

A BI-NATIONAL WATERSHED ATLAS

The Chiquibul, Mopan,
Macal and Belize Rivers

From the
Maya Mountains
to the Caribbean Sea



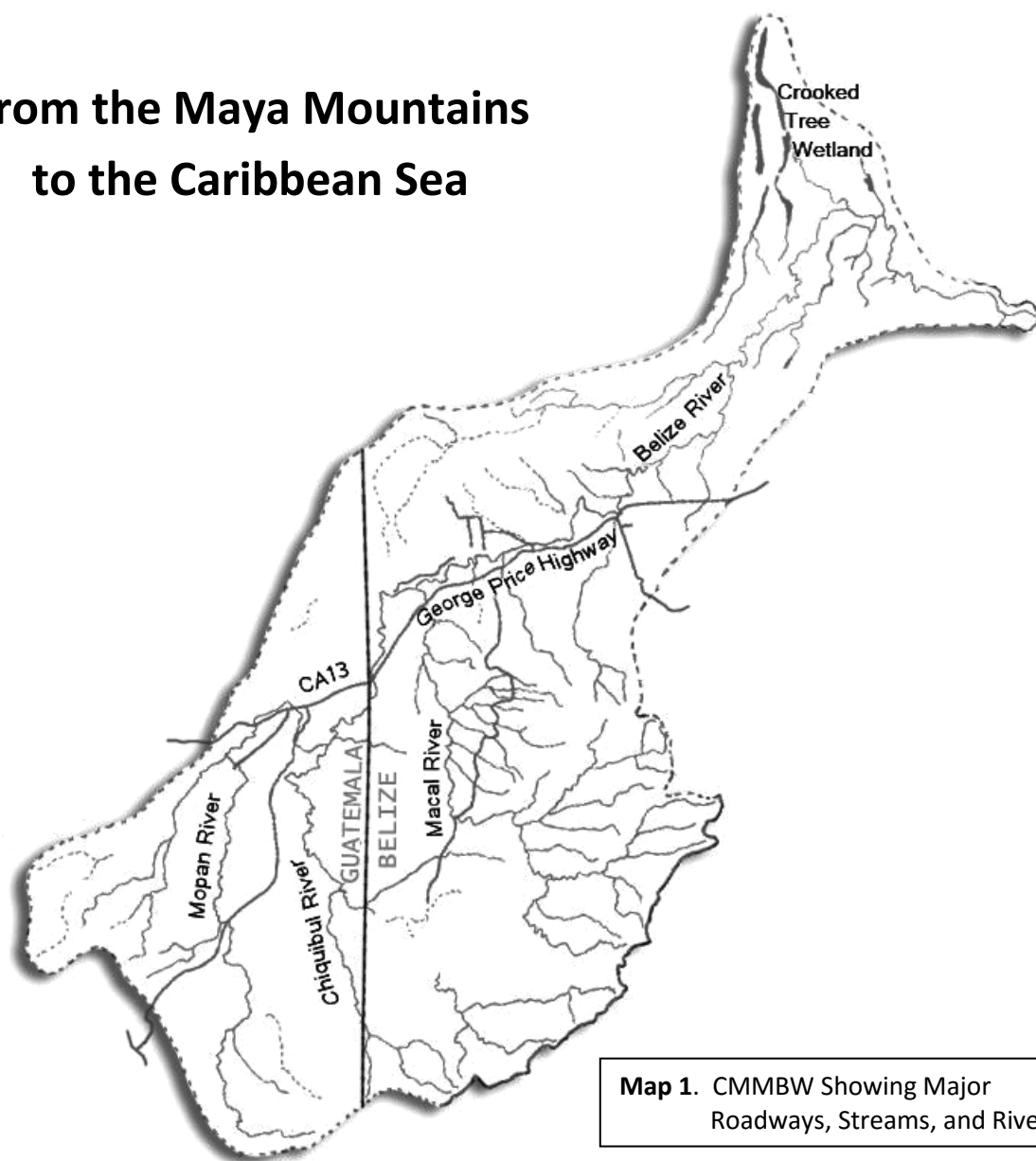
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A Bi-National Watershed Atlas

Written and illustrated by Ed Boles and Reeve Boles

From the Maya Mountains
to the Caribbean Sea



Map 1. CMMBW Showing Major Roadways, Streams, and Rivers



Limpkin

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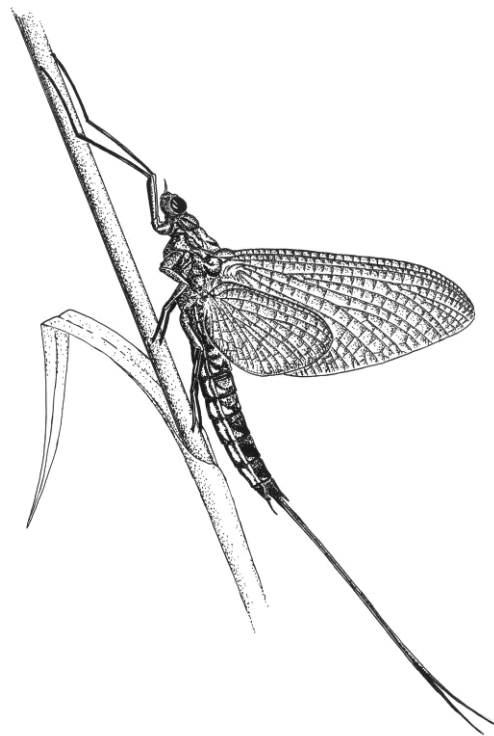
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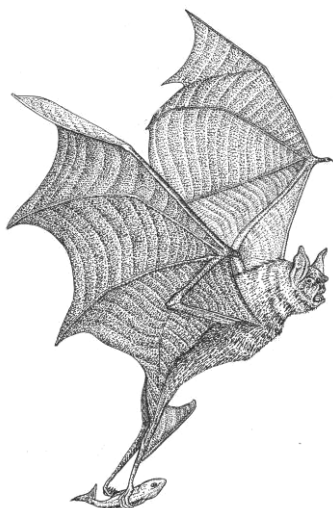
Please address any comments, concerns, omissions or mistakes noticed to fcd@btl.net. This will greatly assist in updating future editions.

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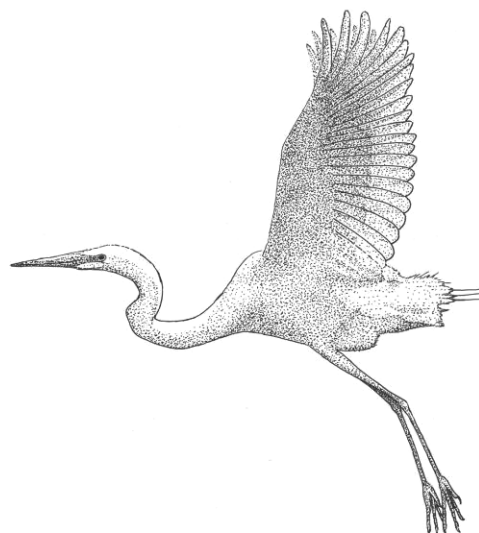
Many of the photographs were provided by the FCD and Tony Rath. Belize Audubon Society provided aerial photographs of the Crooked Tree area. These aerial photographs were made possible through the long term support of LightHawk in conservation efforts throughout the region.



Adult Mayfly



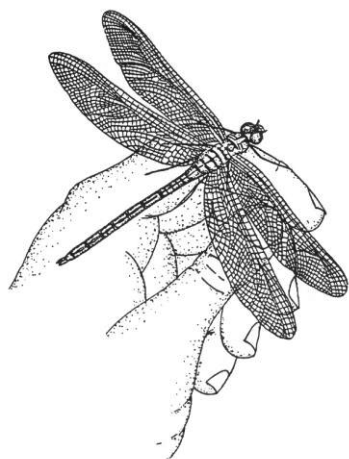
Fishing Bat



Great Egret

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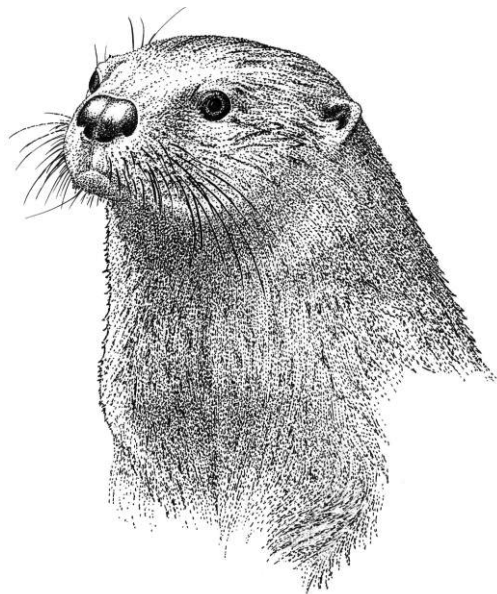
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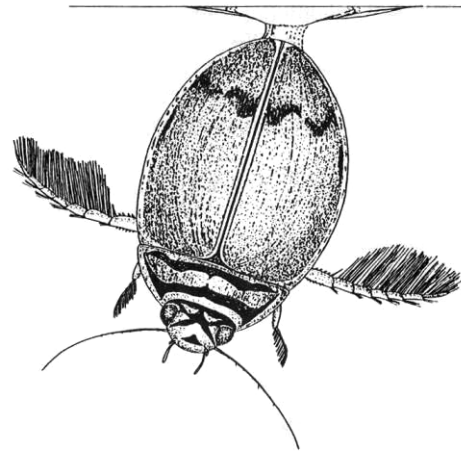
Adult Dragonfly

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Neotropical Otter



PREFACE

This Bi-national Watershed Atlas was commissioned by the Friends for Conservation and Development (FCD) in San Jose Succotz, Cayo District with funding provided by the British Embassy in Belize as part of a project titled, "Bi-national Community Participation In River Conservation." The intention is to provide a concise and factual description of the Chiquibul-Mopan-Macal-Belize Watershed System (CMMBW) that informs watershed residents and resource users about the interconnected ecology, economic importance, environmental issues, and ongoing conservation. This watershed system is of regional importance to the Eastern Peten Department of Guatemala and of national importance to Belize. The Chiquibul River and Mopan River provides water to farmlands and villages throughout Eastern Peten, and almost a third of the Belize population receives their household water from the Belize River. The rest of the Belizean people and tourists drink this same water in many bottled water, soft drink, beer and distilled products. The Belize River Valley encompasses some of the most productive farm lands in the country.

This vital watershed is, at the same time, seriously threatened by many different stresses, including rampant and unnecessary riparian deforestation, increasing water extraction for irrigation agriculture, wastewater discharge, livestock access, gravel mining, over-fishing, pesticide runoff, heavy metals, chemical fertilizers, and suppression of normal flow patterns. Many of these issues can be resolved by identifying the stressors and removing the stress, often resulting not only in reducing impacts, but saving money in the long term for farmers, developers and other resource users. It has long been realized around the world and in Belize that effective watershed conservation must involve all watershed communities. Residents must be aware, informed, and empowered with knowledge; build a collective concern for the health and integrity of their shared watersheds, and promote avenues of positive action among everyone.

Watershed residents are the most important group in the implementation of effective and continual management actions to monitor, restore, and protect the structure and functions of these life-giving ecosystems. Therefore, any plan to develop watershed management strategies must begin and end with the communities residing within and using the resources from that watershed. In order to make wise and appropriate decisions required for the development and implementation of a management plan, community members need to have a deep level of knowledge about their watershed and how it works ecologically, what is impacting it, and what might be done to alleviate environmental stress to the system.

This Atlas is also intended to serve as a supplementary teaching tool for classrooms throughout the watershed, providing youth with a better understanding of the extent of their residential ecosystems, from neighborhood to the landscape scales. It also seeks to introduce concepts of watershed ecology, conservation, and management to those youth who will become tomorrow's leaders and politically involved citizens, and to promote a sense of responsibility for looking after the health of this common watershed system that sustains us.

Throughout the text many terms are highlighted when they are first introduced. These highlighted terms are often defined in more detail later in the text, and are also defined in the glossary at the end of the Atlas. These terms are part of the scientific and conservation vocabulary that all community members should be familiar with in order to better understand ecological concepts and to more accurately express their environmental concerns.

The maps of the watershed were developed from GoogleMaps© 2015-2016 imagery. This is the first time that the people of the world have had access to such recent remote imagery of the Earth. Before the release of these up-to-date images, conservationists, community groups, protected areas managers, and even government agencies had to use images that were often five years old or older. You are encouraged to explore GoogleMaps© and "fly" over and zoom in and out of your neighborhood and surrounding area, all the way out to the entire watershed, from the Chiquibul Forest, Eastern Peten to the Belize River mouth and the Caribbean Sea. You can visualize how things are interconnected as you experience this new technology that is now available to everyone with a computer, tablet, or smart phone.

GoogleMaps© is just one tool available to concerned watershed residents who want to improve the environmental quality of the watershed. Couple this tool with a smartphone that many people now carry with them everywhere, and everyone has a camera, global positioning system, data logger, email, and phone with which to identify, record, and report watershed-related problems and issues early.



Wood Stork

A Bi-National Watershed Atlas

INTRODUCTION

This bi-national watershed includes the Chiquibul River that crosses from the western Maya Mountains into Guatemala and intersects the Mopan River, which in turn crosses into Belize and joins with the Macal River to form the Belize River. In recognition of these important rivers, this Atlas refers to this large system as the Chiquibul-Mopan-Macal-Belize **Watershed** (CMMBW).

This important watershed is vital to the ecology, economy, food security and public health of people within central eastern Peten, Guatemala and central Belize. A third of the watershed lies within the eastern Peten and is home to over 100,000 Guatemalans. The CMMBW is the largest **catchment** within Belize and home to over 130,000 Belizeans.

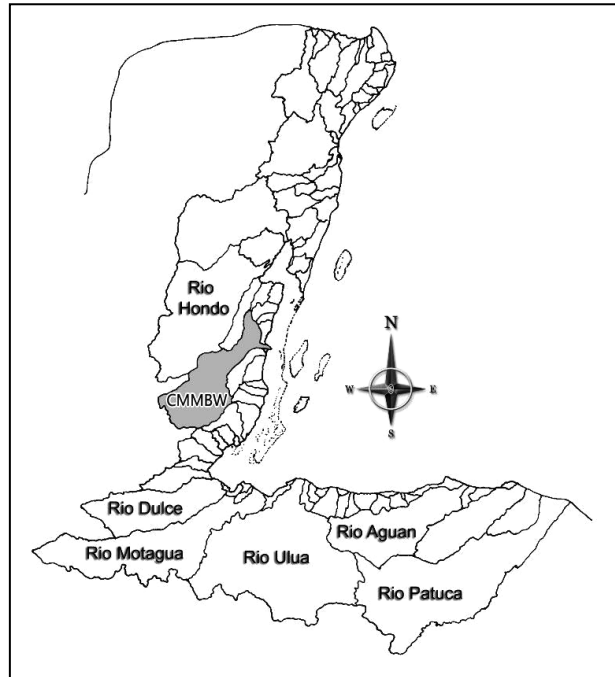
Streams, rivers and **aquifers** of the CMMBW supply water for many villages, towns, cities, farms, tourist facilities, institutions, and small industries. The rich soils of the watershed support large expanses of forests and agricultural fields that contribute to the economies of the eastern Peten and Belize. Waters of the Macal River spin turbines, generating much of the electricity used by Belizeans. Belize river water is harvested, treated, and piped into many homes, businesses, and industries. It is also bottled as purified water, sodas, beers, and rum, and served to Belizeans and international tourists alike.

This extensive and diverse watershed harbors a wealth of wildlife, Ancient Maya history and cultural diversity. Wildlife depicted throughout this Atlas occur in this watershed. Ancient Maya archaeological sites dot the watershed from the foothills of the Chiquibul-Maya Mountains to the sea. Protected areas occur throughout the CMMBW, containing some of the most pristine wilderness areas left within the region. Many of these protected areas are clustered in the **headwaters** within the Maya Mountains.

The Chiquibul River, Mopan River and Labouring Creek headwater streams flow from limestone hills and caves. The Macal River, Barton Creek and Roaring Creek headwaters drain out of the Mountain Pine Ridge area of the Maya Mountains and limestone foothills. These tributaries merge at Branch Mouth to form the Belize River, which then flows through a broad valley of rich **alluvial sediments** and soils. It meanders across a broad coastal **floodplain** on its way to the Caribbean Sea.

The CMMBW occupies the central position within the Mesoamerican Barrier Reef System (MBRS) **drainage basins** (Map 1). These watersheds, from the northern Yucatan to northern Honduras, discharge into the western Caribbean Sea and the Mesoamerican Barrier Reef. The CMMBW is flanked to its north by the Rio Hondo and New

River Watersheds, by the Sibun Watershed to the east, Sittee and South Stann Creek Watersheds to the southeast and Monkey River Watershed along its southern edge (Map 2). The western side of the CMMBW is adjacent to tributaries of the Rio Usumacinta that flows into the southern Gulf of Mexico.



Map 2. Mesoamerican Barrier Reef Drainage Basins

Over the past couple of decades, the quality of water within the CMMBW has deteriorated. We often fail to notice these changes or to fully appreciate the importance of our streams and rivers as long as water is available in sufficient quantities. We are living in a period of **global climate change**, and the flow patterns of streams and rivers are changing. The last major **drought** in the lower CMMBW occurred in 2011, affecting crops, livestock and **potable water** supply to villages and towns, while 2012 was a record wet year. More droughts are expected. Even during average years, near the end of the dry season when **aquifers** have been drained, several communities suffer from water shortages. Coastal residents are threatened by the potential for **saltwater intrusion** into the aquifers that provide their water. Streams and rivers of the CMMBW also frequently flood, sometimes greatly disrupting the lives of the watershed residents, as occurred in October of 2008. Those people living on the edge of the rivers and within the floodplains are particularly vulnerable.

All along the main rivers there are urban areas, gravel and paved roads, large pastures, orchards, and plowed fields that contribute **pollutants** to rivers and streams during and shortly after rainstorms. Sewage, manure, caustic chemicals, pesticides, chlorine, oil, and grease find their way into the streams and rivers in **stormwater runoff**.



Map 3. CMMBW and Adjacent Basins draining into the Caribbean.

Waters of the CMMBW are often contaminated by **point-source pollution**, pollutants coming from a pipe or identifiable drainage ditch, from industries, urban areas, and **water treatment plants**. Heavy loads of organic material, pathogens, suspended sediments, and **solid waste** contribute to water quality problems, being carried by drainage ditches to streams and rivers as stormwater runoff during and immediately after heavy rains. Most of the pollutants are **non-point source pollution**, entering streams and rivers over a wide area, such as pastures, orchards, and fields, rather than a specific point. Small industries, businesses, and households along the river banks historically used rivers for waste disposal systems, people dropping crocus bags of garbage into the river. Many still continue that practice today.

The Macal River is now a regulated river, its flow pattern being at least partially controlled by a series of **hydroelectric dams**. Consequently the flow of the Belize River is also regulated, with moderate **floods** being reduced. Fine organic debris, silts, and clays that would otherwise be frequently purged from the system, build up and reduce water quality.

It is time that we pay attention to our common watershed, recognize the issues that threaten it, and take measures to address those issues. There are many things we can do to help improve the quality of the water and the watershed ecosystem that sustains us. We must work collectively to identify, understand, and resolve the issues while ensuring that all needs are met, including those of families, farmers, industrialists, tourism service providers, future generations, other species, and ecosystems. However, to be effective in our efforts, we must have an understanding of what watersheds are and why they are important. We must develop a greater appreciation for the resources, diversity, complexity, and vulnerability of the CMMBW system in particular. This Atlas was developed in hope of promoting such appreciation and to encourage all of us to take personal and collective actions to restore and protect our shared watershed.

WHY ARE WATERSHEDS IMPORTANT?

We are all interconnected through the global water cycle.

Watersheds are important environmental units of our landscape. Our farms, villages, towns, and cities are interconnected by the streams and rivers that drain watersheds. What happens upstream affects everyone downstream and often what happens downstream imposes upstream impacts. Therefore, all of us must develop a deeper understanding of how our actions can affect others who share our watersheds. We must recognize our responsibilities to protect and care for our land, forests, wildlife, streams, and rivers that provide us with so many

necessary services - clean air, clean water, rich soil, and a diversity of plants and animals.

We are each intimately connected to our watersheds, whether we are aware of it or not. As we twist faucet knobs or dip buckets into streams and rivers to carry water to kitchens and gardens, we are connecting to our watersheds. As we pour wash water down drains or push the handles of our toilets, ultimately sending wastewater back to streams and rivers, we complete that loop of connectivity, a loop that occurs over and over again throughout our daily lives.

Watersheds have been an integral part of our history. Many villages, towns, cities, commerce, and industries have developed along the banks of rivers and streams and the shores of lakes and lagoons. Watersheds around the world are threatened by decades and centuries of abuse and neglect imposed by societies largely unaware of or unconcerned about the critical ecological functions of these systems. Impacts of pollution, agricultural expansion, riparian deforestation, engineering projects, **in-stream gravel extraction**, fish and wildlife over-harvesting, introduction of **invasive species**, and land degradation are affecting not just watersheds, but the very future of our water resources and ultimately our own future.

Many nations lack the resources and expertise to evaluate the ecological health of watersheds, prevent unnecessary environmental damage, identify root causes of existing impacts, and prescribe effective solutions to identified problems. Some countries have laws that protect vital watershed components but are often unable to enforce those laws effectively due to lack of personnel, funds, and

political support. Even if well-funded and staffed, government agencies and conservation groups alone cannot protect watershed systems.

Sustainable conservation efforts can only be achieved jointly through the commitment and involvement of those people who live within the watersheds. To be effective stewards, watershed residents everywhere must have a general grasp of watershed ecology, with specific information on the geography, geology, hydrology, and biology of our particular watersheds.

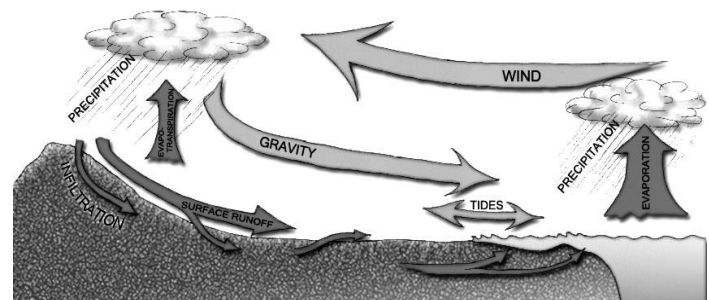
Each of us must reach to discover that personal and often historical connectedness, that sense of place and culture that such discovery inspires. We must teach our children the importance of watersheds and help them to discover their own personal connections so that they too can harbor a lifelong appreciation for these life-supporting water systems. Ultimately we must work to promote effective watershed management throughout the region in order to help preserve our forests, agriculture, and critical marine resources.

WHAT ARE WATERSHEDS?

A watershed is the land-based portion of the **global water cycle** that sits within a **catchment basin**, a depression in the landscape carved largely by flowing water. The sun's heat is absorbed by the surface of seas and oceans, causing water evaporation and build-up of water vapor in the atmosphere. As water vapor rises and cools, through **condensation**, small droplets form into larger water droplets, creating clouds. Clouds blown inland by wind encounter the mountains and are pushed upward, cooling as they rise higher. Water droplets condense together even more as heat is lost, soon becoming large raindrops that fall toward the land. When rains fall in the mountains, some water evaporates back into the sky. Some water soaks into the soil through **infiltration** and is taken up by the roots of trees. Some of the water sinks deeper into the soil to become part of the groundwater. Some of the water flows into thin channels carved into the soil and is funneled into streams, eventually becoming part of the river and flowing back to sea, where the cycle continues again. All life on Earth is connected together through the global water cycle.

A watershed includes a **drainage network** and the land area that sheds water into that drainage network within a catchment basin. The stream network is made up of the smallest streams that merge into larger streams flowing into a trunk river which discharges through an outlet into a larger river, lake, lagoon, or sea. The drainage network also includes **groundwaters** or **aquifers** recharged by infiltration, especially from **wetlands**, that flows into streams and rivers. The catchment basin in which the Chiquibul, Mopan, Macal, and Belize Rivers and their tributaries sit was carved out of granite, quartzite, limestone, and **sediment** layers by flowing

water over the course of many thousands to millions of years. A watershed is a terrestrial and flowing water system containing forest, grassland, agricultural, urban, aquatic, and wetland ecosystems.



Depiction of the Hydrologic Cycle

The upper hilly or mountainous, upslope end of a catchment basin is often defined by a ridge or divide that separates it from adjacent catchment basins. These elevated areas contain the **headwater streams**, usually very numerous short, cold water streams with **bedrock** or **boulder** and coarse **sand** beds, and narrow stream valleys. As streams drop out of the mountains onto flatter land, water slows down and drops cobble, **gravel**, and sand, building up the river bed within the **mid-reaches** section of a watershed. The **lower reaches** of a watershed includes wide and deep sections of the trunk river. This is the **floodplain** end of a catchment made up of fine sand and **silt** deposited over the land over time by each flood event.

The lower reaches of one watershed may not be easily distinguished from neighboring catchments. During high floods, water of adjacent catchment floodplains often merge together as floodwaters back up into wetlands, lowland areas frequently inundated by **floods**. Wetlands are often very rich systems that contribute **nutrients** to streams and rivers. Crooked Tree Wetland is the largest wetland in the CMMBW. It absorbs a large amount of water when the Belize River is in flood, water that would otherwise inundate lower elevation neighborhoods of Belize City and surrounding areas.

A **watershed** is a predominately downstream collection, processing, storage, transport, and distribution system for water, energy, sediment, nutrients, dissolved minerals, organic matter, and living organisms that connects the land and the sea. Flowing water causes continual **erosion** of the landscape, cutting gorges, valleys, and caves into hills and mountains. Watersheds etch their network of collection streams into the terrain, forming patterns resembling the veins of a leaf or the branching of tree limbs. As each stream erodes into soil, rock, and **sediment** layers, water picks up **dissolved minerals**, loose **clay**, sand, pebbles, and stones and carries them downstream.

Flowing water also picks up and carries bits of leaves, wood and other **detritus** downstream. Ultimately the trunk river carries suspended sediments, leaves, wood, and dissolved materials to the sea. As water carries eroded rocks and coarse sand downstream, these materials become broken and worn into smaller and more rounded particles, becoming fine sand and silt. Watersheds erode mountains and hills and form floodplains, lake and lagoon beds, **deltas**, beaches and coastal sea floors with the sediment they produce. **Dissolved minerals** from landscapes contribute to the salinity of marine waters and mineral cycles essential to marine life.

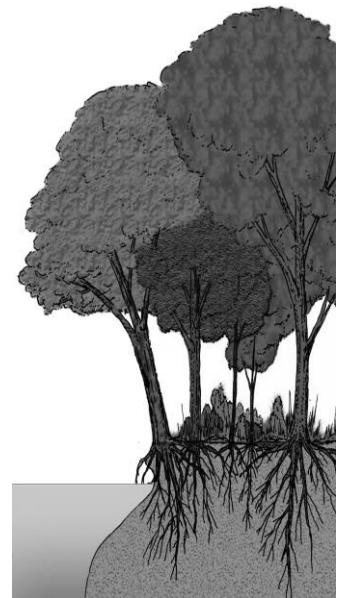
Groundwater is also an important part of watersheds, formed by water that soaks deep into the soil to reach the water table, or seeps into cracks and spaces in deeper layers of rock. These waters slowly dissolve the rocks that hold them and slowly flow into streams and rivers. Swimmers can feel the cold up-welling of groundwater flowing into a stream, river or lake. **Base flow** is groundwater, often rich in dissolved minerals, that is continually discharged from groundwater reservoirs and keeps streams and rivers flowing during the dry season. Wetlands are very important ecosystems that absorb and hold floodwaters, allowing much of that water to recharge aquifers that are spilling back into surface waters.

Forests are important to the ecology of watersheds. Those **steep slope forests** covering hills and mountains help hold the soil together and slow down the rate of erosion by rainfall, streams, and wind. Trees within the forested areas

of a watershed pull water from the soil and release it back into the atmosphere by **transpiration**, the evaporation of water from leaf tissue.

Trees are water pumps, acting to dry out the soil. This allows the soil to absorb more water in the next rainstorm, reducing the volume of water flowing into streams and rivers, helping control floods.

Forests growing along the banks of streams and rivers are the **riparian forests**. Their root systems grow into the riverbank soil and mesh together, helping to reinforce and armor the river bank. Riparian trees also help dissipate the energy in floodwaters, reducing the speed of high flows.



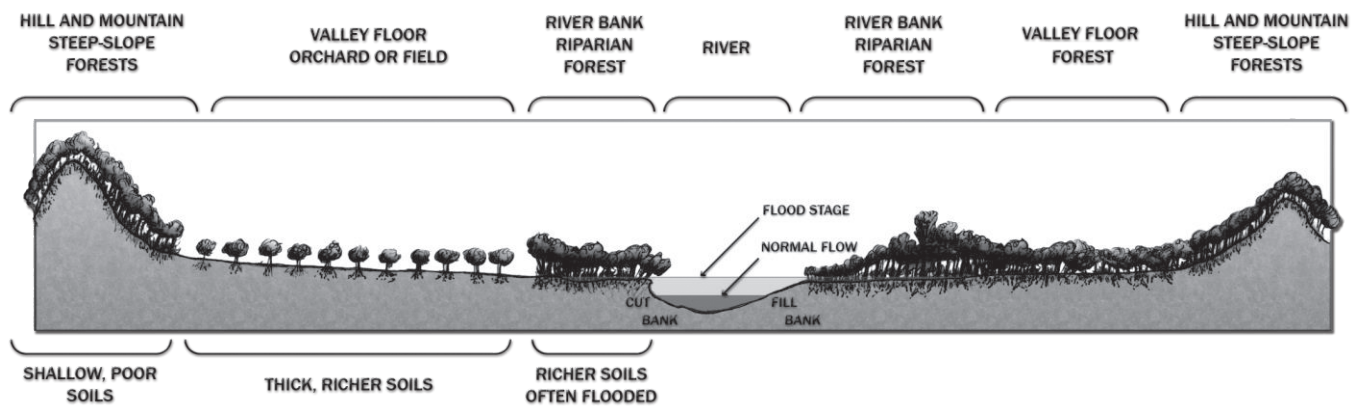
Roots of Riparian Trees

Besides providing shade for aquatic habitats, riparian trees drop old leaves, limbs, fruits, and flowers into the water. Aquatic **fungus** and **bacteria** grow on this dead material from the riparian forests, digesting and consuming the leaf and wood. In turn, single-celled **protozoa** feed on the bacteria, and protozoa and bacteria are in turn eaten by many very small invertebrates.

Larger invertebrates such as snails, crustaceans and insect larvae help shred leaf and limb material, tearing it into smaller and smaller pieces, as they eat the film of fungus, bacteria, protozoa, and other microscopic organisms. Energy and nutrients collected from the soil by riparian trees and stored in leaves and wood, are broken down and eaten by aquatic organisms that are in turn consumed by other aquatic organisms, including fish that are then eaten by people.

When whole trees fall into the water, they provide important aquatic **habitat**, or living space, for fish, invertebrates, algae, fungus, protozoa, and bacteria. Old trees also capture and hold sand and gravel during receding floods and help stabilize river beds.

Riparian forests are one of the most important filter systems within landscapes. Thick riparian forests, together with their organically rich soils, capture or slow down runoff from the terrestrial areas of the watershed following rains, reducing the amount of soil eroded and nutrients lost into the drainage network. These forests can absorb at least some of the **chemical fertilizers**, sewage overflow and other nitrogen and phosphorus materials before they reach the river.



Cross Section of a Watershed Valley Showing Steep Slope, Valley Floor and Riparian Forests

Many **pesticides** are captured in riparian forest soils and are broken down by bacteria before they can flow into streams and rivers. Without riparian forests to provide food, shade, and habitat, and to filter runoff waters, streams and rivers become brown, polluted waterways that support far less species of fishes and other organisms.

Mangrove forests are found along river reaches flowing through the **coastal zone** on their way to the sea. Black mangroves grow along the shoreline and in the low, swampy areas behind the riparian forests. Red mangroves, with their stilted prop roots, populate riparian zones for many kilometers upstream of the sea. These mangrove forests are vital to the protection of the coastline from **storm surge**. They also capture many sediments and nutrients flowing from the land to the sea, as well as producing their own rich crop

of leaves. Mangrove forests are nutrient rich nursery habitats for many important species of fishes and crustaceans.

Watersheds are the natural habitats of most of the people of the world, and therefore the ecosystems most impacted by human exploitation and carelessness. Human societies are integral components of most freshwater ecosystems on Earth. Humans have settled along streams, rivers and lakes since our beginning, reaping the resources and experiencing the natural cycles of these ecosystems. Rivers and streams have served as the routes through which ancient peoples, explorers, and traders accessed interior areas of the continents. Today many of the larger rivers of the world are used as major routes of commerce for the movement of petroleum, coal, raw materials, and manufactured goods to factories and markets.

FLOODS AND HURRICANES

Great floods can cause extensive damage, especially when we build our homes, farms, factories, villages, and towns in floodplains. Floods are important periodic events within the ecology of watersheds. Floods occur when river water rises above its banks, spilling out over the floodplain and inundating riparian forests and wetlands. Floodwaters purge out river pools and backwater areas, and re-suspending buried wood, leaves, and fine organic sediments. Fishes and other aquatic organisms spread into wetlands, lakes and lagoons isolated during low river stages. As floodwaters recede, many fish and other river fauna may be left stranded in **oxbow lakes**, inland **swamps**, and other backwater areas until the next flood event. Rising and receding floodwaters help flush out many nutrients stored in these wetland or backwater areas. The resulting nutrient surge is available for use by downstream river communities and coastal ecosystems.

Major floods also carry huge amounts of sediment. However, studies show that the vast majority of sediment is

carried by floods that occur roughly every two to five years—moderate but frequent events. Sediment carried during normal daily flows is very small in comparison. Although the very large floods carry great amounts of sediments, these floods happen very infrequently compared to smaller floods.

Wood, in the form of twigs to entire trees, continually fall into rivers and streams each season. Even though it takes a long time to break down, wood does not normally accumulate within flowing water systems. Even huge limbs and logs are progressively moved downstream, being picked up as floodwaters rise and deposited further downstream when floodwaters recede. Annual floods flush out the smaller limbs, ten-year floods purge out larger trunks and limbs, and hundred year and larger floods can move some of the oldest and largest logs.

Floods disturb ecosystems, terrestrial and aquatic, often disrupting habitats and reducing or completely eliminating some habitats from entire river sections. However, in doing so, floods create other changes in the landscape, often

diversifying habitats and promoting high but resilient biodiversity. These events are part of a continual cycle, except where disrupted by **levees**, channels, wetland destruction, **dams**, and other engineered designs. The Mopan River rises slowly during the wet season, contributing to flooding on the Belize River. Backwaters of a rising Mopan River frequently flow into the Macal River at Branch Mouth, creating extensive flooding in low areas in and around San Ignacio and affecting areas down to Belmopan and beyond. The Macal River is a “flashy” river by comparison, rising suddenly and creating a backwater effect as its discharge blocks the flow of the Mopan River.

With global climate change happening, drier, but more intensive rainfall and flood potential can be expected. Increasing hurricane formations are expected as surface waters of oceans become warmer. Our steep slope, riparian, and wetland forests are our principle defenses against hurricane and flood damage. They resist erosion, topsoil loss, and river bank failures that happen during floods. Riparian forests composed of tree species able to withstand the force of flowing waters actually dissipate the energy of floods, slowing them down, and reducing the damage caused. Crooked Tree Wetlands absorb much of the floodwater of the Belize River, holding and slowly releasing the water as the river stage drops.

In the coastal zone, mangrove forests composed of red, black, and white mangrove trees, and the Mesoamerican Barrier Reef buffer Belize from the storm surge of hurricanes. Protection and restoration of these forest types, as well as the reef system, are essential adaptation strategies to address consequences of climate change.



Red Mangroves

FOCUSING ON THE CMMBW

Based on the 2010 census data, the CMMBW is home to 37% of the Belizean population, around 130,000 people. About 48% of the Belizean CMMBW population lives in Belize City, 13% in San Ignacio and 10% in Belmopan. Roughly 99,500 Guatemalans live in the Mopan and Chiquibul watersheds, mostly in the five main urban areas (Dolores, San José, Flores, Santa Ana, Melchor de Mencos). The small village of Arenal holds special distinction because it straddles the Guatemala-Belize border near where the Mopan River crosses into Belize before flowing back into Guatemala. The watershed covers about 10,500 km². Almost a third of the watershed (3,300 km²) lies within Guatemala and a little over two thirds (7,200 km²) within Belize (Map 3).

The Mopan River is located largely in the central eastern Peten and includes over seventy large ranches, villages, and towns in Guatemala that are scattered throughout the watershed. This settlement pattern is very different from the Belize side of the Border, where towns and villages are clustered along or near the Western Highway, within the upper Belize River Valley. A smaller cluster of villages occur along the Belize River south of Crooked Tree Wetland, and a few are spaced along the Northern Highway. Collectively, these towns, many smaller villages, farms, and individual houses throughout the watershed on both sides of the border represent a lot of pit privies, septic tanks, water pumps, wash

water drains, urban ditches, old automobiles, crank case oil, and garbage piles. Residents include many hunters, fishers, fire wood gatherers, ranchers, farmers, workers, and others who directly use the resources of the watershed. A great many of our actions can and often do spoil the very forests; yet these streams and rivers that are such a vital part of our lives. But it does not have to be that way.

The flow of the Macal River is currently regulated by three functional dams. The Chalillo Dam includes a 120 million cubic meter **reservoir** and a **powerhouse** with two **turbines**. The downstream Mollejon Dam has a much smaller reservoir that feeds water through a 3.5 km granite bedrock tunnel and into a downstream powerhouse containing three turbines. A third dam is built downstream of the Mollejon Dam at Vaca Falls. Headwater and upper midreach areas of the Macal River are sparsely inhabited, except for areas around the Vaca powerhouse facilities, the Forest Department's Douglas De Silva Forest Station, several private holdings, and the Maya village of San Antonio.

The lower reaches of the Macal River pass along several farms, tourist facilities, and the village of Cristo Rey. The river is flanked on its western bank by the town of San Ignacio and its eastern bank by Santa Elena where it reaches the Hawksworth Bridge, a suspension bridge on the George Price Highway.

Guatemala Villages Towns Cities and Large Farms

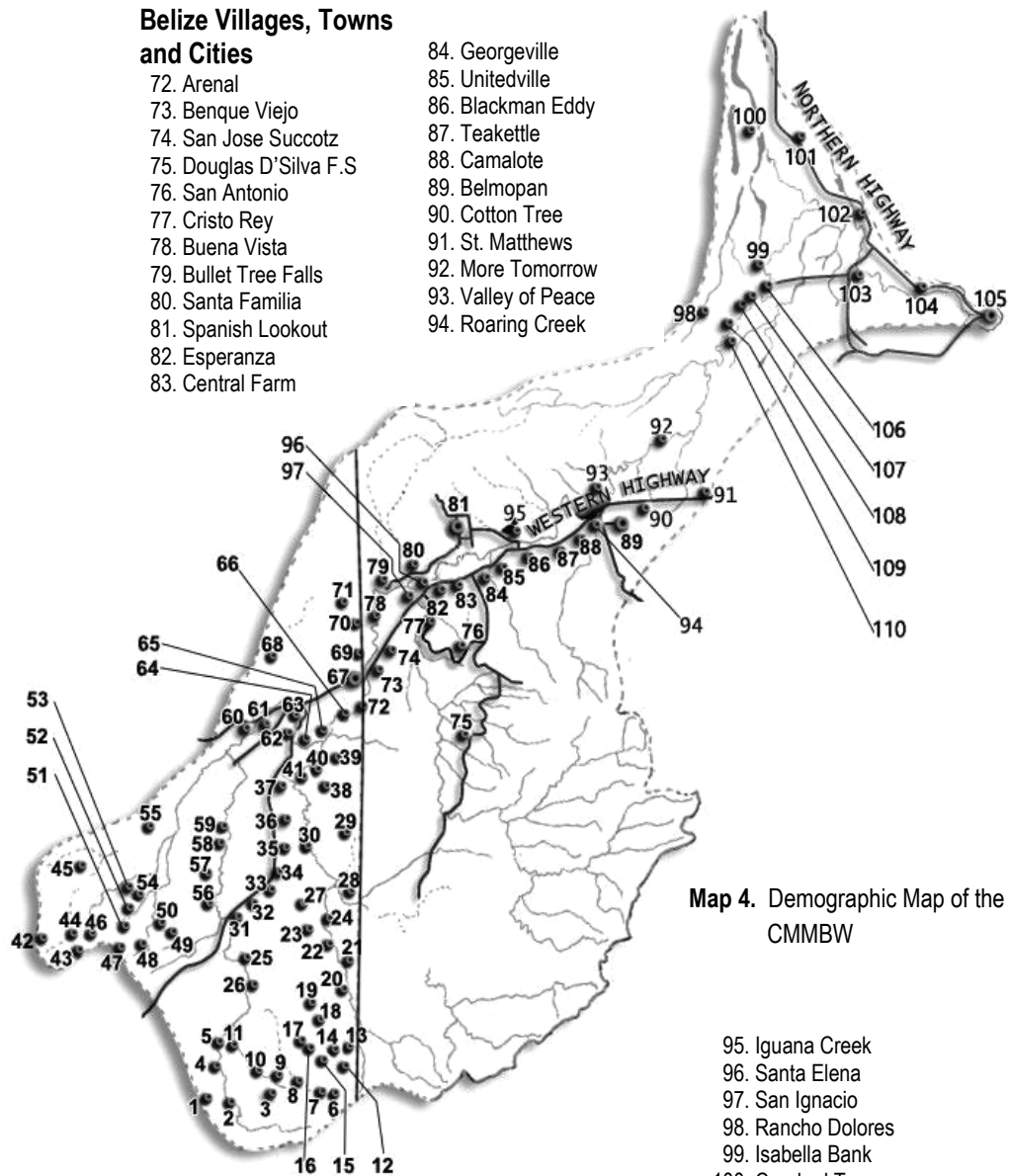
1. Dolores
2. Mopan I
3. Suculte
4. Mopan II
5. Mopan III
6. Sacul Arriba
7. Centro Maya
8. Sacul Abajo
9. Caxebe
10. Xaan
11. El Duende
12. El Naranjon
13. Monte Los Olivos
14. Chicales
15. Bejucales
16. El Toronjo
17. Valle de la Esmerald
18. San Marcos
19. Las Brisas
20. Nueva Armenia
21. San Jose Las Flores
22. Las Flores Chiquibul
23. Finca Maringar
24. Puerta del Cielo
25. El Rosario
26. Las Cees
27. Finca la Ponderosa
28. La Rejoya
29. Esperanza
30. Alta Gracia
31. El Bombillo
32. Calabazat
33. Grano de Oro
34. El Grande de Oro
35. Tikalito
36. El Pulguero Nuevo Horizonte
37. Valle Nuevo
38. El Mameyal
39. El Rondon
40. Nacimiento la Pepezca
41. Santa Rosa Chiquibul
42. Los Pelones
43. Pocitos
44. Nueva Esperanza

45. La Union
46. El Guineo
47. San Felipe
48. Camalote
49. La Esperanza
50. Pito Real
51. Chechenal La Laguna
52. Cecéenla
53. Monterrico

Belize Villages, Towns and Cities

72. Arenal
73. Benque Viejo
74. San Jose Succotz
75. Douglas D'Silva F.S
76. San Antonio
77. Cristo Rey
78. Buena Vista
79. Bullet Tree Falls
80. Santa Familia
81. Spanish Lookout
82. Esperanza
83. Central Farm

84. Georgeville
85. Unitedville
86. Blackman Eddy
87. Teakettle
88. Camalote
89. Belmopan
90. Cotton Tree
91. St. Matthews
92. More Tomorrow
93. Valley of Peace
94. Roaring Creek



Map 4. Demographic Map of the CMMBW

95. Iguana Creek
96. Santa Elena
97. San Ignacio
98. Rancho Dolores
99. Isabella Bank
100. Crooked Tree
101. Biscayne
102. Sand Hill
103. Burrell Boom
104. Ladyville
105. Belize City
106. Bermudian Landing
107. Double Head Cabbage
108. Willows Bank
109. St. Paul's Bank
110. Big Falls

About 3 kilometers downstream, the Macal River meets the Mopan River, marking the beginning of the Belize River. The Belize River Valley is a wide, fertile expanse bordered by limestone hills, and is an important center of agriculture. It was also an important farming region for the Ancient Maya, evidenced by many archaeological sites. The lower reaches of the Belize River meander through savannas, marshes and swamps to reach the sea. This river valley is more developed

than most of the rest of Belize. It includes the Mennonite farming community of Spanish Lookout, the capital city of Belmopan, and many smaller communities scattered along the George Price Highway that roughly follow the river. Many farms are established along the Belize River, often small plots maintained by rural families producing vegetables, fruits and livestock, often on less than a hectare. Also there is large scale agricultural development for citrus, corn, beans,

cattle, and more recently sugar cane. Large-scale, mechanized agriculture is rapidly expanding as Mennonites clear and plant new corn and bean fields to supply Caribbean markets. Now there are big corporate land holdings along Labouring Creek and Belize River where thousands of acres are being cleared to grow sugarcane without regard for riparian forests and wetlands, and a large drainage canal built across what was a very important **wildlife corridor**. Forest cover in the Belize River valley was reduced from 40% of the land area in 1989 to 31% by 2001. This trend has continued and the rate is increasing as more sections of land are being cleared for corn, beans, and sugarcane.

The coastal floodplain of the Belize River lower reaches and river mouth is very low in elevation and often flooded during the rainy season. Belize City is the commercial center and the heaviest populated area of the country. Many small

industries, companies, hotels, stores and businesses are located in or around this marine port city. Ladyville, north of the city, includes the international airport and the largest shrimp farming facility in Belize, now closed.

The Crooked Tree Wildlife Sanctuary lagoon and wetland system is vital for flood control, absorbing and slowly releasing floodwaters threatening low areas of Belize City.

Medium annual rainfall ranges up to 2500 mm in the headwaters, 1000 to 1500 mm north and west and 1500 to 2000 mm along the coast area of the CMMBW. Average daily discharge of the Belize River has been estimated to be a little over 150 m³/s, with peak wet season flows of 550-600 m³/s and low dry season flows of down to 10-20 m³/s. The Hydrology and Meteorology Office in Belize has established seventeen **gauge stations** throughout the CMMBW from Benque Viejo to Belize City but none in the elevated areas.

GEOLOGY, SOILS, VEGETATION, AND MARINE CONNECTIVITY

The Maya Mountains are the dominant feature of the eastern Peten/Belize landscape. The Main Divide segregates the mountain range into the northern and western drainages of the CMMBW and the eastern and southern drainages that include the Sibun Watershed to the east, the South Stann Creek Watershed to the south-east and the Monkey River Watershed in the south. The core of these mountains is made of **granite** formed from **magma** intrusions that repeatedly occurred from 400 to 200 million years ago (Map 4).

Magma pushed up blocks of the fractured crust, consisting of sedimentary rocks of an ancient sea floor, and then slowly cooled deep beneath this overburden over a period of several million years. As the magma cooled, it crystalized into granite rock. The action of rains and water flowing over the surface of the uplifted landscape eroded away much of the old crustal rock material, exposing the granite outcroppings that we see today in the Mountain Pine Ridge. When this molten mass pushed against the crust, shoving it upwards with incredible heat and pressure, many of the rocks around the magma were transformed. Shale

was changed to slate, limestone transformed to marble, and sandstones partially melted and fused into quartzite.

As magma rose from the mantle of the Earth, it brought many metals with it – iron, zinc, mercury, and gold for example. Iron is very abundant and can be seen as red and black minerals in the rocks and as rusty colored slimy seeps where water flows from the rocks and iron-loving bacteria sequester the metal ions. A concession has been granted to Boiton Minerals to work in the Chiquibul National Park. Illegal gold mining by Guatemalans has been impacting headwaters of the Chiquibul River Watershed since 2012.

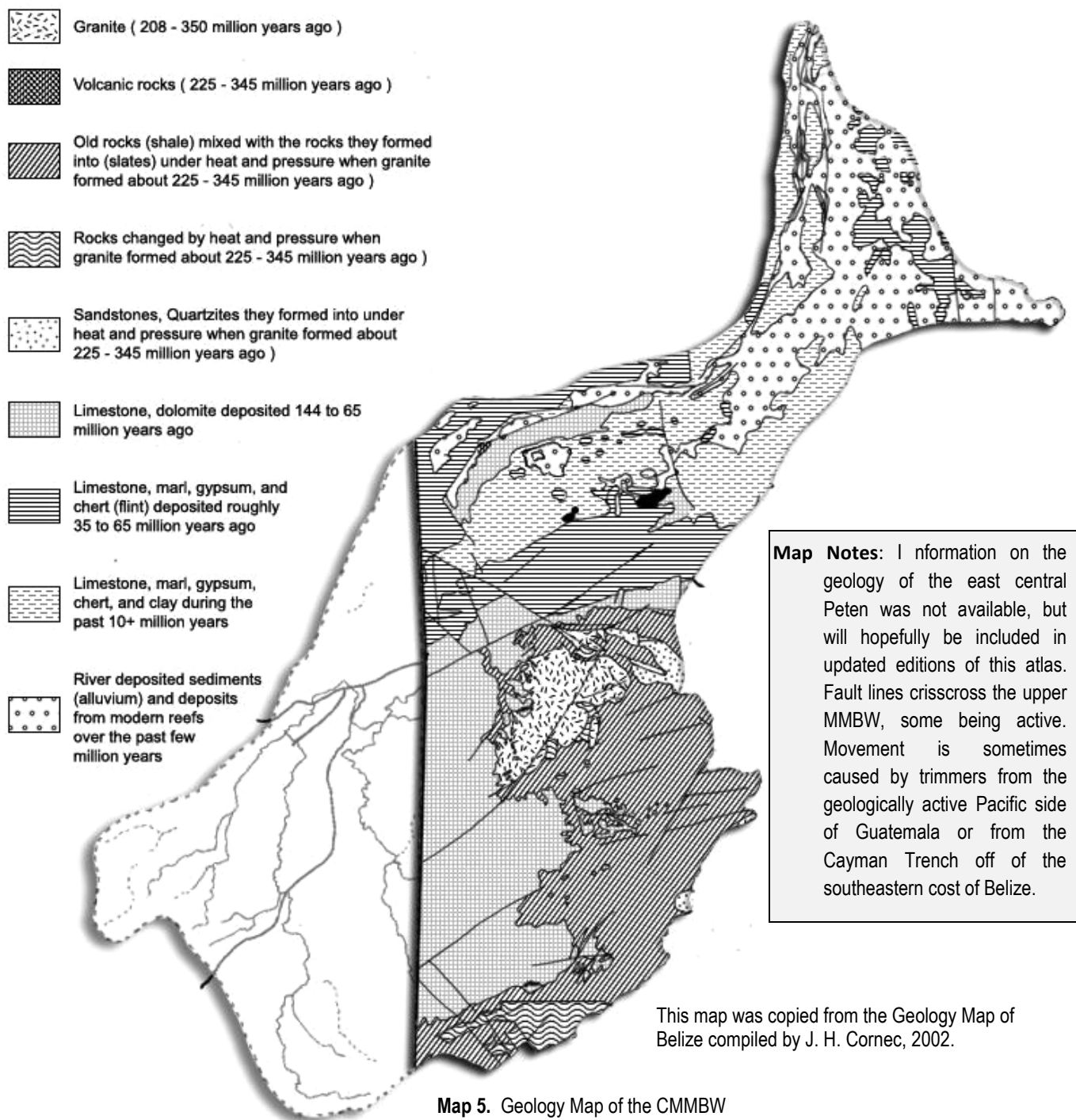
A general geology of the CMMBW is shown in Map 4. Unfortunately information on the geology of the east central Peten was not available. This will hopefully be corrected in updated editions of this Atlas. However, the map indicates that the geological patterns seen in Belize extend into the Peten. The Maya Mountains slant toward the west and vanish beneath the limestone-dominated landscape. The western portion of the CMMBW is largely limestone hills and layers of alluvial sediments (river-transported and deposited materials).



Green Heron



Rosette Spoonbill



Notice the age of each geological area shown on the map. The older rocks were part of an old shallow sea floor that existed long before the Maya Mountains were formed. Maybe the crust was weak at this spot, cracked by pressure and strain from the surrounding areas of the Earth's crust. This allowed the magma to push up a large block of this sea floor around 400 million years ago. But the magma froze into granite before it could break through the surface of the land. Several more intrusions of magma occurred over the next

200 million years or so, each time cooling into granite rock beneath the surface of the landscape. We can see this granite today because the rivers have long since eroded away the layers of rocks that once covered the granite bedrock. Many old cracks within this rock have been filled with silica dioxide that solidified into whitish quartz veins. Only along the southern edge of the CMMBW is volcanic rock found, an area where the magma was able to break through the surface and cool much faster above ground.

Moving from the Maya Mountains toward the sea, the geology layers become younger and younger. These limestone-based layers were formed by sea creatures producing calcium carbonate shells and skeletons each time the sea level rose and covered parts of Belize and the Peten. The most coastal layers are the youngest. Fault lines crisscross the upper CMMBW, some being active at times. Movement is sometimes caused by trimmers from the tectonically active Pacific side of Guatemala or from the Cayman Trench off the southeastern coast of Belize.

Headwaters of the CMMBW flow out of the Maya Mountains of Belize (Macal River, Barton Creek, Roaring Creek), the limestone foothills of the eastern Peten (Mopan River), and the Chiquibul karst in the southern portion of the CMMBW (Chiquibul River). The Maya Mountain Massif, with ridges reaching up to 1000 m, is characterized by basins and plateaus that are highly dissected by streams. The steep sloped stream valleys are typically heavily forested, with riparian forests covering at least 95% of the stream banks. Granite bedrock yields nutrient-poor, slightly acidic soils.

These soils support the very distinctive Mountain Pine Ridge forests that grade into mixed forests growing over shale, slate, and sandstone bedrock (Map 4). Besides Caribbean pine, these open-canopied forests include small oaks, craboo, palmetto, high-silica grasses, white Maya (and relatives), and ferns. These are fire-prone forests that typically burn on a multi-year cycle. Within weeks after a small fire has burned through the pine forests, new green growth covers the ground. Riparian forests within the Mountain Pine Ridge are very different. They contain many moist tropical forest tree species that follow the narrow streams up to the ridges dominated by the pine forests. Typically moderate fires do not burn into these moist forests.

The sea level has risen and receded many times since the formation of the Maya Mountains. When the ancient ocean waters rose during a period of global warming, they would remain high for tens of thousands of years or longer.

Eventually the Earth would cool again, freezing much of the Earth's water into polar glaciers and forcing the oceans to recede until the next period of global warming. During times of high ocean levels, the sea encircled the Maya Mountains, sometimes perhaps with only the tallest peaks above the water. Many ancient marine organisms secreted calcium carbonate shells around themselves for protection. As these creatures died, their shells settled on the bottom of the sea and became part of the sediment. Over time these shells solidified into limestone.

The vast amount of **calcium carbonate** accumulating in the sediment was created not by corals, clams and snails, but by tiny, plant-like single-celled creatures smaller than a pin point.

Each time ocean levels receded, the very soft, soluble and porous limestone would be eroded by rainwater, streams and rivers. Eventually **karst** landscapes are created, limestone areas that have been weathered by flowing water and are riddled with solution valleys, sink holes, and caves.

Limestone rims the Maya Mountain Massif along its northern, western, and southern edges, and reaches into the Peten, forming a landscape of hills and wide valley floors. The southern and western expanse of karst is drained by the Mopan River and its principle tributary, the Chiquibul River. Barton Creek and Roaring Creek drain the northern karst foothills. Sibun River, South Stann Creek, and Monkey River flow out of the karst landscape along the eastern and southern slopes of the Maya Mountains. Soils that form over limestone are typically more alkaline and richer in nutrients. These soils tend to be covered by dry to moist deciduous forests containing many species of trees, often with wide buttresses, prop roots, and branches loaded with orchids, bromeliads, ferns and vines. If undisturbed or carefully managed, these forests typically will maintain closed canopies and rich populations of wildlife.

The Upper Belize River Valley is flanked by the limestone Yalbac Hills to the north and limestone foothills of the Maya Mountains to the south. The valley floor is layered with alluvial deposits of clay, **gypsum**, sand, **chert**, **marl**, and limestone. Lower reaches of the Belize River Valley to the river mouth are made up of alluvium mixed with calcium carbonate from more recent sea level deposits.

CMMBW headwaters continually erode the Maya Mountains. Boulders, cobble, and coarse sand from granite breakdown are rolled, bounced, and washed down streambeds from one flood to the next. When this material is carried out of the mountains and into the flatter mid-reach streams and rivers, the water slows down and drops its load

of sand and gravel, forming an **alluvial fan** at the base of the foothills. This area is often mined for sand and gravel used in road work and construction.

Eventually these materials are picked up and carried further downstream, and broken into smaller particles by the energy of successive floods. They are deposited as alluvial sediments over floodplains, in lagoons, at the Belize River mouth, and along the sea floor as fine sands and mud. Sediments, originally formed by the breakdown of mountains, are colonized by grassbeds and other marine communities.



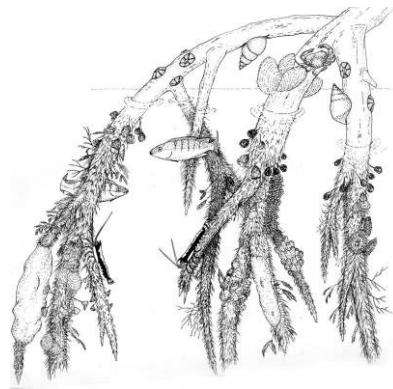
Grassbed community and associated organisms

Limestone dissolved from the landscape is also continually transported downstream as calcium carbonate. This mineral is extracted from the water by marine organisms to become incorporated into reefs and shells of many marine creatures. Some marine organisms, particularly calcareous algae, create calcium carbonate sands around the reef areas when they die, releasing their shell material that becomes incorporated into the sediment.

Just as geology changes from granite, metamorphic rocks, and old seafloor sandstones in the mountains; karst, cobble, and sand and gravel in the mid-reaches; fine sand in the lower reaches; and sand, silt, and clay in the coastal zone near the shoreline, the soils also change. More acidic soils of the mountains, derived from the breakdown of granite and metamorphic rocks, support pine forests with open canopies and grass and sedge understory plants. Soils become more basic overlaying limestone, supporting dry tropical forests on the slopes that grade into moist tropical forests in the valleys.

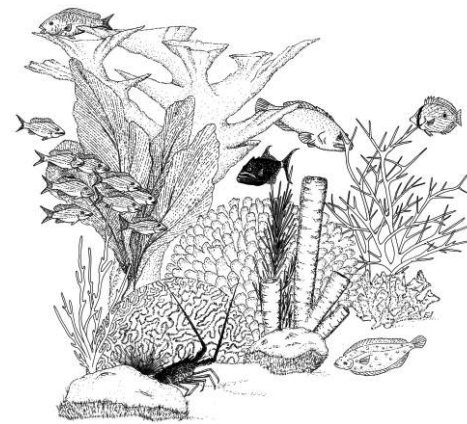
There is a succession of riparian trees, shrubs, vines, and herbaceous plant species from the mountains to the sea. The continual organic detritus, particularly as leaves added to streams and rivers by riparian plants, are constantly being colonized by microbes, consumed by invertebrates, buried by sediments, and swept downstream by floods. This material is eventually carried to the sea as dissolved organic matter, fine particles, and even large tree trunks, along with sediment and water. This conveyor belt of organic matter and the nutrients it contains enriches the coastal zone.

The rivers of the world continually feed the coastal marine waters that overlay the continental shelves, making our shallow marine ecosystems so productive. This linkage between the terrestrial forests of the watersheds and the coastal waters is vital in maintaining the rich diversity and productivity of our mangroves, grassbeds, and coral reefs. These marine ecosystems support the lobster, conch, and scale fish populations that supply the fishing industry.



Mangrove Root Community

Healthy coral reefs are very efficient at taking up nutrients from the waters of many tropical coastal zones. Corals, sponges, tunicates, plume worms and other filter feeders capture organic particles from the water and marine algae absorb the dissolved organic matter before it is all carried out to the open sea. These organisms provide food to many fishes and crustaceans that are in turn harvested by fishers who draw their livelihoods from these coastal waters.



Coral Reef Community

CATCHMENT BASINS, DRAINAGE NETWORK AND SECTION MAPS OF THE CMMBW

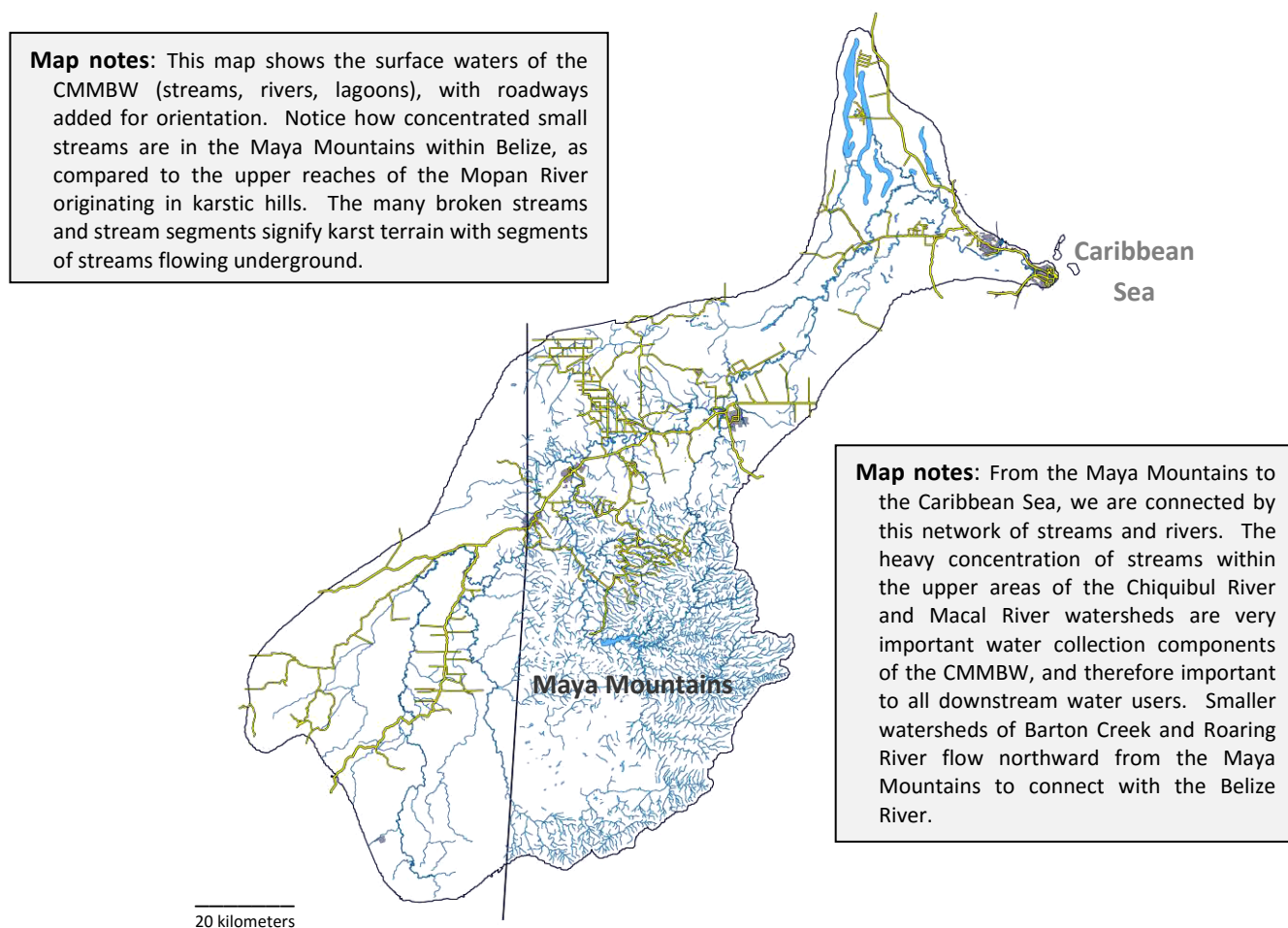
The following maps show details of different sections of the CMMBW. The area covered by each map is shown on Map 5 below. These maps are based on information depicted on the latest version of Google Maps© images dated from 2015 to 2016. Previous maps were based on the set of topography maps (1:50,000 scale) for Belize that were last updated from aerial photography taken from 1988 to 1992. The maps in this Atlas are intended to show general patterns and broad land classification categories were used.

“Natural forests” include all forest types that are not within wetlands. The “Mountain Pine Ridge” forests are also treated as a separate forest type. Swamps, marshes, and flooded lands are lumped into one category of “wetlands”. “Agriculture” includes milpas, plowed fields, orchards, and pastures, and constitutes a single group. “Settled areas”

include towns, villages and cities, with the size of each indicating more the spread of houses rather than actual extent of legal boundaries or population densities. Streams, rivers, lakes, and lagoons were drawn in blue so that these features show up well on the map. Watershed boundaries are depicted in solid lines where there are definite ridges and dots mark approximate boundaries in karst and floodplain areas.

The CMMBW was broken into seven sections based largely on ecological units but also with a concern for fitting each map to the physical space of the Atlas. CMMBW Map sections include: 1. Chiquibul Watershed, 2. Mopan Watershed, 3. Macal Watershed, 4. Upper Belize River Valley, 5. Lower Belize River Valley, 6. Crooked Tree Wetlands, and 7. Belize River Mouth and Coastal Zone.

Map 6. Drainage Network of the CMMBW



CHIQIBUL WATERSHED

This is a very rich natural system in Belize, known for its abundant wildlife and extensive forests. However, over the past decade, the Chiquibul watershed has been severely impacted by illegal hunting, poaching of parrots, especially macaws, illegal logging, and illegal harvesting of xate palm. Economically challenged families in the adjacent eastern Peten District of Guatemala see the abundance of natural resources within the Chiquibul forests. They have been routinely crossing the Guatemala-Belize border, enticed by the locally lucrative *xate* palm market. Florists in the United States and Europe use the fishtail palm as background greenery in floral arrangements because it has a pleasing shape and will stay green for a long time. When Guatemalan *xateros* enter Belize to harvest these palm leaves, which grow wild in the Chiquibul, they also hunt any game they find. If they spot trees that have high economic value, they will fell, slab up, and haul off mahogany, rosewood and other tropical woods back to Guatemala.

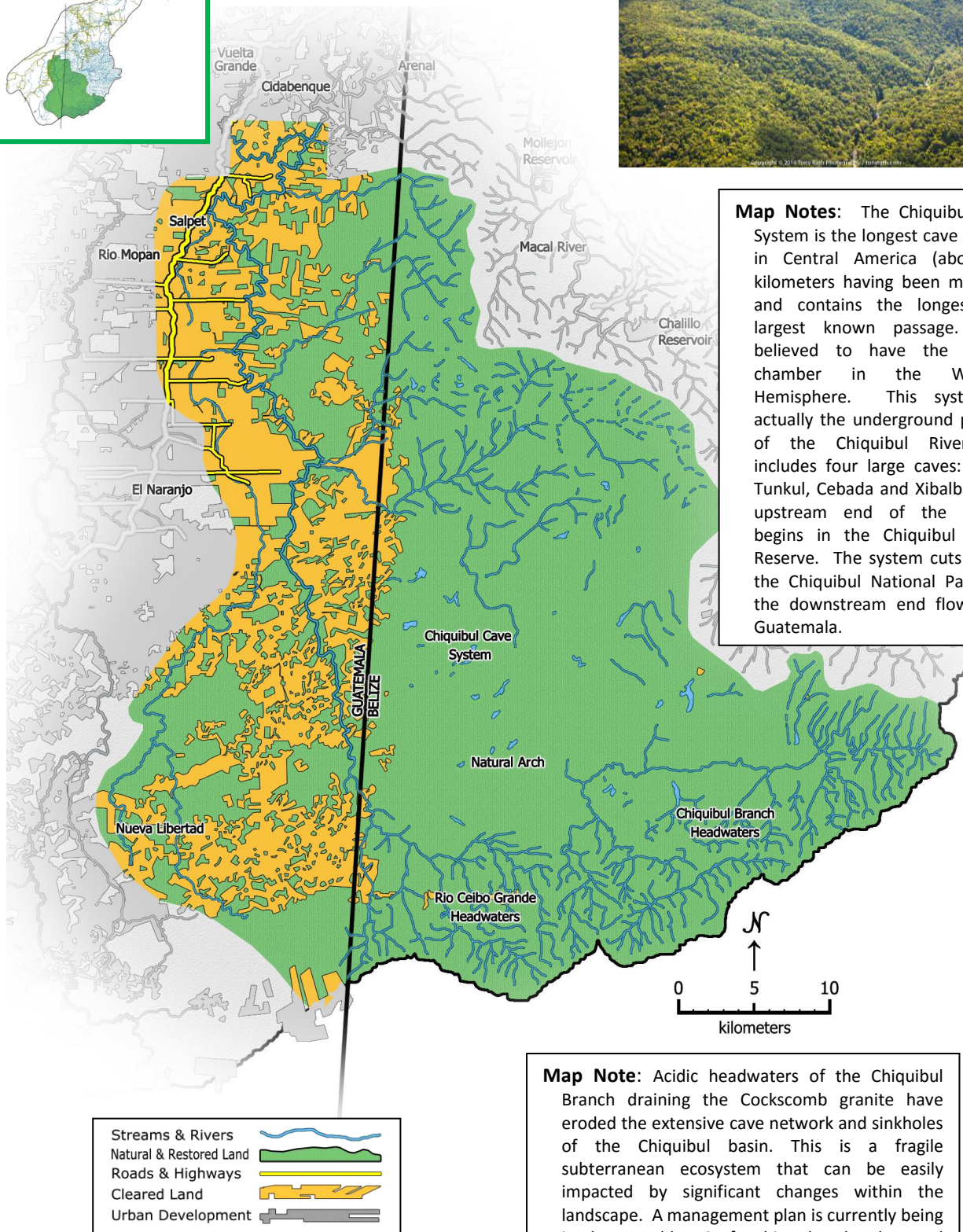
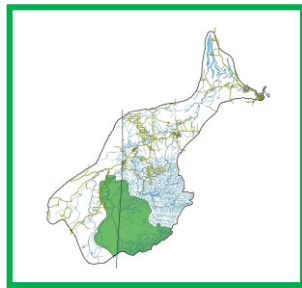
In the past a few agricultural settlers of Guatemala have been established in Belize, within the limited patrolled border

lands. Some have been there for several years before being discovered. It has taken the intervention of officials of Guatemala and Belize, and the Organization of American States to work out a solution for providing illegal Guatemalans with an adequate option, namely providing them with land and opportunities back in Guatemala, and then to oversee the movement of the people and removal of houses and farm structures.

The Friends for Conservation and Development (FCD), given management responsibility over the Chiquibul National Park since 2007, have assembled a team of trained and dedicated rangers to patrol this conservation area in conjunction with the Belize Defence Force and the Police Department. FCD also facilitates a community-focused outreach project that brings Guatemalan and Belizean town and village leaders, educators, and conservation professionals together to focus on the issues of the Chiquibul Forest. Since the very threats to the Chiquibul is of a trans-boundary nature, then the solution must also arise from a bi-national strategy of cooperation (continued on page 22).

Map 7. Chiquibul Watershed

The Great Main Divide, a range of mountains that define the upper end of the Chiquibul River



Map Notes: The Chiquibul Cave System is the longest cave system in Central America (about 55 kilometers having been mapped) and contains the longest and largest known passage. It is believed to have the largest chamber in the Western Hemisphere. This system is actually the underground portion of the Chiquibul River and includes four large caves: Kabal, Tunkul, Cebada and Xibalba. The upstream end of the system begins in the Chiquibul Forest Reserve. The system cuts across the Chiquibul National Park and the downstream end flows into Guatemala.

Map Note: Acidic headwaters of the Chiquibul Branch draining the Cockscomb granite have eroded the extensive cave network and sinkholes of the Chiquibul basin. This is a fragile subterranean ecosystem that can be easily impacted by significant changes within the landscape. A management plan is currently being implemented by FCD for this cultural and natural wonder.

The Chiquibul Watershed flows through a large karst landscape that is pocked with sinkholes. The set of sinkholes shown below was probably formed by the collapse of a large cavern ceiling. The photograph below on the right shows a



Chiquibul Room within Kabal Cave

large opening into the Chiquibul Cave, the ceiling covered in long stalactites. A lone caver can be seen on the floor in the center of the room, giving an indication of the size of this space.



Sink holes containing a segment of forest and cliff faces.

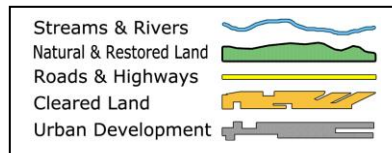
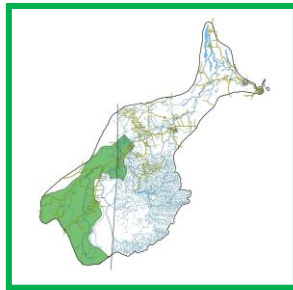
The Chiquibul-Maya Mountain Massif is an important water catchment area. Rains that fall within these mountains are filtered through forest canopies and soils, collected by the dense network of streams and delivered to rivers in the valleys below. This water is vital to the ecology, human health and economics of Belize and eastern central Peten, Guatemala. Many communities, farms, and industries depend on this water. It is essential that the Chiquibul-Maya Mountain watershed system be protected and wisely used in order that these vital ecological services are maintained.

FCD's protection efforts are geared at maintaining the forest cover and their vital watershed and biodiversity maintenance functions, while its education efforts help to generate local community support. Since 2012 FCD brought together 19 community leaders from both Guatemala and Belize and formalized a Bi-national Watershed Alliance. The Alliance operates according to an action plan, holding regular planning and evaluating sessions. The aim is to promote stewardship and a level of co-responsibility for the protection of this natural resource on both sides of the border.

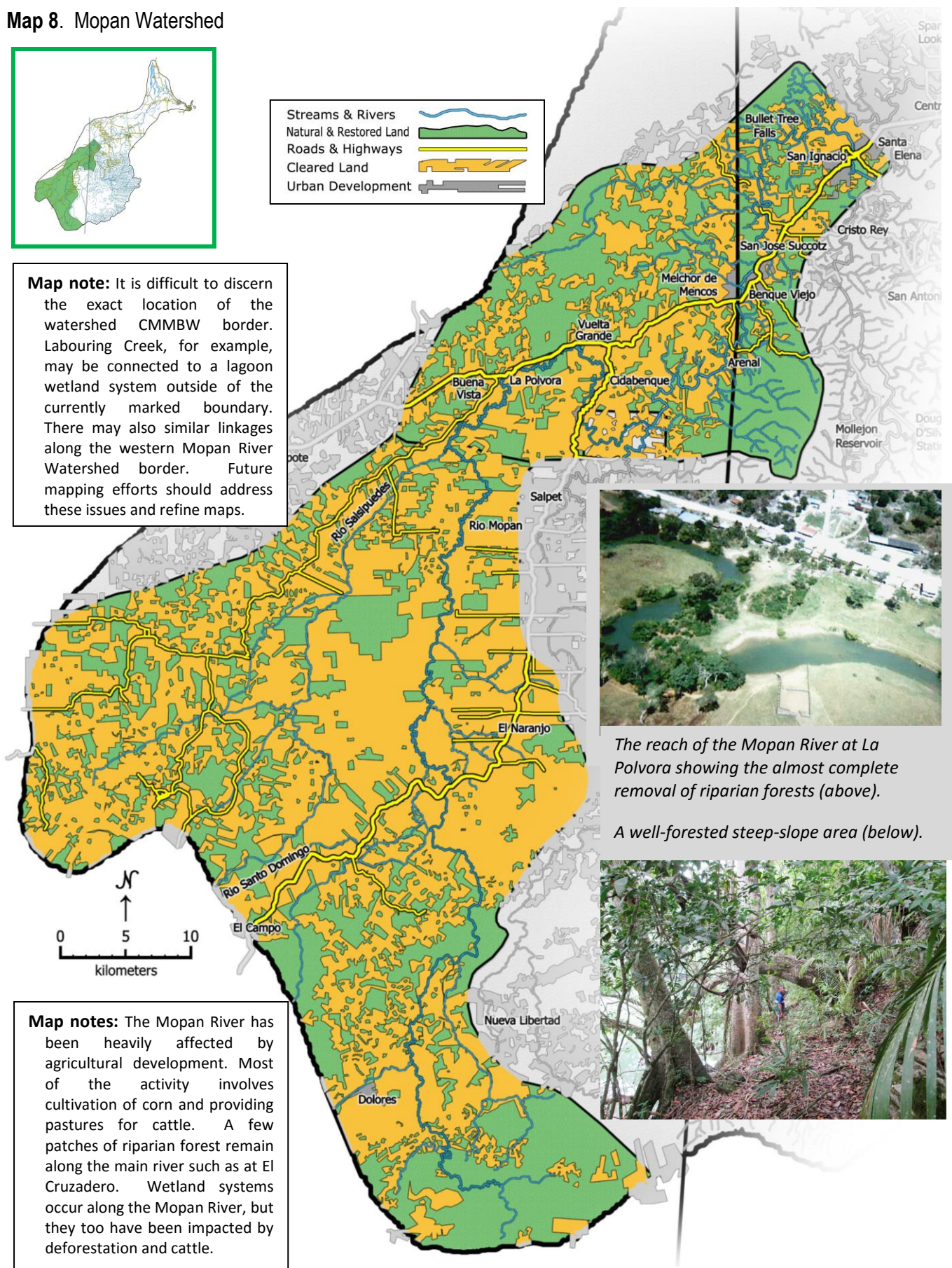


Bi-National watershed conservation efforts undertaken by participating community members of the watershed alliance

Map 8. Mopan Watershed



Map note: It is difficult to discern the exact location of the watershed CMMBW border. Labouring Creek, for example, may be connected to a lagoon wetland system outside of the currently marked boundary. There may also similar linkages along the western Mopan River Watershed border. Future mapping efforts should address these issues and refine maps.



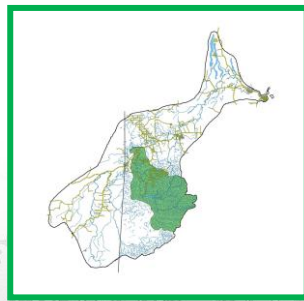
The reach of the Mopan River at La Polvora showing the almost complete removal of riparian forests (above).

A well-forested steep-slope area (below).



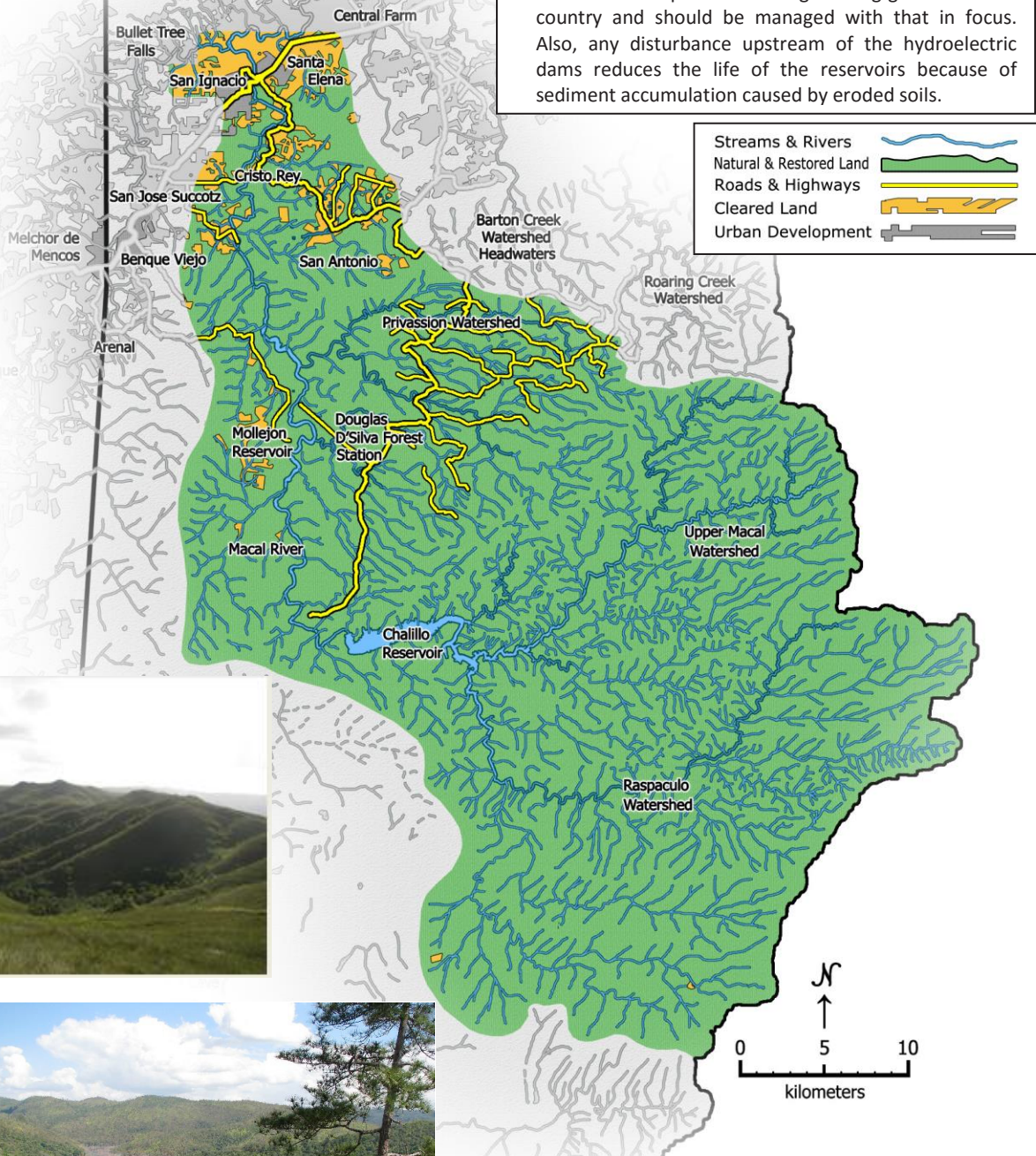
Map notes: The Mopan River has been heavily affected by agricultural development. Most of the activity involves cultivation of corn and providing pastures for cattle. A few patches of riparian forest remain along the main river such as at El Cruzadero. Wetland systems occur along the Mopan River, but they too have been impacted by deforestation and cattle.

Map 9. Macal Watershed



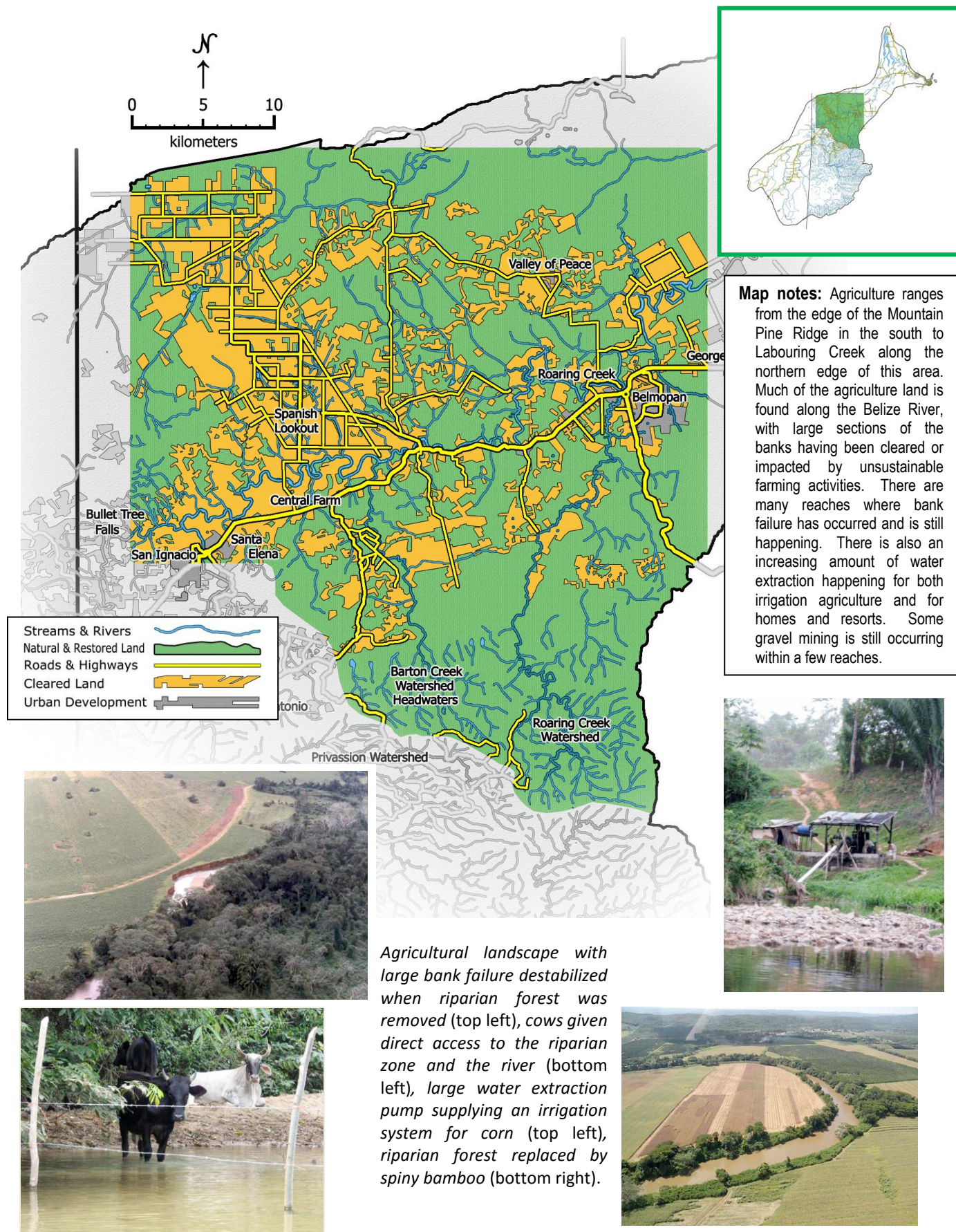
Map Notes: The Macal River Headwaters are made up of many small headwater streams draining out of the Mountain Pine Ridge Forest Reserve. Very little human activity is happening here, outside of selective logging. There are very few inhabited areas - a few resorts, Douglas D'Silva Forest Station, Bull Run, a growing Mennonite settlement and San Antonio.

This is an important water gathering ground for the country and should be managed with that in focus. Also, any disturbance upstream of the hydroelectric dams reduces the life of the reservoirs because of sediment accumulation caused by eroded soils.

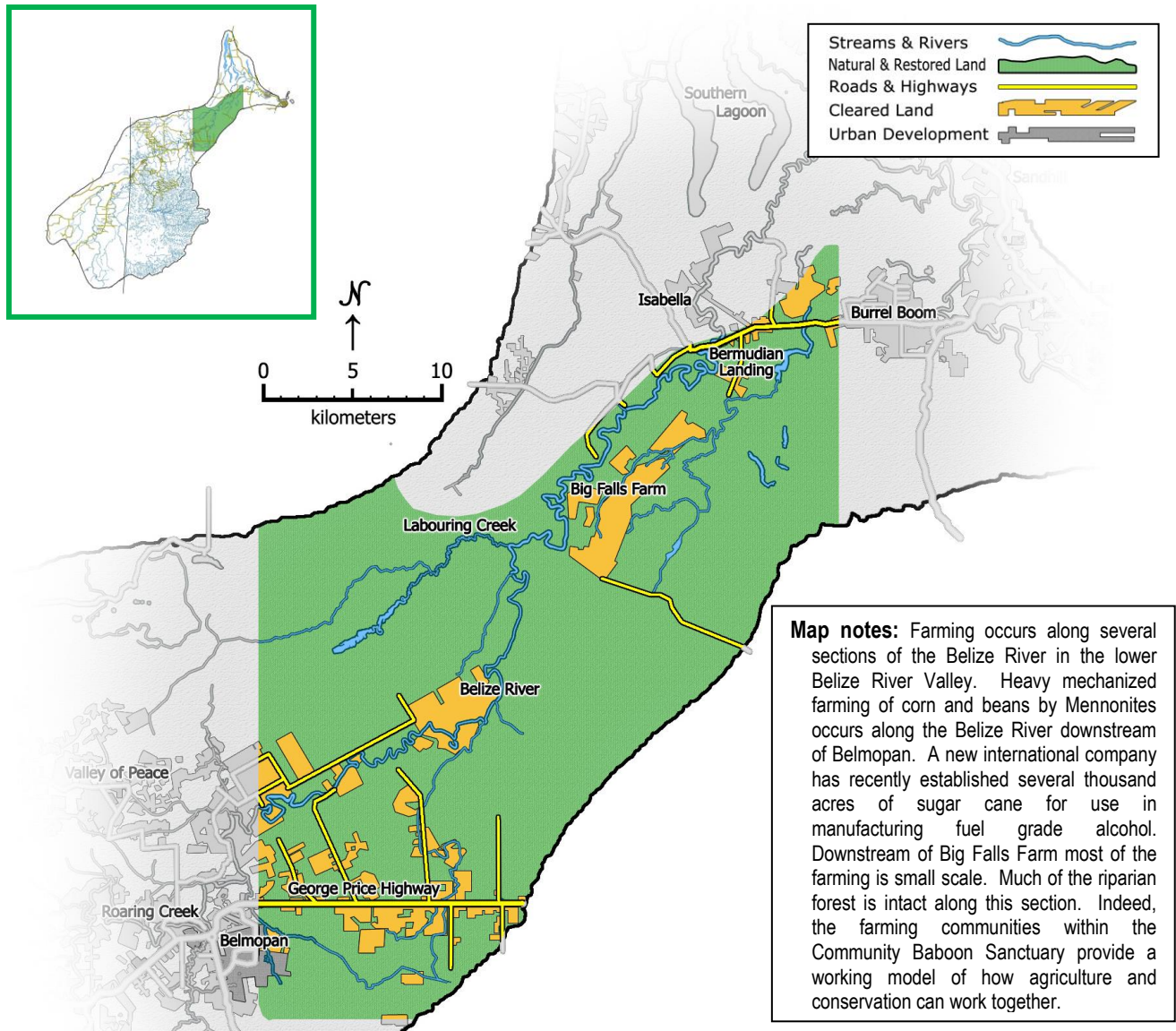


The Bald Hills represents the highest point in the MPR (Upper photo). Riparian forests at the Chalillo Dam site was cleared in preparation for flooding by the dam and subsequently a reservoir of some 19 kilometers was filled with water (lower photo).

Map 10. Upper Belize River Valley (including Barton Creek and Roaring Creek Watersheds)

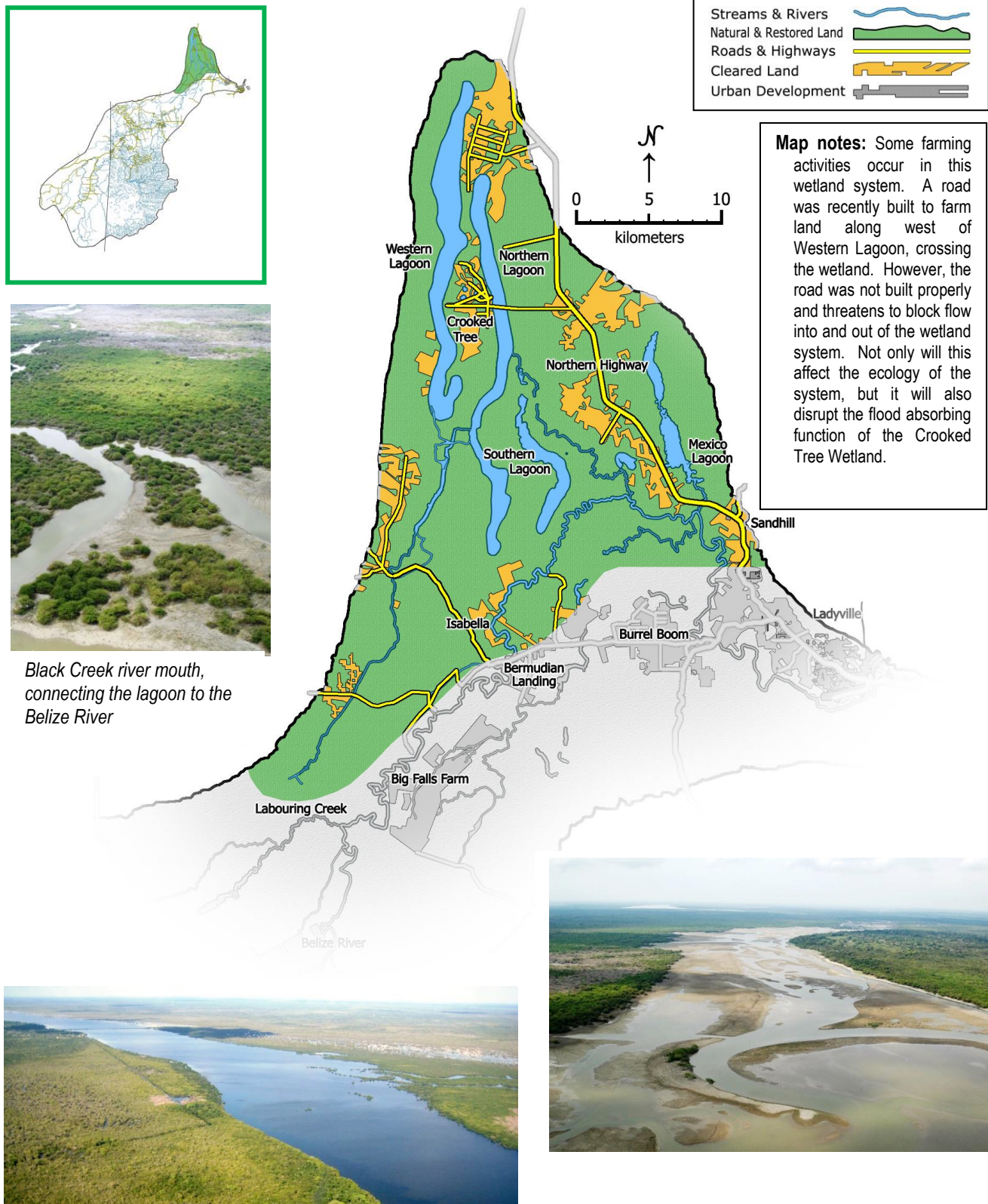


Map 11. Lower Belize River Valley (from Belmopan to Burrell Boom)

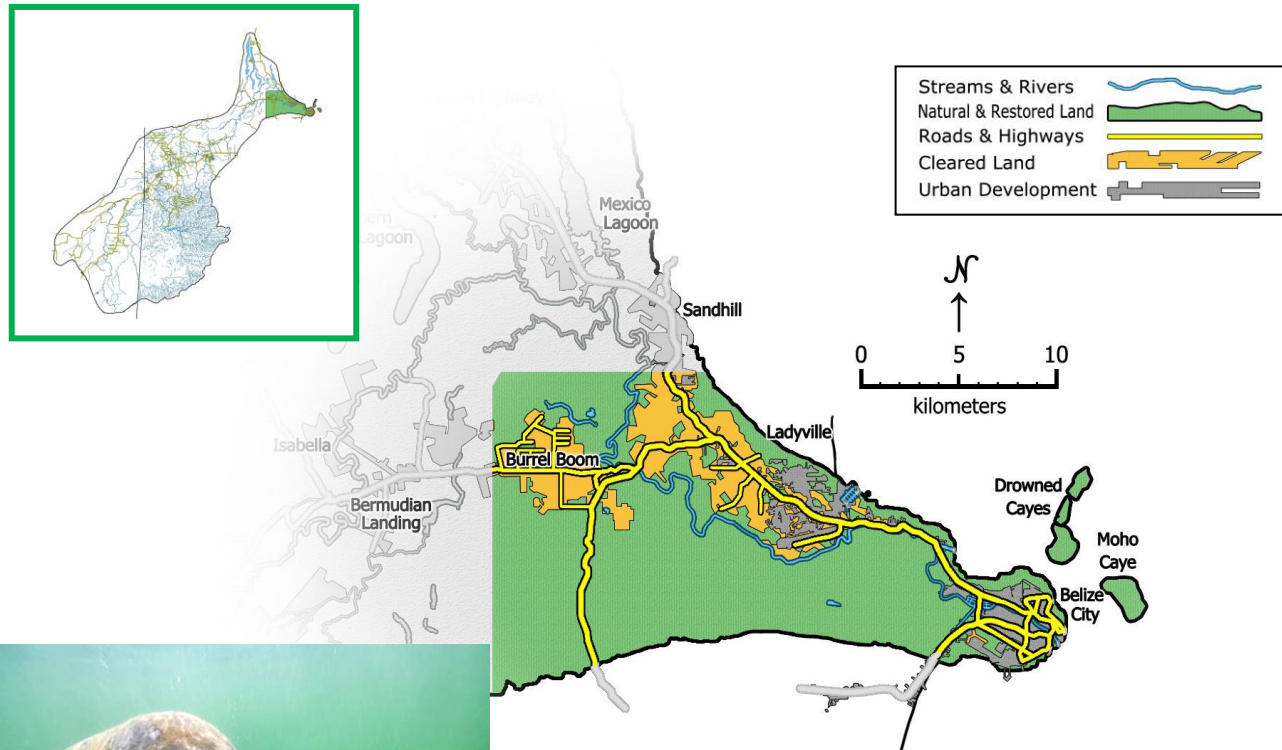


Large stretches of the Lower Belize River Valley riparian forest are rich in wildlife, including black howler monkeys and green iguanas.

Map 12. Crooked Tree Wetlands



Map 13. Belize River Mouth and Coastal Zone



The images above shows the Belize River Mouth and the sediment plume that is discharged into the sea. Haulover Creek is also visible in the photograph, leading from Belize River and flowing through the center of Belize City (GoogleMaps® image). A manatee is observed at Swallow Caye near the shores of Belize City.

Map Notes: Agriculture occurs around the Burrel Boom area along the Northern Highway and between the highway and the Belize River. However, most of the coastal zone reach of the Belize River is largely coastal savanna and mangrove wetland area and is not very high above sea level. Several tourist facilities and the Philip Goldson International Airport occur along the river banks and are associated with riparian forest clearing.

The Belize River discharges into the Inner Channel, the water lying between the mainland and the Mesoamerican Barrier Reef. Large amounts of sediment are discharged into these coastal waters, resulting from upstream riparian deforestation, plowing, in-stream gravel mining and other activities.

A portion of the Belize River flow passes through Haulover Creek that runs through the middle of Belize City. This drainage canal picks up sewage, heavy metals, pesticides, hydrocarbons, and many other pollutants from urban sources. Discharge from Haulover Creek has created a deposit of fine sediments and associated pollutants accumulated in the creek mouth and adjacent marine waters.

CHIQUIBUL RIVER WATERSHED (continued from page 12)

The largely limestone basin of the Chiquibul River drains the southern and south western side of the Maya Mountain Massif. It includes one of the biggest vanishing rivers and one of the longest cave systems in the western hemisphere of the Americas. The cave system is divided into four main caves (Actun Kabal, Actun Tun Kul, Cebada and Xibalba) by a large collapse and several sumps. A major expedition was conducted in 1984, concentrating on Kabal and Actun Tun Kul within the upstream half of the cave system. The expedition team surveyed 55 kilometers of passages that included two of the world's largest caverns, the Belize Chamber and Chiquibul Chamber. A second expedition in 1986 focused on the downstream caves of Cebada and Xibalba, mapping out 27 km and following the Xibalba into Guatemala. The "Puente Natural" or Natural Arch is a well-known karst structure that spans the Chiquibul River.

Currently FCD has a karst management unit responsible for monitoring, exploring, and protecting the Chiquibul caverns. A management plan serves as the roadmap which covers areas of research, education, and tourism opportunities. Ongoing studies of scarlet macaws, jaguars, microinvertebrates, game animal communities, and timber resources are being conducted through FCD's research team and partner universities.

Milpa incursions by Guatemalan farmers has been ongoing since the 1980s and remains one of the most devastating threats to the stability of the Chiquibul Forest. Some incursions of milpa farmers from Guatemala has happened over the past dozen years. Squatters have crossed into the Chiquibul forest and used the land for farming. This situation has been mediated by the Organization of the American States in the past, resulting in

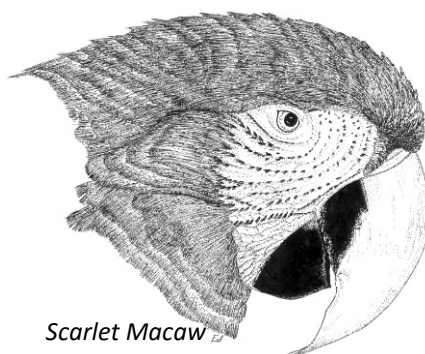
the resettlement of squatters to lands available in Guatemala. But the problem is persistent.

New groups of Guatemalans continue to move into the area whenever patrols by the Belize Defense Force and FCD are reduced. Other problems include illegal timber and xaté extraction and illegal hunting and fishing by both Guatemalans and Belizeans. Recently the presence of the British Army and an increase in military training has occurred, with large numbers of soldiers being put on maneuvers within the area. During jungle training, soldiers clear forests for tents, kitchens, meeting sites, privies and other uses that can also impact local areas.

Gold is being mined from a stream system within the Chiquibul National Park. The process involves removing and physically processing sediments to find small flakes and grains of alluvial gold. Legal and illegal gold mining affect the

water quality of the Chiquibul River. Gold panning by Guatemalans has created heavy impacts on the headwaters due to garbage, faecal deposits and removal of the forest cover. Satellite imagery shows some areas in the highlands that have been scarred by fire, believed to have been caused by Guatemalans camping near the Main Divide.

The Chiquibul River flows into Guatemala, forming part of the north-western border of la Reserva de Biosfera Montanas Mayas-Chiquibul before intersecting the Mopan River. This steep-banked downstream section of the Chiquibul River in Guatemala is an important water source for the twenty or so communities scattered along its lower reach. The Chiquibul River has suffered far less impact and riparian deforestation than the Mopan River. Much of its riparian forests, especially along its steep rocky banks, are still intact.



Scarlet Macaw

MOPAN WATERSHED

Over half of the Mopan River Watershed has been converted to crops and pastures, much of the land having been over utilized. The upper Mopan River, above where it meets the Chiquibul River at the village of Los Encuentros, has experienced the greatest amount of stress caused by heavy deforestation of slopes and large stretches of riparian forests. Many trees have been felled directly into the river, often obstructing flow. Cattle having access to the river's edge compact the soil, graze on young vegetation and introduce faecal material into the water.

The lower Mopan River is somewhat less impacted, but suffers from these same pressures. Some of these lower

reaches have also been completely deforested. Fire is a widely used land clearing tool. Additionally, large towns such as Melchor de Mencos and Benque Viejo, contribute significant amounts of sewage and solid waste to the river. Tourism into the Peten, attracted by nature and archaeological sites, has begun to slowly develop.

In 1970 an all-weather road was built that connected central Petén to southern Guatemala. The partially paved road between Melchor and Flores connects the Mopan River Watershed with the tourist flow between Belize and Guatemala. Increased road access also accelerates deforestation.

The Chiquibul River carries gold from Belize into Guatemala. Men can be seen along the river bank digging up sediments and washing in plastic dish pans, retrieving flakes of gold. Someday alluvial mining may occur on the Mopan.

Land clearing is largely from agriculture and logging, but also urban expansion and development of tourist facilities contribute significantly, especially when construction occurs within the riparian zone. Expansion of the agricultural frontier in the Mopan River Watershed by Guatemalan and Belizean farmers, without regard for the riparian forests, is a serious ecological issue. Increasing population growth in Guatemala is leading to increasing deforestation because increasing numbers of milpa plots are not being left to fallow long enough for forests to regenerate. Soil erosion is becoming an issue in many areas and deforestation of steep slopes is

increasing the potential for slumps and mud slides. Extensive fires in the area, along with increasing cattle and pig ranching, oil exploration (roads, test sites), increasing solid and sewage waste, and expansion of agriculture and settlement into remaining forests are some of the more immediate threats to the ecology of the area.

With a focus on addressing many of these problems, 9 Guatemalan communities and 10 Belizean communities have joined to form the Chiquibul-Mopan-Macal Bi-national Alliance. Activities at the village and town level include restoration, environmental education, and clean up campaigns. This initiative is supported by the Municipality of Melchor de Mencos and the National Association of Village Councils (NAVCO) with finances provided by the British Embassy in Belize.

MACAL WATERSHED

The Macal River Watershed is about 1,500 km² and drains the western flank of the Main Divide. The upper Macal River drains the granite bedrock of the Mountain Pine Ridge Basin. The Raspaculo River, its main tributary, flows out of the more karstic Vaca Plateau and the western area of the Chiquibul-Maya Mountains. Dense vegetation, including large areas of Mountain Pine Ridge, sparse roads, and very few settlements characterize this area. Baldy Sibun within the headwaters is about 1,000 m above sea level.

The Macal River flows roughly 108 km, meandering through bedrock joints and faults on its way to its junction with the Belize River about 3 km north of San Ignacio. The channel system tends to be deeply incised with steep valley walls and exposed bedrock containing many falls, cascades and rapids. This river is known for its intense, but short flood events during the rainy season due to its steep terrain and high rainfall.

The Macal River Watershed includes large expanses of mostly closed-canopied primary and secondary tropical broadleaf forests. These forests represent a portion of the Chiquibul Forest and the Mountain Pine Ridge Forest Reserve. A fertile floodplain lies along the lower reaches, supporting dense jungle vegetation, as well as pockets of agriculture and pastures. Being relatively undisturbed, watershed forests harbor a high wildlife diversity that is currently threatened by illegal hunting.

This is a regulated river that energizes three hydroelectric facilities. It is impounded by the Chalillo Dam, creating a large reservoir that floods the lower end of the Raspaculo River and the Macal River to a point above the Raspaculo junction. Water stored in this reservoir is slowly released to drive turbines downstream, and secondarily serves as a flood control facility. Because high flows can be contained and the release of these waters controlled, the height of floods can be reduced. However, floods no longer

flush out the lower river as they once did, and silt-laden sediments tend to build up in the river bed.

This large reservoir and the forest that was flooded when the reservoir was filled created an extensive **anaerobic** sediment bed, where no free oxygen is available. Anaerobic bacteria capture molecules of mercury eroded from granite and bind them into organic molecules that get absorbed in the food web. Many of the fish in the CMMBW are contaminated with mercury and are a risk to pregnant women and young children. The Chalillo Reservoir is a new kind of aquatic system in this landscape, making it particularly vulnerable to the introduction of non-native species of fish, other animals, and aquatic plants.

Further downstream, the Mollejon Dam created another, much smaller reservoir that feeds water into three turbines, with a third, very smaller dam and single hydroelectric generator at Vaca Falls. These falls were a natural barrier for some species of fishes moving upstream. After construction of this newest dam, the barrier has probably become a more effective filter to upstream migration.

The lower reaches of the Macal River Watershed include the large urban areas of San Ignacio and Santa Elena. Stormwater discharge and drainage ditches from these towns introduce a wide range of pollutants, including sewage, heavy metals, and hydrocarbons, into the local river reach where many people swim.

Rural areas around these urban centers support agriculture, mostly cattle, corn, and beans. Many tourist resorts and large, riverside homes have also been built upstream of the "twin towns," with new water pumps being added to the river by some of the development projects. Large gravel mining pits have been dug in the narrow land between the junction of the Mopan and Macal Rivers below San Ignacio and Santa Elena. Some of these gravel mining operations are still active.

UPPER BELIZE RIVER VALLEY

Spanish Lookout, one of the largest mechanized farming communities within Belize, was founded by Mennonites from Chihuahua, Mexico in 1958. The developing community attracted outside settlers, many working in agriculture or food processing plants (grain, bean, dairy, poultry, meat). Several villages grew up around Spanish Lookout. Most of the surrounding area has been deforested for pasture and crops, except for a few trees along some water courses.

This valley has become one of the greatest impacted areas within the CMMBW, second to the Mopan Watershed. Fields are often heavily tilled and planted in corn and beans. Usually land is plowed up to the break-in-slope along the river, leaving a thin layer of riparian trees, if any. Often after riparian trees have been removed, thick walls of fast growing spiny bamboo grow in their place.

Farms produce beans, corn, potatoes, citrus, chicken, eggs, milk, and beef. Many of these agricultural ventures are heavily dependent on pesticides and chemical fertilizers that, lacking well developed riparian forests, are often washed directly into the river. Aerial spraying of pesticides is becoming a more common practice. Irrigation agriculture is increasing in the area, with Spanish Lookout and other farmers extracting significant amounts of water.

Livestock pastures are mostly found in this upper Belize River Valley. Cattle are produced throughout much of the Mopan River Valley and, as in Belize, with most livestock are given free access to the river and its banks. Many of these pasture sites have been largely deforested. Excessive bank erosion has occurred in response to these unsustainable agricultural practices, as evidenced by bank failure scars and undercutting of exposed bank edges.

In 2005 productive oil wells were established in the Spanish Lookout area following extensive seismographic surveys. This industry represents a potential risk to streams and rivers, but extensive safety precautions have been put into place and so far no major spills have happened.

Included in this section of the watershed are the smaller Iguana Creek and Quaco Creek draining into the Belize River from the Spanish Lookout area, and Barton Creek and Roaring Creek that drain out of the northern portion of the Mountain Pine Ridge Forest Reserve. The Thousand Foot Falls Natural Monument, is on a tributary of Roaring Creek.



Completely deforested river bank and large bank failure



Deforested bank with spiny bamboo on one side and thin tree line on the other bank, but no adequate riparian forest

LOWER BELIZE RIVER VALLEY

Areas in the lower reaches near the smaller communities of Willows Bank, May Pen, Double Head Cabbage and Bermudian Landing are dominated by milpa farming and small scale livestock production. Most of these fields are cleared down to the high water mark using machetes and after the vegetation dries, the fields are set on fire at the start of the rainy season. Gill netting river fish for the market and harvesting undersized Mahogany, Nargusta and Cedar have been long term concerns.

In 1985 Dr. Robert Horwich, a primatologist from the United States, Mr. Fallet Young, a landowner in Bermudian

Landing, and a dozen other landowners formed the Community Baboon Sanctuary to protect the black howler monkeys living along the Belize River. The riparian forest within this part of the Belize River is home to many troops of howler monkeys, green iguanas, crocodiles and other wildlife.

Participating landowners agreed to leave river bank forests intact for wildlife. Over the years new members have joined this community association. Populations of howler monkeys have increased in the area and some troops have been successfully trans-located to other parts of Belize where they once occurred until an epidemic of yellow fever wiped

them out in the mid-1950s. Most of the riparian forest is very healthy along this protected reach because of this unique community-based conservation initiative.

Over the years this area has attracted tourists, birders, researchers, and university groups. Hotels and camp grounds have been developed to accommodate visitors, and many local people supplement their incomes by serving as guides.

Big Falls Farm, downstream of Roaring Creek, operated a major water intake system to flood rice fields. The farm changed from growing rice to producing cattle. Owners of the farm have set aside Cox Lagoon as a private protected area, a wetland, and a lagoon system that is particularly rich in wildlife and is noted for its population of Morelet's crocodiles.

CROOKED TREE WETLAND

The Crooked Tree Wetland is a large lower reach wetland of the Belize River. It catches much of the floodwater that would otherwise inundate Belize City, holding and slowly releasing that water once floodwaters have receded. The entire wetland area is anywhere from 8,000 to 10,000 hectares in size and rich in wildlife.

The wetland accommodates thousands of migratory birds during the dry season, from February to May, to taking advantage of the abundant fish and low water conditions within the lagoons. In 1998 this wetland was declared a RAMSAR site, giving international importance to Crooked Tree Wildlife Sanctuary as a waterfowl habitat, a protected area co-managed by the Belize Audubon Society for the people of Belize. The bird list for Crooked Tree Wildlife Sanctuary contains about 320 species of water, savanna, and woodland birds.

Southern and Northern Lagoons drain through small creeks into the Belize River. The smaller section (650 hectares) on the eastern side of the Northern Highway includes the smaller Mexico Lagoon, that dries up completely during the dry season, and Jones Lagoon. This system drains through Mexico Creek that enters the Belize River just downstream of Grace Bank. During very high waters, Crooked Tree Wetland spills into the New River Lagoon system to its west and north.

Crooked Tree Village has the largest logwood population remaining in Belize. This island village is surrounded by a wetland and accessible only by boat up until 1984 when it was connected to the Northern Highway by a three-mile access road and causeway across Northern Lagoon. Soon after that, many of the wooden houses began to be replaced by concrete houses.

When the first causeway was built across Northern Lagoon, engineers failed to splice in culverts or bridges and water on the north side of the causeway backed up and drowned many of the riparian trees, including some of the logwood, while aquifers on the south side of the causeway

Villages along this reach are typically located next to the river, with areas around each settlement cleared of riparian vegetation. Downstream of many villages are backwater areas where solid wastes, mostly plastic, accumulate as bags of household garbage seem to be routinely thrown directly into the river as a disposal strategy. Besides the sewage seepage from local outhouses and village drainage ditches, discharge from the Belmopan treatment plant flows directly into the river.

Water is extracted from the Belize River by Belize Water Service Ltd. and treated to supply municipal water systems of Belmopan and surrounding villages, Ladyville, and Belize City. Silt accumulation in the lower Belize River is increasing the cost of water treatment.

went dry. After some delay, bridges were spliced into that causeway and some of the problems were corrected. These same issues may occur in the Western Lagoon where a new causeway was built without proper planning and without bridges for water to flow through from one side to the next.

Economic activities include fishing, logging, cattle and charcoal production. Fishermen provide wild-caught tilapia and bay snook for the local market and Belize City. The first Tilapia Festival was held in March, 2003, featuring locally caught tilapia. Crooked Tree Village is known for cashew nuts and cashew wine, with an annual Cashew Festival being held each May. Tourism has also become a significant generator of income for the village, many visitors attracted by the incredible bird life and some of the best professional birding guides in Belize.

The villages of Rancho Dolores and Lemonal are located on Spanish Creek and share some of these wetland resources with Crooked Tree villagers. Residents of these villages are largely farmers, but a few have become guides, taking tourist on horseback rides and canoeing Spanish Creek. The 5,900 acre Spanish Creek Wildlife Sanctuary is a pristine forested area that runs along the stream, and provides important habitat for crocodiles and river turtles, with some jaguars still living in the area. There is some conflict between jaguars and cattle ranchers in the area.



Yellow-crowned Night Heron

BELIZE RIVER MOUTH AND COASTAL ZONE

The lower end of the watershed, from Burrell Boom to the sea, is largely coastal savanna and mangrove swamps. It includes Ladyville and the Philip Goldson International Airport (and its long concrete fence that cuts through the riparian forest along the Belize River) on the Northern Highway. The Burdon Canal Nature Reserve, built in the 1920s as a protected inland waterway for traveling and transporting cargo back and forth between Belize City and the south, intersects Belize River at the western edge of Belize City. However, over the years this protected area is being impacted by development. The Belize River empties into the sea just north of Belize City. Haulover Creek, a canal that cuts through the mangroves behind the sea front, connects the Belize River to Belize City, and runs through the center of the city to reach the sea.

Being a low, wetland area that contains the largest urban center within the CMMBW and the country of Belize, this area has many issues. Besides the conversion of valuable mangrove swamps into lots for construction of neighborhoods, stores and businesses, there are many sources of pollutants generated by the large population.

The largest sewage treatment facility in the country is located within wetland areas of the city. This old dump site is now closed and solid waste is being trucked to the new landfill on the George Price Highway. However the garbage accumulated over many years is still on site and probably still producing leachate that enters the surrounding wetlands.

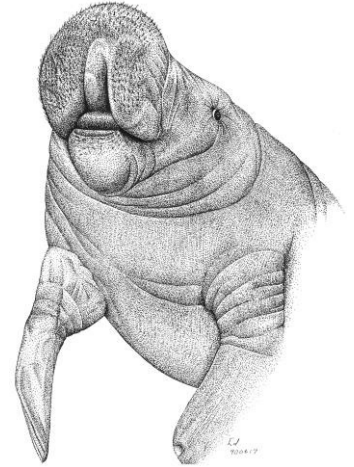
Haulover Creek sediments are anoxic from all of the organic waste that is dumped into the water. These anoxic sediments spread out into the sea around the center of the city and toward the south, creating large areas of anaerobic

mud. Heavy metals, pesticides and other persistent pollutants bound up in the mud become re-suspended each time dredging occurs to keep Haulover Creek and the tributary canals open to reduce flooding.

Coastal zone waters are usually rich in estuarine life. Land crab burrows are everywhere, their holes reaching down to the shallow water table. Puffer fishes can be seen swimming in the shallow edges of the river. American crocodiles and manatees are seen around the river mouth and in the canals.

Belize City is a port city, with ship traffic moving back and forth from the open sea to the industrial port on the south side of the city. Haulover Creek is busy with small fishing boats, sailing dories, and water taxis carrying people between the cayes and the City. It is also the port of call for many cruise ships, with tender boats ferrying tourists from their ships to the Tourist

Village near the mouth of Haulover Creek, where they depart for a day of excursion around the city or local tourist sites. Belize City is still the economic heart of the country where most of the larger businesses, stores and other commerce are concentrated, along with all the serious pollution issues common to coastal low-lying cities.



HISTORY OF THE CMMBW

THE ANCIENT MAYA

The Central Maya Lowlands, including most of present day Belize and the Peten, was a major center of the Ancient Maya world and is still home to the Maya who descended from this early civilization. The Maya Forest today is considered to be a major regional biodiversity hotspot and is characterized by very high numbers of plants known to have cultural and economic value. This indicates that the Maya played an important role in developing the forest plant composition over the past 4000 years.

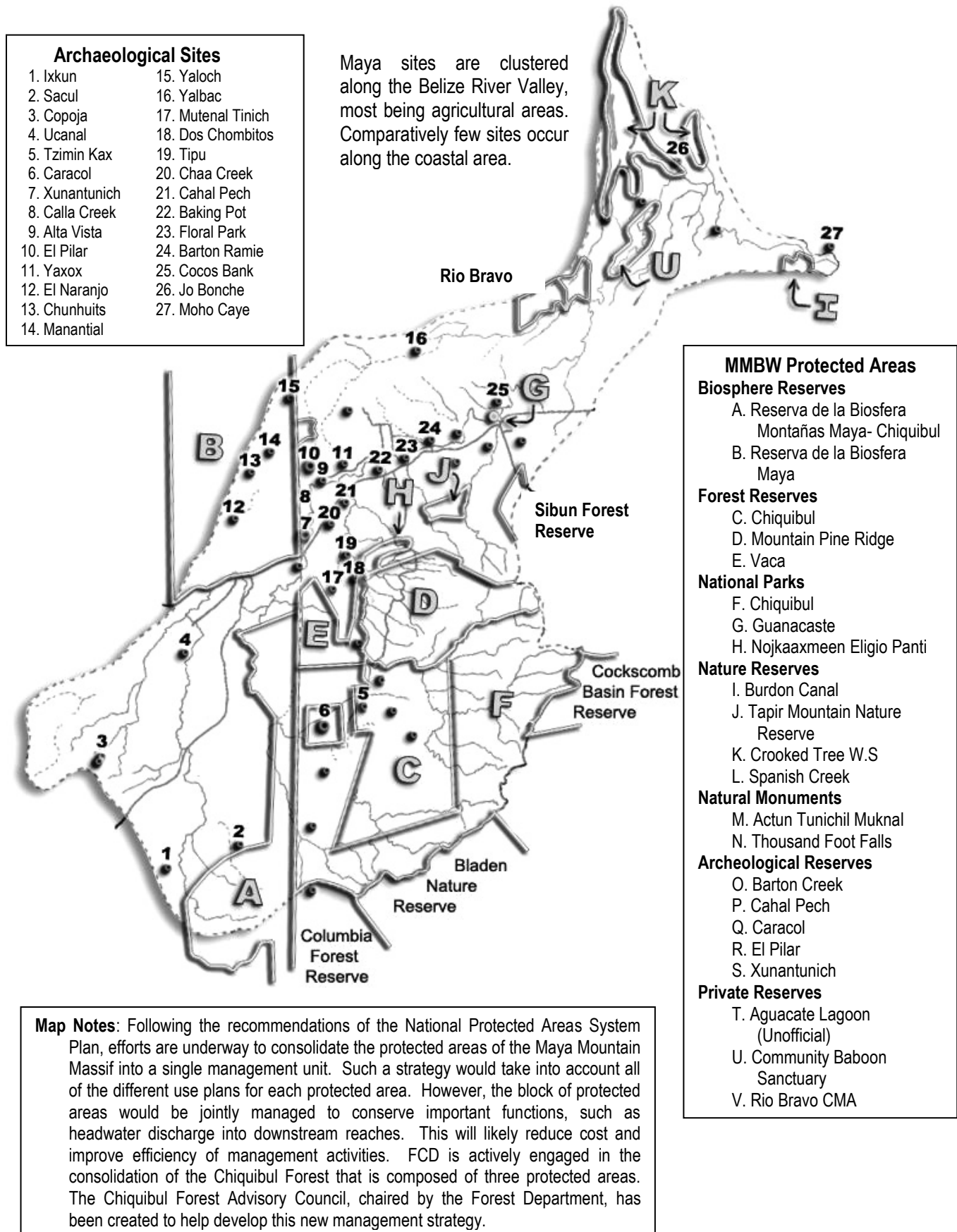
The first people were hunter and gatherer groups thought to have migrated into the CMMBW lowlands about 4,500 years ago. They lived primarily in coastal oak and pine ridge savannas, such as around present day Belize City and the lower Belize River Valley. Maya farming settlements appeared much later in the Peten and Belize, beginning around 2,000 BC. However, pottery and other artifacts did not appear until about 1,000 BC. Early Maya evolved into an

advanced society that peaked somewhere between AD 250-900, with most large central lowland cities becoming abandoned at the end of the tenth century.

For over three thousand years, the Maya were able to maintain a complex social structure within a challenging tropical environment that supported populations estimated to be far in excess of the roughly 230,000 people occupying the CMMBW today. Map 13 shows many Ancient Maya sites scattered throughout the watershed.

The CMMBW was an important Maya settlement area from the earliest times. The highest settlement densities, an estimated 85%, occurred in the well-drained, shallow, fertile soils of ridges and deeper, rich alluvial soils in the flat and sometimes flooded areas within the Upper Belize River valley. These sites were major grain production areas, including Barton Ramie, Baking Pot, and Spanish Lookout. Many of these sites are productive agricultural lands today.

Map 14. Archaeological Sites and Protected Areas of the CMMBW.



Ancient Maya communities within Belize River Valley were moderately sized settlements with widely spaced houses. Sites have yielded many luxury items, such as obsidian blades, marine shell beads, jade and jadeite generally associated with the elite. This suggests that these residents, with a measure of wealth and larger land holdings, were privileged families. Considering the quality of soils, these communities were probably producing cash crops such as cacao, cotton and tobacco that were exchanged for luxury goods. Poorer families occupied marginal lands in the limestone foothills above the valley. Besides farming, these families probably had to supplement their income through the manufacture of stone tools, pottery, and other simple and basic household products.

The Belize River was an important transportation and communication route connecting the coast with Maya centers in the Petén. Mojo Caye was a trade port near the mouth of the river. In the other end of the watershed, navigation up the Macal River was hampered by rapids. The relatively narrow alluvial floodplains limited development of these upstream areas by the Ancient Maya. Although the Mopan River

contains rapids, it flows through a more open terrain and its banks were heavily settled compared to the Macal River.

While the majority of settlements in the upper Belize Valley were adjacent to the Belize River and made up of small mounds that scattered around the landscape, sites in the Macal and Mopan Watersheds seem to have been more clustered around focal centers and consist of larger structures; such as those seen at Cahal Pech, Xunantunich, Buena Vista del Cayo and El Pilar. Cahal Pech was probably the gateway to the Macal River, while Actuncan in the Preclassic, Buena Vista del Cayo in the Classic, and Xunantunich in the Terminal Classic served as gateway cities to the upper reaches of the Mopan River.

An area known as Indian Hill or Chau Hiix, located near Crooked Tree Village consists of pyramid-shaped structures, dams, and canals. This indicates that the Crooked Tree area may have actually been a natural wetland that was extensively modified by the Ancient Maya for agriculture. The Crooked Tree Wetland area was greatly influenced by humans since at least 1200 BC and until the Spanish arrived. It continues to be greatly modified and impacted by human activities today.

COLONIAL TO RECENT HISTORY OF THE BELIZE RIVER

Crooked Tree Village, located in the middle of a large wetland, is one of the oldest continually inhabited places in Belize. It was established as a logwood site since the beginning of the industry in 1650. British seamen built a logwood camp there in 1750 when they retired from piracy of Spanish ships within the cayes to become logwood cutters. Logwood became a very profitable commodity due to the growing textile industry in England. Synthetic dyes were developed during the late part of the 1700s and logwood prices plummeted in the 1760s. During this time, the Spanish were entering the territory and destroying garden plots maintained by slaves who had been brought in as logwood cutters. Many slave rebellions occurred during the depressed years between 1760 and 1770. Many slaves ran away to start a new life in the open expanse of land.

Most logwood and mahogany had been cut from the Crooked Tree area by 1786. There was a brief revival of the logwood industry during World War I but otherwise this resource has not been extracted for dye manufacturing since then. The wetland forests of Crooked Tree are the last remaining logwood stands of significant size left in Belize. In the colonial era, logging was concentrated along the Belize River because of the availability of logwood, mahogany, and chicle (sap used for chewing gum) within floodplain forests and the use of the river to transport logs to the coast.

The lower Belize River Valley was a major logging center from the 1700s through the big logging era of Belize history. Today this area is largely agricultural land. The name "Burrell

Boom" refers to the use of this site for collecting loose logs that were floated downriver and "booming" them together. Logs were stopped by a large chain stretched across the river and boomed together by rope or chain. Logs were then floated down river to waiting ships bound for England. As the logging industry grew and expanded into new areas, new villages and towns were established. Early loggers were selective, leaving most of the forests still intact and able to quickly recover, compared to present-day land clearing for large-scale agriculture and urban growth.

In 1905 the first steam-driven river boat to travel the river, the *Cacique*, reached the banks of Benque Viejo del Carmen. Soon large wooden cargo and passenger boats navigated up and down the Belize River from Belize City to what is now San Ignacio Town, and continued up until the late 1940's. However, completion of the Western Highway in 1947, connecting Belize City with western Belize, spelled the end of Belize River supply boats.

During this era before the highway the Belize River was an important transportation route and trees were valued for tying up canoes and boats. People used the river banks to camp and gather fire wood. A law was passed that actually provided for protection of a 20-m (66 ft.) strip of forest along each river bank. Although not the original intent, this law has been developed into legislation that offers some protection to riparian forests. This law was retained in the National Lands Act and the Land Utilization Act, but is often not observed or enforced.

As the Western Highway was improved and paved and more trucks and cars were brought into the country, dependence on river travel ceased and the land near the river changed to other uses, such as farming and tourism. Hurricane Hattie, with winds of up to 300 km/h, hit Belize City in 1961, destroying about three fourths of the homes and businesses. Hattieville, located in the Sibun River Watershed, was constructed along the Western Highway for many people who lost their homes in Belize City. The houses were built largely from pine and other trees pushed over by the hurricane.

Plans were made to move the capital, named Belmopan after the Belize and the Mopan Rivers, inland near the center

of the country. Construction began on Belmopan in 1967, with phase one completed by 1970. Very slowly, over a couple of decades, many Government ministries and departments and many foreign embassies migrated to the new capital. Today it is the center of government, while Belize City remains the center of commerce.

Belmopan has continued to grow in size, with surrounding settlements becoming incorporated into the city. The University of Belize established its main campus in Belmopan. The Western Highway was re-named the George Price Highway and large highway reconstruction projects are occurring, especially in Belize City, Belmopan, and the San Ignacio and Santa Elena area.

RECENT HISTORY OF THE PETÉN

Up until recent times, most of the Mopan Watershed and the Petén in general were isolated and relatively unknown, supporting a chicle gum trade during the late 1800s and later illegal logging and hunting. By the 1950s the Petén became a frontier for immigrants from the highlands and Pacific coast of Guatemala. At first the area was sparsely populated by small, self-sufficient communities who lived off of what the forest offered. In 1954, under pressure to supply land to a growing population and develop the national agricultural potential, Guatemala promoted the agrarian colonization of the Petén by giving land to landless peasants and indigenous people.

Under military dictatorship from 1954 to 1986, the population of the Petén reached to almost 750,000 by the turn of the century. Consequently, the forests were cleared to grow subsistence crops and create pastures, using practices that were unsustainable. The colonization policy required people to clear the forest and prepare for planting to keep the land. Many settlements were established on land

that could not sustain long-term farming. Private Guatemalan and foreign companies were given control of chicle, timber and oil extraction.

Large ranches produced cattle and the poor were relegated to subsistence agriculture and selling allspice and xate palm, as well as illegally logging of tropical timber. This became a region of strife occupied by the Guatemalan military pitted against the resistance of guerrilla movements in the area.

By the late 1980s this area attracted the attention of international conservation groups such as Conservation International (CI), The Nature Conservancy (TNC), the Rodale Institute and CARE International. They focused on reducing biodiversity loss through the protection of the Petén forests. Faced with the construction of a highway to Petén, giving greater access to the territory, the Maya Biosphere Reserve was established to help conserve wildlife and forests.

PROTECTED AREAS IN THE CMMBW

On a regional scale, the CMMBW provides important linkages within the Mesoamerican Biological Corridor system, pathways for movement of plants and animals among intact forested areas. However, this important land bridge has been fragmented. It is in need of immediate assessment, conservation, restoration, and rehabilitation to help conserve its biodiversity and connectivity within the Central American Isthmus network of protected areas. Protected areas make up a large percentage of the CMMBW, (3,200 km² in Guatemala and 5,700 km² in Belize) (Map 13).

The Maya Biosphere Reserve, about 16,000 km², makes up the northern 40% of the Petén and extends to Melchor de Mencos in the northwestern portion of the CMMBW. About 7500 km² is designated for extraction of non-timber forest products such as *xate* palm leaves for the United States and European floral industry, *chicle* for the Japanese market,

latex and allspice. The Reserva de Biosfera Montañas Maya-Chiquibul in Guatemala lies adjacent to the Belize International Border and connects along its western border with the Chiquibul National Park. The reserve expands in the southwestern end of the CMMBW to include headwaters of the Mopan River. However, this reserve has been heavily deforested over the past couple of decades.

The Chiquibul National Park connects to the Columbia Forest Reserve and the Bladen Nature Reserve to the south, and the Cockscomb Basin Wildlife Sanctuary and the Sibun Forest Reserve to the east. Essentially most of the western Chiquibul-Maya Mountains is under some kind of protected status, including three forest reserves (Chiquibul, Mountain Pine Ridge, Vaca), two national parks (Chiquibul, Nojkaaxmeen Eligio Panti), and one natural monument (Thousand Foot Falls).

Another nineteen thousand acres in the Mountain Pine Ridge is under private ownership, but owners are interested in managing the holdings as a watershed protection area. An expanding Mennonite community, however, poses a threat to stability in the area. Several smaller holdings with resorts also maintain relatively low impacted areas accessible to tourists by trail systems and horseback.

Tapir Mountain Nature Reserve, stretched between the mid-reaches of Barton Creek and Roaring Creek, was a privately donated reserve set up strictly for research and education activities. Some tourism is allowed in one of its cave systems. Guanacaste is a small park occupying the eastern bank of Roaring Creek at its confluence with the Belize River. It is managed by the Belize Audubon Society.

Spanish Creek is important not only for its local natural features, but as a linkage between Rio Bravo lands and protected areas in central Belize. The White Water Lagoon Protected Area borders the Rio Bravo Conservation and Management Area at Labouring Creek and extends to St. Paul's Bank Village on the Belize River, linking the Northern Biological Corridors, including Rio Bravo (Programme for Belize), with the Community Baboon Sanctuary.

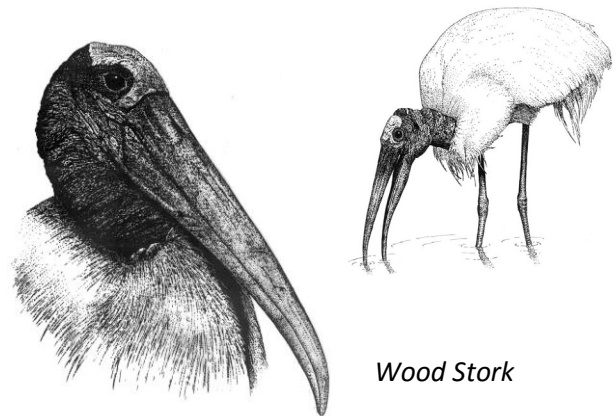
The Chiquibul National Park is the largest protected area in Belize (285,000 acres) and the largest area of protected karst. Other protected sites within the CMMBW having significant karst terrain include the Chiquibul Forest Reserve, Vaca Forest Reserve and Tapir Mountain Nature Reserve.

Archaeological reserves include Caracol within the Chiquibul Watershed, Xanantunich and Cahal Pech within the lower Macal Watershed, and El Pilar within the Labouring Creek drainage. These sites and all caves (because of actual or potential archeological significance) are under the jurisdiction of the Institute of Archaeology.

Crooked Tree area, an important migratory stop for many wading and aquatic bird was declared a protected area in 1984. It is managed by the Belize Audubon Society and a group of community advisors. This network of swamps,

marshes, waterways and lagoons were declared a RAMSAR wetland site in 1998. The sanctuary is divided into two sections and consists of a 300-foot wide strip of land around the water bodies.

The Community Baboon Sanctuary is a voluntary organization that was formally established in 1985 to protect the black howler monkeys living in the riparian forests in the lower Belize River Valley. This is a privately owned sanctuary, with voluntary members from Bermudian Landing, Big Falls, Double Head Cabbage, Flowers Bank, Isabella Bank, St. Paul's, Scotland Halfmoon and Willows Bank.



Wood Stork

Burdon Canal was built in the 1920s as a protected inland coastal savanna waterway for traveling and transporting cargo back and forth between Belize City and the south. The mangrove banks and the canal, linking Belize River with the Sibun River and Northern Lagoon, are now under protected status.

Cox Lagoon on the Big Falls Farm property has been proposed as a protected area for crocodiles and other wildlife, but is not formally established. Other sites, including Mussel Creek, have great potential as habitat for many species of concern.

SELVA MAYA CORRIDOR / CENTRAL BELIZE CORRIDOR

The Selva Maya is the largest expanse of continuous tropical rainforest in Central America and second in size only to the Amazon Forest in all of Latin America. It stretches from southeastern Mexico (Chiapas, Tabasco, Campeche, Yucatan and Quintana Roo), includes the Petén province in Guatemala and extends throughout Belize.

The Selva Maya is made up of tropical montane rain forest, including the Chiquibul-Mayan Mountains, and tropical lowland rain forest of Chiapas and the Yucatan Peninsula in Mexico, Petén in Guatemala and Belize. It also includes some of the largest areas of protected wetlands in Central America. Besides the ecosystems and biodiversity, the Selva Maya contains the region's most important Mayan archeological sites.

Regionally the CMMBW provides important linkages within the Meso-American Biological Corridor System. However; increasing fragmentation compromises this landscape function and immediate conservation and restoration actions are needed to help maintain biodiversity and connectivity. Deforestation has resulted from the establishment of permanent communities in critical areas, government issuance of land leases in protected areas, expansion of agriculture and pasture, frequent forest fires, hydroelectric development, and oil exploration.

The Central Belize Corridor (CBC) connects the CMMBW to the Sibun River Watershed, providing valuable linkage between northern and southern Belize. Development continues to erode segments of this important corridor.

GENERAL IMPACTS IN THE CMMBW

Many challenges within the CMMBW threaten the landscape and aquatic ecology. The most serious issue is deforestation for agriculture. Steep slopes are cleared in some areas, particularly in the Mopan Watershed. This practice greatly increases erosion and risk of mud slides. Steep slope soils are often thin and nutrient-poor in comparison to river valley soils. Corn and other crops can only be produced for just a few years before nutrients are exhausted. Removal of upper forests increases the amount of water reaching rivers, increasing flooding potential. Besides holding soil together and adding organic matter that helps increase the water holding capacity of soils, trees absorb water through their roots and release it back into the atmosphere as water vapor through their leaves.

Riparian or river bank deforestation is a particularly important issue. These forests are the filters of the landscape. They are being stripped out of the watershed at an alarming rate. Once riparian forests are cleared, stream and riverbanks are susceptible to erosion by flowing waters. Often banks slide into the water during high flow events, as seen all along the river in the Upper Belize River Valley.

Stripping out riparian trees removes a major food source for stream and river organisms. These forests supply the bulk of the leaves, limbs, fruits and flowers on which stream organisms depend for food. Shade is also removed and aquatic habitats are exposed to direct sunlight. Water becomes warmer than normal and stresses many of the aquatic organisms.

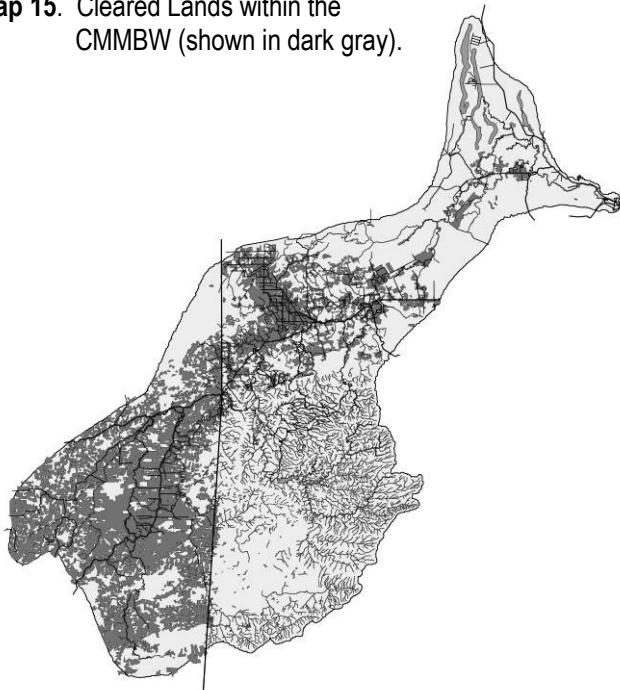


Steep cut bank on Roaring River cleared for corn and beans.



Wetland deforested for agriculture

Map 15. Cleared Lands within the CMMBW (shown in dark gray).

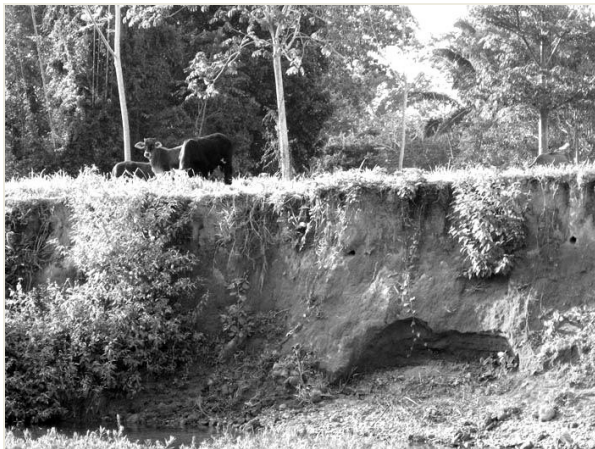


Map Notes: Map 15 shows the cleared land within the CMMBW in dark gray. The majority of the Mopan River Watershed and the downstream portion of the Chiquibul River Watershed are largely denuded, with very few trees remaining within the landscape. Riparian forests have been cleared throughout much of this area. Cleared lands reach the border between Guatemala and Belize, with patches of cleared areas extending into the Chiquibul River Watershed on the Belize side.

Heavy clearing within Belize occurs throughout much of the upper Belize River Valley from the border to downstream of Belmopan. Deforestation is heaviest around Spanish Lookout. Scattered land clearing has occurred south of the Belize River up to the foothills of the Maya Mountains. Within much of this area mechanized Mennonite farmers and now international corporate farms have removed much of the riparian forest along the Belize River, resulting in bank failure.

Manure from pastures is washed into unprotected streams and rivers. Excess nutrients and solar exposure promotes excessive algal growth. Farmers often loose cattle to floods, as well as crops planted close to the river. Crops typically do not survive well in the high energy, frequently flooded stream and river banks and they do not replace the functions provided by natural riparian forests. Besides soil loss and pesticide contamination caused by growing crops on river banks, economic returns are often minimal due to floods and bank failure.

Extensive cattle grazing on riverbanks can also expose soil to erosion. Browsing of tree seedlings and under story plants by cattle can reduce the ability of riparian areas to process and filter out nutrients. Manure adds large amounts of nitrogen to streams and rivers when it is washed in from damaged riparian areas. Horses and cattle trample the soil with their hooves, compacting it and breaking up the soil profile. Riparian forests improve within a few years when cattle are excluded, but full recovery may require decades, depending on the severity of the damage.



Cows grazing steep bank of Belize River showing bank failure

Deforestation for development of homes, tourist facilities, businesses, industries and roads greatly increases the amount of soil being eroded into streams and rivers. When sediment levels within rivers increase, water clarity is greatly reduced or completely eliminated. Turbidity adds to the cost of collecting and cleaning water for public water systems. Excess turbidity also reduces the ability of aquatic plants to capture sunlight, reducing their growth and reproduction. Excess sediments are deposited over downstream river bottoms, embedding river stones and smothering out aquatic invertebrates and fish nesting habitats with fine sand and silt.

River beds may become shallower as sediments build up. River segments may become braided as sand and gravel bars form, dividing the deeper main channel into several shallower, smaller channels. Clogging rivers with sediment reduces the amount of water a channel can hold during floods. Floodwaters therefore spread wider within floodplains, inundating more farms, houses and roads. This increases the economic loss within the CMMBW. Increasing

numbers of people settling along the river banks, as houses and tourist facilities replace riparian forests means that more pollutants enter the river and that more people are risking flood damage.

Sewage, sediment, household chemicals, old motor oil, used tires, yard waste, automobile batteries, and plastic bottles are examples of the typical pollutants from urbanized riparian zones. Periodically the hydroelectric facilities release large amounts of accumulated sediments into the Macal River. Much of the Sediment is fine clays and silts that remain suspended in the water for long periods of time, blocking sunlight and likely interfering with gill breathing organisms. One large sediment plume released into the Macal River ultimately reached the sea as a visible mass of turbid water.



In-stream gravel mining is a practice that greatly disrupts stability of the river bed. Miners use backhoes to reach into the flowing river and scoop out gravel. Sometimes a road is built out into the river to reach distant gravel deposits. When the deposit is depleted, the material used to build the access road is also used. These activities often change the course of the river. Also, when pits are dug in the active river bed, erosion occurs on the upstream edge of the pit, migrating upstream as sediments are destabilized and become susceptible to erosion. The demand for river gravel is increasing around the country as new houses, stores, businesses, tourist facilities, and roads are constructed.



In-stream gravel mining

GENERAL SOLUTIONS TO ADDRESS CHALLENGES

There are many workable solutions to address the issues we face in the CMMBW. All of these solutions have one thing in common—they can only succeed if they have strong community support. Also, the community support must be connected through a cooperative network that provides information, access to expertise within many areas, and involves women, youth, and elders. This network must be bi-national in scope, helping build working linkages among Guatemalan and Belizean communities and promoting collaborative projects that benefit people and the watershed.

We must work to restore our vital steep slope, wetland and riparian forests, and we must begin immediately. Sometimes, when the impact is not severe and healthy riparian forests occur upstream, damaged riparian areas may restore themselves once the cause of the impact is identified and stopped, or at least greatly reduced.

When livestock are removed, for example, seeds from intact upstream forests can be brought in by flowing water, take root in damaged riverbanks downstream, and start growing. In time surviving saplings and other plants grow and mature, replacing lost riparian forests. Fencing cattle out of the riparian zone is a good positive first step.

Water can be supplied to cattle by ponds or by nudge-plate watering troughs that are filled from the river, for example. These troughs are attached to the fence line and a pipe extended to the water. This type of watering trough is equipped with its own pump operated by a large nudge plate which cows learn to use. As a thirsty cow nudges the plate, water is eventually drawn into the trough.

Often restoration efforts pose much greater challenges. Replanting of the riparian zone with local riparian trees may be required. Large, steep banks are a particular problem and sometimes must be stabilized with spiny bamboo and other fast growing plants before trees can take root. In some cases, stones may have to be added to the bottom of steep banks to reduce undercutting by the force of flowing water, or other stabilizing structures made with natural materials. Reduction of sediments from farm lands by the use of cover crops on fallow fields, reduction and treatment of waste discharge from farms and urban areas, and removal of unnatural structures, including car washing facilities that drain into the river may also be needed.

Garbage can be eliminated from the river through the creation of a working solid waste recycling program adapted to small villages and large towns, accompanied by a robust public education program. We should all be composting our organic waste right in our yards, using the compost to enrich our soils. We can sell much of our remaining garbage if each village were to establish a sorting and storage facility for paper, metal, plastic, old batteries, used motor oil and other waste. Recycling companies are often willing to buy and

transport well-sorted garbage, the raw materials of their industry. Creating such a program would involve working with recycling companies in the region, and setting up a cost-effective transport system for the waste sorted to the specifications of the industry. The Department of the Environment must play a more proactive role to impose a practical system of fines for persons using clandestine garbage dumps and working closely with community leaders.

When we clean up our neighborhoods, dry creek beds and gullies of old cars, appliances, cans, bottles and other garbage, we are also reducing mosquito-breeding sites. This in turn helps to reduce the spread of dengue and other diseases, reducing use of pesticides to control mosquitoes, pesticides that also poison people, honey bees, and many other organisms.

Watershed communities are essential to conservation and management of our critical natural resources. Steep slope forests, riparian forests, streams, rivers and wetlands are valuable natural resources that provide essential environmental services. These are all legally protected areas because of these important services. However, there is a cost for conservation. A system of payment for environmental services is desirable as one avenue for acquiring funding to support conservation efforts.

Workable solutions are as varied as the many problems we must face within our watershed. But solutions can succeed only if everyone is willing to get involved and if each of us does our part. Implementing appropriate solutions to these issues also offers the opportunity to involve our youth, giving them a chance to do something positive for the future. As we take action, we also have to monitor our progress and remind ourselves to be patient. Ecological recovery requires time and commitment to the process, sometimes many years, with wildlife populations recovering slower than the habitats. That is why it is so important to take action now!



Youth involved in planting trees

Ecological Services Provided by Forests

Steep Slope Forests

- Transpire rainwater back into the atmosphere
- Help build steep slope soils
- Help hold soils together, reducing erosion
- Help stabilize hillsides, reducing risks of mud slides

Riparian Forests

- Help stabilize the banks of streams and rivers
- Help slow down surface flow into streams and rivers
- Serve as wildlife corridors
- Provide nutrients to streams and rivers
- Shade the water, diversifying temperature range
- Add habitat to streams and rivers as wood and leaves

Mangrove Forests

- Protect shorelines
- Dampen storm surge
- Help control erosion
- Provide nursery grounds for many marine species
- Capture and export large amounts of nutrients into surrounding ecosystems



Well-developed riparian forest along the Macal River

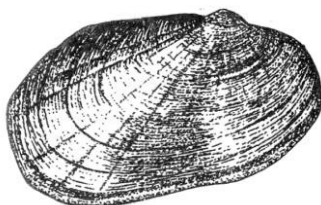
WATERSHED ASSESSMENT AND MONITORING

An **assessment** of a watershed is necessary to fully appreciate the condition of a river system and its catchment. **Monitoring** is the process of applying assessment procedures repeatedly on a scheduled cycle in order to better understand patterns of seasonal change and to follow recovery of streams and rivers. Over the years, environmental agencies and researchers have developed a set of standard procedures to assess streams and rivers. Originally these protocols were designed for use by government agencies charged with surveying and monitoring the integrity of larger streams and rivers. However, it was soon recognized that involvement of resident communities through volunteer organizations and individuals is necessary to effectively monitor watersheds. Involving communities actually helps to promote understanding of environmental issues and enhance positive corrective action. The number of communities participating in watershed assessment and monitoring, and getting involved in making ecological improvements, is increasing around the world.

Measuring physical and chemical characteristics of a stream or river was a primary approach used by many environmental agencies in the early days of assessment and monitoring. Chemical and physical measurements can reveal

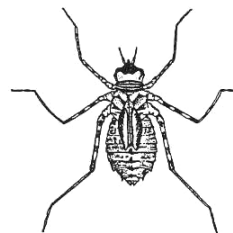
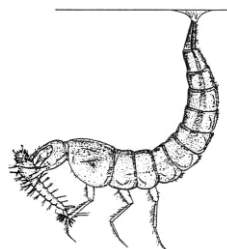
important information about a stream or river. However, the equipment needed to make these measurements is often expensive, requires chemical reagents that must be replaced often, and when meters and probes break they are expensive to replace or repair. Besides that, water chemistry may change rapidly in a flowing water system and may be missed by a monitoring effort that happens once a month.

One of the most common methods of assessment used today involves collecting and identifying the aquatic invertebrates that live within the stream or river bed, particularly in rapids and riffles where water is shallow and fast moving. Often leaf packs and woody debris are sampled in these areas, along with rocks and gravel. This is a much cheaper assessment approach. Tools to collect aquatic invertebrates are usually simple and can often be made from readily available materials. Used in combination with physical and chemical assessment efforts, riparian forest evaluation, watershed mapping, fish surveys and other procedures, standardized invertebrate sampling can be a powerful assessment tool. Results of these combined efforts can characterize the existence and intensity of land use impacts, identify sources and causes of impacts, and help describe ecosystem components.



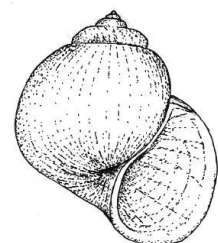
Clam, filter feeder

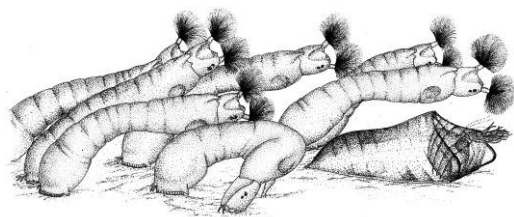
Diving Beetle Larva, predator



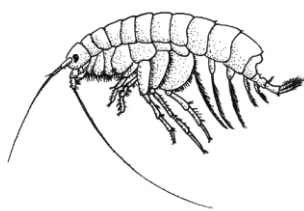
Dragon Fly Naiad, predator

Apple Snail, scraper



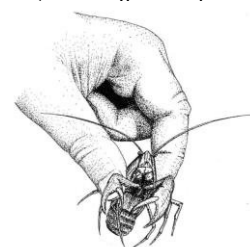


Blackfly larvae, filterers using fine hairs



Scud, a shredder

Crayfish, scavenger and predator



Physical, chemical and biological assessments of an impacted stream or river reach are compared to healthy sites within the same or a neighboring watershed to indicate the degree of environmental degradation that has occurred. Living organisms are sentinels that respond to stress impacting streams and rivers by dying out if conditions are too severe or growing in numbers when conditions are good. Aquatic invertebrate communities are particularly useful in determining the presence of non-point source pollution or a single pollution event that may have moved through the stream or river. Monitoring of these organisms can also detect non-chemical impacts such as flow alteration, habitat destruction, excessive harvest of resources, and the introduction of non-native species. The presence or absence of pollution intolerant or tolerant invertebrates offers important clues, knowing that different kinds of organisms respond to environmental stress in different ways.

Examining the percentages of different feeding types among invertebrates collected can help determine the environmental status of the stream. Some invertebrates are

shredders that tear leaf or woody material into very small pieces. Others are **filterers** that collect particles from the water in nets they spin (certain caddisfly larvae) or using bristles and hairs on legs and mouth parts (some mayflies, blackfly larvae). Others are **scrapers** that graze on the living films of material that grow on any surface submerged in the water. **Predators** are those invertebrates that feed on the other invertebrates within their community and include many beetle larvae, dobson flies, water bugs and dragonfly larvae. Some of these creatures are illustrated on these pages.

Manuals are available that describe sampling and data analysis procedures and provide keys to help in identifying those organisms found. Workshops can be held to train interested community members and set up sample stations. People interested in becoming volunteer monitoring technicians and participating in assessment efforts should contact the Department of the Environment. Operation of a monitoring station on a local stream or river offers an excellent opportunity to get youth involved through schools and universities.

ORGANIZATIONS ACTIVE IN CONSERVATION WITHIN THE CMMBW

The CMMBW is the largest and the heaviest populated watershed in the country. Many organizations are working within the CMMBW, or have recently worked in the area, and are focused on watershed issues and resource use. The list below is provided as a way to recognize those efforts, and to

encourage people with similar interests to communicate, collaborate, and complement one another. It is important that we help one another whenever we can. After all, we are working towards similar goals — healthy environments and a healthy society.

GUATEMALA

- Consejo Nacional de Areas Protegidas (CONAP)- Protected areas management and environmental issues
- Ministerio del Ambiente y Recursos Naturales (MARN)
- Mancomunidad de los Municipios del Sur de Peten – community governance

BELIZE

- Ministry of Agriculture and Fisheries Department- management of Central Farm, Pesticide Control Board, Irrigation Technical Support Unit Fisheries Department- Aquaculture and Inland Fisheries Unit
- Ministry of Natural Resources, Environment and Sustainable Development, Forest Department - Management of protected areas, forests, wildlife and watersheds.
- Department of the Environment - Impact monitoring, water monitoring, EIA process
- Geology and Petroleum Department, Mining Unit- Permit gold mining; granite, marble, limestone and marl quarries, petroleum production, in-stream gravel mining
- Lands and Survey Department - Approve development plans
- Ministry of Health - Drinking water monitoring, approval of sewage treatment facilities
- Ministry of Works - Maintenance of navigable waterways, canals, drainages, roads, bridges and quarries

- Ministry of Labor, Local Government and Rural Development - Rural Development Department- wells
- National Emergency Management Organization - Management of flood impacts and other disasters
- National Institute of Culture and History - Management of archaeological sites and cave systems
- National Meteorological and Hydrological Service – Monitoring Belize River, early flood warning system
- Protected Areas Conservation Trust - Funding conservation efforts in the basin
- Belize Defence Force - Patrol of border in the Chiquibul National Park and other areas

FOREIGN MILITARY

- British Army Training Support Unit- conducting military training maneuvers within basin
- United States Southern Command- conducting training

LOCAL NON-GOVERNMENT ORGANIZATIONS

- Asociación Balam
- Naturaleza para la Vida
- Belize Audubon Society - Co-manages Guanacaste National Park and Crooked Tree Wildlife Sanctuary
- Belize Institute for Sustainable Technology- Recently completed country water resource assessment
- Comité Integral para la Conservación de Cuencas Chiquibul-Mopan – public awareness, clean up and reforestation
- Friends for Conservation and Development – Co-manages Chiquibul National Park with the Forest Department, and the Chiquibul Cave System with the Institute of Archaeology, coordinates the Bi-national Watershed Alliance
- Mesa Intersectorial de Tierra y el Medio Ambiente (MITA) – promotion of good governance in Southern Peten
- Programme for Belize - Management of Rio Bravo Conservation and Management Area and assisting with Spanish Creek Wildlife Sanctuary
- Rancho Dolores Environmental and Development Group - Co-manages Spanish Creek Wildlife Sanctuary with the Forest Department
- Wildtracks - Uplands amphibian monitoring

INTERNATIONAL NON-GOVERNMENT ORGANIZATIONS

- GIZ Selva Maya – supports farmers and cattle ranchers in the Vaca Forest Reserve
- World Wildlife Fund – research and coastal management

UNIVERSITIES

- Galen University, Belize - Environmental program and sustainable development issues
- University of Belize - Natural Resource Management Program and Sustainable Agriculture Program
- University of San Carlos, Guatemala - Agriculture

COMPANIES

- Belize Electric Company Limited (BECOL) - Management of hydroelectric facilities on Macal River
- Belize Water Services Limited - Extraction, treatment and distribution of water from the Belize River
- Bowen and Bowen Coca-Cola Company – bottling and distribution of beverages
- Sandivar – production of sugar cane

GLOSSARY

Algae- single celled or long strands of plantlike growth in water and moist areas of land that can capture sunlight and make sugars for food

Alluvial Fan- river deposited sediments, including cobble, gravel, and coarse sand, that builds up at the base of mountains and hills when rivers flow out of steep elevation into flatter terrain.

Alluvial Sediments- sediments carried and deposited on landscapes by streams and rivers

Aquifer- underground reservoir of water contained in rock, sand or gravel layers

Aquatic Fungus- fungus living in water that are vital in the process of digesting leaf and wood material, similar role to fungus activity in terrestrial ecosystems

Assessment- a usually standardized set of protocols applied to a watershed or piece of the landscape to determine current conditions

Backwater- still water areas- pools, oxbows, flooded wetlands

Bacteria- primitive, single-celled organisms that are responsible for helping break down dead organic material and recycling many minerals within land and water-based ecosystems

Base Flow- the relatively continual flow of water entering streams and rivers from groundwater sources

Bedrock- the base rock material upon which soils and sediments build up, often exposed in river beds or weathered outcroppings

Biodiversity- the biological diversity within an environment often measured as the number of species or taxa of plants and animals

Boulder- a rounded rock fragment larger than a cobble, having a diameter greater than 25 cm

Calcium Carbonate- the mineral that largely makes up limestone and is the main mineral used in shell formation by marine and freshwater organisms such as clams, snails and crabs

Catchment- the bowl-shaped depression in the landscape carved out by flowing water and where a watershed sits

Cave- a passage carved into limestone or other rock that is large enough for a person to walk or crawl through

Chemical Fertilizer- salts containing nitrogen, phosphorus and sometimes potassium that is applied to crops

Clay- clastic mineral particles that are smaller than 1/256 mm and that are held in suspension longer than larger eroded particles

Coastal Zone- the area of marine waters stretching from the highest reach of the high tides on land to the outer edge of the continental shelf

Cobble- rounded rock fragments ranging in size from about 6 cm to 25 cm in diameter

Condensation- condensing of water vapor from the atmosphere into water droplets or dew as water molecules lose heat

Dam- a structure built to hold back the water of a river, usually for the purpose of creating a reservoir

Detritus- dead organic material such as leaves and wood

Dissolved minerals- mineral compounds that are dissolved by water and typically transported downstream

Drainage basin- a concave surface of the landscape that contains streams and rivers that flow into a trunk river; a catchment

Drainage network- the interconnected small, medium, and large streams and the trunk river into which they flow that drains a portion of a landscape

Drought- a period of unusually low rainfall and conditions of water scarcity

Erosion- the removal of rock debris and soil from a landscape by wind, ice, and/or water

Evaporation- change of liquid water into water vapor as water molecules absorb heat

Filterers- aquatic invertebrates that acquire food by filtering out fine particles from moving water with the use of gills, nets and fine hairs

Flood- waters of streams and rivers that spills over the banks and enters floodplain lands

Floodplain- flat areas adjacent to streams and rivers that absorb floodwaters

Gage stations- points established along rivers and streams where metered markers are established that allow the height of the water to be measured

Global climate change- the worldwide phenomenon of long-term changes in temperature, rainfall and other weather patterns as a result of the increasing temperatures in response to the increased carbon dioxide largely from deforestation, burning of fossil fuels and rice production)

Global Water Cycle- the movement of water throughout the Earth as water evaporates from oceans, seas, lakes and landscapes, condenses into clouds, falls as rain or ice, flows to lakes, seas and oceans in streams and rivers to eventually repeat the process

Granite- rock formed from molten magma that rises toward the surface of the Earth around fault areas, but solidifies before reaching the surface, contains largely silica dioxide and breaks down into sand and clay.

Gravel- loose pieces of often rounded rock material smaller than cobble and larger than sand, transported by water and deposited where water slows down

Groundwater- any water that infiltrates into the soil and becoming part of the water table of deeper aquifers

Habitat- the place within an environment where a particular plant or animal lives and grows

Headwater- section of a watershed that is in the upper, elevated end of the system and usually consists of small, shallow, clear streams often canopied by trees

Hydroelectricity- electricity generated by turbines powered by the flow of water from a river or reservoir

Industrial Discharge- liquid waste emptied from a factory or processing plant into a pond, lake, stream, or river by a pipe or drainage ditch

Infiltration- seeping of rainwater into the soil and sometimes down to the water table within a landscape

In-stream Gravel Mining- extraction of sand and gravel out of a flowing river bed using a backhoe, dredge or bulldozer

Invasive Species- species of organisms that were introduced into an area by accident or on purpose where they do not naturally occur, and survive, reproduce, and often compete successfully in their new habitat

Invertebrates- animals that do not have an internal skeleton and in freshwater systems include snails, clams, worms, insects, crabs, shrimp, mites and many other animals

Karst- limestone covered landscape that has been weathered by flowing water

Leaf Pack- leaves accumulated against a rock, log or other obstruction in the faster flowing area of a river

Limestone- rock formed from the shells of ancient marine organisms, most of them microscopic, that have settled to the sea floor and become compressed into rock over time by the weight of water and accumulating sediments

Lower Reaches- river reaches that include the river mouth, usually the reaches that meander across coastal floodplains made up of fine sediments and characterized by deeper and more turbid waters

Magma- molten rock material from the mantle of the Earth that can cool and form igneous rock when it nears the Earth's surface

Mangrove- lower river reach and salt-water swamps made up of tree species that are tolerant of salt water, typically growing in thick forests with roots that help protect coastlines from erosion by waves and storm surge

Mid-reaches- typically wide, shallow stream segments downstream of headwaters, usually beginning where mountains and hills break in slope and the landscape begins to flatten out

Monitoring- the process of applying assessment procedures repeatedly on a scheduled cycle in order to better understand patterns of seasonal change and to follow recovery of streams and rivers

Non Point-source Pollution- pollution that originates from a wide area, such as an agricultural field or urban landscape

Nutrient- a substance or compound that is required by an organism for growth and reproduction

Nutrient Surge- a sudden input of a large amount of a nutrient into a stream or river that often triggers algae blooms

Oxbow Lake- a lake formed when an exaggerated meander of a river becomes isolated from the river channel by sediment

Pesticide- any number of chemical materials produced and applied to kill organisms considered to be pests (insects, mites, fungi, etc.)

Point-source Pollution- pollution that is flowing into a stream or river from a pipe or ditch that can be identified as the source

Pollution- any substance or heat energy that enters an ecosystem in amounts sufficient to cause stress to the organisms living within that ecosystem

Precipitation- the rainfall, snow, sleet and ice that falls onto a landscape from the atmosphere

Potable Water- water that is of high enough quality to be used as drinking water

Powerhouse- the housing unit at an electrical plant that houses the generators that produce electricity

Protozoa- single celled animal like organisms that feed on bacteria and other small particles

Quartzite- sandstone that had been exposed to heat and pressure of a geologic event, partially melting sand grains together

Regulated River- a river in which the flow is controlled by dams, water drawdown or other engineered design

RAMSAR Wetland- an internationally recognized designation of special wetlands around the world considered to be highly important and worthy of special funding for conservation and management

Rapid- an area of the river where water is flowing fast over a steep drop of the river bed, often consisting of large rocks or exposed bedrock

Reservoir- the body of water that builds up behind a dam, a large lake which is used for water storage as water supply, flood control, or as a source of stored energy that can be used to generate electricity

Riffle- a relatively flat but shallow area of a stream or river where the water flows fast, usually where cobble and gravel have accumulated

Riparian Forest- forests growing along the banks or streams and rivers and along shorelines of lakes and lagoons

Runoff- water flowing over the surface of the land during and shortly after rain events

Salt-water Intrusion- movement of deeper layers of salty and denser waters along the coast into fresh groundwater sources when that groundwater is extracted faster than it can be replenished

Sand- particle of rock or mineral coarser than silt and often made up of quartz, often transported by moving water and wind

Scrappers- aquatic invertebrates that scrape off the living film growing on hard surfaces in streams and rivers as a food source

Sediment- cobble, gravel, sand, silt and clay deposited on stream and river beds, and lake, lagoon and sea floors

Sedimentary Rock- Rocks created when sediments are compressed and cemented together

Sewage- waste water generated from toilets that enters septic tanks or sewage collection pipes and carried to a sewage treatment plant

Sewage Treatment Plant- facility designed to collect and hold sewage waste while bacteria and other organisms break down the organic material and some of the disease-causing bacteria die out before it is released usually into river systems

Shale- a very fine grained rock formed from clays

Shredders- aquatic invertebrates that tear apart leaf and wood material in streams and rivers

Silt- particle of rock or mineral finer than sand and coarser than clay, often transported by water and staying suspended longer than sand

Sinkhole- a deep depression or vertical cave entry dissolved into a karst landscape, often with a stream entering into the depression

Slate- shale stone that had changed to the heat and pressure of a granite pluton or similar energy release

Solid Waste- any solid material that is discarded, including plastic, glass, paper, cloth, metal, wood, and other solid materials

Solution Valley- a valley within a karst landscape that has been formed by the solution of limestone, leaving a depression

Steep-slope Forest- forests growing on hillsides and mountain sides, often in thin soils

Storm Surge- the mass of water piled up by hurricane energy that creates damage to property as the hurricane reaches shore

Stormwater runoff- surface water flowing from roof tops, roads, parking lots, compacted soil and other surfaces during and after rain storms that carry many kinds of pollutants

Sump- a cave blockage where the ceiling of the passage dips below the surface of a water body within the cave

Swamp- a wetland area dominated by trees

Topography map- a map that is usually made from aerial photographs taken at a fixed altitude and perpendicular to the surface of the land that shows contour lines (lines that connect all points of the same height above sea level)

Transpiration- movement of water vapor from leaf tissue of trees and other plants into the atmosphere

Trunk river- the central or main river within a watershed that empties into a receiving water body (larger river, lake, lagoon, sea)

Turbine- a rotary engine fitted with an impeller having curved vanes set up to be spun by water or other fluids for the purpose of doing work or generating electricity

Up-welling- area where groundwater flows out of the ground or into a water body

Vanishing stream- a stream within a karst landscape that drops into a sinkhole and disappears underground

Wastewater Treatment Plant- same as a sewage treatment plant, a facility constructed to treat wastewater and remove much of the contaminants before that water is discharged into a natural water body

Watershed- 1) the streams, rivers and groundwaters within a catchment and all of the land that sheds water into those bodies; 2) a collection, storage, processing, transport and distribution system for water, sediment, dissolved minerals, nutrients, organic matter, living organisms and energy that connects the land and the sea or other water body

Water treatment plant- facility that collects water from natural sources, usually rivers, and treats the water for human consumption

Water vapor- water contained within the atmosphere as fine particles or droplets, the heat carrying component of the atmosphere

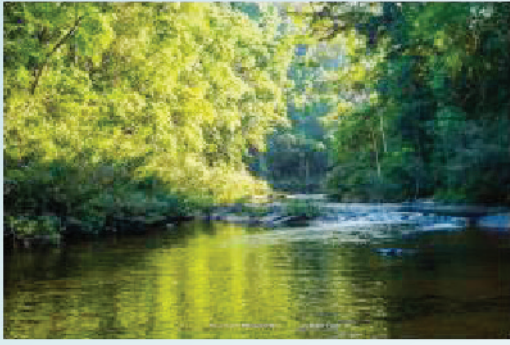
Wetland- an area that is usually dry during the drier times of the year but is covered by water for at least part of the wet season and containing plants that can tolerate being submerged in water for weeks to months

Wildlife Corridor- a swath of often forested land left in a natural state that interconnects protected areas or large forest areas maintained so that wildlife can move between these larger areas

Xate Palm- a group of tropical palms that includes the fishtail palm, whose leaves are sought by the floral industry as background in flower arrangements

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About this Atlas

Eastern Peten in Guatemala and central Belize share the Chiquibul River, Mopan River, and Macal River Watersheds, these waters essentially being the headwaters of the Belize River Watershed. These watersheds provide vital water and fertile soils for important agricultural areas in the Peten and the Belize River Valley such as livestock, corn, beans, vegetables, and citrus. Over 230,000 people live within these watersheds and draw their water from the rivers and aquifers. The Macal River produces hydroelectricity and the protected areas located on these mountainous regions of Belize support rich wildlife populations, as well as timber and non-timber forest products and a vibrant tourism sector. The Chiquibul-Maya Mountain headwaters collect the rainfall that flows through the creeks and rivers and provides the essential and vital ingredients to the inhabitants of both countries throughout the watershed.

Today the Chiquibul-Mopan-Macal-Belize Watershed system, referred to as the CMMBW in this Atlas, is suffering from many different abuses. Loss of streamside and steep slope forests has increased soil loss and sediment loads in the rivers and coastal areas. Excessive amounts of nutrients, pesticides and solid waste from farms, houses, and urban areas further degrade the river. Increasing demand on river water for irrigation agriculture and urban water systems also stresses the watershed system, especially in the dry season when demand is greatest and flows are low. Control of river flow for hydroelectricity production further stresses the system.



This Atlas was developed with the purpose of presenting the status and importance of this vital bi-national watershed system. It is intended for community members, land owners, decision makers, business people, farmers, miners, students, and anyone else connected to, dependent and concerned about the groundwater, streams, rivers, wetlands, and forests of the CMMBW. This Atlas seeks to generate community support and actions for the protection of this important bi-national resource.

