loss and nutrients
Nutrient remediation	Wet land construction, utilize biomasses from each, perennial crops (cattails, grass), algae Concern about salt with retention
Flood control	Increase water efficiency in crops, flooding management
Less demand for fossil fuels	Carbon neutral, less inputs
On-site and downstream EGS	Valuation of holding?
Balance between real on-farm benefits with EGS	

Candidate sites		
Site	Contact	
Deerwood - 12 possibles	Les McEwan	
RM Rosser - infrastructure in place to flood 100 acres of land	Scott Corbett	
6 in EICD	Armand Belanger	
Other options	Blind miles, crown land, low-lying areas, willing landowners	
For each participating site	Need to know the objectives for that location	
Existing examples		
Site	Details	Contact
Lizard Lake	backflooding	Pembina Valley CD
S of Miami	Base of escarpment 70-80 acre watershed, 13 acre feet of water for irrigation with managed discharge	Pembina Valley
BiFrost	Project underway in Interlake Identifying potential sites on higher ground	Len Loewen
Pelly Lakes	Wetland with harvesting	La Salle Redboine CD
DSWMA-STCW/TCMW	Small headwater dams	Deerwood
Stead Glenmore Project	Farmer group	Steve Dalen
Crown land - forest wetlands	Marginal land eg RM DeSaleberry, Ginoux Bog	
Klassen Retention Project		
Forestry Road #3	St Anne	Seine-Rat CD
Carrot River	RM Kelsey	

Integrated Surface Water Management on Farmland in Manitoba Communications Strategy

- Who should our target audience be?
- What are the preferred methods for communications?
- When is the best time to communicate?
 - To tell producers this project is happening
 - To tell producers about the outcomes

Key message:

There are farmers in Manitoba who are considering novel methods to manage surface water differently.

Main communication activities - opportunities identified

Workshops - structured days with a targeted group of farmers, but open to attendance by farmers from across the province. MAFRI and Conservation District staff will assist in communicating to farmers and gaining support for the workshops. Written communication activities - The project and outcomes will be featured on the University Soil Science and IISD websites, Tobacco Creek Model Watershed website and regional and provincial media outlets. Outcomes will be communicated through existing extension program outputs. The final technical report and scientific publications will be completed if appropriate.

Other opportunities - throughout the project we will seek to promote the project principles and communicate the outcomes through other opportunities as they arise for example, during field tours and at stakeholder events where the researchers are invited. Project work may be able to be featured at/in:

- The Annual MAFRI Soil and Manure Management field clinic in August
- The Annual MB Agronomists Conference in Dec
- Farming for Tomorrow – a 2-3 times/year publication focusing on agri-environmental topics. Released to about 3000 farm mail boxes across the province and GO offices across Manitoba.
- The Co-operator or Western Producer may take interest in an interview / article for their readers
- Prairies East Sustainable Agricultural Initiative annual meeting or summer field tour – can highlight the work here.
- Can be presented to the KAP "Environment Committee" for discussion and could be featured in the "KAP Alert" for producers.
- May be potential to be featured as a BMP "mini-series" presentation in Environmental Farm Plan workshops

Audience	Methods
Manitoba conservation and water stewardship MAFRI AESB KAP MASC Hutterite colonies Lake Friendly Funding programs RM's Dairy Farmers of Manitoba Fertilizer Institute CDs RRBC NRPF MCDA AMM Students - ag students, ag colleges Public - need to know what improvements farmers are planning to make Minister - Gord Macintosh	Emails Farm Press - Producer, Cooperator, Grain News Winnipeg Free Press columnists eg Gerrald Flood Community papers MAFRI website e-newsletters KAP Notice to agencies boards Highlight who is involved and what opportunities there are to get involved Talk about \$/acre costs/savings Best to show what solutions are available ie focus on project completion
Timing - project happening	Timing - project completion
Mid-june is when things calm down Take opportunity of weather and tone messages eg if wet - focus is on flood mitigation If dry, focus on storing water Mid June earliest Mid July at latest 2 weeks notice of workshops	Link with other methods Eg. Western Producer does focussed productions

Other - need a one-line message to have an influence. Link it to Lake Winnipeg, make it about Agriculture

Workshop Attendees

In addition to Facilitator Selena Randall, and presenters David Lobb, and Hank Venema, the following people attended the workshop in Carman.

Name	Organization associated with
Kristy-Layne Carr	SRRCD
Cornie Goertzen	SRRCD
Jodi Goerzen	SRRCD
Len Loewen	BIFROST
George Jackson	PVCD/Deerwood
Walter McTavish	PVCD/Deerwood
Maurice Bouvier	MAFRI
Don Cruikshank	Deerwood
Barry Driedger	Deerwood
Dale Robinson	Deerwood
Armand Belanger	EICD
Rick Gamble	Farmer
Justin Reid	LSRCD
Laura Grzenda	MAFRI
Les McEwan	Deerwood
Steve Dalen	Pinnacle
Orest Kaminski	Farmer
Mark Fosty	Farmer
Cam Dyck	Deerwood
Eric Ziegler	Deerwood
Kelvin Hildebrandt	Deerwood
Scott Corbett	Farmer
Don Flaten	UofM
Marla Riekman	MAFRI

Appendix 2

Integrated Surface Water Management: Workshop 2 Report

Prepared By:

Catie Harasym and Christina Kostera -
SLMcLeod Consulting

Prepared For:

University of Manitoba and
Deerwood Soil and Water Management
Association

Table of Contents

1.0 Background	23
2.0 Goals and Objectives	24
<u>2.1</u> Workshop Goal	24
<u>2.2</u> Workshop Objectives	24
3.0 Workshop Process	24
<u>3.1</u> Facilitation Used in Workshop	24
<u>3.2</u> Process Strengths	25
<u>3.3</u> Process Recommendations	25
<u>3.4</u> IISD Decision Making Theatre	26
4.0 Summary of Les McEwans' (Deerwood) Presentation:	26
5.0 Summary of Dr. David Lobb's (University of Manitoba) Presentation: Integrated Surface Water Management – Taking Control of Challenges and Opportunities	26
6.0 Dr. Hank Venema's (IISD) Presentation:	27
7.0 Approaches to Manage On-farm Excess Water	27
<u>7.1</u> Use or Modification of the Drainage System to Accommodate Storage	27
<u>7.2</u> Use of On-Farm Storage	27
<u>7.3</u> Use of Back-Flood Dams	27
8.0 Participant Group Work	28
<u>8.1</u> Technical	28
<u>8.2</u> Implementation	30
<u>8.3</u> Enabling Policy and Procedures	32
9.0 Discussion and Outcomes	34
10.0 Conclusion	35
11.0 Next Steps	36
12.0 Appendix 1: List of Attendees	37
13.0 Appendix II: Integrated Surface Water Management of Farmland and Current Work presentation	Error! Bookmark not defined.
<u>13.1</u> Les McEwan –	Error! Bookmark not defined.
<u>13.2</u> Dr. David Lobb – Integrated Surface Water Management – Taking Control of Challenges and Opportunities	Error! Bookmark not defined.
<u>13.3</u> Dr. Hank Venema -	Error! Bookmark not defined.

1.0 Background

The purpose of the workshop was to develop a sustainable approach to managing farmland surface water and associated nutrients in Manitoba and provide an opportunity for interested landowners to learn more about the contractor-developed scenarios and determine which ones to pursue in case studies. This half-day workshop held on July 6, 2012 at the Radisson Hotel in Winnipeg, Manitoba convened landowners and farm advisors who attended the initial workshop in Carman, others from Rural Municipalities known to have an interest in the project and potential case study sites to offer, researchers and representatives from federal and provincial bodies interested in water management. The project is led by Deerwood Soil and Water Management Association with the Watershed System Research Program at the University of Manitoba and the International Institute for Sustainable Development (IISD), with funding from the Manitoba Rural Adaptation Council (MRAC), Canadian Agricultural Adaptation Program (CAAP). Sheldon McLeod of SLMcLeod Consulting and Selena Randall of Watershed Systems Research Program from the University of Manitoba facilitated the workshop. The workshop commenced with introductions and presentations of current and future research initiatives, followed by facilitated working group (technical group, implementation group, enabling group) discussions examining three proposed scenarios and concluded with a presentation highlighting the workshop's outcomes and next steps.

2.0 Goals and Objectives

2.1 Workshop Goal

To bring landowners/producers, researchers and those preparing policy and programming supports together to explore the possibilities of on-farm surface water management, with a view of enhancing water quality and land use profitability.

2.2 Workshop Objectives

- Increase awareness and understanding of current activity and research on on-farm surface water management practices,
- Examine three approaches to managing on-farm excess water with a view of identifying both practical and technical challenges as well as bio-physical advantages,
- Identify any additional approaches which could accomplish the same ends,
- Develop sufficient conceptual-level information to enable the establishment of some pilot projects to determine the feasibility of the identified approaches,
- Identify the next steps in implementing pilot projects; and
- Introduce participants to aspects of the decision theatre technology and obtain perspectives on its potential application

3.0 Workshop Process

3.1 Facilitation Used in Workshop

The process followed a logical progression consisting of introductions, presentations, group work, lunch and a closing presentation; components were allotted suitable time allowances and transitioned smoothly. Sheldon facilitated the workshop by conducting opening and closing remarks, introducing presenters and ensuring each agenda item remained on schedule.

The planning prior to the workshop was evident both in the presence of all interests groups and the effective execution of the workshop. The process was communicated to participants in advance via an agenda, informing them of the environmental problem being addressed, the groups of participants, the group work process and overall goals and objectives of the workshop.

3.2 Process Strengths

The reaction to the workshop was positive, with many participants eager to express their evaluations and reflections. It was collectively agreed that facilitators were necessary in the process, especially during group work where they maintained focused conversation, answered or re-directed questions, summarized responses into concise points, encouraged equal participation and ensured all the questions were addressed within the allotted time. Facilitators were also responsible for designating a note-taker(s) for the group, which was important in ensuring the information was communicated back to the larger group during the final presentation and for further analysis.

Separating participants into the three working groups had visible advantages. After conversing with several producers, it was evident the small group setting allowed them to speak more comfortably with others who “spoke the same language” and could relate to similar issues. One landowner even made the comment that this was the first workshop that he felt his contributions were valued and will work towards the project’s goals, which he was extremely satisfied with.

Aiding in the process was the spacious conference room, complete with a microphone podium, excellent sound system, circular tables and a separate area for refreshments. The circular tables were accommodating for group work as participants were in clear view of one another and could easily direct their comments to the group. The room also enabled the use of the decision-theatre, which required ample space for the three display screens.

3.3 Process Recommendations

Background information or a summary of key points from the first workshop would have been beneficial, as a refresher to those present and to bring those absent up to date.

Participants had mixed feelings regarding the length of the workshop. While most felt the half-day workshop was accommodating to their schedules and was a sufficient timeframe to address to workshop’s goals and objectives, several landowners could have benefitted from additional time for questions and group discussion.

3.4 IISD Decision Making Theatre

An innovative component integrated into the workshop process was the trial of IISD's decision-theatre. Using large display screens and projection equipment, the theatre aims to provide participants with interactive visualizations which aid in the decision-making process. The theatre consisted of three wrap-around screens intended to demonstrate the scenarios and the anticipated outcomes as if implemented in Manitoba; unfortunately due to technical issues only the centre screen was operable, therefore only providing participants a glimpse of its full capabilities.

After speaking with participants it was collectively agreed that aside from the technical disadvantages, the decision-theatre was an engaging approach for information presentation, would have allowed for greater comprehension of the scenarios and would have been valuable in the overall decision-making process. Participants were eager to witness the theatre's full capabilities and support its use in future workshops.

4.0 Summary of Les McEwans' (Deerwood) Presentation:

The Deerwood Soil and Water Management Association in conjunction with several government bodies, rural municipalities, and organizations created a community-based initiative to develop a watershed management plan surrounding the South Tobacco Creek area. Tobacco Creek Model Watershed (TCMW) is striving towards creating an integrated watershed management plan that incorporates a balance between environmental and economic sustainability. Please refer to Appendix II (13.1) for the complete presentation.

5.0 Summary of Dr. David Lobb's (University of Manitoba) Presentation: Integrated Surface Water Management – Taking Control of Challenges and Opportunities

The University of Manitoba under the direction of Dr. David Lobb has been pursuing various options for nutrient water management on agricultural lands. Dr. Lobb advocates that the status quo of traditional farming techniques is unacceptable and that without human intervention nutrient management will continue to intensify and create even worse conditions. The University of Manitoba in partnership with MRAC and IISD is proposing an integrated surface water management plan where three model scenarios are proposed to better handle nutrient runoff from agricultural practices. Please refer to Appendix II (13.2) for the complete presentation.

6.0 Dr. Hank Venema's (IISD) Presentation:

The International Institute for Sustainable Development presented the potential of an integrated surface water management plan coupled with biomass production. The idea of incorporating on-farm storage, alternative drainage systems or back-flood dams to grow cattails or other marsh crops as a fuel source for biomass production and to intercept nutrients/recycle phosphorous was examined. MATLAB demonstrations were used to illustrate how each modal scenario would be effective within Dr. Lobb's previous presentation. Please refer to Appendix II (13.3) for the complete presentation.

7.0 Approaches to Manage On-farm Excess Water

7.1 Use or Modification of the Drainage System to Accommodate Storage

This model scenario uses the concept of expanding current established drainage systems surrounding agricultural lands. The approach involves expanding the ditches and various other forms of drainage systems to capture larger amounts of runoff and nutrients that would be recycled for irrigating purposes in agricultural production. Cattails or other crops would grow for biomass production around the ditches to capture the nutrients (phosphorous) and for purifying the nutrient-rich runoff.

7.2 Use of On-Farm Storage

This model scenario promotes the creation of large retention ponds on farmland to capture nutrient-rich runoff. The runoff captured in the retention ponds would be recycled on agricultural lands, as well as promote biomass the growth of biomass fuel sources such as cattails around the ponds.

7.3 Use of Back-Flood Dams

This model scenario requires agriculture producers to build berms around the perimeter of the agricultural lands. These berms capture the nutrient-rich spring runoff, and dependent on the season and the amount of moisture, allow the field boundaries to hold in the excess water to either drain to support livestock or soak back into the soil.

8.0 Participant Group Work

8.1 Technical

This group was focused on how the models work, data sources and assumptions, and model outputs. Feedback on the model scenarios effectiveness and evaluation of the decision theatre for the developers were the primary task of this group.

Q: Review of the model scenarios from the perspectives of the data used, the assumptions inherent in the model, other strengths and weaknesses in the model.

The data used in the model scenarios had to account for specific crop choices; it was suggested the model should be broadened to account for more crop types, especially those that may have a greater effect on soil moisture. Data would not account for local knowledge available in the areas, which could be a beneficial resource for the pilot programs. Additionally, the data would have to differentiate between the early nutrient rich water and the later, less nutrient-rich runoff water.

Assumptions that would have to be made in the model scenarios would be as follows:

- Location of where the cattails would germinate,
- Soil types of the agricultural land,
- LiDar exists in the area of proposed pilot projects,
- The water released would be a quantitative not qualitative value,
- The local/provincial government's willingness to support these scenarios,
- Disparity between value to apply and value to remove; and
- Market size and the profitability of the biomass market.

The assumed economic data values account for the pricing associated with biomass processing plants, engineering substitution costs and storage cost. These prices are assumed and are not concrete in the model, creating uncertainty on the profitability of the biomass market.

Strengths in the model scenarios were identified as:

- Adaptable model for deep storage, ravine options, water utilization options, low energy moving options and to moisture deficit areas; and
- Intense detail in the report especially in the environmental initiatives.

Weaknesses in the model scenarios were identified as:

- Time frame of the model scenarios was limited to April to June only, also excluding high water events in the summer,
- LiDar data is limited,
- Economics data for storing water need verification,
- Only one "crop" scenario; and
- Local knowledge was not used in the scenarios

Q: Comments on the usability of the model from the perspective of the contents and the outputs.

The usability of the models in regards to the hydrological, meteorological, and biological outputs are considered to be sound. There is little change in respect of

pursuing water storage, but the economic vision of water storage is considered to be a great output of the proposed scenarios (water storage economics). An interaction to consider in the usability of the water storage is the phosphorous release into the water/soil types. Some soils may release 15 fold, while others have no change.

Inorganic phosphorous sources will be a greater concern in these situations.

Q: Ideas for the implementation or application of the decision theatre technique from the perspective of accessibility and behavioural traits which might make it more or less easy to apply.

The following suggestions were made for implementation/application perspectives to increase better accessibility and behavioural traits to apply in future workshops:

- Wetland conservation
- Phosphorous release model
- Use of passive natural systems
- Deep water dugout storage
- Opportunity for larger storage

It was suggested the decision-making theatre could be used for potential bridging outreach/partnerships with government, landowners, and rural municipalities for future programs.

8.2 Implementation

This group was focused on and predominately made up by landowners who had practical insights into application. The primary task of this group was to provide feedback and identify priorities, implementation barriers, and practical solutions to the model scenarios. This group was divided into two implementation groups.

Q: Provide feedback on the scenarios – what were the positives and what were the negatives on for each?

	Positives	Negatives
Ditches	<ul style="list-style-type: none"> • Use of road allowance • Partially exist already- lower construction rates • Slows the speed of water • Public safety • Re-profiling roadside ditches into two-stage ditches has the least amount of soil displacement 	<ul style="list-style-type: none"> • Design challenges- custom design to incorporate watershed and landscape • Local influences – not everyone is willing to participate
On-farm storage (dugouts)	<ul style="list-style-type: none"> • Most feasible • Water storage- irrigation and cattle production • Accept water from multiple sources • Recreational purposes 	<ul style="list-style-type: none"> • Timely government approval process • Must be familiar with biomass harvesting • Little support for biomass industry- needs government involvement • Requires a network of people for project support
Back-flood dams	<ul style="list-style-type: none"> • Logical for flat farmland 	<ul style="list-style-type: none"> • Converts high value land to low value land- retaining water causes soil to compact and become too saline for use • Requires public involvement • Requires a change of mindset

Q: Are there other approaches which the scenarios did not encompass to some extent? Please describe and identify advantages and disadvantages.

The backflooding scenario was identified as the approach with the largest footprint and the least amount of return. It did not account for the loss of production or the chances of increased salinity.

Biomass production was raised as an economic concern. It would be beneficial but concrete evidence is needed to ensure it will be used, transport costs will be covered and there is a demand for the biomass market.

Rights of way were discussed, and that short term agreements need to be made with the rural municipalities in order to create any of these scenarios.

A high cost for irrigation systems and implementation of the scenarios is a concern among the landowners. Who will cover the costs or provide funding? Is the removal of phosphorous a province-wide initiative for all citizens? Does this mean that all of the province should be contributing towards the removal of phosphorous from Lake Winnipeg? There are producers interested in the concept but it will come down to value of the land and crop values to determine what payments producers will require to carry out these scenarios.

Q: Which approach emerges as a priority? Why?

The linear ditches and on-farm storage were identified as the preferred approaches/scenarios. These approaches were the best uses of agricultural land, lowest risks for saline land, promoted sustainable agricultural practices by creating the smallest footprint and made the most sense in regards to the variability of water availability throughout the growing season.

Q: For the identified priority, what barriers does one need to be ready for? How would one overcome those particular barriers?

The primary barrier that was identified was the challenge to promote these scenarios, as it would be a change in mentality and traditional ways of farming. To counteract resistance to these scenarios, economics behind these scenarios must be verified and proven. If there is a proven return on the changes required, it would encourage more sustainable agriculture practices.

Economic feasibility of the pilot projects was highlighted as a large concern by the implementation group. To address these concerns, it was indicated by both working groups that the government and policy makers need to step up. Additionally, getting funding programs/organizations involved will ease the financial concerns of the land owners.

To ease the barriers identified above, it was suggested that education is provided to the agricultural producers on the economic and environmental benefits of surface water management. By demonstrating scientific evidence prior to starting the pilot projects, current concerns will be addressed.

Q: In terms of shaping the proposal going forward, what should be highlighted for the funders to see? What are the positives which should be emphasized? How would you rank the approach in terms of the likely appetite for adopting it among producers?

Some selling points for possible funders were identified as follows:

- Environmental benefits
- Recreational benefits
- Flood mitigation

- Water quality
- Public health and safety

8.3 Enabling Policy and Procedures

This group was focused on individuals involved with strategic or policy knowledge and interest. They considered whether the scenarios could be implemented across Manitoba now, what the barriers and solutions might be and how the scenarios presented could fit within provincial strategic priorities.

Q: How would you assess the existing capacities for implementing each of the scenarios now? Does the answer to that question cause one of the scenarios to rise to the top, as being more easily done right now?

The existing capacities of the scenarios were all determined to be feasible on a site-by-site basis. The enabling group identified that it would be ideal to pursue all the model scenarios in a pilot study context.

This group identified that the on-farm storage in the form of retention ponds or dugouts are the highest priority; as they are the least complicated and landowners would be the primary player.

The modification of existing drainage systems was ranked as the lowest priority. The approvals and stakeholders involved would be the most complex. Concern was expressed in regards to the integrity of the roads and roadsides.

Q: What are the policy and programming barriers to implementation of each of the scenarios? What are the solutions to those barriers?

The following barriers were identified for the model scenarios:

- Data gaps for identifying adaption areas (ex. LiDar and current water storage)
- Licensing capacity of the province
- Subsidizing the cost of fuel options (cattail pellets vs. coal or other dense forms)
- Difficulty to motivate downstream population to pay for upstream management
- Jurisdictional complexity (Municipal vs. Provincial (inter-provincial))

The following solutions were proposed to the above listed barriers:

- Streamlining the drainage licensing process to ease licensing capacity of the province
- Legislative framework to encourage alternative fuel sources
- Opportunities for agricultural producers to realize economic benefits to enable local motivations for adoption rather than the entire watershed

Q: What are the next steps for making policy and programming adjustments to enable these approaches to go forward? How will these happen? Who will do what?

The next steps were identified with in the group as follows:

- Integrate the integrated surface water management into broader initiatives including the provincial surface water strategy
- Develop framework that include incentives
- Outreach to landowners by MAFRI
- Key players guide in developing designs including the engineering aspects

- Economic modeling surrounding the scenarios to demonstrate benefits

9.0 Discussion and Outcomes

Selena provided a final presentation summarizing the group's responses and how they will be incorporated into the project's next steps. Pilot projects are vital in better understanding flood mitigation, nutrient management, crop diversification, biomass generation and economic farming measures. In moving forward, the following steps were determined- identifying sites for study for multiple purposes, developing proposals for pilot/demonstration sites, identifying sites that have more than one focus (flood control, water management, water quality management, crop production, end use), identifying new sites and focusing the approach for blue box aspects (site selection for the correct water storage options) and green box aspects (crop selection).

The technical group discussed the model scenarios in terms of depicting water's multiple uses and downstream impacts, recognized the model should include multiple scenarios and crop types and that the water storage data needs verification.

The implementation groups established the modification of drainage systems and on-farm storage were the preferred scenarios, as back flooding causes soil compaction and increased salinity after being drained. Projects will be most successful by implementing scenarios on a cooperative scale rather than each landowner managing their own water.

The enabling group determined on-farm storage as being the most feasible and least complicated scenario for approvals and ditch expansion as being the most complex. As each pilot project is site specific, the scenario will be determined by the technical suitability.

Factors to consider include the model's usability, data gaps and licensing capacity in the province. A funding scheme and evidence that cattails will produce economic payback need to be addressed. As well, downstream landowners should be encouraged to fund the project as they are receiving flood mitigation and water quality benefits.

10.0 Conclusion

The workshop was a success with the following outcomes established:

- On-farm storage and modification of current drainage systems were the preferred approaches. They were considered the least complicated and most economically feasible with the least environmental impact. Economic benefits are still to be confirmed with the technical group to help encourage funders and landowners involvement in the pilot programs.
- These initiatives require a community-based approach involving multi-stakeholders including funding programs, all levels government, agricultural producers and the scientific researchers. Through effective communication, the pilot programs can demonstrate the economic and environmental viability to the community, spreading the concept and promoting sustainable agriculture practices.
- Education and outreach is a fundamental component is incorporating a technically feasible, agriculturally practical, economically viable and environmentally acceptable solution.

11.0 Next Steps

While research may be inhibited initially, information collection and collaboration among interested parties can begin immediately. The aim is to move this process along- establish case study sites and begin research within the 2012 year.

The following is a proposed timeline:



12.0 Appendix 1: List of Attendees

Family name	First name	Organization	Working Group
Ali	Genevieve	UofM	T
Bouvier	Maurice	MAFRI	E
Canart	Ryan	UARCD	I
Carr	Kristy-Layne	SRRCD	I
Chen	Xi	IISD	T
Corbett	Scott	UofM	I
Cruikshank	Don	Deerwood	I
Flaten	Don	UofM	T
Fox	Elaine	MCWS	E
Fridfinnson	Eric	BiFrost	I
Goertzen	Jodi	SRRCD	I
Goertzen	Cornie	SRRCD	I
Greenfield	Cliff	PVCD	I
Grzenda	Laura	MAFRI	I
Harasym	Catie	Contractor	I
Jackson	George	PVCD/Deerwood	I
Kostera	Christina	Contractor	I
Lobb	David	UofM	E
Loro	Petra	MAFRI	E
Manaire	Jason	IISD	T
Mazier	Dan	KAP	I
McCandless	Matthew	IISD	T
McEwan	Les	Deerwood	I
McLeod	Sheldon	Contractor	I
McTavish	Walter	PVCD/Deerwood	I
North	April	MCWS	E
Pankratz	Rhonda	MCWS	E
Randall	Selena	UofM	I

Richardson	Ron	MIT	E
Rideout	Yvonne	KAP	I
Riekman	Marla	MAFRI	I
Rossnagel	L	KAP	I
Salvano	Esther	MAFRI	E
Shewfelt	Bruce	AESB	I
Swanson	Darren	IISD	T
Swynstun	Kyle	IISD	T
Timmerman	Mitch	MAFRI	E
Vanrobaeys	Jason	AESB	T
Venema	Hank	IISD	T
Wilson	Brian	MAFRI	E
Ziegler	Eric	Deerwood	I

Appendix 3 Project report

Water Storage and Cattail Biomass Production

Author?

IISD

Date

1. Introduction

This study explored the potential to store excess water on agricultural land, subsequently grow cattail on that same land, and estimate both private and public benefits from the stored water, harvested biomass, and the phosphorus contained within the harvested biomass at three agricultural locations in Manitoba. A simple cattail growth model and a two-dimensional hydrologic model were employed to simulate cattail growth and the water balance during a 90 day period at three physiographically distinct sites in Manitoba. Model simulations were performed under four different climatological scenarios.

2. Methods

Three physiographically distinct sites were selected:

1: South Tobacco Creek Site

- 2 miles SW from corner of 240 & 23
- RM Thompson
- Latitude: 49.353 Longitude: -98.383
- Area: 86,000 m²
- Max simulation volume: 48,585 m³
- Max simulation depth: 5.10 m

2: Icelandic River Watershed Site

- 15 miles west of Riverton
- RM Bifrost
- Latitude: 50.989 Longitude: -97.355
- Area: 155,736 m²
- Max simulation volume: 69,541 m³
- Max simulation depth: 0.46 m

3: Red River Valley Site

- 1 mile north of Canada-US border and 8 miles west of HWY 75
- RM Rhineland
- Latitude: 49.007 Longitude: -97.408
- Area: 63,900 m²
- Max simulation volume: 17,027 m³
- Max simulation depth: 0.53 m

A small rectangular area at each site was defined as the water storage reservoir. LIDAR datasets were available for each site and were used to construct digital elevation models (Figure 2). Four model simulations were performed corresponding to the four different climatological scenarios (Figure 1). Each model simulation was performed on each of the three location sites for a grand total of 12 model simulations. All model simulations were executed using numerical analysis software (MATLAB).

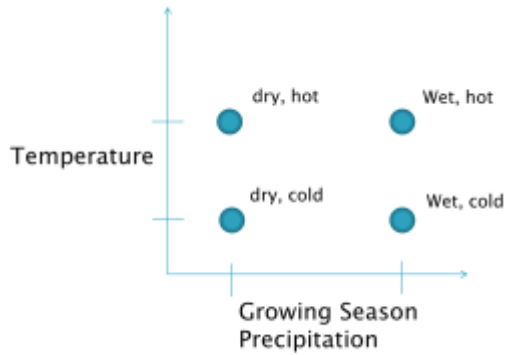


Figure 1. Climate scenarios
 2.1. *MATLAB Modeling*
 2.1.1. *Reservoir Modeling*

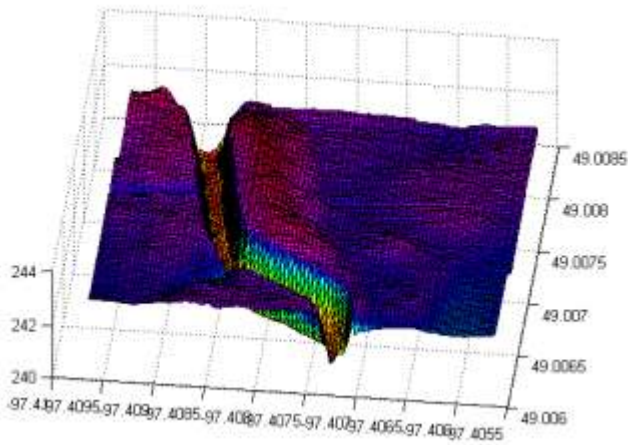


Figure 2. Digital Elevation Model (DEM) for Red River Valley reservoir
 High resolution topographic data (LIDAR) was used to generate a digital elevation model (DEM) for each site (eg. Figure 2). A volume-area curve was calculated for each site reservoir (Figure 3). A set of reference water levels were defined starting from the lowest elevation in the reservoir to the highest elevation in the reservoir. Reference water levels increased by 1 mm and were used to generate the volume – area curve. For each 1 mm increment increase in water level, pixels were identified as either being under or above water. Water surface area was calculated by adding those pixels under water and multiplying them by the area of each pixel. Total water volume was calculated by summing the volumes of each increment. Incremental water volume was calculated using the following equation:

$$Vol_t = d * (A_t + A_{t-1})/2$$

Where d is the depth of each increment (0.001 m), A_t is the water surface area at that increment, and A_{t-1} is the water surface area at the previous increment.

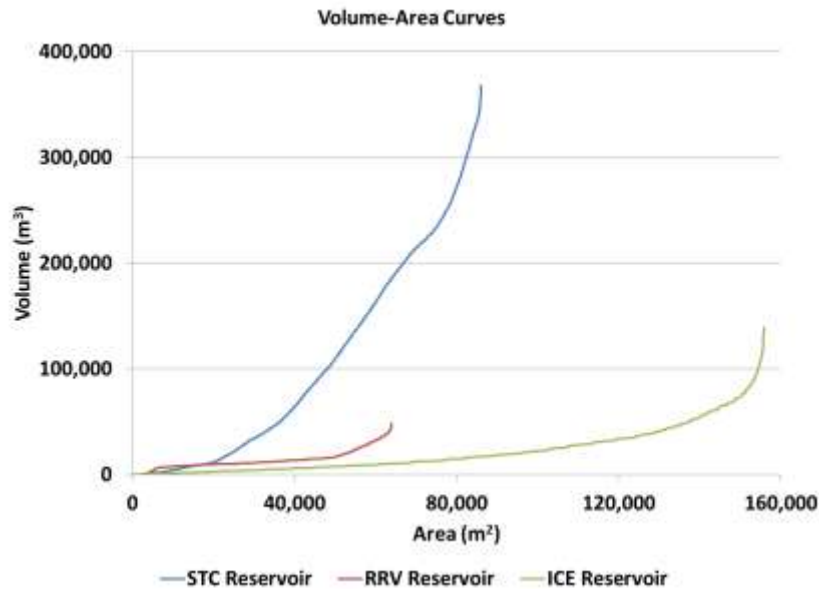


Figure 3. Volume-area curves for each reservoir

2.1.2. Hydrological modeling

A simple two-dimensional hydrologic model was employed using the following equation:
 $Storage_{t+1} = Storage_t + (\text{Vertical Water Balance}) + (\text{Horizontal Water Balance})$

or

$$Storage_{t+1} = Storage_t + (\text{Precipitation} - \text{Evapotranspiration}) + (Vol_{in} - Vol_{out})$$

Winnipeg precipitation data was downloaded from Environment Canada website. The Priestley-Taylor method was utilized for estimating daily potential evapotranspiration using the Winnipeg air temperature and radiation data downloaded from the Environment Canada website. For each of the 12 simulations, horizontal flows of water in and out of the storage reservoirs were assumed to be zero (i.e. $Vol_{in} = Vol_{out} = 0$) therefore making this hydrologic model a one-dimensional model. However, the hydrologic model was coded with the ability to incorporate horizontal flows of water into and out of the storage reservoirs. A constant initial water level is set for each site and the hydrologic model is run for each of the four climatological scenarios.

2.2. Cattail Growth Model

Cattail growth was simulated for a 90 day period starting on April 1st and ending June 30th. The cattail growth algorithm and model parameters were taken from research done by Takashi Asaeda and the team at the Department of Environmental Science and Technology at Saitama University in Japan. Input data was downloaded from the Environment Canada website and consisted of daily mean air temperature and total daily incident radiation. Cattail growth was calculated as a function of incident radiation (photosynthetically active radiation) and mean air temperature.

The following cattail growth algorithm was used:

$$AGB = P_m * K_{co} * \Theta^{T-20} * PAR * LAI$$

AGB = Aboveground biomass

P_m = Maximum net daily photosynthesis rate at 20°C = 25g CO₂ m⁻² day⁻¹

K_{co} = Conversion of carbon dioxide to AGB = 0.65 g g⁻¹ CO₂

Θ = Temperature constant = 1.09

T = Mean daily air temperature

LAI = Leaf area index = f(GDD)

GDD = Growing Degree Days (base 5°C)

$PAR = I_{PAR} / (K_{PAR} + I_{PAR})$

I_{PAR} = Daily total incident photosynthetically active radiation

K_{PAR} = Half-saturation constant of PAR for photosynthesis = 5.8 E m⁻² day⁻¹

2.3. *Economic Valuation*

2.3.1. *Phosphorus Valuation*

Phosphorus was valued at \$119 per kg of P. This was calculated based on the City of Winnipeg's plans to spend \$670M on facilities to reduce phosphorus loading to the Red River by 300 tonnes per year. Based on a 20-year amortization, this equates to \$112 per kg of P per year. This value was then adjusted for inflation to \$119 per kg of P

2.3.2. *Cattail Valuation*

Baled cattail biomass was valued at \$100 per tonne. This value was based on a quick web search of local biomass prices within the province. However, biomass prices fluctuate with changing market conditions.

2.3.3. *Stored Water Valuation*

Stored water was valued at \$110 per acre-foot of stored water. This value was based on earthwork costs of \$70 per square metre for constructing 640 acre, 4 foot deep storage cells. Storage cell construction was based on standard sewage lagoon berm construction. Based on a total cost of construction of \$4.35M and a 30-year amortization, this equates to \$110 per acre-foot of stored water.

3. Results

3.1. South Tobacco Creek Site Results

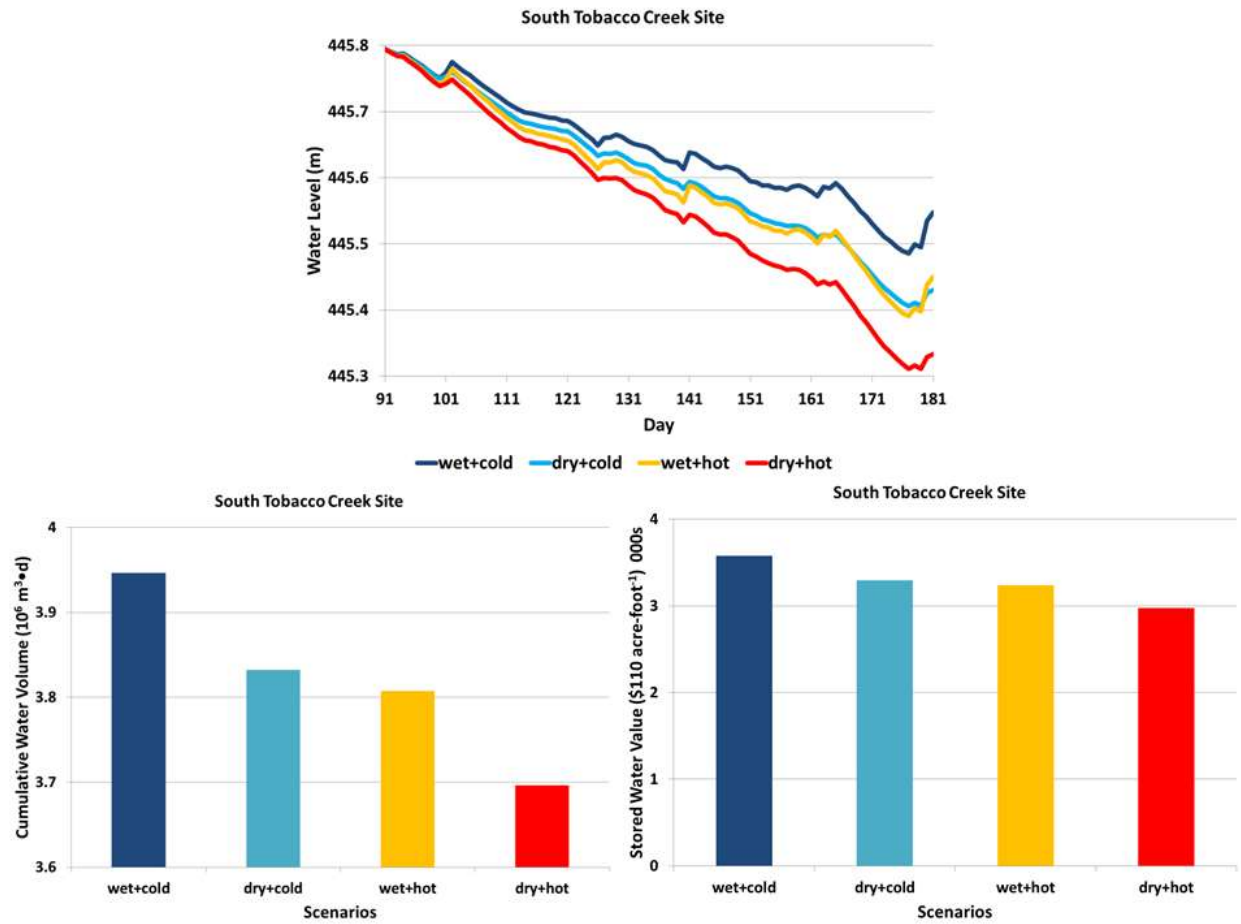


Figure 4. South Tobacco Creek Site water levels (top), cumulative water volume (left), stored water value (right).

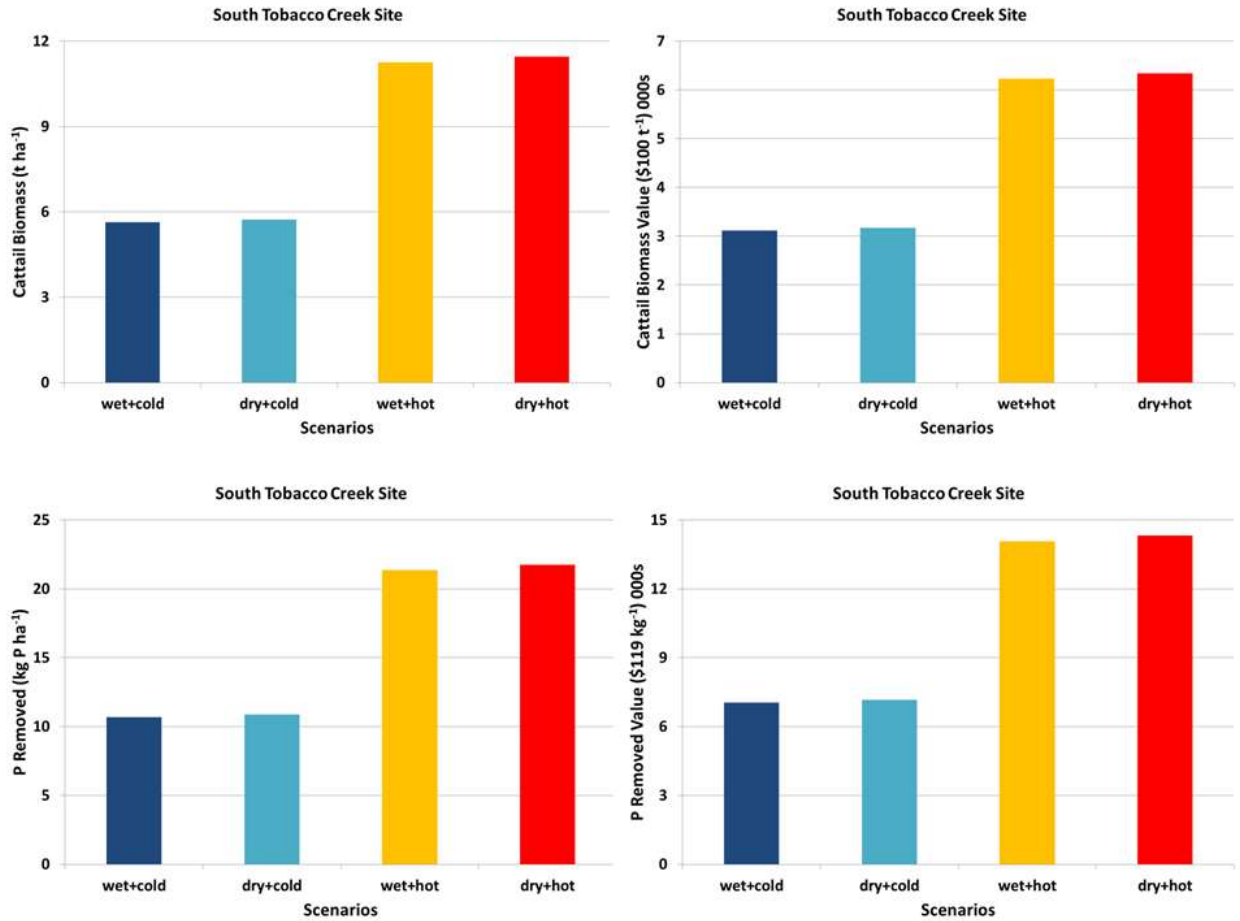


Figure 5. South Tobacco Creek Site cattail biomass yield (top left), cattail biomass value (top right), phosphorus contained within harvested cattail (bottom left), and phosphorus value (bottom right).

3.2. Red River Valley Site Results

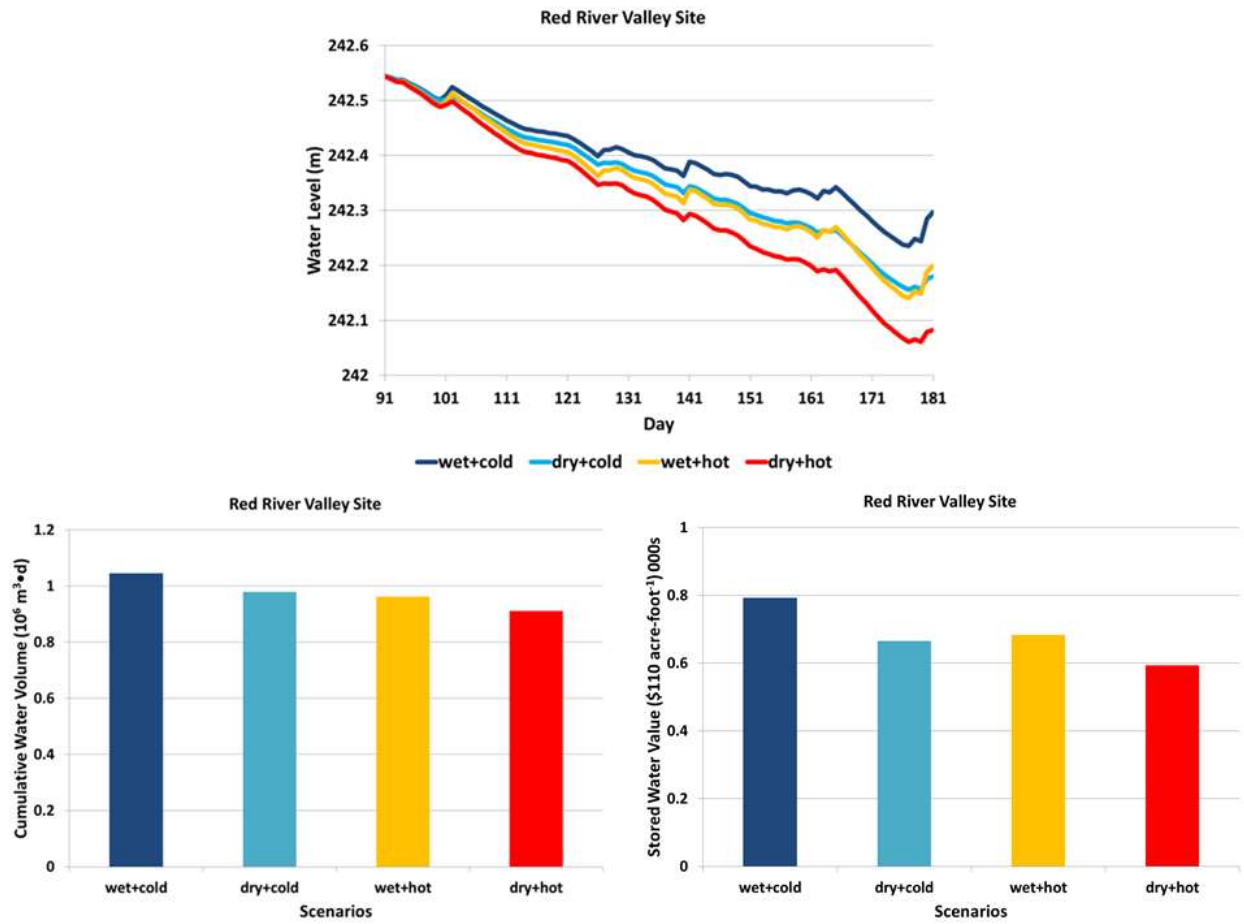


Figure 6. Red River Valley Site water levels (top), cumulative water volume (left), stored water value (right).

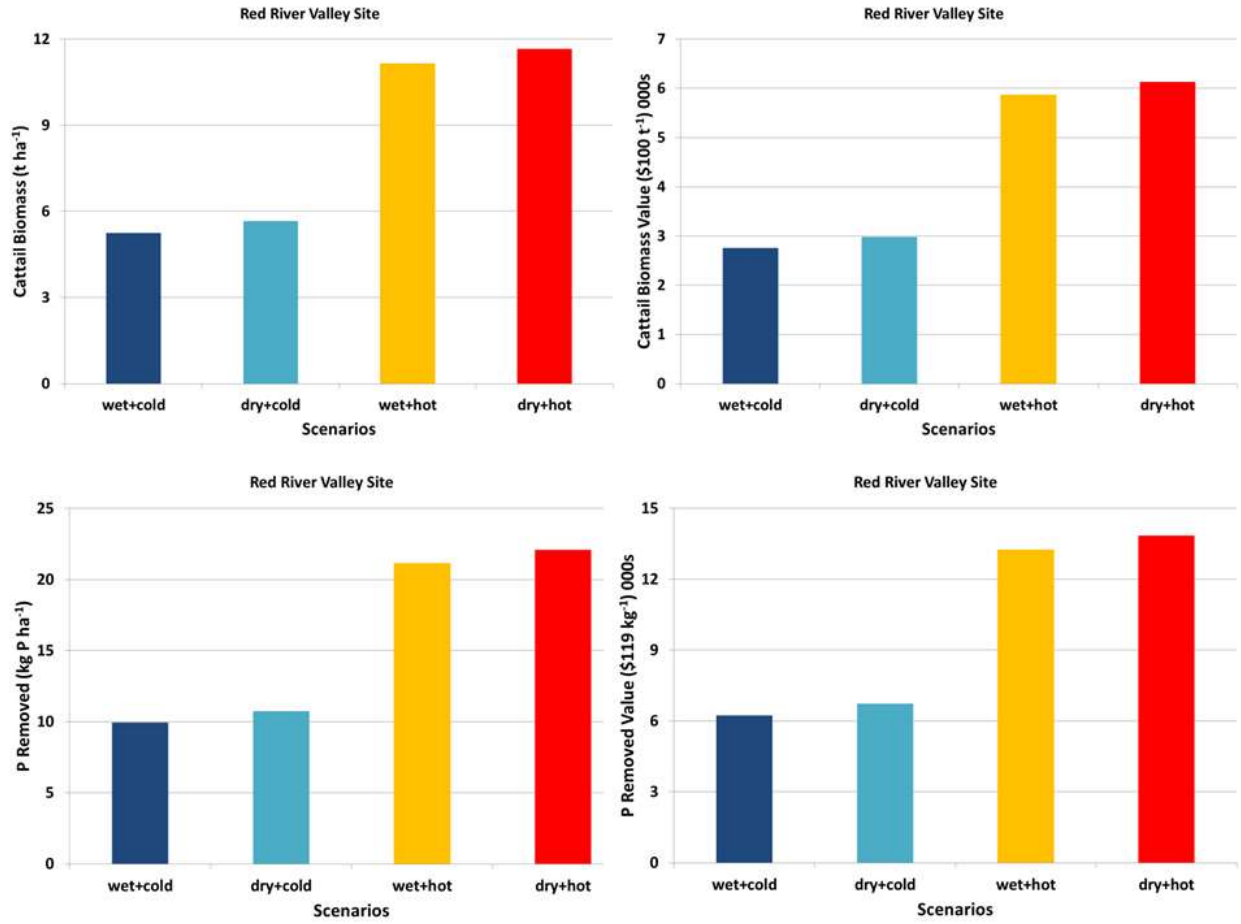


Figure 7. Red River Valley Site cattail biomass yield (top left), cattail biomass value (top right), phosphorus contained within harvested cattail (bottom left), and phosphorus value (bottom right).

3.3 Icelandic River Watershed Site Results

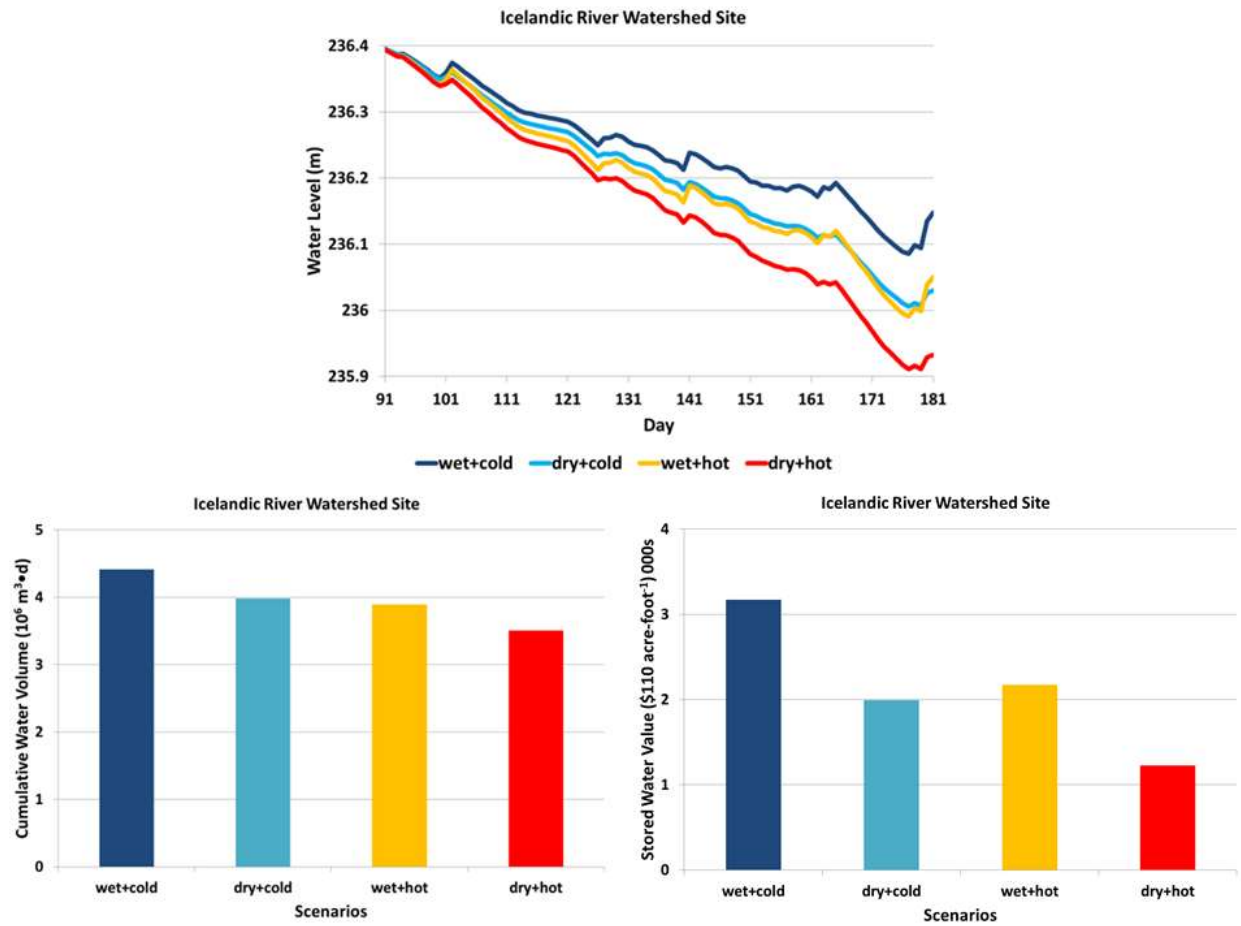


Figure 8. Icelandic River Watershed Site water levels (top), cumulative water volume (left), stored water value (right).

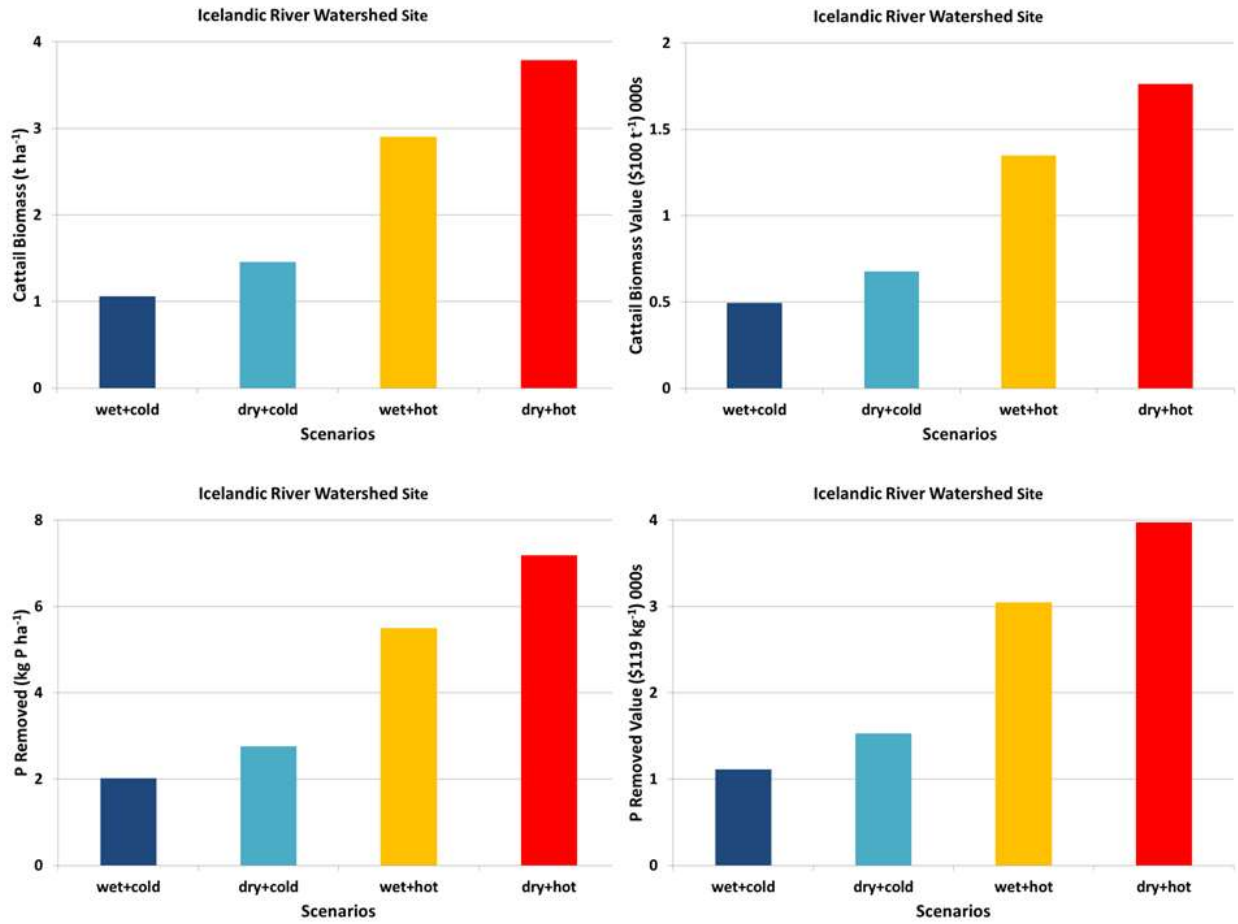


Figure 9. Icelandic River Watershed Site cattail biomass yield (top left), cattail biomass value (top right), phosphorus contained within harvested cattail (bottom left), and phosphorus value (bottom right).

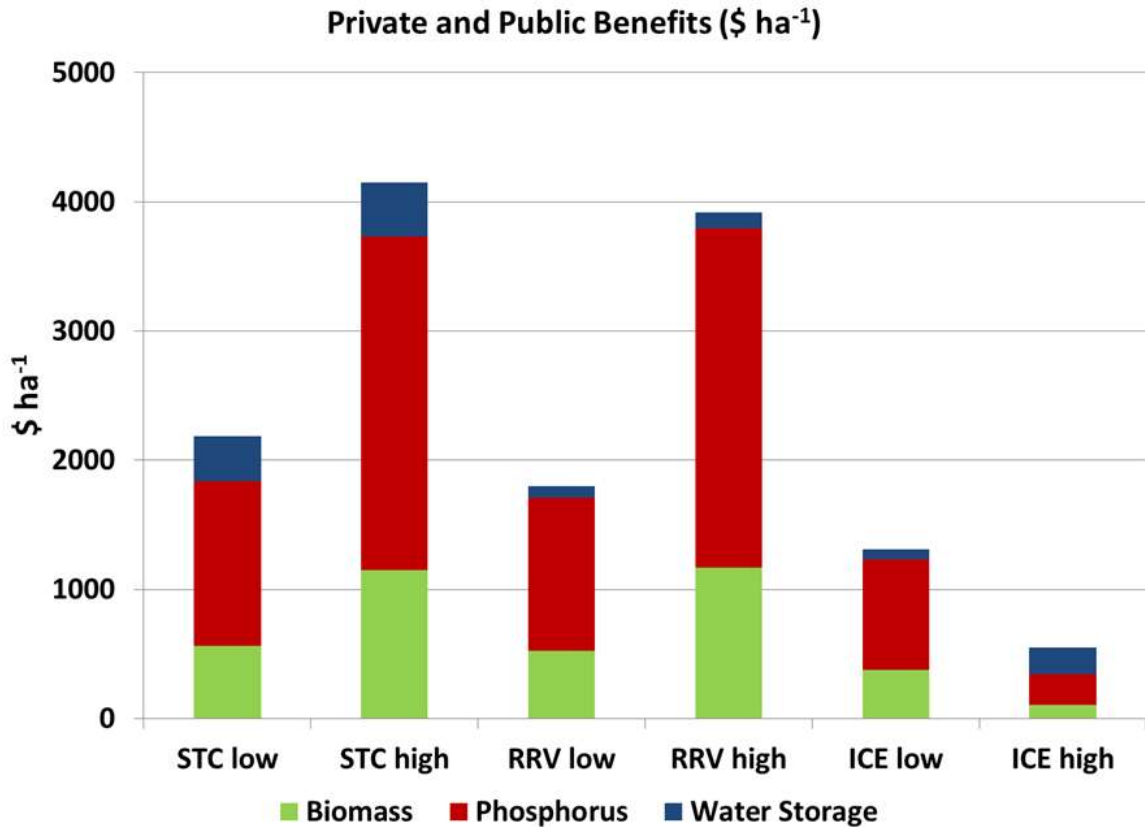


Figure 10. Private and public benefits from South Tobacco Creek (STC), Red River Valley (RRV), and Icelandic River Watershed (ICE) sites for harvested cattail biomass, phosphorus contained within harvested cattail biomass, and stored water.

4. Conclusion

A simple cattail growth model and two-dimensional hydrologic model were used to simulate biomass production and water storage during four climatological scenarios at three physiographic distinct sites in Manitoba. Results indicate large private and public benefits from storing water, harvesting cattails, and removing phosphorus from the environment. The unavailability of LIDAR data eliminates the possibility of performing simulations throughout much of Manitoba. The biomass production model can be changed to simulate growth of other plants.

Bibliography

- Tanaka, N., Asaeda, T., Hasegawa, A., Tanimoto, K. 2004. Modelling of the long-term competition between *Typha angustifolia* and *Typha latifolia* in shallow water—effects of eutrophication, latitude and initial advantage of belowground organs. *Aquatic Botany* (79) 295-310.
- Asaeda, T., Van Bon, T. 1997. Modelling the effects of macrophytes on algal blooming in eutrophic shallow lakes. *Ecological Modelling* (104) 261-287.
- Asaeda, T., Hung Nam, L., Hietz, P., Tanaka, N., Karunaratne, S. 2002. Seasonal fluctuations in live and dead biomass of *Phragmites australis* as described by a growth and decomposition model: implications of duration and aerobic conditions for litter mineralization and sedimentation. *Aquatic Botany* (73) 223-239.
- Asaeda et al. 2005. Latitudinal characteristics of below- and above-ground biomass of *Typha*: a modelling approach. *Annals of Botany* (96) 299-312.
- D.N. Hai et al. 2006. Latitudinal effect on the growth dynamics of harvested stands of *Typha*: a modelling approach. *Estuarine Coastal and Shelf Science* (70) 613-620.
- Knapp, Alan & Yavitt, Joseph. 1995. Gas characteristics of *Typha latifolia* L. from nine sites across North America. *Aquatic Botany* (49) 203-215.
- Sharma et al. 2006. Nutrient cycling in a natural stand of *Typha angustifolia*. *Journal of Freshwater Ecology* (21) 431-438.
- Allirand, J. & Gosse, G. 1995. An above-ground biomass production model for a common reed (*Phragmites communis* Trin.) stand. *Biomass and Bioenergy* (9) 441-448.