1. **Background Statement**

Alberta classifies wetlands into bogs, fens, swamps, marshes, and open water; 90% of the wetlands in the province are bogs and peat. Wetlands occupy about 20% of Alberta’s land area (Government of Alberta, 2013). The province has lost about 50-70 percent of its wetland area because the value of wetlands was not widely understood, and the ecosystem was seen mostly as nuisance or wastelands. However, in the start of the 21st century, Alberta is increasing designing policies or regulations to protect these important ecosystems; some of the important wetland related policies are discussed next.

The Wetland Management in the Settled Area of Alberta: An interim Policy was designed in 1991 to protect wetlands, especially sloughs and marshes, in the settled areas (White region) of Alberta (Alberta Water Resources Commission, 1993). Specifically, the policy sought to manage wetlands by focusing on the following priorities (in descending order of priority or importance) ((Alberta Water Resources Commission, 1993):

1. to conserve wetlands in a natural state,
2. to mitigate degradation or loss of the wetlands and their benefits as close to the site of disturbance as possible,
3. to restore degraded wetlands.

The policy recognized that wetlands in the province are not the same and sought to apply different wetland management rules in different parts of the province (Alberta Water Resources Commission, 1993).

The Wetland Management in the Settled Area of Alberta: An interim Policy applied to half of Alberta. This means wetlands in the other half of Alberta had no protection from drainage. Other policies, acts and regulations work in concert to protect wetlands in the Green areas of Alberta (or Crown lands). The Water Act approves the any activity that disturbs or degrades a wetland using a permit system on a case-by-case basis (Clare and Krogman, 2013). Under this Act, the government of Alberta or the Crown has the right to all water bodies, including wetlands, in Alberta. The primary goal of the Act is to “support and promote the conservation and management of water, including the wise allocation and use of water” (Government of Alberta, 2021). The Public Lands Act provides the legal basis for the governance of public lands in Alberta, which is about 60% of the land area of Alberta (Government of Alberta, 2015). Environmental Protection and Enhancement Act provides the regulatory framework for the management of air, water, land and biodiversity in Alberta towards the protection, enhancement and wise use of environmental resources. All projects are reviewed for their potential environmental impacts and are approved or denied. Specifically, the Act mandates that projects in the following groups conservation, potable (drinking) water, substance release, waste management and miscellaneous (pesticides, designated materials) must seek approval before their commencements (Government of Alberta, 2022). The overarching goal of the Acts above is to protect the environment, including wetlands, for sustainable development in Alberta.

The Alberta Wetland Policy provides unifying framework that brings together all the Acts discussed about to specifically protect wetlands in all areas of Alberta (Green and White regions). This is important because the province by this policy has acknowledged and placed wetland ecosystems into a distinct environmental resource that needs protection. The policy supports that avoid, mitigate, and restore rule of wetland protection. The avoid means that if possible, all activities that may alter wetlands must be avoided; mitigate means that if avoidance is not possible, then potential devastation to the ecosystem must be mitigated through activities such as best management practices; restore means that if wetlands are drained they must be replaced or restored to its pre-drainage area and including its wetland functions.

Talk about relative wetlabd values and replacement options.

Laws protecting wetlands before

Now laws

Details

1. Avoid
2. Min
3. Replace

Others…..

Basically, give enough information that will allow reader to understand method and other sections. Like literature review.

Shari Clare & Naomi Krogman (2013) Bureaucratic Slippage and Environmental Offset Policies: The Case of Wetland Management in Alberta, Society & Natural Resources, 26:6, 672-687, DOI: 10.1080/08941920.2013.779341

Government of Alberta (2021). Water Act., Revised Statutes of Alberta 2000 Chapter W-3 Current as of June 2, 2021. [Alberta Queen's Printer:](https://www.qp.alberta.ca/1266.cfm?page=W03.cfm&leg_type=Acts&isbncln=9780779805570)

Government of Alberta, 2015). Public Lands Act. [Public Lands Act (alberta.ca)](https://open.alberta.ca/dataset/37ce6d42-4a60-4b0e-b5c4-6f5281845ac6/resource/30fead36-a515-42a3-bfe8-edbb58c19c53/download/publiclandsact-nov30-2015.pdf)

Government of Alberta, 2022). [Environmental approvals and assessment](https://www.alberta.ca/environmental-approvals-assessment.aspx) [Environmental Protection and Enhancement Act approvals | Alberta.ca](https://www.alberta.ca/apply-for-environmental-protection-and-enhancement-act-approvals.aspx)

the Crown (or government) retains ownership of all water bodies in the province of Alberta.  Water Act, RSA 2000 c W-3, s 3.

The short answer to this question is that your municipality or the farmer obtain water licences granted by the Government of Alberta. Alberta Environment and Parks, “Water Act” (4 September 2018) Government of Alberta online: .

A typical licence states that the holder is authorized to divert and use water, subject to the terms and conditions of the licence (the applicant specifies what they want to use the water for in their application). [3]

The applicant never gets ownership of the water, no matter how long they hold a licence for, rather they are authorized to use the water. [David R. Percy QC & Greg Lane, “Water Law Q&As” A Legal and Institutional Analysis of Alberta’s Water Allocation System Theme 1 and 2 (December 2013) at Q&A #2 online: <https://albertawater.com/alberta-water-blog/3159-albertawaterlawqasheets>.

It replaces the interim policy. The legislative basis is the Water Act.

1. **Methods**

**2.1. Annual Net Present Benefit of Wetland Drainage**

Annual net present benefit (NPB) of wetland drainage is the benefit that accrues to the landowner from cultivating crops on a drained wetland area. For this App, it was calculated as the difference between the annual net returns of cultivating a field with drained areas and a field with intact wetland areas. In general, the formula for ANPB ($/Acre/Year) is:

= Annual net returns of cultivated field with drained wetland areas

= Annual net returns of cultivated field with intact wetland areas

= Farm profit

EL = Efficiency loss from farm machinery operations and input wastage when wetlands are present on field

AF = Discounting factor =

R = Discount factor

T= Planning horizon

DC = Drainage cost

**2.1.1.** **Overview of Farm Production Profit**

Farm profit for an agricultural firm is the difference between total production revenue and total cost of production. The two main components of total cost are variable cost and fixed cost:

1. Variable cost changes with the level of farm production activity; for example, when the farmer must hire more workers to expand production, the labor cost will be a variable cost. Other examples of variable cost are seed cost, fertilizer cost and fuel cost that change with the level of production activity.
2. Fixed cost does not change with the level of production activity, for example insurance on farm machinery. Other examples of fixed cost are property tax and farm building and machinery repair.

Ideally farmers would want the value of profit to be at least zero, which would ensure the sustenance of the farm business in the long-run.

**2.1.2. Farm Profit of Field with Drained Wetland and Intact Wetland Areas**

Let us say a landowner has drained an acre of wetland and cultivated it with some crops. For our App we:

1. consider Canola, Spring Wheat, Malt Barley, Feed Barley, Flax, Oats, Peas, Soybean and Corn because they are common cultivated crops in Saskatchewan,
2. assume that the yield of cultivated crops will vary depending on the type of soil (black, brown, and dark brown) of the quarter-section (QS) where the wetland is located,
3. producers follow a proportional acreage cultivation, such that a proportion of the wetland drained acreage is used to cultivate a given crop and farming season/year; it is repeated for the annually for the lifespan of farm or planning horizon. For instance, since we consider 9 crops in the App, each crop will be cultivated on 1/9th of the drained wetland area (1 acre).
4. assume that the farmer will not be able to harvest from the drained wetland areas 1 out of ten years; this is the delayed seeding parameter, and the user will be able to change this.
5. assume that crop yield on drained wetland areas will be about 90% of upland yield. The user will be able to change this default value, including whether upland yield is less than yield on drained areas.

The farm profit function () for fields with drained wetland area, which is the sum the net revenue (total revenue – total cost) for all cultivated crop on upland field and drained wetland area is:

Where:

= Total farm profit

= Farm profit on drained wetland area

= Farm profit on drained wetland area

= Yield for the nth crop for upland field

= Yield for the nth crop for wetland area

= Price for the nth crop

= Cost of production for the nth crop

= Proportion of field area devoted to cultivation of the nth crop

= Upland field area (acres)

= Drained wetland area

DS = Delayed seeding

N = total number of crops

In the case of field with intact wetland area, the farm profit component of equation 4 is zero. Again, the cost of production is increased by the efficiency loss estimate that is associated with using farm machinery operations around wetland areas and input wastage from overlap.

**2.1.3.** **Present Value Default parameters**

For this App we use crop production and wetland drainage information in Saskatchewan to estimate the annual net returns of wetland drainage. We use information on crop prices, crop yields on different soil zones, and cost of production from different soil zones from the Saskatchewan Ministry of Agriculture Crop Panning Guide, 2021, as default information in the farm profit function. The farm production information is presented in Table 1; the breakdown of the variable cost and fixed cost components of total cost is provided in Table 2. We also assume a discount rate of 8.3% and a planning horizon of 50-years (Asare et al. 2021) for the farm profit present value function.

**Table 1. Farm Production Information**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Black Soil** | | | **Brown Soil** | | | **Dark Brown** | | |
| **Crops** | **Crop price**  **($/Bushel)** | **Crop Yield**  **(Bushel/Acre)** | **Cost**  **($/Acre)** | **Crop**  **Yield** | | **Cost** | **Crop**  **Yield** | | **Cost** |
| Feed Barley | 3.94 | 91.9 | 354.56 | 76.7 | | 297.47 | 81.8 | | 325.94 |
| Malt Barley | 4.7 | 74.6 | 407.43 | 62.7 | | 351.03 | 67 | | 380.88 |
| Canola | 10.7 | 53.8 | 503.55 | 48.5 | | 412.89 | 50.3 | | 480.07 |
| Corn | 4.7 | 108.2 | 486.6 | 100 | | 437.33 | 72 | | 430.53 |
| Flax | 13.78 | 34.3 | 358.94 | 30.3 | | 309.69 | 33.1 | | 338.73 |
| Oats | 3.02 | 139.4 | 348.91 | 79.1 | | 252.07 | 103.7 | | 310.77 |
| Yellow Peas | 6.85 | 58.4 | 402.94 | 43.7 | | 342.76 | 51.1 | | 376.35 |
| Soybean | 10.66 | 37.1 | 414.33 | 31.6 | | 373.33 | 33.4 | | 395.31 |
| Spring Wheat | 6.42 | 64.7 | 391.07 | 38.9 | | 312.62 | 57 | | 360.47 |

**Table 2. Components of Variable and Fixed cost of Production**

|  |  |
| --- | --- |
| **Variable cost** | **Fixed cost** |
| Seed cost | Building repair |
| Seed Treatment | Property taxes |
| Fertilizer cost | Business overheads |
| Herbicide cost | Machinery depreciation |
| Insecticide cost | Building Depreciation |
| Fuel Cost | Machinery inventory |
| Machinery repairs | Building inventory |
| Insurance premiums | Land inventory |
| Loan interest payments |  |
| Miscellaneous costs |  |

**2.1.4. Present Value User-defined Parameters**

The user will be presented with a selection (based on soil zone) of Table 1, which could be edited with user-defined values to override the App’s default values. Specifically, the user will take these steps to edit the Table 1:

1. Select from a drop-down the soil zone that applies to his/her farm,
2. Edit the parameters in Table 1 for that soil zone.

We will present information in Table 2 to the user to guide their estimations of production costs; but only the total cost of production must be provided in the App. Again, the user will be able to provide values for discount rate and planning horizon in input-forms. The system will use the new information to recalculate the functions and present results that reflect the circumstances of users.

**2.2. Efficiency Loss Function**

Nuisance costs are those that wetlands cause to landowners by reducing the inefficiencies of farm machinery operations (when machines drive around wetlands instead of straight lines) and input wastage from overlaps (Cortus et al. 2011). We assume that efficiency loss varies depending on the wetland location, which determines whether the wetland interferes with farm machinery operations or not, and number of wetlands on the field. We assume that wetlands located at the margins of the field will not interfere with farm machinery operations (that is efficiency loss is 0).

We followed Cortus et al. (2011: Table 3) to generated nuisance factors based on the number of wetlands on the field. We then multiplied the nuisance factor by machinery input cost (fuel cost plus repairs) and 50% of the total wetland area in the field to get the efficiency loss associated with farm machinery operations around wetland areas for the whole field; by using 50% of the wetland area in the field, we are assuming that 50% of the wetland area approximates the effective area around the wetland that affects farm machinery operations. To get the efficiency loss associated with input wastage, we assumed an input wastage factor of 0.1 (Cortus et al. 2011) and multiplied it by the total input cost (including the cost of seed, seed treatment, pesticide, fungicide, and fertilizer). The sum of the efficiency loss associated with machinery operation and input wastage is the total efficiency loss when wetlands interfere with farm operations on the field.

* + 1. **Efficiency Loss Default Parameters**

The default value for number of wetlands in the field is 2. Also, we assume wetlands interfere with farming operations.

* + 1. **Nuisance Cost User-defined Parameters**

The user will be able to modify the number of wetlands on the field as well as whether the wetlands interfere with farming operations. These changes will estimate efficiency loss that is appropriate to the user’s field.

**2.3. Drainage Cost Function**

The dominant form of wetland water management in the Canadian Prairies is the surface wetland drainage; therefore, we will estimate the cost of surface drainage for the drainage cost component of the App.

**2.3.1. Drainage Cost Default Parameters**

For the drainage construction cost, we use $600/acre (Asare et al. 2021) for the cost of wetland drainage construction on the field. Also, assumed a $200 cost, including administrative costs and maintenance/rehabilitation costs, that drainage project is sustained over its lifetime. Therefore, the total one-time cost of draining wetlands on the field is $800/acre.

**2.3.2. Drainage Cost User-defined Parameters**

The user can specify the total cost of constructing the surface drainage on his field in the drainage cost input-widget of the App.

**2.4. Landscape Wetland Drainage Analysis**

The landscape level analysis investigates what happens to an agricultural landscape when wetlands on it are drained. Specifically, it will show the following:

1. wetland supply curve, which is the acreage of wetland areas that maybe drained given different levels of net present benefit of wetland drainage.
2. wetland conservation calculator, which will show the acreage of wetlands that could be save on the landscape given a wetland conservation budget.
3. The cost of draining wetland areas in the best quality fields, that is fields with greater crop yields.

We created the number of fields in the landscape with a “landscape\_num\_fields” function. The function uses the expected number of fields in the landscape and the selected crops to produce an agricultural landscape, such that 1/n (where n is the number of fields) proportion of the number of fields in the landscape is used to cultivate a crop. For instance, assuming we want to cultivate Canola and Spring in the landscape; if the number of fields in the landscape is 100, 50 fields (which is 1/2 \* 100) is used to cultivate one crop, say Canola, and the other 50 fields for Spring wheat.

Moreover, we assumed wetland acreage distribution in the landscape followed a uniform distribution, with minimum and maximum wetland acreage parameters of 0 and 37, respectively (Spence, 2006). Also, the number of wetlands followed a uniform distribution with minimum and maximum values of 0 and 4, respectively. Again, the user can specify the proportion of wetlands in the landscape that interfere with farming operations; for this App we assumed 50% of the wetlands interfere with farming operations because they are not located at the margins of the fields in the landscape.

The formula for estimating the annual net returns from wetland drainage on each field, which is the difference between the annual net returns from cultivating a field with drained wetland areas and a field with intact wetland areas (equation 1), applies to the landscape analysis. However, in estimating the field profits in each landscape (equations 4-6), a single crop is cultivated on the field. The proportional acreage cultivation applies to the whole landscape, when a proportion of the landscape (based on number of crops to be cultivated) is used to cultivate a specific crop. The distributions of crop yields (bushels/acre), crop prices ($/bushel), production cost ($/acre) and drainage cost ($/acre) in the fields of the landscape which are used to estimate the annual net returns are described in the next section.

**2.5. Uncertainties on Crop Yield and Prices**

The values of the main variables (including crop yields, crop prices, production cost, and drainage cost) varies in the fields of the landscape. We obtained crop yield and prices data for the Canadian Prairie provinces from Statistics Canada (2022).

The crop price data is monthly time series from 1980 to 2021; the prices reflect point of first transaction (where fees deducted before a producer is paid are excluded (for example, storage, transportation, and administration costs) and exclude commodity specific program payments (Statistics Canada, 2022). The crop yield data is annual time series from 1908 to 2021.

We fit the distributions of crop yield and crop prices with the “fitdist” function from the “fitdistrplus” R package (Delignette-Muller and Dutang, 2014). The function fits the data (a specific crop yield or crop price) to many empirical distributions (including Weibull, Normal, Gamma and Log-normal) and uses Akaike Information Criteria to suggest the best distribution fit to the data. The “fitdist” uses maximum likelihood estimation procedure. In fitting the univariate crop yield or price data, we did not account for time variant factors such as inflation and interest rates for crop prices and technological change for crop yield, because we assumed the information will be captured in the time series trends. We did not apply the procedure above to corn price and yield, drainage cost because of lack of data; instead, we assumed a uniform distribution for these variables. Moreover, we used the variable distribution information above, for crop yield, crop price, drainage cost and production cost, to estimate the uncertainty associated with annual net return of wetland drainage at the field level. The variable distribution information is summarised in Table 3 below.

**Table 3.** **Variable distributions and their parameters**

|  |  |  |
| --- | --- | --- |
| **Variable** | **Distribution** | **Parameters** |
| *Crop Yield (Bushels/Acre)* | | |
| Canola | Gamma | Shape = 7.34, Rate = 0.11 |
| Feed Barley | Weibull | Shape = 2.53, Scale = 80 |
| Malt Barley | Weibull | Shape = 2.53, Scale = 80 |
| Yellow Peas | Uniform | Minimum = 0.7\* average pea yield  Maximum = 1.3\* average pea yield |
| Soybean | Uniform | Minimum = 20, Maximum = 50 |
| Corn | Uniform | Minimum = 50, Maximum = 130 |
| Flax | Weibull | Shape=2.18, Scale = 35 |
| Spring Wheat | Weibull | Shape= 2.48, Scale=80 |
| Oat | Gamma | Shape=4.59, Rate=0.03 |
| *Crop Yield($/Bushel)* | | |
| Canola | Gamma | Shape = 10.5, Rate = 0.91 |
| Feed Barley | Gamma | Shape = 7.54Scale = 1.65 |
| Malt Barley | Gamma | Shape = 7.54Scale = 1.65 |
| Yellow Peas | Log-normal | Mean log=1.85, Standard deviation log=0.3 |
| Soybean | Gamma | Shape = 15.34, Rate = 1.34 |
| Corn | Uniform | Minimum = 0.7\* average corn price  Maximum = 1.3\* average corn price |
| Flax | Log-normal | Mean log= 2.33, Standard deviation log=0.42 |
| Spring Wheat | Log-normal | Mean log=2.0, Standard deviation log=0.13 |
| Oat | Gamma | Shape=8.52 Rate=1.86 |
| *Production cost($/Acre)* | | |
| Production Cost | Uniform | Minimum = 0.7\* average production cost  Maximum = 1.3\* average production cost |
| *Drainage Cost($/Acre)* | | |
| Drainage Cost | Uniform | Minimum = 200  Maximum = 600 |

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