PNNL-34921

Cataloging and Quantifying Value Streams from Non-Powered Dam Conversion

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Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

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Abstract

Hydropower is a key resource in the United States' renewable energy transition; however, only 3% of existing dams in the United States currently generate electricity. While many non-powered dams (NPDs) have the potential for energy generation, hydropower addition to these dams has been slow. This is likely due, in part, to perceptions that hydropower development has prohibitively long payback periods, especially in comparison to other renewable energy resources that have shorter development processes. On the other hand, powering some NPDs may unlock new value streams in addition to the value obtained from selling generated energy. There is a need to understand and quantify a wider range of additional value streams to help increase the feasibility of such hydropower projects. In this work, we catalog indirect value streams and difficult-to-quantify direct value streams from NPD retrofitting, specifying which stakeholders are affected, and what kind of impacts (positive or negative) might occur. We identify appropriate quantification methodologies for these indirect value streams and describe the best practices around their implementation for NPD site-level analysis. We also demonstrate the quantification of a few indirect value streams for a selected NPD site, allowing for easier integration of these value streams into future studies by providing basis and background for quantifying these elements.

Acronyms and Abbreviations

BT	Benefit Transfer
cfs	cubic feet per second
FERC	Federal Energy Regulatory Commission
LBNL	Lawrence Berkeley National Laboratory
MRIP	Marine Recreational Information Program
MW	Megawatt
NPD	non-powered dams
NREL	National Renewable Energy Laboratory
REA	resource equivalency analysis
USACE	United States Army Corp of Engineers
WTP	willingness to pay
WUA	weighted usable area

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1.0 Introduction

Only 3% of all dams in the United States currently generate electricity, with a vast majority of dams existing for other purposes, such as flood control, navigation, and irrigation (USACE, 2020). This existing infrastructure can sometimes be retrofitted to produce electricity with minimal environmental impacts and lower capital costs. However, powering non-powered dams (NPDs) can be relatively complex as site characteristics determine which technologies may work, how the dam would need to be operated, and which environmental concerns may need to be mitigated. Likely due to these complexities and the length of development, relatively few NPDs have been retrofitted in the past 20 years (36 retrofits between 2000 and 2020) (Hansen et al., 2021). Additional value stream quantification may help enable conversations to improve stakeholder relations, justify additional investment, or negotiate more lucrative contracts. Understanding and articulating the broader economic value of the retrofit to the region could be a helpful step in garnering more support for such retrofits.

Quantification of the value of many additional value streams, especially the indirect value streams, requires non-market valuation methods. These methods have been developed to estimate the value of goods and services that are not traded on markets so traditional valuation methods are not suitable. There is significant precedence for non-market valuation in other contexts, such as traditional hydropower and natural resource management (Boyer & Polasky, 2004; Loomis, 1997; Lowry et al., 2017). However, these techniques have not been applied widely to retrofitting NPDs. Installation of a new dam and associated hydropower project can be associated with major changes to the area, including changes in flow patterns, water conditions, flood control, and the establishment of a reservoir that can be used for water supply and recreation (Kirchherr & Charles, 2016; Mattmann et al., 2016; Briones-Hidovo et al., 2020). Retrofitting an existing dam requires smaller changes to the surrounding environment and ecosystems. The changes primarily come from infrastructure included as part of the retrofit, such as mitigation efforts and improvements to site amenities that make it more attractive for recreation (Witt et al., 2018). Non-market valuation can be used to assess the magnitude of the benefits provided by some of the value streams associated with the entire retrofit project.

In this report, we catalog value streams for NPDs in a way that aligns with both economic theory and practical users' needs. Our catalog provides methodologies applicable to the quantification of each value stream, where possible; and provides links to literature which describes the quantification methodologies. The catalog allows future researchers to quickly identify metrics and calculations which may be relevant to quantifying the value streams of interest. We then demonstrate how one can utilize this catalog by quantifying the value of recreation from a proposed retrofit of a dam in Pennsylvania.

2.0 Cataloging value streams from NPD retrofits

Retrofitting existing non-powered dams has the potential for positive and negative impacts across many sectors and stakeholders. When estimating the total economic value of proposed infrastructure, it is important to avoid double counting and to clearly understand the flow of value streams to different entities.

In Figure 1, we present a diagram to consistently organize value streams from NPD retrofitting. This figure builds on flowcharts for total economic value found in Pearce and Moran (1994) but adds insights into whether the value streams come from electrons (power benefits) or are indirectly related to the electrical system (non-power benefits). It also categorizes according to use and non-use values; use values come from the usage of a resource and non-use values come from knowing the resource exists and may exist in the future.

The purpose of this catalog and diagram is to enable conversations between key stakeholders and to elucidate pathways to remuneration, where possible. For example, system impacts that are not currently remunerated could potentially be discussed in negotiations for bilateral agreements and other contract structures.

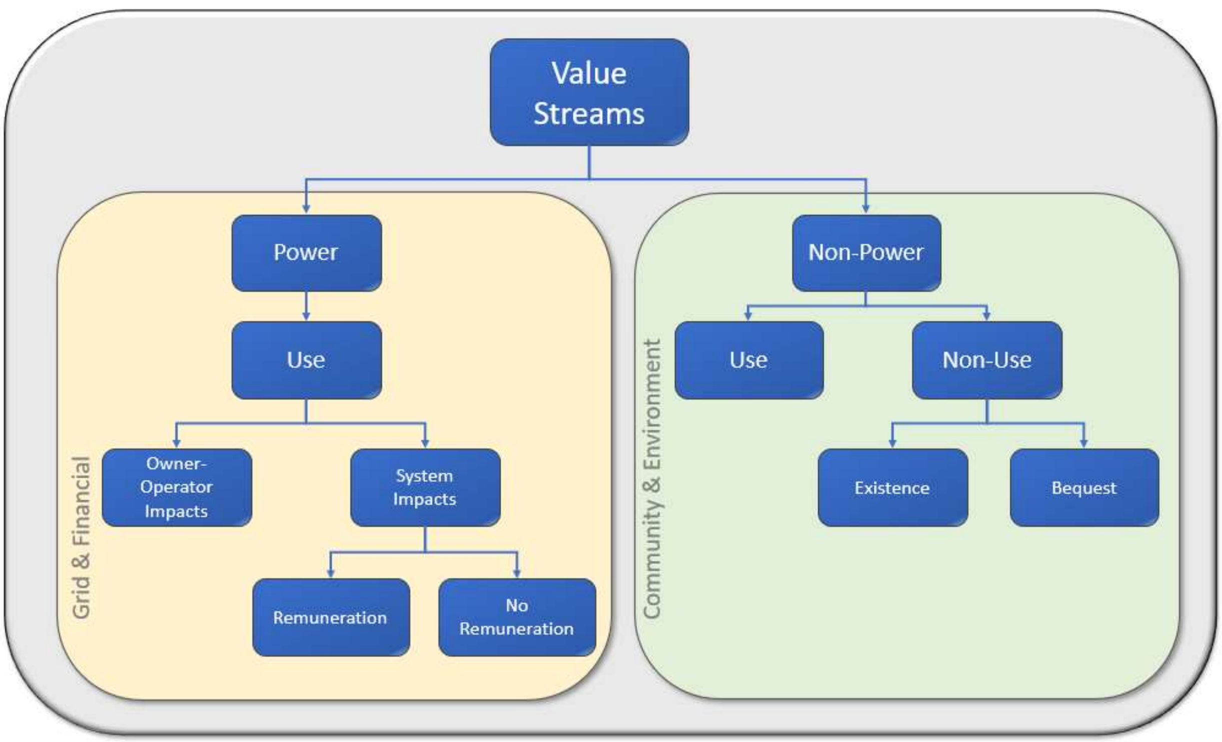

Figure 1. Categorization of value streams by power/non-power and use/non-use

The value streams, organized by each branch of Figure 1, are listed below in each callout box, and can be seen in more detail in the catalog, which is attached at the end of this report.

The catalog distinguishes retrofit value streams as community, environment, or grid/financial impacts (labeled in the “Category” column and shown in blue, green, and yellow respectively in the catalog). This is done to map to the sectors or stakeholders who may be relevant in discussing these potential value streams.

Each row in the catalog is a value stream which can result in positive, negative, or neutral impact to the affected entity. Each value stream is characterized according to the following columns in the catalog:

- Category (Community, Environment, or Grid/Financial)
- Power/Non-Power
- Use/Non-Use
- Owner-Operator/System impacts
- Remuneration to Owner-Operator
- Affected Entities
- Positive or Negative Impact
- Description
- Metrics
- Valuation Approaches
- Difficulty to Undertake
- Relevant Literature

This allows a user to understand key characteristics of the value stream (e.g., who it affects, how it affects them). The catalog also allows filtering of value streams according to any of the above characteristics. For example, if one wanted to view only power-related value streams that are not currently remunerated, that can be easily done through filtering.

The last four columns of the catalog contain information around how to monetize these value streams. The metrics column gives important metrics that might be needed in the calculations listed in the valuation approaches column. The catalog also notes the difficulty of performing these calculations, which is often dependent on the difficulty of estimating the necessary metrics, finding the necessary data, and performing any modeling that might be required. The final column gives literature that is relevant to the quantification of the value stream, either because it gives data or examples of how to do the analysis, or because it describes the quantification methods. The catalog is intended, therefore, as a reference document for those who may want to list and quantify value streams associated with retrofitting an NPD.

In the following sub-sections, we describe the value streams found in each category. Later in this report, we give examples of how to quantify a few of the value streams listed in the catalog as applied to a proposed retrofit.

Grid/Financial Value Streams

The cataloged value streams (both costs and benefits) that affect the grid and/or the owner/operator of the dam are shown in the table below. Not all of these value streams may be relevant to a particular NPD retrofit.

Table 1. Grid/financial value streams

Grid/Financial Value Streams
Benefits
Energy revenue/savings Price arbitrage Capacity

Grid/Financial Value Streams
Regulation Blackstart Transmission upgrade deferral and congestion relief Distribution upgrade deferral Primary frequency response Voltage support Reserves Inertia Grid flexibility Reduced curtailment Renewable Energy Credits
Costs
Operating costs Capital costs

Additionally, whether a site is in a wholesale or traditionally regulated electrical market may determine whether some of these value streams are able to be remunerated through market participation, or if they would need to be remunerated through bilateral contracts or other agreements. There are also a few grid value streams that are not market products and are not remunerated in bilateral contracts, such as inertia, grid flexibility, and reduced curtailment. However, the avoided costs provided by these value streams can still be quantified and may be useful in negotiating contracts.

Two of these value streams are costs (operating and capital costs). The capital costs need to either be levelized to compare with benefits and operating costs or need to be evaluated through benefit-cost analyses.

Community Value Streams

Value streams from the catalog that could impact the community and industries within the region are shown in Table 2. Community value stream below.

Table 2. Community value stream

Community Value Streams
Benefits
Reliability Enabling industry Property value Tax revenue Economic development Renewable goals Energy sovereignty Reduced energy burden Resilience

None of these value streams are typically remunerated to the dam owner or operator, but they do affect the populace near the site, where they are relevant. Some of these value streams are widely utilized in demonstrating regional economic value (i.e., tax revenue, economic development, including workforce development). Others have been identified as important metrics for equity analyses, but are rarely monetized (energy sovereignty, reduced energy burden). Reliability and resilience have numerous metrics which can be used in their measurement, and the methods for their valuation are continuously under revision.

Environmental Value Streams

The value streams in the catalog that impact the environment near the NPD retrofit are shown in Table 3 below.

Table 3. Environmental value streams

Environmental Value Streams
Benefits
Emissions reduction Reservoir existence
Mixed impact
Fish passage Recreation Flood risk Fisheries Water availability Water temperature Flows Forebay elevation Dissolved oxygen Nutrification/eutrophication Erosion/turbidity Stream/river existence

No environmental value streams are currently remunerated to the dam owner or operator, but they are important to the site's licensing and permitting. Many of these value streams are listed as having mixed impacts, as the effects can be very different depending on site characteristics. Mixed impact means that the value stream could be neutral, negative, or even positive in some circumstances. For example, in cases where fish passage is introduced as part of a retrofit project, there could be positive environmental impacts to the site.

3.0 Methodologies for quantifying value streams

The valuation methodologies for the value streams in the catalog vary depending on the characteristics of the value stream. For example, value streams that have impacts to power systems often have methods of measurement, even if they do not exist as a market product. However, power system impacts which are not typically remunerated often require modeling to show how the value stream affects the power system and to quantify avoided costs. Depending on the value stream and the timescale on which impacts are seen, this modeling can be somewhat computationally intensive. These non-remunerated value streams often require information on the power system and its anticipated costs, which can also increase the difficulty of quantification, depending on access to this information. The Pumped Storage Hydropower Guidebook contains detailed information on how to quantify many of these value streams in ways that are usually relevant for non-powered dams (Koritarov et al., 2021).

Quantification methods for community value streams include regional economic impact analysis, such as input-output analysis or computable general equilibrium models, as well as contingent valuation or market-based methods to understand the value of an impact to individuals, households, and industry. There is already well-established literature around regional economic impact analysis. However, while there are publicly available input-output models for hydropower, they have not yet been adapted to non-powered dam retrofitting (NREL, 2016). Conducting such an analysis without a public model often requires the purchasing of data on regional economic multipliers and some expertise in running and interpreting such models. There is also literature on customer and industry willingness to pay for electrical reliability (LBNL, 2018; Sullivan et al., 2015) and ongoing efforts to extend this work to longer duration outage valuation as well (Innovations, 2022). However, some community value streams have not typically been monetized, such as improving energy sovereignty and reaching clean energy goals or policy. It may be possible to estimate metrics around these value streams and utilize those in discussions, potentially even opening up investment and funding opportunities, even if monetization of the value stream is not yet possible.

For environmental value streams, several non-market valuation methods have been developed to estimate the value of environmental goods and services. Travel cost models have been developed that can be used to estimate the value of recreational trips and the value of changes in site amenities and conditions (Bateman et al., 1996; Lupi and Feather, 1998; Lupi & Phaneuf, 2020). Another commonly used non-market valuation method is the hedonic property value method. This method uses data on property sales to estimate how changes in environmental conditions, access to natural resources, and more are reflected by changes in property values (Loomis & Feldman, 2003; Bohlen & Lewis, 2009; Cohen et al., 2017; Lewis & Landry, 2017). Another commonly used method to estimate the value of changes to ecosystems and natural habitats is the stated preference survey. These surveys ask respondents questions about how they would behave in carefully constructed hypothetical scenarios (Phaneuf and Requate, 2016). Using survey methods has significant advantages because they allow for the estimation of the value of environmental goods over a wider range of variations in conditions, and it allows researchers to observe choices about behavior that is difficult or impossible to observe in practice. The primary drawback of stated preference survey methods is that it relies on responses to hypothetical scenarios and concerns that the respondents' actual behavior may differ from their survey responses (Mitchell & Carson, 1989). Stated preference surveys are the primary method used to estimate the value of habitat and species preservation, as the methods based on observed behavior are generally unable to capture their value (Brouwer et al., 2016; Botelho et al., 2017; Sousa et al., 2019).

One of the major difficulties in monetizing many of these value streams is that monetization requires determining the relevant stakeholders and attributing the changes in ecosystem services to the relevant stakeholders (Braat et al., 2012; Brouwer et al., 2013; DeWitt et al., 2020). Usually, physical changes in conditions surrounding a retrofit, such as changes in streamflow, water quality, sedimentation etc. can be measured at the site. Determining how those physical changes correspond to economic value can often be difficult. Stated preference studies tend to focus more heavily on estimating the value of endangered species and charismatic fauna (Richardson and Loomis, 2009). There are few studies that estimate willingness to pay (WTP) for fish species affected by NPD retrofits (Johnston et al., 2012). One method that has been used to circumvent the difficulty in monetizing these physical changes is resource equivalency analysis (REA). REA assesses the value of environmental goods and services as the cost required to create an equivalent amount of habitat or nature preservation. While REA has been used as part of regulatory compliance, it is not a true measure of economic value. REA estimates how much it costs to provide a compensating amount of a resource rather than what the value of that resource is (Zafonte and Hampton, 2007; Yu & Xu, 2016; Desvousges et al., 2018; Pavanelli et al., 2022).

We note that, while this report describes methods of assigning monetary value to community and environmental factors, we recognize that there is inherent value in the quality of life and ecosystem improvements that may come from a retrofit, including tribal access to first foods. It may be difficult or even inadvisable to quantify some of these in monetary terms. Discretion is advised in assessing which value streams will be monetized in any given assessment.

4.0 Example – Quantifying the value of recreation at Allegheny Lock and Dam No. 2

To show how to utilize the catalog, we demonstrate the quantification of two value streams, recreation and fish habitat, at a proposed retrofit in Pennsylvania. The site, Allegheny Lock and Dam No. 2, was built in the 1930s by the United States Army Corps of Engineers but does not have hydropower generation. Rye Development has proposed a retrofit to incorporate 8.46 MW of hydropower generation at the site. The site is located in Pittsburgh on the Allegheny River near the Highland Park Bridge. The riverfront near the site includes undeveloped land, parks, and residential and industrial areas. The University of Pittsburgh has signed a power purchase agreement with Rye to buy the power from the project.

The proposed retrofit has already begun the licensing process with FERC, and there are several studies that have been conducted as part of that process or are underway. We leverage these studies in our valuation analysis here, in order to describe the potential impacts at the site. We demonstrate quantification of two value streams, recreation and fish habitat. We provide these as examples of how to apply the valuation methodologies listed in the value stream catalog. As such, the first example on recreation valuation has more explanation of the overall approach, and we apply similar approaches with less explanation in the second example on fish habitat valuation.

Recreation valuation

We estimate the change in recreational value to the site based on the proposed changes in the project's design basis memorandum (Design Basis Memorandum, part 2). The changes proposed are the addition of restroom facilities, the addition of a fishing platform with a ramp and walkway leading to it, and the addition of paved access and parking for eight vehicles. Estimates were not found in the literature search for the value of a fishing platform, so this study is limited to the value added from the restroom facilities and paving and parking. If the project's implementation were to be different from those in the design basis memorandum, then the value of the changes to recreational value would also change.

We use the benefit transfer (BT) method to quantify the value of the potential recreational improvements. BT uses values from a study at a different location and applies them to the current setting. The estimates from BT are not as accurate as those from a site-specific study at the site under consideration, but they can provide estimates with reasonable accuracy where an original study is not feasible.

The value of access to a site Is the sum of the benefits per user and can be represented by:

$$\mathrm{V} = \sum_{n=1}^{N} b_n \tag{1}$$

Where b_n represents the benefits to visitor n.

If we assume an average benefit per user, this formula becomes $V = Nb$ where N is the number of visitors and b is the average benefit per user. A change in the recreational value of a site can be induced by a change in the number of visitors or by a change in the average benefit per user caused by a change in the characteristics of the site, such as quality improvements (McConnell, 1992).

The simplest method for benefit transfer is value transfer, where the average per-user benefits from a prior study are combined with data on the number of visitors at the new site under consideration. The average per-user benefit can be obtained from a single study or from a meta-analysis of multiple studies. A single study is preferred if there are results available from a study done at a very similar location. Meta-analysis is considered more accurate when there is not a single study from a similar location. Single studies are also used out of necessity when multiple studies are not available. The value transferred can be the value of a recreational trip, or the marginal value of adding, subtracting, or changing site amenities or characteristics.

- We use a meta-analysis value transfer for the total value of the current recreation in the area using Rosenberger (2016) values adjusted for inflation of fishing, hiking, motor boating, and general recreation.
- We use a single study transfer for the change in value from the addition of the restroom, the paved road and the parking lot (Timmins and Murdock, 2007), adjusted for inflation.

Another method for BT is functional transfer, where data from the site being transferred to is input into the econometric model that was estimated at a previous site. The advantage of this method is that it can account for substitution across different sites. This allows for the estimation of the value provided to visitors that would have previously chosen a different site, but now elect to come to the site under consideration. The drawback to this method is that it requires data on the features and amenities at the site under consideration and at other sites that visitors may be considering in the local area. As recreation data is not publicly available on other sites in the area, we do not use this method. Melstrom et al. (2023) showed that value transfer and functional transfer often produce similar results when estimating the change in value from changes in site amenities or conditions.

One of the limitations from using value transfer is that we cannot estimate the total change in the number of visitors. This could be from visitors who elect to now make more frequent trips or due to new individuals who previously would not have made any trips. The models that are used to estimate total changes in the number of trips have strong data requirements beyond those needed for functional transfer, so they are not generally used for benefit transfer (Phaneuf & Requate, 2016).

Why we chose this value stream

In conversations with Rye, they indicated that recreational value was of interest to the local communities. Currently, funding for updates to locks and dams owned by the U.S. Army Corps of Engineers is based solely on commercial traffic and no consideration is given to non-commercial use such recreationists. This has led some local groups to have discussions about how to categorize, quantify, or value the non-commercial traffic at lock and dam sites.

There have been numerous studies that have quantified the economic value of recreational activities including fishing, hiking, boating, swimming and more. These values have been used to quantify the value of infrastructure and public policy.

Methods

Estimation of the recreational benefits is performed in two steps. First, we estimate the number of annual visitors to the site based on surveys conducted as part of the FERC licensing process. Second, estimates of the number of visitors are combined with recreational values using value transfer of the benefits per trip obtained from other studies.

Surveys were conducted on two days as part of the recreation study. The surveys were conducted on Tuesday August 13 and Saturday August 17, 2013 between 4 and 9 PM. The survey found that on these two occasions there were 43 total recreationists with 33 fishers, and 11 of these fishers were within the specified project area. These values are extrapolated to an annual estimate. Estimating the annual number of visitors is done using data obtained from the Marine Recreational Information Program (MRIP) survey conducted by NOAA (NOAA, 2022). The MRIP survey is used to:

- Estimate the visitors for the two days that surveys were conducted based on the average number of visitors between 4 and 9PM.
- Estimate the number of visitors on the average weekday and weekend day in August based on the estimated number of visitors for the two days that surveys were conducted.
- Estimate the total number of visitors for July and August using the estimate of the average weekday and weekend day in August.
- Estimate the annual number of visitors based on the estimate of the total number of visitors for July and August.

We estimate several parameters using data obtained from the MRIP survey. We limited our analysis to visits in the northeast region to represent the conditions more accurately at Allegheny Lock and Dam #2, and we use the sampling weights provided to correct for potential survey selection bias. We estimate that 34% of daily trips occur during the 4PM to 9PM window, that there are 3.5 times as many trips on the average weekend day than the average weekday, and that 31% of annual visits occur during July and August. Some assumptions used are that the two days when the survey was conducted represent an average day, and that the average number of visitors in July is the same as in August. Using these parameter values and the data from the recreational survey, we estimate the annual number of visitors using the following steps:

- 34% of daily trips occur during the window of 4 pm to 9 pm. Using this, we estimate that the 43 visitors observed represent 43 x 100/34 = 126.5 visitors.
- There are 3.5 times as many trips on the average weekend day in August than on weekdays. Of the 126.5 visitors estimated for the two days in the previous step, 28.4 are estimated as weekday visitors and 98.1 as weekend visitors.
- During the average July and August, there are 44 weekdays and 18 weekend days, so the total number of visitors during July and August is estimated as 98.1 x 18 + 28.4 x 44 = 3,015 visitors.
- 31% of annual visits occur during July and August, so this results in an estimate of 3,015 x 100/31 = 9,726 visits per year.

The estimates for the annual number of visitors by activity type is estimated using the same process, with the only difference being the observed number of visitors from the survey. Table 4 shows a summary of the estimated number of visitors by activity type to the dam site.

Table 4. Estimated annual recreational visitors by types

Type	Surveyed visitors (2 days)	Estimated daily weekend visitors during August	Estimated daily weekday visitors during August	Estimated annual visitors

All recreation	43	98.1	28.4	9,726
All fishing	33	75.3	21.8	7,464
Fishers within project area	11	25.1	7.3	2,488
Motor boaters	6	13.7	4.0	1,357
Other	3	6.8	2.0	679
Hiking	1	2.3	0.7	226

Recreation valuation results

Table 5 shows the estimated annual value of recreation at the Allegheny Lock and Dam #2. The average values per trip were obtained from the Recreational Use Values Database (Rosenberger, 2016). The values used are the mean values for the Northeastern U.S. by activity type for the types that have sufficient sample size and are the mean values for the entire U.S. for activity types that have low sample size. The values were escalated for inflation to adjust them from the 2016$ reported values in Rosenberger (2016) to 2023$ using the Bureau of Labor Statistics.[1] These values represent the current total annual value of recreation at the site. The changes in value based on site improvements as part of the project to power the dam would increase the value above this baseline.

Table 5. Estimated value of recreation at the current site

	Annual number of trips	Value per trip ($2023)	Annual Value	95% Confidence Interval
Fishing within project area	2,488	$100.47	$250,000	[$216,000–284,000]
All fishing	7,464	$100.47	$750,000	[$647,000–853,000]
Motor boating	1,357	$131.37	$178,000	[$107,000–250,000]
Other	679	$73.40	$50,000	[$41,000–59,000]
Hiking	226	$98.62	$22,000	[$17,000–27,000]
All recreation total	**9,726**		**1,000,000**	**[$812,000−1,189,000]**

Table 6 shows estimates for the change in economic value of recreation at the Allegheny Lock and Dam #2 site based on the proposed additions. The changes that are used in the estimation

[1] https://data.bls.gov/cgi-bin/cpicalc.pl

are the addition of restroom facilities, and paved road, and parking area. Values were not found in the literature for a fishing platform, so we are not able to estimate the additional value that may provide. We use a value transfer of the value of these amenities from Timmins and Murdock (2006) who estimated that the addition of a restroom provides $4.80 value per trip and that paved road and parking provide $8.25 of value per trip in 2006$. Adding these together and escalating for inflation yields a value of $15.70 per trip in 2023$. We assume that the value added from these site improvements is the same for non-fishing recreational activities.

Table 6. Summary recreational values

	Annual number of trips	Value added per trip from restroom, paving, and parking (2023$)	Annual Value	95% Confidence Interval
Fishing within project area	2,488	$15.70	$39,000	[$14,000−63,000]
All fishing	7,464	$15.70	$117,000	[$42,000−192,000]
Motor boating	1,357	$15.70	$21,000	[$8,000−35,000]
Other	679	$15.70	$11,000	[$4,000−17,000]
Hiking	226	$15.70	$4,000	[$1,000−6,000]
All recreation total	**9,726**		**153,000**	**[$56,000−250,000]**

Fish habitat valuation

The team also considered monetizing the impacts on fish habitat, as the proposed retrofit could potentially have an impact in this area. As part of the retrofit's licensing process, an aquatic habitat analysis has already been conducted. We use this analysis in our valuation. However, the projected impacts on fish habitat are tentative, as a mitigation plan may be developed which would change the predicted values of changes in square footage available for fish species at the dam site. Also, we note that the aquatic habitat analysis found only a 6% reduction in weighted usable area (WUA) in the most extreme case (taking into account fish species, life stage, and flow scenarios), so this value stream may not be significant in practice, even if analyses show a range of possible impacts. In the aquatic habitat analysis, the extreme low flow and the high flow scenarios showed no impact or positive impact to fish habitat. However, in the other flow scenarios, a range of impacts was estimated with most of the species and life stages analyzed showing a decrease in fish habitat. Mussel habitat was also analyzed in the site habitat analysis, but as we did not find relevant literature relating mussel habitat to value for the general public, we have limited our valuation to fish habitat.

Similar to the recreation valuation, we use the BT method in a simple value transfer approach, using two studies on fish habitat valuation. While several studies exist on the value of water quality to the public, we were only able to find a few studies that examine the value of fish habitat area to the public. (R. Johnston et al., 2012) provide estimates of the value per acre of fish habitat to the general public of $0.018 per household per acre of fish habitat (2012$). In a subsequent study, Johnston and Ramachandran (2014) examine the same survey using different modeling techniques and find a value of $0.025 (2013$) per householder per acre of fish habitat. We note that in both studies, they consider habitat for diadromous fish in the Pawtuxet watershed of Rhode Island, and the fish species in the Allegheny #2 are not diadromous, so these values of habitat may be somewhat different for the Allegheny case. As we do not have estimates of the difference in value for diadromous fish habitat versus non-diadromous fish habitat, we present the results as calculated below.

We first converted the WUA impacts on fish habitat at the Allegheny #2 site to square feet. We then took the value of fish habitat from the studies above and adjusted to 2023 dollars and square feet. We also multiplied the impacts across the number of households within 10 miles of the site, and extending to include the city of Pittsburgh, which has about 183,000 households, according to census estimates.[1] Johnston and Ramachandran (2014) found that there are spatial heterogeneities in how the public values fish habitat, as some areas tend to value fish habitat higher or lower than other areas. However, they did not find a spatial pattern to this heterogeneity, and it would require prediction of a neighborhood's likelihood of higher or lower valuation in order to apply any differences in willingness to pay. As we were unable to perform this type of predictive analysis, we simply used the number of households.

Fish habitat valuation results

We present the results across five flow scenarios modeled in the aquatic habitat analysis performed at Allegheny #2, ranging from an extreme low flow scenario of 1,548 cfs to a high flow scenario of 45,200 cfs (Table 7. Results of evaluating fish habitat at Allegheny #2). Different flow scenarios were analyzed in the aquatic habitat analysis because flow rates can affect fish habitat, as different species prefer different depths, flows, and stream bottom substrates. Flow rates are given only at certain exceedance flows, meaning the daily average flow that is equaled or exceeded a certain percent of the days of the flow record. Ergo, a 10% exceedance flow is equaled or exceeded only 10% of the time. We find values ranging from -$7,957 to $1,057, depending on the flow scenario. As we do not know the habitat impacts of other flow scenarios, it is not possible to estimate an average impact for the site. However, this analysis gives an idea of the range of value impacts from the retrofit to households near the site. The impacts are no more than a few cents per household, when spread across the households in the study area.

Table 7. Results of evaluating fish habitat at Allegheny #2

	10% exceedance flow	50% exceedance flow	90% exceedance flow	Extreme low flow	Greatest impact
Flow (cfs)	45,200	15,400	4,510	1,548	11,245
Johnston et al. (2012)	$523	$(1,364)	$(1,128)	$52	$(3,936)

[1] https://www.census.gov/quickfacts/fact/table/pittsburghcitypennsylvania/HSD410221#HSD410221

Johnston & Ramachandran (2014)	$1,057	$(2,758)	$(2,281)	$106	$(7,957)

5.0 Conclusions

Powering NPDs can have impacts beyond the power grid. While there is a wealth of literature on non-market valuation, these techniques have not been applied to NPD retrofitting. Understanding and quantifying the impacts to communities, the environment, and the grid can help enable decisionmakers find ways to make beneficial retrofit projects move forward. In this work, we presented a consistent approach to catalog the value streams that can come from retrofitting an NPD, as well as methods and metrics to quantify them. We also provide an example of quantifying two value streams (recreation and fish habitat) at a proposed retrofit site. The methods outlined in this report vary in their complexity to implement; for example, functional transfer for benefit estimation requires both site data and econometric modeling expertise which may or may not be possible in a given analysis. We also note that there is some uncertainty in the estimation of many of these value streams, especially for those that are not currently monetized. When using value transfer, for example, it is important to bear in mind the differences between sites which may impact value and convey that uncertainty in the results. Future work into the public's willingness-to-pay for key benefits from non-powered dams would enrich the literature from which to draw for subsequent valuations. The goal of this report is to demonstrate pathways toward quantification so that future work can consider these impacts and expand the conversation around retrofitting NPDs and spur further development.

6.0 References

Bateman, I. J., Garrod, G. D., Brainard, J. S., & Lovett, A. A. (1996). Measurement issues in the travel cost method: a geographical information systems approach. *Journal of Agricultural Economics*, *47*(1-4), 191-205. DOI: https://doi.org/10.1111/j.1477-9552.1996.tb00684.x

Briones-Hidrovo, A., Uche, J., & Martínez-Gracia, A. (2020). Determining the net environmental performance of hydropower: A new methodological approach by combining life cycle and ecosystem services assessment. *Science of the Total Environment*, *712*, 136369. DOI: https://doi.org/10.1016/j.scitotenv.2019.136369

Bohlen, C., & Lewis, L. Y. (2009). Examining the economic impacts of hydropower dams on property values using GIS. *Journal of Environmental Management*, *90*, S258-S269. DOI: https://doi.org/10.1016/j.jenvman.2008.07.026

Botelho, A., Ferreira, P., Lima, F., Pinto, L. M. C., & Sousa, S. (2017). Assessment of the environmental impacts associated with hydropower. *Renewable and Sustainable Energy Reviews*, *70*, 896-904. DOI: https://doi.org/10.1016/j.rser.2016.11.271

Boyer, T., & Polasky, S. (2004). Valuing urban wetlands: A review of non-market valuation studies. Wetlands, 24(4), 744-755. doi:10.1672/0277-5212(2004)024[0744:VUWARO]2.0.CO;2

Braat, L. C., & De Groot, R. (2012). The ecosystem services agenda: bridging the worlds of natural science and economics, conservation and development, and public and private policy. *Ecosystem services*, *1*(1), 4-15. DOI: https://doi.org/10.1016/j.ecoser.2012.07.011

Brouwer, R., Bliem, M., Getzner, M., Kerekes, S., Milton, S., Palarie, T., ... & Wagtendonk, A. (2016). Valuation and transferability of the non-market benefits of river restoration in the Danube river basin using a choice experiment. *Ecological Engineering*, *87*, 20-29. DOI: https://doi.org/10.1016/j.ecoleng.2015.11.018

Brouwer, R., Brander, L., Kuik, O., Papyrakis, E., & Bateman, I. (2013). A synthesis of approaches to assess and value ecosystem services in the EU in the context of TEEB. *VU University Amsterdam*.

Cohen, J. P., Danko III, J. J., & Yang, K. (2019). Proximity to a water supply reservoir and dams: Is there spatial heterogeneity in the effects on housing prices?. *Journal of Housing Economics*, *43*, 14-22. DOI: https://dx.doi.org/10.2139/ssrn.2839006

Desvousges, W. H., Gard, N., Michael, H. J., & Chance, A. D. (2018). Habitat and resource equivalency analysis: a critical assessment. *Ecological Economics*, *143*, 74-89. DOI: https://doi.org/10.1016/j.ecolecon.2017.07.003

DeWitt, T. H., Berry, W. J., Canfield, T. J., Fulford, R. S., Harwell, M. C., Hoffman, J. C., ... & Yee, S. J. H. (2020). The final ecosystem goods and services (FEGS) approach: A beneficiarycentric method to support ecosystem-based management. *Ecosystem-based management, ecosystem services and aquatic biodiversity: Theory, tools and applications*, 127-148.

Hansen, C., Musa, M., Sasthav, C., & DeNeale, S. (2021). Hydropower development potential at non-powered dams: Data needs and research gaps. Renewable and Sustainable Energy Reviews, 145, 111058. doi:https://doi.org/10.1016/j.rser.2021.111058

Innovations, R. (2022). Memorandum RE: ICE 2.0 Survey Design. In.

Johnston, R., Schultz, E., Segerson, K., Besedin, E., & Ramachandran, M. (2012). Enhancing the Content Validity of Stated Preference Valuation: The Structure and Function of Ecological Indicators. Land Economics, 88. doi:10.3368/le.88.1.102

Johnston, R. J., & Ramachandran, M. (2014). Modeling Spatial Patchiness and Hot Spots in Stated Preference Willingness to Pay. Environmental and Resource Economics, 59(3), 363-387. doi:10.1007/s10640-013-9731-2

Kirchherr, J., & Charles, K. J. (2016). The social impacts of dams: A new framework for scholarly analysis. *Environmental Impact Assessment Review*, *60*, 99-114. Doi: https://doi.org/10.1016/j.eiar.2016.02.005

Koritarov, V., Balducci, P., Levin, T., Christian, M., Kwon, J., Milostan, C., . . . Weimar, M. (2021). Pumped Storage Hydropower Valuation Guidebook: A Cost-Benefit and Decision Analysis Valuation Framework. Retrieved from United States:

LBNL. (2018). Interruption Cost Estimator (ICE) Calculator. Retrieved from https://icecalculator.com/home

Lewis, L. Y., & Landry, C. E. (2017). River restoration and hedonic property value analyses: Guidance for effective benefit transfer. *Water resources and economics*, *17*, 20-31. DOI: https://doi.org/10.1016/j.wre.2017.02.001

Loomis, J., & Feldman, M. (2003). Estimating the benefits of maintaining adequate lake levels to homeowners using the hedonic property method. *Water Resources Research*, *39*(9). DOI: https://doi.org/10.1029/2002WR001799

Loomis, J. (1997). Use of non-market valuation studies in water resource management assessments. Water Resources Update, 109.

Lowry, T. S., Chermak, J. M., Brookshire, D. S., Shaneyfelt, C., & Kobos, P. H. (2017). Measuring non-market values for hydropower production and water storage on the Colorado River: A white paper investigation. Retrieved from

Lupi, F., & Feather, P. M. (1998). Using partial site aggregation to reduce bias in random utility travel cost models. *Water resources research*, *34*(12), 3595-3603. DOI: https://doi.org/10.1029/98WR02740

Lupi, F., Phaneuf, D. J., and von Haefen, R. H. (2020). Best practices for implementing recreation demand models. *Review of Environmental Economics and Policy*. DOI: https://doi.org/10.1093/reep/reaa007

Mattmann, M., Logar, I., and Brouwer, R. (2016). Hydropower externalities: A meta-analysis. *Energy Economics*, *57*, 66-77. DOI: https://doi.org/10.1016/j.eneco.2016.04.016

McConnell, K.E., 1992. Model building and judgment: implications for benefit transfers with travel cost models. *Water Resources Research*, *28*(3), pp.695-700.

Melstrom, R. T., Kaemingk, M. A., Cole, N. W., Whitehead, J. C., Chizinski, C. J., & Pope, K. L. (2023). Valuing Angling on Reservoirs Using Benefit Transfer. *North American Journal of Fisheries Management*, *43*(2), 400-416. DOI: https://doi.org/10.1002/nafm.10802

Mitchell, R. C., & Carson, R. T. (1989). *Using surveys to value public goods: the contingent valuation method*. Rff press.

National Oceanic and Atmospheric Administration (NOAA) (2022). Marine Recreational Information Program. Retrieved from https://www.fisheries.noaa.gov/recreational-fishing-data/recreational-fishing-data-downloads

National Renewable Energy Laboratory (NREL) (2016). Jobs and Economic Development Impact Model - Conventional Hydropower. Retrieved from https://www.nrel.gov/analysis/jedi/conventional-hydro.html

Pavanelli, D. D., Domingues, D. F., Hoch, P. G., Joko, C. T., de Oliveira Andrade, M. V., Lasmar, M. C., ... & Voulvoulis, N. (2022). Transient Alterations in Streamwater Quality Induced by Pollution Incidents: Interim Losses Calculations and Compensation Alternatives Based on Habitat Equivalency Analysis. *Environmental Management*, *69*(3), 576-587. DOI: https://doi.org/10.1007/s00267-021-01571-x

Pearce, D., & Moran, D. (1994). The Economic Value of Biodiversity (1st ed.): Routledge.

Phaneuf, D. J., and Requate, T. (2016). *A course in environmental economics: theory, policy, and practice*. Cambridge University Press.

Richardson, L., and Loomis, J. (2009). The total economic value of threatened, endangered and rare species: an updated meta-analysis. *Ecological economics*, *68*(5), 1535-1548. DOI: https://doi.org/10.1016/j.ecolecon.2008.10.016

Rosenberger, Randall S. 2016. Recreation Use Values Database – Summary. Corvallis, OR: Oregon State University, College of Forestry. [http://recvaluation.forestry.oregonstate.edu/]

Sousa, S., Botelho, A., Pinto, L. M. C., & Valente, M. (2019). How relevant are non-use values and perceptions in economic valuations? The case of hydropower plants. *Energies*, *12*(15), 2986.DOI: https://doi.org/10.3390/en12152986

Sullivan, M., Schellenberg, J., & Blundell, M. (2015). Updated Value of Service Reliability Estimates for Electric Utility Customers in the United States. Retrieved from Nexant, Inc.: https://eta-publications.lbl.gov/sites/default/files/lbnl-6941e.pdf

Timmins, C., & Murdock, J. (2007). A revealed preference approach to the measurement of congestion in travel cost models. *Journal of Environmental Economics and management*, *53*(2), 230-249. DOI: https://doi.org/10.1016/j.jeem.2006.08.002

USACE. (2020). National Inventory of Dams. Retrieved from https://nid.sec.usace.army.mil/#/

Witt, A. M., Uria Martinez, R., Johnson, M. M., Werble, J. M., Mobley, M. H., & O'Connor, P. W. (2018). United States trends in non-powered dam electrification. *International Journal on Hydropower & Dams*, *25*(4).

Yu, B., & Xu, L. (2016). Review of ecological compensation in hydropower development. *Renewable and Sustainable Energy Reviews*, *55*, 729-738. DOI: https://doi.org/10.1016/j.rser.2015.10.038

Zafonte, M., & Hampton, S. (2007). Exploring welfare implications of resource equivalency analysis in natural resource damage assessments. *Ecological Economics*, *61*(1), 134-145.

Appendix A The Catalog

The catalog of value streams for NPD retrofits is embedded here as an Excel file:

NPD Value Stream Catalog.xlsx

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