Presentation Subject Area: Wastewater Management

Making the Case for Increasing Public and Private Investments in Wastewater Treatment: The Importance of Integrating Effects on Natural Capital

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I. Introduction

Untreated wastewater is the number one direct source of pollution to Caribbean marine ecosystems (CEP 2015). The principle motivation of governments and multilateral organizations to invest in wastewater treatment is often the protection of human health. While a critically important objective, this fails to fully recognize and protect key ***ecosystem services*** that flow from ***natural capital*** in the Caribbean (Exhibit 1). Natural capital such as nursery habitat for fish and safe water for swimming are at risk from the discharge of untreated domestic and industrial wastewater pollution, which, in turn, threatens the commercial fishery and tourism industries and elevates health care costs. By degrading the environment, ecosystem services that are critically important to the economic viability of Caribbean countries are compromised.

Exhibit 1.

Definitions

- ***Capital Costs*** are the costs to plan, design, permit, and build wastewater facilities, including the purchase of land
- ***Co-benefits*** are additional benefits of a project than can be quantitatively or qualitatively described. These include benefits referred to as ancillary, secondary or tertiary. (e.g., improve property values, reverse environmental degradation, protect shorelines, maintain or enhance biodiversity)
- ***Ecosystem Services*** are the stream of valuable, economically important goods and services which ecosystems provide society and businesses
- ***Natural Capital*** is the Earth's stock of natural assets, including land, air, water, and living organisms
- ***Natural Infrastructure*** is the use of natural ecosystems (i.e. constructed wetland) to substitute man-made physical infrastructure which provide additional environmental benefits and can enhance natural capital
- ***O&M Costs*** are the annual expenses to run the facilities including chemicals, manpower, electricity, waste management and disposal
- ***Primary Benefits*** are the intended outcomes of a project (e.g., prevent further environmental pollution, protect human health)

Traditional cost-benefit analyses commonly evaluate wastewater treatment alternatives only for ***capital costs***, long-term operations and maintenance costs ***(O&M costs)***, and system performance. Public health benefits may also be included as a quantified ***primary benefit***, but project impacts on natural capital and associated ecosystem service costs and ***co-benefits*** are not often assessed. Integration of regionally important economic linkages, including the downside of inaction, the additional benefits of action, and leveraging the co-benefits unique to ***natural infrastructure*** (NI) solutions can yield a very different presentation of the value of the investment.

This objective of this paper is to make a case to wastewater managers, government representatives, and non-governmental organizations (NGOs) that considering the value of ecosystem services and natural capital within an economic analysis framework can build a stronger case for, and increase public and private investment in, wastewater infrastructure (NOAA 2013) to be protective of human health and the environment on which the Caribbean economy depends.

II. Wastewater Pollution Impacts

Throughout most of the Caribbean, wastewater treatment is viewed as a lower priority to drinking water treatment, as evidenced by the level of investments in the water sector compared to the wastewater sector. Most wastewater treatment is inadequate, resulting in 85% of wastewater discharging untreated into the Caribbean Sea (Pemberton n.d.) with a toxic mix of freshwater, inorganic nutrients, pathogens, endocrine disrupters, suspended solids, sediments, and heavy metals (Wear and Thurber 2015, Islam and Tanaka, 2004, Pantsar-Kallio, 1999). In fact, some Caribbean countries have no centralized collection systems and depend on poorly functioning septic tanks and pit latrines (UNEP, 2012). Where centralized systems are in place, wastewater infrastructure is often poorly functioning, failing to meet ever-growing demand, or lacking the staff or funding to support long-term O&M—an often underestimated and underfunded expense (WHO and UNICEF 2013, CEP 2015).

Wastewater affects public health by polluting recreational waters, surface water, and groundwater, exposure to which can result in cholera, gastroenteritis, and hepatitis (WHO 2015). In Jamaica, inadequate treatment of wastewater in adsorptive pits has resulted in nitrate contamination of some groundwater sources, which, if extracted for drinking water, can cause methemoglobinemia in infants (Stewart 2005, Underground Water Authority 1996). Additionally, contaminated groundwater and surface water drains toward downstream waterbodies and out to the Caribbean Sea (Stewart 2005), furthering incidents of exposure to waterborne diseases.

Tourists are drawn to the region’s 26,000 km^2 (CEP n.d.) of coral reefs and tropical shorelines. However, in addition to costly human health impacts, wastewater pollution has broad impacts on the environment (UNEP 2004). For instance, nutrient enrichment of rivers causes eutrophication, which stimulates algal blooms that cause red tides (UNEP 2004). In turn, there are human health impacts (e.g., respiratory problems, parasitic shellfish poisoning, amnesic shellfish poisoning), discolored waters, and fish kills and impacts to birds and other animals that feed on marine species (Lallanilla 2013).

Polluted beaches and waters and declining coral reef quality and quantity (a 1.5% percent area loss annually was observed from 1977 to 2001 [Bruno and Selig 2007]) keep tourists away, resulting in a loss of key sources of income for Caribbean nations (Jackson et al. 2014, World Travel and Tourism Council 2014). The Caribbean Sea generates more than US$3 billion annually from tourism and fisheries (IUCN 2014). Economic valuations of coral reefs in Puerto Rico and US Virgin Islands are US$1,161 million and US$210 million dollars per year (2012 dollars), respectively (NOAA 2013). As one in four jobs in the Caribbean and up to 75% of each nation’s GDP come from tourism (Curriculum Press n.d.), impacts to coral reefs will greatly impact a high percentage of the population and the overall economy. And, as coral reefs serve as nurseries for many species of fish and shellfish (Burke et al. 2011), the loss of coral reef habitat strongly impacts the local fisheries industry as well.

Providing clean drinking water to a large percentage of the population has been followed by a focus on wastewater treatment in many regions of the world, in part because the two are often interrelated. Caribbean countries are moving in this direction and beginning to address the associated challenges.

III. Challenges to Addressing the Impacts of Wastewater Pollution

In 1986 several Caribbean countries signed the Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region, which was followed by the Land-Based Sources of Marine Pollution (LBS) Protocol in 1999 (UN 1999). The LBS Protocol is aimed at improving wastewater management coverage and treatment in the region. The Caribbean Regional Fund for Wastewater Management (CReW, 2011–2015) was developed to assist countries in meeting their wastewater related obligations under the LBS Protocol. It is funded by the Global Environment Facility (GEF) and implemented by the Inter-American Development Bank (IDB) and the United Nations Environment Programme (UNEP).

In addition to supporting policy, legal, and institutional reforms and increasing awareness about wastewater management, the CReW Project is testing four pilot financing mechanisms for wastewater investment. These pilot projects are intended to develop national mechanisms that will ensure sustainable financing of much-needed investment in wastewater infrastructure. These financing mechanisms, along with the reforms in policy and laws, awareness raising, and training, are expected to address the key challenges (Exhibit 2 – based on UNEP CEP 2012 Technical Report #62) while also taking into account important locally relevant factors such as environmental sensitivity, political priority, best-fit technology, and funding streams.

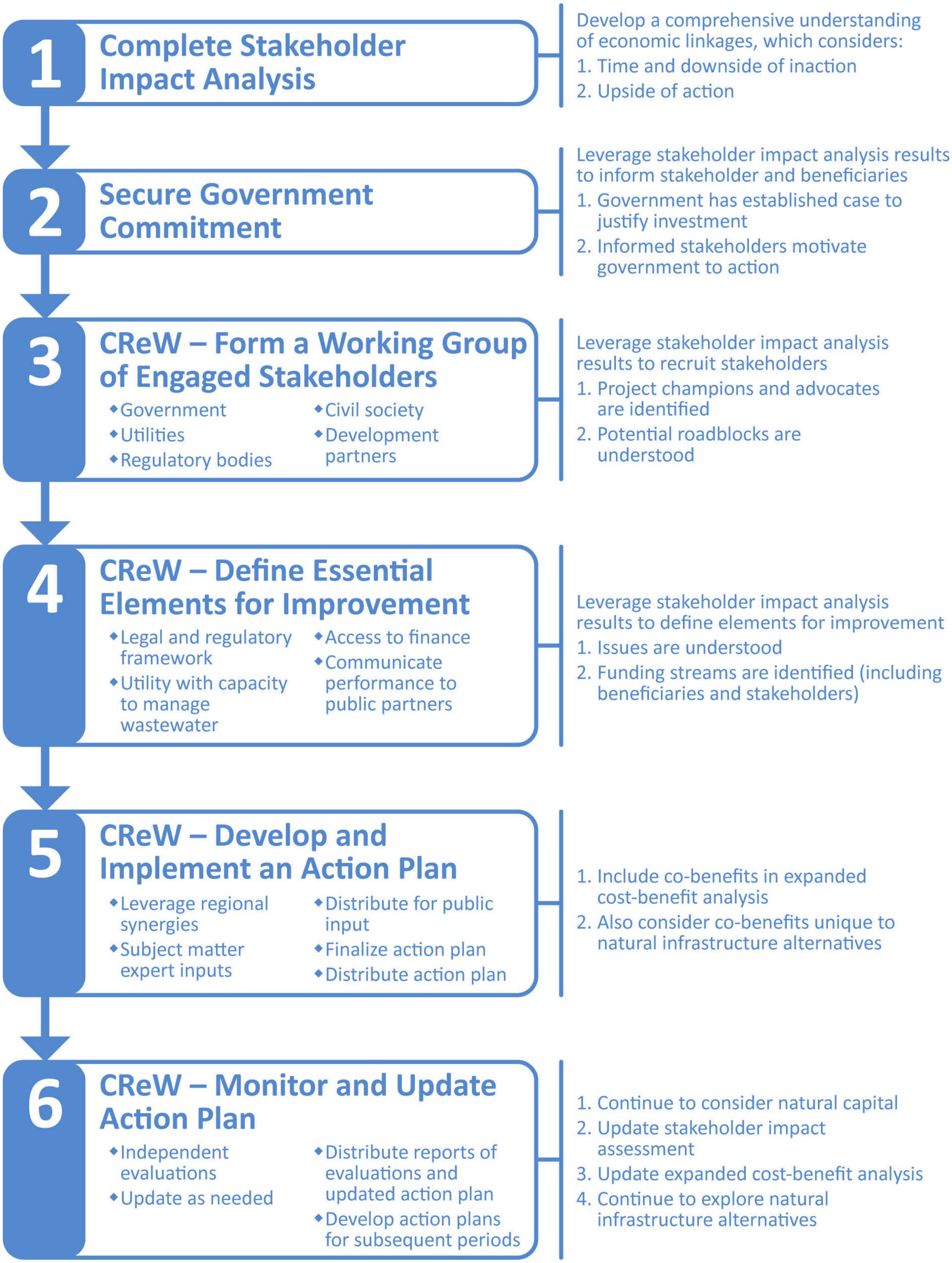
Exhibit 2.

Key Wastewater Challenges

- Lack of awareness of issue
- Lack of concern for issue
- Poor disposal and management practices
- Lack of/poor legislation and policy frameworks
- Lack of/minimal enforcement of regulations
- Low treatment capacity of existing infrastructure
- Aging infrastructure
- Outdated technology

A significant conclusion from the work of the CReW Project is that, although financing for wastewater infrastructure is available, countries often lack the organizational capacity to take advantage of opportunities or are excluded based on legal and institutional prerequisites required in the loan guidelines (UNEP 2014). To address this, CReW recommended the approach outlined in Exhibit 3 (Steps 3, 4, 5 and 6) (UNEP 2014).

Exhibit 3.


1
Complete Stakeholder Impact Analysis
Develop a comprehensive understanding of economic linkages, which considers:
1. Time and downside of inaction
2. Upside of action
2
Secure Government Commitment
Leverage stakeholder impact analysis results to inform stakeholder and beneficiaries
1. Government has established case to justify investment
2. Informed stakeholders motivate government to action
3
CReW – Form a Working Group of Engaged Stakeholders
◆Government
◆Utilities
◆Regulatory bodies
◆Civil society
◆Development partners
Leverage stakeholder impact analysis results to recruit stakeholders
1. Project champions and advocates are identified
2. Potential roadblocks are understood
4
CReW – Define Essential Elements for Improvement
◆Legal and regulatory framework
◆Utility with capacity to manage wastewater
◆Access to finance
◆Communicate performance to public partners
Leverage stakeholder impact analysis results to define elements for improvement
1. Issues are understood
2. Funding streams are identified (including beneficiaries and stakeholders)
5
CReW – Develop and Implement an Action Plan
◆Leverage regional synergies
◆Subject matter expert inputs
◆Distribute for public input
◆Finalize action plan
◆Distribute action plan
1. Include co-benefits in expanded cost-benefit analysis
2. Also consider co-benefits unique to natural infrastructure alternatives
6
CReW – Monitor and Update Action Plan
◆Independent evaluations
◆Update as needed
◆Distribute reports of evaluations and updated action plan
◆Develop action plans for subsequent periods
1. Continue to consider natural capital
2. Update stakeholder impact assessment
3. Update expanded cost-benefit analysis
4. Continue to explore natural infrastructure alternatives

Before implementing the approach recommended by CReW, the government must first be committed to elevating wastewater investment to a higher priority on its agenda (UNEP 2014). This is often impeded by the complexity of the solution sets and their costs, and a lack of awareness and/or concern on the part of stakeholders for the broad-ranging implications and true cost of inaction.

We propose that this desired shift in government and stakeholder priorities could be aided by integrating the value of ecosystem services and natural capital into CReW's proposed approach (Exhibit 3, Steps 1 and 2 and gray text boxes). Adding these components will strengthen support from the outset, increasing stakeholder concern and setting the enabling conditions for government commitments to pursue public and private investment in critically needed wastewater infrastructure. The integration is described in detail in the next section.

IV. Integrating the Value of Ecosystem Services and Natural Capital to Achieve Wastewater Treatment Objectives

Because untreated wastewater impairs the region's natural capital and has broad impacts on human health, comprehensively evaluating the economic benefits of wastewater projects by integrating the value of ecosystem services and natural capital to achieve a country's wastewater treatment objectives is critical.

As shown in Exhibit 3, the process begins by (1) completing a stakeholder impact analysis, which includes mapping the interdependencies between ecosystem services including revenue streams and expenditures for those stakeholder groups most sensitive to impacts of wastewater pollution. This information can be leveraged to inform those stakeholders of the true costs of inaction, thereby building a case for government commitment (2) while laying the foundation to form a working group of engaged stakeholders (3). The information gathered and shared for the analysis will also establish the basis for defining the necessary regulatory framework, defining the capacity requirements, identifying potential funding streams (i.e., beneficiaries of ecosystem services—stakeholders), and establishing the communications with civil society (4). Once the essential elements for improvement are defined, and the working group begins to develop and implement an action plan (5), the information gathered in the stakeholder impact analysis can then be leveraged, as appropriate, to complete the expanded cost-benefit analysis of project alternatives, which includes the value of ecosystem services preserved and enhanced, and any created through the use of NI alternatives. Monitoring and updating of the action plan (6) should include a review and update of the stakeholder impact analysis and a review of opportunities to further leverage NI alternatives as both an ecosystem enhancement and a source of revenue.

1. Complete a Stakeholder Impact Analysis

We suggest that a community begin its stakeholder impact analysis (Exhibit 4) by defining its current state of wastewater treatment. Then, it can develop a comprehensive understanding of economic linkages and their related revenue benefit streams (e.g., tourism, recreation, and fisheries) and expenditures (e.g., human health), thereby quantifying the downside of inaction. This evaluation can lead to a better understanding and articulation of local concerns, priorities, and long-term planning objectives. Then goals and a timeframe for action, which allow the developer to qualitatively or quantitatively define the potential upside of action, can be proposed.

Exhibit 4.

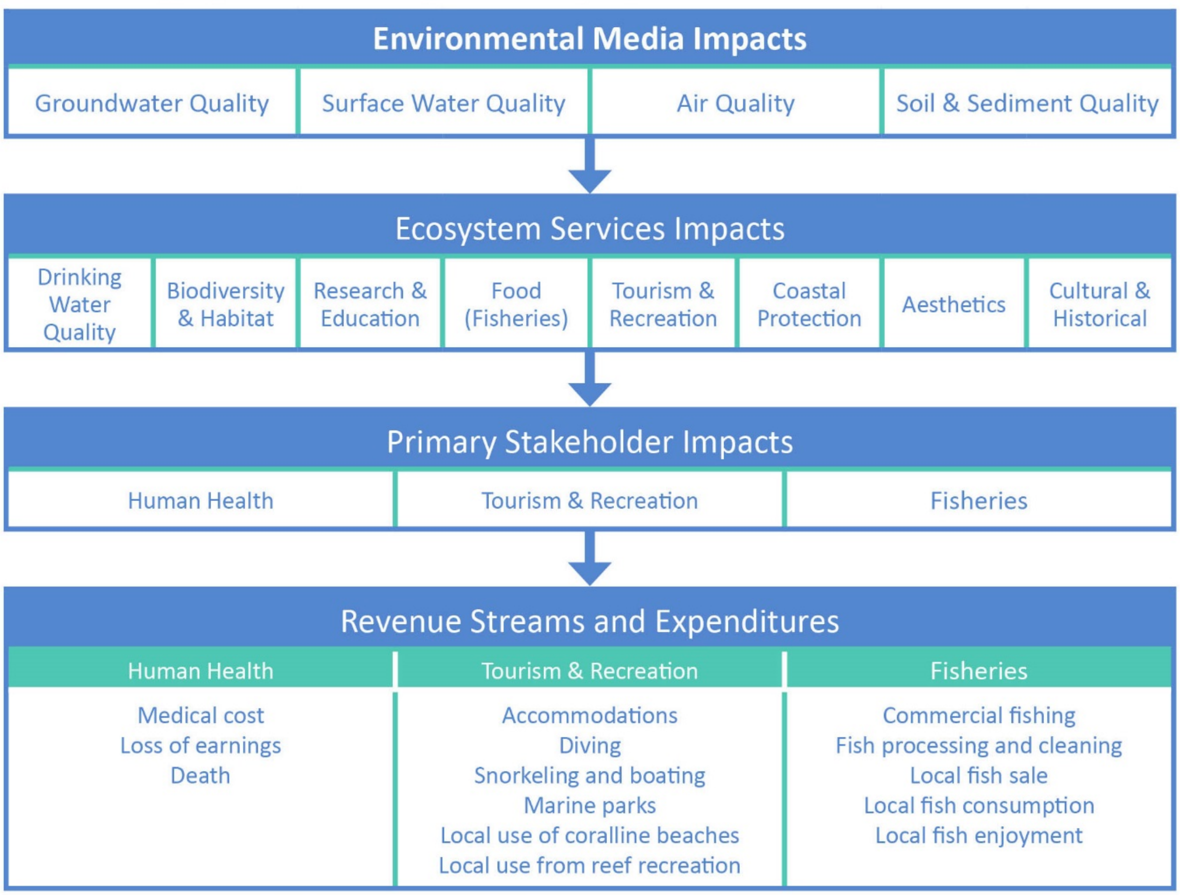
Components of Stakeholder Impact Analysis

- Define current baseline
- Develop a *Comprehensive Understanding of Economic Linkages*
- Define revenue streams and expenditures
- Quantify the *Downside of Inaction*
- Define local concerns, priorities, and long-term planning objectives
- Define goals and timeframe
- Define the *Upside of Action*

Developing a Comprehensive Understanding of Economic Linkages

It is beneficial for project proponents to begin mapping primary stakeholder impacts of wastewater pollution by first assessing its effects on the environment in their area of interest and identifying the network of ecosystem services that are linked to those environmental media (Exhibit 5). This is followed by defining economically significant human uses that may be impacted. This allows the project proponent to identify the primary stakeholders and their related revenue streams and expenditures, thereby quantifying the cost of inaction, and benefits of action.

Exhibit 5. Mapping Economic Linkages to Identify Impacts of Wastewater Pollution



Note: This example mapping is not comprehensive, but outlines a few selected ecosystem services: tourism & recreation and fisheries (revenues streams), and human health impacts (expenditures). Project proponents should select the economic linkages most relevant to their area of interest.

Time and Downside of Inaction

Not addressing wastewater pollution impacts on the environment may come at a high price to Caribbean communities. Coral reefs provide one example. As outlined above, sewage discharging into the Caribbean Sea contains a toxic mix of "freshwater, inorganic nutrients, pathogens, endocrine disrupters, suspended solids, sediments, and heavy metals" (Wear and Thurber 2015). And, as noted by the authors, sewage is often mischaracterized as a single stressor to coral reefs, and the focus is often nutrient pollution impacts. However, when positive feedback loops are considered, it is apparent that sewage acts as a potentially lethal multiple stressor.

Additionally, it is important to consider that the depletion rate of natural capital does not necessarily remain constant over time and can increase exponentially when a tipping point is reached, *"*when small shifts in human pressures or environmental conditions bring about large, sometimes abrupt changes in a system*"* (Ocean Tipping Points 2015). For example, with the multiple-stressor impacts of sewage to coral well underway, increases in non-sewage stressors (e.g., temperature, overfishing, coastal development, ocean acidification, agricultural runoff, unsustainable tourism, shipping, disease [Burke et al. 2011]) will increase the synergistic impacts, potentially accelerating the progression of degradation to a point where recovery is not possible (Ocean Tipping Points 2015). The impact of the loss of a coral reef to a small island nation's economic well-being would be profound. Therefore, inclusion of the no action case and the economic loss over time in the stakeholder impact analysis would provide a reference point for stakeholders to see the true cost of inaction.

Upside of Action

By addressing wastewater pollution impacts, a country not only stems degradation but also may potentially reverse adverse impacts, enhancing the quality and quantity of habitat relative to the current state. This can create more sustainable uses, opportunities, and revenue streams (Exhibit 6). For example, many communities manage their raw sewage by discharging it directly into the Caribbean Sea. This pollutes nearby beaches and waters, limiting the ecosystem services those areas can offer. Ensuring the community wastewater is properly treated both stems the degradation (downside/cost of inaction) and enhances those environments (beaches, nearshore ocean), creating additional value and potential revenue streams for communities in the form of ecosystem services such as recreational uses or increased development.

Exhibit 6

Positive Stakeholder Impacts

- Increase in property values
- Reversal of degradation
- Increased biodiversity
- Growth of sustainable fisheries
- Enabling human uses to a new area (e.g., near shore recreation, swimming)
- Capacity to support increased development without decreasing water quality
- Increase in tourism (e.g., hotels, restaurants, dive shops, bait shops, marinas, etc.)
- Lower costs for drinking water treatment
- Shift public health funding to other priorities
- Increase in employment
- Additional tax revenue

2. Seek Government Commitment

A stakeholder impact analysis that includes the value of a community's ecosystem services will serve to communicate those benefits, to clearly articulate their monetized and non-monetized value, and to inform beneficiaries and stakeholders of the true value of their environmental resources and cost of inaction. Leveraging the stakeholder impact analysis results in this way could aid in overcoming some of the key challenges (Exhibit 3) associated with wastewater management, such as lack of awareness or lack of concern, and motivate governments to commit to addressing the problem.

3. Form a Working Group of Engaged Stakeholders

With beneficiaries and stakeholders (resorts, hotels, restaurants) in ecosystems services clearly defined in the stakeholder impact analysis, project proponents can then move forward quickly to form a working group, which can include industry stakeholders interested in wastewater infrastructure enhancements. As noted by CReW (UNEP 2014), this group should also include government, utilities, regulatory bodies, civil society, and development partners (NGOs). The stakeholder impact analysis would also help project proponents identify advocates and the motivations of those needing to be won over before wastewater infrastructure improvements move forward.

> *"Those who stand to gain the most may be ideal contributors to the preservation of the USVI coral reefs….next to tourists, the second most important beneficiary of the coral reefs is the local community, who benefits from the reef in various ways (e.g. recreation, culture, coastal protection)" (NOAA, 2013).*

4. Define Essential Elements for Improvement

The next step (UNEP 2014) is to define the essential elements for improvement, which are country-specific: improving the legal and regulatory framework, ensuring the utility has the capacity to manage wastewater, ensuring access to financing mechanisms, and communicating performance to the public. The information gathered and shared for the stakeholder impact analysis will have laid the groundwork to define the status of these elements and where improvements are required, as well as having initiated communications with civil society. Potential funding streams should include considerations for sustaining the investment—for ensuring that long-term O&M costs are included and funded. This process will be aided, and pursuit of investment funds strongly supported, by the clearly defined beneficiaries (hotels, restaurants, fishing, tourists, etc.) of the solution that were identified in the stakeholder impact analysis.

5. Develop and Implement an Action Plan

Integrating the monetary valuation of environmental benefits and costs is a best practice that may change the cost-benefit ratio of various project alternatives (Dixon 2013). However, while direct benefits are commonly addressed in the economic case, the value of co-benefits (Exhibit 7) may be missing (Perez et al. 2009). For instance, healthy and intact coastal habitats buffer and protect the shoreline (Hutchins 2015). The potential result is that where projects without these benefits quantified do not have an attractive cost-benefit ratio, they can become very attractive investments when the broader suite of benefits is included. Therefore, we

Exhibit 7.

Potential Co-Benefits of Wastewater Treatment

- Increase in property values
- A slowing or reversal of degradation
- Enabling additional human uses of an area (e.g., near shore recreation, swimming)
- Shoreline protection
- Maintenance of biodiversity
- Maintenance of healthy fisheries
- Capacity to support increased development without decreasing water quality
- Lower costs for water access and treatment

propose that during the development and implementation of an action plan, the results of the stakeholder impact analysis can be folded into the expanded cost-benefit analysis to provide a more comprehensive assessment of the benefits of investment in an individual project or master plan.

Building out an expanded cost-benefit analysis can help identify the most cost-effective and fit-for-purpose solution, such as leveraging lower-cost constructed wetlands rather than more costly high-tech solutions; moving from individual septic to community-scale collection systems with improved treatment performance for rural customers; and, where major treatment works are in place in urban areas, designing upgrades that can meet capacity and performance requirements.

As previously noted, co-benefits can be economically significant, affecting the relative ranking of alternative treatment technologies and the determination of whether alternatives pass the benefit-cost test and thus warrant investment. Therefore it can be important to include them in the expanded cost-benefit analysis. Developing the list of likely types of benefits and costs is the first step. Developing a qualitative stakeholder impact analysis of the likely economic significance of each effect is the second step, and the third step is to conduct a quantitative analysis, where the units depend upon the type of effect (e.g., recreation visitor days, acres of fully functional habitat). Finally, the last step is to assess the economic value of the benefit or cost in monetary terms. The ability to quantify benefits and the type and level of documentation required to defend the valuation will vary. However, in general, it is typical for only a subset of benefits to be monetized. Other potential benefits can be qualitatively described or quantified using other metrics.

Natural Infrastructure

During the development of the action plan, project planners will also want to consider opportunities to leverage natural infrastructure (NI). NI is a planned or managed (often engineered), natural or semi-natural system designed for a specific purpose or function. As an example, wetlands can be used as part of the treatment process for wastewater to contain or degrade pollutants, where land is available. A key benefit of implementing such a natural treatment system (NTS) for wastewater treatment can be lower capital and O&M costs than other physical/chemical “gray” wastewater treatment technologies. These cost savings are well-documented and regularly considered in cost-benefit analyses. The lower long-term O&M costs of NTS can help developing regions avoid potential resource traps that more high-tech systems may create through the need for filters, chemicals, and teams of highly trained operators or contracted services.

Two other natural capital aspects of NI are considered less frequently. First, NI can provide a host of co-benefits. These can include creation of habitat, carbon storage, and the provision of recreational opportunities (e.g., birdwatching). Ecosystem services are created and, depending on what existed in the footprint of the NI before it was constructed, a net environmental benefit can be achieved. When this occurs, the NI not only protects natural capital but adds to it. These co-benefits can be important, economically and ecologically; for that latter, particularly in places where there has been significant losses of freshwater wetlands. In some places, NTS have become local recreational amenities, providing people with nature-viewing and education opportunities and employment (e.g., wildlife managers and tour guides). For example, Wakodahatchee Wetland, a treatment wetland park in Florida, USA, is heavily used by birders, photographers, fitness walkers, and families, and has become a tourist attraction. It started with 165 visitors in 1997 and now conservatively supports 125,000 visits per year. It has been featured in local and national press, and is recognized by the Audubon Society and national birders as a significant destination for bird watching. Concurrently, the wetland achieves significant reductions in total nitrogen (>80 percent) and total phosphorus (>50%), and because it was created as an infiltration system, the wetland returns approximately 400,000 gallons per day (gpd) of ecologically-treated water to the aquifer (Bays et al. 2000).

Second, NI may have a smaller "environmental footprint" than traditional technologies. For example, the construction and O&M of an NTS may require fewer resources and generate less pollution. Both of these aspects (co-benefits and a smaller environmental footprint) can be important with regard to making the case for wastewater treatment using an NTS. A better economic case for individual investments can be made by quantifying the co-benefits unique to NI. This allows one to consider the value of selecting one technology alternative over another with regard to its net environmental benefit (considering the environmental impacts of construction and O&M and any ecosystem services that would be created). In some cases, a wastewater treatment project may result in a net increase in natural capital, effectively contributing to paying back the cost of the initial investment, a return on investment not typically accounted for.

6. Monitor and Update Action Plan

As indicated above, monitoring and updating the action plan should include a review of opportunities to further leverage NI alternatives as both an ecosystem enhancement and a source of revenue. As new projects are proposed, expanded cost-benefit analyses, which include natural capital, could be completed. Additionally, it may be valuable to update the stakeholder impact analysis every one to three years to ensure it captures the value of ecosystem services to stakeholder and beneficiaries—to continue sustaining investment in both long-term O&M and capital improvement projects.

V. Conclusion

The importance of treating wastewater extends beyond human and ecosystem health. It can contribute to the long-term economic viability of Caribbean economies due to their dependence upon the coastal tourism and fisheries industries. A stakeholder impact analysis is a critical first step to identifying those who have the most to lose from failure to act and the most to gain from action. A comprehensive analysis of the economic linkages will aid efforts to attain a government commitment to elevate wastewater investment to a higher priority on their agenda (UNEP 2014), a necessity to proceed down the pathway to project implementation. Later in the process, including the effects of wastewater treatment alternatives on natural capital and ecosystem service costs and benefits in an expanded cost-benefit analysis can reveal the true value of a treatment project for decision-makers and facilitate investment.

VI. References

Bays, J., G. Dernlan, H. Hadjimiry, and K. Vaith. The Wakodahatchee Wetlands: A Multiple-Purpose Treatment Wetland. Water Environment Federation Technical Convention Proceedings. Anaheim, California. 2000.

Bruno, J.F., and E.R. Selig. 2007. “Regional Decline of Coral Cover in the Indo-Pacific: Timing, Extent, and Subregional Comparisons.” *PLoS One. Vol.* **2,** e711.

Burke, L., K. Reytar, M. Spalding, and A. Perry. 2011. *Reefs at Risk Revisited*. World Resources Institute, Washington, DC. http://www.wri.org/sites/default/files/pdf/reefs_at_risk_revisited.pdf.

CEP (Caribbean Environment Programme). 2015. Wastewater, Sewage and Sanitation. United Nations Environment Programme. http://www.cep.unep.org/publications-and-resources/marine-and-coastal-issues-links/wastewater-sewage-and-sanitation.

CEP (Caribbean Environment Programme). No date. “Fifty Facts about Wider Caribbean Coral Reefs.” http://www.car-spaw-rac.org/IMG/pdf/50-facts-about-wcr-coral-reefs.pdf.

Curriculum Press. No date. “The Environmental Impact of Tourism in the Caribbean.” *Geo Factsheet No. 204*. Wellington, UK. www.curriculum-press.co.uk.

Dixon, J. A. 2013. “Implementation Guideline: Economic Cost-Benefit Analysis (CBA) of Project Environmental Impacts and Mitigation Measures for Waste Water Treatment Projects (WWTPS).” *Technical Note No. IDB-TN-530*. Inter-American Development Bank. http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=37693371.

Hutchins, A. 2015. “The Caribbean’s Critical Coasts.” *Caribbean Journal.* http://caribjournal.com/2015/02/02/the-caribbeans-critical-coasts/.

Islam, S., and M. Tanaka. 2004. “Impacts of Pollution on Coastal and Marine Ecosystems Including Coastal and Marine Fisheries and Approach for Management: A Review and Synthesis.” *Mar. Poll. Bull*. Vol. 48, pp. 624–649.

IUCN (International Union for Conservation of Nature). 2014. “From Despair to Repair: Dramatic Decline of Caribbean Corals Can Be Reversed.” http://www.iucn.org/?16050/1/From-despair-to-repair-Dramatic-decline-of-Caribbean-corals-can-be-reversed.

Jackson JBC, Donovan MK, Cramer KL, Lam VV (editors). 2014. Status and Trends of Caribbean Coral Reefs: 1970-2012. Global Coral Reef Monitoring Network, IUCN, Gland, Switzerland. http://cmsdata.iucn.org/downloads/caribbean_coral_reefs___status_report_1970_2012.pdf

Lallanilla, M. 2013. “What Causes a Red Tide?” LiveScience. http://www.livescience.com/34461-red-tide.html.

NOAA (National Oceanic and Atmospheric Administration). 2013. *Summary Report: The Economic Value of U.S. Coral Reefs*. Silver Spring, MD. http://coralreef.noaa.gov/Library/Publications/valuesummaryreport.pdf.

Ocean Tipping Points. 2015. Project Overview. http://oceantippingpoints.org/project-overview.

Pantsar-Kallio, M., S.P. Mujunen, G. Hatzimihalis, et al. 1999. “Multivariate Data Analysis of Key Pollutants in Sewage Samples: A Case Study. *Anal. Chim. Acta*. Vol. 393, pp. 181–191.

Pemberton, Cecil. No date. “Financing Water and Sewerage Systems—A Caribbean Perspective.” http://www.bvsde.paho.org/bvsacd/cwwa/cecil.pdf.

Perez, A. I., R. Cardona, L. Locay, and H. M. Solo-Gabriele. 2009. “Water and Wastewater Infrastructure Priorities for Cuba with Emphasis on Havana, Including Some Benefit-Cost Considerations.” *Cuba in Transition*. American Society for Civil Engineering, Reston, VA. http://ctp.iccas.miami.edu/Appendices/Appendix_C_Water_Wastewater/Perez_et_al_2009.pdf.

Stewart, E. 2005. “Evaluation of Septic Tank and Subsurface Flow Wetland for Jamaican Public School Wastewater Treatment.” Michigan Technological University.

UN (United Nations). 1999. “Protocol Concerning Pollution from Land-Based Sources and Activities to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region.” http://cep.unep.org/repcar/lbs-protocol-en.pdf.

Underground Water Authority. 1996. “Groundwater Quality Assessment of the Liguanea Plains Sub-Basin.” Kingston, Jamaica.

UNEP (United Nations Environment Programme). 2004. Villasol, A., and J. Beltrán. Caribbean Islands, GIWA Regional Assessment 4. Fortnam, M. and P. Blime (eds.) University of Kalmar, Kalmar, Sweden. http://www.unep.org/dewa/giwa/areas/reports/r4/giwa_regional_assessment_r4.pdf.

UNEP. 2012. Technical Report # 66 Caribbean Regional Fund for Wastewater Management: Situational Analysis. The Caribbean Environment Programme.

http://www.cep.unep.org/publications-and-resources/technical-reports/technical-reports

UNEP. 2014. “Review of the Access to, Availability of, and Organizational Readiness for Uptake of Funding for the Wastewater Sector in Selected Participating Countries: Final Report.” Caribbean Regional Coordinating Unit. http://iwlearn.net/iw-projects/3766/technical-reports/review-of-access-to-availability-of-and-organizational-readiness-for-uptake-of-funding-for-the-wastewater-sector-2014.

Wear, S. L., and Thurber, R. V. 2015. “Sewage Pollution: Mitigation Is Key for Coral Reef Stewardship.” *Ann. N.Y. Acad. Sci.* doi: 10.1111/nyas.12785.

WHO (World Health Organization). 2015. Climate Change and Human Health—Risks and Responses. Summary. http://www.who.int/globalchange/summary/en/index4.html.

WHO (World Health Organization) and United Nations Children's Fund (UNICEF). 2013. *Progress on Sanitation and Drinking-Water—2013 Update*. Geneva, Switzerland: WHO Press.

World Travel and Tourism Council. 2014. Annual Economic Impact Report. http://www.wttc.org/-/media/files/reports/economic%20impact%20research/regional%20reports/world2014.pdf