A Roadmap for Restoration of the Monkey River, its Watershed, and its Shore

A plan to address the causes of degradation, restore sand delivery, improve river conditions, and ecosystem health in Port Honduras Marine Reserve

Produced by:
The Monkey River Watershed Association Board of Directors & Nilcia Xi
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Air photo of a gravel mining pit in the active river channel of the Monkey River's Swasey Branch

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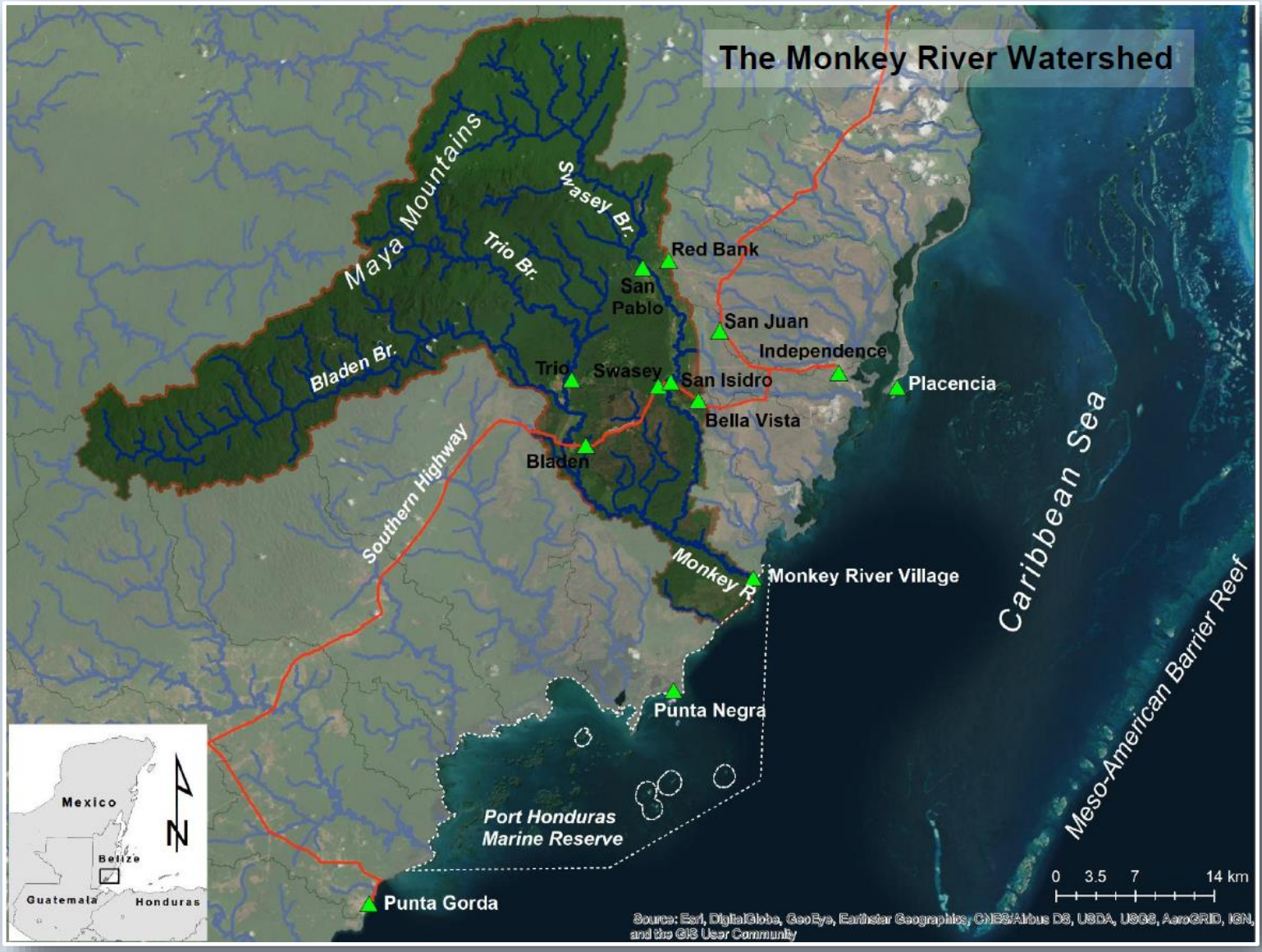


Background

The Monkey River watershed is the land area that collects rainfall and delivers it to the Bladen, Trio, and Swasey branches of the Monkey River and the main river itself. Geology, soils, and human land uses in the watershed determine the quantity and quality of the water that enters the river network for delivery to the Caribbean Sea. The timing and magnitude of water flow in the river channel determines the loads of sand, silt, nutrients, and pollution that are delivered to the floodplain and the ocean. The Monkey River meets the sea at the northern (up-current) end of the Port Honduras Marine Reserve. The Monkey River is important because it supports more than 10,000 people in nine villages and the agricultural industry with water for irrigation and domestic use, bush products, sand and gravel, fish and wildlife, and recreational opportunities. It also feeds protected estuary and marine ecosystems with robust tourism and commercial shellfish industries. Of the many people that use the river daily, the residents of Monkey River Village, at the river's mouth, have the longest history of dependence on the river for their daily needs, including the abundant river sand that used to nourish an extensive beach down-drift of the river mouth.

Monkey River Village's founding families settled on a sandy ridge in the river mouth area in the mid-1800s. The village population peaked in the mid-1900's at nearly 3,000 residents and today is home to 200 people descended from the founding families. The linkage between the village and the watershed is so intimate, that in 1993, the Government of Belize declared the entire Monkey River floodplain as a Special Development Area to "…protect and preserve the natural resources of Monkey River that residents depend on for their livelihood". After 150 years occupying the mouth area, shoreline erosion is creating an unfolding tragedy where more than 30% of lots in the village, multiple homes, and the front line of graves in the cemetery have been washed into the sea, displacing residents. Watershed degradation is the leading cause of erosion. Villagers have struggled to reverse the erosion within their means, but the problem requires a higher level of response.

The majority of the watershed's 10,000 residents live away from the coast in the watershed [Independence (pop. = 4,014), Bella Vista (~5,000), Red Bank (1,201),

Photo credit: Jacob Marlin

Trio (899), Bladen (466), San Isidro (375), San Pablo (250), San Juan (443) and Cowpen (142)], including the growing village of Bella Vista has become a hub of population and commerce. Many residents rely heavily on the watershed for agricultural and grazing lands, and on the river for sand and gravel, irrigation water, livestock water, drinking water, fish and game production, and laundry and washing, recreation, tourism, and floodplain forest products. The residents of the upland communities share a common set of circumstances with Monkey River Village in that changes to water quantity and water quality in their local streams have degraded their quality of life and is exposing them to economic and health risks.

This "*Roadmap for Restoration of the Monkey River, its Watershed, and its Shore"* describes the most likely causes of river degradation and erosion and outlines a long-term vision for restoration of the river and its watershed for the benefit of all users and downstream ecosystems. Specifically, the Roadmap:

1. Defines six restoration goals to achieve the desired states of the river and the shoreline;
2. Describes the actions needed to satisfy each restoration goal;
3. Outlines a science program that will enable better decision making.

Finally, the Roadmap describes a vision of the future where actions taken now lead to benefits to all users

of the Monkey River watershed and helps buffer local populations from negative consequences of sea level rise and climate instability.

The roadmap was prepared by the founding members of the Monkey River Watershed Association (MRWA) with technical advice from the U.S. Geological Survey and university scientists. MRWA is a community-based organization registered in 2017 "…to conserve and restore the integrity of the entire Monkey River Watershed…" and ensure that it continues to provide a multitude of benefits to watershed residents and the Port Honduras ecosystem. MRWA works with a large coalition of organizations including the Belize Foundation for Research and Environmental Education (BFREE), the Toledo Institute for Development and Environment (TIDE), Southern Environmental Association (SEA), and Ya'axche Conservation Trust (YCT).

Causes of river degradation and beach erosion

Experts toured the Monkey River watershed in October 2017 to observe conditions in the river channel, assess potential causes of erosion, and propose studies needed to clarify the situation. The experts concluded that **reduced sand delivery to the coast from upriver—not sea level rise—is the likely main cause of the beach erosion problem**. The technical report suggests that reduced sand delivery to the coast is primarily the result of decades of intensive use of land, water, and river sand in the middle reaches of the river network. Climate change is seen as an important secondary actor that exacerbates problems caused by activities in the watershed. The major findings from the technical report are described below:

- Not enough sand is being delivered to the river mouth to replace the sand being lost to natural shoreline erosion. Two possible causes of lower sand delivery are (1) **lower flood flows** and (2) **less sand supply** in the river channel.
- Floods carry the greatest amount of sand annually. Historically, the river pushed sand and silt several kilometers past the Monkey River mouth into the Caribbean Sea during large floods. It appears that **flood flows have been reduced causing the sand to settle in the river channel above the river mouth area**.
- "Flow piracy" appears to be taking place, where flood waters are diverted from the Swasey Branch and main stem Monkey River into neighboring watersheds through manmade ditches (Big Cr., Sennis River, and Pine Ridge Cr.). Flow piracy could be cutting the peaks off of floods, reducing maximum flow and the rivers ability to transport sand.
- The Monkey River watershed has been the center for Belize's commercial banana production since the 1980's with large farms on all branches of the river. Poor land stewardship practices—including regular clearing of forests right to the river bank in 1980's and 1990's—resulted in large amounts of soil erosion. Banana farms attracted new watershed residents and industries like commercial gravel mining. The construction of the Southern Highway around the year 2000 likely led to a large pulse of fine sediment. One of the cumulative results of watershed activities has been siltation of the river channel in Swasey and Trio branches in particular. **Heavy loads of silt in the river channel displace the amount of sand that can be transported because the finer silt particles get picked up first during floods instead of sand, thereby reducing the amount of sand moving during floods.**
- Sand and gravel have been intensively mined from the Swasey River since the 1990s to build the Southern Highway and numerous cement structures in Bella Vista, Placencia, Punta Gorda, and Independence. **Extraction of sand may reduce the amount of sand supply available to feed the beach at the river mouth**.

Ditches in a newly-prepared banana field on lower Swasey Branch prior to planting. Ditches have strong effects on hydrology.

- Even though most sand moves during large floods, dry season flows still move some sand and silt. **Water extraction from the river for banana irrigation**

reduces river flow and the amount of sand and silt that the river can carry in the dry season.

- **Fisheries and wildlife have been depleted** through the middle reaches of the river since the early 2000s by overharvest and habitat degradation. Habitat degradation has been caused by the factors mentioned above, and increased harvest pressures on fish and game as population got larger and the river became more accessible.
- **Water sources have been contaminated** by human, pig, and cow feces, agricultural chemicals, and nutrients leading to increased public health risk, excessive algae growth, and lower river health.
- **Substantial land subsidence (lowering of the land surface) has made Monkey River Village more vulnerable to storm surge.** Subsidence occurred after Hurricane Iris (2001) removed most of the trees in the village and was further exacerbated in 2009 when an earthquake caused sand compaction. Sand is carried away from the beach by the (usually) north-to-south longshore current in interaction with wave action. **Tropical storms and hurricanes appear to be associated with the fastest rates of beach erosion**.
- **Sea level rise is a slow actor that will exacerbate the sand delivery problem** and put the village at greater risk during future hurricanes. Any climate-driven changes in the timing and amounts of rainfall also threaten to exacerbate the current crisis by affecting sand delivery to the coast.

In sum, changes to the river's hydrology and sediment delivery have overwhelmed the river's capacity to clear out its own channel of sand and silt all the way to the coast. Water quality degradation simultaneously threatens the well-being of thousands of upland residents. To correct the situation, river hydrology and sediment loads must be restored, contaminant sources reduced or eliminated, and the front of Monkey River Village stabilized until the beach begins to build itself back or is put back by human agency.

Restoration goals for the river and shoreline

Examples from other rainforest rivers suggest that rivers restore themselves once their hydrology and sediment loads are returned to a less impacted state and contamination sources are dealt with. Below we propose six restoration goals that, if achieved, have a high potential to improve sand delivery and water quality. The six goals are listed in order of highest to lowest perceived urgency, and can be pursued simultaneously:

1. *Stabilize the Monkey River shoreline* – to protect life and property until natural river sand delivery processes can be restored.
2. *Reverse land subsidence in Monkey River Village* – to decrease the risk of negative outcomes associated with storm surge and sea level rise.
3. *Restore wet season peak river flows* – to give the river back the power to clear its own channel and push sand to the coast.
4. *Reduce the amount of fine sediment entering the channel* – to increase sand transport, maintain soil fertility in the uplands, improve floodplain habitats, and increase groundwater recharge.
5. *Restore dry season river flows* – to increase dilution of pollutants, increase sand and silt transport, and provide sufficient water for irrigation and other human needs.
6. *Leave more sand in the river* — to maintain downstream supply and increase channel stability and habitat quality.

As they are achieved, each goal will result in improved habitat and better water quality throughout the river network. The next section describes a set of actions that, if implemented effectively, will help restore hydrology and sediment dynamics in the river.

The Roadmap

Degraded river function is the result of many decades of intensive development in the watershed. Nonetheless, **immediate actions can be taken now to remove the root causes of river degradation and insufficient sand delivery**. Many of the actions needed to restore sand delivery to Monkey River are the same ones needed to improve local water and habitat quality for upstream communities. The road map summarized in the table below presents a set of restoration actions that have been identified to remove the root causes of river degradation. The list of actions was identified by MRWA in consultation with expert river scientists, watershed communities, and organizational partners. Each action item represents a discrete project within a much larger program to restore the Monkey River.

Goal 1: Stabilize Monkey River beach front and build it back

North-to-south coastal currents and east-to-west wave action are the forces that carry sand away from the Monkey River beach. As watershed restoration is being pursued, MRWA and its partners will protect the existing shoreline by installing physical barriers to wave energy and erosion and then backfill sand behind these. The current strategy relies on filling massive synthetic fabric "geotubes" with sand to create barriers that will last for 10 to 20 years. Geotubes can be installed and maintained with a small commercial dredge.

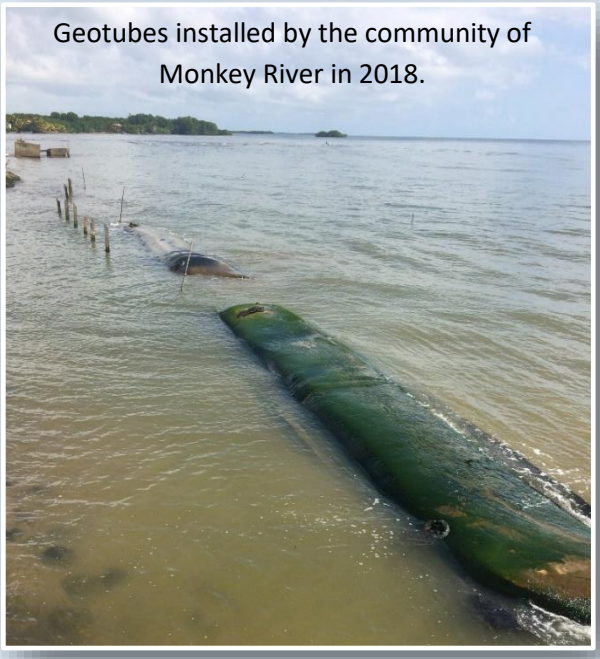
At least one row of shore-parallel geotubes will be placed south (downdrift) of the river mouth to past the burial ground (see figure on page 7). A first row will be placed close to the existing shoreline and will be backfilled with sand to protect the remaining lots in Monkey River. An additional row would be beneficial at the historic margin of the beach at about the 4-foot depth contour. The second row would further reduce wave energy to reduce sand scour. The backwater environment behind the second breakwater row may provide opportunities to establish fringing mangroves or another vegetation to further buffer from waves. Either way, new plantings of salt-tolerant trees and bushes in the newly backfilled area will be critical to reinforce the land and protect against future erosion.

It will be necessary to move relatively large volumes of sand to achieve these outcomes. Such work could be done by contractors using commercial dredge equipment or by residents of the village using a (yet to be purchased) "community dredge" to mine sand from the river mouth. Nourishing the beach, preferably with sand from the river mouth area, will be necessary to reverse further loss of property while river function is restored.

A third strategy to sustain the beach once it has been lined with geotubes, is to pump the sand that is currently clogging the river mouth out to the sand bar that was historically located outside of the river mouth in the sea. Nourishing the historic bar would enable waves and currents to clean, sort, and redeposit the sand onto the beach front.

Goal 2: Reverse land subsidence in Monkey River Village

Monkey River is built on a littoral ridge that was historically nourished by sand and silt deposited when the river flooded the village from behind (upriver). Until large floods are returned to the village, additional dredging of the river mouth and placement of sand on village lots will achieve the dual purpose of raising land elevations and keeping the main river channel open for boat traffic.



Geotubes installed by the community of Monkey River in 2018.

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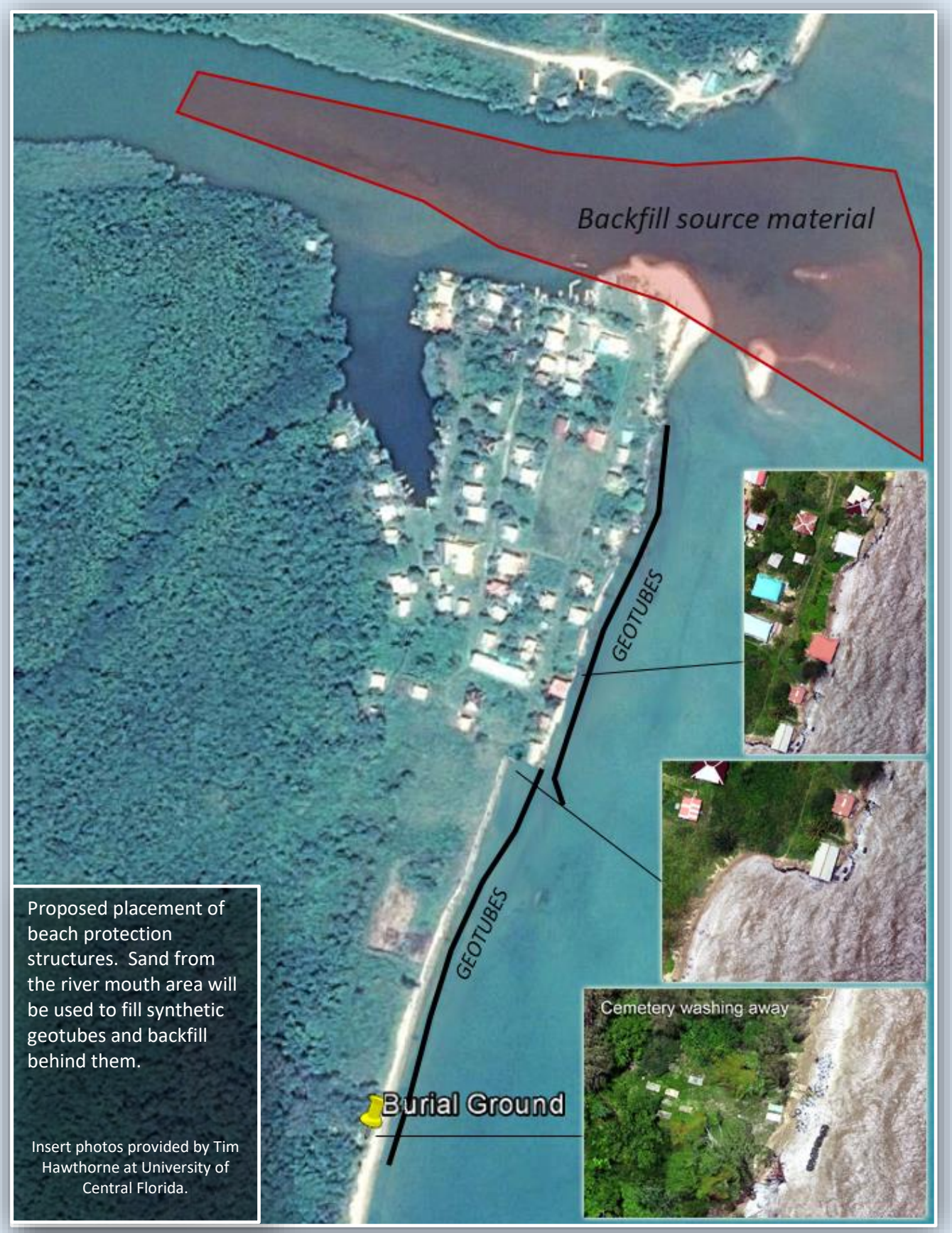
Restoration goal	Problem	Primary cause	Secondary causes	Restoration actions
1. Stabilize Monkey River beach front and build it back	Lives, property, and sacred sites are imminently threatened by land erosion down-current of the river mouth.	Insufficient sand volumes are being delivered by the river to offset volumes lost to natural shoreline erosion processes.	Sea level rise may make the beach more prone to erosion. Intensifying storms associated with climate change may lead to more aggressive wave action and accelerated erosion.	Install a Geotube barrier and backfill behind it with material dredged from the river mouth Use selective plantings of fast growing littoral trees and bushes to stabilize the land surface behind barrier. Artificially nourish the sand bar outside of the river mouth.
2. Reverse land subsidence in Monkey River Village	Land elevations have decreased within the village resulting in increased vulnerability to storm surge and erosion.	Soil compression during a large earthquake in 2009	Total vegetation loss and soil compaction caused by heavy machinery following Hurricane Iris in 2001	Dredge the river mouth area to pump silt/sand into low-spots on the land surface. Plant trees to accelerate soil formation and anchor the land surface.
3. Restore wet season peak river flows	The maximum amount of water moving in the channel during floods has been reduced resulting in lower sand transport volumes.	Inter-basin transfers of flood waters through ditches connected to other watersheds reduce water volumes in the channel.	Inter-basin transfers over naturally low banks into Payne's Creek National Park further reduce volumes in river.	Build flood control structures in highly targeted locations Evaluate re-engineering of banana ditch networks.

4. Reduce the amount of fine sediment entering the channel	Poor soil conservation and channel management has led to "fining" of river sediment. Increased silt displaces sand that is transported by the river because silt is picked up first. Silt degrades local habitat quality and exacerbates nutrient and microbial pollution.	Soil erosion from agricultural land and construction of roads and villages. Extensive riparian clearing and gravel mining starting in the 1980s through today accelerates land-based erosion and contributes additional silt from failing river banks.	Cattle farming is a growing practice in portions of the watershed and presents a new source of fine sediment and nutrients.	Reforest riparian buffers Enforce 66' buffer laws Stabilize problematic river banks using geotubes and other artificial means. Eliminate or severely reduce gravel mining that takes place within the active river channel.
5. Restore dry season river flows	Water levels during the dry season have become reduced giving the river less ability to clear itself of fine sediment during low flows. Lower flow volumes lead to concentration of pollutants during dry season and greater human exposure.	Water abstraction for banana irrigation.	Deforestation and urbanization leading to lower groundwater recharge and less flow from ground water during dry months.	Install more efficient banana irrigation Eliminate all clearing in forest reserve boundaries Restore and protect forests in headwater portions of the watershed and critical recharge areas
6. Leave more sand in the river to maintain downstream supply and channel stability	Substantial quantities of sand are being mined from the river potentially restricting sand supply downstream and creating a channel that is flat wide and unstable.	Historic and contemporary sand and gravel mining in the Swasey, Trio, and Bladen Branches.		Declare a gravel mining moratorium while sustainable harvest targets are determined. Monitor and strictly enforce sustainable harvest limits.


Backfill source material
GEOTUBES
GEOTUBES
Cemetery washing away
Burial Ground
Proposed placement of beach protection structures. Sand from the river mouth area will be used to fill synthetic geotubes and backfill behind them.
Insert photos provided by Tim Hawthorne at University of Central Florida.

Goal 3: Restore wet season peak river flows
MRWA first needs to confirm the locations and volumes of water leaving the watershed during flood events. Based on the new information gathered, solutions must then be engineered to target the specific locations with the greatest water loss. If flood waters are being lost to ditch networks, then flood gates at the ditch mouths and/or re-engineered drainage networks may be necessary. If flood waters are primarily exiting over low river banks, then leveeing these banks with geotubes would help keep flood waters in the river channel where they can do the necessary work of clearing excess sediment.

Goal 4: Reduce the amount of fine sediment entering the channel
The vegetated zone next to the river—the riparian buffer—stabilizes river banks and traps soil and nutrients that would otherwise wash in. Belize's riparian protection law mandates a 66-foot buffer from the high water mark, but this is rarely enforced. Voluntary or enforced riparian protection and restoration will help reduce further siltation of the river. Riparian management includes managing deforestation, cropping, grazing, and gravel mining along the river channel. Riparian restoration and protection not only help the Monkey River Village but will improve water quality, habitat quality, and fisheries for all residents.

Goal 5: Restore dry season river flow
Banana growers take a relatively large portion of total dry season flow to irrigate their crops. Much of the water that is pumped from the river never returns to it. Lower flows in Bladen and Swasey Branches translate to less silt and sand transport, less water available for dilution of pollutants, and less water available for human use. Investments in more efficient irrigation systems (i.e, drip irrigation rather than sprinklers) would leave more water in the river to transport sand and benefit local users.

In the dry season, the river is fed by rain water that percolates into the ground during the preceding wet season. Urban development, deforestation, and ditching result in less percolation of water and more overland runoff. Infiltration is highest under natural vegetation, so protection and restoration of forests is an important action that can help protect dry season flows. The Swasey-Bladen Forest Reserve on the floodplain between Swasey and Bladen Branch is an important recharge area that has been encroached on by squatters. Protecting headwater forests is also crucial, including the Maya Mountain North Forest Reserve which has been de-reserved in places and deforested in others.

Goal 6: Leave more sand in the river to feed the beach
The amount of sand mined out of the Swasey and Bladen Branches is currently unknown, but anecdotal reports suggest that the volumes are substantial. Permanent removal of large amounts of sand will eventually affect the beach downstream, but better information is needed about how much sand should be left in the river. A study on the connections between sand extraction, downstream sand supply, and river channel stability will clarify needed actions, which could include a moratorium on sand and gravel mining and/or establishment of sustainable harvest targets and stronger enforcement.

Science for decision making

Science can help reduce uncertainty about what to do, how, when and where to do it, and whether your actions were successful. But science is time consuming, requires specialized knowledge, can be expensive, and therefore should be used judiciously on the most important questions, such as:

1. What is the history of land use change in the watershed and how and when did this affect sediment transport, the river channel, and the amount of sand on the beach?
2. How has hydrology changed through time? How much flow is attenuated by banana drainage ditches during floods?

Watershed residents completed a baseline assessment of river health in 2000.

3. How will sea-level rise effect the position of the future shoreline, and vulnerability to tropical storms? Will Monkey River eventually be an island cut off from the land?

The expert report by US Geological Survey presents a "minimum recommended" research program that would provide critical information on the questions above. The key components of this program would help support many important decisions.

Monitor weather, river hydrology, sediment movement, and tides. It will be critical to document pre- and post-restoration conditions to support better decision making and report successes to funders and the public. Installation of a sensor network to collect new data will be necessary. Monitoring river hydrology, sediment loads and composition will be important to know whether flows have been restored, and monitoring shoreline position, wave climate, and sea level will provide the information necessary to protect the shoreline. It will be critical (in the next phase of this project) to develop a set of metrics to track conditions in the river and shoreline systems. It is important that the new monitoring network measure these indicators of system response directly.

Test for historic trends in weather and hydrology
The Hydrology Unit in the Ministry of Natural Resources keeps data about rainfall, river flow, and other hydrologic factors throughout Belize. Analyzing these data could confirm if and how hydrology has changed, and also if trends in weather and river flow can be linked to climate change.

Analyze aerial photos and satellite images for changes to land use, river position, and shoreline position
Multiple times a year, space satellites have taken pictures of the Monkey River since the early 1970s and aerial photos of the Monkey River watershed are available as far back as the 1950's. By interpreting images collected through time, we can learn how and when deforestation took place, whether the river channel shows signs of reduced flooding (i.e., lower amplitude meander bends), and how quickly and when beach erosion took place. New data from aerial drones could be a low-cost strategy to monitor the beach. This information will be used to set quantitative targets for reforestation and river conditions.

Map land elevations
A powerful aerial remote sensing technology called Light Detection and Ranging (LIDAR) flown from airplanes or drones will be used to create very high-resolution land elevation maps. These will be used to (1) map the elevations of banana ditches; (2) identify river banks where modifications may be needed to keep water in the channel; (3) map pathways for soil and silt delivery to the river channel; and (4) map sand volumes in sand bars and the beach.

Hope for the best, prepare for the worst

Sea level rise and hurricanes are major threats to all residents of the Monkey River watershed. Sea level rise will slowly flood the low-lying areas around Monkey River Village, potentially cutting it off from the mainland. Risk of storm surge and hurricane winds will intensify and potentially accelerate erosion. Despite these threats, **the will of the residents of Monkey River Village is to remain on their historical lands and restore the beachfront and watershed.** If they leave the village it will be from necessity rather than choice.

Given predictions of stark climate futures, it is critical that Monkey River Village work with the Government of Belize to **evaluate emergency resettlement site(s) and secure titles to land**. The SDA "secured" 16,800 acres of the lower river "…to protect and preserve the natural resources of Monkey River that residents depend on for their livelihood, and to stimulate job opportunities and economic diversification through tourism and agricultural development." Monkey River residents worked with the Physical Planning Department to zone the SDA for multiple uses but given the changes that have taken place since 1993, now is an appropriate time to revisit the SDA zoning plan, strengthen the legal basis for preferential access to the land, and evaluate options for resettlement. If suitable sites in the SDA are unavailable, then alternative sites must be located and secured.

MRWA's Vision of the Future

A strong coalition of partners is formed and funded to install emergency response measures in the river mouth area and restore the watershed upstream. Geotubes are installed along 1,200 feet of Monkey River Village and back-filled, giving MRWA time to work in the watershed and identify potential resettlement options for the community. The Banana Grower's Association is subsidized to re-engineer its agricultural ditch network and irrigation systems. Flood piracy is eliminated, leaving more water in the river to clear out sand during flooding. Strategically placed levees on low-lying river banks keep water in the channel rather than the neighboring savanna. Fine sediment entering the channel is reduced through a combination of riparian forest restoration, forest protection, improved mining practices, and soil management practices. The river channel becomes more stable allowing it to work more efficiently to move sand down-river. Reforestation efforts and higher river flows result in less nutrient and toxic pollution, more abundant bush meat and materials, and improved habitat for fish and wildlife. Investments to improve banana irrigation efficiency and conserve groundwater recharge zones result in higher dry-season flows. Higher dry season flows transport more sand downstream, dilute pollutants, and harbor larger populations of aquatic animals. At the river mouth, the return of high flows flushes sand from the channel and begins building a bar further from shore. The beach begins to build back naturally for the first time in many years. Large floods deepen the main river channel making it easier to navigate and attracting food fishes like snook and snapper. As sea level rise continues, a strategy of shoreline protection, artificial beach nourishment, and contingency planning give the villagers security. The village may eventually become a barrier island that is managed similarly to some of islands near Placencia Village and Belize City. Simultaneously, the residents of Monkey River Village retain property and dignity and have greater security in the face of an uncertain future.

The beach at Monkey River Village in 1994 stretched hundreds of feet past the first row of houses. Restoration will encourage the beach to grow again.

Acknowledgements

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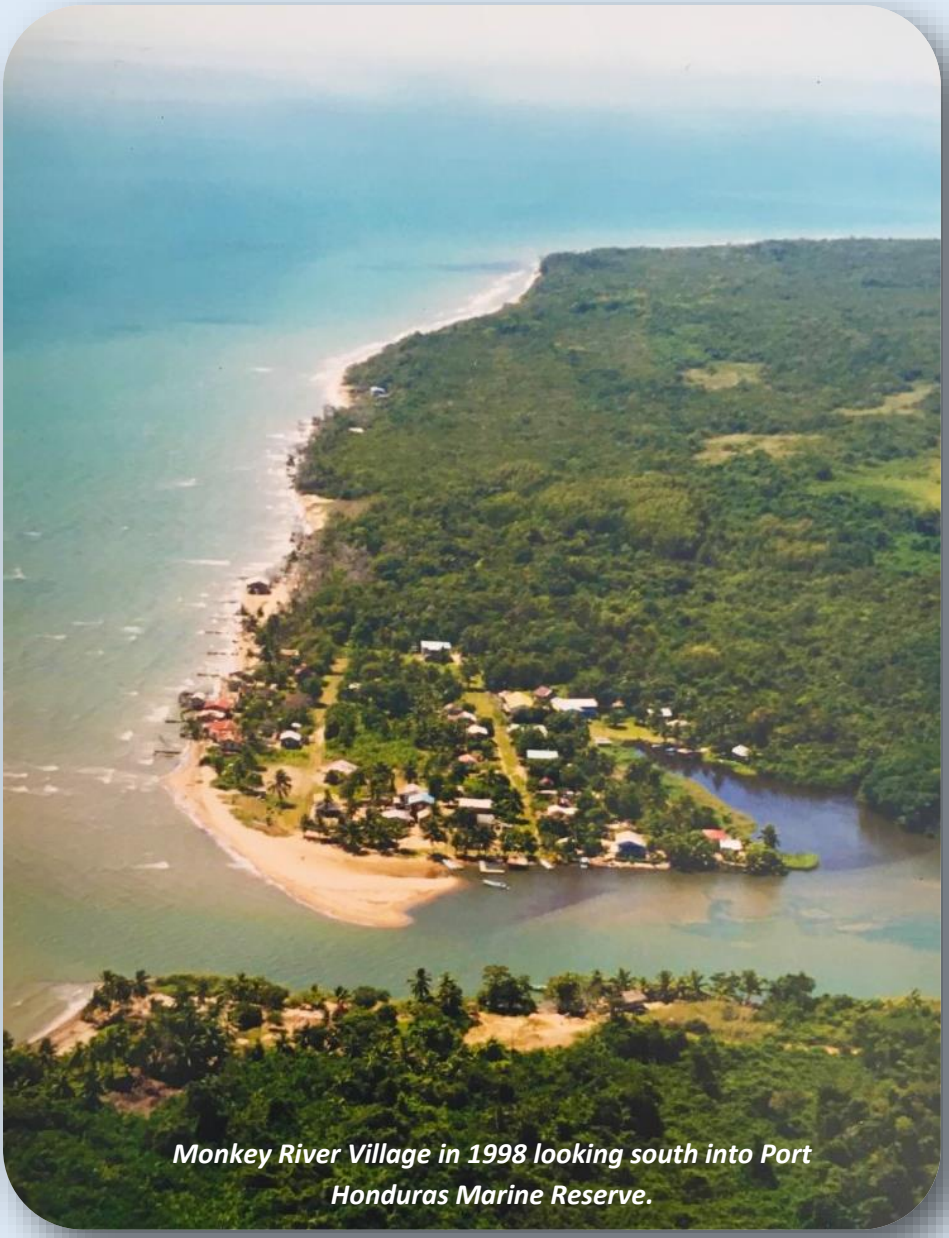

Monkey River Village in 1998 looking south into Port Honduras Marine Reserve.

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