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The Impact of Forestry Practices on Water-Based Recreation in Northern Alberta

by

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The undersigned certify they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **The Impact of Forestry Practices on Water-Based Recreation in Northern Alberta** submitted by Craig Michael Meisner in partial fulfillment of the requirements for the degree of Master of Science in Agricultural Economics.

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ABSTRACT

Forestry operations located near lakes or rivers impact the major ecological values of water clarity and recreational sportfishing through water quality changes. Changes in water quality arise from increased water and nutrient loadings with the removal of trees from the surrounding watershed or catchment area. The forest cover acts as a regulator of the amount of water and nutrients returning to the lake or river and a disturbance, such as forestry or fire, will alter this regulation and negatively impact the aquatic ecosystem. A key nutrient released by forestry is phosphorus. In Alberta's northern boreal forests total phosphorus (TP) is known to be the key state variable regulating the biological productivity of lakes and rivers. It is believed that phosphorus additions, beyond a specific threshold, will have a negative effect on water clarity and fish. This thesis will examine the negative forestry impact of an increase in total phosphorus on water clarity and recreational sportfishing values in northern Alberta.

A Nested Discrete Choice Travel Cost Model is estimated for 58 water-based recreational sites in the northwestern region of Alberta. The model includes recreational, water quality, fish stock and social demographic attributes to explain site choice. The analysis utilizes a Random Utility Model (RUM) framework which explicitly incorporates a random error term into the recreationist's indirect utility function compensating for possible measurement error. A nested structure separating lakes and rivers is created to accommodate for the recreational and biological differences of the riparian systems.

The results indicate that northern Alberta households consider not only the services or amenities of the site (recreational attributes), but also water clarity attributes, such as Secchi depth and algae growth, as well as fish yields. The welfare analysis revealed that a decrease in water clarity represented a loss of $2.66 to $5.30 per household trip and a decrease in the fish population represented a welfare loss ranging from $2.64 to $5.38 per household trip, depending on the level of impact and household size.

This approach provides a framework to examine the concern that northern lakes and rivers are becoming more eutrophic (increased algae growth) from human-induced factors and that the cumulative effect of forestry may exacerbate the decrease in recreational aesthetics and sportfishing experiences. The loss of these aquatic values can be significant and should be incorporated, along with other non-timber values, into the benefit/cost analysis of harvesting near lakes and rivers. Forestry practices are currently under intense scrutiny for their potential impacts upon riparian ecosystems and Forestry Management Agreements are being augmented to protect these ecological services and values.

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Chapter 1 Introduction

1.1 Sustainable Forestry Management

In the past decade, the province of Alberta has begun to develop its forestry sector at a rapid pace for reasons of economic diversification. In doing so, much debate has centered on whether allocation of the forests, in the form of Forestry Management Agreements (FMAs), is sustainable in the long run. The sustainability issue has led research towards understanding the ecological services and non-timber values not typically considered in forest development. Non-timber values, simply put, are all the environmental values contained within the ecosystem except the commercial timber values. These values are not captured through markets or prices and thus are seldom included in the benefit/cost analysis of development. The non-timber benefits of the northern boreal forests range from the recreational to the ecological. Examples include camping, hiking, water-based recreation and wildlife. As well, there are many service flows from forested areas that are not normally considered "non-timber" in nature, such as soils, quality of water and aquatic life, but still provide a benefit to the consumer. These values are not mutually exclusive from one another, thus when you impact one, you also alter another to some degree. If the benefits from ecological and non-timber values are truly large, development of the northern forests should proceed in a more comprehensive fashion and include these possible foregone values in the benefit/cost analysis of harvesting. In response, forestry management has chosen a multiple-use or integrated approach to evaluating forestry impacts. Sustainable forestry management is this approach of considering environmental and social values in a long term or sustainable fashion.

1.2 The Link to National and International Criteria and Indicators

In recognizing sustainable forestry management (SFM), the Canadian government has participated in several international working groups dedicated to defining procedures for sustainable forestry. One international outcome has been the establishment of The Montreal Process[1] which describes specific criteria and indicators (C&I) for SFM. Criteria, in this application, are specific goals to be maintained by evaluating the key indicators of environmental and social factors. The Canadian context of these C&I's was put forth by the Canadian Council of Forestry Ministers (CCFM) in 1995.[2]

The study presented here specifically deals with the non-timber value of recreational sportfishing and the ecological value of water quality.[3] These fall within the CCFM's C&I framework under two sections, water quality and recreation. The water quality section we address is:

> Criteria 3: **Conservation of Soil and Water Resources: *The maintenance of soil and water quantity and quality***
> 3.1: Physical environmental factors
>
> ".... Aquatic factors refer to both physical and chemical properties: for example, flow patterns, water temperature, aeration, sediment load,

[1] The Montreal Process started in June of 1994. In February, 1995 the statement of endorsement, also known as the "Santiago Declaration", was presented along with the criteria and indicators for forest conservation and sustainable management for use by their respective policy-makers.

[2] The CCFM launched their own process to define C&I in 1994 as a result of The Montreal Process in 1994 and the identification of SFM's importance at the UNCED conference in 1992.

[3] This project was established and funded through another Canadian forestry initiative, the Sustainable Forestry Management Network Centres of Excellence (SFM-NCE).

> and chemistry which provide for aquatic plant and animal life. Changes in aquatic environments can negatively affect aquatic life "(CCFM, pg.10).

Recreational activities are inherently linked to water quality through sportfishing experiences and the maintenance of these opportunities:

> Criteria 5: **Multiple Benefits to Society:** ***Sustaining the flow of benefits from the forest for current and future generations***
>
> "....In addition to the significant commercial benefits derived, Canada's forests support a wide range of other activities that provide benefits including tourism, wildlife, recreational use of the forest, aesthetics, and wilderness values. Although not always measurable in monetary terms, these activities are also highly valued by Canadians and provide significant benefits to Canadian society "(CCFM, pg.15-16).

The two statements apply to our study since forestry practices influence water quality (Criteria 3) and this affects fish stocks (Criteria 5). Sportfishing is a major recreational value in northern Alberta and is reflected in total expenditures per annum.[4] The value of water quality, as an ecological service flow from the forest, is suspected to have a significant ecological value to the water-based recreationist.

The analysis performed here evaluates the *non-market* element of water quality and the *non-market* value of sportfishing in northern Alberta.[5] The study region involves 58 water-based recreational sites and the model attempts to determine what influences site choice decisions. The region for analysis is given in Figure 1.[6]

---

[4] In 1995, Alberta anglers spent $130 million on goods and services directly associated with sportfishing and $349 million in total on all goods associated directly and indirectly with sportfishing (Alberta Fish and Wildlife, 1995).

[5] Water quality, arguably, has a market value (i.e. consumptive-use value), but we are concerned with the non-market value derived from water-based recreational activities such as boating, swimming, canoeing, etc.

[6] Map supplied from NRBS Project Report No. 70, Implementation of a Household Survey, 1995 (Drobot Contracting Services Ltd. and Praxis, Ltd. 1996).

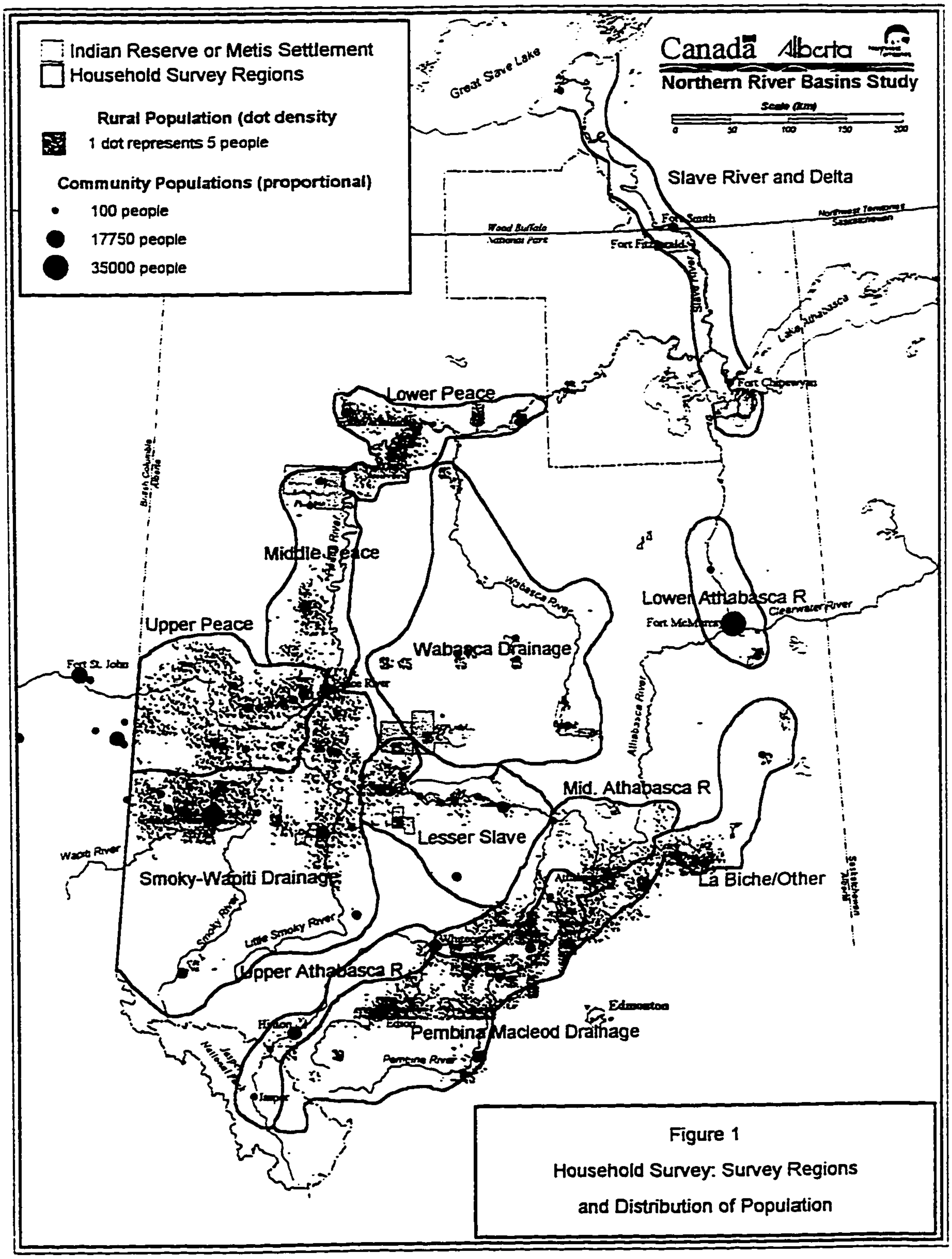


Figure 1

Household Survey: Survey Regions and Distribution of Population

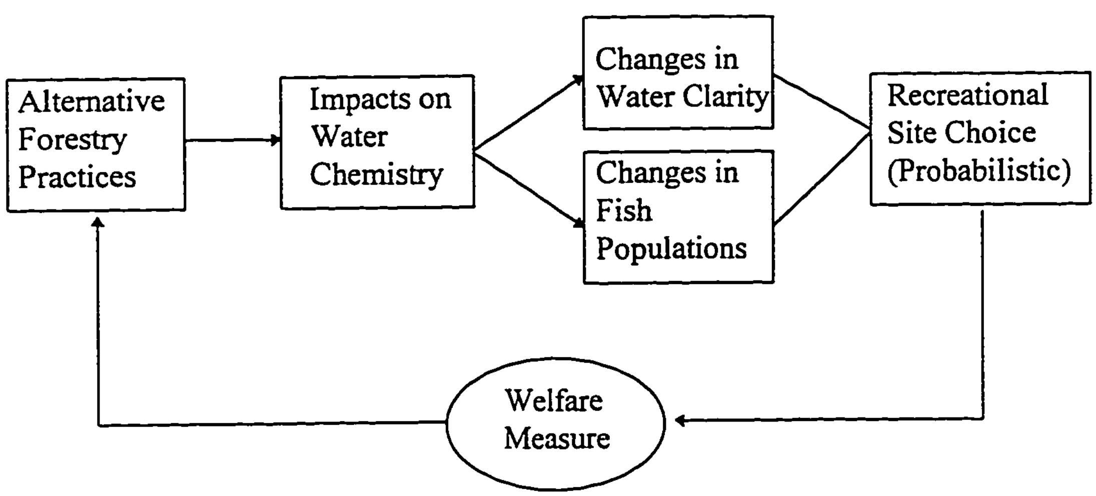
1.3 Forestry Impacts on Water Quality and Recreational Fishing

The variables used in the model for recreational site choice can be broadly categorized as recreational, water quality, fish populations and social demographic. The combination of these categories is cross-disciplinary in approach with an interesting extension over the standard bio-economic analysis.[7] The main difference lies in the human/biological link between the water quality and recreational site choice. In previous studies water quality was commonly treated as a homogeneous scale across sites to proxy actual quality (Adamowicz et al., 1992; Watson et al., 1993). For example, a scale of one to ten was used, with one being poor and ten representing excellent water quality. In this study, water quality was measured using variables that are typical in the profession of limnology. Limnology is the scientific study of physical, chemical, meteorological and biological conditions in fresh waters. The advantage of using a more detailed structure of variables is to aid in the analysis of water chemistry changes from alternative forestry practices. The breaking up of the homogenous water quality measure also strengthens the predictive nature of chemistry changes on aquatic ecosystems. It is well known that particular water quality variables influence the level of aquatic biomass (Schindler et al., 1978; Prepas and Trew, 1983; Bowlby and Roff, 1986). The particular aquatic group for this project is sport fish. Once the water chemical impact is understood, a link to

[7] Although this analysis claims to be somewhat "unique", others such as Bouwes and Schneider (1979); Russell and Vaughan (1982); Caulkins, Bishop, and Bouwes (1986); Smith and Desvousges (1986); Smith and Kaoru (1987); Parsons and Kealy (1992); Parsons and Needelman (1992); Englin and Lambert (1995) have integrated limnological or water chemistry variables into their analysis. The unique aspect to this analysis lies not only in the composition of water quality attributes, but in the prediction equations within the water quality attributes as well as the prediction equations used for fish stocks.

sportfishing can be established. Changes in water chemistry can affect the number, composition, health, age dominance and average life, just to name a few. The analysis here will concentrate on the *population* of fish as a whole. As recreationists frequent a particular site, a recreational value is created through the perception of water quality or clarity and through fishing experiences. If the impacts of forestry are negative towards water clarity or sportfishing, the recreational value of a site falls. The welfare change can then be factored into a benefit/cost analysis assessing the economic impacts of a particular forestry practice. The chain of impacts are represented in Figure 2.

Figure 2: Forestry Impact Linkages to Welfare Measures



1.4 Study Plan

The next chapter begins by defining alternative methods used for benefit valuation. An overview is presented with a detailed description of the tool chosen for this analysis. A decision structure, for the recreationist, is proposed and an explanation of the estimation process is shown. The chapter concludes with a comparative description of the welfare measure used to calculate the impacts of a change in water quality and sportfishing. In Chapter 3, the various data sources are discussed along with the descriptions of variable transformations or predictions which were necessary. In Chapter 4, the development and rationalization of specific variables used in the model and the results, along with the welfare impacts of the change in water quality and sportfishing, are interpreted. The final chapter provides a summary of the analysis, the model's limitations and a discussion of the policy implications.

Chapter 2 Recreational Demand Theory

2.1 Benefit Measurement and Recreational Demand Models

Benefit measurement has been used in the investigation of environmentally sensitive projects for some time. Previous methods aggregated the *tangible* benefits, usually expenditures on the activity, over the project life and incorporated them into a benefit/cost analysis. A measurement problem was quickly identified as some environmental benefits did not possess markets or prices and thus could not be included in the analysis. Examples of such values included recreational activities, wildlife and water quality. These so called 'non-market' values had to be measured or estimated through other means such as proxies or surrogate prices, since changes in the benefits derived from these values affected consumer behavior. This was particularly true for environmentally damaging projects where observable quality changes were becoming apparent through a change in recreational site choice. It was also recognized that certain environmental situations (i.e. damages) were outside the set of current experiences by people, but needed to be potentially valued. Thus new non-market benefit estimation tools were needed to capture these values and move to a more complete project development analysis.

The absence of a formalized structure for price determination creates variability in measuring non-market benefits, depending on the assumptions and models used to describe consumer behavior. The choice of methods primarily depends on the environmental situation being investigated. Alternative methods can use actual behavior or stated preference behavior to create a model. The model is then impacted or shocked to see the effects on the individual's welfare.

The methods of revealing preference apply to recreational demand models where the 'good' is a visit to a site. The next few sections describe the methods of revealing consumer preference and discuss alternative modeling techniques that develop a framework for benefit measurement.

2.1.1 Direct versus Indirect Methods

The main objective of non-market valuation is to derive a money-based measure of the impact of a change in the quality or quantity of a good or service, which is not typically priced in a market. The two most common techniques are the direct (or survey) approach and the indirect (or inferential) approach. The indirect approach uses observable behavior or choices that individuals have actually made. The researcher can then build a model that explains behavior and interpret changes in choice from a change in one or more model variables. Indirect methods are preferred in almost all traditional economic analysis since choices are based on actual behavior. Alternatively, the direct approach simulates a market for goods or services not normally priced.

Contingent Valuation (CV) is one of the most popular direct techniques. As the name implies, the valuation of the good or service is contingent on the assumption that a market for the good exists. CV type questions are structured such that respondents can state their value of the resource in a hypothetical situation.

Surveying across individuals, the questions can be designed to see how demand changes from variability in the quantity or quality of the good. As the demand changes, a non-market value can be constructed and incorporated with the market benefits to equal total resource benefits. An example of a CV type question, in our context, could be a description of the site and situation (a fishing day) with the question: "what would you be willing to pay for a day of fishing at this site over and above all other expenses you might incur".[8] The response to this question is, essentially, the non-market value of the resource for that particular individual. Although the use of CV is well documented in the literature, it has created some controversy over potential biases that may exist when using the technique. The largest concern with CV is the hypothetical nature of the questions.[9] The data for this study are based on actual trips taken to recreational sites and thus an indirect valuation approach is used. The following sections review some of the most popular indirect methods of non-market valuation.

2.1.2 Travel Cost Models

The most popular indirect approach to estimating recreation demand is the Travel Cost Method (TCM). The TCM uses the trip costs incurred, by a recreationist, as a proxy for the market price for that activity. In its simplest form, the demand for a site is a function of the travel cost (price) and socioeconomic characteristics of the

[8] It is important to note the researcher's intention when asking this question. For example, are we measuring the *average* willingness to pay across all fishing occasions, or the *marginal* willingness to pay for an extra day of fishing? The question must be designed such that the respondent understands the difference between the average across all days and one extra day.

[9] For a review of the potential biases see Mitchell and Carson (1989).

individual. A major disadvantage of the standard TCM is that it cannot be used to value quality changes (Adamowicz, 1991). More current versions consider expanding the functional form to include site quality attributes and substitute sites. Subsequent revisions of the TCM have made the approach very popular among a wide variety of applications in transportation and environmental economics (Smith, 1989). We review four major categories of TCM's: zonal or regional travel cost models, generalized travel cost models, hedonic travel cost models and discrete choice models.

Initially, applications of the TCM were developed for valuing recreational sites, where the derived demand was for the services provided by the site (e.g. Hotelling, 1949; Clawson, 1959). The next transformation came from Clawson and Knetsch, 1966, where the model established zones of origin and visits were scaled by each origin county's population and interpreted as a rate of use of the site for the "representative" individual (Cicchetti et al., 1973). These regional TCM's were expanded to include variables describing zonal or regional characteristics, site quality and a measure of the costs and quality of substitute sites (e.g. Donnelly et al. 1985). This improvement of adding site quality though was still overshadowed by the problem of aggregating respondents into zones and not being consistent with utility theory or welfare estimation (Fletcher et al., 1990; Parsons and Needelman, 1992). Since then more sophisticated versions have specifically addressed some of the inconsistencies between the simple TCM and consumer demand theory. Smith (1988), succinctly identified these problems as: the selection of functional forms underlying consumer utility, the role of substitute sites, the treatment of travel time, the process of aggregating zones of origin and/or destination, site quality changes and the addition or deletion of sites in the choice set.[10]

A model that investigates the effect of site quality attributes on the TCM was put forth by Smith and Desvousges (1986). The two stage generalized TCM first estimates an individual demand function, for each site, suppressing any possible collinear attributes. The second stage estimates generalized demand functions for the site attributes by regressing the coefficients from the first stage on the omitted site quality attributes. In effect, the variability due to site attributes is now a function of the individual characteristics and we have estimated attribute demand functions. Although this procedure is valid in understanding which attributes contribute the most to site demand and thus welfare, it does not solve the problem of substitution between sites. The model provides for differences in prices and quality, but not quantity differences of attributes across sites. Another problem is that the number of visits is automatically adjusted by a change in an attribute, which ignores the possible reallocation of visits to other sites.

A refinement of attribute demand was put forth by Brown and Mendelsohn in 1984 using implicit or hedonic prices. The hedonic TCM attempts to impute a price for an environmental good by examining the effect which its presence has on a relevant market priced good. Simply, a non-market value is derived from a market value proxy. The objective is to define the (inverse) demand function relating the

[10] For a discussion on the specific problem of spatial limits of the TCM see Smith and Kopp (1980).

quantity of the environmental good to the individual's willingness to pay for that good. In the recreational sportfishing case, the assumption is that recreationists will only travel further for a higher quality experience and that this increase in travel cost is the value-added of the higher quality. The estimation process is accomplished by, first, regressing the individual's travel cost on the attributes of the site and then taking the partial derivative of this function with respect to each attribute, yielding a hedonic cost or price. Secondly, the hedonic price is regressed on the site attributes to arrive at a system of attribute demand functions. The welfare change is the area under the demand curve between the initial and final environmental quality level. This yields uncompensated consumer surplus measures.[11] Although this model measures qualitative changes directly and factors in site substitution via the quasi-market proxy, the historical setting for most analytical development has been in very controlled environments. For example, air quality levels have been extensively studied through prices in the housing market[12] (Bateman, 1993). The housing market has a clear demand and supply, which may not hold as rigidly for all attributes at recreational sites (Smith and Kaoru, 1987). The household's perception of quality changes among the alternative sites may be subject to imperfect information and imputed prices must be well contained within the market being studied (Bateman, 1993). Smith and Kaoru (1987, pg. 181) state this problem as every individual having a different "price

[11] Consumers surplus is, debatably, not the correct measure for multiple changes in prices, quantity or quality due to the path dependency of the measure. This is re-iterated in Section 2.5: "Welfare Theory".

[12] For air quality studies using the hedonic approach see studies and reviews by: Anderson and Crocker (1971); Waddell (1974); Pearce (1978); Pearce and Edwards (1979); Freeman (1979a,b); Brookshire et al. (1982); Pearce and Markandya (1989); Pennington et al. (1990); Turner and Bateman (1990).

frontier", defined by the different recreational perceptions and opportunity costs of time. Another problem that has not been fully explored is the phenomena of negative implicit prices from estimation. Bockstael, Hanemann and Kling (1985) and Brown and Mendelsohn (1984) reported negative price estimates in their applications. This could be due to the estimated marginal prices being treated as random variables and if measurement error is present, negative prices can result (Smith and Kaoru, 1987). Once again, if each individual has different perceptions of recreational attributes and opportunity costs of time, this could be the source of the measurement error.

The final TCM we examine is the discrete choice or random utility model. The model addresses many of the concerns of Smith (1988) and thus has several advantages over the methods described above. These are: consistency with a utility maximizing framework where the consumer's utility is a function of site attributes and socioeconomic characteristics; site substitutability; the ability to value quality attributes; mimic complex behavioral processes (decision trees); compensate for possible measurement or researcher error from model mis-specification; and welfare measures can be derived directly from the estimated coefficients in the model (Adamowicz, 1991). The disadvantages of the discrete choice or random utility TCM are: the ever possible mis-specification of the behavioral model by the researcher and the difference between objective and perceptual data (Adamowicz, 1991). The behavioral specification of the model is always subject to error. The discrete choice TCM incorporates a random component into the model to compensate for the problem, but this may not be perfect in all cases. The other disadvantage of objective versus perceptual data leads us back to the same problem outlined by Smith and Kaoru (1987), where recreationists have different attribute perceptions and values of time. This is a dilemma when we are measuring *use* values, such as sportfishing, but is particularly troubling when we try to measure *non-use* or *existence* values, where only perceptual data may be available. On the positive side, research has begun to examine integrating objective (actual or revealed) and perceptual (hypothetical or stated) observations to measure non-use values.[13]

The advantages of the discrete choice TCM far outweigh the shortcomings of the generalized or hedonic TCM's. This has created a momentum of research towards discrete choice theory in applications of environmental valuation. This is also the modeling approach utilized in this analysis of the effects of forestry on water quality and recreational sportfishing in northern Alberta. We now give a formal description of the discrete choice or random utility model.

2.2 Discrete Choice or Random Utility Model[14]

In consumer theory, the individual chooses a bundle of goods which maximizes his/her utility subject to a budget constraint. Indirect utility functions characterize the maximum utility that can be achieved given prices and income. Discrete choice theory follows the same reasoning except consumption can only be in specific quantities. Although this may seem restrictive, it actually allows for choices

[13] For an example of this integration between stated and revealed preference data, see Adamowicz (1992).

[14] This section is adapted and paraphrased from Coyne and Adamowicz (1992).

of zero or "corner solutions" in consumption. Discrete, rather than continuous, choices are more realistic since recreationists make decisions based on going to a site or not. Sites cannot be sub-divided infinitely or continuously.

Recreational demand models typically have a finite set of alternative sites or are discrete. The choice of alternative sites is dependent on the utility, U, respondents derive from various attributes, Q, of the site:

(1) $$U_{jn} = U(Q_{jn})$$

where Q_{jn} is a vector of attributes describing site j as perceived by recreationist n. The choice set is defined as C_n, and n is the number of alternative sites (or a subset of sites). Site j will be chosen if :

(2) $$U_{jn} > U_{in} \text{ , for all } j \neq i; \quad i, j \in C_n$$

Site j is preferred to site i, if the utility derived from j is greater than in i. Utility in this framework is treated as a random variable since researchers do not have perfect behavioral information (McFadden 1981, Smith 1989). More formally, utility is modeled to include a systematic/observable component and a random/un-observable component:

(3) $$U_{jn} = V_{jn} + e_{jn}$$

where V_{jn} is the systematic component of utility and e_{jn} is a random element. Thus, the model is also known as a random utility model (RUM). The random element captures any unexplained factors that are not directly modeled. Since utility is formulated as a random variable, RUMs imply a probabilistic rather than deterministic outcome in choices. Thus the probability of individual n choosing site j is:

(4) $$P_n(j) = Pr\{V_{jn} + e_{jn} \geq V_{in} + e_{in}\ ;\ \forall\ i \in C_n\}$$

where V_{jn} is a conditional indirect utility function of the linear form:

(5) $$V_{jn} = \beta_1 + \beta_2 x_{jn2} + \beta_3 x_{jn3}, \ldots, + \beta_k x_{jnk}$$

where x_{jnk} includes the attributes of the alternative sites and the social characteristics of the individual and the β's are the parameters to estimated. Each site will have an associated conditional indirect utility function, V. In Chapter 4, Model Development, the x's or attributes for equation (5) are discussed. Assuming that the individual's utility function has additive error terms, e_{jn}, that are independently drawn from an extreme value distribution (Gumbel), the probability condition of choosing site j is[15]:

(6) $$P_n(j) = \frac{\exp^{V_{jn}}}{\sum_{i \in C_n} \exp^{V_{in}}} \quad for\ i \in C_n$$

where the numerator represents the conditional indirect utility for a specific site, j and the denominator is the sum of the conditional indirect utilities over all the alternatives in C_n. The expression above follows a logistic (logit) probability distribution. The distinction between logit and other forms of random utility is how the error terms are distributed across the alternatives. As mentioned above, the distribution for the logit model is the extreme value. This distribution is preferred since it is relatively easy to fit in estimation, approximates the normal distribution very closely and can be easily

---

[15] Probability expression is from Domencich and McFadden (1975).

implemented in the generalized case of more than two alternatives (Deaton and Muellbauer, 1980, pg. 268).

The choice model in (6) is known as the multinomial logit (MNL) specification where more than two choices (binomial) are possible. Multinomial logit models are frequently used in recreational demand where environmental quality is an important determinant of choice. The MNL model is convenient when the choice set or number of attributes is large. This advantage can also be an important disadvantage when there exists a high degree of correlation between site attributes. If sites are closely related through the estimated attribute's error terms, this may alter the probabilities associated with each site choice. This fundamental concern, in the logit framework, is a violation of the Independence of Irrelevant Alternatives (IIA) property.[16] The property states that the introduction or deletion of one alternative from the choice set can not alter the probability of choosing any of the remaining alternatives. Since the model presented in this project has many alternative sites, it is suspect to this phenomena. To compensate for this problem a nested model structure is proposed and described below.

[16] IIA was first proposed by Arrow (1951b). The theory is based on how social choices should be made given individual's preference structures. This work questioned whether the axioms of consumer preference, on an individual level, could be applied at the social level. The sub-section of IIA that applies to the logit framework here is to impose a rule of transitivity, in choice, which says that the probability of choosing a particular site be unaltered given a change within the choice set. This is the independence across alternative sites.

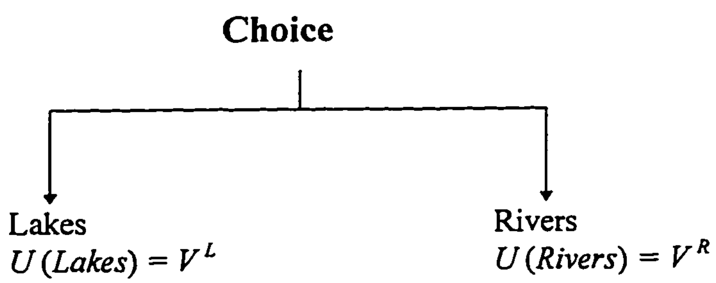
2.3 Nested Multinomial Logit Models

Creating nested model structures is quite often interpreted as formulating a sequential decision process that the household may follow when choosing a recreational site. Although the sequential process is appealing in describing actual behavior, it is not the correct way of interpreting a nested model. Nesting is often used when the alternatives in the choice set are suspect to high correlation amongst the random error terms. This un-observable correlation may be due to the researcher's lack of information rather than the household's actual decision process (Train, McFadden and Ben-Akiva, 1987). From a statistical standpoint, the sites are not independent of each other. Site independence is important since the addition or deletion of a site from the choice set will alter the probability of choosing a particular site. If the site probabilities change, due to different sizes and combinations of choice sets, the model will not be as robust in estimation and sensitive to an unresolved process of choosing a choice set.[17] To alleviate the possibility of correlation amongst similar sites, the nesting or grouping of alternatives into separate *modes* avoids a violation of the Independence of Irrelevant Alternatives (IIA) assumption. The IIA question in this circumstance is: Does the introduction or deletion of a river into a purely lake choice set alter the probability of choosing a lake? Alternatively, does the presence or absence of a lake have any influence on the choice of a river?

[17] Choosing a choice set is still, by practice, an ad hoc procedure. Site selection and spatial limits have become important issues in TCMs (Smith and Kopp, 1980; Fletcher et al., 1990). As well, choosing the nesting structure (decision process) is subject to the researcher's interpretation of where correlation may lie. Alternative nesting structures imply different coefficients estimates and, therefore, different welfare estimates (Kling and Thompson, 1996). For our model, a one level nest, specification error of this type is unlikely as the respondent has only one choice, between lakes or rivers.

The assumption of separating lakes and rivers into a nested structure can take two views. From a recreational perspective lakes may be correlated within, but not across the mode of rivers. Lake decisions may also be gauged by different recreational attributes and thus should be compared to each other, but not to rivers. The other important distinction is from a biological standpoint. With respect to water quality variables, lakes are different from rivers and straightforward estimation would be measuring variability across different aquatic ecosystems. This is comparing apples with oranges. Thus from a recreational and biological standpoint, nesting the model into the two modes of lakes and rivers makes sense. Figure 3 below shows the nesting structure used in this analysis.

Figure 3: Nesting Structure for Site Choice



V^{L} and V^{R} are the conditional indirect utility functions associated with choosing a lake or river. The separation of the choice set into two modes also allows us to define specific utility functions that characterize the different decisions. Parameters specified in V^{L} can be identified with lake decisions and the variables in V^{R} with rivers. The different parametric specifications are contained in Chapter 4: Nested Model Development.

The nested MNL model is similar to the discrete choice model described in the previous section, with the notable difference of two conditional indirect utility functions for the two modes. Formalizing the nested structure, the probability of an individual choosing to recreate at site *j* in mode *m* can be represented as:

(7)
$$P_{jm} = P(j|\, m)\, P(m)$$

where $P(j|\, m)$ is the probability that the individual chooses site *j* conditioned on choosing mode *m*, and $P(m)$ is the probability that the respondent chooses mode *m*. The random utility theoretic structure built in the last section also applies in this case except that the vector of random errors is drawn from a *generalized* extreme value distribution. As noted above, the extreme value distribution can be extended to the generalized (multiple alternative) case. We can summarize the nested model by stating the probability of choosing site *j* from mode *m* as[18]:

(8)
$$P_{jm} = \frac{e^{V_{jm}/\alpha_m}\left[\sum_{i=1}^{J_m} e^{V_{im}/\alpha_m}\right]^{(\alpha_m - 1)}}{\sum_{k=1}^{M}\left[\sum_{i=1}^{J_m} e^{V_{ik}/\alpha_k}\right]^{\alpha_k}}$$

where V_{jm} is the utility associated with recreating at site *j* in mode *m*, α_m is a parameter that measures the degree of substitution between the various modes, *M* is the number of modes and J_m is the number of sites in mode *m* (Kling and Thompson, 1996). Note that the number of sites may vary by mode. The coefficient α_m is also known as the "inclusive value coefficient" or the "dissimilarity parameter." When α_m

[18] Probability expression is from McFadden (1981), Maddala (1983), Morey (1994).

= 1 for all m, the expression in equation (8) collapses to the standard MNL probability in equation (6), where the IIA property holds between all alternatives.

2.4 Model Estimation[19]

The model presented here is estimated using Full Information Maximum Likelihood (FIML) techniques. Estimation of the coefficients is accomplished by defining the log likelihood function as the product of probabilities over a sample of individuals expressed in equation (7):

$$L = \prod_{i=1}^{N} P_{ijm} \tag{9}$$

where the i subscripts are the individuals in the sample of N observations. If the form of model is linear in parameters then the conditional probability of choosing site j is re-stated as:

$$P_{jm} = \frac{e^{\beta' X_{jm}/\alpha_m}\left[\sum_{i=1}^{J_m} e^{\beta' X_{im}/\alpha_m}\right]^{(\alpha_m - 1)}}{\sum_{k=1}^{M}\left[\sum_{i=1}^{J_m} e^{\beta' X_{ik}/\alpha_k}\right]^{\alpha_k}} \tag{10}$$

Maximum likelihood techniques estimate the vector β, in (10), such that the logarithm of L, in (9), is maximized. Ben-Akiva and Lerman (1985) cite McFadden (1974) as showing that $\ln(L)$ is concave, such that a unique maximum exists. The maximum likelihood estimation procedure yields an estimate of β that is consistent, asymptotically normal and asymptotically efficient.

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[19] This section is paraphrased and adapted from D. Watson et al. (1993).

2.5 Welfare Theory

In welfare theory there are three economic measures of valuing a quantity, quality or price change. The three measures are consumer surplus (CS), compensating variation (CV) and equivalent variation (EV). The appropriate use of each depends on the type of change being evaluated. Consumers surplus is derived from Marshallian demand functions whereas CV and EV are derived from Hicks income compensated demand functions. Consumers surplus is not normally used when evaluating an environmental quality change since it suffers from path dependency. Path dependency arises when the order of a change in price, quantity or quality affects the final welfare measure. Consumers surplus is path dependent if there is a change in more than one of these variables. This will create multiple solutions depending on the order in which the changes were evaluated. The other measures, CV and EV, have unique outcomes and are preferred over CS.[20] The main difference between CV and EV is the utility level at which a price, quality or income change is evaluated. Compensating variation measures the amount of money that must be given or taken away from the individual, after a quality change, to keep them at the same initial utility level. Analogously, EV is the money that must be added or subtracted to keep an individual at the new utility level. For our purposes, the analysis will use CV since measuring utility at the initial level is implicit in the model estimation process.

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[20] The path dependency advantage of CV and EV over CS follows from taking the integral of the set of compensated demand functions each time a price change occurs regardless of the order. This follows from the symmetry of the cross price substitution terms, that is, $\partial x_i / \partial p_j = \partial x_j / \partial p_i$ (Young's Theorem).

To measure an environmental quality change we must look at the difference in utility before and after the change. Using the indirect utility function defined in the previous section, V, and the definition above for CV we have:

$$V(P, Q^0, M) = V(P, Q^1, M + CV) \tag{11}$$

The condition says that utility will remain constant after the quality change, Q^0 to Q^1, given the increased compensation, CV. The estimated coefficients of the indirect utility function can be used to elicit CV. The estimated parameters are applied to the choice probabilities for the individual sites in the choice set. Small and Rosen (1981) initially researched welfare measures in discrete choice models and this was extended by Hanemann (1982, 1984). Integrating the estimated coefficients with the definition of CV, the welfare measure used to examine the impact of a quality change is:

$$CV = -\frac{1}{\mu}\left\{\ln\left[\sum_{m=1}^{M}\left(\sum_{j=1}^{J_m} e^{V_{mj}^2/\alpha_m}\right)^{(\alpha_m)}\right] - \ln\left[\sum_{m=1}^{M}\left(\sum_{j=1}^{J_m} e^{V_{mj}^1/\alpha_m}\right)^{(\alpha_m)}\right]\right\} \tag{12}$$

where μ is the marginal utility of income, V_m^1 is the initial state (or quality level) and V_m^2 is the level of utility in the subsequent state (Kling and Thompson, 1996). Applying equation (12) to our analysis, we will assess the compensating variation of an environmental quality change in fish stocks and water quality variables. The CV measure is the amount of money that water-based recreationists must be compensated after a change in water quality or fishing experience to maintain base utility levels.

Chapter 3 The Data Set

Data collection for this model was comprehensive at the outset, but was refined to the four major categories of recreational, water quality, fish stocks and social demographics. The major hindrance in data collection were the water quality or chemistry attributes of northern Alberta lakes and rivers. Since northern lakes and rivers are remote and regional populations are sparse, water chemistry information has not been fully assembled by Alberta Environmental Protection (AEP). In regions where more economic development has occurred, AEP has compiled a more comprehensive inventory of water quality variables. The southern region of Alberta is testament to this by such projects as the Old Man Dam, Pine Coulee Reservoir, Chain Lakes Reservoir and the Highwood/Little Bow Dam. In cases where only partial information was available, prediction equations were utilized to proxy the actual measure of water quality. This is detailed in Appendix A.

The other variable that proved elusive was fish catch rates. The site catch rate would be the ideal variable for this analysis, but for similar reasons mentioned above, a proxy was created utilizing the available water chemistry data. Prediction equations for fish yield (FY; lakes) and total fish standing crop (TFSC; rivers) were computed.[21] Yield indicators or population-based measures may be perceived, by the recreationist, in the same manner as catch rates. The yield equations also provided the important intuitive link of changes in water chemistry on fish populations. The methods of

[21] Total Fish Standing Crop (TFSC) is a measure of the density of fish in a specified area. This variable is used since standing crop can be a function or derivative of yield.

prediction for fish stock variables are elaborated below and also in Chapter 4: Model Development.

3.1 The Northern River Basins Study Data[22]

The Northern River Basins Study (NRBS) was a joint project between the governments of Canada, Alberta and the Northwest Territories that commenced in September of 1991.[23] The study area focused on the Peace, Athabasca and Slave River basin regions. The purpose of the NRBS was to "characterize the cumulative effects of development on the water and aquatic environment of the study areas by coordinating with existing programs and undertaking appropriate new technical studies". The Study Board identified 16 questions that served to focus study activities. One of these questions was:

> #3. Who are the stakeholders and what are the consumptive and non-consumptive uses of the water resources in the river basins? (pg.1)

In response to this question, the Other Uses Component committee was established and a five step work program was developed. After identifying stakeholders and designing a survey, the implementation phase was initiated and coined Project 4121-D3. The survey method was recommended as being the most effective tool because there were no existing data bases that described how northern residents use the aquatic resources of the basin for such things as recreation,

[22] This section on the NRBS is largely paraphrased from NRBS Project Report No.70, January to April, 1995 (Drobot Contracting Services Ltd. and Praxis, Ltd. 1996).

[23] To a lesser extent, the provincial governments of Saskatchewan and British Columbia also played a role.

subsistence, transportation or other purposes or the cultural or lifestyle importance of northern rivers. The main sections of the survey were: general use of water resources, subsistence use of water resources, recreational activities, agricultural water use, water management values/issues and social demographics. An important inclusion in the survey were the attitudes and opinions about present and future water management in the basins (perceptual data). Perceptual data are valuable for measuring the changes in environmental views by people. Using perceptual data is beyond the scope of this project, but would provide a very interesting extension to this analysis. The scope of the household survey was very comprehensive and for our purposes only the recreational and social demographic sections were analyzed.

The household survey approach involved contacting a stratified, random sample of 1,200 households by telephone, soliciting their cooperation with the survey, mailing them the questionnaire, calling and reminding them to complete the survey and conducting the survey over the telephone, if required. The study area was broken into 12 regions and initial intentions were to send questionnaires to at least 90 households in each region, and 180 in each of the larger two regions. As the project progressed, this number was increased to 100 for most regions and 200 in the larger regions. The questionnaire was pretested by 20 households before full implementation occurred. A copy of the NRBS household survey is provided in Appendix B.

A total of 2,621 households were screened in order to find 1,400 that were willing to complete the survey. This represents a participation rate of 53.4 percent.

At the end of the study, 714 questionnaires had been completed, representing 51 percent response rate. The most common reason for not completing the questionnaire was that the household was no longer interested in the survey. After deletion of non-response to origin/destination and compensating for low site frequency (less than 10 visits), the sample size equaled 344 and the total number of recreation destinations was 109.[24] A decision was made at this point to regionalize the analysis since the geography of the province did not rationally permit all 109 site choices to be available to every respondent. In other words, respondents would not consider a site very far away if there exists a substitute site near by. This decision was also supported by the geography north of Lesser Slave lake where east/west road access is limited. The analysis focused on the northwestern area of the province since respondents living in this area indicated recreation sites that were close in proximity to forestry activities or at least had the potential for a forestry impact in the future. A map of the study area and the associated recreational sites is provided in Figure 4.

Regionalization was accomplished by assuming that recreationists would not consider sites far away, if close substitutes existed. From Figure 4, it can be seen that the study area was located north of Edmonton (53^0 31' latitude) and west of 115^0 longitude. Respondents *living* in this area were used in the model whereas

[24] Non-response, in this context, is interpreted as individuals who did not indicate where they live (origin) or where they recreated (destination). Both were necessary to calculate the travel distance. Originally, respondents in the NRBS survey indicated over 400 destination sites. A number of those sites had a low frequency of trips. In estimation, due to the large number of destinations and the low number of respondents associated with them, it was suspected that some sites would not be revealed as significant to the overall model; or to be precise, the attributes they possess would not be significant. Another reason for the deletion of some sites was the availability of water quality data. Sites that were low in frequency and did not have full information were dropped from the choice set.

respondents who lived outside this area were not. It is important to note that regionalizing the sites with respect to origin did not imply that all the indicated recreational destinations were within the regionalized area. Descriptive statistics indicate that the average distance traveled was 333 kilometers, thus the study region contains all of the respondents and approximately 88% of their associated recreational site choices.[25] Regionalizing resulted in a sample size of 180 respondents taking 2254 trips to 58 recreational destinations. The average number of trips taken by the 180 respondents was 13.

[25] Seven of the 58 sites, or 12%, were strictly outside the regionalized boundary. They were not deleted from the choice set, along with the respondents that chose those sites, since they possessed water quality attribute variability important from an alternative specific standpoint.

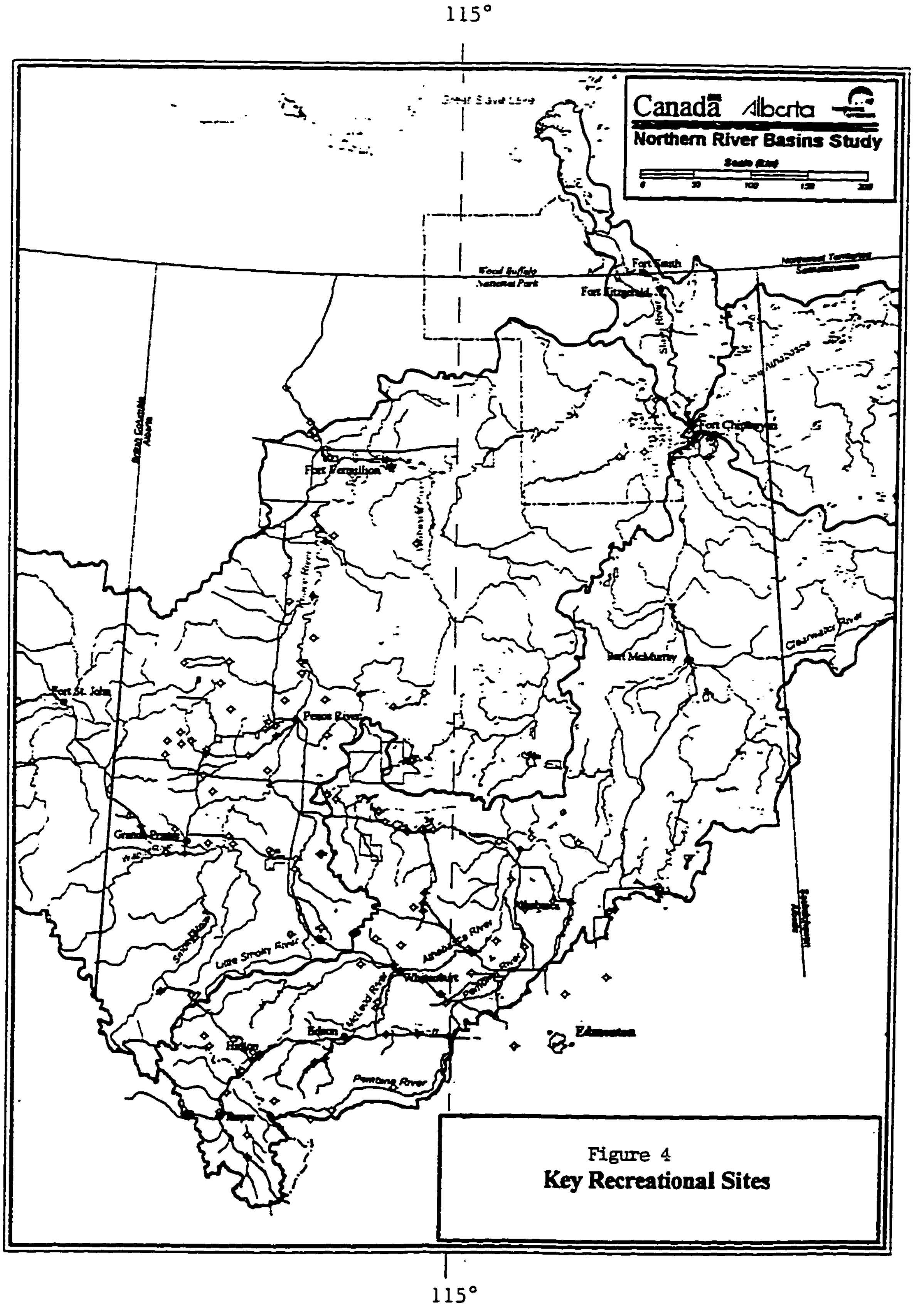

Figure 4
Key Recreational Sites

A unique aspect of the survey was that it was not based on fishing licenses. Typically, recreational sportfishing studies use angling licenses sold as a source to survey. The NRBS data were based on regional proximity to the Athabasca, Peace and Slave River regions. Thus the data set was more representative of the population as a whole, rather than focused on a special group, fishers. Aboriginal communities were also included in the survey region, but in our sample of 180, only 10 responded as being native. This study should also be viewed more as a water-based recreational analysis since the response structure (open-ended) allowed respondents to indicate any activity. Combinations of fishing along with canoeing, boating, swimming, water skiing and picnicking were cited. This does not affect the model as sites are treated as having multiple attributes (Fletcher et al., 1990).

3.2 Site Visitation

An important aspect of any site is the number of times it is frequented. As the number of occasions increases, this reveals the preference for site-specific quality attributes. Site visits were included in Part V, "Recreational Activities", of the NRBS data (Question #40). Respondents were to indicate the site name, usual activity, number of trips per year and the main reason for preferring the site.

A limitation of the NRBS study was that it did not survey the city of Edmonton. This was not surprising since the purpose of the NRBS household study was to survey only basin residents. From a recreational perspective though, Edmonton was too large to ignore since our 58 recreational sites, and their associated benefits, are not exclusive to only northern basin residents. To correct for this, another survey, containing information on Edmonton, was used as a guide to scale up the NRBS survey visits of each respondent to each site. The procedure of scaling the visits up was to approximate what Edmonton residents would have contributed to overall site frequency had they originally been included in the survey region. It is likely that this scaling was conservative since we are not including the other regions south of Edmonton.

The supplementary survey utilized was the 1996 Alberta Recreation Survey Analysis and it contained a province-wide analysis (Alberta Community Development, 1996). The survey asked Albertans to identify their recreational participation patterns and preferences. Of the 10,047 surveys sent out, 3,785 or 37.67% were received. It was found that Edmonton represented about 22.9% of the total returned. Of all the recreational activities indicated in the survey, 14.77% were water-based recreational activities. This study was only concerned with water-based recreation, thus to include Edmonton's water-based recreational contribution to the analysis, each trip frequency was scaled up by 3.38% (multiply 14.77% and 22.9%). As noted above the original number of trips, across the 180 individuals, was 2254. Scaling resulted in the total number of trips as 2333. The adjusted frequency to each named site is given in Figures 5 and 6.

3.3 Distance Calculations

Origin and destination information were obtained from the NRBS household survey. Respondents indicated the city or town they lived in, or the closest city or town. The destinations were tabulated from the NRBS recreational section, where respondents indicated up to three sites that they have frequented in the past year. The road distances between the 75 origins and the 58 destinations were calculated using Rand McNally's TripMaker program (Rand McNally, 1997). Although the accuracy of this tool fared well, it did have limitations in more remote locations. To compensate for this problem, the distance to the nearest location was programmed and then Alberta road map measurements were added to arrive at origin/destination distance. The analysis did not differentiate between road types (i.e. paved, secondary, gravel, etc.). Alternative road types potentially have different travel costs associated with them. This time consuming investigation would require a more sophisticated route analysis with the aid of a Geographical Information System (G.I.S.).

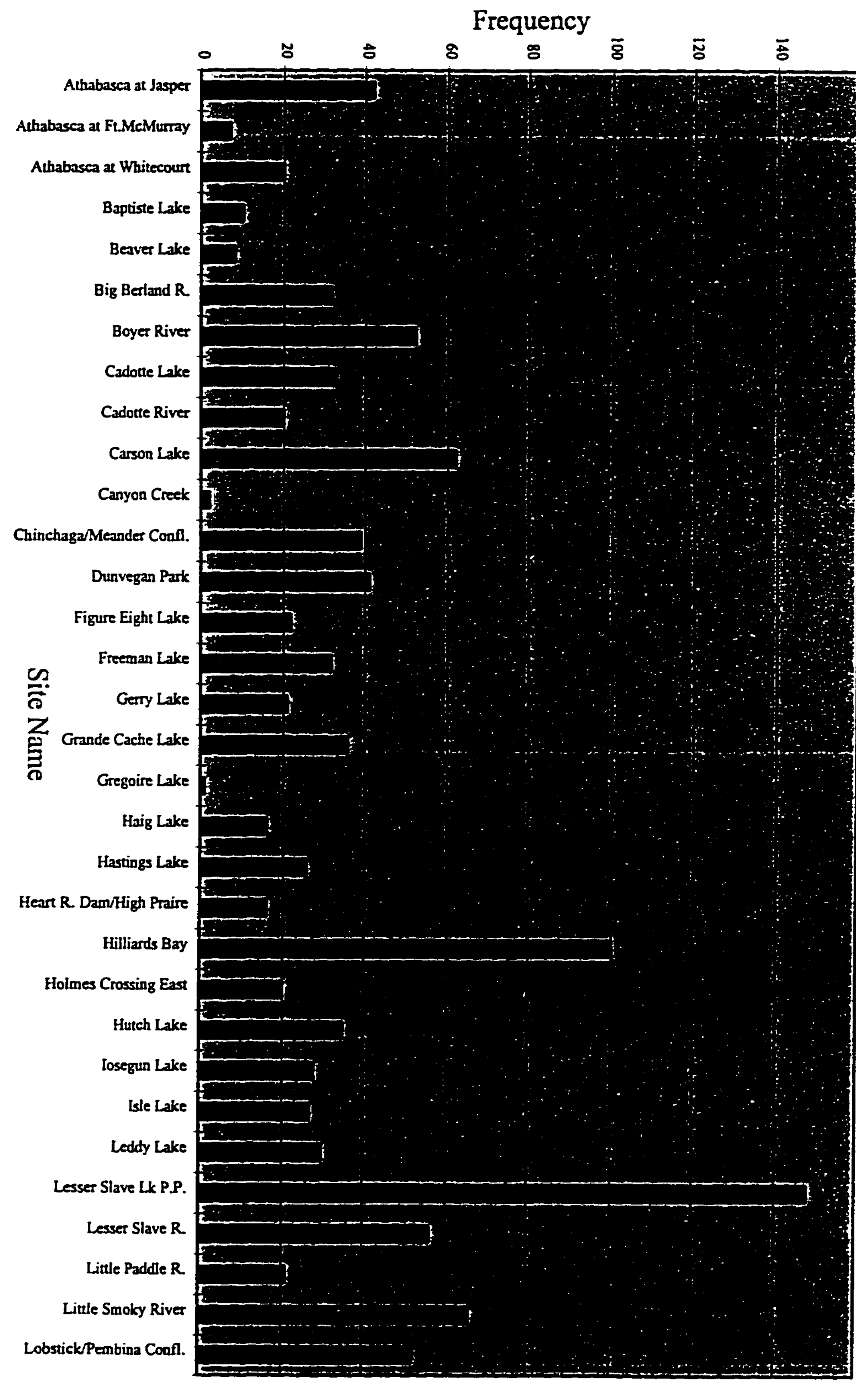

Figure 5: Trip Frequencies: Athabasca River to Lobstick River

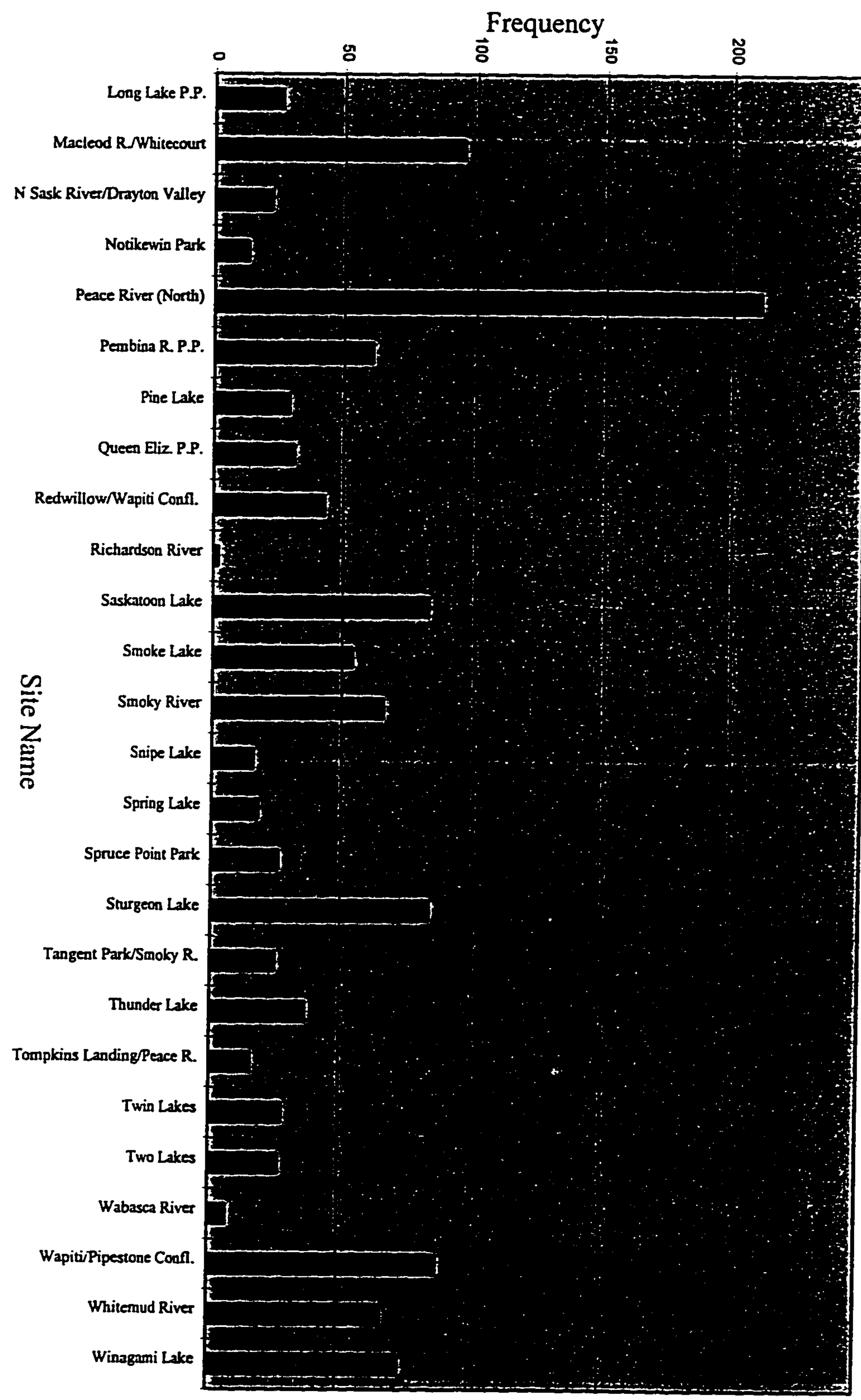

Figure 6: Trip Frequencies: Long Lake to Winagami Lake

3.4 Recreational Attributes

The recreation data were obtained from various sources. A large proportion came from "Camping Alberta" by Joanne Morgan, the 1996 Alberta Campground Guide by the Alberta Hotel Association and "Atlas of Alberta Lakes" edited by Patricia Mitchell and Ellie Prepas. Information on sites located in a provincial park or forest management area came from Lesia Boyko in the Recreation and Protected Areas Division of AEP. Forest fire history from 1931 to 1983 was from "Forest Fire History Maps of Alberta" by G.P. Delisle and R.J. Hall and 1983 to 1995 from Phase III forest cover maps supplied by the SFM-NCE office at the University of Alberta. Fish stocking and fishing and boating restriction information came from the 1996 Alberta Guide to Sportfishing by AEP.

3.5 Water Quality Data

The water chemistry or quality data were obtained from Ron Teir and Dave Trew at the Water Sciences Branch of Alberta Environmental Protection. The data base, Naquadat, housed parameters dating from 1963 to present. The criteria for using these data was to get as close as possible to the NRBS household survey year 1995. If no site sampling occurred in 1995, the closest year was used. As mentioned above, data on remote northern locations can be elusive if the site has low demand.[26]

[26] Teir (personal communication) estimates that one parameter costs about $2000.00 for one sampling. A good water quality analysis can involve more than 50 to 70 variables. Thus only highly recreated sites are measured.

Another useful source was the "Atlas of Alberta Lakes" mentioned above. This compilation of Alberta lakes contained detailed environmental, geographical, recreational and historical information on a number of sites in this analysis.

Sites that were missing important water quality state parameters were dropped from the choice set of alternatives. If a site had one of the key state variables, total phosphorus or chlorophyll *a*, it was possible to predict others. This is elaborated in Appendix A.

3.6 Fish Habitat Predictions

The stock of fish for each site were predicted using estimated equations researched from the literature, and which analyzed sample sites similar to those in northern Alberta. Although no studies of this kind have been performed in the northern boreal forests of Alberta, similar geographic studies were found and utilized for this study.[27] Described below are the predictors that performed the best in the modeling exercise. Predictors that did not perform as well are described in Appendix A.

Since lakes and rivers are not comparable from a biological stance, they do not share similar prediction equations of fish stocks.[28] The best performing predictor of

[27] The geographic studies for the water quality variables focused in areas such as Alberta, Ontario, Sweden and Western Canada. Fish stock prediction studies concentrated in locations such as the United States (i.e. Minnesota, Iowa, Vermont, Wyoming) and Canada (Ontario). Some of the contributing literature was supplied by the Ecologically Based Sustainability (EBS) component of the SFM-NCE.

[28] Although lakes and rivers possess the same attributes, they are not comparable on the levels that exist. For example, if one was to compare the total phosphorus levels between all lakes in the choice set plus one river, the river would appear to be an outlier statistically. Thus lakes should be compared with each other and rivers alike. This is elaborated in Chapter 2: Nested Multinomial Logit Models

fish biomass and yield for lakes in our model was estimated by Hanson and Leggett (1982). Their study compared various indices to predict fish yield and biomass using mean depth, lake surface area, total dissolved solids (TDS), total phosphorus and macrobenthos standing crop. The conclusions reveal that two of the best univariate predictors of fish yield were total phosphorus concentration and macrobenthos biomass/mean depth (r^2 = 0.84 and r^2 = 0.48, respectively). Both of these indices were stronger predictors of fish yield when compared to the morphoedaphic index (TDS/mean depth), total dissolved solids, or mean depth for the same data set. Subsequent multivariate predictors, with and without total phosphorus, proved that total phosphorus was the major explanator in predicting fish yield (Hanson and Leggett, 1982, pg. 259-260). As total phosphorus data were the most complete in our data collection, we chose this prediction equation for the analysis. The univariate fish yield (FY) prediction equation, based on TP was:

(13) $$\text{Log(FY)} = 1.021 \text{ Log (TP)} - 1.148, \qquad r^2 = 0.87, \text{n} = 21$$

where TP is the total phosphorus for lakes and noted is the r-squared value for the regression from which it was derived. Note that the logarithmic transformation of this equation performed slightly better than the initial regression (r^2 = 0.87).

The yield predictor for rivers was borrowed from Hoyer and Canfield (1991) and adapted to our river sites. In their study they tested the hypothesis that stream fertility, as indexed by total phosphorus concentrations, is an important environmental factor influencing fish standing crop. Standing crop has been known to be a function

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and Chapter 4: Nested Model Development, where nesting the model compensates for this by specifying different utility functions for lakes and rivers.

or derivative of fish yield and we used this measure as an indicator of river fish yield. The authors compare geographic trends in phosphorus and total fish standing crop (TFSC) for 79 North American streams and develop a simple regression model to explain the relationship.[29] Although there is a concern that geographical latitude is an important environmental variable influencing the biological productivity of lakes and rivers (Brylinsky and Mann, 1973), Hoyer and Canfield (1991) found that average total fish standing crop for each region shows no relationship to latitude (pg. 26). In studies where latitude was an influence on autotrophic production and algal biomass, total phosphorus has been shown to exert a greater influence than latitude (Schindler, 1978). Total phosphorus concentrations among the 79 streams ranged from 3 to 1400 μg/L and TFSC ranged from 2.3 to 634 kg/hectare. All of the rivers in our analysis fall within this range for total phosphorus. TFSC, along with other fish stock parameters, have not been comprehensively compiled in our study area, thus we make the assumption that the rivers fall into this range. Their initial estimation resulted in a linear relationship (given as equation (24), Appendix A), between average TFSC and average total phosphorus concentrations. Although the relationship was significant across all 79 rivers, the correlation between TFSC and TP for the individual streams was much weaker. Further investigation revealed a non-linear relationship where TFSC increased with greater total phosphorus much more rapidly in streams with TP $\leq$ 15 μg/L. This concentration value became the threshold point where the linear

[29] The authors obtained data on TFSC and total phosphorus for 15 streams in Florida, 19 streams in Vermont, 12 streams in Iowa, 10 streams in Ontario (Canada), 20 streams in Wyoming, 2 streams in Washington and one stream in Missouri.

relationship became non-linear. The final results were divided into two equations given as:

(14) Log(TFSC) = 1.41 Log (TP) + 0.14, for TP ≤ 15 μg/L ; r^2 = 0.40, n = 33,

(15) Log(TFSC) = 0.45 Log (TP) + 1.04, for TP > 15 μg/L ; r^2 = 0.52, n = 46

In our study, 7 out of the 27 river sites had TP ≤ 15 μg/L and thus equation (14) was applicable in our case.

It is important to note at this point that fish yields are usually characterized by a quadratic function over various levels of stock[30] (Clark, 1990). It is well documented that fish stocks will increase at an increasing rate until a maximum is reached called the maximum sustained yield or MSY. At the point of MSY, the population is self-perpetuating or sustainable in the long run, where the growth and mortality rates are equal. Beyond this point, biological competition, habitat thresholds or mortality dominates and the stock growth rate begins to decline until a carrying capacity or natural equilibrium is reached. Population increases beyond the carrying capacity force stocks to return to the optimal carrying capacity due to habitat limitations or mortality. Sportfishing and commercial harvesting are an outside influence on stocks which also affect where the population lies on the yield curve. Visually, the yield curve looks like an inverted u-shaped curve depicted in Figure 7 below.

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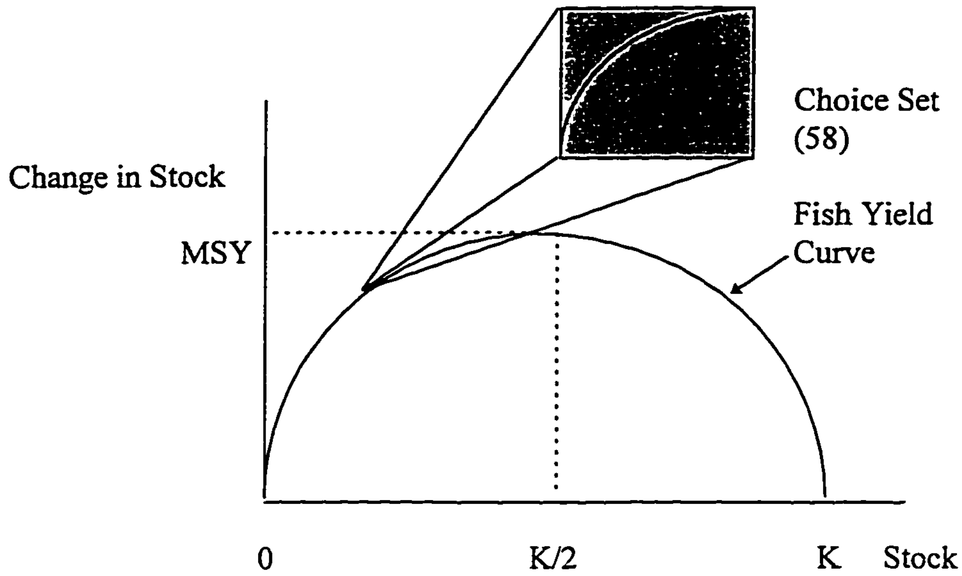
[30] This function is actually defined as the logistic equation: $\frac{dx}{dt} = \dot{x} = rx\left(1 - \frac{x}{K}\right) = F(x)$, where r is the intrinsic growth rate, x is the total stock or population and K is the environmental carrying capacity. The growth rate, $\dot{x}$, is increasing until a maximum is reached (MSY), then declines until the carrying capacity, K, is reached (Clark, 1990, pg.11).

Figure 7: Fish Yield Curve for Changes in Stock



In Figure 7, growth in the stock increases until MSY is reached, then declines to the carrying capacity K. For this part of the study, specification of the yield curve is not necessary since the analysis occurs on only a portion of the curve. This is represented by the shaded box in Figure 7. The methods used for the fish prediction equations utilized this approach (Hanson and Leggett, 1982; Hoyer and Canfield, 1991). This is often the case in limnological prediction where a static analysis is performed with TP varying across sites rather than stocks over the yield curve (Peters, 1986). The approach is analogous in economics, where a marginal change is analyzed holding all else constant. A portion of the yield curve is analyzed with varying TP and the marginal TP impacts are reflected in the stock variables, FY and TFSC. The predictions of FY and TFSC are in Appendix D: Quality Attributes for the 58 Sites.

3.7 Social Demographics

The social demographic data were obtained from Part II of the NRBS household survey (Appendix B). A drawback of the survey were questions relating to the location and amount of time living in the basin areas as well as the composition of household with respect to age and number. There appears to be some overlap between the questions. Although these were interesting from a descriptive perspective, the response structure was too fragmented to be useful in the analysis without merging categories. This part of the survey appears to be designed more for informational purposes rather than econometric modeling. However, three questions were initially useable, the number of people in the household, age and gender of the respondent. Preliminary sample statistics indicated that the average number of people in the household was three, the average age was 39 and of the 180 respondents, 112 were male and 61 were female. The gender question, although useful on an individual basis, is not useful in our exercise since we are examining household decisions.

Given the data from the above sections, spreadsheets were complied and transformed into an estimable data set using GAUSS for Windows NT (1996).

Chapter 4 Model Development, Estimation and Results

4.1 Model Development

In the recreational site choice model a large number of potential variables were collected to reveal site choice. The method of choosing variables to include in the model was a combination of *a priori* beliefs and trial and error. Using *a priori* beliefs or intuition is a common approach for recreation models. This approach yields a final model which is consistent with beliefs and is described by the data. The trial and error method is less attractive since causal relationships may exist in the data but are not consistent with beliefs. It is well known that the trial and error approach is subject to "learning" from the data, or exposing data relationships, rather than true behavioral relations (Train 1979). This is especially true for indirect approaches such as the travel cost model, where a large data set may be collected initially and few significant variables remain in the final model. The method of variable selection was to formulate *a priori* beliefs before data collection, then to use the trial and error approach during model estimation.

Using the above method, the next step in selecting variables is to choose a set of *alternative* and *individual* specific variables. Alternative specific variables are attributes which a site may possess and vary across the choice set of lakes and rivers. If significance is found among these variables this implies a revealed preference for those site-specific qualities. The alternative specific attributes for this project are broadly categorized as distance, recreational, water quality and fish stocks.

Another important consideration is the social context of the recreational decision-maker. For example, a particular site may be preferred by individuals who possess certain social characteristics or individual specific attributes. The individual specific attributes chosen from the NRBS data set were age and the number of people in the household. A description of each category of attribute is provided below and listed along with the coding procedure in Appendix C: Model Variables.

4.1.1 Distance Variable

The main variable in travel cost models is *distance*. Distance is used as a proxy or surrogate measure of price. As the price or cost of a choice occasion varies amongst the alternatives, recreationists will respond in their frequency to the site. If respondents are rational and recreation is a normal good, distant sites (higher cost) will be less frequented. From a statistical standpoint, as distance increases, the probability of site choice decreases. The number computed was the one-way distance to the site. The round trip distance is integrated into the welfare measure in the last section.

4.1.2 Recreational Attributes

The recreational attributes considered for the model range from development to policy/regulatory variables. The development attributes include: *campsites*, campground *facilities*, *day-use* areas, *swimming*, *beaches*, *playgrounds*, *boat launches*, *local development* and paved road *access*. The number of campsites is often important for those who travel longer distances and require an assurance of availability. The absolute number of campsites may be significant, but if the distance factor is important then campsites should be interacted with distance. Both variables will be estimated and interpreted. If the recreationist has a family, they may consider swimming, beaches, day-use areas or playgrounds necessary for picnics or outings. These are expected to positively contribute to site choice.

A campground's facilities may include specific services such as tap water, sewage disposal facilities, washrooms, concession stands and interpretative programs, to name a few. It is suspected, though, that there may exist some overlap between campground facilities, day-use areas and local development. The difference between the three is that the facility measure is concentrated around the campground area, whereas local development is more regional and outside the campground itself. Day-use areas are treated as being separate from the campground area itself, but interaction with the number of campsites may be more revealing. Swimming and beaches may be highly correlated and interactions with water quality variables may reveal preferences for better quality (i.e. water clarity). For data collection purposes all were included to determine the contribution of each to site choice. Local development was measured as an increasing scale of one to three for such conveniences as resorts, cabins, local stores, golf courses and so forth. Paved road access is not included in the local development definition and is treated as a separate variable. Boat launches and paved road access were included as variables important for boating and family orientated water-based recreation.

All of the above development attributes are suspected to positively contribute to the probability of choosing a site, with the exception of local development. The level of development may be positive or negative depending on perception. Recreationists may view development as subtracting from the natural surroundings whereas others may prefer the option of convenience. Thus the sign of this attribute is inconclusive at this point.

The policy/regulatory variables included in the model are: *boating restrictions*, *fishing restrictions*, fish *stocking* and *managed fishery*. These attributes are usually integrated into water management policy by either the local or provincial authorities who want to control the impact of certain activities. If a lake or river has multiple-user activity, they may restrict boating in specific locations or on the water body as a whole. The level of boating restrictions may deter some recreationists from choosing that site. Likewise, if anglers pressure fish stocks or particular fish species, authorities may implement specific catch restrictions. The presence of fishing regulations or the increased level of boating restrictions are hypothesized to decrease the probability of site choice.

The two policy variables involved in this analysis are counterpart to the regulations above. If there exists pressure on the stock or a particular species of fish, the action may be to create a *managed fishery* or implement a fish *stocking* program. As before, these two variables are subject to correlation between each other, but were included initially to examine the effect on site choice. Since both can be considered positive enhancements to the area, the probability of choosing a site will increase with the presence of these programs.

The final two recreational attributes are: *in a provincial park* and *forest fires*. If the site is within a provincial park, respondents may prefer these sites for their reputation of being cleaner, better managed or have the desired recreational attributes. The park variable could be positive or negative, depending on whether the site is subject to congestion (Boadway and Wildasin, 1984). A site that is congested would lower the utility of the respondent and decrease the probability of choosing that site. Upon visual inspection of the site frequencies (Figures 5 and 6), congestion may not be a factor since the highest number of per annum visits is 211 along the Peace River (North) which is close in proximity to Fort Vermilion. Congestion from people who stay over night may not be a problem. The next two highly frequented sites, Lesser Slave Lake Provincial Park and Hilliard's Bay, both have 113 and 189 camping spots available, respectively. The high number of camping spots in this area should accommodate for the frequency of travelers and thus a congestion variable is not considered in this analysis. It is the opinion of this researcher that people will prefer a park site over a non-park site and the estimated coefficient should be positive, increasing the probability of site choice.

The forest fire history of a site is another consideration from an aesthetic point of view (Englin et al., 1996). Of the 58 sites in the choice set, all had forest cover or buffers around the lake or river. A burned out portion of the forest would create a negative impact on the visual aesthetics and decrease the probability of choosing the site. By construction, the variable counted the number of years since a fire, human-caused or natural in disturbance. Therefore, as the forest fire variable increases, this will increase the probability of site choice since the fire is further back in time. For the site to be considered 'burned', the criteria was that the fire had to be within a one mile radius around the site. Sites that did not have a fire between the period of 1931-1995 were given a value of zero to indicate that no fire has occurred in the area.[31]

4.1.3 Water Quality Attributes

The purpose of the water quality attributes was two-fold. Attributes were either collected for inclusion in the model or for prediction of other variables. A large number of variables were collected since it was not known which variables would be important from a predictive standpoint. The full set of attributes initially considered for the water quality analysis were: *total phosphorus*, *chlorophyll a*, *pH*, *color*, *Secchi depth*, *turbidity*, *total dissolved solids* (TDS), *total suspended solids* (TSS) and *percent blue-green algae*. From a biological perspective, these are the major variables used to gauge the quality of the water. From a recreational perspective, though, some are not directly observable or in the decision-making process of the recreationist. Specifically, total phosphorus, pH and TDS are not directly observable and chlorophyll *a* and TSS are not explicit in decision-making. The purpose for these variables is to aid in the prediction of fishing stocks, which is the major observable

[31] It could also be the case that a fire has occurred in the past, but given the 60-70 year regeneration rate of boreal forests, fires before 1931 are now, more than likely, undetectable. Englin et al. (1996) show that the welfare loss decreases over time (maximum loss is at time of fire) to the present where full regeneration has no zero loss.

and decision attribute to recreationists. The most important variable for fish prediction in northern lakes and rivers is total phosphorus (E. E. Prepas, personal communication). Other prediction studies using chlorophyll *a* have been used, but total phosphorus (TP) data in our case were more readily available and no predictions of TP were necessary.[32] For a comparison of other predictors for fish stocks, using state variables, see Appendix A. In summary, the parameters utilized for fish stock predictions were *total phosphorus* and *chlorophyll a* and the water quality attributes included in the model were *Secchi depth*, *color*, *turbidity* and *percent blue-green algae*.

The transparency, or water clarity, is most affected by the amount of algae in the water. The clarity for lakes is measured by estimating the depth that a black and white plate, called a Secchi disk, can be seen. This depth is called the *Secchi depth.* The depth indicates the amount of light penetration that can occur. The extent of light penetration delineates the depth of rooted aquatic plants in lakes and the depth of most algae growth. Aquatic plants (weeds) and algae growth are considered aesthetically un-pleasing to the recreationist. It is a belief that as the Secchi depth of a lake increases, as does water clarity, the probability of choosing the site will increase. Continuing with algae growth, another observable attribute is the *percentage of blue-green algae* out of the total algal species present. Blue-green algae may produce unpleasant tastes, odors, surface scums and are an unsatisfactory food source for many organisms higher in the trophic structure such as fish (Reynolds

[32] For studies using chlorophyll *a* as a predictor of fish stocks see Jones and Hoyer, 1982; for phytoplankton standing crop (biomass) see Bierhuizen and Prepas, 1985.

and Walsby 1975; Keating 1978; Horne 1979; Trimbee and Prepas 1987). Recreational sites that have high percentages of blue-green algae typically display 'algal bloom' problems that occur near the shoreline of a site. This taxa of algae contains the photosynthetic pigment chlorophyll *a* which is, debatably, the major contributor to algal blooms. In general, the development of summer blue-green algal blooms in Alberta is triggered by high water temperatures and the onset of low dissolved oxygen concentrations over bottom sediments, which often results in high total phosphorus concentrations (Mitchell and Prepas, 1990). Total phosphorus concentrations can affect the percentage of blue-green algae and fish population which are the focus of our study. Our assumption is as the percentage of blue-green algae increases, the probability of site choice decreases.

Turbidity and color also affect water transparency. In some shallow water courses, the water may contain suspended silt as well as algae. Turbidity is a measure of particle scattering or the amount of suspended material such as mud, silt and algae. The standard international unit for turbidity is the Nephelometric Turbidity Unit (NTU) and increases in NTU indicate higher counts of suspended material. This measure of quality is used mainly in river and stream analysis. Highly stained or colored water indicates the amount of humic material in the water. Humic color is measured by comparing filtered water to a mixture of platinum (Pt)-cobalt compounds and is presented as units of Pt. Color is often high in water that flows through muskeg or bogs and picks up humic matter. An important consideration for measuring color is the drainage basin around lakes and rivers where humic material tends to concentrate. Northern boreal forests are known to contain a high degree of muskeg or bog material in their soil stratum and thus color is a consideration in our analysis. Increases in both turbidity and color are assumed to decrease the probability of site choice as they are negative aesthetically.

4.1.4 Fish Stock Attributes

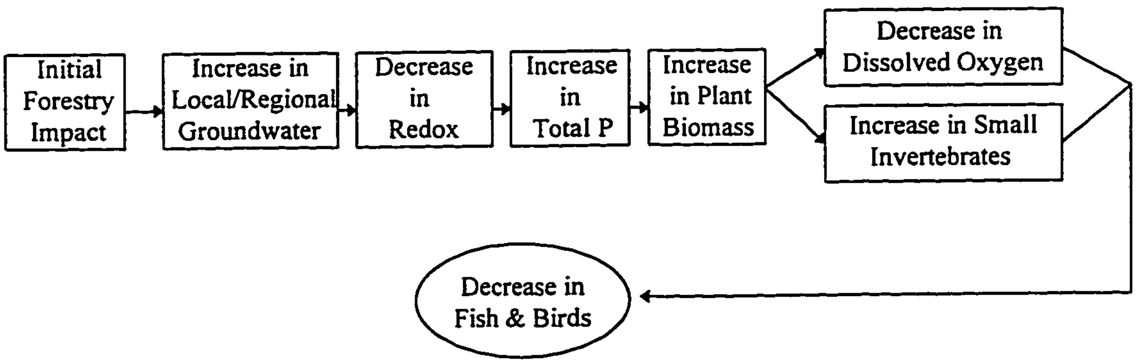
The fish stock attributes are one of the main environmental elements in this analysis. The stock variables were predicted using total phosphorus. Total phosphorus is the key environmental factor regulating the biological productivity of many lakes and rivers (Dillon and Rigler, 1974; Jones and Bachman, 1976; Smith, 1979; Peters, 1986). Consequently, studies of lakes and rivers have shown that there is a strong relationship between phosphorus concentrations and *fish yields* (FY) for lakes and *total fish standing crop* (TFSC) for rivers (Hanson and Leggett, 1982; Yurk and Ney, 1989). Stream research has also long suggested that there is a relationship between stream fertility and TFSC (Kofoid, 1903; Thompson and Hunt, 1930; Hubbs, 1933; Swingle, 1953; Larimore and Smith, 1963; Herrman, 1981). Using total phosphorus as a key state variable was also a matter of recourse due to the decentralized database on fish yields in northern Alberta. Thus predictors were used to calculate fish harvests for the sites. Predictions of fish harvest also contribute to site choice through the angler's perception of catch rates (Carson et al., 1989; Russell and Vaughan, 1982). It is also important to note that this study is not suggesting that total phosphorus is a negative parameter to lake and river fertility. In fact, the converse has been proven to be true up to a threshold level. Phosphorus additions to lakes and rivers can actually increase the level of fish stocks, but beyond a critical level, can be negative by affecting the amount of dissolved oxygen. However, the critical level of phosphorus is site-specific and since we lack such information, we assume that each lake or river may suffer from additional phosphorus loadings from forestry operations in the watershed area. The causal links to forestry are elaborated below.

The link between changes in total phosphorus concentrations due to forestry and its impact on fish stocks is depicted in Figure 8. The drainage basin or watershed is the region of concern when analyzing these impacts.[33] The removal of trees from the area increases the amount of water circulating through the soil (transpiration) since trees absorb groundwater for growth. The absence of trees also increases the amount phosphorus and nitrogen returning to the groundwater.[34] It is believed that, in the case of northern Alberta's boreal forest, nitrogen levels will remain fairly constant, but phosphorus will increase after the forestry impact (Prepas, personal communication). Saturated groundwater soils, which possess an upper *oxidized* layer where benthic organisms occur and a lower *reduced* layer where oxygen becomes

[33] In the past, analysis focused on the area immediately surrounding the lake or river. New research has indicated that the impact should be analyzed through the hydrological or watershed area.
[34] There is another concern that total phosphorus loadings into lakes and rivers can be attributed to surface runoff if the operations venture close to shore; but with the advent of buffer strips, this is less of a concern than in the past. It is hypothesized that the *average* contribution of local and regional groundwater to total nutrient loadings is approximately 30%. Depending on the site-specific hydrological setting of the catchment area, the range of impact can vary substantially; other considerations include topography, soils and vegetation (E. Prepas, 1997).

depleted, or redox potential[35], allow more phosphorus to pulse through to the lake or river. Increased phosphorus and nitrogen loadings promote algae and plant growth (Schindler et al., 1978; Prepas and Trew, 1983). Increased algal biomass uses up more available dissolved oxygen (DO) and increases the number of small benthic invertebrates or "course" species[36] (Bowlby and Roff, 1986). Course species are in competition with larger sport fish and birds for food sources and an increase in small invertebrates, may decrease sport fish (Bowlby and Roff, 1986). In sum, the combined decrease in DO and increase in course species, decrease sport fish and bird habitats.[37]

Figure 8: Hydrological and Nutrient Flow Impacts on Fish and Bird Groups



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[35] This subsurface layer is also known as the oxidation-reduction zone. For a detailed explanation of the chemical and physical exchanges between the upper oxidized layers and the reduced zone, see Odum (1971).

[36] Russell and Vaughan (1982) discuss the possibility that variations in dissolved oxygen will promote the growth of "courser" species of fish and the value of these species is less than the more desirable sport fish.

[37] There exists the possibility of a "top-down effect" of lower DO, inclusive to the "bottom-up (groundwater) effect", on fish habitats. The top-down effect is the possible increase in winterkill due to lower DO. This compounds the effect of decreased DO.

For our analysis, we examine the welfare impacts on anglers from a decrease in fish stocks caused by an increase in total phosphorus loadings. The true impact of an increase in total phosphorus loadings on water clarity or sport fish has not been determined at this point for our specific sites. This research is still ongoing and is expected to confirm, to some degree, the causal linkages in Figure 8. Given this limitation, we rely on expert opinion and realize that these increases in total phosphorus will have an associated range of impacts. The actual level of impact on stocks is discussed in more detail in Section 4.4.1: The Impact of Changes in Water Quality and Fish Yields.

Returning to our model variables, we expect the two estimates of FY and TFSC to be positively signed and a decrease in either will decrease the probability of site choice.

4.1.5 Social Demographic Attributes

The individual specific variables chosen from the NRBS data set were *the number in the household* and *age*. The absolute value of each variable may be interesting to the model, but this can not be examined as this leads to a mathematical estimation problem. Thus each are interacted with distance, which may be more relevant.[38] The interpretation of distance interacted with the number in the household is larger families will be more reluctant to travel far distances. The sign on the

[38] The purpose of interaction is to avoid a singular Hessian matrix in estimation and also to avoid variable exclusion leading to specification error. If we were to exclude these variables, we would be strictly imposing the assumption of demand homogeneity and individuals would not be differentiated within the modeling framework.

estimate should be negative and increases in this value will decrease the probability of choosing a site. The interaction of age and distance is interesting since it asks the question: "Will older people travel further?" If this sign is positive, this could be interpreted as older people having more time or a retirement factor influencing site choice. A negative sign means older people are not willing to travel further, possibly due to health reasons. The sign on this coefficient can not be determined at this point.

4.2 Nested Model Development

Given the variable descriptions above and the nesting structure proposed in Chapter 2: Recreational Demand Theory, we can now specify the conditional indirect utility functions. The utility specifications deal with differences in alternative specific attributes across sites. It is suspected that some of the recreational variables should not be included in the river utility function, since lakes are usually more developed. Thus campground *facilities*, *swimming*, *beaches*, *playgrounds* and *boat launches* are not included in the river function. The boating and fishing restriction variables may be significant in both models, but the management variables of stocking and fishery are more particular to lakes than rivers. Very few rivers in the northern boreal are stocked or have managed fisheries (1996 Alberta Guide to Sportfishing). The park variable was considered for both since it was found that many rivers had historical sites or parks near by. Forest fires were included in the lake and river functions due to the indiscriminatory nature of fire. Of the water quality variables, it was noted that Secchi depth is particular to lakes and turbidity to rivers, while color and percentage of blue-green algae are applied to both. Fish population indicators, fish yield and total fish standing crop, are also unique to lakes and rivers, respectively. The two social variables are included in both functions as these are individual specific, not alternative specific, attributes. The separation of lakes and rivers is to avoid correlation across alternatives, not individuals. The lake and river utility function specifications are listed in Table 1.

Table 1: Conditional Indirect Utility Functions for Lakes and Rivers

Conditional Indirect Utility Functions	
V^L*(Lakes)*	V^R(Rivers)
Distance	Distance
Distance * Campsites	Distance * Campsites
Facilities	-
Dayuse	Dayuse
Swimming	-
Beaches	-
Playgrounds	-
Boat Launch	-
Boating Restrictions	Boating Restrictions
Local Development	Local Development
-	Paved Road Access
In a Provincial Park	In a Provincial Park
Forest Fire	Forest Fire
Stocked	-
Managed Fishery	-
Fishing Restrictions	Fishing Restrictions
Secchi Depth	-
-	Turbidity
Color	Color
% Blue-Green Algae	% Blue-Green Algae
Fish Yield	-
-	Total Fish Standing Crop
Distance * Number	Distance * Number
Distance * Age	Distance * Age

4.3 Estimation and Results

The estimation process was performed in LIMDEP Version 7.0 (Greene, 1995). Due to the internal limitations of the program, only a maximum of 75 alternatives could be analyzed. Initially the model had 109 sites, thus a strictly northern Alberta analysis could not be performed. The northwestern regionalization of our model involved 58 alternative sites and was within the internal limits.

4.3.1 FIML Nested Discrete Choice Multinomial Logit Model

The estimation results for the nested MNL model are shown in Table 2 at the end of this section. The overall significance of the model was high. A likelihood ratio test yielded a χ^2 value of 139.62 which was greater than the critical value for a 5% confidence limit (P= 0.05). Estimated coefficients that are positive can be interpreted as increasing the probability of choosing a site while a negative sign implies a decrease in the probability. Since the estimated utility function for lakes is different from rivers, the parameters in Table 2 are labeled lake (L), river (R) or both (B).

The price proxy, distance, was found to be highly significant and negative indicating the higher the travel costs, the lower the probability of site choice. Of the recreational variables tested, many were found to have a high degree of significance and the signs were in the right direction. The exceptions were campsites, facilities, swimming, beaches and fish stocking programs. The absolute number of campsites were initially found to be insignificant. Distance was then interacted with campsites (Distance-Camp) to reflect the assurance campers need to get a spot the further they travel, but the variable became significantly negative. This was due to the overwhelming influence of distance (negative) over campsites (positive). Campsites were then interacted with day-use areas (Camp-Dayuse) and found to be significant and positive. Facilities and beaches were insignificant in the model, while swimming was significant and negative. This result for facilities may be due to the correlation with day-use areas and local development, and similarly between swimming and beaches. Preliminary descriptive statistics indicated a high degree of correlation between most the recreational attributes. Fish stocking programs were also found to be negative and significant. This outcome may reveal the preference of anglers to fish for more naturally occurring stocks rather than human-induced stocking. A more likely explanation is that stocking is correlated with the managed fishery variable. Another fact about stocked sites is that only 9 out of the 58 sites had stocked fish. Whether low frequency is influencing the estimate is debatable.

The water quality attributes in the model included Secchi depth, turbidity, color and the percent of blue-green algae. Secchi depth was significant and as it increased, so did the probability of choosing a particular lake site. An interesting interaction was performed between Secchi depth, swimming and boat launches. Secchi when interacted with swimming or boat launches remained significant and positive, indicating that lake water clarity is important when associated with these two activities. These results were not included in the final model so as to simplify the interpretation and overall contribution of Secchi depth to the model.

Color and turbidity were initially found to be insignificant and positive. Subsequent interaction with other variables, as Secchi was, did not yield any change. The model that yielded the highest significance (model χ^2, as well as individual *t*-ratios) included log(color) in the lake utility function and log(turbidity) in the river utility function. These logarithmic transformations were found to be significant, but positively signed. These results imply that higher color and turbidity are desirable attributes. This is counter-intuitive and refutes the result with Secchi depth. It is possible that Secchi depth or percent blue-green algae are capturing the same value. Secchi depth was, to a fairly high degree, negatively correlated with color and turbidity, and positively correlated with percent blue-green. The final water quality variable, percent of blue-green algae, was found to be significant and negative implying that increases in this variable subtracted from choosing the site.

Both fish yield and total fish standing crop were found to be significant and an increase in either increased the probability of site choice. The specific transformations that yielded the highest significance were predicted from total phosphorus. These equations were described in section 3.6: Fish Habitat Predictions.

The social characteristics of the respondents were interacted with distance to reflect the changing nature of the variable with respect to distance, everything else held constant. The resultant estimate (Distance-Number) indicates that as the number of people in the household increases, they are not willing to travel as far due to the distance factor. Larger families cost more, in time and money, to transport over longer distances. The age variable was found to be only significant at the 20% confidence level, but the interpretation is still provided. The positive coefficient indicates that as the age of a respondent increases they are willing to travel further. This is understandable if we were to take the time available to retirees into account.

Another possible explanation is older people with families are willing to take trips further away during vacation time in the summer.

Table 2: Estimation Results for the FIML Nested Discrete Choice MNL Model

Variable	*Coefficient*	*Standard Error*	*t-ratio*	*p-value*
*Distance [B]	-0.009012	0.00080948	-11.133	0.00000
Recreational Attributes				
*Distance-Camp [B]	-0.000014324	0.0000026548	-5.395	0.00000
Facilities [L]	0.15629	0.14726	1.061	0.28853
*Camp-Dayuse [B]	0.0018834	0.00027893	6.752	0.00000
*Swimming [L]	-0.75425	0.31726	-2.377	0.01744
Beach [L]	0.1983	0.20707	0.958	0.33823
*Playground [L]	1.0988	0.20364	5.396	0.00000
*Boat Launch [L]	0.82391	0.25265	3.261	0.00111
*Boating Restrictions [B]	-0.15781	0.030328	-5.204	0.00000
*Local Development [B]	-0.48391	0.068342	-7.081	0.00000
*Access [R]	1.5506	0.13018	11.911	0.00000
*In a Park [B]	0.65115	0.076578	8.503	0.00000
*Forest Fire [B]	0.01925	0.0017149	11.225	0.00000
*Stocked [L]	-0.83937	0.10141	-8.277	0.00000
*Managed Fishery [L]	0.40619	0.12552	3.236	0.00121
*Fishing Restrictions [B]	-0.466	0.093704	-4.973	0.00000
Water Quality Attributes				
*Secchi Depth [L]	0.3533	0.099732	3.543	0.00040
*Log (Color) [L]	0.65302	0.08477	7.703	0.00000
Log (Turbidity) [R]	0.063517	0.033731	1.883	0.05969
*% Blue-Green Algae [B]	-0.020082	0.0033284	-6.034	0.00000
Fishing Predictions				
*Fish Yield [L]	0.03691	0.0040775	9.052	0.00000
*TFSC [R]	0.012533	0.0025683	4.88	0.00000
Socio-Demographics				
*Distance-Number [B]	-0.00067576	0.00014159	-4.773	0.00000
Distance-Age [B]	0.000022378	0.000016546	1.352	0.17624
Inclusive Values				
*LAKE	0.54342	0.066737	8.143	0.00000
*RIVER	0.90425	0.11725	7.712	0.00000

* - Statistically significant at the 5% confidence level.

B - Parameter specified in both lake and river utility functions.

L - Specified in only the lake utility function; R - Specified in only the river utility function.

4.4 Welfare Measures

The welfare measures provided in Table 3 are the household per trip compensating variations (CV) of a change in water quality and sportfishing. CV was calculated by incorporating the estimated coefficients from Table 2 above, into equation (12) from Chapter 2: Welfare Theory. Equation (12) measures the difference in an individual's utility before and after an environmental quality change. To convert CV (a utility measure) into a money measure we multiply the difference in CV by one over the marginal utility of income, $1/\mu$. The marginal utility of income is calculated by dividing the estimated coefficient on distance (price) by the average cost of travel per kilometer, 42.3 cents[39] (Alberta Motor Association, 1995). Remembering that the distance was a one-way calculation, we multiply the cost per kilometer by two ($\mu = \beta_{Dist}/(2*0.423)$). The measures below are negative since CV is, by construction in this case, a welfare loss.

To examine how CV changes across households, the total number in the household was varied from a larger family of four to a smaller household of two. The belief is larger families should incur greater losses associated with detrimental quality changes. The total number in the household was the only significant social variable, thus age is not included in the analysis. As a result, number in household is the only individual specific variable differentiating respondents. For computational simplicity, a representative household from the city of Peace River was chosen since it was geographically located in the center of the study region and forestry activity was

[39] This is the average full cost per kilometer, for an intermediate sized car, that averages 20,000 km of travel per year.

present in this area. A representative agent (case) has been used in this manner before as a practical solution to the aggregation and demand heterogeneity issues (Fletcher et al., 1990).

4.4.1 The Impact of Changes in Water Quality and Fish Yields

The alternative-specific impacts of a change in water clarity and fish stocks are reflected in the following variables: Secchi depth, percent blue-green algae (%BG), fish yield (FY) and total fish standing crop (TFSC). Color and turbidity were not considered since turbidity was not highly significant and color was incorrectly signed due to colinearity with Secchi and %BG. As we are concerned with the potentially negative impacts of forestry, we decrease the clarity of water by lowering Secchi depth and increase the percentage of blue-green algae. Since the true impact of an increase in total phosphorus on Secchi depth is uncertain, we decrease Secchi depth by a conservative 5 and 10 percent. As %BG is a positively increasing function of total phosphorus (see Appendix A, equation (19)), we raise total phosphorus (TP) by 10% and this increases the level of algae in the water.[40] The impact of an increase in TP on fish stocks is also under investigation, hence we decrease FY and TFSC by 5 and 10 percent. In sum, the welfare estimates measure the difference in household utility after a decrease in Secchi depth, increase in %BG and a fall in fish stocks.

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[40] The 10% increase is not arbitrary. It is the expert opinion of the Ecologically Based Sustainability (EBS) component of the SFM-NCE that the potential TP increase falls into this range. It is also important to note that larger increases should not be examined as this could affect the static analysis performed in predicting fish stocks; we would be on a different portion of the fish yield curve, whereby explicit yield curve specification would be necessary.

In Table 3, a decrease in lake Secchi depth represents a welfare loss to the household. Depending upon the magnitude, significant losses can result from small changes in lake Secchi due to the large estimated coefficient. Increases in the percentage of blue-green algae, from a 10% increase in TP, are also significant since both lakes and rivers are subject to the impact. As fish populations decrease this represents a welfare loss to the people who fish. Observing the welfare change from 5 to 10 percent, this increases the average loss by 48% ($-2.64 and $-2.76 to $-5.15 and $-5.38). The possibility also arises that an increase in TP may change several of the above attributes simultaneously. The combined effect of an increase in the percent of blue-green algae (from a 10% increase in TP) and a 10% decrease in fish stocks reveals a significant loss to the Peace River household. The individual-specific result of altering the number in household did not change the CV loss by any significant amount; a few cents in most cases. This follows from the small estimated coefficient and therefore changes in household size can be interpreted as not affecting the welfare loss to any significant degree.

The total welfare loss across all respondents is not provided here[41], but by multiplying the individual attribute losses by the total number of trips taken in the sample, 2333, a representative welfare loss can be created. The numbers in parenthesis in Table 3 give the sample loss for each attribute change. Although some appear quite small, we should remember that these are from a sample of 180

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[41] The total welfare loss would involve summing the welfare losses associated with every household (180). The analysis provided here examines two households in Peace River (a family of 2 and 4) with a choice of 58 alternative sites. The total northwestern Alberta welfare loss would involve 180x58 calculations.

Table 3: Household Per Trip Welfare Impacts of Changes in Water Quality and Sportfishing

Quality Change	*2 in Household*	*4 in Household*
5% ↓ in Secchi Depth	$ -2.66 ($-*6206*)	$ -2.67 ($-*6229*)
10% ↓ in Secchi Depth	-5.28 (*-12318*)	-5.30 (*-12365*)
10% ↑ in TP on % Blue-Green Algae	-3.80 (*-8865*)	-3.83 (*-8935*)
5% ↓ in Fish Yield and Total Fish Standing Crop	-2.64 (*-6159*)	-2.76 (*-6439*)
10% ↓ in Fish Yield and Total Fish Standing Crop	-5.15 (*-12014*)	-5.38 (*-12552*)
10% ↑ in TP on % Blue-Green & 10% ↓ in Fish Yield and TFSC	-8.97 (*-20927*)	-9.23 (*-21534*)

Note: Numbers in parenthesis represent the total sample (2333 trips) welfare loss associated with the attribute.

individuals and are more than likely underestimated. According to the descriptive statistics in the NRBS Synthesis Report, total recreational activity in the northern river basins is estimated to be about 1.84 million trips per year, with fishing comprising 29 percent of the recreational trips. Camping and swimming each account for another 18 percent of trips with boating and canoeing at 16 and 4 percent, respectively. The estimated total number of trips across these five activities is 1,559,700 and total user days is 11,796,900 (MacLock and Thompson, 1996, pg. 33-35). Multiplying our per trip welfare measures by these calculations yields very high figures. For example, swimming had an estimate of 336,700 trips, multiplied by a 5% decrease in Secchi depth ($-2.66), is a loss of $895,622; and for a 10% increase in blue-green algae ($-3.80), the loss is $1,279,460. A 10% decrease in fish stocks ($-

5.15), with 525,800 estimated total trips, represents a loss of $2,707,870. In addition, these figures are annual household losses. To correctly factor these values into a benefit/cost analysis, they should be summed, and discounted, over the forest harvesting time horizon (rotation period).

In summary, the CV welfare formulation used here measures the non-timber value of sportfishing and the ecological service value of water clarity, which are then added to other market expenditures on recreation, for a more comprehensive value of the resource. If forestry practices negatively effect water quality or sport fishing experiences, decreasing site frequency, the non-timber and ecological service value of the site falls.[42] A fall in these values have broad policy implications at a local and regional level. The potential policy impacts are discussed in the next section: Summary, Model Limitations and Discussion.

[42] The value of each activity, in general, could also fall assuming no substitution occurs (exit from the recreational activity); but it is more likely that entry and exit will occur at the site level, not at the overall activity level.

Chapter 5 Summary, Model Limitations and Discussion

5.1 Summary

This study analyzed the impact of forestry on water quality and sportfishing values for 58 recreational sites in northwestern Alberta. A nested discrete choice travel cost model was estimated with recreational, water quality, fish stock and social demographic variables to explain site choice. A one level nesting structure, separating lakes and rivers into two distinct conditional indirect utility functions, accommodated for the recreational and biological differences between lakes and rivers.

Significance was found in a large number of the recreational variables with the exceptions of campground facilities and beaches. It is suspected that the insignificance stems from correlation between other recreational variables. Distance interacted with the number of campsites was found to be negative due to the overwhelming negative influence of distance. Age, interacted with distance, was not significant. Swimming, fish stocking, turbidity and color were significant but incorrectly signed, which leads us to believe that the correlation problem applies here as well. Despite the shortcomings with the above variables, overall model significance was high, exceeding the critical value at the 5% confidence limit (P = 0.05).

The welfare analysis considered a decrease in Secchi depth, an increase in the percentage of blue-green algae, and a decrease in fish yields for lakes and rivers. A representative household was chosen from the city of Peace River and the number in the household was varied between two and four. The decrease in Secchi depth decreased welfare to a large extent due to the large estimated coefficient. An increase in the percentage of blue-green algae (%BG) also affected welfare negatively for small changes in total phosphorus. The potential welfare losses associated with Secchi and %BG show that water clarity is an important consideration in recreational site choice. The impact of a decrease in fish yields by 5 and 10% reveals a large welfare loss to the recreationist. As was stated at the introduction of this paper, sportfishing values from an expenditure side are very important for Alberta. The significant welfare losses estimated here confirm the existence of large ecological values for water clarity and sportfishing. These should be included along with other non-timber values in the benefits measure to capture the non-market value of the resource.

5.2 Model Limitations

Recreational demand models which have a large number of alternatives are often suspected to have multicolinearity amongst the attributes. In our case, attribute colinearity may occur across similar lakes or similar rivers, but not between lakes and rivers since the model was nested. In the original NRBS data set, over 400 alternatives existed. After deleting non-responses and low frequencies, sites that were overlapping (geographically) were merged or aggregated.[43] Thus to a degree, the

[43] Although aggregation is a convenient way around some of the colinearity issues, the aggregation process is often ad hoc and may lead to specification problems. The upshot is biased welfare measures. For a discussion of the aggregation issue see Parsons and Needelman (1992).

remaining sites were well differentiated from a recreational and biological standpoint. Model sensitivity to the choice set should ultimately be performed to verify that the choice set is robust in estimation.

Another issue with respect to nesting is the magnitude of the estimated coefficient on variables that are included in both utility functions. Estimation would not yield the same coefficient if they were run as separate models. This is a concern with nesting, where modes often share common variables in their associated utility functions. For example, the coefficient on percent blue-green algae would be different across the two modes as the absolute levels differ between lakes and rivers. As an improvement to the overall model, although not specifically addressing the coefficient problem, another nesting level could be added to further differentiate large and small lakes or rivers. Additional nesting would also address some of the concerns relating to the transferability of the prediction equations across different sizes of lakes or regions.

The NRBS social data were a limiting factor on differentiating individuals within the modeling framework. As was noted in Chapter 3, the NRBS social data appeared to be designed for descriptive rather than analytical purposes and main economic variables were not included. A key variable for socio-economics is income. This variable, along with subsequent interactions, would reveal how individuals, in different income brackets, respond to environmental quality changes in water and fishing. An expenditure question on water-based activities, of some sort, would have also provided a similar interpretation.

The calculated marginal utility of income term, μ, was simplified and represented a lower bound estimate of the welfare loss. An important consideration would be the inclusion of the value of time (VOT) spent on the activity. Depending on the assumptions underlying the VOT, welfare measures can vary dramatically. The simplest assumption is that the VOT does not matter, but this is unrealistic as people do make observable tradeoffs between work and leisure. The actual value to use is contentious since the VOT may differ across alternative activities and blocks of time (Fletcher et al., 1990). This also raises the issue of comparability between different activities and time lengths. For instance, a commuter trip that involves one hour of road travel per day (work-related) may have a different value than a week-end fishing trip at the family cabin (leisure-related). In our case, we need to distinguish between alternative recreational activities. To improve our measure, the opportunity cost of travel time *to* a recreational site and the time spent *at* the site, should be factored in.[44] For practical purposes most measures have centralized around some transformation of the individual's income or wage. If we include the value of travel time to a site in our analysis, the result is obviously a larger welfare loss since it is an additional cost to the individual or a benefit to the site.[45] We must exercise caution when incorporating the VOT. If we differentiate respondents with respect to their

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[44] For a good discussion and suggested readings on the value of time in travel cost models, refer to Fletcher et al., 1990.

[45] The addition of the opportunity cost of *travel time* could be easily factored in if we assume everyone has the same value of travel time. We could augment the marginal utility of income by the addition of another cost term: $\mu = \beta_{Dist}/((2*0.423)+(\underline{2*0.1523}))$. The second term is the average hourly manufacturing wage rate for an average work week of 37.5 hours (converted to cents per kilometer), multiplied by the two way travel to a site (Statistics Canada, personal communication). The larger denominator yields higher welfare losses to the household. The value of time spent *at the site* could be different from the above, but would follow the same method of inclusion.

individual opportunity costs of time, we violate the homogeneity assumption of the marginal utility of income when calculating CV according to equation 12. To solve this problem one would have to calculate the individual CV for each respondent in the sample. To the extent that our welfare measures do not incorporate a value of time, they are underestimates of the true loss to the household.

The prediction equations used for the water quality and fish yield variables were not site-specific. For the analysis presented here, the question arises of how "transferable" are the prediction equations. To the best of this researcher's knowledge, limnological prediction does borrow from other geographical locations with sites that possess similar variable limits or ranges. Ultimately, water sampling and creel studies in northern Alberta would provide such information. At this point in time, the study area is under investigation for the linkages between TP and aquatic biomass.[46] The incorporation of a specific relationship between TP and fish stocks would improve the welfare impact analysis and decrease uncertainty in the measure. Due to timing issues, site-specific results were not available for inclusion into this paper.

5.3 Discussion

The welfare calculations revealed potential benefits from water quality and recreational fishing. Although the trip numbers indicated in the NRBS synthesis report gave a more representative loss to the region, these values still pale in

[46] The EBS component of the SFM-NCE is primarily responsible for this investigation.

comparison to the timber revenues generated by forestry companies. So what are the incentives for treating these values as significant? Firstly, the interpretation of these ecological values is that they are one layer, of many, that should ultimately be valued. Other service flows include recreational hunting, camping, hiking and so forth. Combined, these activity values can be significantly higher than the two attributes investigated in this study. Secondly, these values are per annum measures and over the 60-70 year rotation period of most boreal stands the loss of these values can be significant, especially when recreational expenditures are factored in. As well, the loss in recreational or tourism expenditures, across all activities in an FMA region, can affect the public's perception of forestry activity or even of a particular company. The resultant impact of public perception may be very valuable to the company in the bid to renew their FMAs on an "evergreen" basis.[47]

Although modern forest harvesting techniques try to reflect disturbances that occur in nature, this may not hold in our analysis. For example, cut blocks are usually designed around forest fire patterns mimicking natural fire cycles. Turning over the soils, with machines, is another technique used to aerate the soils before revegetation. These attempts each have their own purpose or goal, but in our case alternative harvesting techniques cannot mimic the nutrient-cycling that occurs between the soils and the hydrological system around lakes or rivers. Specifically, the exchange of total phosphorus will not be the same.

[47] Alberta FMAs are normally 20 to 25 years in length, with the option to renew on an evergreen basis.

In response to the potential impacts of deforestation around lakes and rivers, forestry companies have created protective zones or buffer strips, where no cutting occurs. Their initial purpose was to preserve visual aesthetic and wildlife values, but are now being incorporated into landscape management units (LMUs) where all values are taken into account.[48] The mitigation effectiveness of varying buffer widths, to alleviate phosphorus impacts, is dependent on the site-specific soil and hydrological conditions that exist. Buffer widths will have to be designed around the watershed area rather than just visual aesthetics or cost-effective grid-like patterns. Although there is little argument over the positive aspects of buffer zones, preliminary investigation indicates that the required watershed analysis would be a time consuming and costly process of dealing with the impacts on lakes and rivers. If provincial governments require such detailed site assessments in Forestry Management Agreements, this cost will have to be factored into the feasibility of harvesting a particular site. This additional cost impact may delay harvesting in a certain area and in others, may even be unfeasible given the non-timber and ecological services the forest provides. To this extent, forestry companies are becoming partners in the interdisciplinary research effort to understand the environmental values in the forest and what value society places on them.

The importance of understanding the environmental relationships that occur in a watershed area cannot be over emphasized. Forestry operations that do not consider

[48] LMUs are defined as a heterogeneous environmental configuration repeated across several kilometers (Olson, 1997). The LMU area that pertains to this study, the watershed or hydrological setting, is one of many that requires effective management.

non-timber values run the risk of irreversibly damaging sensitive areas which currently have significant value, but due to budgetary constraints, have not been fully quantified. From a regional policy standpoint, the results of this study show that the non-timber or ecological service values of water-based recreation are highly dependent on water clarity and sportfishing. At the provincial policy level, the feasibility of continuing programs such as Alberta Fish and Wildlife's fish stocking program are also based on the estimated value of water-based recreation. Thus it is important to continue non-timber valuation at a watershed and terrestrial level surrounding lakes and rivers. Given the CCFM's criteria and indicators at the outset of this paper, we see the beginnings of this process in the form of defining where forest companies should focus resources. It is the continuing research objective of the SFM-NCE to understand these values along with other biological and social relationships, bringing us closer to a more complete definition of sustainable forestry management.

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Appendix A: Water Quality and Fish Yield Predictors

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As mentioned in previous sections, some water quality parameters for northern Alberta lakes and rivers have not been comprehensively compiled by Alberta Environmental Protection, thus predictors were sought to compensate for any data gaps. Predictors are often used in limnology to establish relationships between key state and map parameters. In our case, the use of predictors was limited, for all variables, to avoid increasing the variability of the coefficient in estimation.

A.1 Chlorophyll *a*

The data for chlorophyll *a* (Chl *a*) were not as complete as with total phosphorus (TP). Chl *a* was used as a variable in the prediction of fish harvest below, thus a predictor for Chl *a* using TP was constructed. The article selected for the analysis, by Prepas and Trew (1983), evaluated the phosphorus-chlorophyll relationship for lakes off the Precambrian Shield in Alberta. Their findings show that summer TP is the best predictor of summer Chl *a* by:

(16) $$\text{Log(Chl } a) = -0.661 + 1.146\ \text{Log(TP)su}, \quad r^2 = 0.81,\ n = 34$$

where (TP)su is the summer TP. This predictor was found to be the most significant when there exists substantial variation in the seasonal patterns of TP. The use of equation (16) requires caution as this estimate did not remove saline lakes from the subset in estimation. For our purposes, only one saline lake was identified in the choice set, Saskatoon Lake (TP = 836 µg/L), with a trip frequency of 83 trips or 3.6%

of total trips. Thus the use of equation (16) should not bias any predictions to a large degree.

A.2 Secchi Depth

Secchi depth has long been an indicator of the trophic state of natural waters due to the simple and inexpensive collection process. Secchi depth was considered for lakes in this analysis since it is an observable water quality parameter to the recreationist. The paper chosen for the analysis of Secchi depth is by Håkanson (1995). His study estimated Secchi depth using different combinations of state variables (total P, lake color and pH) and map parameters (i.e. percent of rock in the catchment, Rock % and Lake % of drainage area, etc.) over various sampling periods (i.e. 12 or 36 months). The total sample consisted of 88 Swedish lakes that are of similar geomorphology as what could be found in northern Alberta.[49] For our analysis, Secchi depth (Sec12) was selected and calculated using a stepwise regression of the form:

$$(17) \quad \text{Log(Sec12)} = 1.172 - 0.05 * \sqrt{\text{Color}}12 - 0.219 * \text{TP12}^{0.2}, \quad r^2 = .80, \text{n} = 63$$

where 12 is a yearly mean and TP is total phosphorus measured in μg/L. This predictor was chosen for its high r^2 from estimation and it contained the state parameters collected for this study. Note that increases in Color or TP, decrease

[49] There are about 83,000 lakes in Sweden, of which about 81,000 belong to this type (small glacial lakes). The same proportions ought to apply also for Finland, Canada, Russia and northern USA (Håkanson, pg.37). The lake parameters in our analysis needed to fall within the range (min./max.) specified in Håkanson's 88 lake sample. Most of the lakes met this requirement.

Secchi depth. The assumption for this study is decreases in Secchi depth will decrease the probability of choosing a site.

A.3 Percentage of Blue-Green Algal Biomass[50]

The relative proportion of blue-green algae (%BG) in total phytoplankton biomass has been considered an important water clarity attribute for this study as many Alberta lakes and rivers are naturally eutrophic and require a variable to capture this effect on recreational aesthetics. According to Trimbee and Prepas (1987), total phosphorus (TP) is a key state variable in the prediction of blue-green algal biomass. To predict blue-green algae, Trimbee and Prepas (1987) updated the sampling information from a study completed by Smith (1986). The data were then transformed, to approximate a normal distribution, with the equation:

(18) $$\text{BG index} = \ln(\%BG / (100 - \%BG))$$

where %BG is the percent of total phytoplankton biomass made up by blue-green algae. The BG index can range from - 4.595 (%BG = 1) to 4.595 (%BG = 99). With the transformed data, they estimated several BG indices with the best predictor, based on TP, as:

(19) $$\text{BG index} = -5.00 + 2.62 \log TP, \qquad r^2 = 0.63, n = 36$$

Using our sample TP values for each site, individual BG indices in (19) were calculated and factored into (18), rearranged as:

---

[50] This section, including the predictors and discussion, is paraphrased from Trimbee and Prepas (1987).

(20) $$\%BG = \frac{100e^{BGindex}}{1 + e^{BGindex}}$$

to arrive at the %BG predictions for the 58 lakes and rivers. As TP increases, %BG will increase and it is assumed that this will create unpleasant water conditions for recreational activities.

A.4 Fish Yield for Lakes and Total Fish Standing Crop for Rivers

Fish yield (FY) and total fish standing crop (TFSC) are not discussed at length here since this topic is covered in sections 3.6, "Fish Habitat Predictions" and 4.1.4, "Fish Stock Attributes". What is provided here are the other fish stock predictors initially modeled, but found to be less significant than those covered in the main text.

Three other alternative measures for lake fish yield were estimated and one other for river total fish standing crop (TFSC). For lakes, a predictor by Jones and Hoyer (1982), based on chlorophyll *a*, was estimated in the model. Jones and Hoyer (1982) argue that the relationship between mean summer phytoplankton standing crop (Chl *a*) and angler harvest is stronger than that between fish yield and total phosphorus, alkalinity or the morphoedaphic index (total dissolved solids/mean lake depth). The equation modeled was:

(21) $$\text{Fish Harvest (kg/ha)} = -1.8 + 2.7\,(\text{Chl } a), \quad r^2 = 0.91,\ n = 25$$

Since chlorophyll *a* data were not as complete, increasing variability, this predictor did not perform as well as those based on TP. Two other predictors were by Peters (1986) who found that total phosphorus, alone, can be used in the determination of many biological variables. The two fish yield measures that refer to our application were:

(22) Fish Yield (mg ww/m^2*yr) = 7.1(TP), $r^2 = 0.87$, n = 21,

(23) Fish (mg ww/m^2) = 590($TP^{0.71}$), $r^2 = 0.75$, n = 18

where the units are in milligrams wet weight per meter squared (annually) and TP was in mg/m^3. The significance of equation (22) was as high as equation (13) by Hanson and Leggett (1982) used in the final model. The two were practically interchangeable in estimation. The only difference was that (13) had slight more significance and FY was conveniently in the same units (kg/hectare) as TFSC.

Hoyer and Canfield (1991) estimated a linear and non-linear function for TFSC for rivers. Both predictors used data on 79 North American streams located in Wyoming (n=20), Vermont (n=19), Florida (n=15), Iowa (n=12), Ontario (n=20), Washington (n=2) and Missouri (n=1). In their paper the initial linear model, of the form:

(24) Log(TFSC) = 0.59 Log (TP) + 0.82, $r^2 = 0.79$, n = 79

did not fit some of the river sites. More specifically, the model did not accurately predict TFSC for rivers with low levels of TP. The critical value for TP hovered around 15 μg/L. Thus two regressions were estimated, one for TP ≤ 15 μg/L and one for TP > 15 μg/L.[51] Our findings indicated that the non-linear model out-performed the linear model. For our analysis, there were 7 rivers with TP ≤ 15 μg/L and 20 with TP > 15 μg/L. It is suspected that the non-linear model out-performed the linear

[51] See section 3.6 "Fish Habitat Predictions" for the two TFSC equations.

model due to the 7 rivers with low TP. These 7 rivers are highly frequented with 306 total trips or 13% of the total number of trips taken. Therefore, the 7 rivers possess quality attributes that are important to households.

Appendix B: The NRBS Household Survey

VERSION ONE

Canada Alberta Northwest Territories

Northern River Basins Study Household Questionnaire

Part I. Introduction

Your telephone number ____________________

Thank you for agreeing to answer this questionnaire. One of the objectives of the study is to find out how Northerners use and value the Peace, Athabasca and Slave Rivers. Your household was selected at random to help provide this information. We need your cooperation to answer a series of questions about how you and members of your household make use of the water resources of the region. We are collecting information from about 1,200 households. Individual responses will be kept confidential.

Part II. General Questions

1a. Where are you currently living? *(Circle one answer.)*

A. Town/city (specify) ____________________ *(Go to question 2.)*
B. Farm
C. Cottage/rural subdivision
D. Native reserve
E. Metis settlement
F. Other (specify) ____________________

1b. *(if B to F selected)* What is the name of the closest city, town, hamlet or village?

____

2. How long have you been living in this location? *(Circle one answer.)*

A. Less than 1 year
B. Between 1 and 5 years
C. Between 5 and 10 years
D. Between 10 and 15 years
E. Between 15 and 20 years
F. More than 20 years

3. How long have you been living in the Peace, Slave or Athabasca River basins? *(Circle one answer.)*

A. Less than 1 year
B. Between 1 and 5 years
C. Between 5 and 10 years
D. Between 10 and 15 years
E. Between 15 and 20 years
F. More than 20 years

4. Which one of the following major rivers is nearest your current residence? *(Circle only one answer.)*

A. Athabasca River
B. McLeod River
C. Pembina River
D. Peace River
E. Wapiti River
F. Smoky River
G. Little Smoky River
H. Wabasca River
I. Slave River

5. About how far away is this river from your current residence?

_____ Kilometre Or _____ Miles

6. Do you identify yourself as? *(Circle one answer.)*

A. Aboriginal ——> Are you on a registered Tribal roll? Yes _____ No _____
B. Metis
C. Non-native

7. Which of the following categories best describes your household? *(Circle only one answer.)*

A. Single person
B. Couple with no children
C. Couple with children
D. Extended family
E. Single parent family
F. Two or more unrelated adults
G. Two or more related adults
H. Other *(describe below)* _____

8. Including yourself, how many people are in your household? _____ people

9. Of these, how many are in the following age categories?

A. Under 5 years old _____
B. 5 to 9 years old _____
C. 10 to 14 years old _____
D. 15 to 19 years old _____
E. 20 to 34 years old _____
F. 35 to 44 years old _____
G. 45 to 54 years old _____
H. 55 to 64 years old _____
I. 65 years and older _____

10. How old are you? _____

11. Are you? _____ Male _____ Female

12. In which industries are you and members of your household currently employed? *(Circle all that apply.)*

A. Agriculture
B. Trapping/commercial fishing
C. Oil and gas
D. Forestry (logging)
E. Manufacturing (lumber, paper, etc.)
F. Construction
G. Transportation/communications/utilities
H. Retail or wholesale trade
I. Finance, insurance, other services
J. Government (health, education)
K. Unemployed
L. Other *(describe below)* _____

Part III. General Use of Water Resources

The next part of this questionnaire asks some general questions about how you and members of your household use the water, fish, plants and wildlife in the river basin.

13. What is the source of your household's everyday drinking water? *(Circle one answer.)*

A. Municipal water plant ——> *(Go to question 15)*
B. Bottled water ——> *(Go to question 15)*
C. Well
D. Lake water Which lake? _____
E. River water Which river? _____
F. Dug out
G. Spring water
H. Other *(describe)* _____

14. Do you treat this water in any way before drinking it?

_______ Yes (*describe*) _______________
_______ No

15. Are there any problems with the amount of water available from this source throughout the year?

_______ Yes (*describe*) _______________
_______ No

16. Are there any problems with the quality of water available from this source throughout the year?

_______ Yes (*describe*) _______________
_______ No

17. Over the last 10 years, have there been any noticeable changes in the quality or amount of water available from your usual water supply?

_______ Yes (*describe the changes you have noticed such as amount, smell, colour, taste, clarity*) _______________
_______ No

18. Do you agree or disagree with each of the following statements?
(Check only one answer for each question.)

	Totally Agree	Agree	Disagree	Totally Disagree	Unsure
A. Water quality in the Peace, Athabasca and Slave Rivers is not really a major issue at the moment so new restrictions on industrial, agricultural or municipal water use are not required.					
B. Pollution of northern rivers is only a concern in a few locations and more enforcement of existing standards will solve these problems.					
C. Contamination of northern rivers is a major problem and some industries or municipalities should be forced to reduce effluent discharges, even if it means closing some operations.					
D. Existing water management regulations are interfering with economic development in the region and should be reduced or eliminated.					
E. New effluent discharges should not be allowed until a river basin plan has been completed.					

Part IV. Subsistence Use of Water Resources

19. Do you or any members of your household use any water resources for subsistence? By subsistence, we mean harvesting fish or wildlife only for your consumption or as a source of income.

_______ Yes
_______ No ——> *(Go to Yellow Section, Page 11, Question 39.)*

20. How often do you or members of your household participate in the following subsistence activities? *(Check appropriate answer for each activity.)*

	Daily	Weekly	Monthly	Yearly
Fishing				
Trapping				
Hunting				
Other *(specify below)*				

____

Subsistence fishing

If you or members of your household do <u>not</u> participate in subsistence fishing, go to Question 27.

21a. List the three main species of fish and indicate how many pounds of these fish you and members of your household actually catch in an average year.

Name of species	Average annual catch *(specify pounds or kilograms)*
#1	
#2	
#3	

21b. Of these three species of fish, which would you prefer to catch. *(List in order of preference.)*

Preference	Name of species
#1	
#2	
#3	

22. In which three main bodies of water do you and members of your household usually fish and what proportion of your total catch comes from each? *(List in order of importance.)*

Importance	Name of water body	Percent (%) of annual catch
#1		
#2		
#3		

23. Do you or members of your household fish in the mainstems of the Athabasca, Peace or Slave Rivers or any of their major tributaries?

_______ Yes _______ No

If yes, please indicate the three most important sites along these rivers and indicate the proportion of total catch that comes from each location. *(To help describe the site, use the* *__nearest major landmark__* *that people would know.)*

Importance	Name or Description of Site	Percent (%) of annual catch
#1		
#2		
#3		

24. Over the past 10 years, have you or any members of your household noticed any changes in the number, quality or health of fish you have caught?

_______ Yes _______ No

If yes, describe the types of changes you have noticed.

Number: ______________________________
Quality: ______________________________
Health: ______________________________
Other: ______________________________

25. Of the fish you catch, how much of the total annual catch:

	Percent (%) of annual catch
Is eaten by you and members of your household?	
Is given away or sold to others for their consumption?	
Is fed to dogs or other animals?	

26. How many pounds or kilograms of caught fish does a typical person in your household consume in an average week?

_____ Pounds OR _____ Kilograms OR _____ Number of fish eaten

Subsistence trapping

If you or members of your household do *__not__* *participate in subsistence trapping, go to Question 32.*

27a. List the three main species of furbearers and indicate how many of these animals you and members of your household __actually__ trap in an average year.

Name of species	Average annual catch *(specify pounds or kilograms)*	Average number of animals trapped per year
#1		
#2		
#3		

27b. Of these three furbearers that you trap, which would you prefer to trap. *(List in order of importance.)*

Preference	Name of species
#1	
#2	
#3	

28. Describe the location of your trapping area or if you are a registered trapper, indicate your registered trapline number. *(To help describe the area, use the nearest major landmark that people would know.)*

____

____

____

29. Do you or members of your household trap within 10 kilometres (6 miles) of the mainstems of the Athabasca, Peace or Slave Rivers or any of their major tributaries?

_______ Yes _______ No

If yes, please indicate the three most important locations along these rivers and indicate the proportion of total catch that comes from each location. *(To help describe the area, use the nearest major landmark that people would know.)*

Importance	Name or Description of Site	Percent (%) of annual catch
#1		
#2		
#3		

30. Over the past 10 years, have you or any members of your household noticed any changes in the number, quality or health of the furbearers you trapped?

_______ Yes _______ No

If yes, describe the types of changes you have noticed.

Number: ____

Quality: ____

Health: ____

Other: ____

31. Do you or members of your household eat any parts of the animals you trap?

_______ Yes _______ No

If yes, please indicate the type of animal you trap, all portions of the animal you eat, and the number of animals that your household eats in an average year.

Type of Animal	Parts eaten	Number eaten per year

Subsistence hunting

If you or members of your household do not participate in subsistence hunting, go to Question 39.

32. In an average year, about how many animals do you or members of your household kill for food (subsistence hunting) each year?

_______ Animals killed

33a. List the three main species of animals and indicate how many of these animals you and members of your household actually hunt and kill in an average year:

	Type of animal	Number killed per year
#1		
#2		
#3		

33b. Of these three species of animals, which would you would prefer to hunt? *(List in order of importance.)*

Preference	Type of animal
#1	
#2	
#3	

34. Do you or members of your household hunt within 10 kilometres (6 miles) of the mainstems of the Athabasca, Peace or Slave rivers, or any of their major tributaries?

_______ Yes _______ No

If yes, please indicate the three most important sites along these rivers and indicate the proportion of total kills from each location. *(To help describe the area, use the nearest major landmark that people would know.)*

Importance	Name or Description of Site	Percent (%) of animals killed
#1		
#2		
#3		

35. Over the past 10 years, have you or any members of your household noticed any changes in the number, quality or health of animals killed for food?

_______ Yes _______ No

If yes, describe the types of changes you have noticed.

Number: ____________________
Quality: ____________________
Health: ____________________
Other: ____________________

36. Of the animals that you have killed, what proportion of the meat:

	Percent (%) of animals killed
Is eaten by you and members of your household?	
Is given away to others for their consumption?	
Is fed to dogs or other animals?	

37. How many pounds or kilograms of wild game meat does a typical person in your household consume in an average week?

_______ Pounds **OR** _______ Kilograms

General questions

38. While you are subsistence fishing, trapping or hunting, do you ever consume or use river or lake water?

_______ Yes _______ No

If Yes, do you treat this water in any way before drinking it?

_______ Yes *(describe how)* ____
_______ No ____

Part V. Recreational Activities

39. For each of the following recreational activities, please indicate how often you or members of your household participate in the activities listed below. Also indicate the average length of trips in days and the average number of household residents participating on these trips.

Main Activity	Number of trips in an average year	Average length of trip (days)	Average number of household members on the trip
Fishing			
Boating			
Swimming (lakes/rivers)			
Canoeing			
Camping			
Hunting			
Other			

40. List in order of preference, the sites on rivers and lakes that you and members of your household visit most often for recreational purposes. Also, indicate the usual recreational activity on these trips, the number of trips to each site in an average year, and the main reason for preferring this site. *(To help describe the area, use the <u>nearest major landmark</u> that people would know.)*

	Site #1	Site #2	Site #3
Site name or description			
Usual activity			
Number of trips per year			
Main reason for preferring site			

41. Do you or members of your household use the mainstems of the Athabasca, Peace or Slave Rivers, or any of their major tributaries for recreational purposes?

_______ Yes _______ No *(If No, go to Question 45.)*

If yes, please describe the three locations along these rivers that you use most often, indicate the usual recreational activity at each site, and state the number of trips taken to each site in an average year. *(To help describe the area, use the <u>nearest major landmark</u> that people would know.)*

	Site #1	Site #2	Site #3
Site name or description			
Usual activity			
Number of trips preferring site			

42. List, in order of importance, the three species of fish that you prefer to catch recreationally from themainstems of the Athabasca, Peace or Slave Rivers or any of their major tributaries and indicate how many pounds or kilograms of these fish you and members of your household catch in an average year from these locations. *(Include the numbers of fish you keep and release.)*

Importance	Type of fish	Average annual recreational catch *(specify pounds* OR *kilograms)*
#1		
#2		
#3		

43a. On average, about how many pounds or kilograms of fish caught from these locations do you and members of your household consume per year?

_______ Pounds OR _______ Kilograms OR _______ Number of fish eaten

43b. Which, of these fish species you catch recreationally, do you eat?

44. On average, about how many pounds or kilograms of fish caught from these locations is given away to others?

_______ Pounds OR _______ Kilograms OR _______ Number given away

45. Over the past 10 years, have you or any members of your household noticed any changes in the water, fish, animals or plants along the mainstems of the Athabasca, Peace or Slave Rivers or any of their major tributaries?

_______ Yes _______ No

If yes, describe the types of changes you have noticed.

Water: ______________________________
Fish: ______________________________
Animals: ______________________________
Plants: ______________________________
Other: ______________________________

46. When involved in water-based recreational activities in the region, do you ever consume river or lake water?

_______ Yes _______ No

If yes, do you treat this water in any way before drinking it?

_______ Yes *(describe how)* ______________________________
_______ No ______________________________

Part VI. Agricultural Water Use

47. Are you or any members of your household involved in farming of any sort?

_______ Yes
_______ No ——> *(If No, go to White Section, Page 15 Question 57.)*

48. Which of the following terms best describes your farming operation? *(Circle one answer.)*

A. Grains/oilseeds
B. Mixed farming (grain and livestock)
C. Specialty crops *(describe)*_______________
D. Livestock only ——> *(Go to question 55.)*

49. How many acres do you plant or harvest in an average year? _______ acres

50. Please list the types of crops you grow.

____
____
____

51a. Do you irrigate any of these crops?

_______ Yes _______ No
If yes, what is the source of this water? *(Name the waterbody.)*_______________

51b. Do you have a water license? _______ Yes _______ No

51c. Home many acres of land do you irrigate in an average year? _______ acres

51d. How much water (total volume) do you use in an average year?_______ acres-feet OR
_______ inches/acre/year

52. Do you use any herbicides?

_______ Yes _______ No

If yes, please list the types of herbicides you normally use and the amount (by weight or by volume) applied in an average year.

Name or brand of herbicide	Amount applied in an average year *(specify weight or volume)*
1.	
2.	
3.	
4.	
5	
6.	
7	
8.	

53. Do you use any pesticides?

_______ Yes _______ No

If yes, please list the types of pesticides you normally use and the amount (by weight or by volume) applied in an average year.

Name or brand of pesticide	Amount applied in an average year *(specify weight or volume)*
1.	
2.	
3.	
4.	
5	
6.	
7	
8.	

54. Do you use any fertilizers?

_______ Yes _______ No

If yes, please list the types of fertilizers you normally use and the amount (by weight or by volume) applied in an average year.

Name or brand of fertilizers	Amount applied in an average year *(specify weight or volume)*
1.	
2.	
3.	
4.	
5	
6.	
7	
8.	

Farmers without livestock, go to Question 57.

55. How many of each of the following types of livestock do you have?

Type of livestock	Number
1. Cattle	
2. Horses	
3. Pigs/swine	
4. Sheep	
5. Poultry	

Other livestock *(specify)*	Number
6.	
7.	
8.	
9.	
10.	

56. Please describe how you normally dispose of livestock manure.

____

____

____

Part VII Water Management Values and Issues

57. Although this section appears to be lengthy, the answers to these questions are very important. We appreciate you taking the time to complete these questions. In your opinion, what three factors have had the greatest effect on the amount or the quality of water in the major river basin in which you live (Peace, Athabasca or Slave) over the last 20 years?

Factor 1. ____________________
Factor 2. ____________________
Factor 3. ____________________

Thinking about the first factor you mentioned:

58. Describe the ways in which it has affected water quality, fish, wildlife, vegetation or the health of the river.

Factor 1. ____________________

59. Describe the ways in which it has affected you or members of your household.

Factor 1. ____________________

60. If no steps are taken to control your Factor 1, describe how you think the health of the rivers will be affected over the next 10 years.

Factor 1. ____________________

61. If no steps are taken to control your Factor 1, describe how you think the health of members of your household will be affected over the next 10 years.

Factor 1. ____________________

62. If the Northern River Basins Study were to suggest ways for managing this problem, what actions do you think they should recommend?

Factor 1. ____________________

Thinking about the second factor you mentioned:

63. Describe the ways in which it has affected water quality, fish, wildlife, vegetation or the health of the river.

Factor 2. ____________________

64. Describe the ways in which it has affected you or members of your household.

Factor 2. ____________________

65. If no steps are taken to control your Factor 2, describe how you think the health of the rivers will be affected over the next 10 years.

Factor 2. ____________________

66. If no steps are taken to control your Factor 2, describe how you think the health of members of your household will be affected over the next 10 years.

Factor 2. ____

____

67. If the Northern River Basins Study were to suggest ways for managing this problem, what actions do you think they should recommend?

Factor 2. ____

____

Thinking about the <u>third factor</u> you mentioned:

68. Describe the ways in which it has affected water quality, fish, wildlife, vegetation or the health of the river.

Factor 3. ____

____

69. Describe the ways in which it has affected you or members of your household.

Factor 3. ____

____

70. If no steps are taken to control your Factor 3, describe how you think the health of the rivers will be affected over the next 10 years.

Factor 3. ____

____

71. If no steps are taken to control your Factor 3, describe how you think the health of members of your household will be affected over the next 10 years.

Factor 3. ____

____

72. If the Northern River Basins Study were to suggest ways for managing this problem, what actions do you think they should recommend?

Factor 3. ____

____

73. Below are three groups of potential threats to water quality and water quantity in the northern river basins. For each of the three groups, please indicate in the side boxes:

the one that you are most concerned about and
the one that you are least concerned about.

(Answer each group on its own. Overlap among groups has been done on purpose.)

Group 1:

Most concern *(check only one)*	Threat to water quality/quantity	Least concern *(check only one)*
	1. Agricultural run-off (pesticides, herbicides, fertilizers)	
	4. Draining wetlands and muskeg	
	5. Discharges of municipal sewage	
	7. River flows controlled by dams	

Group 2:

Most concern *(check only one)*	Threat to water quality/quantity	Least concern *(check only one)*
	1. Agricultural run-off (pesticides, herbicides, fertilizers)	
	2. Groundwater contamination	
	5. Discharges of municipal sewage	
	8. Discharges from pulp mill	
	9. Airborne pollutants	
	11. Industrial wastes/tailing ponds	

Group 3:

Most concern *(check only one)*	Threat to water quality/quantity	Least concern *(check only one)*
	4. Draining wetlands and muskeg	
	5. Discharges of municipal sewage	
	6. Seismic exploration/road and pipeline development	
	7. River flows controlled by dams	
	8. Discharges from pulp mills	
	9. Airborne pollutants	
	10. Uranium contamination (e.g. Lake Athabasca)	
	11. Industrial wastes/tailing ponds	

74. For each of the three groups of management actions listed below, please indicate in the side boxes:

the one that you think would be the most effective in dealing with current problems and
the one that you think would be the least effective.

(Answer each group on its own. Overlap among groups has been done on purpose.)

Group 1:

Most effective *(check only one)*	Management action	Least effective *(check only one)*
	1. Change land use practices (forestry, agriculture) to reduce erosion and pollution	
	4. Protect traditional fishing, hunting & trapping	
	5. Enforce existing pollution laws	
	7. Preserve and maintain ecosystems	

Group 2:

Most effective *(check only one)*	Management action	Least effective *(check only one)*
	1. Change land use practices (forestry, agriculture) to reduce erosion and pollution	
	2. Improve municipal wastewater treatment	
	5. Enforce existing pollution laws	
	8. Make polluters pay an annual fee based on the volume they produce	
	9. Improve treatment of municipal drinking water	
	11. Develop a management plan for the entire basin	

Group 3:

Most effective *(check only one)*	Management action	Least effective *(check only one)*
	4. Protect traditional fishing, hunting & trapping	
	5. Enforce existing pollution laws	
	6. Reduce industrial effluent loads	
	7. Preserve and maintain ecosystems	
	8. Make polluters pay an annual fee based on the volume they produce	
	9. Improve treatment of municipal drinking water	
	10. Increase monitoring of water quality	
	11. Develop a management plan for the entire basin	

75. One of the responsibilities of the Northern River Basins Study is to assess the health of northern rivers. Describe the three most important ways that you would measure the health of a river. *Please write in your response to the first question in the boxes provided. For the other questions, circle one answer per box.*

Measure 1	Measure 2	Measure 3

76.

	Measure 1	Measure 2	Measure 3
A. How do you think this measure of river health has changed over the last 20 years?			
B. How often do you think this measure of river health should be monitored?	A. Hourly B. Daily C. Weekly D. Monthly E. Yearly F. Every 5 years G. Every 10 years	A. Hourly B. Daily C. Weekly D. Monthly E. Yearly F. Every 5 years G. Every 10 years	A. Hourly B. Daily C. Weekly D. Monthly E. Yearly F. Every 5 years G. Every 10 years
C. Who do you think should be responsible for monitoring this measure of river health?	A. Government B. Industry C. Universities D. Independent agency E. Public F. Other	A. Government B. Industry C. Universities D. Independent agency E. Public F. Other	A. Government B. Industry C. Universities D. Independent agency E. Public F. Other
D. Who do you think should be responsible for paying for monitoring this measure of river health?	A. Government B. All water users C. Industrial water users D. Other	A. Government B. All water users C. Industrial water users D. Other	A. Government B. All water users C. Industrial water users D. Other

77. What are the three most important recommendations you would like the Northern River Basins Study to make?
#1 ________________
#2 ________________
#3 ________________

78. Please list any recreational, environmental, agricultural or professional organizations to which you or any members of your household belong.

____

79. Do you have any other comments that you would like to make to the Northern River Basins Study?

____

Thank you for completing this survey. Please return it in the self-addressed stamped envelope provided before February 15th, 1995.

Appendix C: Model Variables

Appendix C: Table 4: Model Variables

Recreational Attributes	Measurement
Origin/Destination Distance	Kilometers (one way)
Distance * Campsites	Kilometers * Number of Campsites
Campground Facilities	0 = Limited Facility 1 = Fully Serviced
Camp * Day-Use Area	# of Campsites * Day-Use Area (1=Yes; 0 =No)
Swimming	1 = Yes ; 0 = No
Beach	1 = Yes ; 0 = No
Playground	1 = Yes ; 0 = No
Boat Launch	1 = Yes ; 0 = No
Local Development (resort)	1 = Little ; 3 = Fully Developed
Access Road Paved	1 = Yes ; 0 = No
Stocked	1 = Yes ; 0 = No
Managed Sportfishery (local)	1 = Yes ; 0 = No
Fishing Restrictions (local)	1 = Yes ; 0 = No
Boating Restrictions	0 = No Restrictions 1 = Power Boats (limited) 2 = Small Crafts Only 3 = No Boating Allowed
In A Park (Provincial)	1 = Yes ; 0 = No
Forest Fire (1931-1995)	Years since last fire
Water Quality Attributes	
Secchi Depth	Meters
Turbidity	Nephelometric Turbidity Units (NTU)
Color	Milligrams/Liter Platinum-Cobalt (Pt)
Percent Blue-Green Algae	Percent out of total algae species present
Fish Stock Attributes	
Fish Yield	Kilograms/Hectare
Total Fish Standing Crop	Kilograms/Hectare
Social Demographics	
Distance * Number in Household	Kilometers * Number in Household
Distance * Age of Respondent	Kilometers * Age of Respondent

Appendix D: Quality Attributes for the 58 Sites

Appendix D: Quality Attributes for the 58 Sites

Site	Name	Number of Campsites	Facility	Day-Use Area	Swimming	Beach	Play Ground	Boat Launch	Boating Restrict	Local Develop.
92	Baptiste Lake	50	1	1	1	1	0	1	1	3
151	Beaver Lake	140	0	1	1	0	0	1	1	1
246	Cadotte Lake	0	0	0	0	0	0	0	0	1
52	Canyon Creek	15	0	0	0	0	0	0	0	3
102	Carson Lake	182	1	1	1	1	1	1	1	3
41	Figure Eight Lake	42	0	1	1	1	1	1	2	2
131	Freeman Lake/Swan Hills	6	0	1	0	0	0	0	2	1
261	Gerry Lake	0	0	0	0	0	0	0	0	1
58	Grande Cache Lake	22	0	1	0	1	0	0	0	1
65	Gregoire Lake	140	1	1	1	1	1	1	1	2
244	Haig Lake	6	0	0	0	0	0	0	0	1
170	Hastings Lake	40	0	0	0	0	1	1	0	1
32	Hilliards Bay	189	1	1	1	1	1	1	1	3
49	Hutch Lake	11	0	1	1	1	0	1	0	1
262	Iosegun Lake	50	0	1	1	1	0	1	1	1
100	Isle Lake	18	0	1	1	1	1	1	1	2
89	Leddy Lake	0	0	0	0	0	0	0	0	1
5	Lesser Slave Lake Prov. P.	113	1	1	1	1	1	1	1	3
60	Long Lake Prov. P.	220	1	1	1	1	1	1	1	2
42	Pine Lake	1080	1	1	1	1	1	1	1	3
76	Queen Elizabeth Prov. P./Lac Cardinal	55	0	1	1	1	1	1	1	2
10	Saskatoon Lake	96	1	1	1	1	1	1	1	3
17	Smoke Lake	47	0	1	1	1	0	1	1	2
16	Snipe Lake	0	0	0	0	0	0	0	0	1
26	Spring Lake/Edmonton Beach	336	1	1	1	1	1	1	1	1
31	Spruce Point Park	182	1	1	1	1	1	1	1	3
8	Sturgeon Lake	222	1	1	1	1	1	1	1	3
129	Thunder Lake	127	1	1	1	1	1	1	1	2
44	Twin Lakes	60	0	1	1	1	1	1	2	1
23	Two Lakes	86	0	0	0	0	0	1	1	1
12	Winagami Lake	64	1	1	1	1	1	1	1	3
63	Athabasca R. at Ft.McMurray	41	1	1	0	0	0	0	0	3
29	Athabasca R. at Jasper	1147	1	1	0	0	1	0	0	3
39	Athabaska River at Whitecourt	164	1	1	0	0	1	1	1	3
97	Big Berland	12	0	0	0	0	0	0	0	1
394	Boyer River	8	0	0	0	0	0	0	0	1
9	Cadotte River	0	0	0	0	0	0	0	0	1
47	Chinchaga/Meander River Confl.	8	0	0	0	0	0	0	2	1
37	Dunvegan Park on Peace River	67	0	1	0	0	1	0	1	1
316	Heart River Dam at High Praire	0	0	0	0	0	0	1	1	1
267	Holmes Crossing East at Ft. Assiniboine	15	0	1	0	0	0	0	0	1
75	Lesser Slave River	20	0	0	0	0	0	1	0	1
285	Little Paddle River at Mayerthorpe	30	0	1	0	0	1	0	0	2
6	Little Smoky River	19	1	0	0	0	0	0	0	2
172	Lobstick R./Pembina R. Prov. P. Confl.	130	1	1	1	1	1	0	2	2
95	Macleod River at Whitecourt	70	1	1	0	0	1	0	0	2
278	N Sask River at Drayton Valley	48	1	1	0	0	1	1	1	2
90	Notikewin Park by Peace R.	19	0	1	1	1	0	0	0	1
11	Peace River at Ft. Vermilion	10	0	1	0	0	0	0	1	1
157	Pembina River Prov. P. at Entwistle	130	1	1	1	1	1	0	2	2
266	Redwillow R./Wapiti R. Confl.	5	0	1	1	0	1	0	2	1
85	Richardson River	2	0	0	0	0	0	0	0	1
22	Smoky River at Grande Praire	13	0	1	0	0	0	1	0	1
80	Tangent Park on Smoky River	84	0	1	0	0	1	1	2	2
50	Tompkins Landing by Peace R.	0	0	0	0	0	0	0	0	1
45	Wabasca River	0	0	0	0	0	0	0	0	1
21	Wapiti R./Pipestone Creek Confl.	99	1	1	1	0	1	1	1	2
2	Whitemud River	0	0	0	0	0	0	0	0	1

Quality Attributes for the 58 Sites

Site	Name	Access Road Paved	In A Park	Forest Fire	Stocked	Managed Fishery	Fish Restrict	Total P ug/L	CHLa ug/L	pH Level	Color mg/L Pt
92	Baptiste Lake	1	0	2	0	1	1	65	28	8.2	23.5
151	Beaver Lake	1	1	47	0	1	1	33	10.6	8.3	32.5
246	Cadotte Lake	0	0	1	0	0	0	110	66.4	7.8	60
52	Canyon Creek	1	0	47	0	0	0	28	9.1	7.3	25.23
102	Carson Lake	1	1	54	1	0	1	24.5	10.9	7.86	10
41	Figure Eight Lake	1	1	0	1	1	1	75	38.1	8.58	28
131	Freeman Lake/Swan Hills	0	0	0	0	0	0	37.3	12.4	7.8	50
261	Gerry Lake	0	0	0	0	0	0	108	64.6	8.1	6.73
58	Grande Cache Lake	1	0	2	0	0	0	16.8	4.36	8.46	26.9
65	Gregoire Lake	1	1	0	0	1	1	23	6.2	7.5	23
244	Haig Lake	0	0	14	0	0	1	40	15.3	7.85	22.4
170	Hastings Lake	0	0	0	1	1	0	115.5	72.5	9	10.1
32	Hilliards Bay	0	1	0	0	1	1	22.2	6.5	7.3	60
49	Hutch Lake	1	0	0	0	0	1	214	174.1	7.6	290
262	Iosegun Lake	1	0	0	0	1	1	52.6	23.9	8.7	17.9
100	Isle Lake	0	0	0	0	1	1	109	65.5	8.4	22.4
89	Leddy Lake	0	0	0	0	0	0	62	28.9	8.1	9.24
5	Lesser Slave Lake Prov. P.	1	1	51	0	1	1	12	2.7	7.3	25.23
60	Long Lake Prov. P.	1	1	0	0	1	0	48.2	25	8.4	16
42	Pine Lake	1	0	0	1	1	1	54.8	26.3	8.4	18.6
76	Queen Elizabeth Prov. P./Lac Cardinal	1	1	0	0	0	0	286.3	265.4	8.14	23
10	Saskatoon Lake	1	1	0	1	1	1	835.5	49.1	9.06	41
17	Smoke Lake	0	0	0	0	1	1	39.2	25	8.4	21.3
16	Snipe Lake	0	0	39	0	0	1	97.8	56	7.98	12.3
26	Spring Lake/Edmonton Beach	1	0	0	1	1	1	21	8	8.4	10
31	Spruce Point Park	1	0	0	0	1	1	28	9.1	7.3	25.2
8	Sturgeon Lake	1	1	3	0	1	0	65.9	45.2	8.2	19
129	Thunder Lake	1	1	0	1	1	0	49	20.6	7.95	66
44	Twin Lakes	1	0	0	1	0	0	45.1	18.2	8.4	23
23	Two Lakes	0	0	3	0	0	0	12	2.7	8.3	16
12	Winagami Lake	1	1	2	1	1	1	123.4	81.3	8.6	200
63	Athabasca R. at Ft.McMurray	1	0	0	0	0	0	43	17	7.93	20
29	Athabasca R. at Jasper	1	1	0	0	0	0	13.2	3.07	7.7	39
39	Athabaska River at Whitecourt	1	0	28	0	0	1	8.3	1.57	7.88	20
97	Big Berland	1	0	0	0	0	0	5.9	0.96	8.14	2
394	Boyer River	1	0	0	0	0	0	33	11.6	7.73	145
9	Cadotte River	0	0	0	0	0	0	249.1	217	8.08	60
47	Chinchaga/Meander River Confl.	1	0	0	0	0	0	86	46.5	7.5	115
37	Dunvegan Park on Peace River	1	1	0	0	0	0	47	19.4	7.81	20
316	Heart River Dam at High Praire	0	1	0	0	0	0	119.1	74.5	7.69	65
267	Holmes Crossing East at Ft. Assiniboine	1	0	0	0	0	0	28.5	9.4	7.96	10
75	Lesser Slave River	1	0	0	0	0	0	18.7	5.1	7.92	15
285	Little Paddle River at Mayerthorpe	1	0	0	0	0	0	245	211.8	7.8	110
6	Little Smoky River	1	0	39	0	0	1	17.5	4.63	7.9	25
172	Lobstick R./Pembina R. Prov. P. Confl.	1	1	0	0	0	0	14.6	3.55	7.91	48
95	Macleod River at Whitecourt	1	0	0	0	0	0	8.1	1.51	7.91	9
278	N Sask River at Drayton Valley	1	0	0	0	0	0	1.93	0.185	8.35	7
90	Notikewin Park by Peace R.	0	1	0	0	0	0	106.2	63.1	7.9	150
11	Peace River at Ft. Vermilion	1	1	54	0	0	0	30	10.1	7.39	25
157	Pembina River Prov. P. at Entwistle	1	1	28	0	0	0	15.7	3.95	7.81	18
266	Redwillow R./Wapiti R. Confl.	1	0	0	0	0	0	15	3.7	8.37	35
85	Richardson River	0	0	17	0	0	0	64.2	30.4	7.26	22
22	Smoky River at Grande Praire	1	0	0	0	0	0	68.3	33.3	7.97	36
80	Tangent Park on Smoky River	1	0	0	0	0	0	54	23.7	8.07	40
50	Tompkins Landing by Peace R.	0	0	0	0	0	0	137.7	91.9	7.71	35
45	Wabasca River	0	0	0	0	0	0	74	37.4	7.59	45
21	Wapiti R./Pipestone Creek Confl.	1	0	52	0	0	0	31	10.6	8.2	30
2	Whitemud River	0	0	0	0	0	0	200	158	8.07	70

Quality Attributes for the 58 Sites

Site	Name	Secchi Depth(m)	Turbidity (NTU)	TDS mg/L	TSS/NFR mg/L	TFSC kg/hectare	Fish Yield kg/hectare (TP)	Blue-Green Index	% B-G Algae
92	Baptiste Lake	2.7	4	188	0	0	5.046433296	-0.250167006	43.77823938
151	Beaver Lake	2.8	0	227	0	0	2.525821947	-1.021493478	26.47365913
246	Cadotte Lake	1.7	24	216	35	0	8.634991841	0.348448835	58.6241375
52	Canyon Creek	2.25	4.75	108	0	0	2.135739845	-1.208445958	22.99761363
102	Carson Lake	3.97	5.28	160	1	0	1.863539369	-1.360384859	20.41777597
41	Figure Eight Lake	2.4	0	131	4.5	0	5.840332191	-0.08733949	47.8178997
131	Freeman Lake/Swan Hills	2.3	3.2	52	0	0	2.862297144	-0.882122861	29.27380632
261	Gerry Lake	3	0	190	0	0	8.474725778	0.327570239	58.11680615
58	Grande Cache Lake	3.4	0	156	2	0	1.267770893	-1.789689682	14.31107736
65	Gregoire Lake	3.3	3.4	60	4.2	0	1.747125573	-1.43227307	19.27447607
244	Haig Lake	3	0	99	0	0	3.073995668	-0.802602823	30.94690253
170	Hastings Lake	2.8	0	573	11.5	0	9.076035918	0.403964799	59.96398718
32	Hilliards Bay	2.4	16.5	108	17	0	1.685102748	-1.472555207	18.65545457
49	Hutch Lake	0.5	6	685	0	0	17.03540499	1.105684086	75.13236164
262	Iosegun Lake	3	0	79	0	0	4.065616823	-0.49101735	37.96539352
100	Isle Lake	2.4	0	161	0	0	8.55485109	0.338057425	58.37185711
89	Leddy Lake	3.3	0	337	0	0	4.808746852	-0.303933774	42.45961223
5	Lesser Slave Lake Prov. P.	3.6	4.75	108	0	0	0.899174645	-2.172545135	10.22431801
60	Long Lake Prov. P.	3.1	0	209	6	0	3.718698992	-0.59041676	35.6539236
42	Pine Lake	2.9	3.5	450	4	0	4.2393078	-0.444394937	39.06942435
76	Queen Elizabeth Prov. P./Lac Cardinal	1.8	0	352	0	0	22.93055659	1.436871932	80.79697847
10	Saskatoon Lake	1	0	740	3.5	0	68.43957907	2.65549971	93.43491541
17	Smoke Lake	3.1	0	91	0	0	3.011237945	-0.825590504	30.45782413
16	Snipe Lake	2.8	2.5	89	4.1	0	7.658363406	0.2146878	55.34667468
26	Spring Lake/Edmonton Beach	4.1	1	341	0	0	1.592157034	-1.535785448	17.71487821
31	Spruce Point Park	3.1	0	108	0	0	2.135739845	-1.208445958	22.99761363
8	Sturgeon Lake	2.8	0	78	1	0	5.117784661	-0.234520214	44.16371965
129	Thunder Lake	1.9	0	212	4	0	3.781727204	-0.57168627	36.08478179
44	Twin Lakes	2.9	2.3	60	4	0	3.474675478	-0.66605746	33.93802027
23	Two Lakes	4.1	0.8	148	0	0	0.899174645	-2.172545135	10.22431801
12	Winagami Lake	0.78	0	247	0	0	9.710302915	0.479245718	61.75697463
63	Athabasca R. at Ft.McMurray	0	20	133	43.3	39.23756197	0	-0.720312646	32.73241398
29	Athabasca R. at Jasper	0	9.32	250	0	52.481863	0	-2.0640963	11.26357591
39	Athabaska River at Whitecourt	0	1.8	248	2	27.2835018	0	-2.592015398	6.965406697
97	Big Berland	0	1.1	172	0	16.8616992	0	-2.980367729	4.832071557
394	Boyer River	0	102	233	268	33.03741777	0	-1.021493478	26.47365913
9	Cadotte River	0	24	186	35	123.4260641	0	1.278499166	78.2194193
47	Chinchaga/Meander River Confl.	0	14	626	5.6	61.70975594	0	0.068385942	51.70898258
37	Dunvegan Park on Peace River	0	32.6	105	42.1	41.64000553	0	-0.619103612	34.99853483
316	Heart River Dam at High Praire	0	27	163	13	76.29047567	0	0.438888815	60.79942258
267	Holmes Crossing East at Ft. Assiniboine	0	38.6	183	31.1	30.05436345	0	-1.188306467	23.35619597
75	Lesser Slave River	0	1.4	115	4	22.8247789	0	-1.667774991	15.87210558
285	Little Paddle River at Mayerthorpe	0	26.3	189	42	122.0862292	0	1.259615141	77.89598493
6	Little Smoky River	0	5.7	309	14.9	21.85301913	0	-1.743240312	14.89018222
172	Lobstick R./Pembina R. Prov. P. Confl.	0	9.05	217	9	60.4975137	0	-1.949395518	12.46192858
95	Macleod River at Whitecourt	0	1.7	207	1.5	26.3611211	0	-2.619769251	6.787689155
278	N Sask River at Drayton Valley	0	4.8	170	4.7	3.48847653	0	-4.25183985	1.403813876
90	Notikewin Park by Peace R.	0	46	161	64	70.79673211	0	0.308446234	57.65059592
11	Peace River at Ft. Vermilion	0	3	111	9.2	31.04163716	0	-1.129942313	24.41717471
157	Pembina River Prov. P. at Entwistle	0	3.9	151	2	20.34551526	0	-1.866742911	13.39190449
266	Redwillow R./Wapiti R. Confl.	0	4.6	193	5	62.8475968	0	-1.918640901	12.80132001
85	Richardson River	0	3.4	52	5	50.9674743	0	-0.264258226	43.43172314
22	Smoky River at Grande Praire	0	24.5	191	29.5	53.10065829	0	-0.193817756	45.16966772
80	Tangent Park on Smoky River	0	32.5	151	10	45.56556457	0	-0.461128349	38.67181822
50	Tompkins Landing by Peace R.	0	20	111	16.5	83.84785948	0	0.604006923	64.65724912
45	Wabasca River	0.48	5.2	326	3	55.94898614	0	-0.102612894	47.43692622
21	Wapiti R./Pipestone Creek Confl.	0	34	174	22	31.72397795	0	-1.092632362	25.11229116
2	Whitemud River	0	112	232	165.5	107.0029347	0	1.028698589	73.66635123

Appendix E: NRBS Copyright Disclaimer

Verbal consent for the use of the NRBS survey, maps and material was given by:

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