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Chapter 8

The Role of Socioeconomic and Behavioral Modeling in an Integrated, Multidisciplinary Dam-Management Study: Case Study of the Boardman River Dams

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Additional information is available at the end of the chapter

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1. Introduction

The Boardman River flows through Grand Traverse and Kalkaska Counties in Northwest Michigan before flowing into Grand Traverse Bay at Traverse City. Approximately two million recreation user days are estimated to occur on the Boardman River each year. Many of these recreators come to fish the river, others enjoy scenic trails, camping, and paddling.

Beginning in 1867, four small dams were constructed on the Boardman. The dams were constructed primarily to generate hydropower. However, as the dams have aged their commercial viability as hydroelectric stations diminished. As a result, Traverse City Light and Power did not seek to renew the leases of those dams. Because of this, the dams' owners (Grand Traverse County and the City of Traverse City) sought a cost-effective, environmentally and socially responsible dam-management outcome. The resulting process is considered one of the most comprehensive studies of its type ever undertaken in the United States. This process created the Boardman River Dams Committee (BRDC), an inclusive and diverse group of property owners, private citizens, agencies, nonprofits, businesses, scientific experts, and students. The BRDC involved over 1,000 people in 180 public meetings and the assessment of 91 options for the future of the dams. In April 2009, the Traverse City Commission and Grand Traverse County Board of Commissioners reviewed the scientific data and recommendations provided by the BRDC, and voted to remove three of the dams and install fish passage on the fourth.

Simulation modeling was an important tool used to aid transparency and decision-making. The implications of physical changes in conditions on the river were integrated mathematically using the over-arching structure of Figure 1.

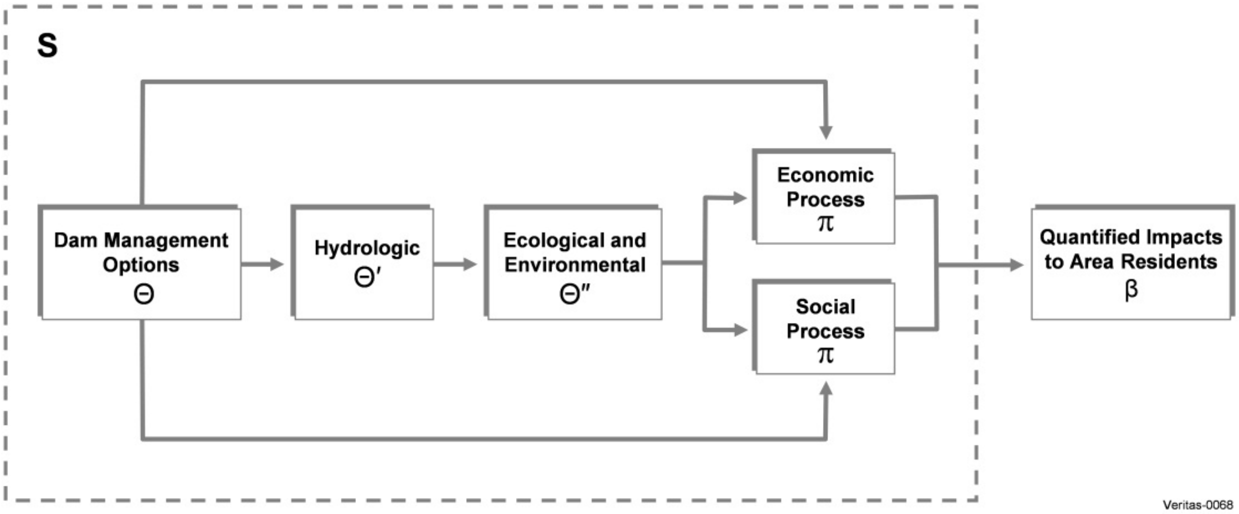

Figure 1. Mathematical notation for the integrated assessment

Mathematically, the Boardman River system was characterized as (S,Θ). In this framework S represents the integrated physical, hydrologic, ecological, environmental, and socioeconomic relationships that link dam management alternatives with socioeconomic outcomes.

Dam-management alternatives that are relevant to local socioeconomic conditions are represented by Θ. Prime notation is used to represent level of control. Factors that can be directly controlled are typically closely coupled to alternative-related physical characteristics such as the existence and operational status of the dams, and presence or absence of fish passage technology.[1] Relevant, indirectly controllable hydrologic, ecologic, and environmental characteristics are represented by Θ' and Θ''.[2] Consequently, the specification of a resource characteristic as Θ means that it is both relevant to socioeconomic processes and either directly or indirectly related to the physical status of the Boardman River dams.

Economic benefit estimates were based on the simulation of observable socioeconomic processes following the structure detailed in [1]. Socioeconomic processes that are impacted by changes to Θ are represented by π. These are specific, continually occurring collections of events. A particular person choosing how to spend a day off is an example of a socioeconomic process as is a real estate transaction.[3] Because the complete properties of socioeconomic processes are rarely observed, quantitatively assessing the system performance requires using indicators. In the mathematical structure, these indicators are identified as β.[4]

[1] By "closely coupled" we refer to changes that can be known with certainty. For example, the removal of a dam also eliminates a portage.

[2] The use of prime notation to represent degree of control (and thus degree certainty) recognizes that expert judgment and reduced form modeling (as opposed to detailed structural modeling) may be used to identify changes to the Θ.

[3] Mathematically this is represented with π, subscripting by i for time periods and j for individuals and superscripting by R for recreation.

[4] These properties are developed as part of the public policy model of [1].

To ensure that they are both mathematically tractable and useful for policy analysis, we require that indicators have the following qualities:

1. They are generated through socioeconomic activities.
2. They are real numbers that can be measured.
3. Evaluating their statistical properties conveys a sense of system performance.
4. Structural simulation modeling allows conducting policy experiments by comparing baseline and counterfactual outcomes.
5. Measures of changes in economic welfare are available from models that simulate changes in the indicators.

Recreational pressure provides an example. Recreational pressure estimates meet requirements 1 and 2 because the number of trips taken to the Boardman River over a particular time period is a measurable quantity that is generated through a socioeconomic process. With respect to requirement 3, recreational pressure does provide an indication of system performance. For example, an estimate of average recreational pressure that is "high" combined with an estimate of variation in pressure that is "low" could indicate "good" performance. As for 4 and 5, behavioral models of recreation site choice are specifically designed to predict both trips and economic welfare under baseline and counterfactual conditions.

With this structure, required information for socioeconomic modeling of the system includes the following:

1. Dam operation characteristics—Θ
2. Recreation site and residential property attributes—Θ
3. Recreational use patterns and values—β
4. Property values—β
5. Dam costs and revenues—β

Because alternatives are evaluated through the identification of changes in Θ and simulation of changes in β, identifying expected changes in β requires characterizing Θ and β in Baseline and mathematically modeling the relationship between Θ and β to allow simulating outcomes under various dam-management alternatives. Following [2], policy implications are identified by evaluating differences across Θ and β in Baseline and counterfactual experiments as a mathematical simulation. This requires identifying Baseline conditions and the mathematical structures that link policies to outcomes.

Information requirements include

1. the population of affected recreators
2. relevant site characteristics for both the site being evaluated and potential substitute sites
3. travel costs from recreator origins to sites.

1.1. The mathematical models

Mathematical models were applied for recreation (fishing, paddling, trails, and camping), economic impacts, hydroelectricity value, and property value.

The mathematical structure applied for recreation is the probabilistic site choice model. This modeling structure, based on choice theory, has the advantages of being professionally accepted, useful for policy-simulation predictions, consistent with economic theory, and capable of identifying resource values.[5]

These models identify the probability of a specific outcome (in this case, the selection of a recreation site), conditioned on the site characteristics of all relevant choices for recreators (e.g., distance from the site to the angler's home, expected catch rates, etc.). In the site choice framework, a recreator chooses a site by comparing characteristics across all sites. The mathematical structure is presented in Equation 1 below.

$$P_i(j) = \frac{\exp(V_{ij})}{\sum_{j=1}^{J} \exp(V_{ik})} \tag{1}$$

where $V_{ij} = f(\Theta, S)$

This equation represents the probability that on any particular recreation choice occasion, a recreator (identified by i) will choose to visit a particular site (identified by j). Note that this likelihood, identified by $P_i(j)$, is determined on the basis of both site characteristics (Θ) and parameters representing the values recreators hold for those site characteristics (S).

This mathematical construct identifies visitation likelihood. However the probability that a recreator will visit a site is not an observable β that can be used to evaluate the performance of the system. Pressure is a closely related and commonly employed β. To estimate pressure for any given site *j*, $P_i(j)$ is summed over all recreators' choice occasions.[6]

The hedonic decomposition of recreation sites into site characteristics and the representation of these site characteristics in the site-choice framework allow an evaluation of important information including changes in visitation probability, changes in site pressure, and changes in resource value. This is accomplished by developing an equivalent mathematical structure with appropriately altered Θ for policy alternatives and finding the difference in trips between this policy simulation model and the base case. Equation 2 presents the mathematics for an individual.

$$AnnualChoiceOccasions_i \left[\frac{\exp(V_{ij})}{\sum_{j=1}^{J} \exp(V_{ik})} - \frac{\exp(\overline{V}_{ij})}{\sum_{j=2}^{J} \exp(\overline{V}_{ik})} \right] \tag{2}$$

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[5] The statistical basis for choice theory is the standard conditional logit model [3, 4].

[6] In the simulation context, this is accomplished by multiplying the likelihood of selecting each site (equation 1) by the total number of trips.

where $V_{ij} = \int(\Theta,S)\overline{V}_{ij} = \int(\overline{\Theta},S)$

Aggregating over individuals identifies changes in trips for each site due to the policy that changes Θ to $\overline{\Theta}$.

Estimates of changes in economic value improve the ability to assess resource performance. The distance from an individual's home to a site is a critical variable in a site-choice model because it represents the fuel cost and travel time required to visit each site.

When distance is converted to travel cost, the site-choice framework supports the calculation of monetary changes in value associated with changes in site characteristics. The mathematical form used to identify dollar-based changes in value associated with a policy that changes Θ to $\overline{\Theta}$ is the difference between the utility levels scaled by the relative impact of travel costs. Equation 3 presents the mathematical structure used to evaluate the change in annual value that a recreator attributes to the policy that changes Θ to $\overline{\Theta}$.

$$CV_i = \frac{AnnualTrips_i}{\phi_i}\left[\ln\left(\sum_{j=1}^{J} e_{ij}^{V}\right) - \ln\left(\sum_{j=1}^{J} e_{ij}^{\overline{V}}\right)\right] \tag{3}$$

where $V_{ij} = \int(\Theta,S)\overline{V}_{ij} = \int(\overline{\Theta},S)$

CVi refers to the compensating variation or dollar valued willingness-to-pay that recreator *i* has for the change from Θ to $\overline{\Theta}$. This is the amount of money that would make him indifferent between Θ and $\overline{\Theta}$.[7]

Mathematical structure (S) for property value is the hedonic price approach as developed by [5]. In this structure, property value, identified as market price, is determined according to property characteristics.

$$P = V_i \tag{4}$$

Properties are those with characteristics influenced by the Boardman River dam system

$$V_i = f(\Theta, S) \tag{5}$$

meaning that the expected market price relates to the state of the Boardman River system,

$$P = f(\Theta, S) \tag{6}$$

It is apparent that the change in property value stems directly from the difference in states of the system between current conditions and an alternative.

$$\Delta Value = \int(\Theta,S) - \int(\overline{\text{O}},S) \tag{7}$$

[7] This information is useful for evaluating changes via a utilitarian perspective, such as benefit-cost analysis [6].

Under the assumption that identification of partial effects is sufficient, the expected change in value can be determined by identifying the shadow values of any changing property attributes.[8]

$$\Delta\ Value\ =\ dP\ /\ d\Theta \tag{8}$$

These values are identified as model coefficients in empirical studies that use hedonic analysis to evaluate the relationship between market prices and house characteristics. Given studies that evaluate relevant characteristics, results from these studies can be calibrated and applied in mathematical simulation.

The evaluation of local economic impacts is typically accomplished via a mathematical economic technique called input/output (I/O) analysis [7]. I/O analysis was developed to address policy issues with respect to income, sales, demand, local infrastructure, and plant closing.

In I/O models, changes in final demand for one industry affect other industries within a local economic area.

- *Direct effects* represent the initial change in the industry in question.
- *Indirect effects* are changes in inter-industry transactions as supplying industries respond to increased demands from the directly affected industries.
- Induced effects reflect changes in local spending that result from income changes in the directly and indirectly affected industry sectors.

Multipliers measure total changes in output, income, employment, or value added. Parameters required to specify I/O models include the following:

- *Output multipliers* relate the changes in sales to final demand by one industry to total changes in output (gross sales) by all industries within the local area.
- *Income and employment multipliers* relate the change in direct income to changes in total income within the local economy.
- *Value added multipliers* are interpreted the same as income and employment multipliers. They relate changes in value added in the industry experiencing the direct effect to total changes in value added for the local economy.

Data requirements include outputs and inputs from other sectors, value added, employment, wages and business taxes paid, imports and exports, final demand by households and government, capital investment, business inventories, marketing margins, and inflations factors (deflators). These data are available both for the 528 producing sectors at the national level and for the corresponding sectors at the county level. Data on the technological mix of inputs and levels of transactions between producing sectors are available from detailed input-output tables of the national economy.

[8] The identification of partial effects is most appropriate when expected changes are not dramatic and widespread.

Valuing an asset in financial terms is accomplished by valuing the (net) stream of income resulting from ownership. Because this income occurs at different point in time, values are discounted to present values as indicated in the equation below:

$$NPV = (TR - TC)r \tag{9}$$

In this equation, total value is the net present value of total annual revenues minus total annual costs.

Total revenues are composed of hourly price and quantity information by service. The various electrical services could include energy, renewable energy, and ancillary services as indicated below.

$$\begin{aligned} TR_{Annual} = & \sum_{Hours=1}^{8760} MW_{Energy} \bullet Hours_{Energy} \bullet P_{Energy} \\ & + \sum_{1}^{8760} MW_{renewableEnergy} \bullet Hours_{renewableEnergy} \bullet P_{renewableEnergy} \\ & + \sum_{1}^{8760} MW_{AncillaryServices} \bullet Hours_{AncillaryServices} \end{aligned} \tag{10}$$

Revenues are composed of hourly price and quantity information. Hourly generation quantity is identified as:

$$Q_{hour} = aV_{hour} \tag{11}$$

where Q_{hour} is hourly electricity production, V_{hour} is the volume of hourly flow and a is a positive constant that converts flow to electricity that is specific to technology and hydraulic head.

Annual costs are:

$$TC_{Annual} = Annual\ Cost_{Overhead} + Annual\ Cost_{Government} + Annual\ Cost_{MDNR} + Annual\ Cost_{FERC} \tag{12}$$

Information requirements include hourly electricity quantities and prices going out into the future. Quantities are identified via a combination of river flow and dam-specific information, including head and turbine efficiency.

1.2. Baseline data and transfer studies

The analysis divides the river into 11 segments. The segments were chosen for their distinct characteristics. For example, each impoundment is physically different than the free-flowing sections in between. Each impoundment is represented by its own segment, and each river section between the inlet of one impoundment and the next upstream dam is represented by a distinct segment. Table 1 contains segments used in this assessment. Figure 2 provides a map.

Site number	Location	Size
1	From mouth of Boardman River to Union Street Dam	1,2 miles
2	Boardman Lake	339,0 acres
3	From inlet of Boardman Lake to Sabin Dam	2,2 miles
4	Sabin Pond	40,0 acres
5	Keystone Pond	103,0 acres
6a	From inlet of Keystone Pond to midpoint	6,9 miles
6b	From midpoint to Brown Bridge Dam	6,9 miles
7	Brown Bridge Pond	191,0 acres
8	From inlet of Brown Bridge Pond to Forks	6,0 miles
9	North Branch of the Boardman River	23,5 miles
10	South Branch of the Boardman River	10,0 miles

Sources: [8–10]

Table 1. Boardman River segments

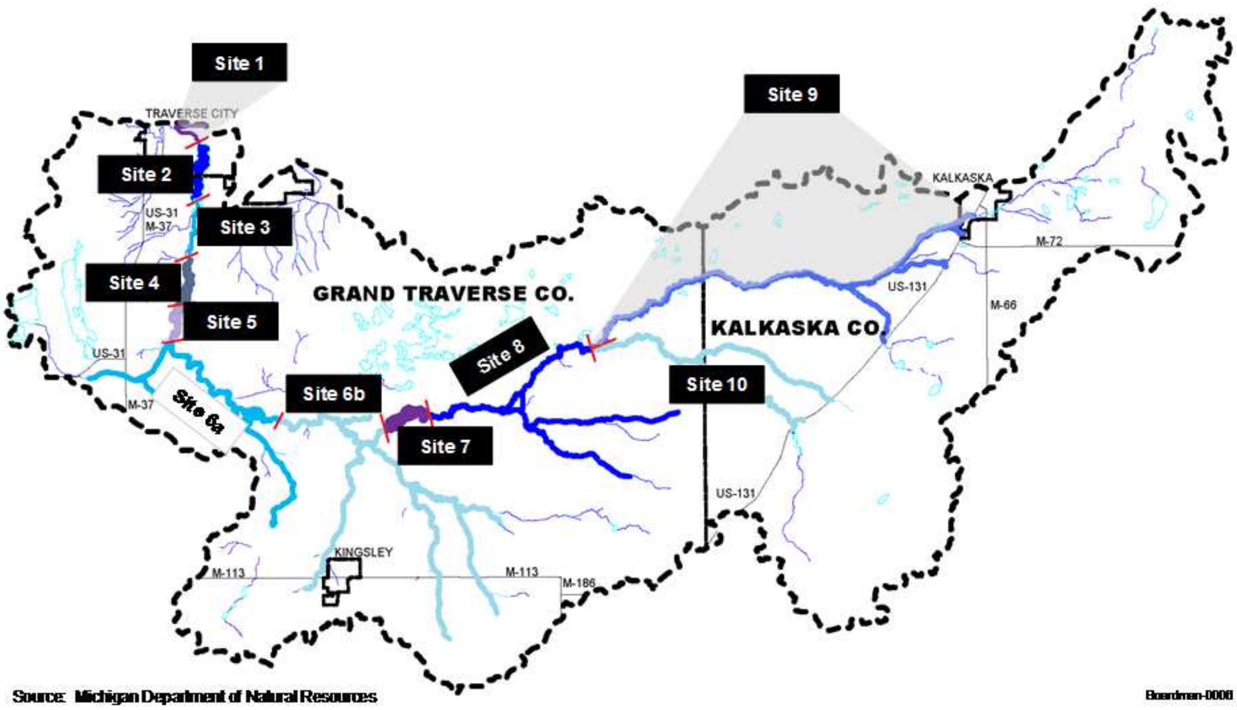

Figure 2. Location of segments 1–10 along the Boardman River

As Table 1 shows, the segments are numbered 1–10, with Segment 6 split into 6a and 6b. Segment 6 is physically homogeneous under our definition of a free-flowing river between impoundments. However, given its location between two impoundments, it has the potential to be affected by one or more of the dam management alternatives. By dividing it, the potentially affected recreation sites are closer in size to each than they would be without this division. Although Segments 9 and 10 are also relatively large when compared to the others, they are less likely to be affected by the dam management alternatives, given their locations well above the Brown Bridge Dam.

Pressure estimates for Boardman River anglers come from an on-site creel study that the Michigan Department of Natural Resources (MDNR) conducted during the 2005 season for Segments 1–8 of the Boardman River. The MDNR data collection included angler counts, as well as the number of fish caught by fish species. From these data, the MDNR developed statistically based seasonal estimates for the Boardman River in terms of the number of angler trips and hourly catch rates by species.

Based on the MDNR results, we developed pressure estimates, by segment, for this assessment by undertaking the following steps:

- Allocate the total number of MDNR days across Segments 1–8 of the Boardman River.
- Extrapolate angler day estimates from Segment 8 to Segments 9 and 10.
- Separate the number of angler days for each segment into resident days and visitor days.

Table 2 contains the resulting allocation of the fishing days across the various segments and residents or visitors.

Segment	Resident days	Visitor days
1	880 to 1 440	220 to 360
2	720 to 1 120	180 to 280
3	800 to 1 200	200 to 300
4	160 to 240	40 to 60
5	320 to 560	80 to 140
6a	1 680 to 2 720	420 to 680
6b	1 680 to 2 720	420 to 680
7	960 to 1 520	240 to 380
8	1 760 to 2 720	440 to 680
9	5 840 to 8 960	1 460 to 2 240
10	2 000 to 3 200	500 to 800
Total	16 800 to 26 400	4 200 to 6 600

Table 2. Annual number of resident and visitor angling days on the Boardman River

To simulate the implication of changes in site characteristics, we employ a recreational fishing study conducted by [11], which covers fishing sites across the state of Michigan and explicitly covers varied fishing experience, including inland rivers and inland lakes, as well as anadromous fishing opportunities, all of which are relevant to the Boardman River analysis. Because this statistical model studies the same activity on the same population, we can use both the site characteristics and the estimated parameters presented in the [11] study and reproduced in Table 3 below.

Characteristic	Mean
Trip cost	-15
Great Lakes warm, walleye catch rate	6,63
Great Lakes warm, bass catch rate	1,45
Great Lakes warm, pike catch rate	0,36
Great Lakes warm, perch catch rate	-2,75
Great Lakes warm, carp catch rate	0,87
Great Lakes cold, constant	-14,75
Great Lakes cold, Chinook catch rate	5,14
Great Lakes cold, Coho catch rate	5,45
Great Lakes cold, lake trout catch rate	3,23
Great Lakes cold, rainbow catch rate	2,19
Inland lakes warm, shore constant	-14,06
Inland lakes warm, interior constant	-7,8
Inland lakes warm, warm lake acres/1,000	21,58
Inland lakes cold, shore constant	-11,43
Inland lakes cold, interior constant	-18,48
Inland lakes cold, cold lake acres/1,000	3,73
Rivers/streams warm, shore constant	-10,09
Rivers/streams warm, interior constant	-11,21
Rivers/streams warm, top quality miles/100	5,35
Rivers/streams warm, second quality miles/100	-3,58
Rivers/streams cold, shore constant	-15,23
Rivers/streams cold, interior constant	-19,24
Rivers/streams cold, top quality miles/100	5,09
Rivers/streams cold, second quality miles/100	0,05
Anadromous runs, shore constant	-10,57
Anadromous runs, interior constant	-7,78
Anadromous runs, Chinook catch rate	3,37
Anadromous runs, coho catch rate	-0,3
Anadromous runs, rainbow catch rate	8,04

Table 3. Parameters for fishing site choice

Site characteristics to populate the model are based on physical site characteristics and MDNR quality and catch rate designations. MDNR [12] sets out its quality designations in the Manual of Fisheries Survey Methods II. The stream miles are categorized based on their quality. Those of high quality are rated either “top quality” or “second quality.” Top quality stream miles are characterized by containing good self-sustaining fish populations. Second quality streams are characterized by containing significant fish populations, which are appreciably limited by such factors as inadequate natural reproduction, competition, siltation, or pollution.

Table 4 contains the lake segments, or impoundments, for the Boardman River. The table indicates the types of species in the various segments, based on conversations with representatives from the Grand Traverse Conservation District (GTCD) [13], the MDNR [14], and the fisheries reports prepared for this project [8,15].

Segment	Species type	Acres
2	Warm	339
4	Warm	40
5	Warm	103
7	Warm	191

Table 4. Current conditions of the impoundment fishing sites

Table 5 contains the current conditions for the river segments of the Boardman, Segments 1, 3, 6, 8, 9, and 10. The number of stream miles that are "top quality" and "second quality" refers to the MDNR designation of fishery conditions previously described. Additionally, because Segments 1 and 3 support anadromous runs, the current conditions for these sites includes catch rates (number of fish caught per hour) for Coho Salmon, Chinook Salmon, and Rainbow Trout, based on information from the 2005 Boardman River Creel Survey [16].

Segment	Species type	Anadromous catch rates		Miles of top quality	Miles of second quality
1	Anadromous Warm Cold	Coho Chinook Rainbow	0,001 to 0,014 0,006 to 0,042 0,084 to 0,237	1,2	0,0
3	Anadromous Cold	Coho Chinook Rainbow	0,000 to 0,001 0,002 to 0,006 0,067 to 0,084	0,0	2,2
6a	Cold	N/A		6,9	0,0
6b	Cold	N/A		6,9	0,0
8	Cold	N/A		6,0	0,0
9	Cold	N/A		23,5	0,0
10	Cold	N/A		10,0	0,0

Sources: [13–14,16]

Table 5. Current conditions of the Boardman River fishing sites

The last type of information that completes the picture of current conditions for recreational fishing is a description of the substitute sites. Substitute sites play a key role in the determination of angler satisfaction.

We used three criteria in the selection of substitute sites. The first criterion was that the substitute site be within 150 miles of some portion of the Boardman River. We selected this distance criterion to be consistent with the [11] study. The second criterion was to incorporate a variety of potential fishing opportunities consistent with the real world. Thus, the selected substitute sites include inland lakes, rivers, and Lake Michigan sites. Finally, when possible substitute sites met the first two criteria, we selected those with the most recent data available in terms of the site features identified in the [11] model.

Table 6 contains the number of angler days to the inland lake substitute sites, as well as the current conditions. Table 7 describes the number of days and the current conditions for the substitute sites that are rivers. Table 8 contains information related to the number of days and the current conditions of the Lake Michigan substitute sites. The items in this table correspond to the features used in the [11] study for Great Lake sites. Unlike the inland lake or river sites, the features of these sites that affect angler satisfaction are the catch rates for the various cold and warm water species.

Site	Number of days	Species type	Acres
Houghton Lake	107 000	Warm	20 075
Lake Leelanau	31 000	Warm cold	8 607
Long Lake (Alpena County)	17 000	Warm	5 341
Green Lake	8 000	Warm	1 994
Higgins Lake	26 000	Warm cold	9 600

Sources: [17–18]

Table 6. Current conditions of the inland lake substitute sites

Site	Number of days	Species types	Anadromous catch rates	Miles of top quality	Miles of second quality
Rogue River (Kent County)	20 000	Anadromous	Coho 0,001	7,5	5,0
		Cold	Chinook 0,043		
			Rainbow 0,095		
Manistee River (from Hodenpyl Dam to Red Bridge)	8 000	Anadromous	Rainbow 0,112	12,9	0,0
		Cold			
		Warm			

Sources: [18–20]

Table 7. Current conditions of the inland river substitute sites

	Elk Rapids	E. Grand Traverse Bay	W. Grand Traverse Bay	Leland	Manistee
Angler days	9 930	9 974	21 977	6 294	63 815
Catch rate:					
Walleye	0,0010	0,0000	0,0000	0,0000	0,0001
Bass	0,0038	0,0037	0,0011	0,0031	0,0001
Pike	0,0000	0,0000	0,0000	0,0000	0,0002
Perch	0,4967	0,0465	0,1097	0,0005	0,0153
Carp	0,0000	0,0000	0,0000	0,0000	0,0000
Chinook	0,0141	0,0652	0,0558	0,0897	0,1757
Coho	0,0018	0,0006	0,0014	0,0004	0,0047
Lake trout	0,0087	0,0409	0,0267	0,0083	0,0051
Rainbow	0,0308	0,0014	0,0007	0,0448	0,0061

Source: [21]

Table 8. Current conditions of the Lake Michigan substitute sites

In addition to fishing, the Boardman provides canoeing and kayaking opportunities. Site-specific data on the current number of paddling days along the Boardman River are not readily available. For this reason, we rely on estimates from local individuals with first-hand knowledge of paddling use of the Boardman. These estimates from knowledgeable locals are validated using publicly available data on paddling participation rates and trip-taking frequencies.

The relative proportion of resident to visitor days was used to allocate the total days by segment across residents and visitors. These results appear in Table 9 below.

Segment	Resident days	Visitor days
1	120 to 180	80 to 120
2	50 to 60	About 40
3	300 to 1 140	200 to 760
4	50 to 60	About 40
5	30 to 300	15 to 200
6a	600 to 2 400	400 to 1 600
6b	600 to 1 800	400 to 1 200
7	50 to 600	40 to 400
8	1 500 to 3 600	1 000 to 2 400
9	0 to 10	—
10	0 to 10	—
Total	3 300 to 10 160	2 215 to 6 760

Sources: [22–23]

Table 9. Annual number of paddling days on the Boardman River

Parameter	Mean
Whitewater quality	2,82
Parking quality	-2,04
Crowding	2,19
Water quality	-1,39
Scenic rating	2,99
Predictability of water level	-0,92

Table 10. Coefficients calibrated to local conditions and scaled to fishing model

Mathematically modeling site-choice for paddling on the Boardman River requires identifying both site characteristics and parameterization of the relative importance that paddlers attach to each of these characteristics. One study [24] presents a statistical model for paddling; however, it was developed for a different location and population. This study reflects whitewater paddling opportunities in Ireland. Although topography in Ireland is likely more varied than that of northern Lower Michigan, the Irish study considers a range of whitewater sites.

To apply this study [24], we calibrated the parameters to reflect the specifics of the Boardman River and the surrounding area. To accomplish this calibration for site characteristics, we rely on the perceptions of recreators, a tactic which has professional acceptance [25] because it is the recreators' perceptions of the site's characteristics, whether aligned with factual information or not, that drive site selection. The [24] researchers query paddlers' opinions by asking them to rate the rivers they paddle on a 1–5 scale. The relevant site characteristics are:

- perceived whitewater quality
- perceived quality and safety of parking
- perceived crowding
- perceived water pollution
- perceived scenic quality
- perceived predictability of the water level prior to arrival.

We replicate this on the Boardman River by conducting an informal survey similar to the one used by [24], which reveals paddler's opinions on the site characteristics of the Boardman River and other nearby rivers. In the questionnaire, we ask respondents to rate their perceptions of the Boardman's features with respect to paddling on a 1–5 scale. The one exception to this 1–5 scale is the perceived quality of whitewater, which is based on a 0–4 scale.[9] Table 11 below reflects the average of the responses we received, and Table 10 above shows the coefficients calibrated to local conditions.

[9] Although Irish whitewaters are based on a 1–5 scale, we converted that to a 0–4 scale for this assessment to reflect the likely perceived absence of whitewater for portions of the Boardman River.

Seg. #	Description	Current whitewater quality	Parking	Crowding	Water quality (pollution)	Scenic rating	Predictability of water level
1	From mouth to Union Street Dam	0,0	3,8	3,8	3,0	1,8	4,6
2	Boardman Lake	0,0	4,0	3,9	2,9	3,0	4,8
3	Inlet of Boardman Lake to Sabin Dam	0,0	3,1	4,0	4,3	4,8	4,6
4	Sabin Pond	0,0	3,3	4,4	4,3	4,4	4,6
5	Keystone Pond & Boardman Dam	1,0	3,5	4,1	4,3	3,6	3,5
6	Inlet of Keystone to Brown Bridge Dam	1,6	4,0	3,4	4,0	4,6	4,2
7	Brown Bridge Pond	0,0	4,3	4,3	4,4	5,0	4,4
8	Inlet of Brown Bridge Pond to forks	0,4	4,2	3,2	4,2	4,8	4,2
9	North branch	0,0	2,7	4,7	3,7	5,0	4,3
10	South branch	0,0	2,7	4,7	3,7	5,0	4,3

Table 11. Boardman River paddling site characteristics

We used information from Trails.com and the Michigan Atlas and Gazetteer [26] to compile a list of substitute sites. The list included the Au Sable, the Betsie, the Pine, and the Platte Rivers. As part of the questionnaire described above, we included a question about these substitutes and asked respondents to rate them in the same way that they rated the Boardman. Additionally, we provided the respondents with an opportunity to name other substitute sites and rate them. The responses to the questionnaire identified four potential substitute sites for the Boardman.

Table 12 below provides the information on the perceived site characteristics for the substitute sites. The second column of Table 12 contains an estimate of the total number of paddling days for the substitute sites. This number is a necessary input for modeling. We used a similar methodology to the top-down approach using verifiable data. The MDNR provides an estimate of the number of paddling days statewide [27]. Based on an estimate of the miles of navigable river statewide [28], we estimated the average number of days that a typical river mile supports. We applied that number to the number of river miles for the substitute sites. The results appear in Table 12.

The Boardman River enhances the recreation experience for a variety of trail activities, including hiking, walking, biking, and horseback riding. Several segments of the Boardman River support designated trails, particularly around the impoundments. In the segments farther upstream, portions of the Michigan Shore-to-Shore Riding Trail and the North Country Trail follow the Boardman.

Substitute sites	Number of trips	Current whitewater quality	Parking	Crowding	Water quality (pollution)	Scenic rating	Predictability of water level
Au Sable	54 000	0,0	3,7	3,7	4,7	4,0	4,5
Betsie	15 000	0,3	3,7	3,7	4,3	4,3	3,5
Pine River	11 000	2,0	4,7	3,7	4,7	5,0	4,5
Platte River	4 000	0,2	3,2	1,8	4,8	4,1	4,8

Table 12. Current conditions of the representative substitute paddling sites

Public pressure estimates for trail activity days along the Boardman River are not readily available for most segments. We use a “top down” approach to estimate trail activity pressure. This approach starts with a total number of activity days and then allocates these days to sites based on trail miles. The trails along the Boardman River are used not exclusively for hiking, but also for biking, walking, and horseback riding. These latter activities can occur on streets and concrete sidewalks in neighborhoods, paved roads in rural areas, and on land without any developed trails. We have based our estimate of the number of Boardman River trail days on data that primarily reflect day hiking.

Table 13 shows the estimated number of days of trail activities on the Boardman River under current conditions. The number of resident days ranges from about 72,000 to 154,000 days per season while the number of visitor days ranges from about 18,000 to more than 23,000 days per season.

For the visitor days in the other segments, we use a similar methodology as we did for the resident days in these segments. The total number of visitor days is gleaned from tourism studies [29–31].

Segment	Resident days	Visitor days
1	12 000 to 14 000	3 000 to 4 000
2	20 000 to 24 000	5 000 to 6 500
3	1 500 to 4 000	500 to 625
4	4 000 to 11 000	1 000 to 1 250
5	2 000 to 6 000	700 to 875
6a	800 to 2 000	300 to 375
6b	5 000 to 15 000	2 000 to 2 500
7	4 500 to 13 000	1 500 to 1 875
8	5 000 to 14 000	2 000 to 2 500
9	11 500 to 33 000	1 200 to 1 500
10	6 000 to 18 000	900 to 1 125
Total	72 300 to 154 000	18 100 to 23 125

Table 13. Annual trail activity days on the Boardman River

Because no appropriate empirically estimated site-choice model is available for trail activities, we develop site characteristics and parameters, based on expert judgment, and link them to the fishing and paddling model. For site characteristics, we have selected scenic quality and trail miles as the relevant site characteristic. As the paddling model also incorporates scenic beauty, we import the scenic beauty coefficient from the paddling specification, and apply it to the trail activities model. To specify the importance of trail miles, we rely on expert judgment. Table 14 contains the calibrated importance parameters for trail activities.

Parameter	Mean	Variance
Scenic beauty	2,99	0,009085
Trail miles		

Table 14. Coefficients calibrated to local conditions and scaled to fishing model

Recreational spending by residents is not included in this assessment. The rationale behind this distinction is that local spending is transferred from one sector to another in the local economy [32–34]. If, for example, changes in the Boardman River result in increased recreational usage by residents, these residents may spend more money on bait, bottled water, and canoe rentals. However, it also means that locals spend less on other local activities. This specification assumes these local expenditure differentials offset one another with respect to local economic impacts. To estimate current expenditures on the Boardman River, we researched the publicly available information on recreation expenditures, by activity.

Table 15 details the results of our research. For each of the four recreational activities, this table contains estimates of the spending per activity day. In some cases, a range is provided, which is explained below on a study-by-study basis. All estimates have been converted to 2007 dollars using a composite created from various consumer price indices (CPIs) that best reflect the expenditure categories. For example, if the original study provided a breakdown that revealed that one-third of the spending went toward lodging, one-third was spent on gas, and one-third was spent in restaurants, we created a composite inflation factor weighted to reflect the CPIs for lodging, gasoline, and restaurant meals at one-third each.

Recreational activity	Dollars spent per visitor day (U.S. $ 2007)	Source
Fishing	$24,27	[35]
	$23,65 to $74,58	[36]
Paddling	$37,10	[37]
	$96,87	[32]
Camping	$48,34 to $65,29	[36]
	$14,06	[38]
Hiking	$18,87 to $72,47	[36]
	$29,23	[32]

Table 15. Sources of recreational spending estimates

Site-specific data on the pressure of the Boardman River by campers are not readily available. However, an approximation can be developed from publicly available data based on information gleaned from various websites [39–40] and presented in Table 16. Only segments 8 and 9 have developed campsites. With the exception of Ranch Rudolph, all of the campgrounds along the Boardman are State Forest Campgrounds (SFCs).

Based on this information, we use data from the MDNR to estimate the seasonal occupancy for a typical SFC site. The MDNR provides an estimate of the number of SFC campsites throughout the state [27]. The MDNR has also estimated the number of statewide camping nights at those SFCs annually from 2000 through 2006 [40]. Dividing the number of camping nights at SFCs by the number of SFC sites yields the typical number of camping nights that a campsite hosts during the season. Because camping activity likely varies from year to year due to weather differences, we use the range of seasonal days to estimate the occupancy of a typical SFC campsite during the season.

Segment Number	Name of Campground	Number of Campsites
1	None	0
2	None	0
3	None	0
4	None	0
5	None	0
6a	None	0
6b	None	0
7	None	0
8	Forks SFC	8
	Scheck's Place SFC	30
	Scheck's Place Trail Camp (SFC)	50 (based on space for 200 individuals)
	Ranch Rudolph	25
9	Guerney Lake SFC	36
10	None	0
Total		149

Sources: [39–40]

Table 16. Campsites along the Boardman River

According to the MDNR [27], virtually all camping occurs outside of the county of residence. Thus, for purposes of this assessment, we assume that all Boardman River campers are not residents of either Grand Traverse or Kalkaska County. The number of camping nights presented in Table 17 will be used in the tourism expenditures assessment presented elsewhere. This table shows that the number of annual camping nights spent along the Boardman River is between 4 000 and 6 500. The majority of these nights are located in Segment 8.

Segment number	Camping nights
1	0
2	0
3	0
4	0
5	0
6a	0
6b	0
7	0
8	3 000 to 5 000
9	1 000 to 1 500
10	0
Total	4 000 to 6 500

Table 17. Annual number of camping nights spent along the Boardman River

Mean expenditures for each recreation activity are shown in Table 18. The table shows that visitors to the Boardman River spend almost $2 million per year in the local economy. More than half of these expenditures are associated with trail activities by visitors. Table 18 shows the amount of visitor spending for each recreation activity. In total, recreational visitors to the Boardman River spend almost $2 million per year in the local economy.

Activity	Recreational spending (U.S. $/year)
Fishing	$298 200
Paddling	$317 400
Camping	$207 300
Trail activities	$1 110 300
Total	$1 933 200

Table 18. Current level of recreational spending by visitors to the Boardman River

To estimate impacts to the local economy, we used a program developed by researchers at Michigan State University called the Michigan Tourism Spending and Economic Impact Model (MITEIM).[10] As described above, this program estimates economic impacts to the local economy by tracing the flow of the tourism dollars (direct effects) through the local economy. It provides an estimate of the sales, jobs, income, and tax revenues that accrue to the local economy from recreational visitors to the Boardman River.

Tourism spending accounts for over $1,3 million in direct sales to the local economy. Direct sales are less than the tourism expenditures due to the leakages from the local economy described earlier. When indirect and induced effects are included, the addition to the local

[10] Some of these researchers were also involved in the development of IMPLAN (Impact Analysis for Planning). MITEIM is based on the same concept and parameters as IMPLAN. See reference [42]. We selected it for use in this assessment because it is specific to tourism in Michigan. We believe this program provides an impact analysis more tailored to the Boardman River assessment.

economy exceeds $2 million. Almost 40 local jobs can be attributed to Boardman River visitors. Personal income refers to the portion of direct sales that become salaries and wages in the local economy. It is the contribution to the local economy, not counting the costs of non-labor inputs. Finally, the local tax revenue, associated with Traverse City's hotel tax is approximately $7 000 per year.[11]

Changes to the dams on the Boardman River may affect property values, particularly residential property values. Commercial and industrial properties derive their values for their utility in generating an income stream. Changes in the Boardman River are unlikely to affect the income-generating ability of the nearby commercial and industrial properties.

Public lands generate value to society from their public uses, which we will capture through the recreation analyses. We do not anticipate that the current uses that of the public lands surrounding the Boardman River are likely to change with a change in the management strategy of one or more dams. That is, we would still expect these lands to support fishing, paddling, camping, and hiking to some extent even if one or more of the dams are removed. While the public lands have an asset value, it can only be realized through the sale of the land to a private party. Because we do not anticipate that changes in the Boardman River will result in the sale of public lands, we do not believe that a meaningful change in the public lands' asset value will occur.

We rely on a geographic information systems (GIS) database provided by Grand Traverse County [43] to describe the current values and key characteristics of the residential properties near the Boardman River.[12] Table 19 summarizes these key features for residential properties within ½ mile of the Boardman River or its impoundments, by segment. The information in the table includes the number of residential parcels, the number of parcels with frontage, the total number of acres across the parcels, and the total assessed value of all of the properties. This table shows that there are nearly 4 000 residential parcels within a ½ mile of the Boardman River. For these parcels, the total amount of acreage sums to nearly 7 500 and their total value is more than $331 million.

To estimate changes in residential property values associated with removal of one or more of the dams along the Boardman River, we adapt a statistical model developed by [44]. This study investigates the differences in value of residential properties near small impoundments and free-flowing rivers relative to properties near a recently removed impoundment. One of the most important features was that the study contain empirical analysis consistent with predicting changes in value that correspond to the potential dam removal scenarios for the Boardman River. The Provencher, Sarakinos, and Meyer study does so.

[11] To the extent that some visitors stay outside of Traverse City, then this estimate is an overestimate.

[12] Admittedly, the database from Grand Traverse County does not include residential properties in Kalkaska County. However, properties along the Boardman River in Kalkaska County are in Segments 9 and 10, well upstream from any of the dams. Dam removal will not materially affect properties in Kalkaska County.

Segment	Description	Number of residential parcels within ½ mile	Total no. of acres	Total current assessed value (U.S. $ millions)
1	From mouth to Union Street Dam	1 304	233	$137
2	Boardman Lake	1 778	403	$130
3	Inlet of Boardman Lake to Sabin Dam	166	403	$9
4	Sabin Pond	42	305	$4
5	Keystone Pond and Boardman Dam	61	504	$5
6	Inlet of Keystone to Brown Bridge Dam	493	4 759	$40
7	Brown Bridge Pond	8	276	$1
8	Inlet of Brown Bridge Pond to forks	69	576	$5
9	North branch	N/A	—	—
10	South branch	N/A	—	—
	Total	3 921	7 459	$331

Table 19. Residential property near the Boardman River

The study [44] also has other features that correspond to the Boardman River assessment area. For example, the impoundments in this study are relatively small in size, ranging from 8 acres to 194 acres. The sizes of these impoundments correspond fairly well to the sizes of the impoundments along the Boardman River.

Three of the Boardman River dams were used for electricity production. It is possible that they could be used for electricity again.

An equation including the hydraulic head, flow rate of the water, and a horsepower conversion constant is used to calculate the hydropower potential of the Boardman River dams.

$$\text{Power} = \text{Head} \bullet \text{Flow} \bullet \text{Constant}\left(64{,}4 \ / \ 550 \bullet 0{,}7457\right) \quad (13)$$

The constant is formed by taking the weight of water, 64,6 lb/ft3, and dividing it by the horsepower constants consisting of 550 ft lbs multiplied by 0,7457 kWh, both values are equivalent to the unit of 1 horsepower.

The head for Sabin Dam (20 feet), Boardman Dam (41 feet), and Brown Bridge Dam (33 feet) were reported in the dam brochure from Traverse City Light and Power. The flow rate of the water is available from the U.S. Geological Survey Surface-Water Daily statistics for the Boardman River, site #04126970, which is located above Brown Bridge Road on the Boardman River at latitude 44°39'24", longitude –85°26'12". The daily flow rate is given in cubic feet per second and is the mean value for each day. This mean value can be used for each of the 24 hours in a day. Current data supported are only from the date 30 September 2007 and earlier. If the rate of flow is below 100 cubic feet per second (CFS), then the efficiency of the power produced is reduced, therefore; any hourly rate that is below 100 CFS, is not calculated and the rate for that hour is zero.

An important feature of the annual profit function is that while hourly quantities of generation are easily identified, hourly prices of electricity and RECs going forward through time. In markets that are expected to transition to deregulation, the uncertainty of future prices and resultant low availability of consistent price estimates further complicates the problem.

2. Conclusions

The socioeconomic impacts associated with alternative outcomes for the Boardman River dams were evaluated by performing counterfactual experiments that simulate changes in the current conditions that arise from various disposition alternatives. These simulations estimate changes in recreational usage, tourism expenditures, property values, and electricity production that result in changes in one or more of the existing dams. Corresponding changes in the river characteristics that influence recreation, property values, and electricity production were estimated for each alternative. These were used to quantify the associated changes in social welfare for various alternatives, providing an empirical basis for decision-making. There were 91 potential management options across the four dams. Of these, the following seven were evaluated most closely.

Alternative 1:

Alternative 1 is repairing and retaining the dams. The repairs to the dams will not materially alter the fishing or recreation opportunities, or the existing nature of the impoundments. We predict no measurable impact on resident recreation values, visitor expenditures, or property values. The characteristics of the existing fishery will not change. Nor will the paddling opportunities. We expect no changes to the existing trails and campsites. Similarly, we predict no changes in property values associated with the implementation of Alternative 1.

Alternative 25:

With the removal of Sabin and Boardman dams, we anticipate that the corresponding changes in stream hydrology and fish habitats will change the recreation opportunities associated with the Boardman River. Under Alternative 25, the impoundments associated with these dams will become free-flowing river segments. The removal of the dams will change the nature of the fishery for several segments. Specifically, anadromous species are predicted to become available as far upstream as the Brown Bridge Dam. In addition, catch rates for anadromous fish species in western Grand Traverse Bay are predicted to improve somewhat. Boardman Lake, however, will continue to offer warm water fishing experiences. Moreover, some segments will offer more "whitewater" under this alternative than current conditions do, consequently changing recreational paddling opportunities. The former impoundments are predicted to become more scenic, as well.

Relative to current conditions, implementing Alternative 25 will increase the welfare of resident recreators by approximately $112 000. This welfare increase represents the present value over 30 years. In addition, we expect tourism spending to increase. The present value estimate of the increase in tourism spending over 30 years is $1,38 million. Finally, once the fishery improvements have realized their maximum potential, we expect that the tourism-based jobs will increase by 4 jobs.

In addition to the recreation and tourism changes described above, Alternative 25 will result in likely changes in residential property values in parcels near Sabin Pond and Keystone Pond. We find that the value of an individual residential parcel in the vicinity of Sabin Pond and Keystone Pond could fall, on average, by as much as 6 percent following removal of the dams, if all other influences on property values are held constant. About two years after the removal, the affected properties are predicted to begin to increase in value. Twenty years after removal, the properties, on average, could increase in value by as much as 18 percent, or approximately one percent per year, relative to current conditions.

Initially if Alternative 25 were implemented, within ½ mile of the Boardman River the aggregate assessed value of the properties could fall by as much as $0,6 million. Over time, the aggregate assessed value may increase by as much as $1,7 million. The present value of the stream of property value impacts is $1,04 million. When considering the results, it is important to keep in mind that calculated changes in value represent the expected change associated only with dam removal. Changes in market values are likely to occur over time for reasons unrelated to dam removal.

In terms of the property value impacts, it is important to understand several aspects. First, the impacts will not be equally distributed across residents of Grand Traverse County. Initially, individual property owners may experience a decline in the value of their individual properties that is proportionally greater than the overall impact. Over time, those same owners may experience a gain in value that is proportionally greater than the overall impact. Second, the statistical model applied for this assessment represents the average impact. Not all affected properties will experience the average impact. Some individual parcels may increase or decrease in value in amounts greater to, or less than, the predicted average impact.

Alternative 41a:

With fish passage modifications on all four dams, we anticipate that recreation opportunities will improve in some of the Boardman River segments. Specifically, these modifications will improve fishing somewhat in the river segments downstream of Brown Bridge Pond. In addition, catch rates for anadromous fish species in western Grand Traverse Bay are predicted to improve somewhat. The dam modifications will permit the passage of anadromous fish species as far upstream as the north and south branches. The existing impoundments will continue to support only warm water fisheries. None of the modifications will result in improvements to the existing whitewater features or scenic quality of the segments. Additionally, we do not anticipate any changes in property values associated with the dam modifications.

Relative to current conditions, implementing Alternative 41 will increase the welfare of resident recreators by approximately $83 000. This welfare increase represents the present value over 30 years. In addition, we expect tourism spending to increase. The present value estimate of the increase in tourism spending over 30 years is $1,44 million. Finally, once the fishery improvements have realized their maximum potential, we expect that the tourism-based jobs will increase by 4 jobs per year.

Alternative 41b:

Alternative 41b adds re-powering each of the dams to the fish passage modifications of Alternative 41a. Because the re-powering does not influence the river differently from 41a, impacts are identical except for the value of electricity generated. Electricity quantities are identified using a combination of river flow and dam-specific information, including head and turbine efficiency as identified in [45]. At the expected level of hourly generation and historical hourly prices annual revenues are estimated at $452 000. Michigan's "21st Century Electric Energy Plan" [46] recommends a portfolio standard that requires load-serving entities to provide 10 percent of their energy sales from renewable energy options by the end of 2015.[13] Load-serving entities can meet the standard in several ways including buying qualifying renewable energy credits.[14] Revenue from renewable energy credits is estimated at $15 per megawatt hour beginning in 2015. With this value and electricity prices that increase at 3% the estimated net present value over 30 years for re-powering the dams is $9 100 000.

Alternative 43:

With the removal of Sabin dam and modifications of Boardman and Brown Bridge Dams, we anticipate that changes in stream hydrology and fish habitats will alter recreation opportunities associated with the Boardman River. Under this alternative, Sabin Pond will become a free-flowing river segment. The removal of Sabin Dam will change the nature of the fishery for this segment. In addition, the dam modifications will permit the passage of anadromous species as far upstream as the north and south branches. In addition, catch rates for anadromous fish species in western Grand Traverse Bay are predicted to improve. Moreover, some segments will offer more "whitewater" under this alternative than current conditions do, consequently changing recreational paddling opportunities. The former

[13] The Michigan Public Service Commission will review the performance of the program before 2015 and decide whether to extend the goal to 20 percent of energy sales from renewable energy options by the end of 2025.

[14] A renewable energy credit is a "unique, independently certified, verifiable record of the production of one megawatt hour of renewable energy."

impoundment is predicted to become more scenic, as well. The existing warm water fisheries for Boardman Lake, Keystone Pond, and Brown Bridge Pond will not be materially affected.

Relative to current conditions, implementing Alternative 43 will increase the welfare of resident recreators by approximately $133 000. This welfare increase represents the present value over 30 years. In addition, we expect tourism spending to increase. The present value estimate of the increase in tourism spending over 30 years is $1,50 million. Finally, once the fishery improvements have realized their maximum potential, we expect that the tourism-based jobs will increase by 4 jobs.

In addition to impacts on recreation values and tourism expenditures, the removal of Sabin Dam will likely affect the property values of residential parcels near the existing impoundment. The above discussion related to Alternative 25 provides the context and caveats associated with estimated changes in property values. Total assessed value of residential parcels within ½ mile of the Boardman River would change if Alternative 43 were implemented. Initially, the aggregate assessed value of the properties could fall by as much as $0,2 million. Over time, the aggregate assessed value may increase by as much as $0,7 million. The present value of this change is $0,43 million.

Alternative 79:

With the removal of Sabin, Boardman, and Brown Bridge Dams, we anticipate that the corresponding changes in stream hydrology and fish habitats will result in changes in recreation opportunities associated with the Boardman River. Under this alternative, Sabin Pond, Keystone Pond, and Brown Bridge Pond will become free-flowing river segments. The removal of these dams will change the nature of the fishery not only for the existing impoundments, but for other segments as well. Specifically, anadromous fish species are predicted to become available as far upstream as the north and south branches. In addition, catch rates for anadromous fish species in western Grand Traverse Bay are predicted to improve. Boardman Lake, however, will continue to offer warm water fishing experiences. Moreover, some segments will offer more "whitewater" under this alternative than current conditions do, consequently changing recreational paddling opportunities. The former impoundments are predicted to become more scenic, as well.

Relative to current conditions, implementing Alternative 79 will increase the welfare of resident recreators by approximately $241 000. This welfare increase represents the present value over 30 years. In addition, we expect tourism spending to increase. The present value estimate of the increase in tourism spending over 30 years is $1,58 million. Finally, once the fishery improvements have realized their maximum potential, we expect that the tourism-based jobs will increase by 5 jobs.

Finally, property values near the current impoundments will likely be affected by the dam removals. The above discussion related to Alternative 25 provides the context and caveats associated with estimated changes in property values that result from the implementation of

Alternative 79. The total assessed value of residential parcels within ½ mile of the Boardman River would change if Alternative 79 were implemented. Initially, the aggregate assessed value of the properties could fall by as much as $0,6 million. Over time, the aggregate assessed value may increase by as much as $1,9 million. The associated present value is $1,18 million.

Alternative 81:

With the removal of Sabin, Boardman, and Brown Bridge Dams and modifications to the Union Street Dam, we anticipate that the corresponding changes in stream hydrology and fish habitats will result in changes in recreation opportunities associated with the Boardman River. However, in the expert judgment of the fisheries biologists working on this project, the measurable changes to recreation opportunities are no different from those that will occur under Alternative 79. The estimated economic value associated with residents' recreation experiences and the estimated increase in tourism spending and jobs are as reported above. Similarly, because the dam removals are the same under Alternative 79 and Alternative 81, the estimated impacts on property values under Alternative 81 are the same as those under Alternative 79, which are reported above.

Based on the results of the integrated process, the dam owners decided to remove the Sabin, Boardman, and Brown Bridge dams and modify the Union Street dam for fish passage. Stated environmental benefits include enhancing and restoring 3.4 miles of native cold water habitat, reconnecting 160 miles of high-quality river habitat, and restoring more than 250 acres of wetlands. Brown Bridge dam has been drawn down, and is scheduled for removal in summer 2012. Environmental permitting for removing the other dams is underway.

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