EARTH ECONOMICS

NATURAL CAPITAL BENEFITS OF THE SAN JUAN BAY ESTUARY WATERSHED

April 2017

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Taking nature into account

Office 253.539.4801
Fax 253.539.5054

Address 107 N. Tacoma Avenue
Tacoma, WA 98403

Earth Economics
http://www.eartheconomics.org/
info@eartheconomics.org

Report Version 1.1

Primary Authors:
Lola Flores, Project Director, Earth Economics
Corrine Armistead, GIS analyst, Earth Economics
Matt Chadsey, Executive Director, Earth Economics

Year: 2017

Suggested Citation:
Flores, L., Armistead, C., Chadsey M. 2017. Natural Capital benefits of the San Juan Bay Estuary Watershed. Earth Economics, Tacoma, WA.

Acknowledgements- Thank you to all who supported this project:

100 Resilient Cities Initiative for connecting Earth Economics to the City of San Juan via its Platform Partner Program

Funding from the Kresge Foundation

Municipio Autónomo de San Juan: Alejandra M. Castrodad-Rodríguez, Principal Ejecutiva de Resiliencia y Gabriela Fernandez-Nieves, AECOM Analyst.

Earth Economics: Maya Kocian (sponsor); Tania Briceno (research); Ken Cousins (editor); Jessica Hanson (editor)

We would also like to thank Earth Economics' Board of Directors for their continued guidance and support: Alex Bernhardt, David Cosman, Elizabeth Hendrix, Greg Forge, Ingrid Rasch, Molly Seaverns, and Sherry Richardson.

Cover Photo: Lynn Englum

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Fax 253.539.5054 Tacoma, WA 98403

Forward

The City of San Juan, Puerto Rico, is part of the 100 Resilient Cities (100RC) initiative, a global effort to strengthen cities' capacities to adapt, grow and thrive when faced with shocks and long-term stresses. *San Juan Resiliente* is particularly focused on strengthening city systems' capacity to reduce individuals, communities and institutions' exposure and susceptibility to impacts, while increasing their access to the knowledge, tools and resources for autonomous adaptation.

The San Juan Bay Estuary, running through the heart of the city, tells the story of two distinct urban experiences. On its shorelines lie the drivers of Puerto Rico's institutional and economic life, next to communities that for decades have endured severe socioeconomic distress, poor housing conditions and exposure to public health hazards. The Estuary and its communities are particularly susceptible to impact partly because of exposure to the hazards threatening insular Caribbean contexts, but also because of historical development practices that have severely degraded the ecosystem's functions.

To this end, San Juan has collaborated with Earth Economics, a 100RC platform partner, to complete *Natural Capital Benefits of the San Juan Bay Estuary Watershed*. This report informs San Juan's resilience strategy by quantifying and valuing the benefits that the region's vast and diverse ecosystems contribute to local communities and the economy. These benefits include disaster risk reduction, flood mitigation, habitat functions and recreation, among many others. The results will be immediately applicable in understanding and prioritizing the core strategies outlined in *San Juan Resiliente*. More importantly, this work will provide stakeholders engaged in the Collaborative Research activities with a shared vocabulary and methodology to describe the critical, complex relationships between the city of San Juan and its surrounding ecosystems.

Faced with increased exposure to current and future extreme hazards, the sustainability of the Estuary, its communities and the Island depend strengthening the resilience of the systems and assets that provide the foundation for Puerto Rico's economy, food supply chain, and government. Understanding the Estuary's ecosystem services is of paramount importance as we design initiatives to protect our residents, guarantee the city's essential functions and maximize resources' value for current and future generations. This research, the shared learning experience and, ultimately, the protection and stewardship of these natural resources constitute crucial steps in the right direction.

Alejandra M. Castrodad-Rodríguez

Principal Ejecutiva de Resiliencia
Municipio Autónomo de San Juan

Office 253.539.4801 *Address* 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

Executive Summary

The abundant natural capital of the watershed of San Juan Bay Estuary is a critical part of the regional ecosystem and economy. The wetlands and mangroves of the coastline around the city of San Juan support rich biodiversity, erosion control, and moderate flood events. These benefits – and others produced by functional natural systems – are known as ecosystem services, and they represent significant, long-term contributions to San Juan's local economy. This is the first study to estimate the dollar value associated with these critical ecosystem services within the city and surrounding watershed.

Around the world, planners and policy makers are starting to include the value of natural capital assets (e.g., watersheds, forests, shorelines) and ecosystem services to better understand and value relationships between healthy environments, resilient economies, and thriving communities. Including these assets yields a more complete understanding of the contribution of restoration and stewardship projects and ultimately fosters more practical, cost-effective policy outcomes.

This analysis finds that the watershed's natural capital contributes $14 million to $61 million in ecosystem service benefits each year, around 33 percent of which are provided within San Juan's municipal jurisdiction. These can be viewed as assets providing a flow of benefits over time, similar to a building or a bridge. Over a 100 year period at a three percent discount rate, this amounts to an annual asset value of between $447 million and $1.9 billion. With stewardship to maintain the health and function of that natural capital, this annual economic contribution can continue in perpetuity. Given the limited economic studies currently available for San Juan's nearby ecosystems, these estimates are rather conservative, addressing only those factors for which supporting research is available. As more detailed ecological and economic research on the region's ecosystems emerges, these estimates are quite likely to grow.

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Introduction

The Natural Capital Valuation of the San Juan Bay Estuary Watershed was conducted by Earth Economics, a 100 Resilient Cities Platform Partner, in collaboration with the City of San Juan's Urban Resiliency Office. The study's purpose is to estimate the current natural capital and ecosystem service contribution of the watershed, with special attention to benefits provided within the City of San Juan. This baseline assessment will inform San Juan's resiliency strategy, facilitating the integration of ecosystem service values in future project and policy analyses.

For many years, natural capital (watersheds, forests, shoreline) has been treated quite differently than built capital. While construction of roads, bridges, or water conveyance systems has nearly always been discussed as vital investments with significant economic benefits, dollars allocated to ecosystem restoration and stewardship have more often been considered as costs (or lost opportunities) to be minimized. One reason for this disconnect has been that, until relatively recently, it has not been cost-effective to identify and monetize the benefits that people receive from nature (i.e., ecosystem services). Advances in the field of Ecological Economics and rapidly growing scholarly research on the economic contribution of functional natural systems have facilitated more reliable estimates of the full value provided by nature. These estimates can now be combined with conventional economic methods to integrate ecosystem service provision into important financial analyses such as benefit-cost or return-on-investment.

When ecosystem services are degraded, communities lose. Healthy shoreline, riparian buffers, robust forests, and mature wetlands all provide flood protection, slowing flood waters and absorbing storm energy. Increasingly frequent storms – on of the many factors associated with climate change – makes the mitigation of extreme events one of the more important ecosystem services for communities. As ecosystems are degraded and developed, communities incur real ongoing costs to replace services that nature previously provided for free, typically with expensive and maintenance-intensive constructed flood control structures.

Site Overview

The 56,275-acre watershed feeding the San Juan Bay Estuary surrounds the capital city of San Juan, Puerto Rico, on the island's northeast coast. About 27,000 acres (48 percent) of the total watershed area are under the City's jurisdiction. While pockets of forests and wetlands are

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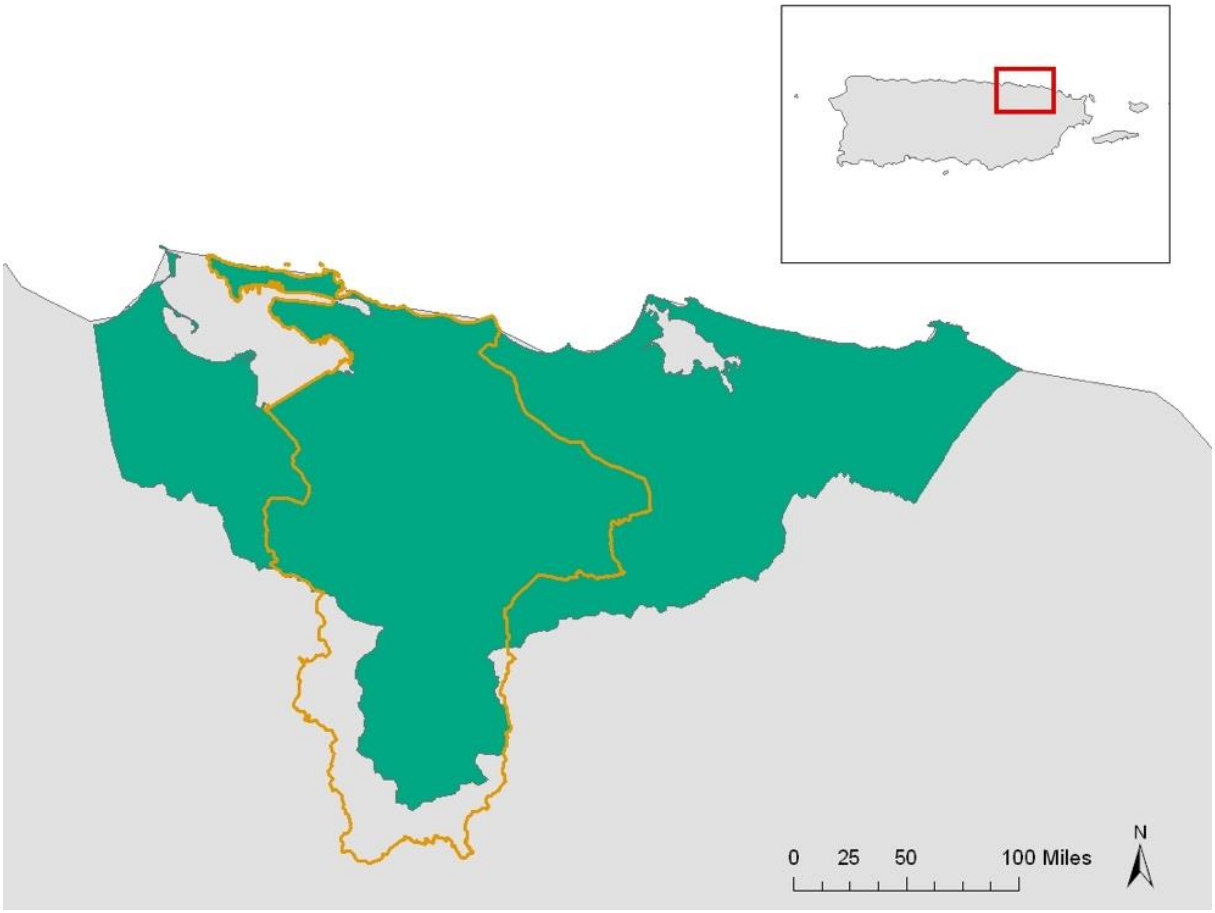
found in the watershed, much of the area, especially within the city limits, has been converted to high-density urban land use. This has typically occurred in stages, as forests are replaced by agriculture, which is in turn displaced by urban development. Of the total mangrove forests in the watershed, only 7 percent are within the San Juan municipality. The same is true for wetlands – the area 7 percent of emergent wetlands are found in the San Juan Bay Estuary Watershed, even though the city maintains approximately half of the watershed's shoreline.

Figure 1. San Juan Bay Estuary Watershed



Valuation Approach

The study involves four major steps:

Step 1. Identification and Quantification of Landcover Classes: Geographic Information Systems (GIS) data, including landcover (GAP 2006) and watershed and jurisdiction outlines,

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were used to calculate the extent of each landcover type (e.g. wetland, forest, shoreline) within the study area.

Step 2. Identification and Valuation of Ecosystem Services: The economic contribution of each ecosystem service–landcover combination (e.g. climate stability–forests) was estimated using the benefit transfer method (described below). Where the supporting research provided low and high value estimates, these have been reported. Where valuation estimates for particular ecosystem service–landcover combinations were not available, no values were reported here. This is not meant to suggest that such ecosystem services contribute no value at all – only that rigorous research on those contributions was not publically available at this time.

Step 3. Annual Value of Ecosystem Services: The sum of all annual estimates for the ecosystem services provided per-acre by each landcover type were then scaled by the extent of corresponding landcover classes within the study area to calculate the total annual contribution of ecosystem services within the study area. The annual contributions of all landcover types were then combined to calculate the total annual value contributed by ecosystem services to the local economy.

Step 4. Net Present Value Calculations: Net Present Value was calculated for the study site over 100 years at two discount rates: zero percent and three percent. Net Present Value and discount rates are methods designed to allow the benefits accrued over many years to be compared to investments and returns in the present day.

Ecosystem Services Framework and Valuation Methods

Like other forms of capital, natural capital provides a flow of goods and services. These are the basis of all other economic activity, as they provide clean water, breathable air, nourishing food, flood risk reduction, waste treatment, climate stability, etc. Without natural capital, many of the benefits we receive for free could not exist, and would need to be replaced and maintained at a high cost. Working together, economists and ecologists are often able to identify the presence, quantity, and economic contribution of ecosystem services in a particular location.

A range of valuation techniques are available depending on the specific circumstances, including:

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- **Market Pricing:** The current market value of goods produced within an ecosystem (e.g., food, fiber).
- **Replacement Cost:** The cost of replacing the services provided by functional natural systems with man-made infrastructure (e.g. a water treatment plant to replace natural water filtration).
- **Avoided Cost:** Ecosystem services can help communities avoid harm that would have been incurred in the absence of those services (e.g. flooding reduction by wetlands and riparian buffers).
- **Production Approaches:** Ecosystem services which enhance output (e.g. rain-fed irrigation can increase crop productivity).
- **Travel Cost:** Demand for some ecosystem services may require travel, the cost of which reflects the implicit value of those services (e.g. tourists traveling long distances for extended vacations near San Juan's beaches).
- **Hedonic Pricing:** Property values vary by proximity to some ecosystem services (e.g., homes with water views often sell for higher prices than similar homes without such views).
- **Contingent Valuation:** Estimates of value based on surveys of the values assigned to certain activities (e.g., willingness-to-pay to protect beach quality).

The valuation of some ecosystem services is well-understood and straightforward. For others, no generally accepted methodologies exist, although their significance may be described qualitatively. The ecosystem service descriptions and categorizations used in this report (see

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Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

Table 1) are derived from work by DeGroot et al. (2002) and Sukhdev et al. (2010).[1,2]

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Table 1. Ecosystem Services Definitions

Good/Service	Economic Benefit to People
Provisioning Services	
Food	Producing crops, fish, game, and fruits
Medicinal Resources	Providing traditional medicines, pharmaceuticals, and assay organisms
Ornamental Resources	Providing resources for clothing, jewelry, handicrafts, worship, and decoration
Energy and Raw Materials	Providing fuel, fiber, fertilizer, minerals, and energy
Water Storage	The quantity of water held by a water body (surface or ground water) and its capacity to reliably supply water
Regulating Services	
Air Quality	Providing clean, breathable air
Biological Control	Providing pest and disease control
Climate Stability	Supporting a stable climate at global and local levels through carbon sequestration and other processes
Disaster Risk Reduction	Preventing and mitigating natural hazards such as floods, hurricanes, fires, and droughts
Pollination and Seed Dispersal	Pollination of wild and domestic plant species
Soil Formation	Creating soils for agricultural and ecosystems integrity; maintenance of soil fertility, sediment transport for fish spawning areas.
Soil Quality	Improving soil quality by decomposing human and animal waste and removing pollutants
Soil Retention	Retaining arable land, slope stability, and coastal integrity
Water Quality	Improving water quality by decomposing human and animal waste and removing pollutants
Water Capture, Conveyance, and Supply	Providing natural irrigation, drainage, groundwater recharge, river flows, drinking water supply, and water for industrial use
Navigation	Maintaining water depth that meets draft requirements for recreational and commercial vessels
Supporting Services	
Habitat and Nursery	Maintaining genetic and biological diversity, the basis for most other ecosystem functions; promoting growth of commercially harvested species
Information Services	
Aesthetic Information	Enjoying and appreciating the presence, scenery, sounds, and smells of nature
Cultural Value	Using nature as motifs in art, film, folklore, books, cultural symbols, architecture, media, and for religious and spiritual purposes
Recreation and Tourism	Experiencing the natural world and enjoying outdoor activities
Science and Education	Using natural systems for education and scientific research

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Fax 253.539.5054
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Tacoma, WA 98403

Benefit Transfer Method

The benefit transfer method (BTM) is broadly defined as "the use of existing data or information in settings other than for what it was originally collected".[3] As such, BTM is an efficient means of generating broad-based estimates at a fraction of the cost and time necessary to conduct multiple primary studies, which may require more than $50,000 per service–landcover combination. BTM plays an important role in the field of ecosystem services valuation, as it is often the most practical option available for producing reasonable estimates.[4]

BTM begins by identifying primary studies of similar ecosystems and communities as reported in peer-reviewed journals, and reviews each to ensure that only those with compatible assumptions and landcover types are included. Each value estimate in these studies is then standardized for units of measure, inflation, and landcover classification to ensure "apples-to-apples" comparisons, as these estimates are "transferred" to the study site (e.g., the San Juan Bay Estuary Watershed). In this sense, BTM is similar to a home appraisal, in which the features and pricing of similar nearby homes are used to estimate the appraised value of other homes. While neither process is perfect, they are able to quickly and efficiently generate reasonable values for policy and project analysis. Where primary studies report a range of values (to reflect the uncertainty or variability within the research area), low and high per-acre value estimates have also been reported here.

Study Findings

The San Juan Bay Estuary Watershed covers 56,275 acres along the northeast coast of the island of Puerto Rico. According to the best-available landcover data, 32,081 acres of the watershed are classified as either urban development, barren land, or bare rock, and are not valued here. This analysis focuses on the contribution of the remaining 24,194 acres of natural capital assets within the watershed, comprised primarily of forests, mangroves, and pastures.

The National Gap Analysis Program (GAP), a project of the United States Geological Survey (USGS), mapped Puerto Rico's landcover in 2006. Landcover classes are based on the NatureServe Ecological Systems Classification, which focuses on species biodiversity. However, many of these landcover classes were aggregated based on GAP landcover descriptions, owing to the limited availability of primary valuation data. Accordingly, since this valuation is unable to account for the differential ecosystem services provided by forest of varying age, younger secondary evergreen forests and mature secondary evergreen forests have been aggregated. Table 3.

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Address 107 N. Tacoma Avenue
Tacoma, WA 98403

Table 2 compares GAP landcover classifications with the resulting classifications applied here. The combined landcover areas valued, both for the watershed as a whole and the subset of area under the city's jurisdiction, are displayed in Table 3.

Table 2. GAP 2006 Landcover Classification and Earth Economics Landcover Classification

GAP 2006 Landcover Classification	Earth Economics Landcover Classification
Woody agriculture and plantations: Palm plantations	Cultivated, Agro-Forestry
Mature secondary lowland moist alluvial evergreen forest	Forests, Evergreen
Mature secondary lowland moist non-calcareous evergreen forest	
Young secondary lowland moist alluvial evergreen forest	
Young secondary lowland moist non-calcareous evergreen forest	
Mature secondary moist limestone evergreen and semi-deciduous forest	Forests, Mixed
Young secondary moist limestone evergreen and semi-deciduous forest	
Lowland moist riparian forest	Forests, Riparian
Lowland moist riparian shrubland and woodland	
Lowland moist non-calcareous shrubland and woodland	Forests, Unspecified
Mangrove forest and shrubland	Mangroves
Gravel beaches and stony shoreline	Non Herbaceous, Bare Rock
Rocky cliffs and shelves	
Fine to coarse sandy beaches, mixed sand and gravel beaches	Non Herbaceous, Sand
Moist grasslands and pastures	Pastures
Lowland moist alluvial shrubland and woodland	Shrubland
Moist limestone shrubland and woodland	
High-density urban development	Urban, Developed
Low-density urban development	
Salt water	Water, Estuaries
Freshwater	Water, Unspecified
Freshwater Pterocarpus (e.g., Bloodwood) swamp	Wetlands, Forested/Woody
Emergent herbaceous non-saline wetlands	Wetlands, Grass/Herbaceous
Emergent herbaceous saline wetlands	
Seasonally flooded herbaceous non-saline wetlands	
Seasonally flooded herbaceous saline wetlands	
Artificial barrens	Barren Land

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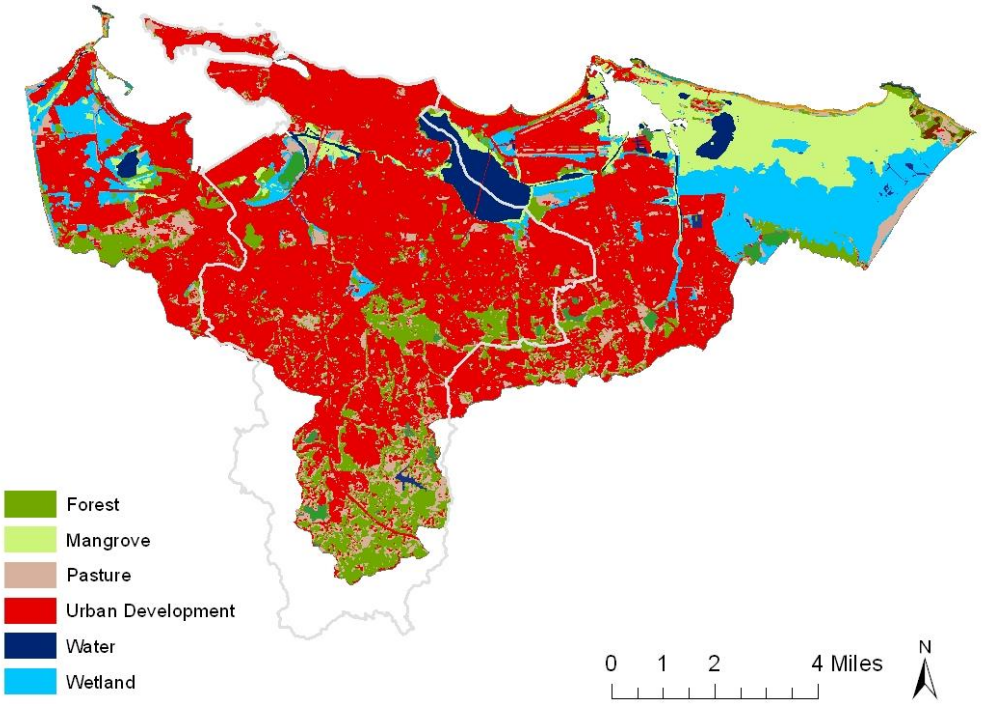
Table 3. Landcover Acreage in San Juan Bay Estuary Watershed

Landcover Classification	Total Acres Valued	Within City Jurisdiction	
		Acres	Percent
Cultivated, Agro-Forestry	87	0	0%
Estuaries	1,873	702	37%
Forests, Evergreen	4,027	2,775	69%
Forests, Mixed	567	46	8%
Forests, Unspecified	919	741	81%
Mangroves	4,821	342	7%
Pastures	5,338	2,859	54%
Sand	211	24	11%
Shrublands	481	139	29%
Water, Unspecified	133	47	35%
Wetlands, Forested/Woody	133	0	0%
Wetlands, Grass/Herbaceous	5,604	378	7%
Total	**24,194**	**8,054**	

Figure 2. Landcover within the San Juan Bay Estuary Watershed



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Fax 253.539.5054
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Valuation of Ecosystem Services Across Landcover Classes

This section focuses on publically available estimates for services produced by ecosystems similar to those in the San Juan Bay Estuary Watershed.

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Table ***4*** identifies the ecosystem services that could be valued, by landcover type. The services valued in this report are shaded in blue, while services for which estimates were not available have been left blank. It should be noted that only 13 of 21 ecosystem services were valued across twelve landcover types, indicating significant gaps in the scholarly literature. Remedying these knowledge gaps would significantly improve the accuracy of a comprehensive estimate of the contribution of the watershed to human wellbeing.

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Tacoma, WA 98403

Table 4. Gaps Analysis- Ecosystem Service Values Present in All Landcover Types

	Cultivated, Agro-forestry	Estuaries	Forests, Evergreen	Forests, Mixed	Forests, Unspecified	Mangroves	Pastures	Sand	Shrublands	Water, Unspecified	Wetlands, Woody/Forest	Wetlands, Grass/Herb
Provisioning Services												
1. Food						■						■
2. Medicinal Resources			■									
3. Ornamental Resources												
4. Energy and Raw Materials	■		■	■		■			■			
5. Water Storage									■			
Regulating Services												
6. Air Quality					■							
7. Biological Control												
8. Climate Stability					■							
9. Disaster Risk Reduction						■			■			
10. Pollination and Seed Dispersal	■											
11. Soil Formation												
12. Soil Quality												
13. Soil Retention												
14. Water Quality					■	■					■	
15. Water Capture, Conveyance, and Supply					■							
16. Navigation												
Supporting Services												
17. Habitat and Nursery	■		■			■	■					
Information Services												
18. Aesthetic Information		■								■		■
19. Cultural Value												
20. Recreation and Tourism		■	■	■	■	■		■	■			■
21. Science and Education												

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Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

Annual Value of Natural Capital in the San Juan Bay Estuary Watershed

Non-urbanized areas of the San Juan Bay Estuary Watershed are dominated by grassy wetlands, pasture, mangrove, and evergreen forests, followed by estuaries and other forest types. Shrublands, sand and woody wetlands comprise most of the remaining areas. Table 5 summarizes these estimates across all landcover types, with all ecosystem service values combined for each landcover type. For example, each acre of evergreen forest has been estimated to provide $459.17 in energy and raw materials, and $380.29 in medicinal resources each year. To this, we add $22.07 in habitat value, based on a study of similar Costa Rican forests.[5] The recreational value of evergreen forests is estimated to range from $7.00 to $23.81 per-acre, per year.[6,7] Combined, each acre of evergreen forest contributes between $869 and $885 in ecosystem services each year. The annual contribution of the ecosystem services produced by each landcover type is detailed in Appendix A.

Table 5. Annual Contribution of Ecosystem Services within the San Juan Bay Estuary Watershed

		Per-acre Value (USD/acre/year)		Annual Value (USD/year)	
Landcover	**Acres**	**Low**	**High**	**Low**	**High**
Cultivated, Agro-forestry	87	$272	$306	$23,705	$26,639
Estuaries	1,873	$1,129	$8,492	$2,115,422	$15,905,741
Forests, Evergreen	4,027	$869	$885	$3,497,570	$3,565,264
Forests, Mixed	567	$1,692	$1,826	$959,092	$1,035,450
Forests, Unspecified	919	$2,104	$5,536	$1,933,567	$5,087,648
Mangroves	4,821	$2,015	$5,202	$9,714,411	$25,080,867
Pastures	5,338	$34	$37	$179,997	$199,961
Sand	211	$5,909	$5,909	$1,246,723	$1,246,723
Shrublands	481	$128	$668	$61,712	$321,332
Water, Unspecified	133	$34	$34	$4,551	$4,551
Wetlands, Forested / Woody	133	$188	$4,656	$24,983	$619,213
Wetlands, Grass / Herbaceous	5,604	$235	$1,464	$1,318,509	$8,202,967
Total	**24,194**			**$21,080,243**	**$61,296,357**

To calculate the total annual contribution of each landcover type and its associated ecosystem services, per-acre value estimates were scaled by the extent of that landcover type within the watershed. Thus, the annual landcover values are presented in both per-acre terms, and for the full extent of each landcover type within the watershed. As a whole, ecosystem services within the San Juan Bay Estuary Watershed are estimated to provide between $21 million and $61

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million each year. Given the limited availability of valuation studies across all ecosystem services and landcover types present within the watershed, these estimates are only partial – that is, if future valuation studies address the contribution of ornamental resources or soil formation in evergreen forests, these estimates are quite likely to increase. As such, they can be considered a conservative "minimal" estimation of the contribution of ecosystem services within the watershed.

Annual Value of Carbon Sequestration and Energy Savings

In addition to benefit transfer values, primary data has been collected for some watershed-specific values. The US Forest Service completed a tree inventory of the San Juan Bay Estuary Watershed in 2011, assessing characteristics and volume of trees.[8] Based on this assessment, forest, mangrove, and urban trees in the watershed are estimated to sequester an additional 28,384 metric tons of carbon annually. This equates to a value of $4,044,690 per year, based on a value of $142.33 per metric ton of carbon estimated by the US Interagency Working Group on Social Cost of Carbon.[9]

Urban trees within the San Juan Bay Estuary Watershed also provide other benefits, including urban heat island mitigation, shade, and serving as windbreaks. USFS calculated that urban trees helped San Juan residents reduce the energy needed to heat or cool residential and commercial buildings by 19,034 MWh each year. Based on the average price of electricity in the San Juan area, USFS determined that urban trees provide an annual savings benefit of $5,214,566 to residential and commercial customers.[10]

Net Present Value Calculations

In addition to the annual flow of ecosystem service benefits summarized in Table 5, it is useful to calculate the "asset value" for the watershed's natural capital, or the Net Present Value of all benefits from ecosystem services that will accrue over the course of a hundred years. Net Present Value is calculated using a "discount rate," or what economists call the "time preference for money," in which a person typically prefers a dollar today, rather than a dollar (or somewhat more) at a future date. A stronger preference for immediate returns lead to higher discount rates, while a zero percent discount rate indicates that benefits today are valued no more (nor less) than benefits in the future. The three percent discount rate used here is in the range proposed by many economists for valuation of natural capital. The purpose and application of discount rates is one of the more hotly debated topics in economics, but despite

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Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

this, asset values help policy makers to appreciate the total worth of an asset over time, and are a critical tool for planning long-term investment and stewardship efforts.

As carbon is sequestered over time, forests, urban trees, and woody mangroves store increasing volumes of carbon. Across the San Juan Bay Estuary Watershed, trees currently store approximately 319,384 metric tons of carbon, which translates to $45,511,882, based on the social price of carbon mentioned above.[11] Because this value represents the current "stock" of carbon held in trees (rather than the annual "flow" of sequestration), it has been included in the final Net Present Value calculation of the watershed's natural capital, with the ongoing sequestration of carbon added to that stock each year.

Overall, a conservative estimate of the asset value of the natural capital in the study area is between $712 million and $1.9 billion when valued at a three percent discount rate over the next 100 years. At a zero percent discount rate, San Juan Bay Estuary Watershed asset value is estimated between $2.1 billion and $6.1 billion, and $548 million and $1.5 billion at a 4.12% discount rate, as seen in Table 6.

Table 6. Total Asset Value of San Juan Bay Estuary Watershed's Natural Capital

Discount Rate	Low(USD)	High(USD)
0%	$2,154,000,000	$6,175,000,000
3%	$712,000,000	$1,982,000,000
4.12%	$548,000,000	$1,505,000,000

From this it is clear that the natural assets of the study area provide enormous value to local and regional economies and communities. Again, it is important to remember that these are conservative estimates, owing to the limited valuation research relevant to the watershed's ecosystem services (see

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Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

Table *4*). Furthermore, while these estimates a limited to one hundred years, with effective stewardship, these ecosystems should continue to provide benefits in perpetuity.

Valuation Discussion

Given the limitations of data and relevant valuation studies, these findings should establish a starting point for ongoing discussion and research. Accordingly, the following concerns should be considered in future policy decisions and research efforts:

- **Natural Capital Provides Significant Value to the San Juan Economy:** This study is able to report only a portion of the full contribution of ecosystem goods and services.
- **These Values are Highly Conservative.** Many landcover–ecosystem service contributions could not be valued due to a lack of studies commensurate to Puerto Rico's ecosystems and climate. Primary research and valuation studies of tropical shrubland, beaches and wetlands are especially sparse, as are landcover data that better characterizes urban/open space ecosystems, valuation of the ecosystem services of freshwater swamps, and the value of recreation within the Caribbean. As new research becomes available, the total recognized contribution of ecosystem services is certain to increase.
- **Contiguous Habitat and Habitat Corridors Provide Many Co-Benefits.** There is a significant body of research on the value of contiguous habitat and migration corridors for birds, animals, and even plants. These benefits are the product of many complex local interactions, which must be studied *in situ* – while interconnections within and between ecosystems are critical for ongoing adaptation to shifts in climate and precipitation, BTM is not often the best tool for estimating the value of such benefits.
- **Strong Links Between the Economy, Community, and Natural Environments Builds Long-term Resilience.** As temperatures rise, rainfall intensifies, and droughts deepen, ecosystem services will become even more important to successful adaptation and resilience. Loss of ecosystem services often creates a need for infrastructure to replace that functionality, which is often less resilient and costlier to build and maintain.

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Fax 253.539.5054
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Opportunities for Additional Economic Analysis

This analysis provides a framework for discussing ecosystem services and valuation data available through published studies through the application the benefit transfer method. Further economic analysis should provide policy makers with a more detailed and comprehensive understanding of the value of local ecosystems to the regional economy.

Generate More Values Using Function Transfer

One way to address the lack of primary data applicable to the San Juan Bay Estuary Watershed is what is known as "function transfer," an approach where functional models of ecosystem services of other somewhat similar locales are recalibrated with local information to estimate the production of ecosystem services at the new "target" site. Function transfer methods are often more complicated, but can fill in important gaps in local ecosystem service data.

Economic Impact Analysis of Recreation

Beach recreation in San Juan is part of the local culture. Recognizing formal recreation areas and informal recreation such as beachcombing, jogging, swimming at Puerto Rico's many beaches could play a significant role in the local economy. Better accounting of these activities will quite likely increase recreation value estimates beyond those reported in this study.

Comprehensive Benefit-Cost Analysis (BCA) of Development Options

Traditional BCAs are often narrow in scope, limited to items such as home construction costs, sale prices, tax revenue, and other common project measures. A comprehensive BCA attempts to capture a much wider range of project or land use policy implications, and it can help in expanding our understanding of both benefits and costs, as well as the range of available options.

Beyond the ecosystem services addressed in this study, supporting more parks and beaches could reduce healthcare costs, reduce stormwater management costs, reduce heat island impacts, and increase home values. Amenities such trails may improve employment opportunities, and lower the costs of commuting, especially for low income residents. More comprehensive approaches to benefit-cost analysis provide a more complete understanding of the available policy options and expected impacts. The value of this approach has national support – in 2015, the US Department of Housing and Urban Development (HUD) launched a $1

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billon National Disaster Resilience Competition that required comprehensive BCA analyses from all applicants.

Better Data Yields Better Long-term Decisions

Decision makers often lack an informed understanding of the contribution of natural capital and ecosystem services to local economies and communities. Where natural capital is undervalued, BCA and Return on Investment (ROI) calculations portray natural capital restoration and stewardship projects as less worthy. Insufficient investment in restoration and stewardship then leads to declines in natural system functions that compromise local economies and communities – communities must pay higher taxes and fees to compensate for services that nature no longer provides for free.

Globally, communities are seeking out ways to restore balance and save tax dollars. In many instances, the solution has been to restore local environments as they were 50 or 100 years ago. This may mean restoring river flow, rebuilding riparian vegetation, and reconnecting floodplains to mitigate the harm of extreme weather events. Often, the restoration of natural system functions offers the most cost-effective, resilient, and durable solution to critical problems. Anecdotal evidence indicates that healthy natural capital is also good for business, especially attracting and maintaining highly skilled, engaged workforces.

Once again, because this study is limited by the availability of relevant studies, the values included here are highly conservative, representing more of a “floor” of ecosystem service contributions, rather than reflecting the full value of natural capital within the San Juan Bay Estuary Watershed. These estimates can – and should – be expanded over time, but even given the limitations, this assessment presents the most comprehensive data available to inform long-term investments for the future of the City of San Juan.

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Appendix A. Ecosystem Services provided by Each Landcover Type

Table 7. Ecosystem services provided by cultivated lands and pastures (per-acre per year)

	Cultivated, Agro-forestry		Pastures	
Ecosystem Services	**Low**	**High**	**Low**	**High**
Aesthetic Information				
Air Quality				
Climate Stability				
Disaster Risk Reduction				
Energy & Raw Materials	$32	$32		
Food				
Habitat	$37	$71	$34	$37
Medicinal Resources				
Pollination & Seed Dispersal	$203	$203		
Recreation & Tourism				
Water Capture, Conveyance, & Supply				
Water Quality				
Water Storage				
Totals	**$272**	**$306**	**$34**	**$37**

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Table 8. Ecosystem services provided by evergreen, mixed and unspecified forests (per-acre per year)

Ecosystem Services	Forests, Evergreen		Forests, Mixed		Forests, Unspecified	
	Low	High	Low	High	Low	High
Aesthetic Information						
Air Quality					$196	$196
Climate Stability					$1,154	$1,154
Disaster Risk Reduction						
Energy & Raw Materials	$459	$459	$2	$6		
Food						
Habitat	$22	$22				
Medicinal Resources	$380	$380				
Pollination & Seed Dispersal						
Recreation & Tourism	$7	$24	$1,690	$1,820	$108	$108
Water Capture, Conveyance, & Supply					$108	$108
Water Quality					$538	$3,970
Water Storage						
Totals	**$869**	**$885**	**$1,692**	**$1,826**	**$2,104**	**$5,536**

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Table 9. Ecosystem services provided by sand, shrublands and estuaries (per-acre per year)

	Sand		Shrublands		Estuaries	
Ecosystem Services	**Low**	**High**	**Low**	**High**	**Low**	**High**
Aesthetic Information					$745	$4,681
Air Quality						
Climate Stability						
Disaster Risk Reduction			$45	$62		
Energy & Raw Materials			$17	$427		
Food						
Habitat						
Medicinal Resources						
Pollination & Seed Dispersal						
Recreation & Tourism	$5,909	$5,909	$33	$33	$384	$3,811
Water Capture, Conveyance, & Supply						
Water Quality						
Water Storage			$34	$145		
Totals	**$5,909**	**$5,909**	**$128**	**$668**	**$1,129**	**$8,492**

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Table 10. Ecosystem services provided water, unspecified and mangroves (per-acre per year)

	Water, Unspecified		Mangroves	
Ecosystem Services	**Low**	**High**	**Low**	**High**
Aesthetic Information	$34	$34		
Air Quality				
Climate Stability				
Disaster Risk Reduction			$619	$1,808
Energy & Raw Materials			$24	$373
Food			$2	$858
Habitat			$3	$1,204
Medicinal Resources				
Pollination & Seed Dispersal				
Recreation & Tourism			$9	$255
Water Capture, Conveyance, & Supply				
Water Quality			$87	$705
Water Storage				
Totals	**$34**	**$34**	**$744**	**$5,202**

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Table 11. Ecosystem services provided by wetlands, forested/woody and grass/herbaceous (per-acre per year)

	Wetlands, Forested / Woody		Wetlands, Grass / Herbaceous	
Ecosystem Services	**Low**	**High**	**Low**	**High**
Aesthetic Information			$20	$110
Air Quality				
Climate Stability				
Disaster Risk Reduction				
Energy & Raw Materials				
Food			$57	$142
Habitat				
Medicinal Resources				
Pollination & Seed Dispersal				
Recreation & Tourism			$15	$1,211
Water Capture, Conveyance, & Supply				
Water Quality	$188	$4,656		
Water Storage				
Totals	**$188**	**$4,656**	**$93**	**$1,464**

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