Experimental Economic Evaluation of Offset Design Options for Alberta – Research Report

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by

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Executive Summary

Conservation offsets are being considered by the Government of Alberta as a strategy to meet regional land use planning objectives under the Land Use Framework. This report summarizes research on offset policy options carried out under the project "Experimental Economic Analysis of Conservation Offsets in Alberta" for the Alberta Land Use Secretariat. Offset policy development requires careful evaluation of alternative rules in order to understand the impact on ecological outcomes and costs. The research supports the policy recommendations in a separate summary report for the project. The research has two components:

- **Economic/Ecological Impacts Modeling** – simulation of the implications of alternative offset rules on economic and ecological outcomes;
- **Market Design Experiments** – identification of market complexities associated with offset policies for Alberta and experimental testing of alternative market designs.

The offset policy options evaluated in this study were generated through discussions with a Project Advisory Committee consisting of industry, NGO and Government Department representatives. Based on input from the Advisory Committee we examined a suite of hypothetical offset scenarios that were selected to highlight key drivers of ecological and economic outcomes. The research does not consider the broader legislative and regulatory framework required to support an offset policy, such as regulation of an offset market; baselines and requirements for specific activities; and monitoring and compliance issues.

Summary of the Offset Policy Scenarios and Results

We assessed the impact of an offset policy for the forested region of Alberta over a 30 year time horizon. The region is primarily boreal forest and public land. The analysis was confined to the forestry and energy sectors, the primary industrial users of public forest land. The energy sector modeling includes oilsands and conventional oil and gas, but not emerging carbonate and shale gas developments which could have impacts at least as large as the oilsands with a different regional distribution. It was assumed that forestry and energy companies are required to hold offsets for all impacts. Equivalence between offsets and impacts was calculated using a measure of biodiversity intactness which converted area into a quality adjusted hectares score. The score distinguishes between upland and lowland ecosites. To examine the effect of additional ecological and social criteria for equivalence we restricted trade within geographically defined trading zones including regional planning areas; grizzly habitat areas, and natural sub-regions for some scenarios.

All activities on public land were assumed to be temporary but varying in intensity and duration. The offset requirement is for the life of the impact and erased when an area is reclaimed and a reclamation certificate is issued. Offsets are modeled as annual or multi-period contracts and are created in two ways. *Conservation Offsets* are created by the delay or cancellation of projects; *Reclamation Offsets* are created through reclamation and restoration activities. We considered four different policies or eligibility rules for offsets: Conservation offsets only; reclamation offsets only with a 5 year lag for accreditation of offsets; conservation and reclamation offsets with a 5 year accreditation period; and conservation and reclamation offsets with a 20 year accreditation period. The key findings from the research are summarized below.

Economic Costs

By far the program with the greatest cost is the one that only allows reclamation, resulting in a loss of 38.4% in potential net present value (NPV) from forestry and energy activities over 30 years. The reason for the high cost is the significant reduction in economic activity that is required to meet no net loss requirements in the initial periods of the offset program while investments in reclamation are accredited (e.g. a 5 year loss in economic activity). When conservation offsets are introduced the costs drop to less than 1.5% of NPV. For the low cost scenario the costs average about $17 million per year, or less than $10 per capita. It should be noted that some of these costs could replace current industry expenditures on ecological management which would reduce the net cost. An alternative option for reducing the cost of the reclamation only scenario is to allow companies to count ecological benefits from reclamation immediately upon signing an offset contract, or reducing the accreditation period to zero. However this will increase ecological risk and will still be more expensive than a combined conservation and reclamation offset program. Under the low cost programs nearly all of the offsets will come from the forest sector which highlights the need to clarify rules for creating offsets on public lands under existing or new tenures.

Effects of Regional and Ecological Trading Zone Constraints on Cost

The costs of imposing additional geographic constraints on offset trades in order to better address the equivalence between gains and losses are low. Adding regional, grizzly habitat, and natural sub-region trading zone constraints resulted in less than a 0.5% increment to the total cost of the offset program. The small cost increases from the sub-regional and grizzly constraints reflect the wide availability of those habitat types throughout the boreal. However, coarse filter strategies based only on habitat loss and restoration may be insufficient for some species, particularly when time lags for ecological recovery are significant.

Ecological Outcomes

For the base case scenario with no offsets the average level of biodiversity intactness for the boreal region drops by 3% from 86.7 to 83.6 over 30 years. For the reclamation only scenario with a 5 year accreditation period the average level of the intactness index stayed constant suggesting no net loss in ecological condition over time. However this is misleading as the result is driven by the rule for accrediting benefits rather than actual ecological gain. From an ecological perspective a 5 year time lag is unrealistic and it is likely that ecological degradation is higher with a different time profile than represented here. However it will still be less than the base case scenario. Increasing the accreditation period for reclamation benefits to 20 years resulted in a very low level of reclamation for scenarios with conservation offsets. The three scenarios which include conservation offsets have a similar profile for change in ecological condition with average intactness decreasing over 30 years by approximately 1.5%. The decreases in intactness occur in spite of the no net loss constraint imposed by the offset requirement due to the inclusion of conservation offsets because some of the conservation offsets violate the principle of additionality, that is, they come from lands that wouldn’t have been developed under the base case.

Regional Distribution of Cost Burden and Offset Activities

The results from the scenarios can be disaggregated to look at the regional implications of offset rules. With no offsets the Lower Athabasca, where the majority of the oilsands are located, has the highest development value, followed by the Lower and Upper Peace regions. Under all of the scenarios, the Lower Peace bears the highest burden of cost in terms of reductions in development opportunity. This means that activity levels in other regions are being “subsidized” by reduced activity in the Lower Peace, and that resources in the Lower Peace are of lower economic value. The Lower Peace experiences the greatest gains from reclamation under all scenarios that include reclamation, however, the amount of reclamation in the Lower Peace falls when regional trading constraints are imposed. This suggests that reclamation activity is being substituted away from the other regions towards the Lower Peace with interregional trading.

Market Institution

The market design component of the research highlights the importance of price discovery in setting up any institution to trade offsets. Price discovery mechanisms such as auctions were argued to be superior to in-lieu fees or conservation funds for managing the financial and ecological liabilities associated with offsets. However funds could be employed to put a ceiling on offset prices if necessary to ensure costs are publically acceptable. Of the mechanisms tested, the double auction with package bidding and the combinatorial call auction were both highly efficient and stable mechanisms for price discovery that should be considered further. Bilateral offset trading performed poorly.

Reducing Exposure

Upfront offset requirements are realistic under any kind of regulated offset market. Even if requirements are only partial this will introduce some exposure for buyers who run the risk of losses in the offset market if they are not able to assemble the full suite of required offsets to undertake their project at a feasible cost. The nature of developers needs highlights the importance of establishing a futures market for offsets to enable multi-period contracting and packaging of offset contracts over time. The experimental analysis of alternative market mechanisms demonstrated the impact that exposure problems have on market outcomes. Market surplus is highest when exposure for buyers is reduced. On the other hand sellers have market power and extract most of the trade surplus when buyers face exposure problems. Markets with exposure problems are also more volatile. Simple institutions such as bilateral trading were shown to increase exposure for buyers and performed poorly even with the fairly simple offset policies considered here. Alternatively, institutions that allow package bidding and forbid partial execution of trades reduce exposure with large improvements in efficiency. The analysis also demonstrated efficiency gains from allowing resale and credit stacking.

Distributional Issues

We show that eligibility rules and offset requirements will significantly affect market structure and market power. In the experiments, sellers had market power over buyers and were able to extract profits from developers over and above the actual cost of producing the offsets. Since public lands are a public resource the ability of sellers to reduce developer profits that would otherwise be captured through leases and royalties is an important policy issue. Revenue neutral auctions which return surplus to developers, or other options to capture the trade surplus going to sellers should be evaluated in future with the goal of reducing opportunities for third parties to capture development benefits.

Value of Smart Markets

Developers and conservation organizations tend to advocate for simplicity in offset rules and market institutions. This can translate into an overly simplified definition of equivalence and an emphasis on bilateral trading institutions. The risk of relying on simplicity is that the offset program will not result in any significant ecological benefit and thus be a waste of money. Furthermore the costs of participating in an offset market will be higher than they need to be. Public and industry support for such a program may fall. Until recently difficulties in designing markets that could match offset buyers and sellers facing complex rules would have been a barrier to implementing some offset policy options. Fortunately, given advances in computer technology and economic theory it is possible to design "smart" markets to solve complex coordination and optimization problems with very little burden on market participants. Given the complexities associated with an Alberta offset market it may be desirable for Government or a centralized agency to provide a smart market platform to facilitate transactions.

Table of Contents

Table of Tables

Table of Figures

1. Conceptual Framework

In order to understand the offset market we start with the preliminary concepts of supply and demand. Offset **Demand** is the relationship between the quantity of offsets desired by developers (buyers) and the price of offsets. If offsets are required for development, the maximum price that buyers are willing to pay for offsets will be equal to the net present value of the potential revenue stream generated by development. Offset **Supply** is the relationship between the quantity of offsets and the price of offsets. Similar to demand, the price that sellers are willing to accept to provide offsets is equal to the net present value of lost revenues from forgoing development, and any direct costs incurred during reclamation and restoration.[1]

The decision each landowner[2] makes with respect to the offset program is illustrated in Figure 1. A landowner compares the net present value of the project with the price of an offset. If the price of an offset is higher than the net present value of development, an offset will be created. If the offset price is lower than the net present value, an offset will be purchased and the project will go forward.

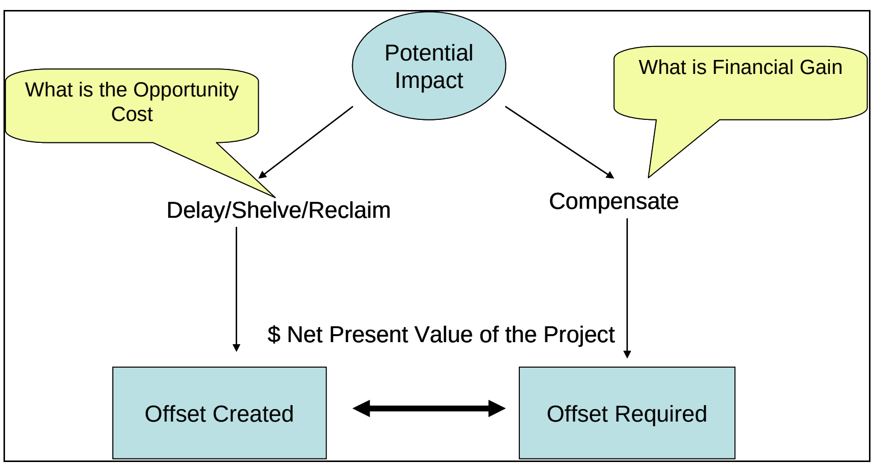

Figure 1 The Offset Market Decision

[1] Henceforth the term reclamation will refer to both reclamation and restoration.
[2] For simplicity we will refer to both landowners and lessees on public lands as landowners.

By aggregating the individual decisions for offsets we can derive demand and supply curves for offsets which show the relationship between net present value (willingness to pay/willingness to accept compensation) and quantity demanded/supplied as measured by quality adjusted hectares (Figure 2). Developers of high valued sites have a high willingness to pay for offsets and will be buyers. Conversely, developers with sites of marginal values will become sellers. The demand curve is downward sloping from left to right showing that willingness to pay is decreasing reflecting the diminishing returns of development opportunities on the landscape. The supply curve is upward sloping reflecting the increasing opportunity cost of setting aside higher value projects as the number of offsets increases. The market provides a price signal to landowners about the relative value of land in conservation and development given the goals of the offset program. The offset market clears when supply is equal to demand at price and quantity (p*,q*) in Figure 2 below.

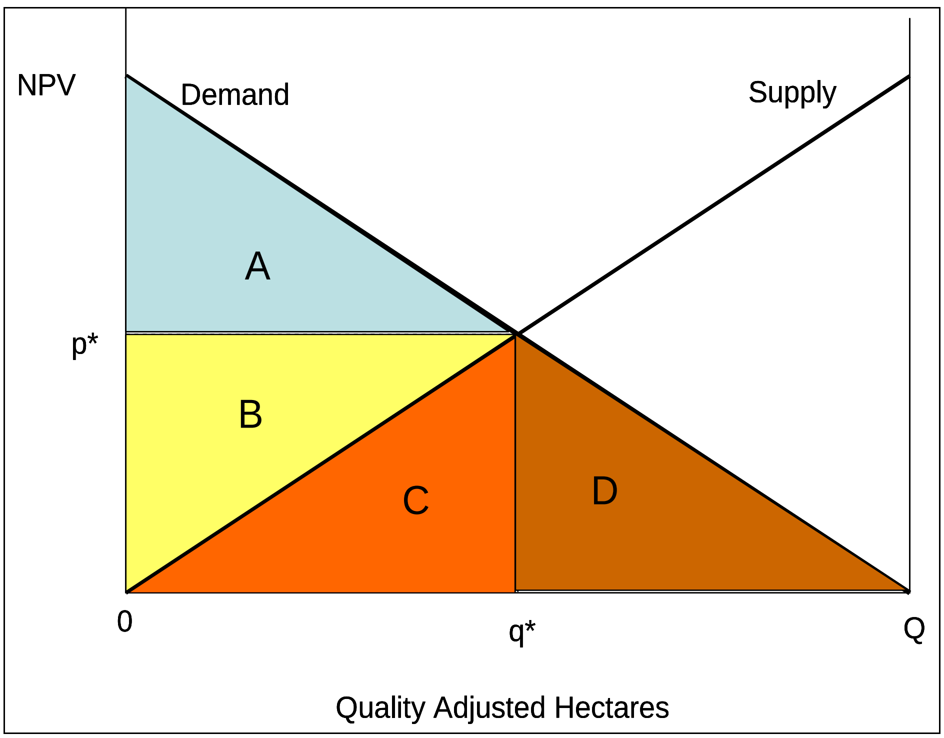

Figure 2 Offset Market Equilibrium

Figure 2 illustrates the costs of the offset program, the gains from trade from an offset market, and the distribution of the gains between buyers and sellers. Without any offset policy, development will occur until NPV of further development is zero at Q. The total economic value of development without offsets is equal to the area under the demand curve A+B+C+D, or the sum of the net present value for each unit of land disturbed.

The business as usual scenario can be compared to the outcome under an offset program. If the offset market clears at (p*,q*) the cost of the offset program to developers is equal to the area C+D. Area C represents a transfer of revenue from developers to offset providers and reflects the true cost of offsets, which is equal to the lost net present value from the foregone development opportunities and/or direct costs of reclamation. Area D is the additional loss resulting from foregone development as fewer projects (Q-q*) go forward. This value is not a transfer from developers to offset providers, but is a cost to society. Note that C is not a cost to society; it is a cost to developers which is counterbalanced by a gain to offset providers. Since C is a transfer, it does not represent a net social cost even though it represents a cost to developers.

The areas A and B show the remaining economic value that will be distributed between offset buyers (area A showing the difference between development value and the price paid for offsets) and sellers (area B showing the difference between the price of offsets and the true cost of offsets). Note that prior to the offset program these values only went to developers. With the offset program, some development value above the cost of the offset program (e.g. area B) will be redistributed to offset sellers. The market institution determines how offset prices will be set and the distribution of the rents between buyers and sellers.

1.1 Determinants of Offset Demand and Supply

Offset demand is driven by regulatory requirements for development. There are three regulatory scenarios that could drive offset demand in Alberta:

- Offsets are a regulatory requirement for development; that is, all site impacts *must* be compensated with an offset. In this case the demand for offsets is equal to the net present value of development. This is the most restrictive and therefore the highest cost of the scenarios, and is the scenario that is modeled in this analysis.

- Offsets *may* be used to meet a regulatory requirement but are not mandatory; that is companies may use an offset or some other compliance option to manage disturbance. In this case the willingness to pay for offsets is capped by the price of alternative compliance options. For example in the Alberta carbon offset market firms that are required to reduce greenhouse gas emissions can pay a $15/tonne charge, purchase an offset, or reduce emissions directly. In choosing a compliance strategy, a firm will consider the relative costs of each option however the price of carbon offsets is effectively capped at $15/ton.

- There is no regulatory requirement for offsets. In this case participation in an offset market is completely voluntary and may be motivated by marketing advantages or social license to operate. The voluntary scenario is difficult to model since the benefits of participation are less tangible and difficult to measure.

Offset supply is determined by eligibility rules for creating offsets. Common criteria for eligibility are permanence and additionality which ensure that ecological benefits from offsets are real. Additionality is difficult to measure since it requires determining whether or not conservation lands that count as 'offsets' were actually at risk of development, and whether the activities that generate offsets are above regulatory requirements or baselines. There are significant challenges associated with permanence on public lands. Permanence is feasible on private lands where landowners have the right set land aside in perpetuity through easements subject to constraints such as surface right access for sub-surface mineral leases. On public lands, lessees only have temporary rights to develop and permanent offsets are not an option.

There are also significant challenges in determining additionality. For offsets generated by reclamation activities, the benefits will have to be distinguished from those that would have occurred under existing reclamation requirements. In theory activities that accelerate reclamation could be counted as additional, provided an agreed upon baseline rate of reclamation could be established. For offsets generated from delay or cancellation of development projects, additionality requires establishing that the land would have been developed without an offset program, which is difficult to determine without private information on actual land values. The final factor influencing offset supply is the time lag allowed between undertaking offset activities such as reclamation, and the date at which benefits of reclamation are counted (i.e. the time lag between reclamation activities and certification of offset credits). The longer the time lag between reclamation and accreditation the lower the initial supply of available offsets from reclamation.

1.2 Specification of Offset Metrics and Rules

The basis of an offset program is the requirement that the damage caused by a development (the impact) is equivalent to the conservation gain from the offset. Equivalence is based on a number of site attributes which convert the damage to biodiversity caused by the development project into “units” to be spent on conservation in order to meet the goals of the program. Offset rules determine the flexibility for meeting program goals as well as the degree of segmentation of offset types in the market. For clarity we distinguish between *Offset Metrics* and *Offset Rules*. Offset metrics measure and differentiate the ecological units that are gained and lost in offset trades. Offset rules and mitigation ratios define the substitutability between ecological units.

Offset rules typically consider the following site characteristics for establishing equivalence:

- Size - the area or quality adjusted area of the site;
- Quality – the condition of the site;
- Similarity – the types of ecosystems, habitats, and species represented in the offset and impact sites;
- Timing – timing and duration of impacts and benefits;
- Proximity – nearness of the offset to the impact site.

In this analysis the primary metric used to measure ecological losses and gains is a quality adjusted hectare calculated by weighting the size of the impact/offset site a measure of biodiversity intactness developed by the Alberta Biodiversity Monitoring Institute (ABMI). The intactness index measures ecological condition at each site. Ideally, an offset site should also have similar representation in terms of species, communities, or landforms to the impact site. Most offset programs use geographic proxies and mitigation ratios to account for similarity between site types. Proximity ensures that ecological benefits occur in the same area as losses and may be used to account for both social and ecological goals.

Offset rules determine the level of substitutability between ecological units in impact and offset sites. In some cases rules may require strict equivalence with exactly the same attributes represented by the impact and offset sites. Rules may also direct offsets towards equivalent or better sites through preferential trading ratios or exchange rates. Quality adjusted hectares are implicit rules that use relative ecological condition to determine substitutability. For example, two hectares of habitat of 50% quality can offset one hectare of habitat of 100% quality. This is the same as saying that 50% degraded and pristine habitat are substitutable at a 2-1 ratio. Alternative trading rules could require that replacement habitat be “at least as good as” the habitat lost, so that substitution can only be of higher quality. Similarly, trades can be restricted to the same types of habitat or trades between different types of habitat could be allowed to occur but with a ‘penalty’. For example 10 hectares of standard habitat would be required to compensate for 1 hectare of grizzly habitat lost.

1.3 Biodiversity Intactness

Land disturbance affects biodiversity in a variety of ways, ranging from habitat loss and creation to more subtle changes in habitat quality. The biodiversity intactness index integrates the responses of different species that are both positively and negatively affected by disturbance relative to what would be expected in the absence of development. The index represents an assessment of the condition of biodiversity, ranging from completely degraded biodiversity (0) to completely intact biodiversity (100) as would be found in the absence of any land disturbance. By using the intactness index to calculate quality adjusted hectares, we can compare changes in ecological condition between the development site and the offset site.

The data and methodology used to calculate the intactness index are explained in detail in ABMI (2008, 2009). The analysis has been adapted to enable the prediction of the spatial variability of biodiversity intactness across the boreal forest, and has been updated with additional monitoring data obtained since the 2009 report. For this research biodiversity intactness indices were calculated for Alberta Township System sections (approximately 270 ha) for the boreal region.

Biodiversity intactness is predicted as a function of the percentage of successional and alienating disturbance in a geographic unit (section), the percentage of lowland, and location measured by latitude and longitude. Total disturbance is equal to successional plus alienating disturbance. Successional disturbances are disturbances that grow back to some form of native vegetation, and include cutblocks, seismic lines, power lines, and pastures. Alienating disturbances permanently disturb the soil and eliminate or replace vegetation. These include cultivated crops, roads, urban, well pads, and industrial sites. The types of disturbances included in the intactness index model are outlined in Table 1 below.

Table 1 Types of Disturbances Considered in Biodiversity Intactness Models

Footprint Type	**Description**
Crop	% area converted for crop and accompanying activities
Pasture	% area converted for pasture
Clear Cut	% area clear cut for timber extraction
Partial Retention	% area with >20% retention for timber extraction
Industrial	% area converted for industrial activity with surface soil removal
Municipal	% area converted for urban and rural residential and commercial
Roads	% area converted for linear features such as roads and highways that are paved or gravel
Soft Linear	% area converted for linear features such as seismic lines, pipelines and skid rows that are grass or natural vegetation and don't remove soil

Intactness was modeled for the 55 most common bird species and the 82 most common vascular plants in the ABMI dataset. The predicted equation below provides a reasonable fit to the overall relationship. To simplify the presentation, the equation below omits the effects of geographic location:

$$\text{Intactness} = 100-(0.910+0.00837*\mathbf{p})*\mathbf{s}+(0.0115+0.000074*\mathbf{p})*\mathbf{s}*(\mathbf{s}+\mathbf{a})-(7.396\text{e-}05+1.064\text{e-}07*\mathbf{p})*\mathbf{s}*(\mathbf{s}+\mathbf{a})^2 -(1.026+0.01286*\mathbf{p})*\mathbf{a}+(0.00303+0.000183*\mathbf{p})*\mathbf{a}*(\mathbf{s}+\mathbf{a})-(1.326\text{e-}05+6.549\text{e-}07*\mathbf{p})*\mathbf{a}*(\mathbf{s}+\mathbf{a})^2;$$

where ***s*** is the percentage of successional disturbance in a section, ***a*** is the percentage of alienating disturbance and ***p*** is the percentage of lowland ecosystem. The formula was applied to the boreal region as well as foothill areas north of 53°N to project biodiversity intactness by section for the region. The resulting map is shown in Figure 3 with red areas representing 0% intact and blue areas 100% intact. Variations in between red and blue are not distinguishable on this map because of the high resolution of the data.

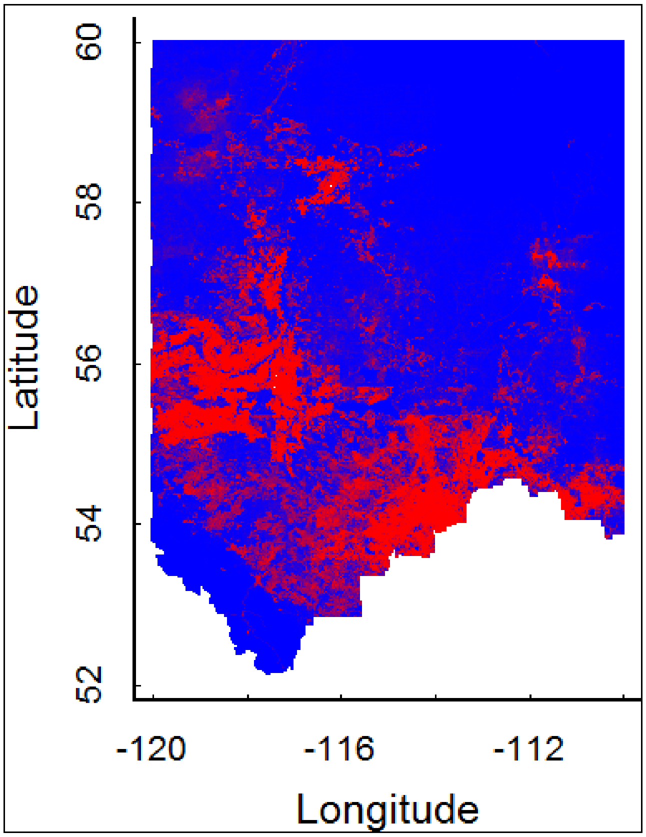

Figure 3 Map of biodiversity intactness in northern Alberta

The equation above captures the general shape of the relationship between predicted biodiversity intactness and land use disturbance but there is still a great deal of scatter among individual points. The fit of the equation across the 0-100% range of successional disturbance (green) and alienating disturbance (red) is shown in Figure 4 below, for sections with 0% lowland (top line), 40% lowland (middle line) and 80% lowland (lower line). Sites with a mix of successional and alienating disturbances fall between the green and red lines (at whatever level of percent lowland). The range of variation in the data represents a biodiversity risk that could be addressed in future versions of the intactness measures, and also incorporated into offset metrics through mitigation ratios.

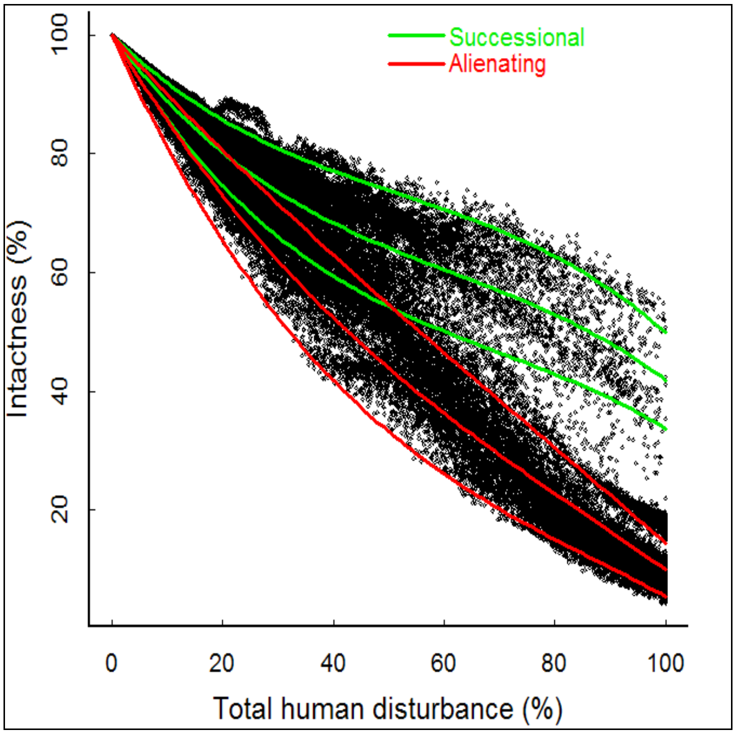

Figure 4 Tradeoffs between Human Disturbance and Ecological Intactness

There are a number of improvements which could be made to the intactness index to ensure a better match in condition between offset and impact sites. For example, disturbance information from satellite images of ABMI sites should be ground-truthed to improve the reliability and validity of the independent variables. In addition one may want to apply the actual disturbance models for each species, rather than a general (average) equation for all species. The analysis should be refined and updated as more information is obtained including more detailed eco-site information if it becomes available since upland vs. lowland is only a coarse approximation of variation among eco-sites. Finally, using only two types of land disturbance (successional and alienating) results in relatively coarse relationships. The relationships can be refined to establish separate relationships for individual disturbance types but this requires additional surveying to ensure a balanced statistical design. The calculation of similarity between sites was beyond the scope of this study. However the data could also be used in the future to calculate site specific similarity metrics.

2. Economic and Ecological Tradeoff Analysis

In May 2010, the project team met with an Advisory Committee to prioritize a suite of offset policy scenarios for further evaluation. The scenarios are based on the following characteristics:

Offset Unit/Metric: Quality adjusted hectares based on biodiversity intactness index

Offset Rules:

1. No restrictions
2. Restrict trades to within Alberta's land Use Framework planning regions;
3. Restrict trades to Alberta's natural sub-regions;
4. Restrict trades to outside of Grizzly habitat where applicable.

Sectors: The analysis was confined to the forestry and energy sectors, the primary industrial users of public forest land.

Offset Requirements: It is assumed that forestry and energy companies are required to hold offsets for all impacts. For forestry companies this includes impacts from harvest. Note that this policy is not consistent with existing rights, however it highlights the relative ecological costs and economic benefits of different activities and where offsets might come from. All activities on public land are assumed to be temporary, although they may occur over several years or decades. The duration of the offset obligation remains until an area is reclaimed and a reclamation certificate is issued.

Eligibility Rules: Offsets can be temporary or permanent. For the purpose of this study the offsets are annual or multi-period contracts. Permanent offsets can be incorporated within this framework. Offsets can be created in two different ways. *Conservation Offsets* can be created by the delay or cancellation of projects on public lands, or by contracts and easements on private lands. *Reclamation Offsets* are created through reclamation and restoration activities on either public or private lands. Note that we do not address the important issue of how long a temporary offset would need to be protected in order to count as an offset, or who would be liable for the offset.

We consider four different eligibility scenarios for creating offsets:

- Conservation offsets only

- Reclamation offsets only with a 5 year lag between reclamation and certification of benefits;
- Conservation and reclamation offsets with a 5 year lag for certification of reclamation benefits;
- Conservation and reclamation offsets with a 20 year lag.

The offset rules and eligibility scenarios were combined into eight scenarios including a base case with no offsets. The modeled scenarios are illustrated in the highlighted rows and columns of Table 3 below. Scenario Set 1 refers to the set of scenarios highlighted in Column 1 which includes each eligibility rule and no restrictions on trade. Scenario Set 2 highlighted in Row 3 looks at each of the four trading constraints with a common eligibility rule defined by both conservation and reclamation offsets with 5 year time lags.

Table 2 Modeled Offset Scenarios

Base Run – No Offsets	**Offset Rules**			
	Units	**Trading Constraints**		
Eligibility Rules	Scenario 1 Quality Adjusted Hectares (QAH)	Scenario 2 QAH + Land Use Framework Planning Regions	Scenario 3 QAH + Alberta's Natural Subregions	Scenario 4 QAH + Alberta's Natural Subregions + Grizzly Habitat
Conservation Offsets Only	**X**			
Reclamation Offsets Only (5 year lag)	**X**			
Conservation and Reclamation Offsets (5 year lag)	**X**	**X**	**X**	**X**
Conservation and Reclamation offsets (20 year lag)	**X**			

The costs and ecological benefits of the offset program are based on a simulation model developed in EXCEL that was used to generate supply and demand functions for offsets under different offset rules, and solve for the market clearing price and quantity. The model solves for the economic cost of an offset program in terms of the foregone net present value of development. The modeling also shows which sites will be conserved under different offset rules. We can then look at the trajectory of land use on different patches of land (whether they are under development, conservation, or reclamation in any period), and determine what the effect on conservation outcomes is over the entire landscape. The simulation covers the boreal forest region of Alberta (approximately 240,000 sections of land), the majority of which is in public land. The simulation is over a 30 year time horizon divided into six 5-year time steps or decision points.

2.1 Net Present Value Data

Net present values for the forestry and energy sectors were derived from the TARDIS model (Hauer et. al 2010; Nanang and Hauer 2008). TARDIS solves the following problem: maximize the joint net present value of forestry, conventional oil and gas, and bitumen activities over the forested extent of the province over 50 years with 5 year time increments. The activities represented for each 5 year interval include:

- Area of timber harvest by age class and species type by township and period;
- Drilling activity by section and stratigraphic interval for conventional gas and oil;
- Project and drilling activity by ¼ township for SAGD bitumen extraction;
- Bitumen mining activity by ¼ township within the mining area.

Development values are maximized subject to the following economic and resource constraints:

- Forest land constraints which require harvest area per age class cannot exceed the amount of land in each age class at a given time;
- Forest dynamic constraints that update age class distributions from period to period;
- Volume constraints which require harvested area volumes to be constrained by timber yield curves;
- Spatial mill demand constraints for 35 mill locations that require mill demand to be less than or equal to capacity;
- Oil and gas reserve values determined by energy production curves by section and stratigraphic interval;
- Drilling capacity constraints caused by limited capacity to increase capital and labour in the energy sector at a given time as well as capacity constraint projections for bitumen production; and
- Underlying reserve constraints which link projections for oil and gas activity to past drilling data and potential reserves estimates taken from the Energy Resource Conservation Board projections found in their ST98 series publications.

TARDIS was used to generate estimates of land values for each of the following sectors: forestry, conventional oil and gas, and bitumen extraction. The model also generated optimal schedules of development over the 50 years for each section of land. The schedule of activities and the values associated with the schedule were used to generate the demand curve for offsets in each period in the model.

2.2 Spreadsheet Model

Output from TARDIS was exported to EXCEL in aggregated form to examine the impact of offset policy scenarios. The spreadsheet model is a linear program which optimally reschedules forestry and energy sector activities in the presence of offset requirements. The variables in the model are development projects and offsets which take place on a section level. Specifically, the variables over which the model optimizes are sections of forestry harvest, sections of energy development, sections of conservation offsets and sections of reclamation offsets. Conservation offsets are no-development zones that once set aside cannot be developed in a given time period. Conservation offsets do not improve the ecological quality of a site, only guarantee that it will not be developed. The intactness index of the site placed in a conservation offset is used to offset the decreases in intactness caused by development. There are 6 five year periods in the offset market model, covering 30 years rather than the 50 years of TARDIS output. The spreadsheet model is driven by profit maximization and seeks to find a market clearing equilibrium given the net present values generated by TARDIS.

In order to reduce the size of the problem the data were aggregated by classes of land (indexed by i) using seven criteria so that land sections containing similar characteristics were grouped together. The seven criteria were:

1) LUF region (Lower Athabasca, Lower Peace, North Saskatchewan, Upper Athabasca, Upper Peace);
2) Natural Sub Region;
3) Grizzly Range (inside grizzly range or not);
4) Earliest period of development (1^{st} 10 years, 2^{nd} 10 years, 3^{rd} 10 years or later)
5) Energy land value class in $/section (0-100, 100-250, 250-500, 500-1000, 1000-10000, 10000-100000, 100000-1000000,1000000+);
6) Forest land value class $/section (0-50, 50-100, 100-250, 250-500, 500-1000,1000-10000, 10000-100000, 100000+;

7) Biodiversity intactness class (0-33, 33-66, 66-95, 95+);

The spreadsheet model maximizes the net present value of profits net of reclamation costs by choosing the optimal schedule of sections to develop or to use as offsets through either reclamation or conservation. In more detail, the objective can be expressed:

Maximize Total NPV = $\sum_{i,t} NPV_{it}^{forest} \times x_{it}^{forest} + \sum_{it} NPV_{it}^{energy} \times x_{it}^{energy} - \sum_{it} C_t^{reclaim} x_{it}^{reclaim}$

Where *i* is an index over the aggregated land classes and t represents time period. The x_{it} variables for forest, energy and reclamation are the number of sections to develop according to the optimal schedule developed in the TARDIS model for that section. The strategy includes a forest harvesting schedule (i.e. number of ha to cut in the section in each period) and number of wells to drill in each period and operate thereafter. If t=0 then the schedule is implemented starting in period 0, and if t=1 then it is delayed one five year period, and so on.

The NPV_{it} coefficients in the objective function of the spreadsheet model were computed by averaging all the net present values (which were outputs from TARDIS) over all the sections that were placed in the aggregate class. The biodiversity intactness index was also averaged within each aggregate land class. The reduced data set included a total 3,433 aggregate land classes or data points. The model chooses the x_{it}*'s* to maximize the objective function subject to 3 types of constraints:

1) Bounded development variables;
2) Restrictions on offsets; and
3) A market clearing condition for offsets.

Bounded Development Variables:

These constraints place bounds on the number of sections that can be developed, harvested, and the number of wells drilled. In general these constraints simply require that the number of sections developed cannot exceed the number available for development, and that the solution in the spreadsheet model matches the solution from TARDIS in terms of numbers of sections harvested and the number of wells drilled. The bounded development constraints are:

1) Sections developed <= available sections (one for each land class);

2) Total number of sections harvested <= demand for sections to harvest;

3) Wells drilled <= demand for wells.

The first constraint restricts the number of sections developed in an aggregate land class to the number of sections that fall into that land class. The constraint is actually a set of 3,443 individual constraints, one for each aggregate land class. The second constraint adds up the number of sections harvested and ensures that this is less than the demand for sections to harvest, which we take to be the number of sections harvested in the optimal harvest schedule from TARDIS. We take this to be the demand because the TARDIS model maximizes profits and the optimal schedule of harvest lands can be considered a derived demand. It is important to note that in the TARDIS model harvest scheduling is at the aggregate stand level (ie species type, age class), therefore the portion of a section actually harvested may be significantly less than one. The third constraint is similar to the second constraint, except that it applies to the energy industry. It requires that the total number of wells drilled in each period over all developed sections is less than or equal to the number of wells drilled in the optimal TARDIS schedule by period.

Restrictions on Offsets:

These constraints simply ensure that the number of sections reclaimed or put into conservation offsets in each land class do not exceed the number of sections present in each land class. The constraints are:

1) Reclaimed sections per land class <= Sections available for reclamation in land class;
2) Conservation Offsets per land class <= available sections in land class.

Market clearing condition for offsets

This constraint is what allows us to represent an offset market in our model. Without this constraint the solutions to the spreadsheet model will simply mimic the solutions in TARDIS, which does not incorporate offsets. Simply expressed the constraint is:

1) Intactness loss <= intactness gains from reclamation + conservation

To implement this constraint the biodiversity intactness indices were projected for each land section. Decreases in the intactness index were estimated for each schedule of harvest and energy development for each aggregate land class. Similarly gains in intactness were estimated for reclamation activity for each aggregate land class. The equations may be implemented as stated above or in parts. For example to examine only offsets resulting from reclamation the last term on the right hand side showing intactness in conservation areas could be dropped from the equation. Similarly, to look only at conservation offsets the reclamation portion of the equation on the right hand side could be dropped. One important factor in setting up the equation for market clearing is the time between the reclamation activity and the delivery of the ecological benefit. By default the model is set up to have a 5 year lag which implies biodiversity benefits are credited after one period. We also set up the equation to have a 20 year lag. This is fairly optimistic from an ecological perspective. For this modelling exercise we do not attempt to justify the recovery periods used but choose different lag periods for illustrative purposes.

2.3 Results

Offset Costs

Results for Scenario Set 1 are shown in Table 4 and Figure 5. The value of the unconstrained objective function was approximately $299 billion in discounted profits for the base run scenario with no offsets. The NPV are based on $2008 dollars and use a discount rate of 4%. The column labelled “Difference from Base” is the difference between the value of the objective function under the offset scenario and the base run. This difference represents the cost of implementing the offset system in terms of forgone profits and the costs of putting resources into reclamation. By far the system with the greatest opportunity cost of $115 billion is the offset system that permits reclamation only. This represents a decrease of 38.4% in the objective function. When conservation offsets are introduced the costs drop to less than 1.5% of NPV or approximately $0.5 to $4.5 billion (see the last three rows of Table 4). Increasing the lag time for accreditation of offset benefits from 5 years to 20 years increases costs by $4 billion. It is important to note that these costs are not annual costs but borne over the 30 years of the simulation. For example, for the low cost scenario the costs average about $17 million per year, or less than $10 per capita. However costs are higher in the first periods with discounting.

Table 3 Net Present Values of Profits for Scenario Set 1 ($Million)

Run	Objective Function	Difference from Base	% Difference from Base
Base run	$299,438	---	---
Reclamation only (5 yr lag)	$184,410	$115,029	-38.4%
Conservation Offsets Only	$294,914	$4,524	-1.5%
Reclamation (5yr lag) + Conservation Offsets	$298,931	$508	-0.2%
Reclamation (20yr lag) + Conservation Offsets	$294,908	$4,530	-1.5%

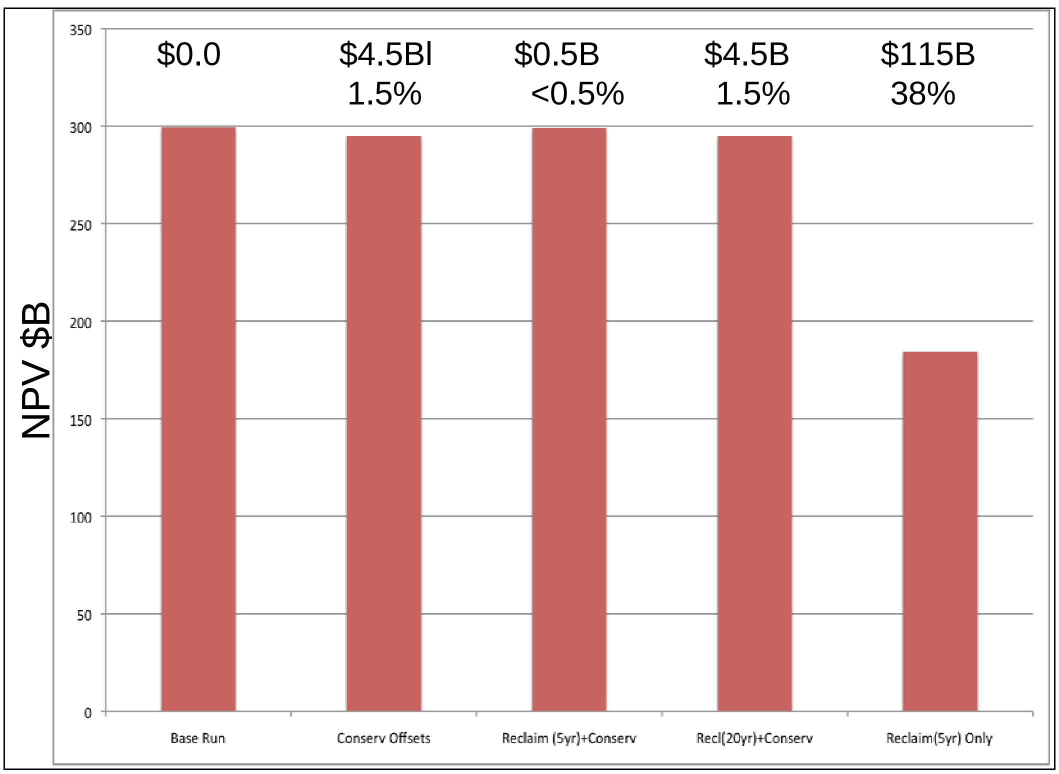

Figure 5 Offset Costs by Scenario (Total and % NPV) for Scenario Set 1

While it may seem that the addition of conservation offsets is the overriding factor that determines whether opportunity costs are low or high, it is really a function of the time lag between when reclamation activity occurs and the time when the increase in the ecological indicator caused by the activity is realized. In the reclamation only scenario there is no way to maintain the level of ecological condition in the first period (because of the 5 year lag), except by significantly decreasing development activity which leads to the significant decrease in NPV. The longer the lag in crediting ecological benefits, the more costly the reclamation only scenario will be. If companies are allowed to count the offset credits before the change in intactness happens and/or at the time the reclamation activity is completed, then the high costs of the "reclamation only" offsets scenario will be mitigated. However, this will come at an ecological cost because the ecological indicator will be allowed to decrease both at the site level and at the global level (the average over the all sites) during the recovery period after the reclamation activity takes place. The addition of the "conservation offsets" option allows the companies to buy time before the reclamation offsets produce their desired results. This is why the reduction in NPV for the conservation offset model runs is much less.

Effects of Planning Region, Natural Sub-Region and Grizzly Habitat Constraints

The purpose of the second set of scenarios was to determine if restrictions on the area in which offset trades can take place significantly affects costs. The results of imposing trading constraints by planning regions, natural sub-regions, and grizzly habitat are shown in Table 5 and Figure 6.

Table 4 Offset Costs for Scenario Set 2 ($ Million)

Model Run	Objective Function	Opportunity Cost (Difference from Base run)
Base Run	$299,438	---
Reclamation (5yr lag) + Conservation Offsets	$298,931	$508
LUF regions	$298,903	$535
NSR	$298,867	$572
NSR+Grizzly	$298,863	$576

When offset trades are restricted by planning region, the objective function is virtually identical to the reclamation (5 year lag) + conservation scenario discussed earlier. Costs increase by a small amount of about $27million over 30 years, suggesting that there are sufficient opportunities for offsets within each planning region, although the types of offsets may vary. Restricting the offset trades to the smaller natural sub-regions increases costs slightly more, but the total cost compared to the base run is still less than 0.5% of NPV. Adding a restriction for Grizzly habitat also increases costs but again the incremental increase is small (roughly the same as for natural sub-regions). The small cost increases from the sub-regional and grizzly constraints reflect the wide availability of those habitat types throughout the boreal. However, coarse filter strategies based only on habitat loss and restoration may be insufficient for some species, particularly when time lags for ecological recovery are significant.

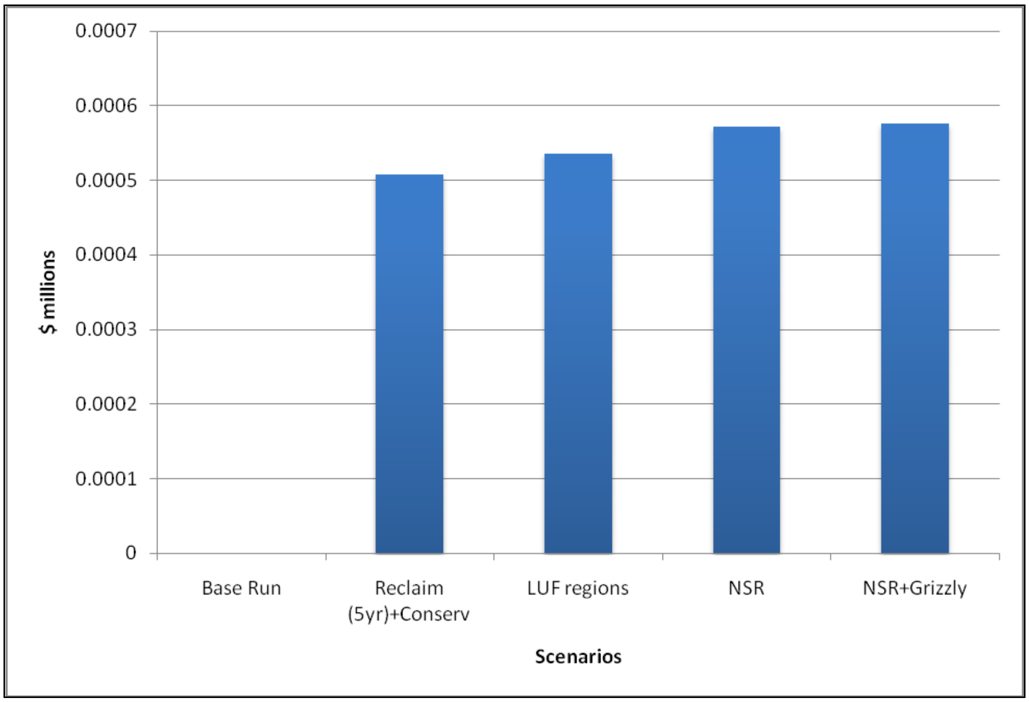

Figure 6: Effects of Geographic Constraints on Offset Costs (Scenario Set 2)

Ecological Outcomes

The change in ecological condition for Scenario Set 1 is shown in Figures 7-9. The change in average biodiversity intactness for the region for each scenario is shown in Figure 7. For the base run with no offsets the average level of the intactness index drops by 3% from 86.7 to 83.6 over 30 years. For the reclamation only run with a 5 year lag the average level of the intactness index stays constant over time. This is driven by the market clearing equation which requires that decreases in intactness from development must be offset by increases from reclamation benefits. Note that from an ecological perspective this assumption is unrealistic and it is likely that ecological degradation is higher with a different time profile than represented here. The average level of intactness for the other three runs which include conservation offsets falls by approximately 1.5% over the 30 year period. Intactness decreases in these scenarios due to the inclusion of conservation offsets because some of the conservation offsets violate the principle of additionality. The decline represents the ecological loss due to counting conserved sites, which would never have been developed under the base run, as offsets in the conservation offset scenarios. Even though there is some loss due violation of additionality, these three runs still show a 50% improvement in ecological condition relative to the base run.

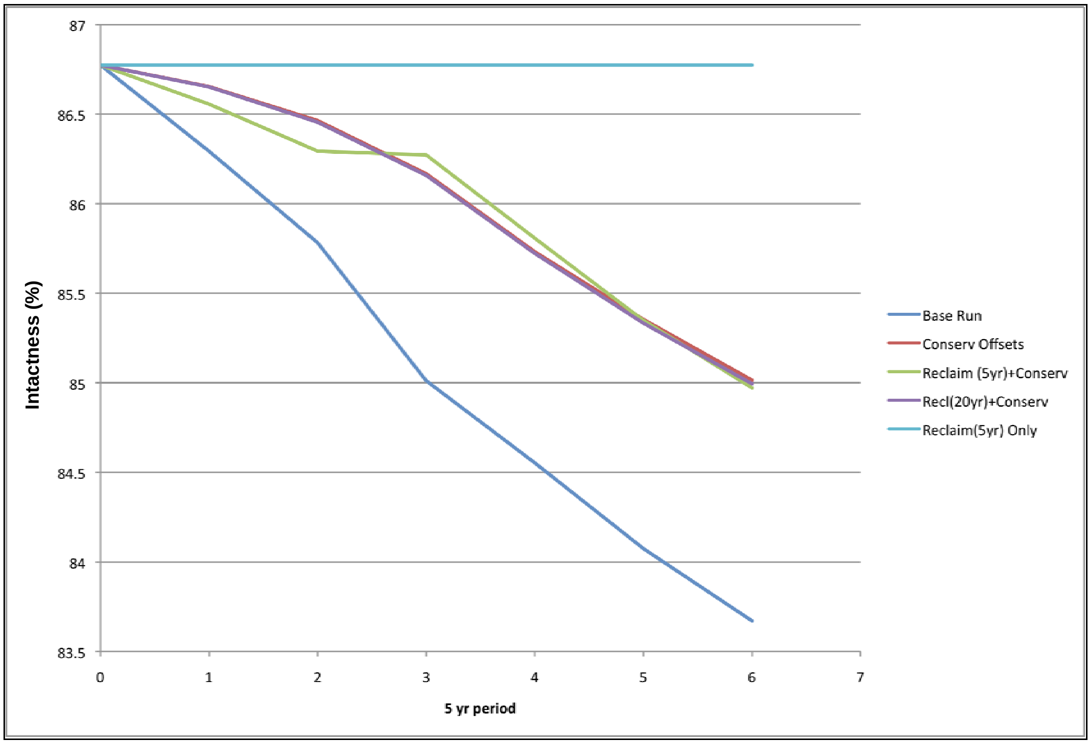

Figure 7 Impacts of Offsets on Ecological Condition (Scenario Set 1)

Figures 8 and 9 illustrate the contribution to ecological losses by sector under the different scenarios. A comparison shows that under the base run the contributions to losses are somewhat higher for forestry (1.8%) than for energy (1.2%). Under a reclamation only policy, the losses from forestry go to zero while energy continues to have an impact (~0.5%) suggesting that energy's losses will be offset by reclamation of both forestry and energy sector disturbances. For the scenarios with conservation offsets there is virtually no change in the contribution to losses from energy sector activities relative to the base run suggesting that activities from the energy sector will not change substantially and that the forest sector will be the offset provider for the energy sector. Finally, the last two scenarios of conservation offsets only, and conservation offsets with reclamation offsets credited with a 20 year time lag show virtually identical time paths of ecological losses. This is true for both the forestry and energy sectors. This demonstrates that the choice of compliance is very sensitive to the accreditation period, and that with a 20 year lag virtually no reclamation will take place. Furthermore, all three scenarios that use conservation offsets rely on conservation offsets from the forest sector. These would be generated by the delay or cancellation of harvest activities which would be in violation of their current tenure agreements. In addition because the forest sector is responsible for reforestation, there may be limited opportunities for reclamation offsets from forestry. The importance of forestry offsets in minimizing the costs of the offset program highlights the priority for resolving baseline and tenure issues for the forest sector in any subsequent analysis of offset policy options.

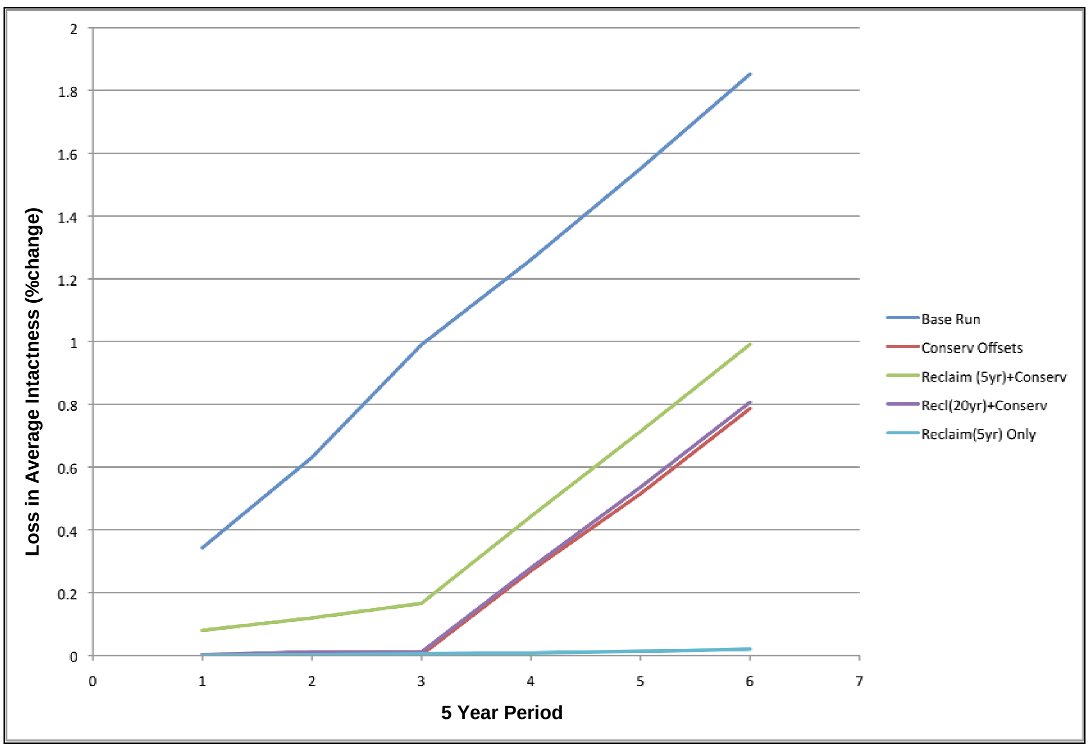

Figure 8 Losses in Ecological Condition due to Forestry

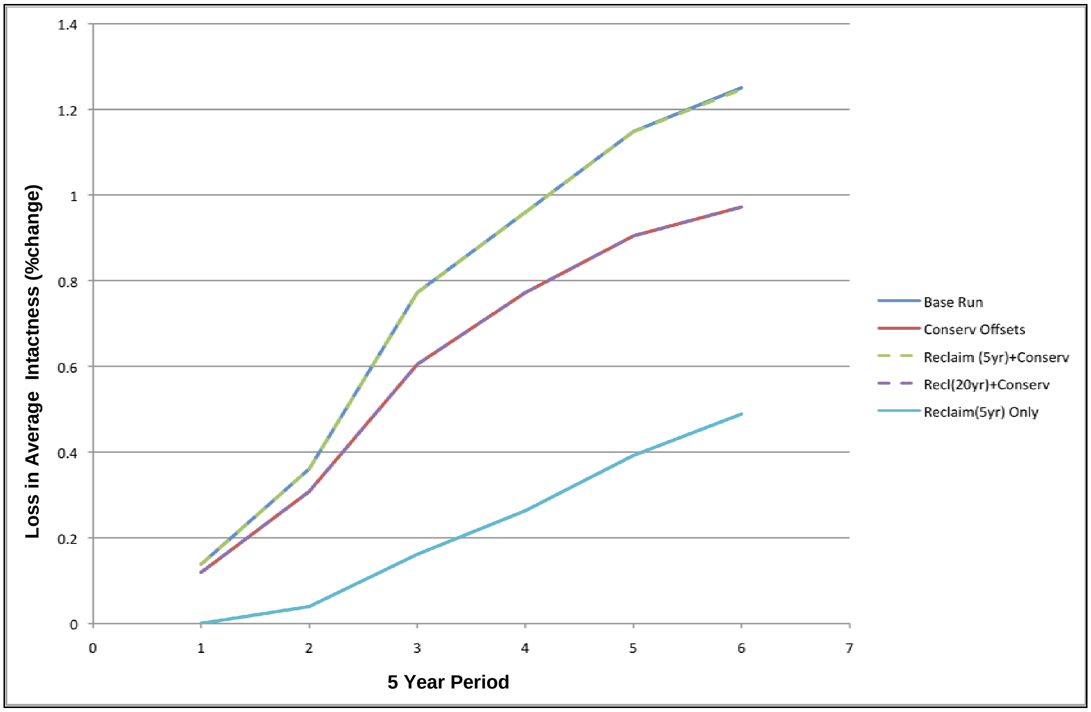

Figure 9 Losses in Ecological Condition due to Energy

Regional Distribution of Offset Costs and Benefits

The results from the scenarios can be disaggregated in order to look at the regional implications of offset rules. In this section we examine four scenarios. Three are "global" in the sense that there are no geographic constraints on where offsets may be located. These three scenarios are conservation offsets only, reclamation offsets (5 year lag) only, and conservation offsets and reclamation offsets (5 year lag) combined. The fourth scenario, which is based on combined conservation and reclamation offsets, constrains offsets to be located in the same Land Use Framework planning region as the development. Tables 5 and Figure 10 show the regional distribution of offset costs under the different scenarios. Under the base run, the Lower Athabasca, where the majority of the oilsands are located, has the highest development value, followed by the Lower and Upper Peace regions. Under all of the scenarios, the Lower Peace bears the highest burden of cost in terms of reduction in development opportunity. This means that activity levels in other regions are being "subsidized" by reduced activity in the Lower Peace under the global scenarios. More than twice the size of the Lower Athabasca, the Lower Peace is the largest and most remote of all of the planning regions. The analysis shows that while the Lower Peace has the second highest development value in total, it also has a significant number of projects that would be considered economically marginal compared to the other regions. As a result high value development opportunities in the Lower Athabasca and Upper Athabasca and Upper Peace regions are offset by delays in development in the Lower Peace Region.

Table 5 Costs of Offset Program by Region as % NPV

Opportunity costs	Base Run	Conservation Only	Conservation & Reclamation (5yr)	Reclamation Only (5yr)	LUF Constrained (Conservation & Reclamation (5yr)
Lower Athabasca	-	0.81%	0.03%	35.85%	0.04%
Lower Peace	-	6.14%	0.78%	63.47%	0.49%
North Saskatche-wan	-	3.33%	0.08%	14.35%	0.49%
Upper Athabasca	-	0.77%	0.22%	32.57%	0.40%
Upper Peace	-	0.52%	0.14%	29.05%	0.28%
Total	-	1.51%	0.17%	38.41%	0.18%

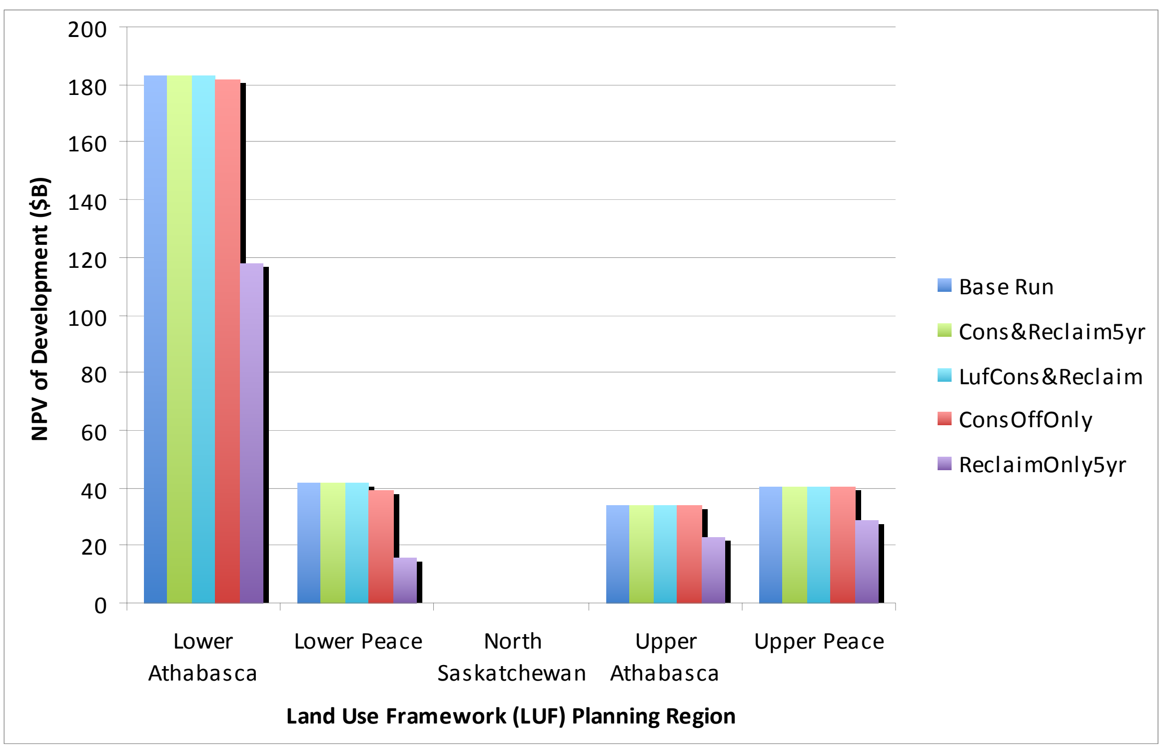

Figure 10 Net Present Value of Development by Region

Figures 11 and 12 show the distribution of ecological gains as measured by the sum of changes in intactness by region and by type of offset. Figure 11 shows the ecological gains from conservation offsets across the different planning regions under the different scenarios. The Upper Athabasca has the most gains from conservation offsets followed by the Lower Peace. Figure 12 shows that the Lower Peace has the most gains from reclamation overall. However, imposing the planning region constraint increases reclamation activity in all of the regions except for the Lower Peace. This suggests that without trade boundaries, reclamation activity is being substituted away from the other regions towards the Lower Peace

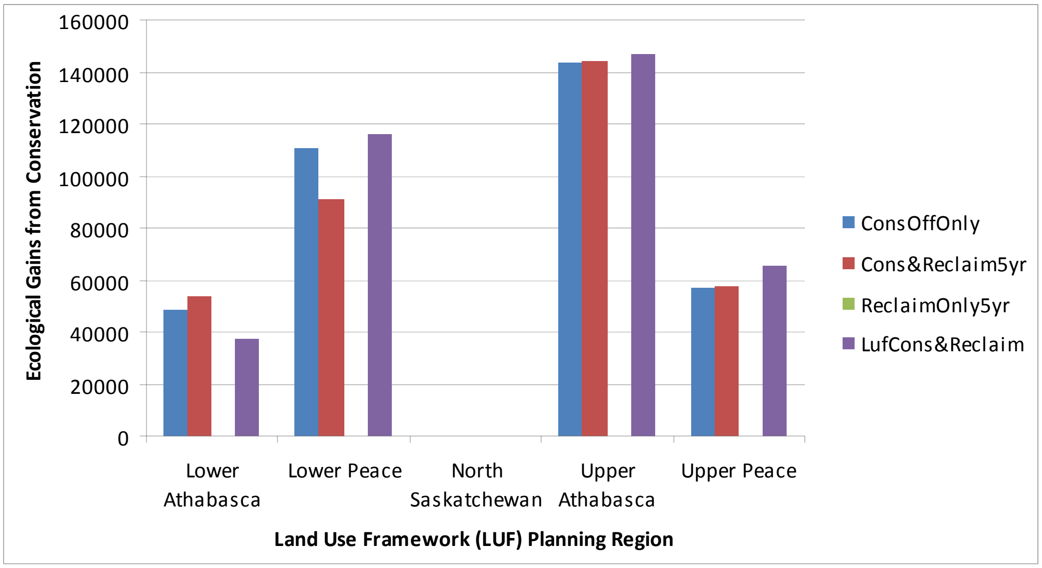

Figure 11 Ecological Gains from Conservation Offsets by Region

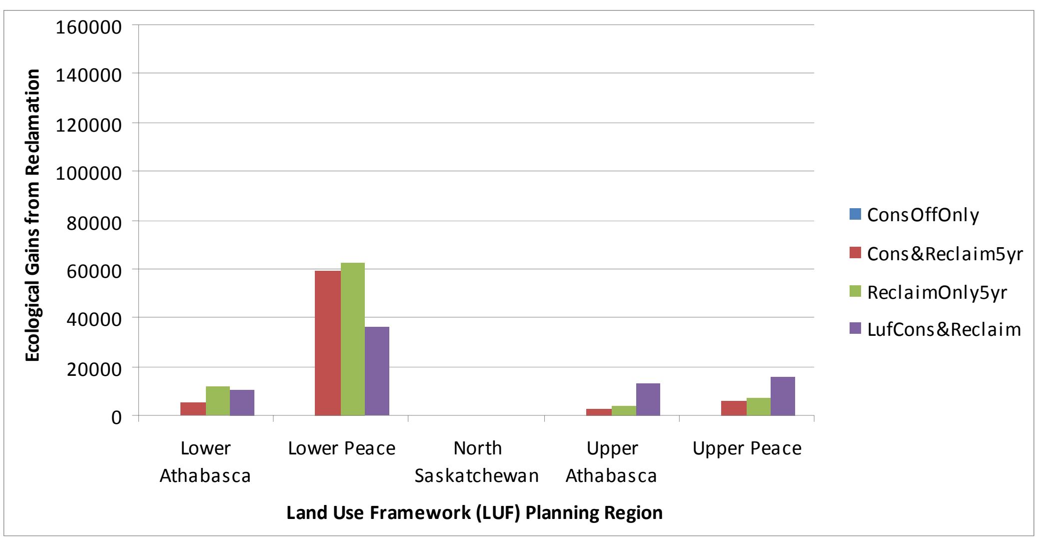

Figure 12: Ecological Gains from Reclamation Offsets by Region

2.4 Gaps and Limitations

The analysis presented above depends critically on assumptions about when benefits from offsets are counted. Currently the model looks at 5 year and 20 year time lags. The reclamation only program is very costly however this is due to the significant reduction in activity in the first period which would be required while investments in reclamation "catch up" to development needs. Conservation offsets help add flexibility to the system in the initial periods while reclamation is occurring. An alternative approach would be to count reclamation benefits up-front which would also relax the first period offset constraint. The costs of this scenario were not modeled. However given the significance of conservation offsets in the compliance strategy it is clear that reclamation only will still be a higher cost option. Given the importance of conservation offsets in minimizing costs, it is necessary to understand how the delay and cancellation of projects could be accommodated on public lands within the existing tenure system.

While the 5 year certification period imposes significant economic costs, it is likely that conservation benefits might not occur for a much longer time frame, perhaps 50-100 years. Similarly, the appearance of no net loss under a reclamation only program is an accounting result and not a reflection of actual ecological benefits. Developing ecological criteria for establishing certification periods would help clarify the actual ecological benefits from reclamation offsets and the ecological as well as economic role for conservation offsets in the meantime. Finally, in the absence of good information, very crude assumptions about reclamation costs were relied upon in these scenarios. Reclamation costs for different types of footprint need to be validated. The offset scenarios use very coarse measures of similarity (grizzly habitat, upland/lowland ecosite types, and natural subregion boundaries). A refinement of similarity requirements either for specific species or ecosite types would likely further increase program costs.

3. Market Design

3.1 Market Institutions

In this component of the research we investigate how different market institutions and market design features may impede or facilitate transactions in offsets. A market institution is a set of incentives that governs the behaviour of firms and individuals. Market institutions vary in their level of organization and how risks to buyers, sellers, and third parties are managed. The offset market institution establishes the manner in which a price and quantity for an offset trade are determined. Market institutions vary in their efficiency and their potential to manage economic and ecological risk. For example, an offset scheme may be implemented by payment into a fund used to purchase offsets (see Box 1). Funds and in-lieu fees are often favoured by developers because their offset requirements can be resolved quickly and with certainty which sheds their liability (Crowe and ten Kate, 2010). The problem with funds is that there is no mechanism for price discovery to ensure that the liabilities are adequately funded. If the fee is too low the fund will not be able to cover the environmental loss and either a financial or environmental liability will have been passed on from developers. If the fee is too high the developer will have paid more than necessary. A related problem is that the agency managing the fund may find itself in a difficult negotiation position with sellers when buying offsets, with sellers able to negotiate higher prices than would otherwise be the case. Markets that match both buyers and sellers simultaneously ensure that the financial and environmental obligations from offsets are evaluated at the time of the impact decision.

Box 1. Alberta's wetland compensation program

Alberta's Water Act requires that an approval be obtained before undertaking a construction activity in a wetland. Where it is not possible to avoid wetland impacts, compensation through restoration of a drained wetland is required. Compensation requires developers to pay a pre-determined fee into a fund established for wetland restoration work. Wetland restoration is the responsibility of recognized Wetland Restoration Agencies such as Ducks Unlimited Canada (currently the only recognized agency in Alberta). These agencies are responsible for selecting, developing, and maintaining restored wetlands. The benefit to developers is a reduction in the cost and time required for restoration projects compared to restoring a wetland area on their own. The Restoration Agency accepts the long-term management responsibility or liability of the restored wetland. In theory the amount of the payment is based on the agency's cost to restore and manage the same type of wetland however there is no mechanism for the Restoration Agent to discover those costs *prior* to approval of the wetland loss, and therefore no guarantee that the development would have been approved if the true cost of wetland restoration were factored in.

Almost all conservation contracting in Alberta is through bilateral negotiation, although brokers and bulletin boards exist for some products such as carbon offsets and water licenses. While bilateral trading seems appealing because it is “simple”, it is not always desirable. Finding appropriate offsets can be outside the area of expertise of developers, it can be time consuming and costly to find offsets, and bilateral negotiation may allow offset providers to extract resource rents in large scale regulatory programs. Furthermore the characteristics of the commodity that is being traded and the rules that govern the offset transactions may require a market institution that can handle multi-lateral rather than bilateral transactions in order to be efficient.

Commodity exchanges are market institutions that engage buyers and sellers simultaneously to trade large quantities of goods. Initially ‘open outcry’ and later electronic exchanges formed as institutions to facilitate negotiations and transactions between buyers and sellers. Services provided by exchanges include standardized contracting and financial settlement. An exchange may also act as the counterparty on all contracts, which reduces individual contract risk. In this study we consider two distinct mechanisms for price discovery that could be used by an exchange: double auctions and call markets. In a double auction buyers and sellers simultaneously present bids/offers to buy/sell. All bids and offers in the double auction (or at least the highest bid and lowest offer) are made known to all market participants. Transactions may be initiated and executed by any market participant whenever an acceptable offer/bid is found. In a double auction prices vary depending on who is in the market at a given time. Competitiveness is encouraged by forcing participants to post binding bids and offers. Since there is a probability that a transaction will be executed for the prices that are posted participants have an incentive to post competitive prices and to clear trades that are beneficial as it may not be possible to find an equally advantageous trade in the future.

A call market is different from a double auction in at least two important ways. First bids and offers may arrive anytime however they remain unexecuted until the market is called at which point existing bids and offers get matched into trades. Second, most call markets result in a single ‘clearing’ price, usually the price that clears the maximum number of items. Until the market is called the system may show a provisional price to participants and allow bid and offers to be revised. Call auctions can run for different periods. They can be as short as a minute or may be closed by a clock that depends on the activity of buyers and sellers. The key difficulty in designing a call auctions lies in the hold out problem. Buyers and sellers like to see the provisional price of a call auction, but they do not have an incentive to reveal their own information until the very end of the auction. Individuals have a strategic incentive to jump into the market at the last minute in order to produce an outcome that favours their interest. In call markets this type of behaviour is typically controlled with activity rules that prevent participants from making bids at the end of the auction unless they made bids in initial rounds and from under-bidding their original positions. Call markets also may also randomize over bid/offer prices or stop times in the market to increase the risks of waiting to make competitive bids until the last minute.

3.2 Case Study of NVX

While market design has been applied to a number of interesting problems in the last decade, the Native Vegetation Exchange (NVX)[3] in the Australian State of Victoria is the only example where market design has been applied to conservation markets (Nemes et al. 2008). The 2002 Native Vegetation Management Framework set out to reverse the long-term decline in the extent and quality of native vegetation in Victoria. To achieve the policy goal The Victorian government designed an offset scheme. Individuals or firms wanting to proceed with development involving destruction of native vegetation are required to obtain a permit and an offset. Vegetation offsets are mostly supplied by private landholders who register the vegetation as permanently protected on the land title and sign a management plan that describes the activities they will carry out to maintain the vegetation in good condition. The landholder is then able to sell the vegetation credits as an offset.

The market for native vegetation offsets embodies a number of complexities that have the potential to restrict or even prevent transactions from taking place. The NVX was designed and programmed at the Laboratory for Experimental Economics and Political Science at California Institute of Technology (Caltech) to overcome impediments to efficient transactions. Below we provide a brief description of some of the complexities associated with Victoria's native vegetation offset program and then explain how NVX addresses these complexities to make transacting in the market simpler and more effective.

Regulatory complexities. The government has specified 'like-for-like' offset requirements that include provisions over a number of native vegetation characteristics including location, conser-

[3] The NVX was previously known as the 'electronic BushBroker'

vation significance, habitat quality, and habitat/vegetation type. The rules govern permissible exchanges and market participants must understand the 'like-for-like' rules in order to identify potential trading partners. Understanding the rules is an onerous task given their intricacy and number. Moreover they are often ambiguously defined. The complexity of the rules may prevent market participation, increase transaction costs for those that choose to participate, and lead to illegal land clearing owing to the burden placed on developers. The NVX provides a single, unambiguous interpretation of the 'like-for-like' rules which is programmed into the NVX. NVX is effectively used as a verification mechanism that only allows compliant transactions to take place. This ensures that any transaction occurring in the NVX is consistent with the 'like-for-like' requirements and eliminates the need for market participants to understand the rules. The NVX is expected to significantly reduce the transaction costs for participants, and the administrative burden on government.

Ecological complexities. Native vegetation patches are highly heterogeneous goods segmented into 28 bioregions, over 300 different floristic communities, 4 conservation significance levels, and 100 quality groupings. In total there are several million potential types of vegetation patches that may exist and be eligible offsets depending on the 'like-for-like' rules. The highly heterogeneous nature of the good being traded may cause some difficulty for market participants trying to find trading partners. While vegetation characteristics are important for ensuring that the program is achieving ecological goals, buyers and sellers are only concerned with whether they are "eligible" to trade with each other or not. NVX allows buyers and sellers to filter the market and to restrict the view to only those market participants with whom they are eligible to trade. Thus understanding the characteristics of the good being traded is not necessary in order to interact with the market.

Indivisibilities. **I**ndivisibilities in offset supply and demand arise because there is limited ability to adjust sizes of the clearing and offset sites to tailor offsets to individual needs. The sizes that buyers wish to purchase almost universally do not match available offset sizes on a one for one basis. This means that if two parties wish to transact bilaterally then one will inevitably have to buy more (or sell less) than they would prefer. The NVX is designed for multilateral transactions. A group of buyers can collectively buy an offset from a single seller; a group of sellers can also sell offsets to a single buyer; and groups of buyers and sellers may also trade.

Synergies. Synergies arise when landowners have several offset patches which they are reluctant to sell separately because there are economies of scale (decreasing marginal costs) from managing patches together. Similarly, buyers may have several clearing patches for which they wish to buy offsets. For example, building a freeway or a shopping centre may result in the clearing of several vegetation patches, and there may also be higher values associated with purchasing multiple offsets at once. Buyers facing all or nothing requirements may be reluctant to buy individual patches due to the risk of failing to purchase the whole package of offsets required for development and the possibility of losing money. The NVX solution allows for *c*ombinatorial bidding where buyers and sellers can submit bids and offers for single goods as well as for packages of goods. To address the problem of not finding a sufficient number of offsets, buyers and sellers can fashion 'all-or-none' offers for a package of items. This feature prevents buyers (sellers) from being exposed to the possibility of buying (selling) only one patch and not being able to buy (sell) the rest.

Strategic challenges. There is a natural tendency for buyers and sellers to act strategically when facing competition by withholding information from the market, or free riding off of the provision of information by competitors. This strategic posturing may be compounded when information remains hidden from market participants or when there is a fixed time limit as in a call market. This behaviour reduces market efficiency and may greatly reduce trading activity. In order to overcome strategic challenges the market must create competitive pressures. Even small variations in the market design can have large effects on market competitiveness. NVX provides a number of tools to encourage competition on both sides of the market and to nudge participants into an agreement. Examples include advanced search functions, smart query functions, and "market making" functions which allow *any* market participant to broker a trade among any other participants. With NVX market participants maintain control over the modification, execution and cancellation of any of their offers in the system. This provides participants with maximum flexibility to enter or exit the market.

The provision of information has the potential to positively influence the market outcomes, but there is also the possibility to overwhelm market participants with information that does not help with decisions. Strategic information is provided to the participants regarding their position relative to the competition. The market provides answers to questions such as: "who are my potential trading partners?"; "who is looking at my offers?"; "how much do I need to offer to win?"; and "what would it take for the competition to displace me?". A range of search and query functions is available for both buyers and sellers to help optimize their positions for both bilateral and multilateral trades. By using the advanced search function, buyers and sellers have the opportunity to fashion a trade to suit their preferences by including or excluding their competitors or any other parties from a multilateral trade.

It is crucial that that the institution does not favour either buyers or sellers. Institutions have the capacity to influence prices and efficiency by distinguishing the available information or strategic tools for buyers and sellers. The NVX system is symmetric in the sense that both buyers and sellers are required to post binding offers and both can deviate from the posted prices. All market participants can access all the information available to any of the buyers or sellers at any time. Also, all strategic tools are available for all market participants. These features ensure that the institution does not limit the flexibility of market participants or create bias for either the buyers or the sellers.

3.3 Alberta Offset Market Design

An offset program in Alberta will have similarities as well as unique complexities and challenges compared to NVX. In Figure 15 we illustrate the general approach to designing an optimal offset market for Alberta. In Step 1, market complexities associated with the offset policy are identified. In the next step potential options to address market complexities are recommended based on existing literature and practical applications. The challenges and recommendations are summarized in Table 6. In Step 3, some of the design features are evaluated using lab experiments.

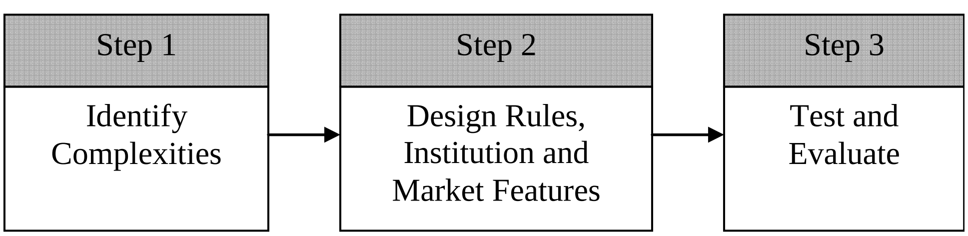

Figure 13 Market Design Research Approach

Table 6 Complexities and Potential Solutions for the Alberta Offset Market

Complexity	Challenge	Design Solution
Duration	Developers need to offsets to manage impacts of different timing, duration, and intensity.	Trade contracts of different vintage (when the offset is established) and duration.
Timing	Companies require offsets on an "as need" basis	Continuous double auction
Ecological	Segmentation of offset requirements to meet ecological requirements for equivalence	Hard wire rules into trading platform and allow combinatorial bidding
Indivisibility	Offset and Impact sites are fixed in size	Multi-lateral trading and combinatorial bidding
Synergy	Packages of offsets are worth more than individual offsets	Combinatorial bidding

Duration Issues. Duration refers to the length of time that an offset continues to provide benefits and/or the impact persists. Figure 16 shows how both impacts and offsets may have different duration and may begin in different periods. On private lands, landowners have the option of selling contracts of different duration, such as short term annual contracts, multi-year contracts, or permanent easements. Since there is no mechanism to permanently set aside public lands (except by designation of a park) the only option on public lands is for the offset to be temporarily contracted. The length of the agreement that can be contracted on public lands will ultimately be determined by the type of tenure. Since we do not know the rules under which contracting for conservation offsets will take place on public lands, we assume that there can be multi-year contracts for either delay or cancellation of projects or for reclamation.

We assume that offsets are required prior to project approval and that the obligation continues until a reclamation certificate is issued. Once a certificate is issued the developer may be allowed to resell part of or the entire offset. The duration of the offset requirement will be determined by the nature of the activity and disturbance, and the length of time that the impact continues to exist. Some disturbances such as forestry access roads may be required for only short periods of time. On the other hand, infrastructure for in-situ bitumen extraction may persist on the landscape up to 60 years. In addition, while many impacts may ultimately be reclaimable some impacts will be permanent. Developers will require a range of current and future contracting options to address impacts of different duration that may arise at different times from projects that roll out over decades (see Figure 14). Therefore it is important that offsets are distinguished by the period (or 'vintage') in which they are created and their duration (annual, multi-year, or permanent).

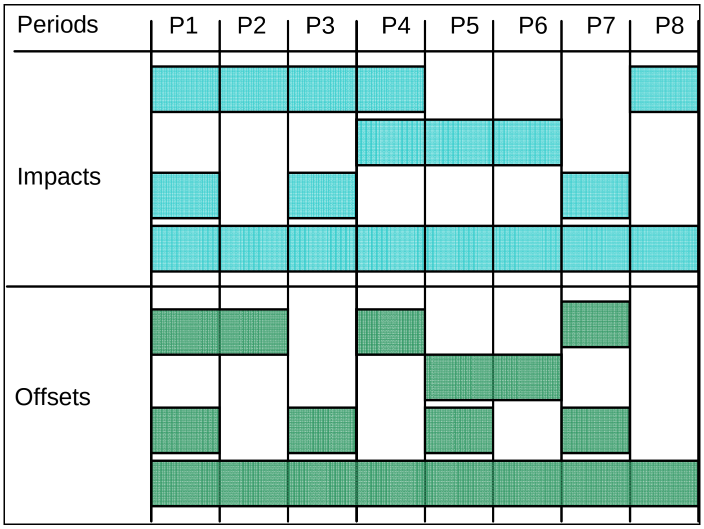

Figure 14 Duration of Impacts and Offsets over Time

The need to match offsets and impacts of different length and vintage presents a significant market design challenge. The obligation to obtain an offset for each period in which an impact is created can be met in various ways. For example, the buyer could enter the market sequentially every period and purchase offsets. However, sequential markets may increase transaction costs and also increases the exposure of buyers to price risk (offsets becoming more expensive over time) and to project risk (right offsets are not available and the project cannot proceed). A simultaneous market in current and futures contracts would give buyers the opportunity to acquire all offsets up-front. In a futures market the price is determined in the current period but delivery of the offset takes place in the future. This arrangement can create price certainty for both buyers and sellers.

Timing Issues. Offset markets must be responsive to the timing of industry needs. For example the energy sector is very responsive to changes in prices and new information about resource potential. Since petroleum and natural gas (PNG) lease auctions are held bi-weekly, developers will want to see price and offset market activity information to have an idea of how to structure their bids for PNG leases. In addition, companies will want to have access to offsets as development needs arise. Timing issues may be addressed by the choice between a double auction or call market. There are important tradeoffs in the choice between a call market and double auction. If there are not very many buyers and sellers at one time then the market is characterized as ‘thin’. This may reduce efficiency of the double auction, particularly if the market is highly segmented. On the other hand, call markets suffer from the drawback of being periodic (offsets are not necessarily available ‘on demand’) and in addition the structure of the close of the market makes it prone to strategic manipulation.

Ecological Complexity. The biodiversity intactness index simplifies each ecologically heterogeneous hectare of land to homogeneous and fungible units. Trading equivalent units reduces the complexity of the offset market however there may be circumstances in which this measure of equivalence is insufficient to adequately represent gains and losses. In some cases additional information about the similarity of sites in terms of species composition, habitat, or ecosystem types may be required in order to ensure ecological integrity. Similar segmentation may be required to deal with species at risk. When offset units are heterogeneous, matching ecological impacts with offsets may require additional market design and support to generate efficient outcomes. As in the NVX, the rules may be hard-wired into the trading platform and combinatorial auctions may be used to formulate bids for packages of types of offsets when there is significant ecological segmentation.

Indivisibilities. In Alberta the sizes of the impact sites are determined by the requisites of the development. While there may be options to reduce the area of environmental damage for a particular project the impacts are not infinitely divisible. Offsets may also be indivisible as landowners make discrete management decisions on individual fields or parcels of land. With indivisibilities bilateral transactions are inefficient because buyers may end up with more offsets than required and sellers may not be able to obtain the full value of their parcels. Resale lets developers dispose of all or parts of their previously purchased offsets if they do not need them anymore. While resale reduces inefficiency the problem is not entirely eliminated since coordination of market participants is necessary to make sure that there is no value left sitting on the table. An alternative solution is multilateral trading where sellers split their offset patches and sell the pieces to multiple buyers.

Synergies. Negative or positive synergies could arise from bundling offsets for both buyers and sellers. Positive synergies on the buyer and seller side come from fixed up-front transactions costs such as legal fees which create economies of scale. Buyers may have increasing marginal benefits, for example if there are economies of scale and scope for industrial projects. In addition they may face "all or nothing" requirements which increase their willingness to pay for packages. Sellers on the other hand may face decreasing marginal costs over time due to the need for less intensive site management as the offset becomes established. Marginal costs may also fall because of the increased productivity of the site over time. There could also be negative synergies over time if sellers find it costly to tie up sites in multi-year contracts due to a loss in option value. In this case sellers will have to be paid a premium to keep the site in a contract for more than one year, resulting in an increased average cost per unit. As with NVX, complexities related to synergistic values are solved by allowing combinatorial or package bidding. Smart markets use constrained optimization to maximize values in a combinatorial auction and their efficacy has been demonstrated through experiments for other goods (Plott, 1994; Roth, 2002).

3.4 Experimental Testing of Market Design Options

A series of experimental tests was carried out to evaluate different design features for the offset market. The market game consists of trading offsets over two periods which is sufficient to capture the salient duration features of the offset market. The experiments were conducted with student subjects at the University of Alberta from February 22nd to March 17th, 2011. Students were recruited from a student pool. Students that had previous experience with market experiments were preferred since the markets were relatively complex. The experiments lasted 2 hours. Each participant was paid a $10 show up fee and earnings based on their performance in the market game. Average profits were targeted at $60 per student per session. Participants were given a half hour power point presentation explaining the market rules and available strategies. The presentations showed examples of how to submit bids and offers, and how the market would clear. There were two practice rounds prior to the actual experiment during which participants could ask questions. Each experiment consisted of 8 trading periods with each trading period running for five minutes.

Each market consisted of 10 players with 5 buyers and 5 sellers. The participants were randomly assigned to their roles as either buyers or sellers, and had to maintain the role throughout the experiment. Participants earned money by trading; those who did not trade earned nothing for the trading period. Buyers and sellers traded two different commodities; commodity A and commodity B which represented contracts of two different periods or vintage. Sellers were given a fixed capacity to produce each commodity as well as a unit cost associated with producing the commodity. Buyers were given a requirement for each commodity and the revenue associated with each purchase. The quantities and value data used in the experiments were assigned randomly to different buyers and sellers in each period. Earnings in each period were added up and counted towards final earnings. During each period players had a timer showing the remaining time in the current period. They were also given a calculator which could also be accessed from the screen to figure out their bids and offers. At any given time participants could see their inventory of products, the bids and offers for different products, and the prices and number of units from previous trades.

Experimental Treatments

Below we describe the experimental treatments. The treatments are summarized in Table 10. In total there were 8 treatments with three repetitions of each treatment.

Market Institution

The market institution refers to whether a double auction or a call market institution was used. The first five treatments used a double auction with participants posting binding bids and offers which could be revised at any time prior to execution. Trades were automatically executed by the computer as soon as the bid price matched or was greater than the offer price. Where the bid exceeded the offer price, the final price and distribution of the trade surplus was determined by the last bid or offer. The posting of bids and offers in the call market was similar to the double auction. However trades were not executed until the end of the period. In order to foster competition and prevent hold out problems, the final prices were randomized over the bids.

Market Segmentation

Market segmentation refers to whether commodities A and B (contracts in periods 1 and 2) could be sold as packages. The first three treatments with sequential and simultaneous markets do not allow packaging of A and B. In the remaining treatments buyers and sellers have the option of buying and selling A and B either separately or together. Note that in this case there are three prices to keep track of: prices for A, prices for B, and prices for A+B.

Synergies

Synergies between commodities A and B were implemented for some (not all) buyers and some (not all) sellers for all treatments. For the sellers we assume decreasing marginal costs for packages of A+B. For buyers we assume increasing marginal benefits for packages of A+B.

Indivisibility

Indivisibility was introduced for both buyers and sellers. On the buyer side, all or nothing requirements were introduced for participants that required both A and B, analogous to buyers requiring all offsets for the whole project up-front. Buyer indivisibility was assumed for all treatments. In treatments 5 and 8 we also introduce indivisibility on the seller side meaning offsets are created in fixed sizes.

Partial Execution

If buyers and sellers both have indivisibilities and partial execution is not allowed then buyers may be forced to buy a larger offset than required. Partial execution of offset requirements was not allowed in treatments T4-T7 for buyers, and T5 and T7 for sellers.

Resale

If partial execution is not allowed resale allows buyers to get rid of excess offsets. Resale was introduced in T5 with indivisibilities on both the buyer and seller side. Divisibility on the seller's side eliminates the need for resale on the buyer's side.

Market Periods

Offsets can be sold either sequentially in each period that they are required, or simultaneously, having markets for both periods open at once. A simultaneous market for A+B is analogous to a current and futures market. Treatments 1A and 1B use a sequential market while the remaining treatments use a simultaneous market.

The treatments are summarized in Table 7 below. In T1, the buyers and sellers trade in two consecutive markets. In T1A participants trade Product A first followed by Product B. In T1B, the markets for A and B are switched with B clearing first and then A. The difference between the two markets is that B is a narrower market with fewer items available for sale. In T2, the simultaneous auction makes it possible to sell (buy) both A and B simultaneously in which case the joint costs for A+B (joint revenues) may be less (greater) than the individual costs (revenues) from selling (buying) A and B separately. In this case the reduced costs (increased revenues) apply even if the products were sold in two separate transactions. However, in T2 participants can not structure package bids. This can be compared to T3-T7, where the synergy values can be expressed through package bids.

Buyers face indivisibilities in all treatments (T1-T7) and are warned of potential losses in the instructions. In particular, buyers require both A and B to realise revenues. This creates a potential exposure problem which is eliminated in the markets that do not allow partial sales for buyers (T4-T7). Note that exposure is not a problem in the call market which only matches full buyer bids (T6 and T7). If there is indivisibility on both the buyer and seller side and no partial executions are allowed then it is difficult to perfectly match buyers to sellers and both parties are exposed (T5 and T7). In this case there is a risk that buyers end up purchasing more offsets than they actually want as is the case with T5. In T5 we allow buyers to resell the residual A and B. This reduces buyer exposure but not completely since buyers may not be able to resell everything. The difference in efficiency between the call and double auction markets when there is seller indivisibility can be seen by comparing T5 and T7.

Table 7 Summary of Experimental Treatments

Experimental Treatment	**Market Institution**	**Market segments**			**Partial execution**		**Re-sale**	**Synergies**		**Indivisibility**		**Market Periods**	
		A	**B**	**A+B**	**Supply**	**Demand**		**Supply**	**Demand**	**Supply**	**Demand**	**Sequential**	**Simultaneous**
T1	DA	X	X		X	X		X	X		X	X	
T1B	DA	X	X		X	X		X	X		X	X	
T2	DA	X	X		X	X		X	X		X		X
T3	DA	X	X	X	X	X		X	X		X		X

T4	DA	X	X	X	X			X	X		X		X
T5	DA	X	X	X			X	X	X	X	X		X
T6	Call	X	X	X	X			X	X		X		X
T7	Call	X	X	X				X	X	X	X		X

3.4 Experimental Results

The performance of the offset market is evaluated on several criteria: market surplus, price, distribution of market surplus, and volatility of the surplus.

Market Surplus

Market surplus is defined as the total gains from trade. The surplus from any particular trade is the difference between the true value of the offset to the buyer and the true opportunity cost to the seller. As long as a buyer is willing to pay more than the actual cost of an offset, there is a gain from trade which is measured by the trade surplus (A+B in Figure 1). An efficient market will encourage transactions until there are no more gains from trade. The results related to market surplus are shown in Table 8 which shows potential surplus and actual surplus as both a value and percentage of potential. Note that the potential surplus is lower in T5 and T7 than the other treatments because indivisibilities on both the buyer and seller sides reduced the feasible set of transactions.

The efficiency for all treatments ranged from 80% to 94% of potential surplus. Treatments T4 and T7 achieved the highest total surplus and T7 also achieved the highest efficiency in spite of being a more complex market than T4 with indivisibility on both the buyer and seller side. T4 is a double auction with package bidding that did not allow partial execution. The only difference between T3 and T4 (both allow packages) is that T3 allowed partial execution, creating exposure for buyers. As a result buyers in T3 were hesitant to bid in order to avoid losses and T3 was relatively inefficient. T7 was a combinatorial call auction. The improvement of T7 over T4 is a result of the global optimization performed by the call market which considers all bids simultaneously rather than asynchronously as in the double auction.

Table 8 Market Surplus by Treatment

Treatment	Potential Surplus	Actual Surplus	% Surplus Realized
T1	66.00	53.13	80%
T1B	66.00	58.77	89%
T2	66.00	53.94	82%
T3	66.00	57.34	87%
T4	66.00	59.32	90%
T5	66.00	52.37	79%
T6	63.50	57.11	90%
T7	63.50	60.00	94%

Treatments T1, T2, and T5 have the lowest overall surplus. In these three markets buyers are completely exposed. Even though T2 allows simultaneous trade in markets A and B, there is no way for buyers to express the value of the package A and B. Buyers respond by holding back bids and from time to time suffering losses. In T1A buyers suffered losses because they purchased product A in the first market but then couldn't gather a sufficient number of offsets to meet all or nothing requirements in the subsequent narrower market for product B. This problem was somewhat mitigated by opening the narrower market first in T1B. In T3 the package bidding option allowed buyers and sellers to express preferences for packages but also left buyers exposed. The benefit of reducing exposure by eliminating partial trade options is shown by the improvement of T4 over T3. A comparison between T7 and T5 shows the value of the combinatorial call auction over a double auction with resale since in T5 it is impossible to perfectly match buyer and seller requirements on a one-one basis.

Price

Price is related to the efficiency of the market, as well as the distribution of surplus. There is no single market clearing price in a double auction because each trade is executed on an individual basis at a different price. In a call auction bids and offers are matched until the market clears. In the case where goods are homogeneous, this results in a single market price. However for packages and heterogeneous goods with multiple attributes (e.g. vintages and duration) there is no single value that can be assigned to each attribute. Figure 15 shows the average price for each product in each treatment. The prices for A and B were similar on average among the sequential markets T1, T1B, and the simultaneous market T2. Prices are the highest in T3 when sellers had the greatest market power over buyers' joint values and the lowest on T4 when buyers had more market power because of the rule excluding partial execution. In the double auctions Product A and B prices were similar. The prices for A+B are higher in the markets which allow package bidding, reflecting the value of synergies.

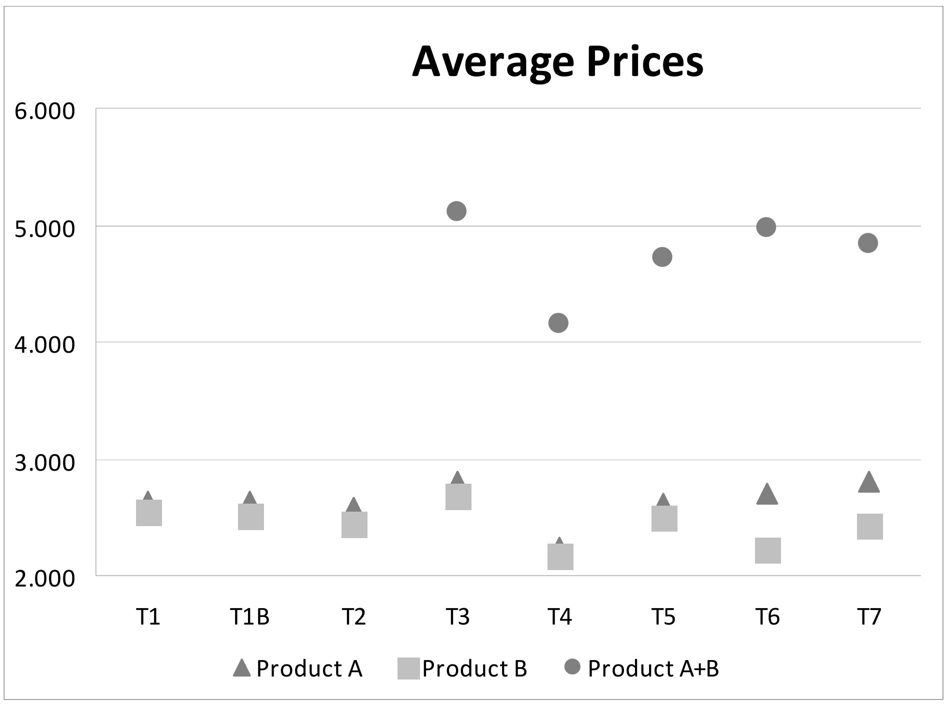

Figure 15 Average Offset Price by Product and Treatment

Distribution of Surplus

Figure 16 shows the distribution of the trade surplus between buyers and sellers. Buyer surplus is the difference between the value of the offset to the developer and the price of the offset. Similarly, seller surplus is the difference between the offset price and the actual cost of the off-set. As long as price is greater than cost, the seller extracts a rent from the developer's profits. The distribution of buyer and seller surplus reflects buyer and seller power in setting market prices. As expected buyers received less surplus in treatments T1, T1B, T2, T3 and T5 where they were exposed. The lowest surplus for buyers was in T3 where they were exposed on both the individual product and the joint product markets. The only treatment where buyers retained more surplus than sellers was T4, the double auction with no partial executions. In this treatment buyers were not exposed in any way and they could negotiate the prices on an open market.

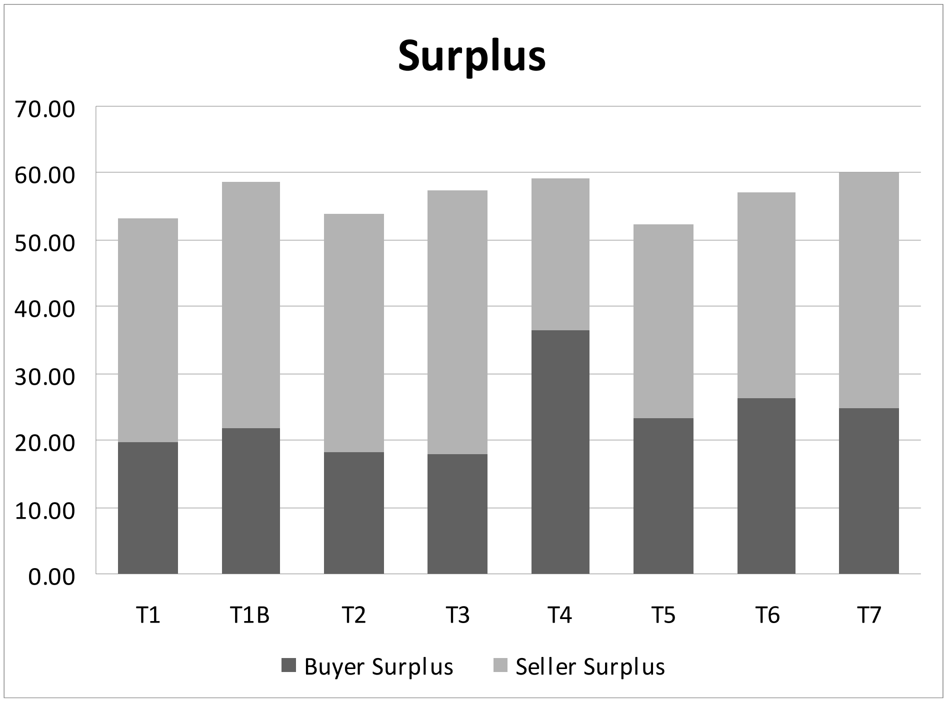

Figure 16 Trade Surplus Distributed by Buyers and Sellers Under Different Rules

Volatility

Volatile prices and volatility in the surplus signal that the properties of the market are not stable. This is to be expected if there are asymmetries in demand and supply and exposure problems resulting from indivisibilities and synergies which hamper the price discovery process. Volatile prices suggest that the signals being sent by buyers and sellers are not facilitating price discovery (i.e., discovery of willingness to pay and opportunity cost) and that agents may be unable to capture the entire market surplus. Figure 17 shows the variation of the surplus over the different treatments. As expected, the markets with the highest variation in the level of surplus are the ones where buyers and sellers are the most exposed, T1, T2, and T5. The most efficient markets, T4 and T7, also had the least price volatility suggesting the reliability of price signals and stability in the behaviour of participants.

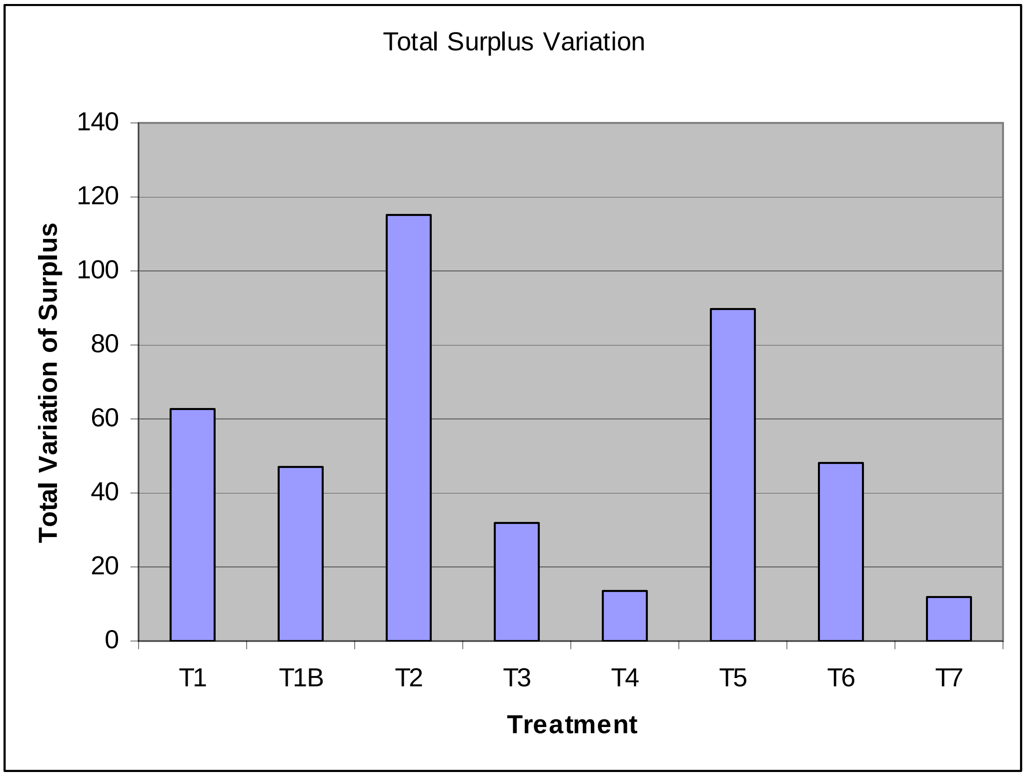

Figure 17 Variation in Market Surplus by Treatment

3.5 Discussion and Next Steps

The experiments enabled us to test important aspects of an Alberta offset market at significantly lower cost and risk than a pilot in the field. The experiments were designed to assess efficiency and to elucidate specific bidding behaviour under different treatments. If the experimental tests confirm that the market achieves an efficient outcome and the results provide information about how and why it does so, then we can proceed with further testing and refinement of candidate institutions. The performance of the various institutions tested in the treatments is summarized in Table 9. The results show that two treatments outperform all of the other treatments and merit further consideration. These are the double and call market institutions that allow package bidding and forbid partial execution. Below we summarize the specific lessons learned from the experiments and directions for further research.

Table 9 Summary of the Performance of Different Institutions

Treatment	Efficiency	Total Surplus	Distribution	Volatility
T1A	L	L	S	H
T1B	L	L	S	H
T2	L	L	S	H
T3	L	L	S	H
T4	H	H	B	L
T5	L	L	S	H
T6	M	M	S	H
T7	H	H	S	L

H=high; M=medium; L=low; S=seller; B=buyer

Design Rules and Market Institutions to Reduce Exposure

The results demonstrate the impact that exposure problems have on market outcomes. Market surplus is highest when exposure for buyers is reduced whereas sellers have market power and extract most of the trade surplus when buyers face exposure problems. Markets with exposure problems are also more volatile. Simple institutions such as bilateral trading can increase exposure for participants and perform poorly even with the fairly simple offset policies considered here. Exposure problems are created by regulatory requirements for offsets that seem reasonable such as up front offsets. However even if offsets for current impacts can be obtained, developers are still exposed if they can't go into the market at the beginning of a project and manage their offset needs over the entire life of a project. Exposure problems can be reduced by institutions that rules that allow developers to simultaneously trade current and futures contracts for offsets. Institutions that allow package bidding improve over simultaneous markets, and rules that forbid partial execution of trades reduce exposure even further. The combinatorial call market with no partial execution minimizes exposure by design since the platform aggregates and optimizes over all bids simultaneously.

Enable Multi-Period Contracting

Upfront offset requirements are realistic under any kind of regulated offset market. Even if requirements are only partial this will introduce some exposure for buyers that can't be completely offset as long as there are indivisibilities and synergies in offsets and development projects. The results highlight the need for futures markets that allow for multi-period contracting and packaging of offset contracts over time.

Reduce Indivisibilities where Possible

Governments should not increase the indivisibility problem by introducing needless rigidity into offset eligibility rules. Resale of un-used portions of offsets should be allowed where indivisibility is unavoidable. This is analogous to allowing credit stacking.

Double Auction Versus Call

The choice of a call market or a double auction has important implications for how an offset program will be implemented, and how participants will buy and sell offsets. We identified several tradeoffs associated with the call versus double auction including waiting times, opportunities for strategic behaviour, and thickness of the market. Market segmentation, indivisibilities and synergies make it difficult for a double auction to make globally efficient matches if participants are arriving asynchronistically unless there is significant resale. However this increases transactions costs for participants. The results of the experiments suggest that both the call market and the double auction institution produce favourable results. For the purposes of these experiments the programming of a combinatorial double auction was not feasible. We attempted to approximate some of the characteristics of these auctions through bilateral package auctions. However future testing should explore the performance of a more sophisticated double auction platform against the call market. Further testing and comparison of these two institutions is warranted.

Distributional Issues

In the experiments, sellers are able to extract significant profits from developers. This is partly driven by the data that were used. Unfortunately it was not possible to use realistic data for the experiments as the outputs from the TARDIS and EXCEL models did not match the requirements for the experiments. Eligibility rules and offset requirements will significantly affect market structure and market power, and may substantially reduce the market power of sellers. Nonetheless, at least part of the market power comes from the exposure problem buyers face under the rules. Public lands are a public resource and the ability of sellers to reduce developer profits that would otherwise be captured through PNG auction prices and royalties is an important policy issue. Revenue neutral auctions which return surplus to developers, or other options to capture the trade surplus going to sellers should be evaluated in future under more realistic baselines and policy scenarios, in order to reduce opportunities for third parties to capture development benefits.

Value of Smart Markets

Developers and conservation organizations tend to advocate for simplicity in offset rules and market institutions. This tends to translate into less rather than more segmentation of the offset requirement irrespective of the underlying ecological requirements. In addition, bilateral trading is also viewed as simpler. The NVX case study and the experiments conducted in this research show that governments should not be deterred from developing more complex offset programs. The risk of relying on simplicity is that the offset program will not result in any ecological benefit and thus be a waste of money, and that costs of participating in an offset market will be higher than they need to be. Support for such an offset program may fall. Until recently difficulties in designing markets that could match buyers and sellers facing complex rules would have been a barrier to implementing some offset policy options, even if they were preferred from a cost-benefit perspective. Fortunately, given advances in computer technology and economic theory it is possible to design smart markets to solve complex coordination and optimization problems with very little burden on market participants. Given the complexities associated with an offset market it is expected that an optimal offset market institution would not autonomously emerge and it may be desirable for Government or a centralized agency to provide a smart market platform to facilitate transactions.

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