PITI-ASAN WATERSHED MANAGEMENT PLAN

By

Maria Kottermair

WATER AND ENVIRONMENTAL RESEARCH INSTITUTE
OF THE WESTERN PACIFIC
UNIVERSITY OF GUAM

Technical Report No. 138

September 2012

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This report was funded primarily by an Environmental Science Scholarship from the National Oceanic and Atmospheric Administration (NOAA) Office of Ocean and Coastal Resources Management through the University of Guam Water and Environmental Research Institute (WERI) via the Guam Bureau of Statistics and Plans, Guam Coastal Management Program (GCMP) (Award#: NA07NOS4190177). Additional funding for this report was provided by WERI via the Guam Hydrologic Survey. Funding sources listed here refer to this report only and do not include funding sources for the Conservation Action Plan meetings, other workshops, or data sources this report is based on. The content of this report does not necessarily reflect the views and policies of the Department of the Interior, nor does the mention of trade names or commercial products constitute their endorsement by the United States Government.

Watershed Management Plan

Piti-Asan, Guam

Hydrologic Unit Code (HUC) - 20100003-000-006

September 2012

ABSTRACT

The Piti-Asan watershed was identified by Guam resource agencies as one of four priority watersheds in need of restoration. It is centrally located on the western shore just southwest of the capital Hagåtña. The watershed with an area of almost three square miles encompasses the main villages of Piti and Asan and is adjacent to the Piti Bomb Holes Marine Preserve. The watershed is physically and socio-economically very diverse. Physical characteristics include volcanic and limestone bedrock and different land cover such as forest, savanna, and wetland. Socio-economic characteristics include private, local, and federal government property owners, as well as low and high-income residents, individual residences, and planned unit developments. Large areas are under conservation status in the watershed including three War in the Pacific National Historic Park Units and the Masso Conservation Area. The main pollutants impacting water quality in this watershed are sediments and bacteria (fecal coliform). The major threats posed to the overall health of the watershed and specifically to water quality are erosion and associated sedimentation, development, wildland fires, invasive species, and pollutants. The three overall goals identified in this management plan are to 1) improve water quality of receiving water body, 2) improve habitat, and 3) increase public support for watershed protection. Management strategies provide specific objectives and action steps along with a time line and funding sources to archive each goal.

KEYWORDS: Guam, Piti-Asan, watershed, management plan, watershed characteristics, values, conservation status, water quality monitoring, conservation targets and threats, management strategies;

ACKNOWLEDGEMENTS

I would like to thank Vangie Lujan for the NOAA scholarship and Dr. Gary Denton for providing additional funding and, most importantly, his unwavering support. Thanks to Dr. Yuming Wen for taking me on as his student. I am very grateful for Esther Taitague from Guam Coastal Management Program (GCMP) and Adrienne Loerzel from the National Oceanic and Atmospheric Administration (NOAA) for all their help and support throughout this project. Especially Esther for getting me started on this project, providing valuable documents and comments, and Adrienne for pushing me (in a positive way) to finalize it, for editing the plan in all its stages, and, very importantly, for the fresh supply of nourishing vitamins from her garden. A big thank you to Victor Torres from GCMP for providing the GIS base data and lots of other very valuable information. Also big thanks to David Hirschman from the Center for Watershed Protection, Anne Kitchell and Michelle West from Horsley Witten Group for all their input, great workshops, and field trips. A special thank you to Rosanna Barcinas for her constant support and encouragement.

A number of additional people provided valuable information, datasets, and/ or comments including Kathy Chaston (NOAA); David Burdick, Ray Caseres, Mely De Leon, Tom Quinata, Calvin Saruwatari (BSP); John Jenson, Sharam Khosrowpanah, Sydonia Manibusan (WERI); Trina Leberer, Steven Victor (TNC); Brent Tibbatts, Diane Vice (DAWR); Justin Santos (FSRD); Annie Leon Guerrero, Margaret Aguilar (GEPA); Carmen Denton, Rodney Toves, Joe Garrido (GWA); Judy Amesbury, Darlene Moore (MARS), Michael Duncan (NAVFACMAR); Valerie Brown, Marybelle Quinata (NOAA); James Oelke, Amanda deVillers, Jenny Coffmann, Mike Gawel, Nina Peck , Tahzay Jones (NPS); Charles 'Chip' Guard (NWS); Ben Gumataotao (Piti Mayor); Peggy Denney (iRecycle); Robert Gavenda, Bart Lawrence, Jeffrey Wheaton (NRCS); Mark Defley (RC&D); Richard Randall (UOG); Cari Eggleston, Fred Amidon (USFWS). Thank you all for your contribution.

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ACRONYMS AND ABBREVIATIONS

BMP	Best Management Practices
BSP	Bureau of Statistics and Plans, Government of Guam
CAP	Conservation Action Plan
C-CAP	Coastal Change Analysis Program (NOAA)
CLTC	Chamorro Land Trust Commission
CNMI	Commonwealth of the Northern Mariana Islands
CRI	Coral Reef Initiative
CWA	Clean Water Act
CWP/HW	Center for Watershed Protection/ Horsley Witten Group
DAWR	Division of Aquatic & Wildlife Resources, Department of Agriculture, Government of Guam
DLM	Department of Land Management
DoAG	Department of Agriculture, Government of Guam
DOI	U.S. Department of Interior
DPW	Department of Public Works, Government of Guam
EEC	Environmental Education Committee
EMAP	Environmental Monitoring and Assessment Program
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency, U.S. Department of Homeland Security
FHWA	Federal Highway Administration
FSRD	Forestry and Soil Resources Division, Department of Agriculture, Government of Guam
GCMP	Guam Coastal Management Program, Bureau of Statistics and Plans, Government of Guam
GEA	Guam Environmental Alliance
GEPA	Guam Environmental Protection Agency, Government of Guam
GHURA	Guam Housing and Urban Renewal Authority, Government of Guam
GIS	Geographic Information System
GovGuam	Government of Guam
GPD	Guam Police Department, Government of Guam
GSA	General Services Administration, Government of Guam
GWA	Guam Waterworks Authority, Government of Guam
GWQS	Guam Water Quality Standards
JTWC	Joint Typhoon Warning Center
LiDAR	Light Detection and Ranging
MCG	Mayor's Council of Guam, Government of Guam
MDA	Micronesian Divers Association
MP	Marine Preserve
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service, U.S. Department of Interior
NRCS	Natural Resources Conservation Service, U.S. Department of Agriculture
N-SPECT	Nonpoint Source Pollution and Erosion Comparison Tool
NWS	National Weather Service, National Oceanic and Atmospheric Administration
OCRM	Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration
PEALS	Professional Engineers-Architects-and-Land-Surveyors
RC&D	Resource Conservation and Development
SGSWCD	Southern Guam Soil and Water Conservation District
SWARS	Statewide Assessment and Resource Strategy
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
UOG	University of Guam
UOG-CES	Cooperative Extension Service, University of Guam
UOG-MARC	Micronesian Area Research Center, University of Guam
UOGML	Marine Laboratory, University of Guam
USCB	U.S. Census Bureau
USCRTF	U.S. Coral Reef Task Force
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WAPA-NHP	War in the Pacific National Historic Park
WERI	Water & Environmental Research Institute, University of Guam

1. Introduction

The island of Guam has experienced several economic booms since World War II and with each significant environmental changes. The island's environment has been adversely affected by various human activities including poor land development and land use practices, introduction of invasive species like the brown tree snake, and overexploitation of natural resources like the fruit bat. To restore degraded habitats and improve water quality, a ridge-to-reef approach has been promoted by various local and federal resource agencies over the last decade. With population increases expected from migration and military expansion activities, effective management of natural resources is crucial to ensure a high quality of life for Guam's people.

In 1998, an interagency work group formed on Guam in response to President Clinton's Clean Water Initiative. The group worked on a Unified Watershed Assessment (GovGuam, 1998) that categorizes Guam's 20 watersheds based on water quality. Watersheds needing restoration were placed in Category I; watersheds needing preventative action to sustain water quality in Category II; watersheds with pristine conditions on public lands in Category III; and watersheds with insufficient data to make an assessment in Category IV. Northern Guam, Ugum, Talofofo, and the Piti-Asan watershed were placed in Category I. Over the last several years, the Guam Coastal Management Program and its networking agencies have made significant efforts to improve the overall health of watersheds, particularly the Piti-Asan watershed (Figure 1).

The Piti-Asan Watershed Management Plan outlines Guam’s strategic and integrated approach to improving watershed health in Piti and Asan. By identifying goals, objectives, and specific action steps, this plan lays out the framework for local and federal government as well as community groups to protect natural resources and to improve watershed functions and conditions.

The primary purpose of this document is to compile existing information relevant to the management of natural resources in the Piti-Asan watershed and to develop an implementation plan for watershed restoration efforts. Various government agencies and other organizations have done work in this watershed in the past and in the present; *e.g.*, conducting scientific research, monitoring water quality, developing management strategies, and working on actual restoration projects. To augment existing information about the watershed, additional data was obtained from spatial analysis, field investigations, and meetings with resource partners. Conservation targets, threats affecting the targets, and management strategies to address these threats are primarily based on the Draft Conservation Action Plan (CAP) for the Piti Bomb Holes Marine Preserve and Adjacent Watershed (TNC, 2009) and a field assessment by the Center for Watershed Protection and the Horsley Witten Group (CWP/HW, 2010).

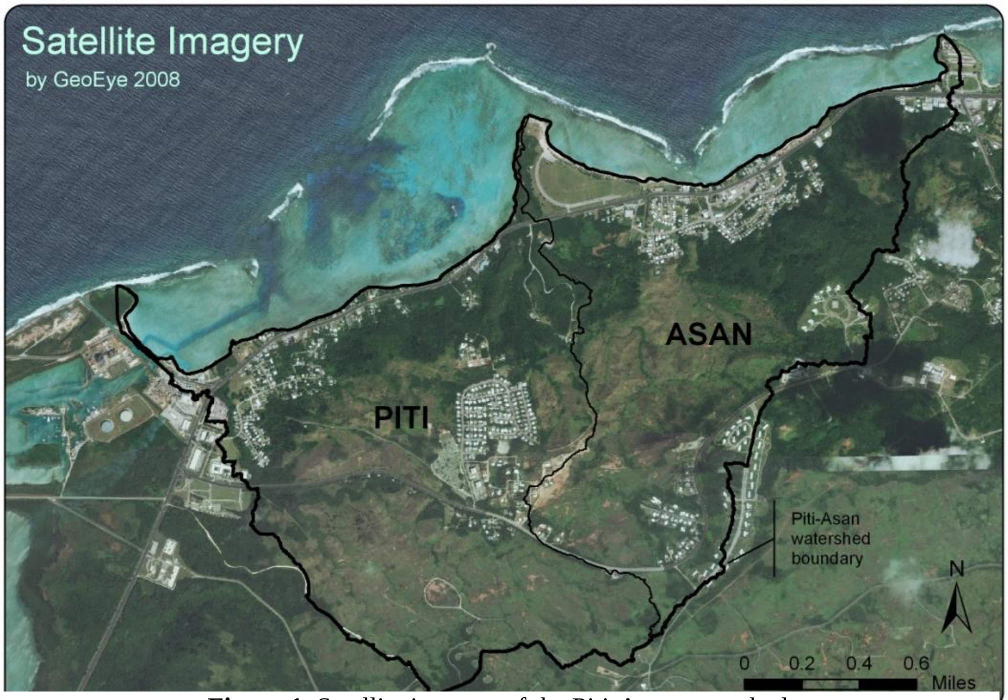

Figure 1. Satellite imagery of the Piti-Asan watershed.

Vision and Goals

The vision and goals for the watershed were determined by the Piti Conservation Action Plan (CAP) team. Although originally determined for the Piti watershed only, the goals here were slightly modified and extended to the Asan watershed.

V I S I O N

Piti-Asan will be the model of a community-based, management-driven, environmentally friendly watershed with sustainable resources in harmony with the environment and continuance of cultural traditions and the enjoyment of future generations.

1. Protect and improve the water quality of the rivers and the marine environment by reducing sediments and other pollutants from erosion and urban stormwater runoff.

2. Promote watershed stewardship, historic preservation, and interagency coordination by developing a comprehensive management approach for the Piti-Asan watershed that can serve as a model for other watersheds on Guam.

2. Watershed Profile

The Piti-Asan watershed is assigned the 14-digit hydrologic unit code (HUC) 20100003-000-006 in the Unified Watershed Assessment (GovGuam, 1998).

The watershed profile describes the physical environment and socio-economic characteristics of the watershed. The information in this section is primarily based on literature review and analysis of spatial data using a Geographic Information System (GIS). Although care was taken to use the most current and accurate data, the data used for this analysis may contain errors and may not reflect current conditions. For clarification, especially on land ownership, the appropriate agency should be contacted. Also note that the total area in each category may not always be consistent due to differences in the shoreline delineation of each GIS layer.

Physical Description

Location

Guam is the largest and southern-most island of the Mariana Archipelago in the western North Pacific. The island is about 30 miles long and between 4 and 9 miles wide with a landmass of 212 square miles. The Pacific Ocean borders the island on the east and the Philippine Sea on the west.

The Piti-Asan watershed is located along the northwestern shore of central Guam (Figure 2) with a size of about 2.9 square miles. It extends from Adelup in the east to Piti Power Plant (Cabras Island) in the west and inland to the ridgeline on Nimitz Hill with Sasa Valley Tank Farm to the south.

The watershed encompasses parts of the Piti and Asan municipalities. It includes both the Piti and Asan village centers along the coast, Nimitz Hill Estates (a planned unit development), single residential homes scattered along the upper ridgeline, and military officer's housing (Figure 3, Appendix A). Route 1 (Marine Corps Drive) and Route 6 (Spruance Drive) are the main roads within the watershed.

Figure 2. Municipality map of Guam.

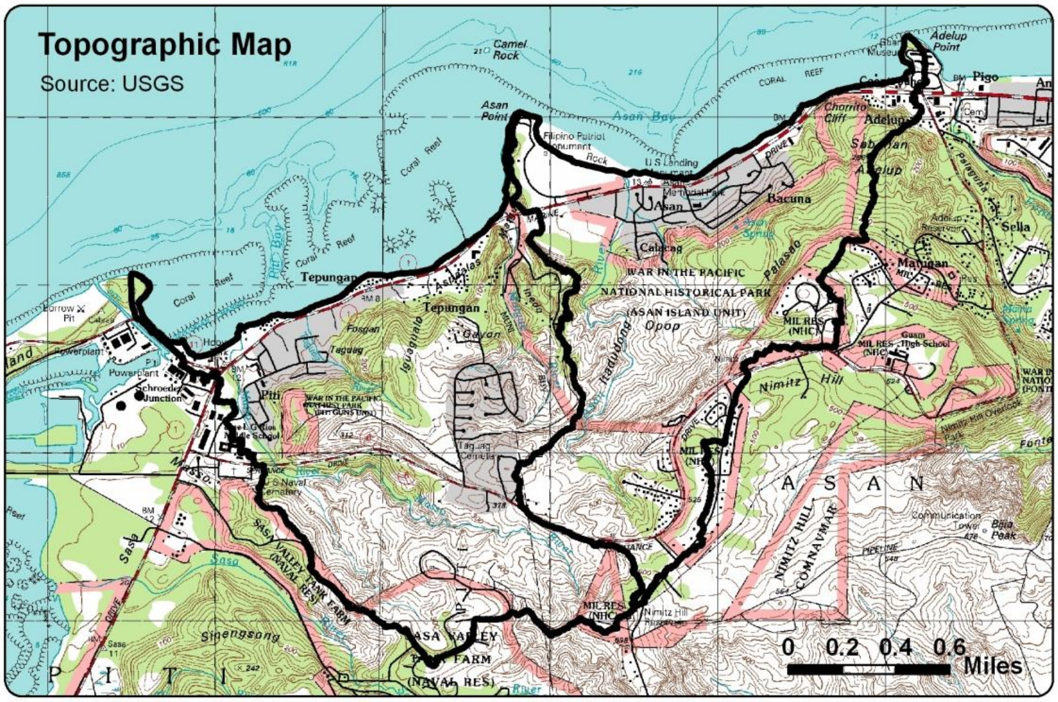

Figure 3. Topographic map of the Piti-Asan watershed.

Topography

Elevations within the Piti-Asan watershed range from sea level to 729 ft (222 m) at the southeastern boundary of the watershed, about 1.5 miles (2.4 km) inland (Table 1, Figure 4). Slopes are generally mild on the coastal plain with slopes less than 15% but steeper on the hillside (Table1, Figure 5). About 36 percent of the watershed has slopes greater than 30%.

Table 1. Elevation and slope in acres and percentage.

Elevation*	Acres	%
0–50 m	751	40
50–100 m	574	30
100–150 m	338	18
150–200 m	20 9	11
> 200 m	10	<1
Total	1882	100

*1 m = 3.3 feet

Slope	Acres	%
0–3%	216	11
3–7%	221	12
7–15%	316	17
15–30%	444	24
30–60%	510	27
> 60%	175	9
Total	1882	100

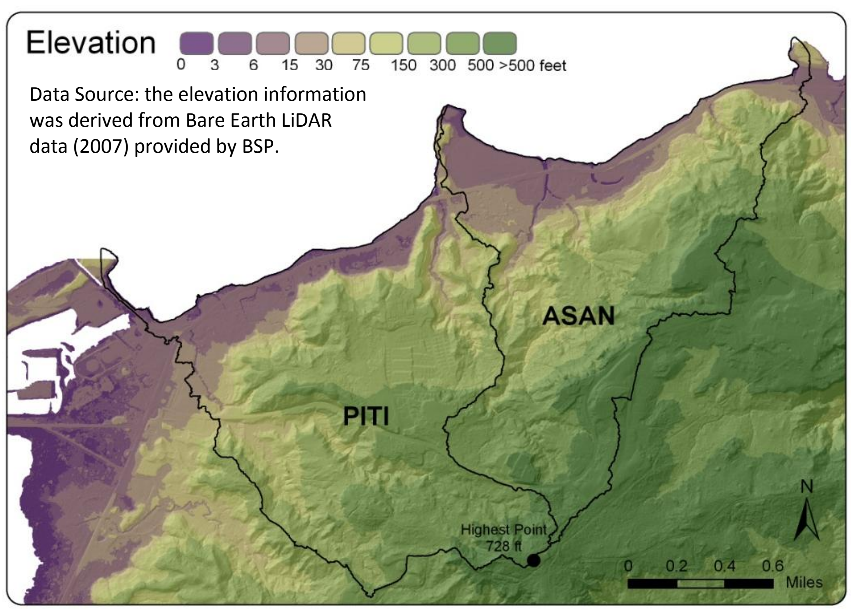

Figure 4. Elevation map of the Piti-Asan watershed.

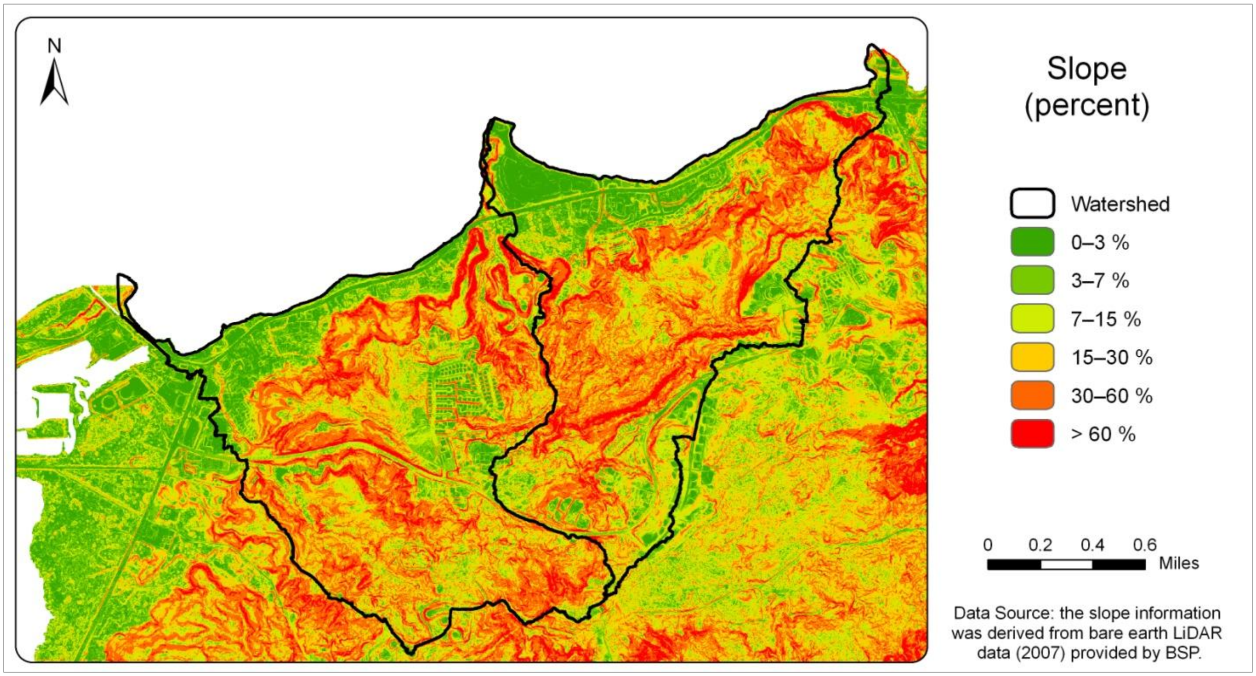

Figure 5. Slope map of the Piti-Asan watershed.

Climate

Guam's climate is marine, tropical with mean annual temperatures of 81° F and little seasonal variation. The island has a dry (Jan-Jun) and a wet season (Jul-Dec). Guam's location in the world's most active ocean basin results in frequent tropical cyclones (Lander, 1994). Tropical cyclones are usually associated with extreme rainfall. For example, Tropical Storm Tingting on June 28, 2004, exceeded 20 inches of rainfall in 24 hours.

Precipitation on the island ranges from 85 to 115 inches annually (Gingerich, 2003; Lander and Guard, 2003). The Piti-Asan watershed receives an average of about 90 to 105 inches of rain per year depending on the location with lower rainfall toward the northeast (Lander, and Guard, 2003). A rain gage operated by the Joint Typhoon Warning Center (JTWC), which was located at the Admiral's Headquarters on Nimitz Hill, recorded rainfall between 1951 and 1997 (Figure 6, Table 2).

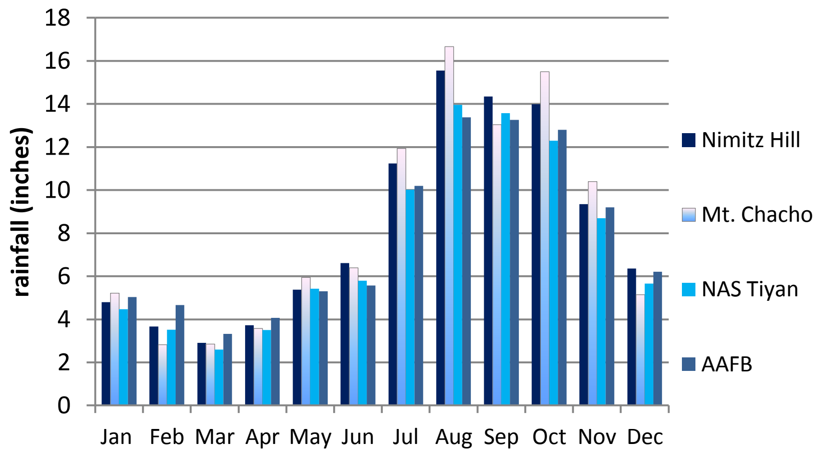

Figure 6. Average monthly rainfall distribution of the Nimitz Hill rain gage and other nearby rain gages. *Source: Guam NWS, unpublished.*

Table 2. Average monthly precipitation of four stations 1951–1997. Nimitz Hill is the only station within the watershed boundary. *Source: Guam NWS, unpublished.*

Station Name	Average Precipitation (inches)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Nimitz Hill (JTWC)	4.80	3.66	2.91	3.73	5.37	6.62	11.24	15.55	14.35	13.99	9.35	6.36	97.27
Mt. Chachao	5.22	2.82	2.85	3.58	5.95	6.40	11.94	16.67	13.04	15.50	10.40	5.15	99.51
NAS Tiyan	4.87	3.54	2.92	3.79	5.43	6.72	11.32	15.22	14.43	13.47	9.02	6.31	91.68
AAFB	5.03	4.66	3.32	4.07	5.30	5.57	10.20	13.38	13.27	12.79	9.19	6.20	92.99

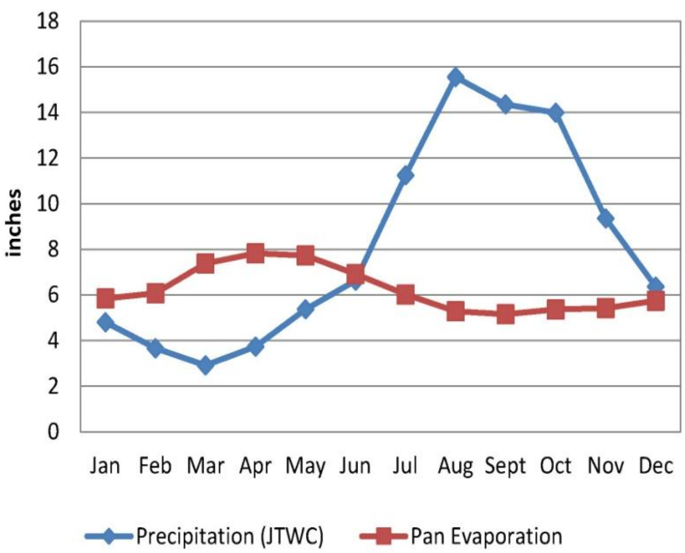

Figure 7. Comparison of rainfall and pan evaporation. *Source: WRCC. 2010.*

Monthly pan evaporation rates for Guam are available from the Guam Weather Service Meteorological Observatory in Finegayan (Dededo) from 1957 to 1998 (Figure 7 and Table 3). Pan evaporation rates in combination with a specific pan coefficient and crop coefficient can be used to determine unique evapotranspiration for different plants. Plant evapotranspiration indicates the water requirement of a plant to grow in a specific climate. During the dry season (Jan-Jun), when pan evaporation rates exceed precipitation, some plants may require irrigation for optimal growth. For that reason, planting is generally done sometime during the wet season.

Table 3. Average pan evaporation at the Guam Weather Service Meteorological Observatory 1957-1998. *Source: WRCC, 2010.*

Evaporation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Inches	5.84	6.07	7.38	7.82	7.73	6.92	6.02	5.28	5.15	5.36	5.42	5.74	74.73
% of Annual	7.8	8.1	9.9	10.5	10.3	9.3	8.1	7.1	6.9	7.2	7.3	7.7	100.0

Geology

Guam has two main geologic regions: an uplifted limestone plateau in the north and volcanic uplands in the south. The two regions are separated by the Adelup-Pago fault line. The highly permeable limestone in the north allows water to infiltrate directly into the rock, so rivers are unable to form. In contrast, the volcanic region in the south supports a large river system. Through tectonic uplift and sea level changes in the past, limestone caps some volcanic ridges in the south (Tracey *et al.*, 1964). Three distinct volcanic formations have been identified by Siegrist and Reagan (2007) based on Tracy *et al.* (1964): Facpi Formation (~43 million years ago), Alutom Formation (~37 million years ago), and Umatac Formation (~20 million years ago).

The Piti-Asan watershed is just southeast of the Pago-Adelup fault (Figure 8). Most of the watershed was formed by the Alutom Formation. The coastal plain is mainly Alluvium and beach deposit. Parts of the

Asan Beach Unit National Historic Park are infill (Figure 9). The lower reaches of the watershed are covered by Mariana limestone while the higher reaches in the northeast are covered by Alifan limestone, the aquifer rock for many perched springs in southern Guam (Gingerich, 2003; Mink, 1976).

The northeastern part of Nimitz Hill has many cave features including fissures, sinkholes, pits, and shelter caves (Taboroši, 2004). The complex cave system developed in the Alifan Limestone that sits on top of volcanic terrain.

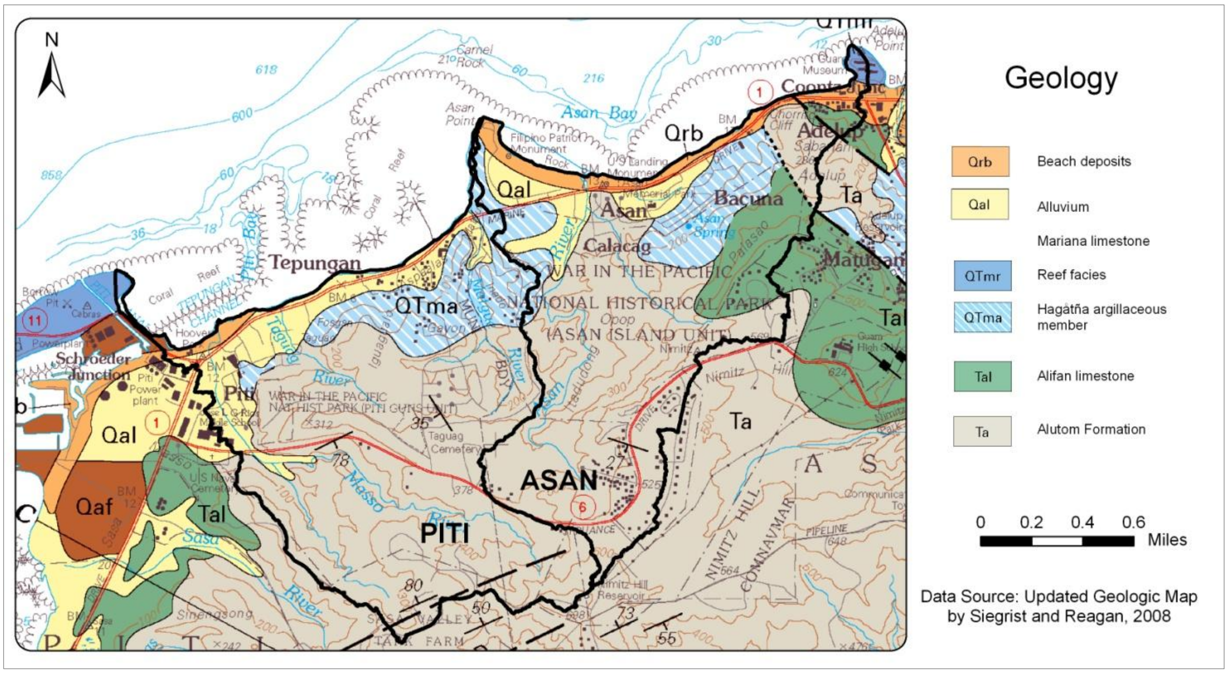

Figure 8. Geologic map of the Piti-Asan watershed.

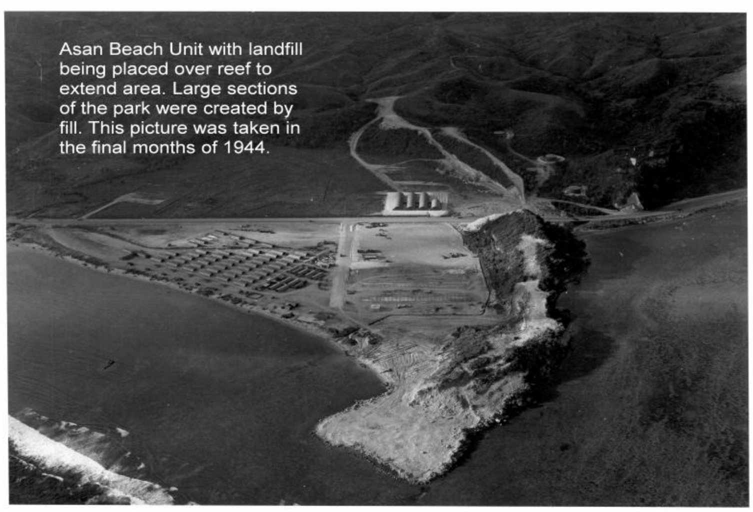

Figure 9. Aerial view of Asan Beach Unit in 1944. The Asan Point and some other parts of the park are infill. The road cut through the ridge is natural and has only been slightly widened (Oelke, pers. comm.). *Photo courtesy of NPS/ UOG-MARC.*

Soils

Soils in the Piti-Asan watershed can be classified into six major soil groups based on properties such as soil depth, substrate, and location in the landscape. Table 4 and Figure 10 show general characteristics and locations of the six soil groups. The following description is based on the Guam Soil Survey by Young (1988).

Agfayan soils are very shallow and shallow, and well drained. They derive from marine deposited, tuffaceous sandstone. Akina soils are very deep and well drained. They formed from volcanic tuff and tuff breccia. Both Agfayan and Akina soils are found on side slopes and ridge tops. These two soils are very prone to erosion and poorly suited for agriculture or urban development. Inarajan soils are found in flat areas such as valley bottoms and coastal plains. These soils are deep and very deep, somewhat poorly drained, and subject to flooding during the rainy season. They formed in alluvium from volcanic material and marine sediment.

Pulantat clay is shallow and well drained; formed on argillaceous limestone. Ritidian soils are very shallow and well drained. The soil is extremely cobbly clay loam over porous limestone. Rock outcrop appears as jagged pinnacles and sheer cliff facies of unweathered, porous limestone. Urban land consists mainly of impervious surfaces.

The coastal plain of the Piti-Asan watershed is characterized by Urban land and Inarajan clay groups. The areas underlain by limestone on the lower reaches are either Pulantat clay or Ritidian-Rock outcrop. The higher reaches of the watershed (about 62%) are primarily volcanic soils, namely Agfayan, Akina, and related soils.

Table 4. Soil groups in the Piti-Asan watershed.

Soil Group	Description	Acres	%
Agfayan & related soils	Shallower soils over weathered volcanic rock	504	27
Akina & related soils	Deeper soils over weathered volcanic rock	650	35
Inarajan clay	Bottomland soils in the river valleys	156	8
Pulantat clay	Soils over a limestone substrate	254	13
Ritidian-Rock outcrop	Very shallow soils on limestone plateau and escarpment	129	7
Urban land	Coastal fill over existing soils (mostly impermeable)	181	10
Total		1874	100

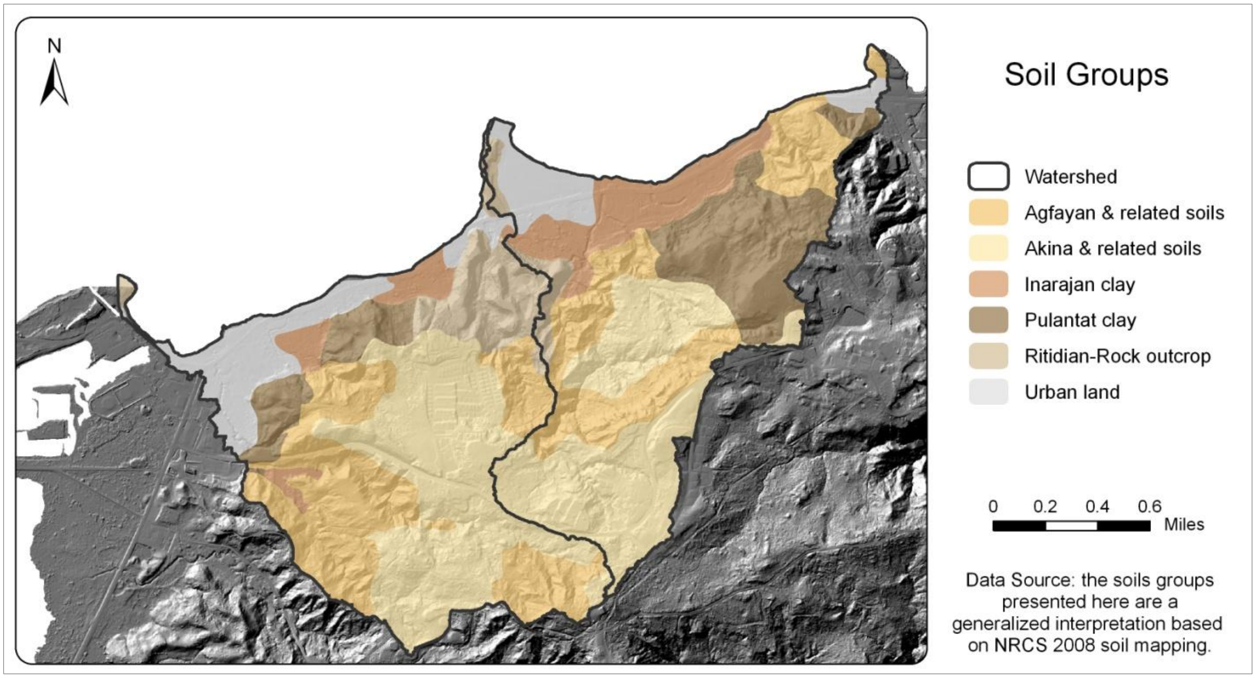

Figure 10. Soil map of the Piti-Asan watershed.

Table 5 shows the breakdown of the soil map units in the watershed. The most common soil map units are the Agfayan-Akina association and the Akina-Badland complex, which are both found on the hillside. The coastal plains are mostly Urban land, Inarajan clay, and Ritidian-Rock outcrop.

Table 5. Soil map units in the Piti-Asan watershed.

Soil Map Unit	Piti (Acres)	Asan (Acres)	Total	
			Acres	%
Agfayan-Akina association	253	111	364	19
Akina-Badland complex	178	167	345	18
Pulantat clay	72	146	218	12
Ustorthents-Urban land complex, nearly level	117	64	181	10
Akina-Urban land complex	95	71	166	9
Inarajan clay	26	108	134	7
Ritidian-Rock outcrop complex	99	30	129	7
Akina-Badland association	33	55	88	5
Agfayan clay	45	37	82	4
Agfayan-Akina-Rock outcrop association	0	54	54	3
Akina silty clay	44	6	50	3
Pulantat-Urban land complex	0	36	36	2
Inarajan Variant mucky clay	22	0	22	1
Agfayan-Rock outcrop complex	0	5	5	0
Total	984	8990	1874	100

Land Cover

The most recent land cover classification for Guam is based on QuickBird satellite imagery from 2006 (NOAA, 2009). The land cover is classified into nationally standardized classes (NOAA, 1995). The Coastal Change Analysis Program (C-CAP) classification scheme contains 25 different classes (NOAA, 2011), 21 of which are found on Guam. Estuarine Aquatic Bed, Tundra, and Snow/ Ice are the only classes not found on the island. As shown in Figure 11, the Piti-Asan watershed is characterized by 14 land cover classes.

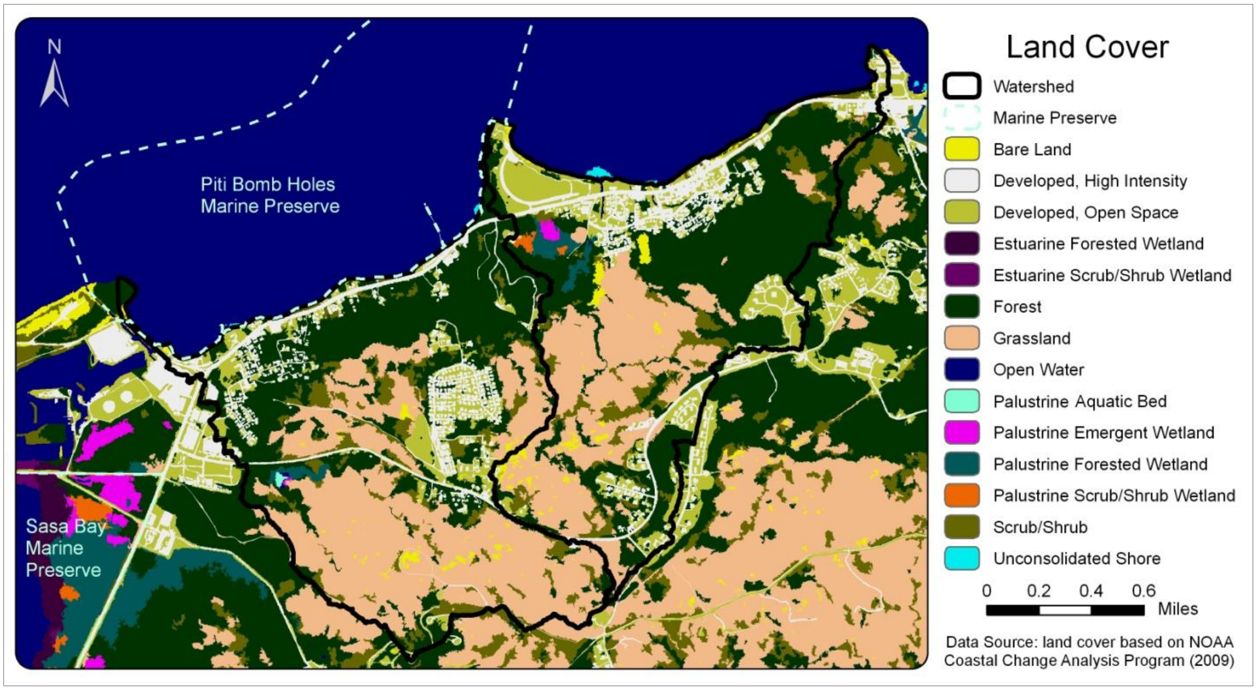

Figure 11. Land cover map of the Piti-Asan watershed.

The land cover classes are summarized in Table 6 with the following definitions based on NOAA (1995):

- Developed, High Intensity – constructed surfaces mostly made of concrete, asphalt, or roofing and usually impervious. This class has little or no vegetation.
- Developed, Open Space – manicured areas, lawns, and golf courses.
- Grassland – natural herbaceous cover, locally known as savanna.
- Forest[1] – trees > 6 meter in height.
- Bare Land – bare soil, rock, sand, silt, gravel, or other earthen material with little or no vegetation; burned areas are also contained in this class.
- Palustrine Aquatic Bed – tidal and non-tidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is below 0.5 percent.
- Palustrine Wetland[2] – non-tidal wetlands including marsh and swamp with salinity < 0.5 ppt.
- Shrubs – true shrubs and young trees < 6 meters in height.
- Unconsolidated Shore – substrate (usually sand) lacking vegetation.

[1] in NOAA classification called evergreen forest.
[2] generalized, actual classification includes subcategories as shown in Figure 11.

Forest and savanna (grassland) are the dominant land cover classes covering over two-thirds of the entire watershed (Table 6). Forest cover is concentrated along the coastline and lower elevations. The eastern part of the Asan watershed is almost entirely forested with the exception of the coastal village itself. The upper reaches of the Piti-Asan watershed are mostly covered by savanna. About 21 percent of the watershed is considered developed while about half the developed area is impervious. The developments are concentrated in the two coastal villages of Piti and Asan, Nimitz Hill Estates, and along the ridgeline. Scrub and shrub cover about 8 percent. Wetland areas only take up about one percent of the total watershed, but have an important function in the ecosystem. One wetland area with open water is the Masso reservoir and the surrounding area comprising about 6 acres. Another palustrine wetland area with 18 acres but no open water is located in the Asan Inland Unit National Park close to Marine Corps Drive. Bare Land covers about two percent and is scattered within the savanna complex in the Masso and Asan watersheds.

Table 6. Land cover in the Piti-Asan watershed.

Land Cover	Piti (Acres)	Asan (Acres)	Total	
			Acres	%
Forest	332	336	668	35
Grassland/ Herbaceous	380	240	620	33
Developed, High Intensity	103	106	209	11
Developed, Open Space	73	108	181	10
Scrub/Shrub	81	63	144	8
Bare Land	12	23	35	2
Palustrine Wetland	5	18	23	1
Palustrine Aquatic Bed	1	0	1	<< 1
Total	987	894	1881	100

Benthic Habitat

The benthic habitat in the two bays adjacent to the watershed (Figure 12) is very diverse, especially in Piti Bay. The central area of Piti Bay is a complex mosaic of different habitat types: pavement and sand covered by seagrass and microalgae near the shore and pavement and aggregate reef covered by various corals in the deeper areas. The western side of the bay is mainly pavement covered with turf and, within the Tepungan Channel, with sand. The eastern side is also pavement covered with turf along the shore and corals in deeper water (Burdick, 2005).

The reef flat in Asan Bay is comprised of pavement covered by microalgae and coral. The bay is divided by the Asan cut where the aggregate reef along the reef crest extends almost to the shore. The fore reef is chiefly pavement covered with turf.

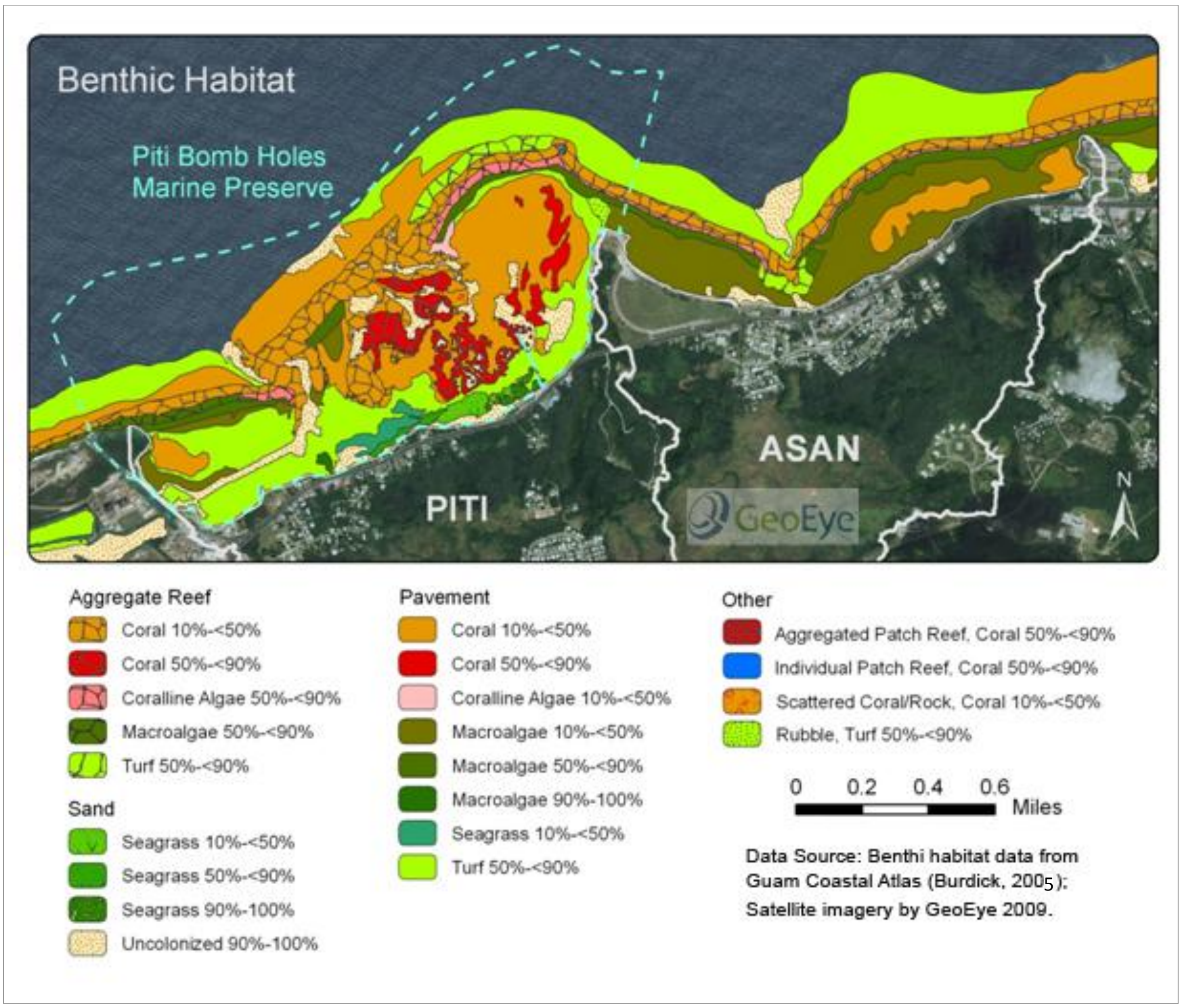

Figure 12. Benthic habitat map of Piti and Asan Bay.

Water Resources

Surface Waters

The Piti-Asan watershed is the drainage area for Piti Bay and Asan Bay (Figure 13). Several rivers, perennial and ephemeral, drain into each bay (Figure 14). The major rivers in the Piti watershed are Masso (2.4 mi), Matgue (0.9 mi), and Taguag river (0.7 mi), and in the Asan watershed Asan river (1.8 mi). The total length of the mapped stream network in the Piti-Asan watershed is approximately 8.1 miles. The largest drainage areas are Masso with 504 acres and Asan with 511 acres (Table 7).

Table 7. Size of sub-watersheds of the Piti-Asan watershed in acres and percentage.

Watersheds	Acres	%
Piti	989	53
Masso	504	27
West Masso	(165)	
East Masso	(242)	
Lower Masso	(97)	
Taguag	141	12
Matgue	223	8
Remnant Areas	121	6
Asan	895	47
Asan	511	27
West Asan	(393)	
East Asan	(119)	
Palasao	193	10
Chorrito	37	2
Adelup	34	2
Remnant Areas	119	6
Total	1884	100

The watershed boundaries were derived using ArcHydro, a GIS extension, based on a 2-meter resolution digital elevation model derived from 2007 bare earth LiDAR data. New boundaries were delineated for several reasons. The main reason was that the drainage boundary of the Piti-Asan watershed derived by the Natural Resources Conservation Service (NRCS) years ago (likely hand-digitized from USGS topographic maps) did not extend all the way to Adelup. The second reason was the lack of available sub-watershed boundaries. Another reason was the availability of high resolution base data (LiDAR) for improved accuracy. Although watershed boundaries were recently derived based on a 10-meter digital elevation model for the Natural Resources Atlas of Southern Guam (Khosrowpanah *et al.*, 2008), the Piti-Asan watershed was not included because of its more central location.

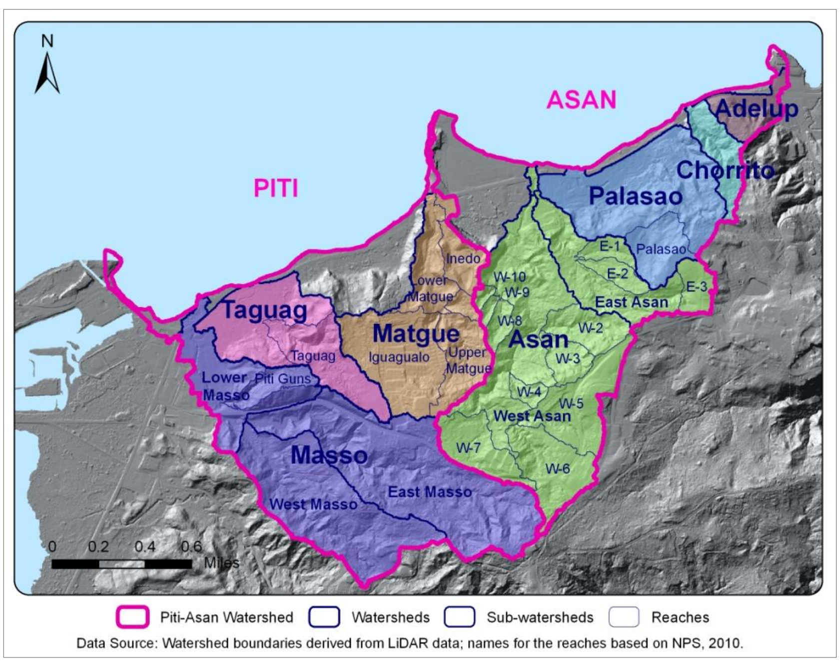

Figure 13. Map of Piti-Asan watershed with sub-watersheds and reaches.

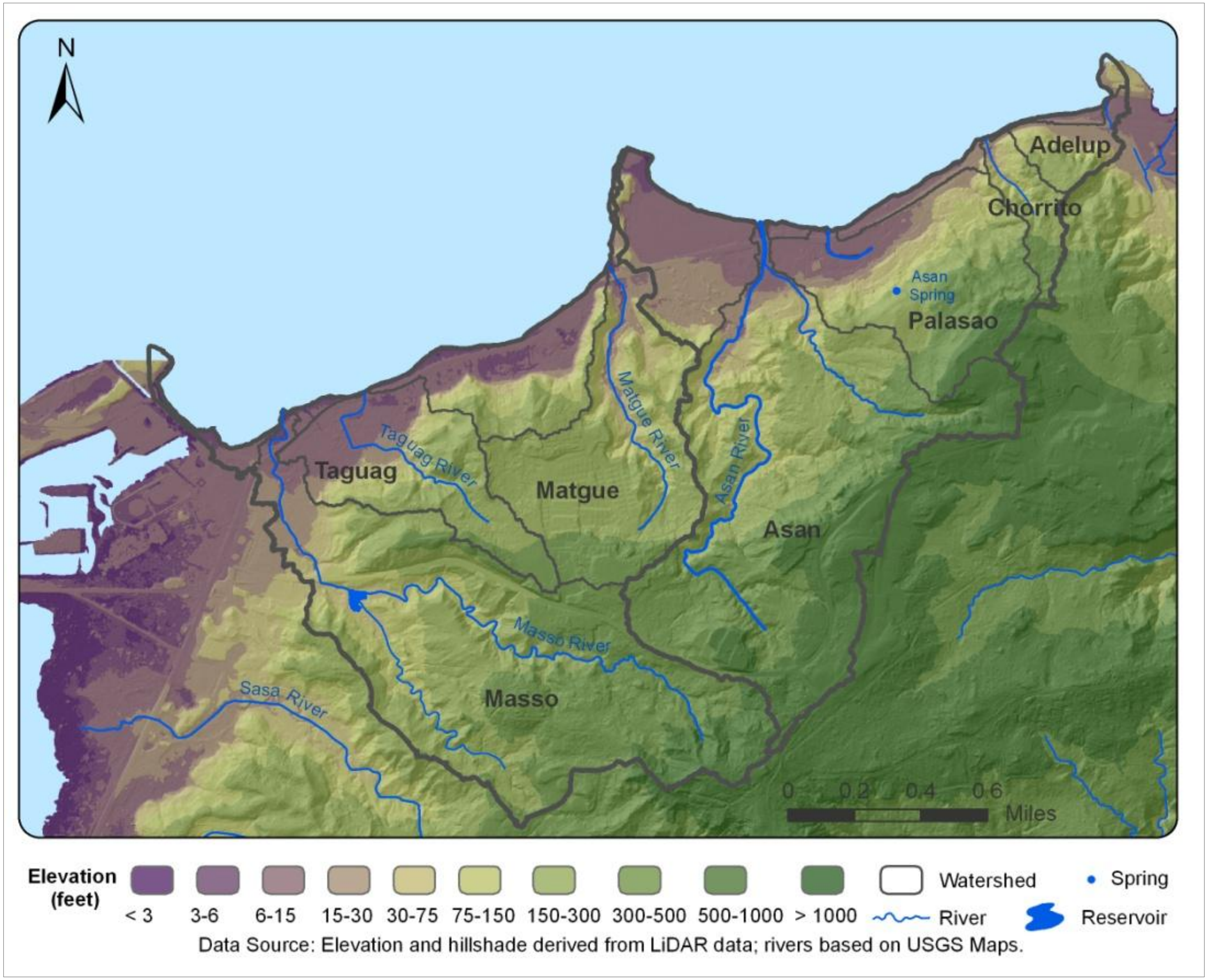

Figure 14. Map of Piti-Asan watershed with rivers, springs, and existing reservoir.

The watershed has two man-made, concrete dams, a larger one on the Masso River and a smaller one on the Asan River. The dam at Masso Reservoir was built by the U.S. Navy after World War II as a source of fresh water, but it was shut down within a few years because of sedimentation problems. According to a historic map of 1944 (Appendix B), another dam once dammed the northern fork of the Masso River . The dam at Asan River was probably built by the Japanese to provide water for irrigation (*e.g.*, rice paddies) or other human use (Jennison-Nolan, 1980).

A reservoir or pond may have been located on the hillside halfway between today's Asan village and Flag Circle (Figure 15), according to an old Japanese military map from World War II (Oelke, pers. comm.). A comparison of the location of the supposed reservoir on the map with historic photographs from that time (Figure 15) shows an area that could have been a pond (Oelke, pers. comm.). The apparently flat surface of the pond is contrasted by its surroundings. A field survey by James Oelke (NPS), Dr. John Jenson (WERI), and the author in March 2011 did not reveal any evidence of a reservoir, nor does a historic account of the village by Jennison-Nolan (1980) mention it. However, other historic vertical aerial photographs from 1946 and 1953 show the distinct area which could have been the reservoir. Furthermore, an overlay of these photographs and a digital elevation model (DEM) in a GIS reveals a depression at the location supporting the argument that it existed there. Although the depression is open to one side it could have been easily dammed. Further field investigation might provide evidence of a dam. The supposed reservoir was likely fed by groundwater as no stream passes through the area. The water from this pond might have been used by the farmers in the area to irrigate rice fields. Even if it was not an actual reservoir with standing water year-round, it was likely a wetland.

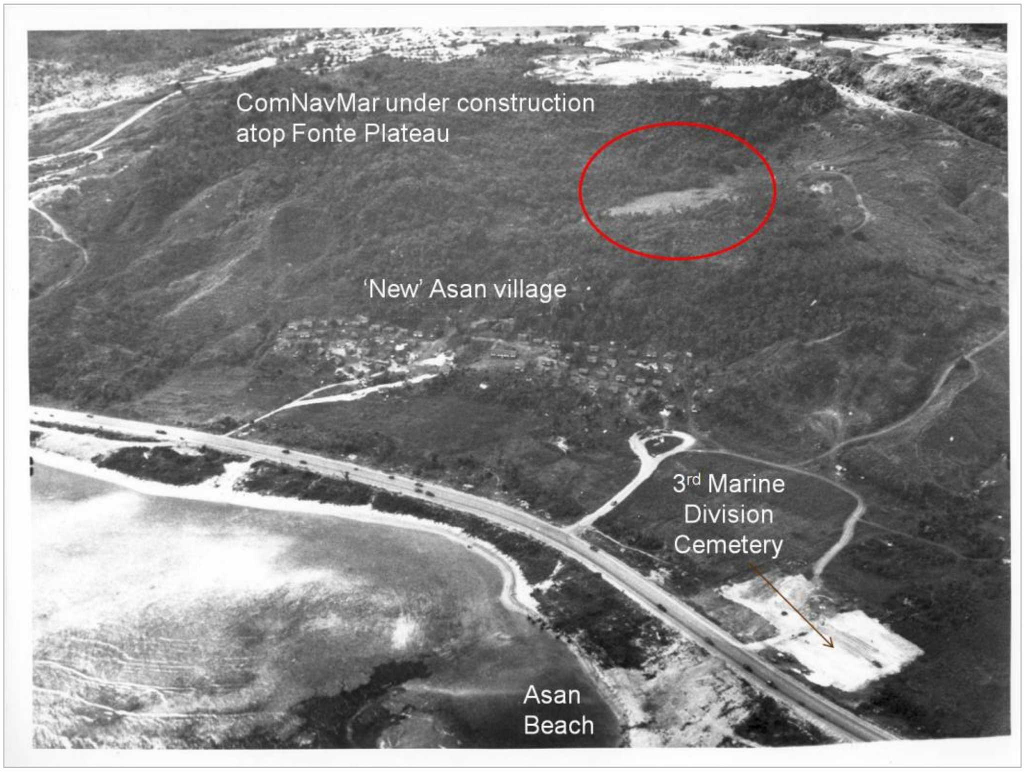

Figure 15. Aerial view of Asan village and Nimitz Hill with supposed reservoir (red circle) in fall 1948. *Photo courtesy of NPS/ UOG-MARC.*

Streamflow data in the Piti-Asan watershed is very limited and only available for the Asan River with a drainage area: 1.04 mi^2 where the U.S. Geological Survey (USGS) has been operating a crest-stage gage (records peak stage between inspections) since 2002 (USGS, 2009). The gage is located on the inland site of the bridge on Marine Corps Drive. A maximum discharge of 3,920 ft^3/s was recorded July 5, 2002 (Typhoon Chata'an) and a maximum gage height of 13.75 ft on December 8, 2002 (Typhoon Pongsona).

Stream geomorphology has been assessed for several stream channels (reaches) in the Asan watershed (NPS, 2010). Results of the assessment of seven streams, E-1, W-1, W-2, W-7, W-8, Palasao, and Lower Asan, are as follows:

- The Lower Asan has a high stream impact;
- The five numbered channels are incised, while Palasao is stable, and the Lower Asan is widening;
- Palasao is in good condition and the other six reaches are in fair condition;
- Palasao has low sensitivity, the Lower Asan has high sensitivity, and the five numbered reaches have extremely high sensitivity.

Groundwater

Groundwater seeps to the surface at the volcanic-limestone interface as perched spring water at numerous places in the Piti-Asan watershed. However, the only spring mapped is the Asan Spring located on the hillside above Asan village. About 0.31 square miles of the Alifan Limestone drain into the spring (Mink, 1976). A pump was first installed there with a dependable flow of 0.2 million gallons per day (mgd) in 1915 (Mink, 1976). Pump rate ranged from 0.14 to 0.80 mgd between 1937 and 1956 (USGS, 1962). The pump rate in 2003 was about 2.4 mgd (Garrido, pers. comm.). The spring was used to supply water to the village of Asan and parts of Piti until 2003. The spring operation, managed by the Guam Waterworks Authority (GWA), was discontinued due to water quality issues, specifically coliform bacteria.
In addition, the impound containing treated water had a crack where polluted groundwater was able to seep into the impound. Since the chlorination system was inadequate for the bacteria levels, the Asan Spring was no longer a feasible drinking water source at that time. However, GWA has plans to mitigate the treatment and storage issues and to use the spring once again as a water supply in the near future (Denton, pers. comm.).

Flood Zones

Flood zones delineate areas according to the risk of flooding. The Federal Emergency Management Agency (FEMA) defined flood zones by severity and type of flooding in the area. These designations are primarily for insurance rating purposes. The definitions of the FEMA Flood Zone Designations found in the Piti-Asan watershed are shown in Table 8.

Table 8. Definitions of the FEMA Flood Zone Designations found in the Piti-Asan watershed. *Source: FEMA, 2011.*

Risk Area	ZONE	Description
High	A	Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas; no depths or base flood elevations are shown within these zones.
	AE	The base floodplain where base flood elevations are provided.
	AH	Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
	AO	River or stream flood hazard areas and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones.
	VE	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
Moderate to Low	X	Zone X is the area determined to be outside the 500-year flood and protected by levee from 100-year flood.

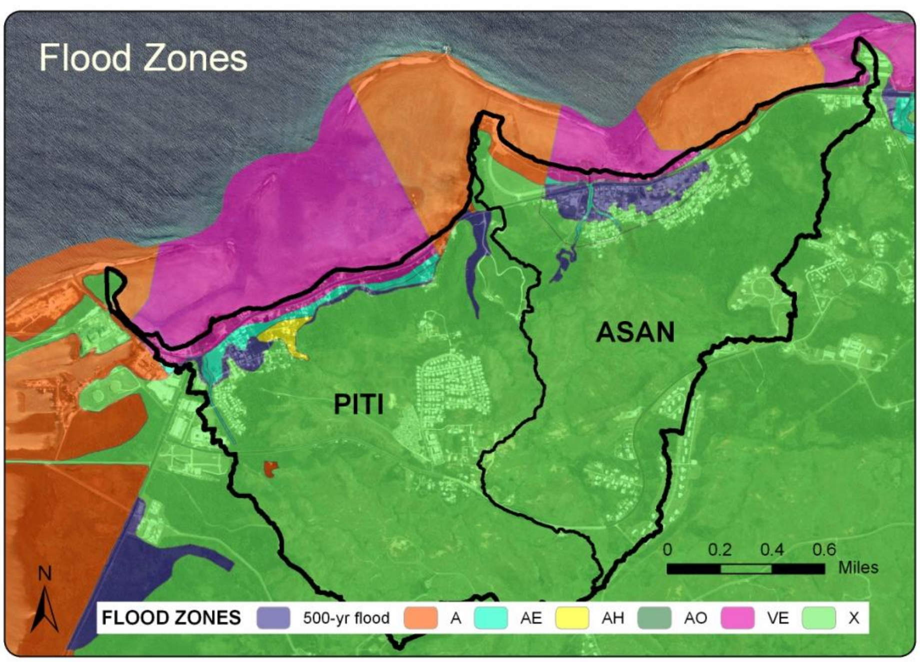

Figure 16. Flood zone map of Piti-Asan watershed. *Source data: FEMA, 2007.*

The only areas within the watershed considered high flood risk are along the coast (Figure 16). Most houses in Piti village are within the 100-year flood. In Asan village, the low-lying part is mainly within the 500-year flood and the higher elevated areas are considered minimal flood hazard.

Socio-economic Description

History

Piti and Asan were mostly fishing villages in pre-historic times but, during the Spanish occupation (1565-1898), became farming villages growing taro, rice, and sugar cane on the coastal flats (Babauta, 2009a&b). However, fishing was still practiced; fish weirs were still maintained in the late 19th century (Moore and Amesbury, 2009).

The two villages, like most other villages, were only one or two streets wide. In Asan, about 596 people lived on a single coconut-lined road prior to World War II (Jennison-Nolan, 1980). Before WWII, Asan Beach served as a Leper Colony, prison, and Marine Corps camp. After the war, the site first became Camp Asan, then Civil Service Camp, a hospital annex, and a Vietnamese refugee camp in 1975. Typhoon Pamela in 1976 destroyed all remaining buildings. The site was subsequently cleared (NPS, 2012a).

Piti village was located near the present power plants (Figure 17, Appendix B). It had a boat landing site for passengers and cargo. During the early days of the U.S. Navy administration, a Navy Yard was built inland of the landing. Piti had a piped water system by 1910 providing residents with free water from the Masso reservoir (Moore and Amesbury, 2009). Whether the current reservoir is in the same location today as the historic reservoir is unclear; the location of a dam in 1944 (see Appendix B) is on the northern fork of the Masso river right above the confluence. A written account from 1905 also mentions a dam at Masso river, which provided water to a large rice swamp near Piti village (Moore and Amesbury, 2009). The village today known as Piti was called Tepungan. A channel, called Tepungan Channel, was dredged by 1933. The channel was used to transport coal from the storage area on Cabras Island to the Hagåtña power plant (Moore and Amesbury, 2009). Cabras Island used to be an actual island until a causeway connected it to Guam. The Navy also used the island as a quarantine station. The road from Piti to Hagåtña, known as Chorillo Road, was rebuilt in 1901/02 and the name was changed to Agana-Piti Road (after WWII to Marine Drive, then Marine Corps Drive). In 1941, the road was paved, the first asphalt road on Guam (Moore and Amesbury, 2009).

Figure 17. Historic and modern aerial view of Cabras Island; a) July 20, 1944 *(Source: NPS, 2012b)* and b) July 12, 2012. Note the area of today's power plant that was infilled and the small refuge harbor on the far left in the 2012 picture that did not exist in 1944.

The villages of Piti, Tepungan, and Asan suffered great damage from WWII. Asan along with Agat were the primary landing sites of the American Marines in the recapture of Guam July 21, 1944. Large areas of the Piti-Asan watershed are now protected as War in the Pacific National Historic Parks (see p. 35). After the war, Piti village was established between Asan Point and the causeway. The Navy built Hoover Park between Marine Drive and the causeway as a recreation beach for its troops (Moore and Amesbury, 2009). The site of the old Piti village and Navy Yard is now the fuel farm and the power plant.

Demographics

The numbers in this section are based on the 2000 U.S. Census. To date, only the population numbers by village have been released for Guam from the 2010 U.S. Census. Demographic profile data and data summary files will be released later this year.

According to 2000 U.S. Census data (Figure 18), residents of the Piti-Asan watershed live in parts of four census tracts (9544, 9543, 9538, and 9537) with the majority of the population within the watershed living in tracts 9537 and 9543. The military owns tract 9538, which includes about 15 households, and tract 9544, which has no documented residents. The population numbers per block group in 2000 are summarized by block group in Table 9. The total population living within the watershed boundary in 2000 is estimated to be around 2103 people. However, this number has likely decreased since the total number of residents in the Piti village has decreased by 12.7 percent between 2000 and 2010 and only slightly increased in Asan-Maina by 2.2 percent (USCB, 2011). Most of the southern villages have experienced a population decrease during that time period. However, with the anticipated military buildup, the population of the island is expected to increase, especially in areas like the Piti-Asan watershed that are close to one of the military bases.

Table 9. Population, number of households, and estimated population within watershed boundary per block group in 2000. *Source: USCB, 2000.*

Census Tract -Block Group	Village/ Area	Population	Number of Households	Est. Population within Watershed
9537-1	Asan - Maina	950	239	44
9537-2	Asan Village	1002	272	1002
9537-3	Asan - Nimitz Hill	94	27	66
9538-1	Navy - Nimitz Hill	44	14	22
9543-1	Piti - Nimitz Hill	822	263	263
9543-2	Piti Village	222	61	222
9543-3	Piti Village	484	124	484

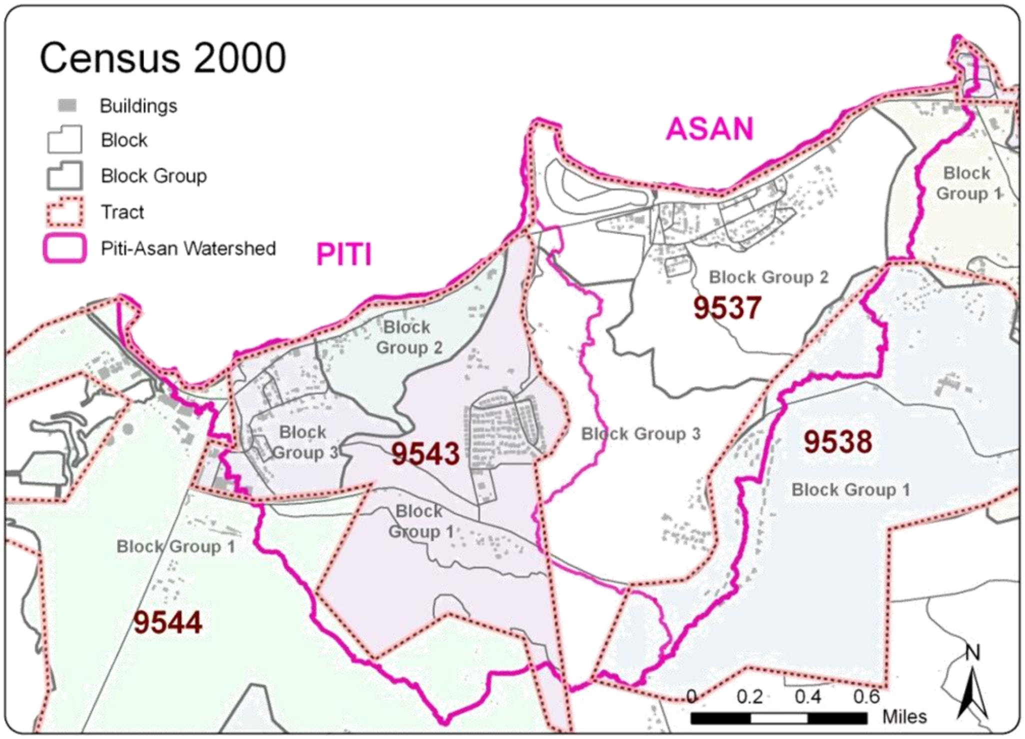

Figure 18. Map of 2000 census divisions with blocks, block groups, and tract boundaries. *Source data: BSP.*

The majority of the people living in the watershed are classified as Pacific islanders (Table 10). The only census block group with a majority of the population being Caucasian (classified as "white" in the census) is 9538-1, where Navy personnel and their families live. The block group that includes the subdivision known as Nimitz Hill Estates also has a high percentage of Caucasians.

Table 10. Ethnicity by tract and block group. *Source: USCB, 2000.*

Ethnicity	Tract-Block Group Area						
	9537-1 Maina	9537-2 Asan Village	9537-3 Asan-Nimitz	9538-1 Navy	9543-1 Piti-Nimitz	9543-2 Piti village east	9543-3 Piti village west
Total population	950	1002	94	44	822	222	484
Population of one ethnic origin or race	892	887	81	43	710	187	417
Pacific Islander alone	741	676	46	1	368	160	346
Asian alone	95	108	14	1	86	16	46
White alone	48	77	19	37	230	9	23
Black or African American alone	3	2	0	0	11	0	1
Other ethnic origin or race alone	5	24	2	4	15	2	1
Population of two ethnic origins or races	58	115	13	1	112	35	67
Pacific Islander	48	94	8	0	76	23	57
Other	10	21	5	1	36	12	10

The average household income in the watershed varies widely between the block groups (Table 11). The block groups located closer to the coast (9537-1/2 and 9543-2/3) had lower average household incomes in 1999 (≤$63,000) than block groups along Nimitz Hill (≥$88,500). The highest average income in the watershed is in block group 9538-1 where mostly high-ranking military officers reside. The high number of households with no earnings (20%) in Asan village is likely due to housing provided by the Guam Housing and Urban Renewal Authority (GHURA), which provides housing assistance to low-income families.

Table 11. Income of households and poverty status of population by block groups. *Source: USCB, 2000.*

Income/ Poverty Status	Tract-Block Group Area						
	9537-1 Maina	9537-2 Asan Village	9537-3 Asan-Nimitz	9538-1 Navy	9543-1 Piti-Nimitz	9543-2 Piti village east	9543-3 Piti village west
Total households	239	272	27	14	263	61	124
With earnings	195	226	23	13	242	50	115
No earnings	44	46	4	1	21	11	9
Average income in 1999 ($1000s)	63.4	55.7	96.2	111.9	88.5	36.4	55.7
Total population	946	1000	94	44	819	221	481
Income in 1999 below poverty level	176	227	18	2	52	85	66
Income in 1999 at or above poverty level	770	773	76	42	767	136	415
Per capita income in 1999 ($1000s)	15.9	15.1	27.6	35.6	28.3	10.0	14.3

Land Ownership

The land parcel dataset may contain errors and should, therefore, be viewed with caution. Up-to-date data could not be obtained from Department of Land Management at this time. There are on-going projects to update this dataset.

About one-third of the watershed is privately owned (Table 12 and Figure 19). Almost half of the Asan sub-watershed (334 acres) and about two percent (21 acres) of the Piti sub-watershed are owned by the National Park Service (NPS) (Table 9). However, the national park boundary extends beyond the land owned by NPS (compare Figure 19 and 27). About 280 acres in the Piti sub-watershed belong to the Chamorro Land Trust Commission (CLTC). These lands are owned by a Government of Guam (GovGuam) trust but may be leased for homes, agriculture, or commercial ventures. About 104 acres of ancestral lands were identified in the GIS analysis, but the current area may be larger. Ancestral lands are lands which were previously privately owned but condemned for public purposes (often by the Federal Government) but are scheduled for return to the last private owner of record or to their estate. The military owns about 178 acres of the watershed, mainly areas on the ridgeline and in the Masso catchment which extends much further southwest. No data was available for the remaining areas shown in gray in Figure 19.

Table 12. Land ownership in the Piti-Asan watershed in acres and percentage.

Land Ownership	Acres		
	Piti	Asan	Total (%)
Private	380	242	622 (33)
NPS	21	334	355 (19)
CLTC	280	0	280 (15)
Military	85	93	178 (9)
Ancestral	58	46	104 (5)
GovGuam	27	44	71 (4)
No Data	138	136	274 (14)
Total	989	895	1884 (100)

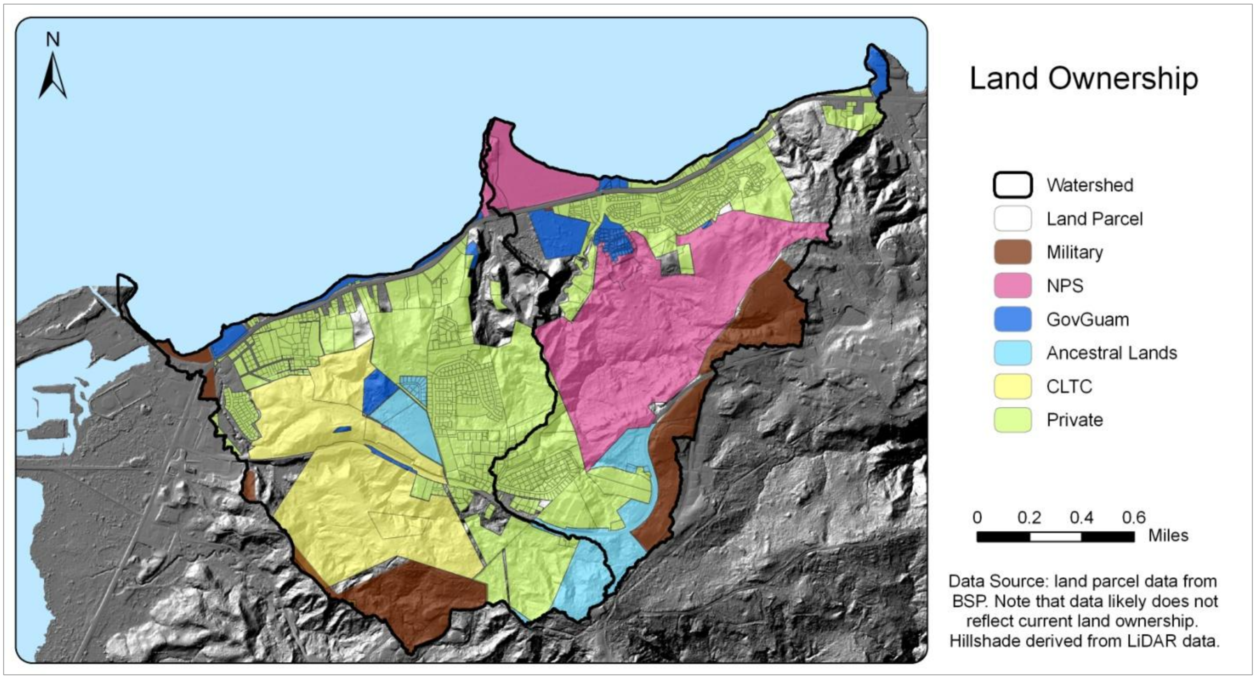

Figure 19. Map of land ownership in the Piti-Asan watershed.

Land Use Zones

Land use zones regulate the use of the land and were first established by the GovGuam Department of Land Management (DLM) in 1967. Some lands have been re-zoned since then. The map is based on a draft GIS layer from BSP and may contain errors. For example, the entire Asan village is classified as agricultural but the majority of these parcels should be zoned residential since most of them have residential homes built on them. An up-to-date dataset could not be obtained from DLM at this time.

Almost two-thirds of the watershed is zoned agricultural (Figure 20, Table 13). Much of this land belongs to the National Park Service. Despite the large area zoned agricultural, commercial farming activities are not known in the watershed. About 22 percent is zoned military lands, mostly located on the ridgeline and in the Asan NHP. Only about 16 percent is zoned residential, but this land should be larger if Asan village is considered residential. Less than two percent is zoned commercial and industrial, located next to Marine Corps Drive.

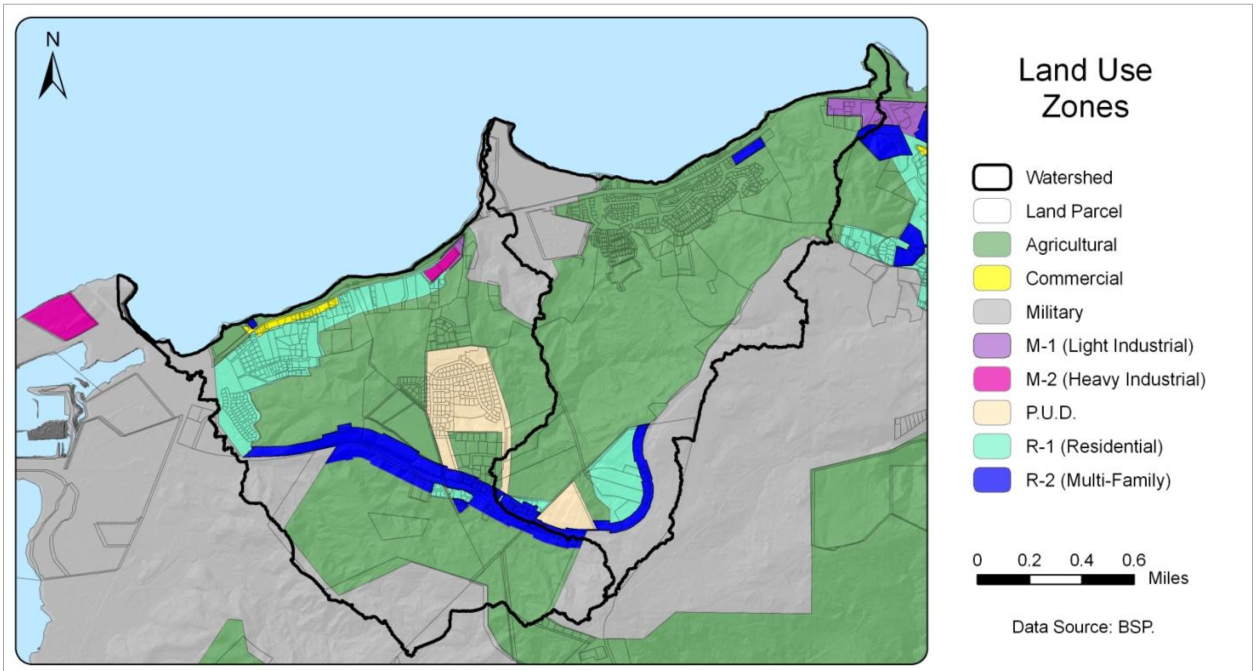

Figure 20. Map of land use zones in the Piti-Asan watershed.

Table 13. Land use zones in the Piti-Asan watershed in acres and percentage.

Land Use Zones	Code	Piti (Acres)	Asan (Acres)	Total Acres	Total %
Agricultural	A	536	593	1129	60
Military	M	207	210	417	22
Residential (One-Family)	R-1	99	33	132	7
Residential (Multi-Family)	R-2	67	27	94	5
Planned Unit Development	P.U.D.	64	18	82	4
Commercial	C	7	0	7	<< 1
Industrial (Heavy)	M-2	4	0	4	<< 1
Industrial (Light)	M-1	2	10	12	1
Total		986	891	1877	100

Stormwater Infrastructure

Culverts along Marine Corps Drive were surveyed with a Global Positioning System unit in March 2011 (Figure 21). Six culverts were identified along the Asan shoreline and seven culverts along the Piti shoreline. However, three of the seven in Piti Bay were clogged by sand and partially overgrown with vegetation ocean-side. The number and status of ponding basins in the watershed are unknown.

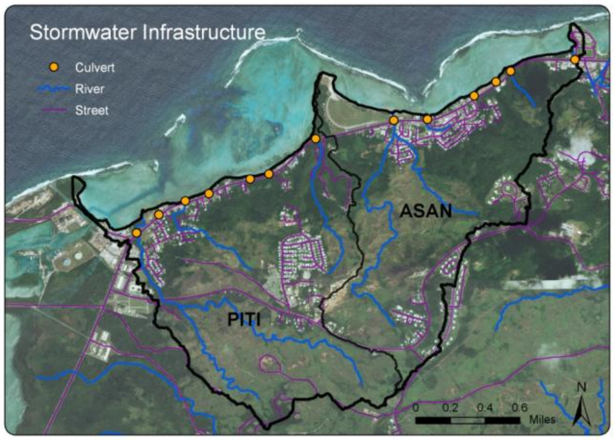

Figure 21. Map showing culverts along the shoreline.

Water and Sewer Infrastructure

According to Guam laws, buildings within 200 feet of existing sewer main lines or sewered buildings must be connected to the sewer system. A recent study by the Water and Environmental Research Institute (WERI) in 2006 showed that 31 percent of buildings surveyed within Piti village were not connected to the sewer system, although they are required by law (Table 14, Figure 22). Buildings in Asan village were not surveyed in this study. Septic tanks and pit toilets are major sources of fecal coliform and nitrates. Even though the Piti-Asan watershed is not situated above the Northern Guam Lens Aquifer, and thus does not impact water quality of the main drinking water source, leaking septic tanks and other potential contamination sources could still impact the water quality of rivers, groundwater (*e.g.,* Asan Spring), and marine environment.

Table 14. Number of sewered buildings in the Piti-Asan watershed. *Source: WERI, 2006.*

Sewered Buildings	Total
Surveyed	78
Sewered	54
Not sewered	24
a. within 200 ft of Main Sewer Line	6
b. within 200 ft of Sewered Building	3
within a. and b.	9
No data	768
Total	846

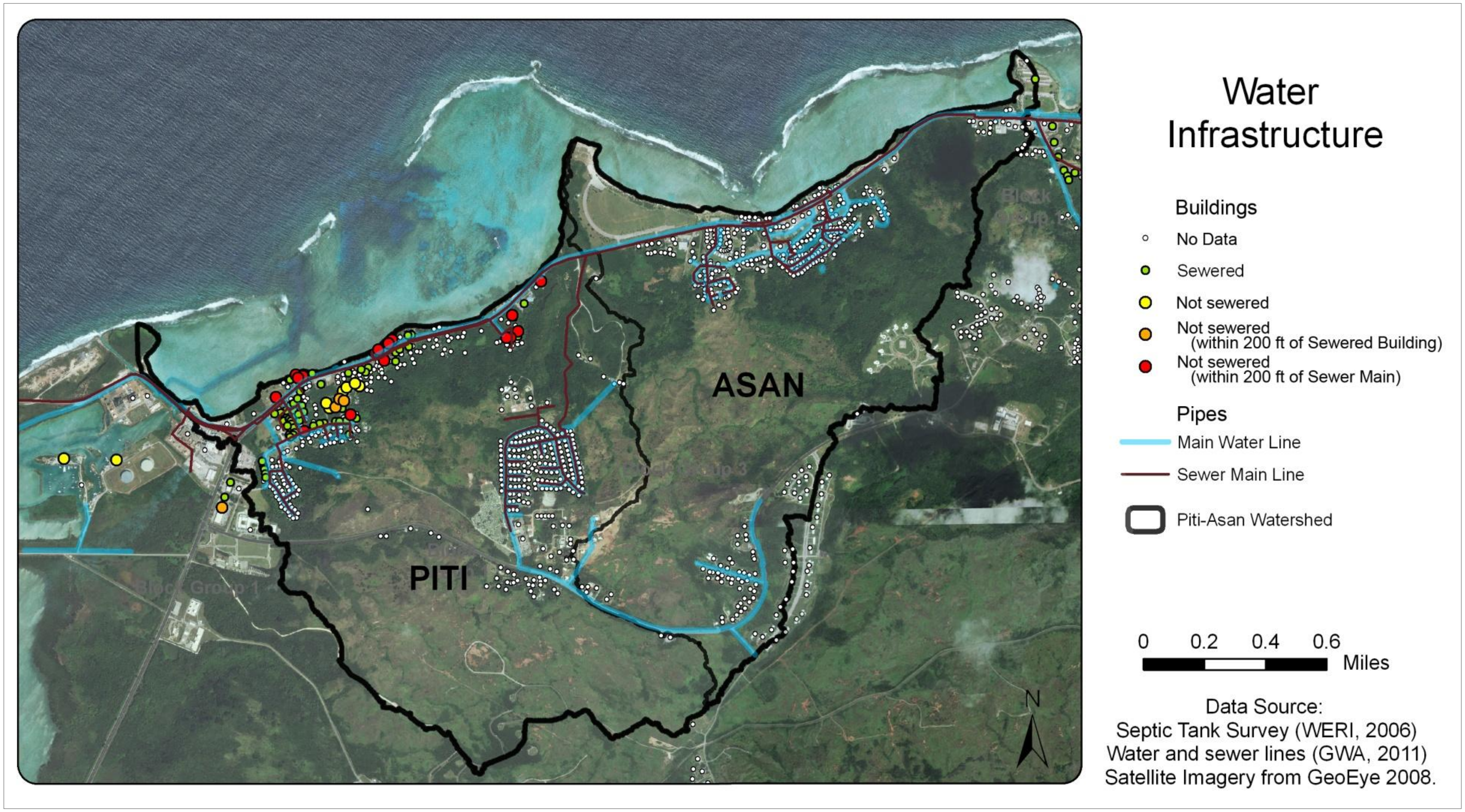

Figure 22. Map of the water infrastructure in the Piti-Asan watershed.

According to U.S. Census data, the majority of houses in the watershed are connected to the public water and sewer system (Table 15). Although Figure 22 does not show any water or sewer lines in the military housing area on the top of Nimitz Hill, all buildings are connected to the Navy's water and sewer system (Duncan, pers. comm.). GIS data of water and sewer lines could not be obtained from the U.S. Navy. Water to houses on Nimitz Hill including Nimitz Hill Estates comes from Fena Lake and is distributed by the Navy (Toves, pers. comm.). Only four housing units in the watershed relied exclusively on other water sources such as river water.

Table 15. Water supply and wastewater systems of housing units. *Source: USCB, 2000.*

Water Infrastructure	Tract-Block Group Area						
	9537-1 Maina	9537-2 Asan Village	9537-3 Asan-Nimitz	9538-1 Navy	9543-1 Piti-Nimitz	9543-2 Piti village east	9543-3 Piti village west
Total housing units	254	312	30	64	335	76	136
Source of Water							
Public system only	254	306	27	63	332	71	134
Public system and catchment	0	5	2	0	3	4	2
Individual well	0	1	0	0	0	0	0
Catchment; tanks; or drums only	0	0	1	0	0	0	0
Some other source (standpipe; spring; river, *etc*.)	0	0	0	1	0	1	0
Sewage Disposal							
Public sewer	78	247	4	61	288	53	124
Septic tank or cesspool	172	63	25	3	45	18	10
Other means	4	2	1	0	2	5	2

Development

Residential areas within the watershed are concentrated in the coastal lowland plains of Piti and Asan, at the Nimitz Hill Estates development, and in the military housing area on the plateau. Based on 2000 U.S. Census Data, the majority of houses in Piti village were built in the 1960s and 1970s (Table 16). The original homes in the Nimitz Hill Estates subdivision on the Piti side were built in the 1970s but residents and developers continue to build new houses adjacent to the subdivision. The main village of Asan was redeveloped by the Guam Housing and Urban Renewal Authority (GHURA) in the 1980s to make home-ownership affordable to low- and moderate-income families. The redevelopment included straightened streets with sidewalks and uniform two-story high concrete buildings, many of which GHURA still owns (Babauta, 2009a). Although Asan village (Tract 9537-2) was similarly developed as Piti village (Tract 9543-2&3), the number of new houses in Asan village in the last few decades is much higher than in Piti village (Table 16). The tracts with the highest increase in new homes since 2000 are likely the Nimitz Hill area (9543-1 and 9537-3). The central location of the watershed in addition to spectacular views on the hillside makes this area very attractive to high-end residential development.

Table 16. Year housing units built by tract and block group. *Source: USCB, 2000.*

Housing Units Built	Tract-Block Group Area						
	9537-1 Maina	9537-2 Asan Village	9537-3 Asan-Nimitz	9538-1 Navy	9543-1 Piti-Nimitz	9543-2 Piti village east	9543-3 Piti village west
Total housing units	254	312	30	64	335	76	136
Built 1999 to March 2000	6	55	5	0	40	2	11
Built 1995 to 1998	26	44	6	0	15	11	7
Built 1990 to 1994	37	29	5	2	36	11	8
Built 1980 to 1989	50	39	2	0	37	15	10
Built 1970 to 1979	83	80	4	50	196	18	47
Built 1960 to 1969	43	51	5	4	7	17	42
Built 1950 to 1959	8	10	2	1	3	2	9
Built 1940 to 1949	1	3	1	7	1	0	1
Built 1939 or earlier	0	1	0	0	0	0	1

Proposed Development

Hanjin Development

Another residential subdivision has been proposed on a 33-acre lot between Nimitz Hill Estates and Marine Corps Drive. The property owner, Hacor, Inc., submitted a request for a zone change from agricultural “A” to multi-family residential “R-2” to allow the development of a residential subdivision built in two phases (DC&A, 2011a). Phase 1 on the upper part adjacent to Nimitz Hill Estates includes 60 stand-alone dwellings and 18 duplexes. Phase 2 (adjacent to Route 1) includes 68 condominiums and 48 townhomes and an access road from Marine Corps Drive. Due to concerns of overdevelopment of the property and opposition from Nimitz Hill Estates residents, the Guam Land Use Commission (GLUC) approved a zone change only for the lower half of the property closer to Marine Corps Drive (PDN, 2012). This part of the property, however, is steeper and currently forested requiring more clearing and grading while the upper part is flatter savanna.

JHP Development

A 240-unit residential subdivision is planned on a 10-hectare (25-acre) lot east of Nimitz Hill Estates and Nimitz Towers (Figure 23). JHP Development intends to build 21 single-family detached homes, 22 two-story townhouses (86 units), 15 five-story condominiums (133 units), tennis courts, swimming pool, parking facilities, walking trails, convenience store, *etc.* (FC Benavente, 2007). The developer first applied for a zone change from agricultural “A” to multi-family residential “R-2” and a zone variance to the GLUC in 2007. Concerns by the Application Review Committee were primarily infrastructure-related (freshwater supply and wastewater system) and the proximity to the streams, which the developer wanted to address. The application was approved by the GLUC in May 2008. To date (July 2012), the property has remained undeveloped.

The proposed development lies on uneven terrain with steep slopes. The Asan River and a small unnamed stream pass through the property. A small pond that is located on the west side of the lot. The development, which may be up to 60 feet high, will be visible from many areas in the watershed (Figure 23), including the NHP Asan Units.

Figure 23. Model of the proposed JHP development.
Source: FC Benevente, 2007.

Smaller developments in the immediate vicinity highlight the need for effective erosion and sediment control (ESC) measures. Although they are on a much smaller scale, those developments had inadequate ESC measures and caused severe erosion, including gullying. A big concern is that a development of much larger size close to the river may contribute much larger amounts of sediments to the river and subsequently to Asan Bay. Even with currently available best management practices for erosion control, sediment levels in the river may rise during the construction phase.

Smaller Residential Development

The biggest individual-lot development in the watershed is concentrated along J Street next to the scheduled JHP Development. While several high-end homes have already been built over the last five years, several more lots have been graded and are ready to be built upon. Another gravel road off J Street was just put in (Figure 24). Many of the lots have steep slopes along their boundary as a result of grading and are very prone to erosion.

Two adjacent lots with a total size of about 1.5 acres across the entrance to Mama Sandy Road on Route 6 have recently been completely cleared and graded with steep slopes on the boundary (Figure 24). Two homes are currently being built on these lots.

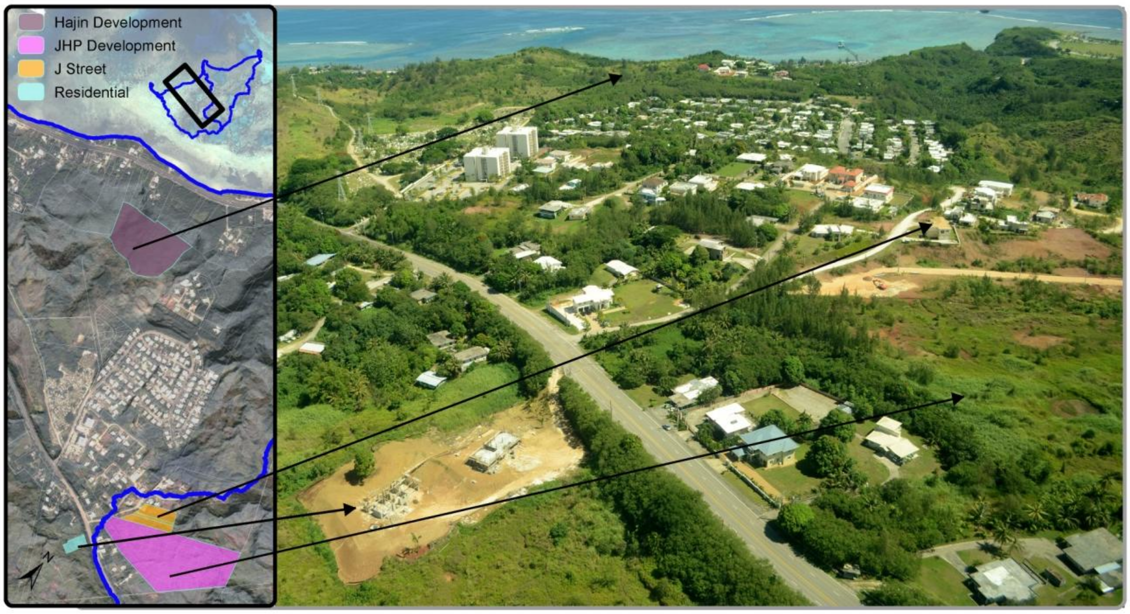

Figure 24. Map (left) and aerial view (right) of on-going and proposed development on Nimitz Hill. The aerial photo was taken June 20, 2012.

Outside the watershed boundary

Adelup Sabana, LLC, has submitted a proposal to build the "Annok I Tasi Towers" just outside the northern boundary of the Piti-Asan watershed near the Pacific War Museum. The zone change application for the three 260-foot towers has been put on hold because of public concerns about aesthetics, height, viewshed, runoff issues, and access (Caseres, pers. comm.). The consultant is now addressing these issues before approaching DLM and the GLUC again.

The planned Piti Industrial Park is located outside the watershed boundary, further south along Marine Corps Drive. Other than potential economic benefits to the Piti village and its people, no direct impacts from this development to the Piti-Asan watershed are anticipated.

3. Watershed Values

Fauna and Flora

Guam once supported a variety of native fauna and flora including over 100 known native bird species, three mammal species, six reptile species, several species of tree snails, 5000 marine species, and 320 plant species (DAWR, 2006). However, many native species are now listed as endangered or extirpated on the island due to human factors such as introduction of invasive species, loss of habitat, and over-exploitation, in addition to natural factors like severe storms (DAWR, 2006). Table 17 lists animal and plant species that are listed as endangered or threatened by the local or federal governments. Species on the federal list of the Endangered Species Act (ESA) receive federal protection and are eligible for funding under the ESA of 1973, as amended. Currently, the federal list includes 12 animal and one plant species. The Guam list includes the federally listed species (except the leatherback and loggerhead sea turtles) and an additional 19 animal and two plant species. Some species on the list, like the Mariana fruit dove and the Micronesian honeyeater, are already extirpated on Guam. Other species like the Guam rail (*ko'ko'*) have been extirpated from the wild for many years. However, successful breeding in captivity and eradication measures of invasive species (rats and monitor lizards) in certain areas have made it possible to re-introduce them to the wild. The Department of Agriculture's Division of Aquatic and Wildlife Resources (DAWR) released 16 individuals on Cocos Island in November 2010. As of May 2012, 15 *ko'ko'*s are still on the island along with eight chicks (Vice, pers. comm.).

The Piti-Asan watershed contains a variety of habitat, including limestone forest, ravine forest, savanna complex, strand vegetation, and wetlands. Native species including some endangered and threatened species live within the watershed boundaries. For example, the common Mariana Moorhen has been observed in the Masso Reservoir over many years (USFWS, GIS data layer). Although it disappeared during recent restoration work, it has since been seen at the reservoir. Two sets of chicks have been sighted in the Masso Reservoir in 2012; three chicks in January, and five chicks in May (Tibbatts, pers. comm.). Another endangered species that may be nesting along the watershed's shoreline is the green sea turtle. Native tree snails were recently observed nearby at the veteran's cemetery (Randall, pers. comm.) and at the Matgue River, also in Piti (Tibbatts, pers. comm.). Although no rails currently live in the wild on the main island of Guam, fencing in addition to other measures within the Masso Conservation Area could make the rail reintroduction possible.

Regulated animal species on Guam include the coconut crab (*Birgus latro*), wild pig (*Sus scrofa*), deer (*Cervus mariannus*), and black francolin (*Francolinus francolinus*) (DAWR, 2002). The water buffalo, locally known as the *karabao*, is a protected species. The *karabao* was traditionally used for farming but today people have them as pets and some even use them as a tourist attraction. One *karabao* can often be seen with its owner around the Fish Eye Park. Many different plant species can be found in the watershed due to the wide variety of habitats. A botanical survey conducted in the War in the Pacific National Historic Parks (WAPA-NHP) (Yoshioka, 2008) found 138 plant species with 39% native species in the Asan Beach Unit, 194 species with 50% native species in the Asan Inland Unit, and 146 species with 34% native species in the Piti Guns Unit. The report by Yoshioka (2008) offers detailed information on significant species found in each park unit broken down by habitat type.

Guam's natural resources are managed primarily by DAWR. The agency developed a Guam Comprehensive Wildlife Conservation Strategy to effectively manage, preserve, protect, and restore the island's natural resources, especially those species of greatest conservation need (DAWR, 2006).

Table 17. Endangered and threatened species list for Guam.
Source: USFWS, 2010; DAWR, 2006 & 2002.

Group/ Common Name	Scientific Name	Chamorro Name[1]	Status on Guam			
			Federal list[2]	Local list[3]	Extirpated from the wild	Extirpated on Guam
Birds						
Crow, Mariana	*Corvus kubaryi*	Åga	E	E		
Dove, Marina fruit	*Ptilinopus roseicapilla*	Totot		E		x
Dove, white-throated ground	*Gallicolumba x. xanthonura*	Puluman apaka/ fache		E		x
Fantail, rufous	*Rhipidura rufifrons uraniae*	Chichirika		E		
Flycatcher/ broadbill, Guam	*Myiagra freycineti*	Chuguangguan	E	E		x
Honeyeater, Micronesian	*Myzomela rubratra saffordi*	Egigi		E		x
Kingfisher, Guam Micronesian	*Halcyon cinnamomina cinnamomina*	Sihek***	E	E	x	
Moorhen, Mariana common	*Gallinula chloropus guami*	Pulattat	E	E		
Rail, Guam	*Rallus owstoni*	Ko'ko'	E	E		
Starling, Micronesian	*Aplonis opaca guami*	Såli		E		
Swiftlet, Island/ Mariana gray	*Aerodramus vanikorensis bartschi*	Yåyaguak	E	E		
White-eye, bridled	*Zosterops conspicillatus conspicillatus*	Nossa'**	E	E		x
Mammals						
Bat, little Mariana fruit	*Pteropus tokudae*	Fanihi	E	E		x
Bat, Mariana fruit (=Mariana flying fox)	*Pteropus mariannus mariannus*	Fanihi	T	E		
Bat, Pacific sheath-tailed	*Emballonura semicaudata*	Payesyes		E	x	
Molluscs						
Tree snail, Guam	*Partula salifana*	Akaleha'		E		
Tree snail, Mariana Islands	*Partula gibba*	Akaleha'		E		U
Tree snail, Mariana Islands fragile	*Samoana fragilis*	Akaleha'		E		U
Tree snail, Pacific	*Partula radiolata*	Akaleha'		E		U
Reptiles						
Gecko, Micronesian	*Perochirus ateles*	Guali'ek		E		U
Gecko, Pacific slender-toed	*Nactus pelagicus*	Guali'ek		E		
Gecko, Oceanic	*Gehyra oceanica*	Achi'ak		E		
Sea turtle, green	*Chelonia mydas*	Haggan Betde	T	E		
Sea turtle, hawksbill	*Eretmochelys imbricata*	Haggan Karai	E	E		
Sea turtle, leatherback	*Dermochelys coriacea*	-	E			
Sea turtle, loggerhead	*Caretta caretta*	-	T			
Skink, azure-tailed	*Emoia cyanura*	Guali'ek Halom Tano'		E		U
Skink, moth	*Lipinia noctua*	Gauli'ek Halom Tano'		E		U
Skink, slevin's	*Emoia slevini*	Gauli'ek Halom Tano'		E		U
Skink, snake-eyed	*Cryptoblepharus poecilopleurus*	Gauli'ek Halom Tano'		E		U
Skink, tide-pool	*Emoia atrocostata*	Gauli'ek Kanton Tasi		E		
Plants						
Fern, tree	*Cyathea lunulata*	Tsatsa	-	E		
Lagu, Hayun	*Serianthes nelsonii*	Hayun Lagu	E	E		
Tree, fire	*Heritiera, longipetiolata*	Ufa-hålomtåno	-	E		

* E= Endangered, T=Threatened, U= Unknown; [1] *based on DAWR (2002 & 2006);* [2]*USFWS (2010);* [3] *DAWR (2006);*

Natural & Cultural Resources

Natural resources are still harvested within the watershed for food and other purposes (Figure 25). For example, breadfruit and mango trees are known in the Asan area especially along the hillside below the admiral's housing and the Asan ridge (Ramirez, pers. comm.). Some people also catch freshwater shrimp, fish (like umatang and tilapia), and eel in the rivers, especially the Asan and Masso Rivers. The Masso Reservoir has been a popular fishing ground for tilapia, shrimp, and other freshwater organisms (Tibbatts, pers. comm.). Residents also harvest kangkong that grows in the rivers in Asan village. Asan Cut is well-known among fishermen for its fish that feed on the nutrient-rich water near the river outlet. Other natural resources in the area that may still be harvested include betel nut (*pugua*), local yams (*dagu*), and bamboo. Subsistence farming within the national park boundary has been observed during a field trip as shown in Figure 25.

Figure 25. Subsistence farming within the NPS boundary. Collected lemons can be seen in the foreground.

The Piti-Asan area is historically very significant. Archaeological findings date back to the pre-latte period (1 AD - 800AD) (Oelke, pers. comm.). During World War II, U.S. forces landed along the coastline of Piti and Asan (and also Agat) on July 21, 1944, a date that is still celebrated locally as the liberation of the island from Japanese forces. The National Historic Parks established in these areas serve as reminders of that significant event in history. Japanese defense structures such as gun emplacements, caves, and pillboxes can still be seen today. Large areas of the watershed can be considered a cultural landscape although no site has been officially registered in the National Historic Register yet.

Public Access, Outdoor Recreation, and Facilities

The watershed offers a variety of recreational activities on land and in the sea. Figure 26 shows the location of the parks and public facilities within the watershed. Piti Bay, a marine preserve (MP) with very limited legal fishing and no harvest of invertebrates and other marine species, is a popular recreational area for marine sports like diving and paddling. The Fish Eye Marine Park, a commercial business, operates an underwater observatory in the preserve and a visitor center across the street with over 180,000 visitors a year (Fish Eye, 2012). Other commercial businesses include restaurants, dive shops, and mom-and-pop stores.

Three of seven War in the Pacific National Historic Park Units are found within the watershed boundary. The Asan Beach Unit is a favorite place for picnicking, running, kite flying, and hiking. The park also hosts free events like “Movies in the Park” and guided hikes. The Asan Inland Unit includes a popular lookout featuring a spectacular panoramic view of the World War II invasion landing site and the harbor. The Piti Guns Unit offers a short hiking trail to a lookout but is less visited than the other two sites. Other public parks in the watershed are the Pedro Santos Memorial Park, Tepungan Beach Park (Fish Eye Public Park), Asan Memorial Park, and Adelup Park. The Pedro Santos Memorial Park is currently being up-graded to an eco-park (see Section 3 Conservation Status). The Tepungan Beach Park is primarily used as an access point to the marine preserve. Asan Memorial Park (directly east of the Asan NHP) is mainly used for fishing access and picnicking. The Adelup Park (partially in the watershed) is used as a soccer field in the evenings and for public events. Piti village also has a baseball field behind the school.

The watershed area also offers a number of hiking opportunities such as Asan Falls, which is near Nimitz Hill Estates. The area is also a popular ground for geocaching (www.geocaching.com), a modern treasure-hunt with a GPS unit. Over 30 geocaches have been hidden within the watershed.

Figure 26. Map of public parks in the Piti-Asan watershed.

4. Conservation Status

Conservation Areas

Large areas within the watershed (Figure 27) are dedicated to conservation: the Piti Bomb Holes Marine Preserve, three War in the Pacific National Historic Park Units, and the Masso Conservation Area. The conservation areas include terrestrial and submerged lands. (Note: the areal extent of the conservation areas in this section are derived from GIS data and may differ from the actual extent).

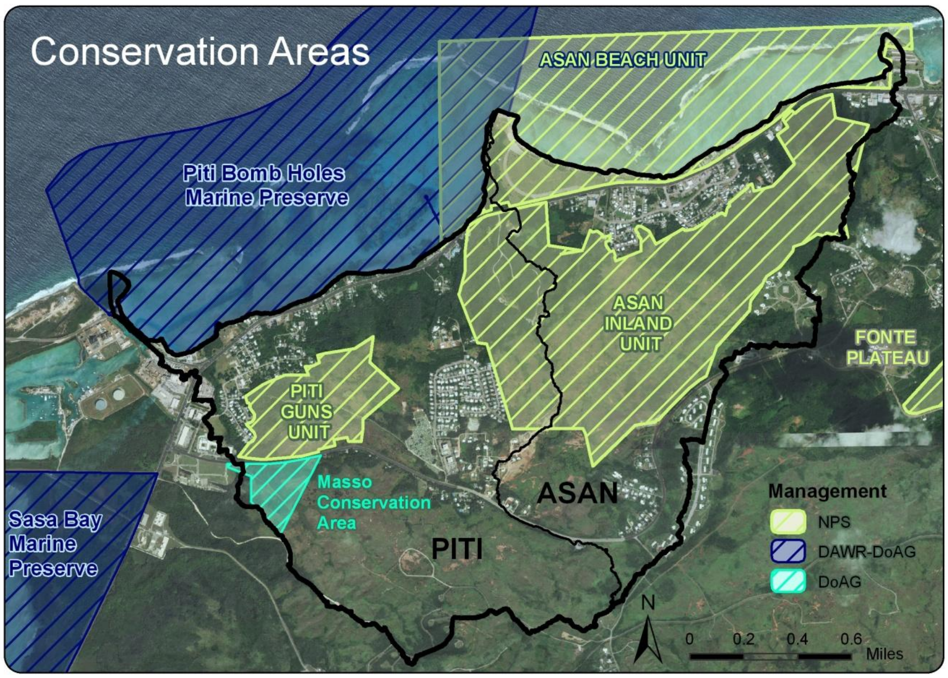

Figure 27. Map of conservation areas in the Piti-Asan watershed.

Piti Bomb Holes Marine Preserve

Area:	~ 883 acres (3.6 km^2)
Conservation area since:	1997, enforced since 2001
Management:	Department of Agriculture, DAWR
Features:	Diverse marine habitat
Designation, use:	Marine preserve, recreational and commercial use (diving, snorkeling, paddling, *etc*.; Fish Eye Underwater Observatory; Snuba operation)

The Piti Bomb Holes Marine Preserve (Piti Preserve) encompasses a shallow lagoon complex with a fringing reef. The preserve offers a unique habitat on Guam and one of the most diverse in all of Micronesia with shallow sea-grass beds, pavement covered with macroalgae and turf, hard and soft corals, natural and artificial channels, and sink holes. The sink holes ("bomb-holes") are collapsed caves filled with sand, which provide an important habitat for fishes, coral, and other marine invertebrates. The largest sink hole has about 200 species of fishes and a variety of marine invertebrates.

The preserve is a popular site for divers, snorkelers, and other recreational users. The man-made Tepungan Channel at the western end of the bay provides water to the power plant. The shoreline adjacent to the preserve is heavily utilized by visitors, residents, and commercial businesses.

The Piti Preserve is one of five marine preserves (MPs) on Guam. Public Law 24-21 established the MPs in 1997, but they were not fully enforced until 2001. The Department of Agriculture Division of Aquatic and Wildlife Resources (DAWR) is responsible for management and enforcement of the preserves. Within the MPs, taking of aquatic animals is restricted. All types of fishing, shell collecting, the use of gaffs, and the removal of sand and rocks are prohibited in a preserve, unless specifically authorized. Limited offshore fishing is allowed in all the preserves. Trolling is allowed in all the preserves from the reef margin seaward but only for pelagic fish. In the Piti Preserve, fishing for seasonal fish is authorized by special permit only for juvenile rabbitfish (*mañåhak*), juvenile skipjacks (*i'e*), juvenile goatfish (*ti'ao*), juvenile fusiliers (*achemson*), and mackerel (*atulai*). Violators can get fined up to $500 and/or imprisoned up to 90 days.

Public Law 27-87 created a marine preserve eco-permitting system to address non-fishing activities in Guam's marine preserves.

War in the Pacific National Historic Park

Area:	718 acres (2.9 km^2) within the watershed, off-shore area not included
Conservation Area since:	1978
Management:	National Park Service
Features:	3 units within the Piti-Asan WS, historic sites
Use:	Memorial park, various recreational uses

The Piti-Asan watershed includes three WAPA-NHP Units: Asan Beach, Asan Inland, and Piti Guns. The WAPA-NHP was established in 1978 with the enactment of Federal Public Law 95-348. The Asan Beach Unit comprises an area of 54 acres. This site has a very rich history (see p. 18). Today the area known as Asan Beach Park is a memorial park with a wide open grass field, a walking path, and picnic tables, which make it a popular recreational area.

The Asan Inland Unit is the largest single unit with an area of 569 acres. The upper boundary of this unit includes the Asan Bay Overlook and Memorial Wall, a popular tourist destination with a spectacular view of the landing sites and the harbor.

The Piti Guns Unit is the smallest unit with 24 acres. It is situated on the hillside above Piti village. A path through the limestone forest and a grove of mahogany leads past three Japanese coastal defense guns to a lookout. The guns were part of the Japanese fortification efforts, but were never fired since they were not fully operational at the time of the U.S. invasion in 1944. The area was used by the U.S. Department of Agriculture as an Experimental Agricultural Station from 1909 until 1932 and then by the island government as an agricultural school until 1940 (NPS, 2004).

Masso Reservoir and Watershed

Conservation Area:	29.5 acres
Conservation Area since:	2006
Management:	Department of Agriculture
Features:	Man-made reservoir, grassland, forest, Mariana moorhen habitat
Use:	Managed recreational area

The Masso valley at the southern part of the Piti-Asan watershed boundary is a conservation area that the Navy turned over to the Government of Guam under the condition of developing and maintaining it as a conservation area as referenced in Executive Order No. 2006-14. The Masso Reservoir is intended for public benefit use, public fishing and recreation, conservation, protection, and management of fish and wildlife, and the restoration of native and/ or endangered species and ecosystem function (GovGuam, 2006).

The Masso Reservoir was constructed by the Navy in 1945 by damming the Masso River (Tibbatts, pers. comm.). It was only used as a water supply until 1951 because of severe sedimentation problems (Wiles & Ritter, 1993). Between 1978 and 1982, DAWR upgraded the site by repairing the spillway, removing Phragmites, planting exotic plants, and stocking the reservoir with fish for public fishing. In 1983, the management program was stopped because of vandalisms and illegal fishing methods (Wiles & Ritter, 1993). In 1999, the local government planted about two acres with Acacia trees, which mostly established well (Figure 28). In 2004, extensive improvement and restoration efforts of the reservoir and adjacent area began (Tibbatts, pers. comm.). Since the recent completion of the restoration work, the Masso conservation area has attracted an increasing number of recreational fisherman, hikers, and campers.

Figure 28. Aerial view of Masso Conservation Area. Photo was taken June 20, 2012.

Restoration Projects (completed and on-going)

The following section describes completed and on-going restoration projects in the Piti-Asan watershed. Some of the projects are also shown in Figure 29. A summary of all the projects listed here as well as proposed projects can also be found in Table 26 on pages 67-69. The map IDs listed here refer to Figure 40 on page 70.

Project:	**Masso Reservoir Restoration** *(Map ID #1)*
Implementation:	Department of Agriculture, DAWR
Funding:	$531,043 (F-11-D-1 by Sport Fish Restoration)
Scope:	Restore reservoir by dredging and installing sediment traps, install fishing platform
Time Frame:	~ 2004–September 2011 (completed)

The Masso Reservoir was dredged to its original depth as part of a multi-year restoration project managed by DAWR. As a result of sedimentation accumulation over the years, the depth of the reservoir had been reduced to as little as four feet. About 15,000 cubic yards of sediment were dredged and reused on site. The reservoir is now between six feet (eastern side) and 10 feet (close to the fishing platform) deep. A sediment trap has been installed upstream. A new fishing platform was successfully installed and is already used by recreational fisherman. The first big organized event that utilized the fishing platform was a fishing derby for children as part of the 2012 Earth Day activities.

Project:	**Masso Reservoir and Watershed Mitigation** *(Map ID #1)*
Implementation:	Department of Agriculture, FSRD
Funding:	$235,0000 from Navy as compensatory mitigation for MILCON P-431 Alpha and Bravo Wharves Improvements
Scope:	Reduce soil erosion through reforestation and other methods (*e.g.*, fencing)
Time Frame:	October 2008 (Note: only partially implemented but at DoAG costs)

This mitigation project was a cooperative agreement between the Navy and DoAG (Navy, 2007). The project, implemented by the Forestry and Soil Resources Division (FSRD), aimed to enhance water quality entering the Piti Preserve by reducing the amount of sediments transported by the Masso River into the bay (Navy, 2008). The objective was to restore 27 acres of the Masso watershed to reduce erosion and associated sedimentation. This involved converting portions of savanna into forest by planting nitrogen-fixing trees, planting a green belt for fire protection, and installing fencing to reduce ungulate damage (DAWR, 2007). The original project also included erosion pin monitoring to show the effectiveness of the erosion control programs. In October 2008, 1600 Acacia trees were planted and 4,400 in August 2009, respectively (Santos, pers. comm.). Unfortunately, the area DoAG started implementing this mitigation project was not exactly the area stated in the Memorandum of Understanding and the Navy took the entire funding back to use it for reforestation in the Atantano watershed instead. The cost for the already planted areas had to be carried by DoAG. The fencing project was never implemented.

Project:	**Masso Watershed Restoration** *(Map ID #1)*
Implementation:	Guam Coastal Management Program, BSP
Funding:	$23,000 to Marianas RC&D (CRIGU08 from DOI & NOAA, OCRM)
Scope:	Plant 5 acres with Acacia and native trees, educational signage, community stakeholder meeting, establishing educational stewardship group
Time Frame:	July 2010 – September 2010 (completed)

This restoration project continues the conservation efforts of the Masso Valley watershed restoration to restore the soil, reduce erosion and sedimentation, replant native forest, and improve coral reef health (BSP, 2010). In partnership with FSRD, five more acres within the conservation area were planted with Acacia trees. Native plants were planted between already established Acacia trees. Another component of this project was education and community engagement. Education includes permanent educational signage and presentations to stakeholders and educational programming. Community engagement includes establishment of stewardship programs like clean-up programs with students. As part of this project, several hundred volunteers have planted approximately 2,800 trees; about 2500 Acacia trees and the rest natives including *noni*, *nanasu*, and *kafo* (Santos, pers. comm.).

Project:	**Masso River Bridge Embankment Restoration** *(Map ID #2)*
Lead/ Organization:	Department of Public Works, Division of Highways
Funding:	$330,000 (#GU-NH-0006(011), Contractor Chi Corporation)
Scope:	Restoration and protection of bridge piers and embankment of bridge
Time Frame:	May 2010 – 2011 (completed)

This project involved the restoration and protection of the bridge piers and embankment at each of the four corners of the Masso River bridge on Assumption Road. Crews also modified the drainage conveyance from the road to the river, installed corrective pavement work, and made safety improvements (Parsons, 2009). Vegetation, especially bamboo, has been removed around the bridge and gabion baskets have been installed to stabilize the streambanks.

Project:	**NRCS David Flores Streambank Protection** *(Map ID #3)*
Lead/ Organization:	Natural Resource Conservation Service
Funding:	$91,807 (Emergency Watershed Project from Congress)
Scope:	Streambank stabilization
Time Frame:	June 2005 (completed)

This project was conducted in response to the damage of Tropical Storm Tingting in 2004. The streambank was stabilized with gabions to protect the property (including the sewage line from the house) and to prevent sediments flowing into the river (Wheaton, pers. comm.).

Project:	**NRCS 2007 Slope Stabilization** *(Map ID #4)*
Lead/ Organization:	Natural Resource Conservation Service
Funding:	$1,260,163 (Emergency Watershed Project from Congress)
Scope:	Slope stabilization of 2004 landslide on Mama Sandy Road
Time Frame:	2007 (completed)

This project was in response to a serious landslide on Sanhilo Circle in the Nimitz Hill Estates also caused by Tropical Storm Tingting. After investigation by NRCS experts (Garjo, 2005), the slope was stabilized with a combination of "hard" and "soft" techniques.

Project:	**Pedro Santos Memorial Park Improvement** *(Map ID #6)*
Organization:	Guam Coastal Management Program, BSP
Funding:	CRI-GU-07 & CRI-GU-08
Scope:	Feasibility study, improvement of existing structures, "Eco-Park"
Time Frame:	Phase I completed (Jan 2011), Phase II pending

The 6.5-acre Pedro Santos Memorial Park has been closed for many years. After the completion of a feasibility study (DC&A, 2009), the Guam Coastal Management Program (GCMP) contracted a company to upgrade the park. The improvement project aims to reduce erosion and sedimentation, minimize recreational overuse of the Fish Eye area, and serve as an educational park on stormwater stewardship by incorporating best management practices. Some of the recommended concepts include "green" parking lots and bioswales collecting roadway runoff. Phase I of the project (pavilion, bathroom, and walkway) is already completed. Phase II (landscaping and bioswale) is pending.

Project:	**Pedro Santos Memorial Park Raingarden** *(Map ID #6)*
Organization:	Guam Coastal Management Program, BSP; GEPA; NOAA
Funding:	~ $50,000 from NOAA
Scope:	Conduct one-day raingarden installation workshop
Time Frame:	September 2012 (completed)

A raingarden workshop was held September 7, 2012. The one-day workshop included presentations and hands-on installation. Over 40 people from various governmental agencies and the community participated. The raingarden was installed on three sides of the pavilion encouraging infiltration of the roof runoff. The raingarden is a slightly depressed area filled with sand, compost, and mulch and planted with various mostly native plants. It includes also a slightly slanted ditch filled with small rocks to convey the roof runoff to the raingarden.

Project:	**Stream Bank Stabilization in the Piti Watershed** *(Map ID #5)*
Implementation:	Guam Coastal Management Program, BSP
Funding:	$110,500 to Marianas RC&D (CRI-GU010 from NOAA, OCRM)
Scope:	Streambank stabilization plan and implementation in the Masso watershed
Time Frame:	October 2010 – ongoing

A streambank stabilization plan was developed for areas needing improvement in the Piti Watershed (DCAS, 2011b). The plan includes a site assessment of the erosion problems, priority ranking of streams (based on severity, ease of implementation, *etc.*), and recommended treatment using biotechnical engineering methods rather than traditional hard structure methods (*e.g.*, riprap or other concrete structures). As of September 2012, the contractor is still in the process of obtaining all required permits before actual construction can begin.

Project:	**Asan-Piti Public Outreach**
Lead/ Organization:	Guam Coastal Management Program/ BSP
Funding:	$39,130 to UOG-CES (#NA06NOS4190236 from NOAA, OCRM)
Scope:	Community watershed stewardship program
Time Frame:	October 2009 (completed)

This public outreach program was designed to create public awareness about watersheds and encourage Piti-Asan residents to work with natural resource officials in restoration and protection efforts on their own properties. The outreach campaign lead by University of Guam Cooperative Extension Cooperative (UOG-CES) included town hall meetings and community activities over the course of two months. The town hall meetings for the villagers of Piti and Asan consisted of presentations about watersheds, conservation measures, and the Masso Reservoir restoration project by DAWR. Conservation measures discussed during the meetings included recycling, composting, mulching, fruit tree care, rain gardens and rainwater catchments. Participants were encouraged to take part in the Guam Yard Project, which awards homeowners with a sign if they have met the criteria of implementing a certain number of conservation measures. The Guam Yard Project has been developed by the UOG-CES but the project has not been kick-started yet. Community activities included cleanups, tree planting, and a collection day for used motor and cooking oil, and vehicle batteries. A rain garden was also installed in front of the Piti church as part of this project (Denny, pers. comm.).

Project:	**Asan Flood Control River – Rehabilitation Project** *(Map ID #7)*
Organization:	Department of Public Works (Highway Maintenance and Construction Section)
Funding:	unknown
Scope:	Removal of sediment and vegetation buildup
Time Frame:	November – December 2011 (status not confirmed)

The project site is located at the Asan River in the Asan village along Ramona Street and Mnsgr J.A. Leon Guerrero Street. This project includes removing sediment and vegetation buildup in the river bed and on the slopes of the rock revetment with mechanical means. The estimated amount of sediments to be removed is 970 cubic yards (DPW, 2011).

Project:	**Community Coral Reef Monitoring Program for Guam**
Organization:	NOAA National Marine Fisheries Service, Pacific Islands Regional Office, Habitat Conservation Division
Funding:	80,000 annually (NOAA's Coral Reef Conservation Program)
Scope:	Coordination of volunteer group to monitor coral reefs
Time Frame:	July 2012 – June 2014

This new program is geared towards community involvement in conservation and restoration while monitoring the effectiveness of restoration projects. Volunteers will monitor benthic habitat (% cover for basic categories such as coral, algae, sand), macroinvertebrates (clams, sea cucumbers, sea urchins, trochus, *etc.*), and water quality parameters (*e.g.*, temperature, pH, turbidity, conductivity, and dissolved oxygen). Fish monitoring may be added at a later time. The currently selected project sites are Piti-Asan, Manell-Geus, and Umatac but may be extended to other areas. A core group of 10-20 volunteers per site is anticipated to survey the site every other month or more frequently if volunteer participation allows. The program coordinators are trying to extend the two-year program another year by making it self-sufficient or incorporating it into another organization (Brown, pers. comm.).

Project:	**Stewardship - I love my Watershed**
Organization:	Guam Coastal Management Program/ BSP
Funding:	Internal
Scope:	Promote watershed stewardship
Time Frame:	On-going

As part of larger public outreach efforts, the Guam Environmental Education Committee (EEC) and Guam Coastal Management Program initiated an "I love my watershed"-campaign. The campaign uses events to encourage people to spend more time outside in nature and learn about Guam's watersheds and the issues affecting them. One such event, hosted on June 19, 2010, featured hiking tours of the Masso Reservoir area. Guides talked about the dredging project, native and invasive species, and other topics to about 150 participants.

Project:	**Cleanup Events**
Organization:	Guam Coastal Management Program, BSP; MDA, and others
Funding:	Various
Scope:	Cleanup rivers and shoreline
Time Frame:	On-going

The biggest island-wide cleanup is the annual Coastal Cleanup coordinated by GCMP. Other organizations like the Micronesian Diver's Association (MDA) also sponsor cleanup events throughout the year in the Piti-Asan watershed, especially Masso area.

Figure 29. Examples of restoration sites in the Piti-Asan watershed. From top left to bottom right: re-vegetation site in Masso watershed above the reservoir; Masso Reservoir with fishing platform; slope stabilization site (behind house) of 2004 land slide; NRCS streambank protection with gabions; Pedro Santos Memorial Park improvements; and raingarden installation at Pedro Santos Memorial Park.

5. Water Quality and Monitoring Programs

Surface water quality is primarily monitored by the Guam Environmental Protection Agency (GEPA). The agency's monitoring program implements the Guam Water Quality Monitoring Strategy, which aims to protect the island's fresh and marine water resources through consistent monitoring and collection of reliable scientific data (GEPA, 2012).

The Guam Water Quality Monitoring Strategy is based on the Guam Water Quality Standards (GWQS) (GEPA, 2001) as mandated by the Federal Clean Water Act (CWA). Every state and territory is required under the CWA to provide U.S. Congress every two years with an assessment of the quality of all its waters (section 305(b)) and a list of those that are impaired or threatened (section 303(d)). Guam sub-mitted its first assessment, called the Integrated Report, in 2006. The information in this section is based on the 2010 Integrated Report (GEPA, 2010a) unless otherwise cited.

The GWQS define different categories for Guam's waters based on their quality and primary designated uses (Table 18).

Table 18. Ground Water Quality Standards categories for Guam's waters.

Category	Quality	Description	Primary Designated Uses
M-1	Excellent	Marine Waters	Whole body contact recreation, aquatic life, consumption
M-2	Good	Marine Waters	Whole body contact recreation, aquatic life, consumption
M-3	Fair	Marine Waters	Limited body contact recreation, aquatic life, consumption
S-1	High	Surface Waters	Whole body contact recreation, drinking water, aquatic life, consumption
S-2	Medium	Surface Waters	Whole body contact recreation, drinking water (with treatment), aquatic life, consumption
S-3	Low	Surface Waters	Limited body contact recreation, aquatic life, consumption
G-1	Resource	Groundwater	Drinking water
G-2	Recharge	Groundwater	Recharge to G-1

Based on monitoring results and its designated uses (Table 18), each water body is classified by reporting category types:

Category 1 All designated uses are supported.

Category 2 Available data and/ or information indicate that some, but not all for the designated uses are supported.

Category 3 There is insufficient available data and/ or information to make a use support determination.

Category 4 Available and/ or information indicate that at least one designated use is not being supported, but a TMDL is not needed.

Category 4a A TMDL to address a specific segment/ pollutant combination has been approved or established by GEPA.

Category 4b A use impairment cause by a pollutant is being addressed by the state through other pollution control requirements.

Category 4c A use is impaired, but the impairment is not cause by a pollutant.

Category 5 Available data and/ or information indicate that at least one designated use is not being supported or is threatened, and a TMDL is needed.

A water body that does not meet the GWQS for its designated use needs to be listed under the 303(d) list of impaired waters. The waters on this list need to be prioritized and a Total Maximum Daily Load (TMDL) needs to be developed. A TMDL specifies the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards.

In summary, the main water quality concerns in the Piti-Asan watershed are bacteria and turbidity levels. Various monitoring programs of fresh and marine waters are described in the following paragraphs. Figure 30 shows the location of the water monitoring stations of the various programs.

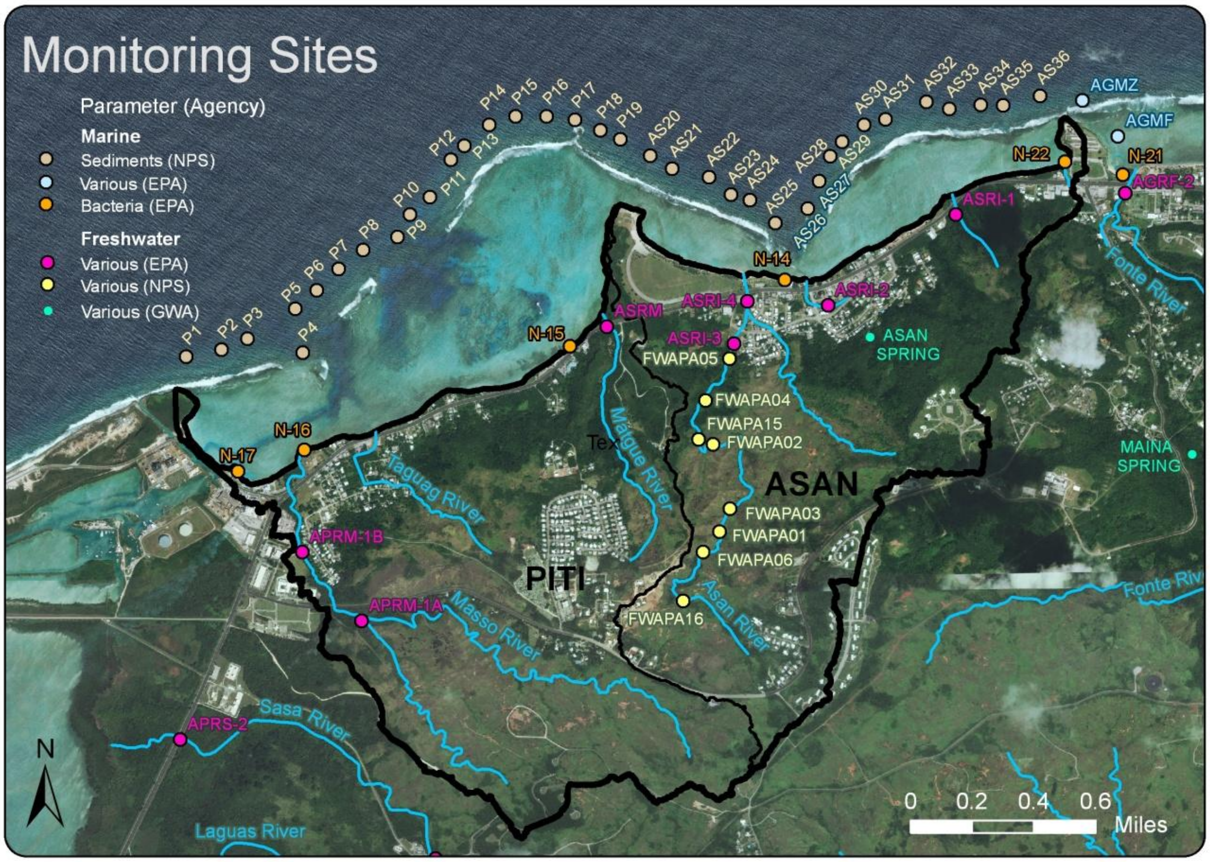

Figure 30. Monitoring sites in the Piti-Asan watershed and adjacent bays**.**

Fresh Waters

Rivers and Streams Monitoring

The major rivers within the watershed, Asan (1 & 2), Matgue, and Masso (1 & 2), are all classified as S-3 meaning their primary designated uses are limited body contact recreation, aquatic life, and consumption. According to the 2010 Integrated Report, only the Matgue River has been assessed and put into reporting category 2; the other rivers are in category 3 for “not assessed”. Masso reservoir, as the only wetland within the watershed listed in the report, is also in reporting category 3. In spring 2011, water quality from the Masso River was assessed as part of GEPA’s Status and Trends Monitoring Program (see Table 19). The results indicate very high levels of turbidity, but also elevated levels of total suspended solids, and E. coli (LeonGuerrero, pers. comm.).

The water quality in selected streams in the Piti-Asan watershed was tested by GEPA in 1975-77, 1997, 2009, and 2011 (Table 19, Figure 30) as part of the Environmental Monitoring and Assessment Program (EMAP) or Status and Trends Monitoring Program. Parameters tested include temperature, phosphorus, turbidity, pH, nitrate, fecal coliform, dissolved oxygen saturation, and total suspended solids. The EMAP protocol calls for random sampling of surface and marine water resources on a two-year rotating basis, with fresh waters sampled one year and marine waters sampled the next.

Table 19. GEPA's river monitoring stations with location, time frame, and number of samples.
Source: GEPA, unpublished; GEPA, 2010.

Assessment Unit ID	River Name	Classification	Location	Samples	
				Date/Time Frame	Number
ASRI-1	Unnamed Creek 2	S-3	Next to church outside village	-	0
ASRI-2	Unnamed Creek 1	S-3	Behind church in village	5/6/1997–12/1/1997	5
ASRI-3	Asan River 1	S-3	Across from baseball field	5/6/1997–12/1/1997	5
ASRI-4	Asan River 2	S-3	Inland side of bridge in village	-	0
ASRM	Matague River	S-3	Inland side of bridge	4/6/2009–10/6/2009 Spring 2011	5
R-2742-41*	Matague River	**	Below Nimitz Hill storm drain	4/22/1975–4/5/1977	12
G-5	Taguag River	**	unknown	-	0
R-2741-53*	Taguag River	**	Taguag River Bridge on Route 1	4/22/1975–4/5/1977	13
APRM-1A	Masso River 2	S-3	Access dirt road behind cemetery	5/6/1997–12/1/1997	5
APRM-1B	Masso River 1	S-3	At bridge on Assumption Road	5/6/1997–12/1/1997 Feb–April 2011	5 3
R-2741-32*	Masso River	**	Bridge	4/22/1975–4/5/1977	13

*old station, currently not monitored
**not classified

The National Park Service (NPS) has been monitoring the Asan River closely since 2007 as part of its Inventory and Monitoring Program. Water quality is tested on a quarterly basis at four fixed and four random stations. Parameters tested include temperature, conductivity, chlorophyll, turbidity, ortho-phosphate, and total nitrogen. Freshwater community surveys (fish, crustaceans, and snails) and habitat characterization are conducted at eight fixed and eight temporary stations on an annual basis. Over the last four years significant changes in the form of species shifts have been observed and may be linked to documented changes in habitat (Jones, pers. comm.). Depth sensors and stream rating curves, which will be developed for the Asan River at the upper and lower boundary of the Park, will provide discharge information in the near future. NPS is also planning to install a sediment analyzer at the two monitoring stations in the near future (Jones, pers. comm.).

The Water and Environmental Research Institute at the University of Guam is currently conducting a study to model the dynamic response of the watershed (Manibusan, pers. comm.). Part of the study is measuring stream flow, stream level, and turbidity on a monthly basis for one year. One monitoring site is at the Asan River and one site at the Masso River.

Groundwater Monitoring

Groundwater within the watershed was tested at Asan Spring during operations (until 2003) by GWA. The water was analyzed for semi-volatile, volatile, and synthetic organic compounds on a quarterly basis or as required by GWA. The spring had high levels of coliform bacteria. Historic geochemistry results are also available from 1976 (Mink, 1976) and 1949 (USGS, 1962).

Near Coastal and Marine Waters

Recreational Beach Monitoring

Water quality is tested weekly by GEPA at 42 tier-one beaches as required under the Beaches Environmental Assessment and Coastal Health (BEACH) Act. Tier-one beaches are easily accessible, highly frequented beaches with a high number of possible pollution sources, which require frequent monitoring. The samples are analyzed for concentrations of an *Enterococcus* bacteria indicator. Advisories are issued when *Enterococci* concentration in a single sample is greater than 104 colonies/100mL and/or when the geometric mean of the single sample and four previous weeks' results are greater than 35 colonies/100mL. A BEACH advisory is in effect at least until the next sample event.

Beach monitoring sites within the Piti-Asan watershed include the beach west of Adelup Park (N22), Asan Bay (N14), Piti Park/ Bay (N15), Pedro Santos Memorial Park (N16), and United Seamen's Service (N17), see Figure 30 above. Table 20 shows the number of days on advisory and number of advisories for these sites since 2008. N16 had one of the highest frequencies of advisories on Guam in 2010 and 2011 (GEPA, 2011 & 2012).

Table 20. GEPA's weekly beach monitoring advisories in the Piti-Asan watershed between 2008 and 2011. *Source: GEPA, 2010b & unpublished*.

ID	Location	Number of days on advisory* (Number of advisories)				
		2008[1]	2009[1]	2010[2]	2011[2]	*2012[3]*
N22	Beach west of Adelup Park	63(9)	52 (7)	74 (11)	90 (13)	*21 (3)*
N14	Asan Bay Beach	277 (40)	219 (30)	214 (32)	299 (42)	*105 (14)*
N15	Piti Bay	132 (19)	142 (20)	79 (12)	271 (41)	*118 (16)*
N16	Pedro Santos Memorial Park	291 (42)	200 (28)	319 (47)	337 (48)	*126 (17)*
N17	United Seamen's Service	0 (0)	21 (3)	22 (3)	109 (15)	*0 (0)*

[1] fiscal year; [2] calendar year; [3] January-June;
*generally an advisory is in effect for about seven days (+/- 1) until it is lifted or a new advisory is issued;

All 42 tier-one beaches, including five sites in the Piti-Asan watershed, exceeded GWQS for bacteria and were placed on the 2008 list of impaired waters. Potential bacteria sources were identified by GEPA (Table 21) but are not complete; *e.g.*, population estimates for feral ungulates could be helpful but are not available (LeonGuerrero, pers. comm.).

A TMDL has been approved for 17 northern beaches in March 2010. The beaches within the watershed and remain in reporting category 5 for "impaired waters" (GEPA, 2010b). As of July 2012, a TMDL document for the remaining beaches including the ones in the watershed is currently being developed but is still in its early stages. The document tries to identify and quantify potential sources of bacteria and identify the reduction needed for a beach to meet designated use criteria (LeonGuerrero, pers. comm.).

Table 21. Potential sources of high bacteria concentrations at the beach monitoring sites as identified by GEPA. *Source: LeonGuerrero, pers. communication.*

ID	Location	Sources of Pollution	Comments
N22	Beach west of Adelup Park	Upgradient pig farm, stormwater runoff, and identified sewer overflow/ cleanout issues.	Asan village has been identified as a GWA priority area for sewer line repair.
N14	Asan Bay Beach	Stormwater runoff issues, outdoor dog kennels, clearing and grading, and recreational use pollution.	
N15/ N16	Piti Bay/ Pedro Santos Memorial Park	Illegal dumping issues including household waste, sewer overflow issues, non-sewered buildings, clearing grading, stormwater runoff issues, and to recreational use pollution.	These two stations receive water from Matgue, Taguag, and Masso River.
N17	United Seamen's Service	Recreational use pollution and stormwater runoff issues.	

Marine Water Monitoring

Sediment loads in Asan Bay were studied by Minton (2006) during 2003-2004. Due to the very high sediment loads and potential adverse effects on the reef organisms a more extensive study is currently being conducted by NPS and the UOG Marine Lab in Asan and Piti Bay. Data collection at 36 sites (Figure 30) includes turbidity and light loggers at a ten-meter-depth contour (deVillers, pers. comm.).

Besides the EMAP program that includes sampling of marine waters, GEPA is also helping DAWR in monitoring water quality at current fish survey transect sites in the marine preserves and non-preserve control sites as part of the Marine Preserve Water Quality Assessment Program (GEPA, 2010). The Piti Bomb Holes Preserve has 11 sampling sites on the shore, reef flat and fore-reef slope; the Asan Bay as the control site has 5 sampling locations along the shore and fore-reef slope. Stations will be monitored on a monthly basis (ideally) or quarterly for standard water chemistry parameters.

Out of 66 marine bays, eleven were placed on the 303(d) list of impaired waters but neither Piti Bay nor Asan Bay are on the list; they were both classified as reporting category 2.

6. Conservation Targets and Threats

Targets

Conservation targets and threats posed to these targets (see next section) were identified and ranked during the Conservation Action Plan (CAP) meetings for the Piti Bomb Holes Marine Preserve and adjacent watershed (TNC, 2009). A CAP is a conservation approach that follows an adaptive management framework of setting goals and priorities, developing strategies, taking action, and measuring results. The process includes assessing values, threats, and conservation status but also developing and implementing conservation measures. The CAP for Piti was developed by a multi-disciplinary team mainly with representatives from Government of Guam agencies during workshops facilitated by the Nature Conservancy in January 2008, April 2008, and August 2009. Since the CAP focuses on the Piti Bomb Holes Marine Preserve but this watershed management plan focuses on land-based sources of pollution in the Piti and Asan watershed, the CAP was only partially integrated into this plan.

The conservation targets identified by the CAP team were native forest, fresh water ecosystem, native terrestrial wildlife, coral reef ecosystem, and reef fish. As the coral reef ecosystem and reef fish are beyond the scope of this plan, they are not further discussed here.

The overall biodiversity health of the conservations targets was ranked at fair (Table 22). Upland forest was ranked as poor primarily due to invasive species and loss of coverage from clearing. Most of the targets were ranked as fair due to overharvest and habitat loss (TNC, 2009).

Table 22. Summary of viability ranks for conservation targets. *Source: TNC, 2009.*

	Conservation Targets	Landscape Context	Condition	Size	Viability Rank
1	Coral Reef Ecosystem	Fair	Fair	Fair	Fair
2	Native forest	Poor	Poor	Poor	Poor
3	Fresh Water Ecosystem	Fair	Fair	-	Fair
4	Native Terrestrial Wildlife	-	-	Poor	Poor
5	Reef fish	Fair	Fair	Fair	Fair
Project Biodiversity Health Rank					Fair

Internal strengths and weaknesses and external opportunities and threats (SWOT) were also identified in the CAP. Strengths include the fact that the area is well-studied, the number of completed and on-going projects, the success of existing management actions, and the mayor's commitment to additional work. Weaknesses include need for educational training for mayor's staff and tour operators, need for better regulations and enforcement for tour operations and burning permits, time and capacity issues, *etc*. Opportunities include a proposed Guam Seashore Reserve Plan, an eco-permit program, and partnerships with federal agencies and schools. Threats identified include over-development on Nimitz Hill, upland erosion, invasive species, illegal fishing in marine preserve, and fires.

Table 23 summarizes the target ranks and overall rank for each of the ten threats identified. Invasive species were ranked very high. Other threats affecting the conservation targets most important to the community in Piti included various forms of unsustainable land use practices like urban development, pollution, wildland fires, and illegal fishing.

Table 23. Summary of threat ranks for conservation targets. *Source: TNC, 2009.*

	Project-specific Threats	Threats Across Targets: Coral Reef Ecosystem (1)	Native Forest (2)	Fresh Water Ecosystem (3)	Native Terrestrial Wildlife (4)	Reef Fish (5)	Overall Threat Rank
1	Invasive species	Medium	Very High	Low	Very High		Very High
2	Urban development		High		Very High		High
3	High levels of pollutants	Very High				Medium	High
4	Illegal fishing					Very High	High
5	Sedimentation	Very High					High
6	Wildland fires		Very High				High
7	Degraded habitat			Medium		High	Medium
8	Poor land use practices		High	Medium			Medium
9	Recreational use	Medium				Medium	Medium
10	COTS	Medium					Low
Threat Status for Targets and Project		Very High	Very High	Medium	Very High	High	Very High

Threats

The threats described here are stresses to the conservation target from the last section. Coral reef ecosystem and reef fish were not further considered here as this management plan on focused on land-based sources of pollution as mentioned earlier. The specific threats described here were identified in the CAP (TNC, 2009), a field report by CWP/HW (2010), and during field assessments by the author.

Invasive Species

Freshwater Ecosystem

The only river system in the Piti-Asan watershed with a known invasive species problem is the Masso River and Reservoir (Tibbatts, pers. comm.). In the river below the reservoir are *Oreochromis mossambicus* (tilapia) and *Hydrilla* (waterweed) and above the reservoir are *Poecilia reticulata* (guppy), *Gambusia affinis* (mosquito fish), and likely some *O. mossambicus*. In the reservoir itself are *G. affinis*, *O. mossambicus*, and *Hydrilla.* The population densities of the latter two species were much reduced as a result of the dredging and will hopefully not reach pre-dredging population densities again. Since the recent dredging and restoration work, *Kuhlia* (flagtail) from nearby rivers have been released in the reservoir. This species will be monitored to ensure DAWR stocking efforts keep pace with fishing extraction and compared to *Kuhlia* populations in the northern fork above the reservoir. As an active predator *Kuhlia* should be feeding on young invasive species such as *O. mossambicus* and *Poeciliids* (Tibbatts, pers. comm.).

Although present, non-native species are not considered a problem in the other major rivers in the watershed due to their low population density and limited distribution. For example, *O. mossambicus* is present in the lowest reaches of the Asan and Matgue River, *Poeciliids* also in the lowest reaches of the Matgue River, and *Bufo* tadpoles in the Taguac River (Tibbatts, pers. comm.).

Terrestrial Ecosystem

The magnitude of ecological damage invasive species can cause is exemplified in the brown tree snake introduction to Guam. Accidently introduced to Guam after World War II, the snake population has boomed across the entire island since then. The decline and even extirpation of the native avifauna is mainly attributed to the brown tree snake. Only three out of 12 native forest bird species (Mariana crow, Micronesian starling, and island swiftlet) can still be found in the wild (DAWR, 2006). Another common threat posed to native birds and other species are rats. The rats feed on bird eggs and nestlings and inhibit recovery of many bird species.

Other introduced species that have established in the Piti-Asan watershed include amphibians, fire ants, coconut rhinoceros beetles, and freshwater turtles, which have been seen in the Masso Reservoir (Tibbatts, pers. comm.).

Invasive species can seriously harm the native fauna and flora. The animal species most detrimental to native plants is probably the pig, followed by the deer. Pigs disturb the soil, thereby increasing the erosion potential and decreasing recovery of plants. Deer like to feed on new shoots, thereby inhibiting revegetation efforts.

Weeds are ubiquitous on the island and are a serious threat to native forests because they choke the vegetation underneath and spread very fast (Figure 31). One very common weed is cadena-de-amor (chain-of-love). The African tulip tree is also considered invasive because it suppresses native plant growth by taking over the habitat.

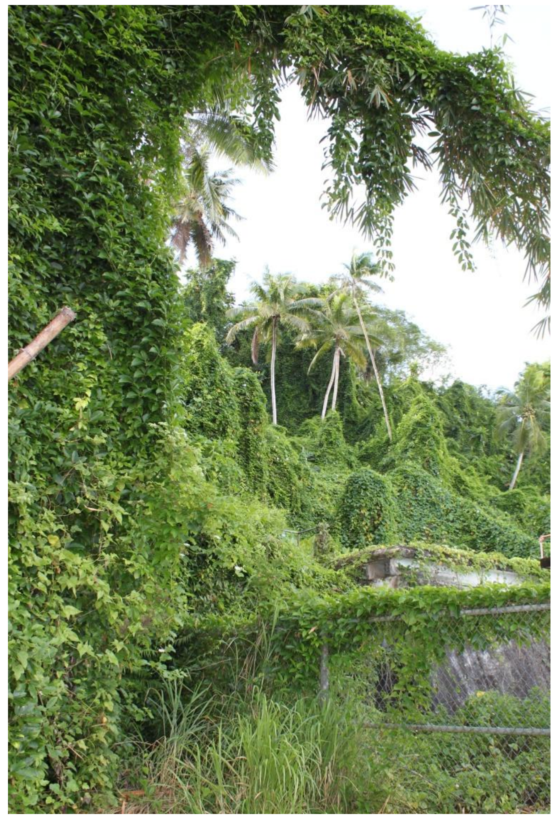

Figure 31. Vine covering large area along the hillside behind Asan Spring.

Erosion & Sedimentation

Soil erosion and associated sedimentation degrades the quality of the topsoil, impacts water quality, and can have detrimental effects on the coral reef system as research has shown (*e.g.*, Minton and Lundgren, 2006; Minton, 2006). It is a serious problem in southern Guam because of the highly weathered, easily erodible volcanic soils, seasonal wet and dry cycles, sloping terrain, and surface runoff. Once the nutrient-rich topsoil is eroded, it is hard for plants to re-establish and erosion continues, leading to badland development. Certain land use practices like poor development practices, mis-managed farming, wildfires, and off-roading may accelerate erosion rates and badland development. Farming practices are not further described here since they do not pose a threat in this watershed. Off-roading is currently not considered a major issue in this watershed but in the immediate vicinity on Channel 10 (PCR, 2009). However, all-terrain-vehicles have been observed in the Asan Inland Unit (Oelke, pers. comm.) and should be closely monitored to prevent badland development.

Soil Erosion from Degraded Lands.

Soil erosion and sediment delivery to rivers in southern Guam were quantified as part of the Guam State-Wide Assessment and Resource Strategy (SWARS) to prioritize areas in need of planting or other treatment to reduce erosion and sedimentation (FSRD, 2010). The erosion and sedimentation rates were derived using a GIS-model called N-SPECT (Nonpoint Source Pollution and Erosion Comparison Tool).

N-SPECT estimates sheet and rill erosion, but not mass wasting, gully-, or streambank erosion. Table 24 and Figure 32 show the estimated amount of sediments that erodes annually in the watershed. However, the actual sediment load delivered to the rivers is much less since sediments are often trapped in depressions or by vegetation (Figure 33). The model assumes a linear decrease of sediments delivered to the rivers with distance from the river (FSRD, 2010).

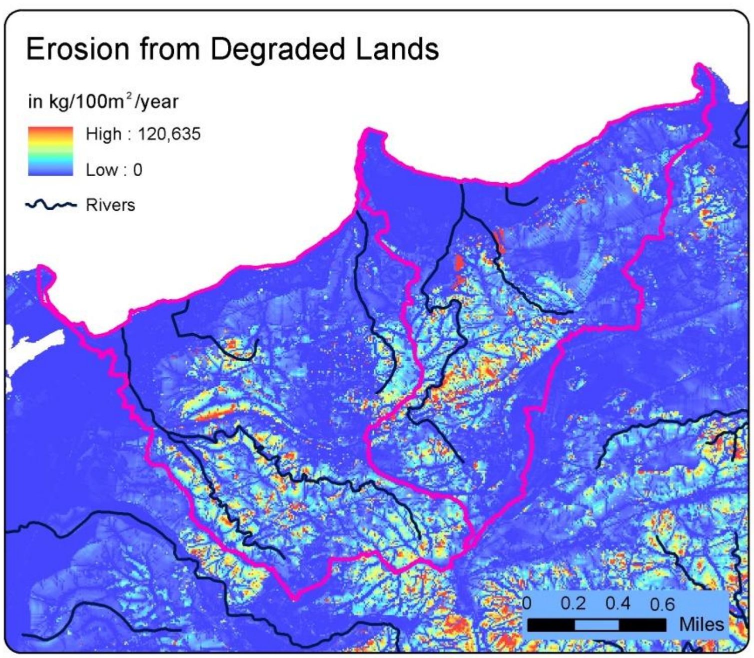

Figure 32. Erosion from degraded lands in the Piti-Asan watershed.

The estimated erosion in the Piti-Asan watershed is about 37,497 tons per year. The estimated amount of sediments that actually reach the river is about 12,374 tons per year. Since only mapped rivers were considered in Figure 33), smaller ephemeral streams may still receive a large volume of sediments during the rainy season. Comparing Figure 32 and 33 shows that areas with no streams contribute zero or little sediments to the river although erosion may still take place as shown in Figure 32.

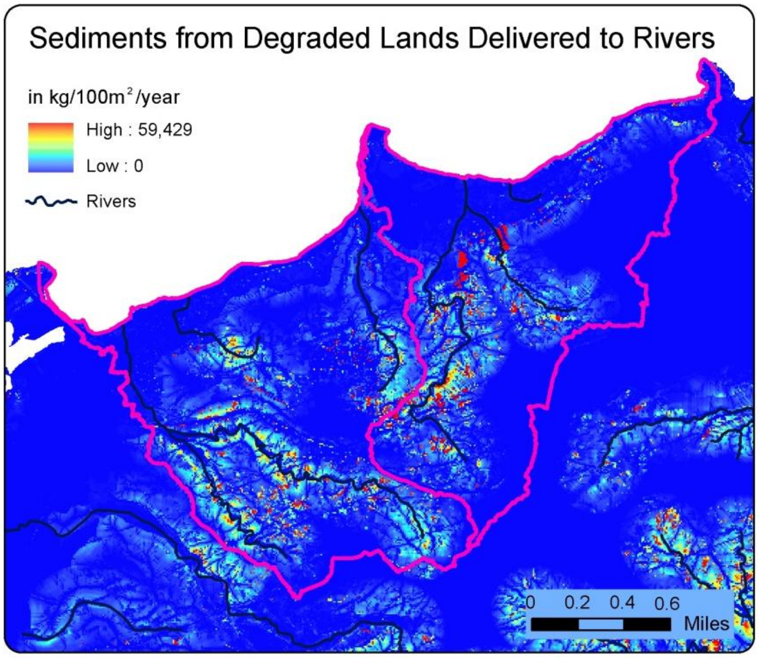

Figure 33. Sediments from degraded lands delivered to rivers.

Table 24. Estimated erosion and sediments delivered to rivers in the Piti-Asan watershed broken down by sub-watersheds. The numbers were derived from the N-SPECT model developed for the SWARS (FSRD, 2010). Note that the numbers here may differ slightly from the numbers in the SWARS report due to the different watershed boundaries the calculations were based on.

Watershed \ Annual Yield	Estimated Erosion		Est. Sediments Delivered to Rivers	
	Average (tons/ acres)	Total (tons)	Average (tons/ acres)	Total (tons)
Piti	20.41	20175	6.85	6774
Masso	28.43	14327	8.99	4532
West Masso	30.16	4990	9.66	1599
East Masso	31.15	7532	10.23	2474
Lower Masso	18.68	1806	4.75	459
Taguag	15.28	2159	5.48	775
Matgue	14.36	3199	5.89	1311
Remnant Areas	4.06	490	1.30	157
Asan	19.37	17322	6.26	5599
Asan	27.76	14193	9.48	4847
West Asan	29.07	11420	(9.07)	3563
East Asan	23.41	2772	(10.84)	1284
Palasao	11.28	2181	2.29	443
Chorrito	12.06	451	1.06	40
Adelup	6.73	228	2.87	97
Remnant Areas	2.27	270	1.46	173
Total	19.91	37497	6.57	12374

Streambank Erosion

Sediments from actively eroding streambanks might be the biggest contributor to sediments in the streams and marine environment in the watershed. Severe streambank erosion has been observed in the Asan River (deVillers, pers. comm.) and in the Masso River, but is likely to occur in the other rivers in the watershed as well (Figure 34). Streambank erosion is a serious concern since the eroded sediments cannot be trapped by plants, and are almost instantly transported into the river. In contrast, sediments from upland erosion might be trapped in depressions known as sediment sinks or by vegetation and not be transported into the streams.

Figure 34. Example of streambank erosion in the lower part of Asan River. *Photo courtesy of Amanda DeVillers.*

Mass wasting

Due to the nature of the volcanic substrate, certain areas in the watershed are prone to mass wasting. Especially during high rainfall events, as common during tropical cyclones, the upper more permeable soil layer can become saturated and slope failure can occur (Doerge and Smith, 2008). A serious land slide affecting several houses on Sanhilo Circle in Nimitz Hill Estates occurred on June 27, 2005, after Tropical Storm Tingting struck the island (Figure 35). The slope was later stabilized by NRCS (see also Appendix C). Another serious landslide occurred on the cliff side close to Adelup several years ago. A scar in the vegetation is still visible today. Apparently, a homeowner built too close to the cliff, cutting into the toe of the slope, undermining its stability.

Figure 35. Landslide at Nimitz Hill Estates that occurred when Tropical Storm Tingting hit the island on June 27, 2005. *Photo taken July 12, 2007 by Robert Gavenda, (Marshall-Garsjo, 2005).*

Erosion affecting homeowners is an on-going issue. Piti Mayor Ben Gumataotao is also concerned about this. He contacted the Department of Public Works (DPW) to address the issue and even showed DPW staff the site but he has not gotten any feedback (Gumataotao, pers. comm.). One area of particular concern is near the former landslide site.

Shoreline Erosion

Erosion along the Piti-Asan shoreline is a problem common on many beaches on southern Guam. Almost the entire shoreline of the watershed consists of stretches of sand beaches. Only few areas, like Adelup Point, Asan Point, and Cabras Island have a rocky shoreline. Remnants of former structures, exposed roots, and undercut shoreline are evidence of the retreating shoreline. Previous efforts of stabilizing the shoreline proved inefficient (Figure 36). The area should be monitored closely and measures need to taken before the erosion affects Marine Corps Drive. Three specific stretches in Piti along Route 1 were identified as candidates for highway shore protection in a report by Sea Engineering, Inc. (2007).

Figure 36. Eroding shoreline along Piti. Concrete was poured over limestone to stabilize the shoreline; structures are eroding and may affect the road soon.

Wildland Fires

Wildland fires are a serious problem on the island especially during the dry season. About 750 wildland fires burn each year on Guam with estimates that up to 80 percent are intentionally set (Neill and Rea, 2004). Wildland fires are often set by hunters to facilitate deer hunting, since deer are attracted to the new shoots that grow following a fire. Frequent fires have an adverse effect on erosion by destroying soil-stabilizing vegetation and exposing the soil to runoff. They can also impact species composition by spreading non-native, more fire-tolerant species (Minton, 2006).

The Piti-Asan watershed experiences frequent fires. In the WAPA-NHP Asan Inland Unit alone, four fires were recorded between June 2003 and May 2005, burning about 19.5 hectares (Minton, 2006). In 2006, almost the entire Masso watershed burned (KGTF, 2006). According to maps by Neill and Rea (2004), an average of 1-4 fires per year per square kilometers occur within the savanna areas of the Piti-Asan watershed. The risk of severe fires in a 300-ft perimeter of forest fragments is generally considered low to moderate in this watershed, according to maps generated for SWARS (FSRD, 2010).

A fire management plan has been developed by NPS (2006) for all the park units.

During 2001, a RARE campaign called *Na Para i Guafi* was launched to prevent illegal hunting practices and irresponsible fire use in southern Guam. The ultimate goal of the campaign was to reduce sedimentation on the coral reef.

Development

Poor construction practices are a major threat to water quality as erosion and sediment control are frequently overlooked during the construction process. Often, contractors fail to install adequate control measures and only rectify the situation if citations or stop work orders are issued (Figure 37). Without proper erosion and sediment control, large amounts of sediments can enter the waterways.

Current Guam Soil Erosion and Sediment Control Regulations (PL 25-152) focus mostly on construction-related sedimentation and stormwater management but have little to no post-construction requirements. However, revisions to these regulations, currently under review, include managing post-construction stormwater runoff from new land development and/ or re-development which needs to be contained on-site or adequately treated to meet current water quality standards before discharging it off-site. The large development on J Street (Figure 38) is documented in a time series 2003—2009 in Appendix C.

Figure 37. Example of a poor construction practice at the Masso bridge. A backhoe drove into the river bed destroying the river bed structure. Sediment fences along the bridge were only installed after the contractor was cited. *Photo courtesy of David Burdick.*

Figure 38. Exposed soil (left) and deep gullies (right) on a development site on J Street on Nimitz Hill in 2008. Silt fences were not effective as they did not trap the eroded sediments from the gullies and nearby areas. *Photos courtesy of CWP/HW (2010).*

Pollutants

Wastewater, commercial hazardous waste, or residences (*e.g*., from cleaning solutions, fertilizer or herbicides) are potential sources for water pollutants. These contaminants can enter waterways through untreated stormwater runoff. The weekly testing of beaches by GEPA show high bacteria counts in the Piti-Asan area (see chapter 4) resulting in frequent beach advisories. In February 2011, a sewage spill was detected along the upper reach of the Matgue River affecting the river itself and the Tepungan Territorial Beach Park (aka Fish Eye Park) (GEPA, 2011). GWA addressed the issue as soon as they were notified. During monitoring efforts in 2009, GEPA observed high E.coli concentration, high ortho-phosphorus, and low dissolved oxygen concentrations (Leon Guerrero, pers. comm.), indicating that the sewer lines may have been leaking for a couple of years. Several years ago, GEPA and DWAR were responding to an alleged sewage spill into the Masso watershed by a port-a-potty company located on Route 6. However, the spill could not be confirmed by inspectors (Leon Guerrero, pers. comm.).

An illegal dump site had been established behind the Asan mayor's office for several years, but as of August 2012 it seems that the mayor was able to discourage people from dumping their household waste there.

CWP/HW (2010) identified a number of municipal and commercial pollution prevention opportunities in the Piti-Asan watershed (see Appendix D). Recommended actions include proper management of outdoor storage and waste materials, preventing improper discharge into the drainage system, and improving or maintaining stormwater infrastructure.

Improper stormwater management not only degrades water quality but may cause or exacerbate flooding problems. An example of improper stormwater management is shown in Figure 39. Some areas in Piti village have flooding problems; at Jose L.G. Rios Middle School classrooms frequently flood during heavy rains (see Appendix E).

Figure 39. Clogged culvert along Marine Corps Drive in Piti.

7. Management Strategies

This chapter outlines management strategies to restore and protect the Piti-Asan watershed. The specific goals and objectives address existing impairments and threats described in the previous chapter. The strategies are mainly based on conservation strategies developed in the Draft Conservation Action Plan (CAP) for the Piti Bomb Holes Marine Preserve and Adjacent Watershed (TNC, 2009) and a field assessment by the Center for Watershed Protection and the Horsley Witten Group (2010). Other strategic plans like the Guam Natural Resources Strategy 2012 (Sablan, 2008), the Guam Statewide Forest Resource Assessment and Resource Strategy (SWARS) 2010—2015 (FSRD, 2010), and the Guam Local Action Strategy (LAS) were also reviewed and incorporated where applicable. The strategies in this document were reviewed by an interagency team representing GCMP, GEPA, DoAG, NOAA, NRCS, NPS, and WERI in October 2011.

The first section provides an overview of the goals as well as objectives and strategic actions to address each goal. Each goal also has a list of criteria (indicator and targeted load, level, or value) to measure success in achieving a particular goal. The goals and objectives are not listed in any particular order, except Objectives 2.3-2.4. Table 24 outlines the implementation plan for the strategic actions with project lead and partners, funding source, estimated cost, and timeframe.

Restoration projects referenced under strategic actions 1.1.a and 1.2.a are listed in Table 25 and shown on a location map in Figure 38. The list includes completed, on-going, and proposed projects. The proposed projects were prioritized based on relative scores developed by the planning team representing various agencies (GCMP, GEPA, and NRCS). The scoring criteria include 1) significance as pollution source; 2) impact on goal (load reduction, increase in indicators, *etc.*); 3) severity of threat addressed; 4) stakeholder buy-in; 5) public or political will; 6) project cost; and 7) likelihood of funding. Each project was ranked based on a score between one and three assigned to each criterion (Table 25).

Table 25. Project ranking criteria.

Decision criteria	Scoring		
	1	2	3
Significance as pollution source	Not significant	Minor source	Major source
Impact on goal (load reduction, increase in indicators, *etc.*)	Not significant	Some impact	Large impact
Severity of threat addressed	Not significant	Minor threat	Major threat
Stakeholder buy-in	No interest	Some support	Strong support
Public or political will	No interest	Some support	Strong support
Project cost	Greater than $50,000	$25,000 - $50,000	Less than $25,000
Likelihood of funding	No potential source	Potential source identified	Funding secured or very likely
Relevance to management measures and objectives	Limited relevance	Some connection to measures and objectives	Strongly relevant to stated measures and objectives

Goal 1. Improve Water Quality of Receiving Water Body

Objective 1. Reduce bacteria loads and turbidity levels in rivers and other receiving waters.

Objective 1.1. Reduce amount of stormwater runoff.

Strategic Action: Improve existing infrastructure to manage stormwater runoff.
Strategic Action: Ensure new development includes practices to manage stormwater during and post construction.

Objective 1.2. Reduce pollution in surface water runoff.

Strategic Action: Treat municipal and commercial pollution based on sources identified in previous surveys.
Strategic Action: Establish monitoring and enforcement systems to ensure ongoing compliance.

Objective 1.3 Reduce sediments in surface water runoff.

Strategic Action: Minimize sediment loading from construction sites.
Strategic Action: Reduce erosion from developed areas.
Strategic Action: Revegetate badland sites.

Table 26. Criteria to measure success for goal 1.

Indicator	Targeted load, level or value
Bacteria levels (*Enterococci* concentration)	The number of beach advisories, which are based on the level of *Enterococci* bacteria, should be reduced by 50% (based on 2010 numbers) by 2016.
Turbidity	Statistically significant reduction of turbidity levels by 2016 in Asan and Masso river where monitoring of water quality is already on-going.
Trash	Reduce the amount of trash collected during the annual coastal cleanup and other cleanups by 50% by 2014.
Commercial and municipal waste	Cleanup of at least 80% of previously identified potential point-source pollution sites (see CWP/HW 2010) by 2013.
Acreage of re-vegetated badlands	Ensure that the degraded area in the Masso Conservation Area recently planted with Acacia trees and natives (about 20 acres) is at least 80% established by 2014.
Enforcement of stormwater regulations	Increase the number of inspections by 50% by 2013.

Goal 2. Improve habitat.

Objective 2. Increased canopy cover of native species and reductions in terrestrial and aquatic invasive species populations.

Objective 2.1. Prevent habitat degradation.

Strategic Action: Reduce number of wildfires and acres burned.
Strategic Action: Establish aggressive arson enforcement and prosecution, including increased surveillance.
Strategic Action: Reduce the damage of ungulates.
Strategic Action: Establish vegetative buffers.

Objective 2.2. Assess degraded habitat quality and restoration needs.

Strategic Action: Measure existing forested areas using standard habitat descriptors (cover, density, ungulate pressure, *etc.*).
Strategic Action: Develop site-specific habitat treatment recommendations for all degraded land.
Strategic Action: Develop habitat treatment recommendations for streambanks and in-stream habitats as appropriate.

Objective 2.3. Conduct restoration projects on a site by site basis.

Strategic Action: Engage community, government, and private landowners in planning and implementation processes.
Strategic Action: Implement recommendations identified in assessment and treatment plans.

Objective 2.4. Maintain sites as needed.

Strategic Action: Identify short-term and long-term maintenance issues and appropriate actions.
Strategic Action: Engage partners and volunteers to implement maintenance projects.

Table 27. Criteria to measure success for goal 2.

Indicator	Targeted load, level or value
Detailed and up-to-date vegetation map of watershed	Complete by end of 2012.
Number of fires	Reduce to two or less fires over three year period (over 50% reduction).
Acreage of treated degraded land	Ensure that the degraded area in the Masso Conservation Area recently planted with Acacia trees and natives (about 20 acres) is at least 80% established by 2014. Additional conversion of at least 5 acres of degraded land.
Turbidity	Statistically significant reduction of turbidity levels by 2016 in Asan and Masso river where monitoring of water quality is already on-going.
Stabilized streambank	Complete at least 75 meters (~250 feet) by end of 2012.
Hydrilla	Keep 30% of water surface at Masso Reservoir (near floating fishing platform) free of Hydrilla to allow for easier fishing activity.
Kuhlia population	Ensure that stocking efforts keep up with demands of the fishery by tagging and recapturing Kuhlia.
Number of watershed stewards/ volunteers	Have at least 100 people within the watershed participate in one or more outreach projects (*e.g.,* tree plantings, Guam Yard Project) annually.

Goal 3. Increase Public Support for Watershed Protection.

Objective 3. Ensure successful implementation of plan by increasing stakeholder involvement and reporting progress.

Objective 3.1. Track and report project activities.

Strategic Action: Assign watershed coordinator to oversee implementation of plan and coordinate with stakeholders and volunteers.
Strategic Action: Develop monitoring program to document project outcomes.
Strategic Action: Establish effective reporting mechanism (press, meetings, *etc*.) to provide information to community, policy makers and funders.

Objective 3.2. Increase watershed awareness.

Strategic Action: Conduct public outreach campaigns targeted to community residents and other stakeholders for specific watershed concerns.
Strategic Action: Establish community partnerships to work on watershed projects and maintenance activities.

Table 28. Criteria to measure success for goal 3.

Indicator	Targeted load, level or value
Number of watershed stewards/ volunteers	Have at least 100 people within the watershed participate in one or more outreach projects (*e.g.* tree plantings, Guam Yard Project) per year.
Number of Facebook friends for Piti-Asan watershed page	100 friends by 2012.
Guam Yard Project	20 participants within watershed by 2015.

Table 29. Implementation plan for the management strategies by goals and objectives. The table lists project lead and partners, funding source, estimated cost, and timeframe for each action step.

Goal 1. Improve Water Quality of Receiving Water Body

Strategic Action	Action Step	Project Lead	Project Partners	Funding Source	Estimated Cost	Time-frame
Objective 1.1. Reduce stormwater runoff.						
Improve existing infrastructure to manage stormwater runoff.	Retrofit infrastructure for residences, publicly-owned areas, government-owned buildings, and roads by incorporating BMPs including bioretention, rain gardens, multi-celled ponding basins, permeable pavers, rainwater catchment. (see Table 25 and Appendix D)	**DPW**	**GEPA GCMP NOAA FHWA**		**See Appendix D**	**On-going (as funding is available)**
	Issue press releases to showcase retrofitted projects.	**EEC**	**Agencies**			**As needed**
Ensure new development includes practices to manage stormwater during and post construction.	Adopt revised stormwater regulations meeting criteria of the 2006 Guam/ CNMI Stormwater Manual (as of 10/13/11 under in-house review at GEPA).	**GEPA**	**GCMP NOAA**	**Internal**		**6 mon**
	Train DPW and GEPA staff (building permit staff, inspectors, engineers) in stormwater control and inspection.		**GEPA GCMP**			
	Conduct additional workshops on revised rules and regulations and user's manual for Guam Contractor's Association, Chamber of Commerce, GHRA, and PEALS. Offer certification to ensure better turnout. Note: First workshop done by GEPA/USEPA in Aug. 2011, without certification	**GEPA/ GCMP**	**USEPA HW CWP**	**CZM grant CRI Possibly Navy, EPA**	**$60,000**	**Sept 2012**
	Develop collaborative reporting structure, including natural resource agencies, mayors, and public, to identify violations.	**GCMP**	**GEPA, DoAG, MCG, DPW, NRCS, others**	**CZM**		**Ongoing**
	Hire additional staff to enforce policies.	**GEPA, DPW**	**GCMP**	**CRI (initial)**	**$50,000**	**1 yr**
	Explore a formal mechanism (*i.e.*, USCRTF resolution, letter from Governor, *etc.*) for engaging Department of Transportation on tying Highway funds to compliance with regulations.	**GCMP**	**GEPA, USEPA, NOAA**	**internal**		

Goal 1. Improve Water Quality of Receiving Water Body

Strategic Action	Action Step	Project Lead	Project Partners	Funding Source	Estimated Cost	Time-frame
Objective 1.2. Reduce pollution in surface water runoff.						
Treat municipal and commercial pollution based on sources identified in previous surveys.	Retrofit infrastructure for residences, publicly-owned areas, government-owned buildings, and roads by incorporating BMPs including bioretention, rain gardens, multi-celled ponding basins, permeable pavers, rainwater catchment. (see Appendix D)				**See Appendix D**	**2016**
	Reassess previous surveys periodically to identify changes to identified sources or new sources.	**GCMP**	**NPS, GEPA, CWP/ HW**	**GCMP**	**(in junction with CWP workshops)**	**2013**
	Conduct public awareness campaign of waste storage and wastewater discharges and engage homeowners, government offices and businesses. Integrate component into www.guamwaterkids.com and www.protectguamsfreshwater.com.	**EEC**	**GEPA, GCMP, DoAG, GWA, WERI**	**GEPA, GCMP, CRI**		**2013**
Establish monitoring and enforcement systems to ensure ongoing compliance.	See Goal 1.1.					
Objective 1.3. Reduce sediments in surface water runoff.						
Minimize sediment loading from construction sites.	See Goal 1.1	**DPW, GEPA**	**GEPA, GCMP, DoAG, EEC**	**GEPA, GCMP, CRI**		
	Train construction workers on good vs. bad practices through video presentation and field guide booklet. Note: training and field guide (HW, 2012) completed in Aug/ Sept 2012	**CWP/ HW**	**GEPA, GCMP, DPW, EEC**			**2012**
Reduce erosion from developed areas.	Work with residences and businesses to promote better landscaping practices.	**GEPA, GCMP**	**MCG, UOG, EEC, NRCS**			**2013**
	Identify willing landowners and implement best management practices and retrofits if appropriate.	**GEPA, GCMP**				**2013**
Revegetate badlands	Finish site assessment of Piti-Asan Watershed to determine highest priority areas for work.	**GCMP**	**DoAG WERI**	**NOAA**		**In progress**

Goal 1. Improve Water Quality of Receiving Water Body

Strategic Action	Action Step	Project Lead	Project Partners	Funding Source	Estimated Cost	Time-frame
Revegetate badlands (cont'd)	Develop and implement site plans with federal landowners.	**GEPA, GCMP**	**NPS, NRCS, SGSWCD, others**			**2012**
	Develop and implement site plans for GovGuam properties.	**GEPA, GCMP**	**NRCS, GSWCD DPW, NGOs, others**			**2013**
	Engage private landowners to revegetate eroded areas on their property.	**GCMP**	**FSRD, SGSWCD NGOs**	**CRI**		**2013**
	Develop monitoring and maintenance programs as appropriate for individual sites.	**Landowners**				**2014**
	Maintain streambanks by working with partners to monitor and replant streambanks with native vegetation if needed.		**DFSR, NRCS, community**			**2013**

Goal 2. Improve habitat.

Strategic Action	Action Step	Project Lead	Project Partners	Funding Source	Estimated Cost	Time-frame
Objective 2.1. Prevent habitat degradation by reducing wildfires and damage by ungulates.						
Reduce number of wildfires and acres burned	Continue anti-arson outreach and education which was started as a RARE Pride campaign.	**GCMP**	**EEC**			**2012**
	Ensure earlier notifications of fires through community watch programs.	**FSRD, GFD**	**EEC, GFD**			**2013**
	Establish fire breaks (*e.g.*, prescribed burning).	**FSRD**	**GFD**			**2013**
Establish aggressive arson enforcement and prosecution, including increased surveillance	Acquire dedicated time of the natural resource prosecutor.	**GCMP, AG**				**2012**
	Engage GPD to enforce natural resource laws, including arson.	**FSRD**	**GFD, GPD**			**2014**
	Implement community watch program through FSRD.	**FSRD**	**GFD, GPD,**			**2014**

Goal 2. Improve habitat.

Strategic Action	Action Step	Project Lead	Project Partners	Funding Source	Estimated Cost	Time-frame
			EEC			
Reduce the damage of ungulates	Install ungulate fences around the Masso Conservation Area.	**FSRD**		**NAVY**		
	Engage hunters and the community to participate in outreach events such as the pig hunting derby.	**GCMP**	**DoAG**			**2012**
Establish vegetative buffers						
Objective 2.2. Assess degraded habitat quality and restoration needs.						
Measure existing forested areas using standard habitat descriptors (cover, density, ungulate pressure, *etc.*)	Update GIS vegetative cover layer using up-to-date imagery.	**USFS**	**DoAG, BSP**	**USFS**	**In-house**	**On-going (until 2013)**
	Update vegetative cover layer using GIS by expanding the NPS GIS database. Note: new land cover classification using WorldView2 imagery in the works.	**USFS**	**BSP**	**USFS**		**On-going**
	Refine map using NPS GIS database and conducting field surveys, partnering with UOG classes and others as appropriate.	**DoAG**	**UOG, GCC, GCMP**			**2012**
Develop site specific habitat treatment recommendations for all degraded land.	For badlands – plant grass.	**DoAG**	**NRCS, NPS**			**On-going**
	For grasslands – plant trees.	**DoAG**	**NRCS, NPS**			**On-going**
	For forested areas – plant natives.	**DoAG**	**NRCS, NPS**			**On-going**
Develop habitat treatment recommendations for streambanks and in-stream habitats as appropriate.	Address setback requirements to rivers					**2013**
	Hire a contractor to develop a streambank stabilization plan using vegetative methods.	**GCMP**	**RC&D**	**CRI**		**Completed**
	Depending on the selected stream or river site, install the recommended method to stabilize the streambank.	**GCMP**	**RC&D**	**CRI**		**Ongoing**
	Control invasive plant and animal species	**DoAG, NPS**	**GCMP partners**			**Ongoing**

Goal 2. Improve habitat.

Strategic Action	Action Step	Project Lead	Project Partners	Funding Source	Estimated Cost	Time-frame
Objective 2.2. Conduct restoration projects on a site by site basis.						
Engage community, government and private landowners in planning and implementation processes.	With Piti and Asan Mayors, identify landowners and establish partnerships.	**GCMP**	**Mayors, DLM**			**By 2014**
	Conduct outreach and education programs to reach other community members and develop support for the projects.	**GCMP**	**EEC**			**On-going**
	Introduce education component (*e.g*., forest stewardship).	**FSRD**	**EEC**	**In-house**		**2013**
	Involve volunteers.	**EEC**		**In-house**		**On-going**
Objective 2.3. Maintain sites as needed.						
Identify short-term and long-term maintenance issues and appropriate actions.	Develop invasive species plans (*i.e.* hydrilla, chain of love, *etc*.).	**DoAG**	**EEC, GCMP**			**2012**
	Establish monitoring protocols for stream and terrestrial sites.	**DoAG**	**GCMP, NPS, NRCS**			**2012-2013**
	Develop maintenance schedules for areas of concern.	**DoAG**	**GCMP, NRCS**			**2013**
Engage partners and volunteers to implement maintenance projects.	Conduct public education and outreach programs to highlight site significance and project needs.	**GCMP**	**EEC, Mayors**			**2013**

Goal 3. Increase Public Support for Watershed Protection.

Strategic Action	Action Step	Project Lead	Project Partners	Funding Source	Estimated Cost	Time-frame
Objective 3.1 Track and report project activities.						
Ensure implementation of plan and coordinate with stakeholders and volunteers.	"Revive" the Watershed Planning Committee.	**GEPA**	**GCMP, DoAG, NRCS, SGSWCD, others**	**In-house**		**2012**
	Assign watershed coordinator.	**GCMP**	**GEPA**			**2012**
Develop monitoring program to document project outcomes.	Identify critical gaps for assessing outcomes of key watershed projects.					**2012**
	Secure resources to accomplish additional monitoring.					**2013**

Goal 2. Improve habitat.

Strategic Action	Action Step	Project Lead	Project Partners	Funding Source	Estimated Cost	Time-frame
	Create long-term plan for monitoring required to assess projects.					**2014**
Establish effective reporting mechanisms (press, meetings, *etc*.) to provide information to community, policy makers and funders.	Issue press releases and public service announcements.					**As needed**
	Create social media sites (*e.g.*, Facebook) to post milestones.	**GEPA**	**GCMP**	**In-house**		**2012**
	Engage policy makers with regular updates and events to highlight funding and/or regulation needs.					
Objective 3.2. Increase watershed awareness.						
Conduct a public outreach campaign targeted to community residents and other stakeholders	Conduct pre-survey to gauge existing knowledge of and support for watershed protection and restoration.					**2013**
	Create mini-campaigns specific to watershed goals and existing knowledge/support based on pre-survey results.					**2014**
	Conduct post-surveys to determine effectiveness and inform continuing education and outreach projects.					**2015**
Establish community partnerships to work on watershed projects and maintenance activities	Host a range of community stewardship activities suited to different stakeholders and targeting specific watershed issues.					**On-going**
	Promote the Guam Yard Project (a program by the UOG Cooperative Extension Service to award private homeowners for implementing conservation and print sign for it.	**UOG-CES**	**GCMP, SGSWCD**			
	Collaborate with agency partners and community members to develop new programs for outreach and for watershed conservation work.					

Table 30. Summary of completed (green), on-going (blue), and proposed (red) restoration projects with priority ranking in the Piti-Asan watershed based on CWP/HW (2010). Restoration projects in bold and italicized were selected by CWP/HW as high priority stormwater retrofit demonstration projects and are described in more detail in Appendix D.

ID on Map (Fig.38)	Name	Site Description		Project Type						Priority Ranking
		Existing	Proposed	Slope Stabilization	Stormwater Retrofit	Stream Restoration	Maintenance/ Pollution Prevention	Stewardship	Education	
1	Masso River/ Assumption Rd Restoration and Buffer Planting	• Streambank erosion near Assumption Rd bridge • Site of several cleanups	• Recommended tree planting along buffer (school side) and removal of debris from scupper drain.			√	√	√		
2	Masso Reservoir Conservation Area	• Reservoir dredged • Revegetation of several acres • Installation of fishing platform	• Plant more natives as soil conditions improve by nitrogen-fixing trees (Acacia trees).	√		√		√	√	
3	NRCS 2007 Slope Stabilization	• Site of 2004 landslide • slope was stabilized with “hard” and “soft” techniques	• Monitor vegetative establishment and erosion reduction.	√	√					
4	NRCS Flores Streambank Protection	• NRCS installed gabions to protect property and to prevent sediments flowing into the river		√	√	√	√			
5	Masso Streambank Stabilization	• Eroding stream banks.	• Site assessment report completed. • Construction pending but already contracted out.							
6	Pedro Santos Memorial Park	• Upgrading park to demonstrate BMPs and reduce pressure from Tepungan Beach Park. • Phase I (pavilion, bathrooms, walkway) completed.	• Phase II (landscaping, parking lot, bioswale) pending.		√			√		13
7	Asan Flood Control River Rehabilitation	• Flood control channel with concrete banks.	• Trash cleanups, plant native trees along channel banks. • Remove debris blockages at all bridge and utility line crossings to prevent flooding and utility line breaks. • DPW is in the process of dredging this part of the channel.			√	√			14

ID on Map (Fig.38)	Name	Site Description		Project Type						Priority Ranking
		Existing	Proposed	Slope Stabilization	Stormwater Retrofit	Stream Restoration	Maintenance/ Pollution Prevention	Stewardship	Education	
8	***GSA (General Services Agency)***	• GovGuam disposal/ recycling yard	• Bioretention for rooftop and parking lot runoff, cisterns for rooftop downspouts. • Provide secondary containment for hazardous substances, relocate barrels behind fire station.		√		√			14
9	***Rios Middle School***	• Flooding issues in classrooms and parking lot. • Sediments from this site flow into ditches and then bay.	• Mulch and erosion control matting in courtyards, grid/grass pavers in side parking. • Bioretention and Install diversion trench to it to redirect runoff. • Maintenance of sediment sumps/ forebay.		√			√	√	14
10	***Tepungan Beach Park (Fish Eye)/ Bus Loop***	• Flooding issues in parking lot. • Pollution from buses.	• Install stormwater wetland on west side of parking lot to alleviate flooding. • Install perimeter coral stone filter for water treatment at bus loop.		√		√	√		13
11	J Street Development (next to Mama Sandy)	• New development, some lots cleared and graded but failed or non-existent erosion and sediment control (gullies abundant), some slopes very steep.	• Seed and stabilized exposed soils. • Install or repair erosion control practices (esp. perimeter controls). • Inspect site after significant rainstorm. • Work with homeowners/developer.	√			√	√		16
12	***Asan River/ Limtiaco Ct. Raingarden***	• Runoff from residential street draining into cul-de-sac next to river.	• Install community rain garden and plant native canopy trees along stream buffer. • Install educational signage and picnic tables.		√	√		√	√	13
13	Stream Restoration	• Stream (unnamed) flows from forest to open area. • Turbid conditions observed.	• Potential site of sediment traps but requires more investigation.			√		√		11
14	***Asan Mayor's Office/ Community Center***	• Staging area for trash, overflowing dumpsters • Parking lot flooding	• Demonstration site with educational signage. • Raingarden to manage roof runoff, enhance existing drainage swale to alleviate parking lot flooding. • Trash cleanup in wetland and stream buffer areas. • Pollution prevention activities related to facility cleaning and material collection. • Plant native trees		√	√	√	√	√	13
15	Adelup Government Complex	• Mainly runoff from parking lot into car and roof.	• Raingarden to limit runoff (good as a demonstration site).		√			√	√	12

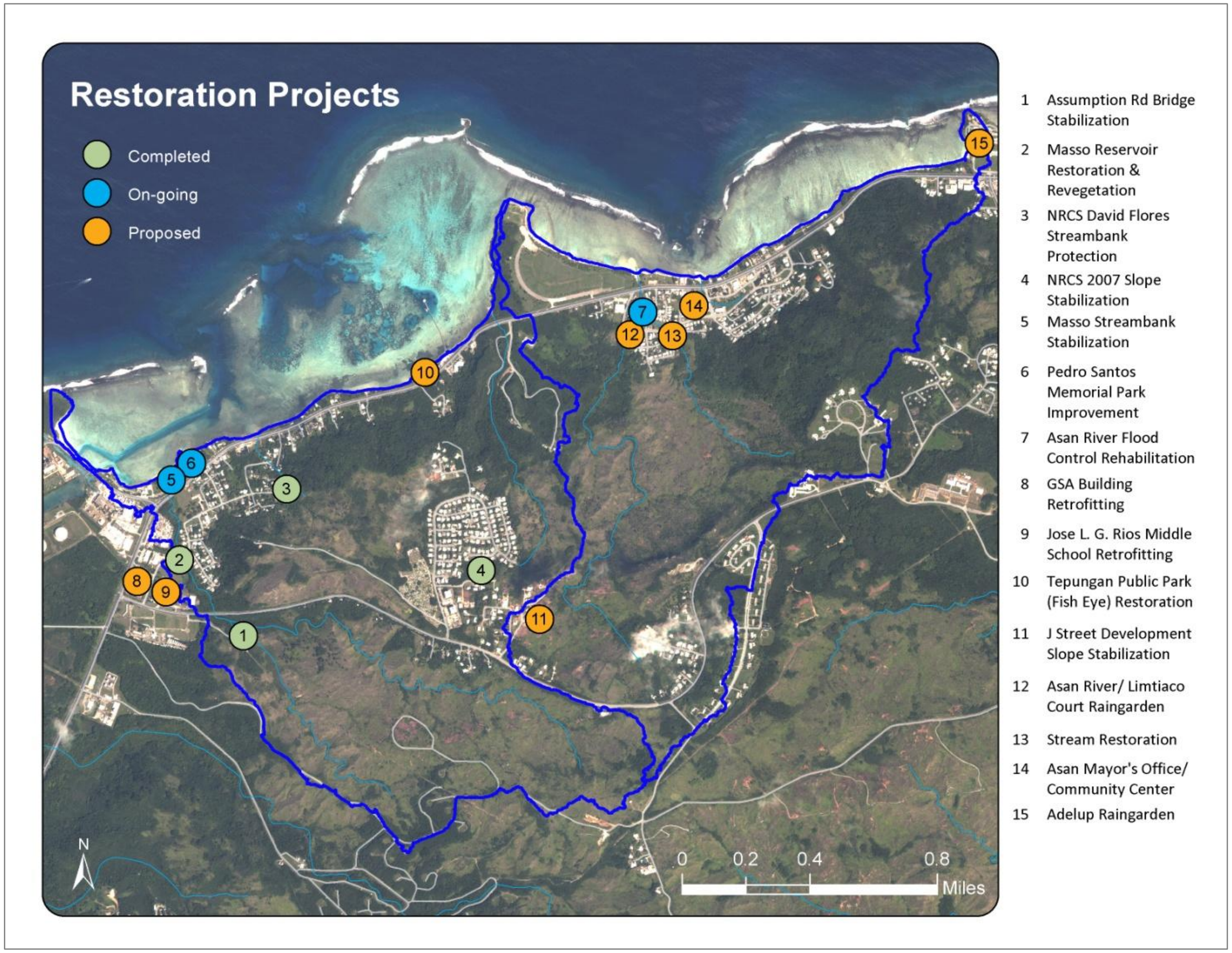

Figure 40. Map of restoration projects in the Piti-Asan watershed and immediate vicinity.

8. Next Steps

The projects outlined in the previous chapter should be implemented as soon as possible. The following steps are recommended to implement this plan and report progress. The steps presented here are primarily based on recommendations by CWP/HW (2010).

1. Establish a Watershed Clearing House

It is often difficult to find out about current or completed projects, or to find copies of reports and other documents. Currently, there is not one place, physical or virtual, that stores all resources related to watershed management on Guam. A website that acts as a repository of official reports, documents, maps and GIS data, raw monitoring data, photos, and other materials is essential to avoid duplication of efforts and to make informed management decisions. Placing these materials online also would make them readily accessible to a wider audience, including the general public as well as resource managers.

The digital Natural Resources Atlas of Southern Guam developed by WERI and IREI (Khosrowpanah *et al*., 2008) contains information about the physical and environmental characteristics of southern Guam watersheds. The information can be downloaded in various formats from www.hydroguam.net. Although the framework already exists to include other resources such as reports or media, no information has been uploaded to these sections at this time. It would be a cost effective and timely project to extend this existing website to serve as the island's watershed clearing house. For example, each watershed could have its own dedicated page where information about current or completed measures can be compiled.

Other options include a digital newsletter, subscription-based services providing notices about new information, a public forum where citizen can post questions and concerns, and a project page where volunteers can find out about community projects.

2. Report Status of Conservation Efforts

A tracking system should be established to report progress on active projects to funding entities and other stakeholders. The tracking system may be part of the clearing house website mentioned above. It could simply state the status of each project and, if available, provide actual status reports.

3. Combining Efforts

All the above steps should be implemented with collaboration and input of key stakeholders from the local and federal government agencies (BSP, GEPA, DoAG, GWA, DPW, NOAA, NRCS, NPS, U.S. Navy) and mayors' offices as well as the Southern Guam Soil Conservation District, the University of Guam (WERI, UOGML), non-profit organizations (*e.g*., TNC, i-recycle, GEA), schools, and private businesses. Private businesses with a special interest in a healthy marine environment should include all tour operators within the watershed, namely the Fish Eye Marine Park and dive operations like the Micronesian Divers Association (MDA) and Sunset Grill. Also, additional monitoring efforts need to be coordinated with existing efforts from various agencies. For example, the water quality monitoring NPS is currently conducting in the Asan River can be supplemented with monitoring data (rainfall, stream flow and turbidity) in the Masso River WERI researchers are currently collecting. Collaboration of local government agencies with NPS is especially important because of the park's large area within the watershed but also because of the resources (*e.g*., off-island experts) the park has access to which can benefit the local government. Monitoring data should be exchanged between the different entities to maximize monitoring and research efforts.

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Appendices

A: Maps of Piti and Asan Area (GovGuam, 2008)

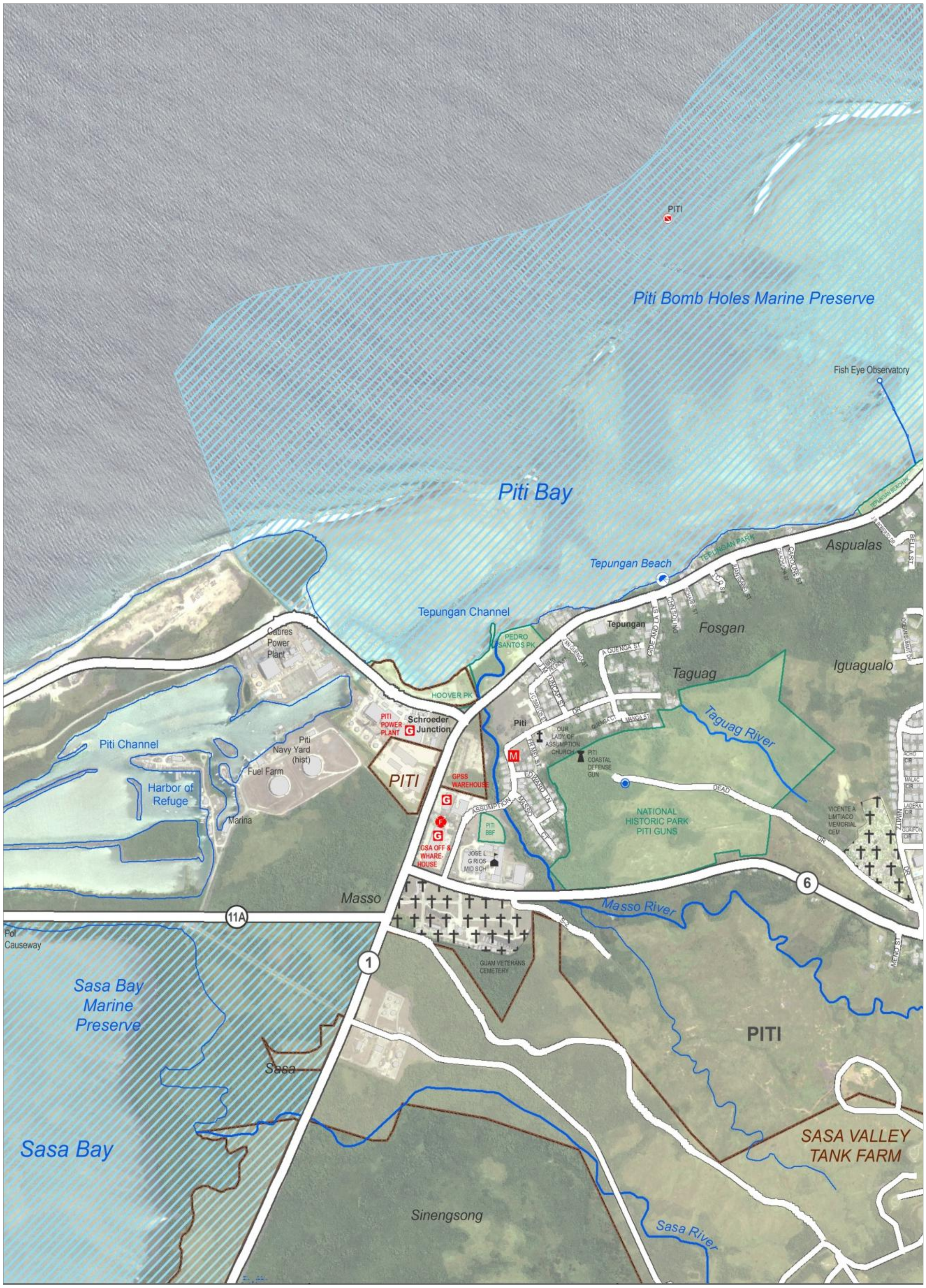

Figure A-1. Map sheet showing Piti area. *Source: BSP, 2008.*

Figure A-2. Map sheet showing Asan area. *Source: BSP, 2008.*

B: Historic Maps and Photographs

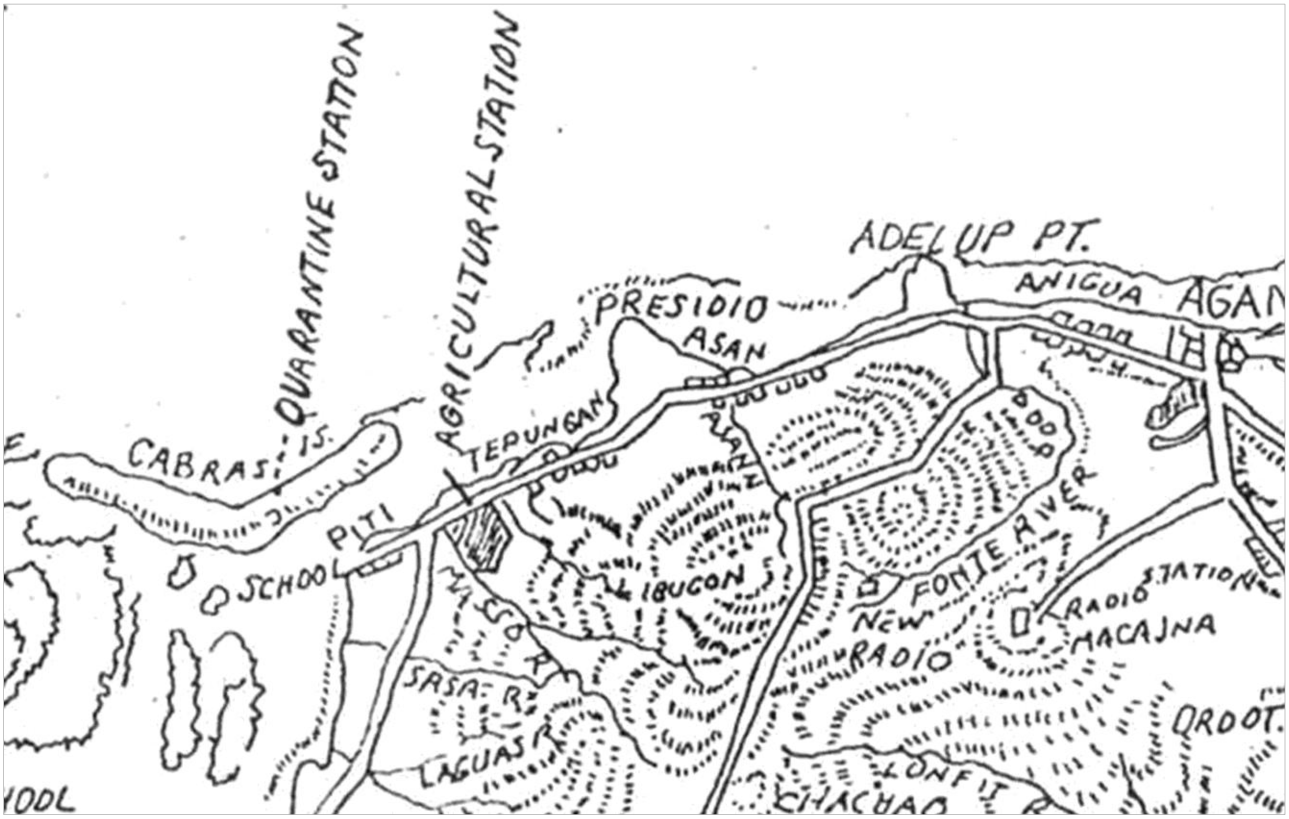

Figure B-1. Section of a 1902 map by the U.S. Navy. Note the village of Piti was located further south than today. The area we call Piti village today was called Tepungan. Cabras Island was only accessible by boat then. *Map courtesy of UOG-MARC.*

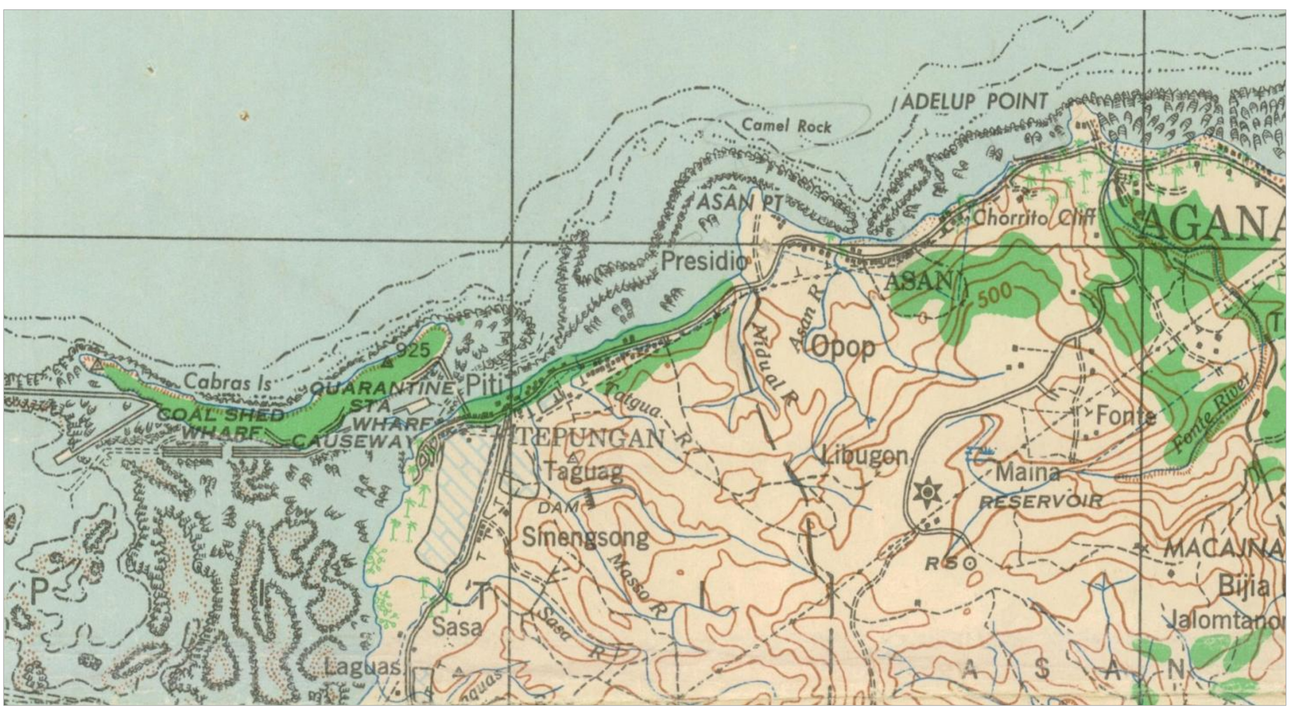

Figure B-2. Section of a 1944 map by the U.S. Army. At that time a causeway was already connecting Cabras Island to Piti. Note the dam on the northern fork of Masso River. This may have been a different dam than the one we see at Masso reservoir today since today's dam is right below the confluence of the two forks. *Map courtesy of UOG-MARC.*

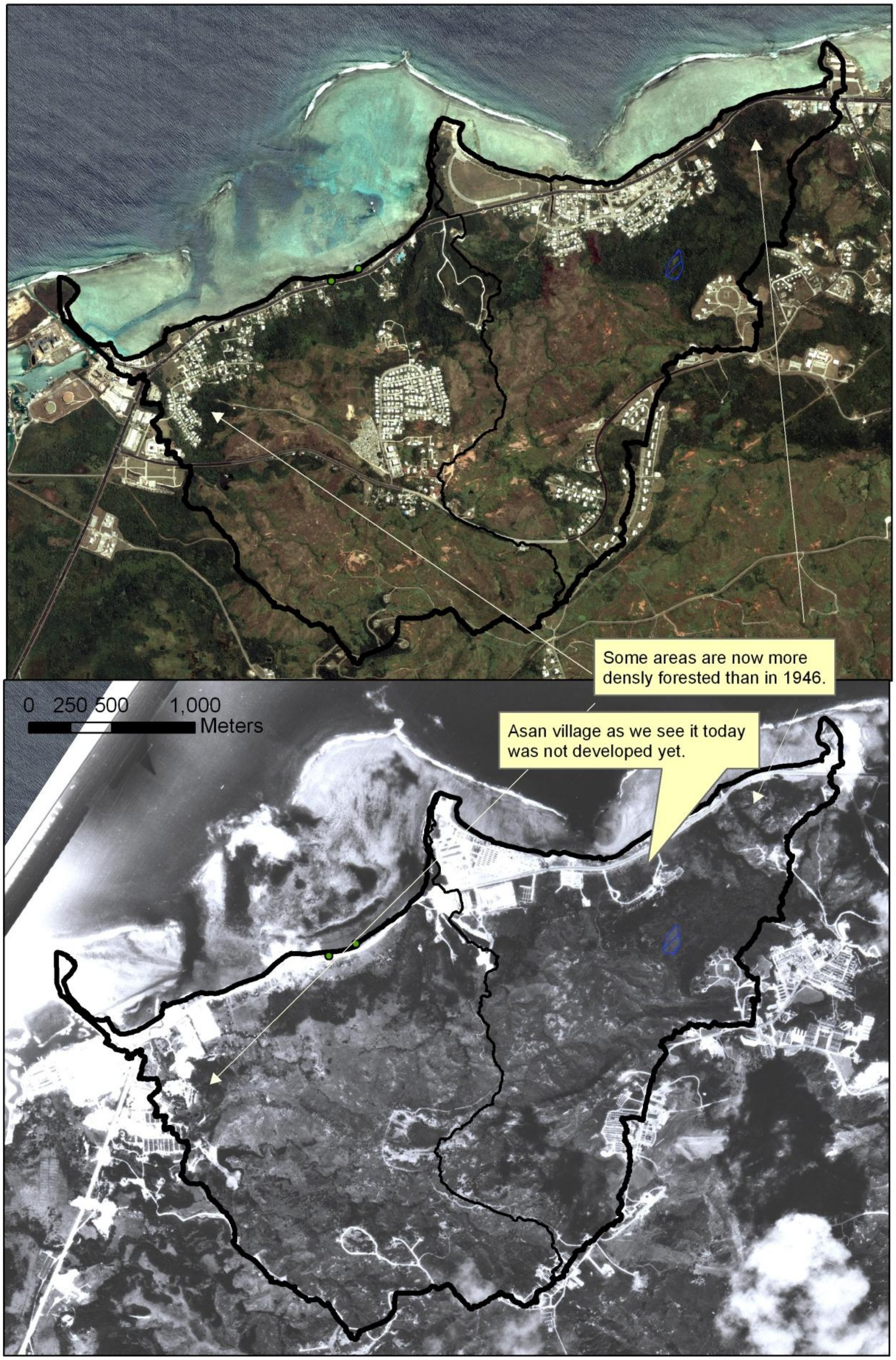

Figure B-3. Comparison of the 2006 QuickBird Satellite imagery and a geo-referenced 1946 aerial photograph *(Courtesy of UOG-MARC)*.

C: Development - Photo Series 2003-2009

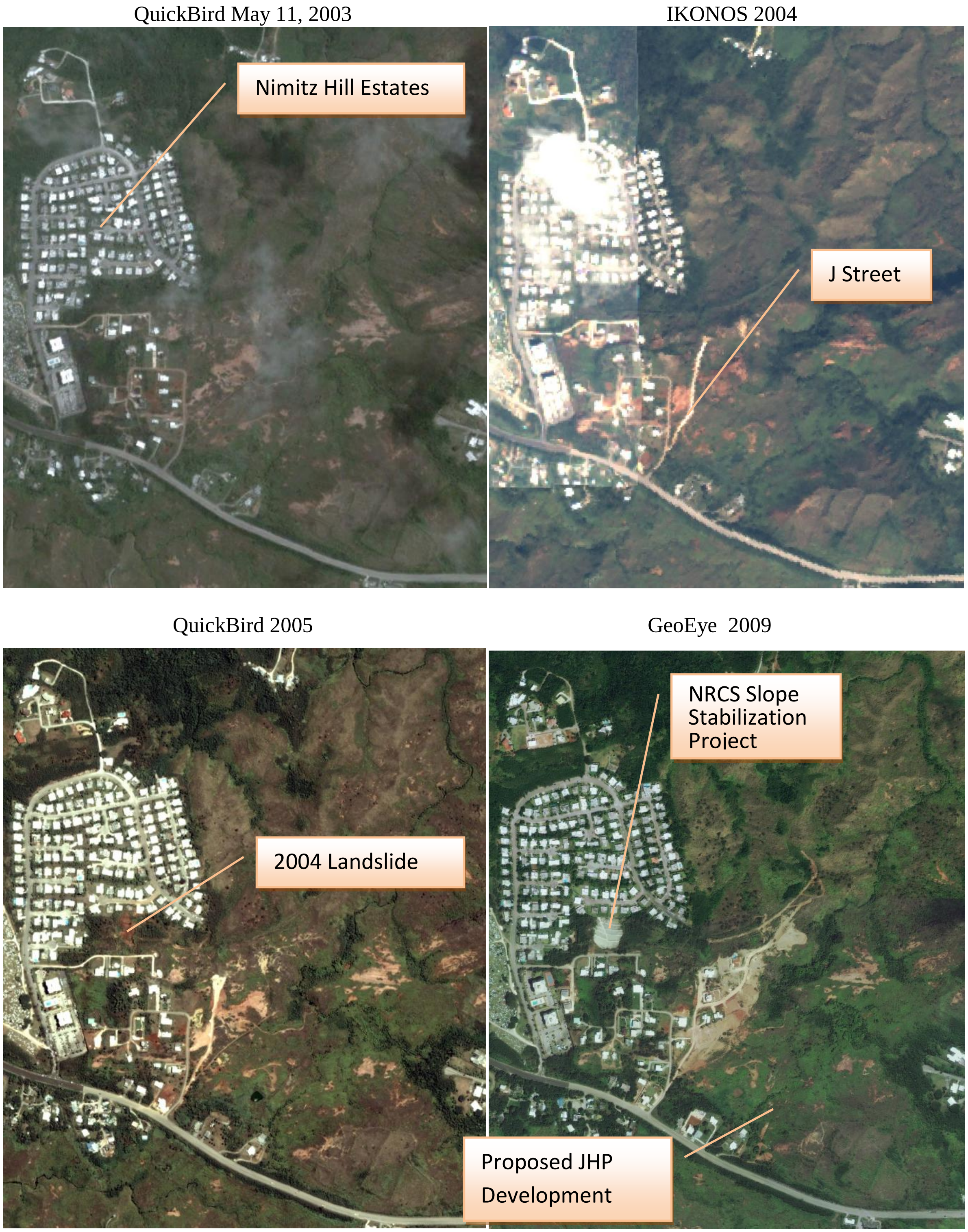

Figure C-1. These satellite images were taken between 2003 and 2009. They show Nimitz Hill Estates on the left, new development east of Mama Sandy Street, and the proposed JHP subdivision site. Note the site of the 2004 landslide (Marshall-Garsjo, 2005), which was later stabilized by NRCS. Also note the large exposed area at the new development site. Many lots in this area are still empty and actively eroding. This area drains into the Asan River; large amounts of sediments from this area may be transported into the river and degrade habitat.

D: High Priority Restoration Projects *(Source: CWP/HW, 2010)*

GSA BUILDING

Bioretention area to treat roof and parking lot runoff

Project Summary

Project Rank	High
Estimated Cost	$$

Site Description

The GSA building is operated by the State of Guam and is used to store and transfer waste materials such as used/broken office supplies, electronics, equipment, old vehicles, etc. Much of this material is stored uncovered, outside, and comes into contact with stormwater. There is a high potential for automotive fluids and other chemicals to be washed into roadside ditches during rain events and be carried to the bay.

Existing Conditions

Runoff from the front half of the GSA building is conveyed via external roof drains onto the front parking lot area. This runoff, combined with runoff from the parking lot, drains as sheet flow into a grassed area adjacent to the road. This area also receives runoff from a portion of the adjacent Marine Corps Drive. Runoff is then conveyed from this grassed area into a storm drain channel (Figure D-1).

Proposed Concept

Create a bioswale to capture and treat roof, roadway, and parking lot runoff. Provide 1 foot of storage depth in the system. Create a coral stone overflow to the existing conveyance system (see Figure D-2). The underlying soils will need to be evaluated to determine if an underdrain is needed to provide adequate drainage. This project can be used as a demonstration site for managing stormwater from roads and public facilities.

Figure D-1. Runoff from portion of rooftop and front parking drain to grassed area, then through culvert under Marine Corps Dr.

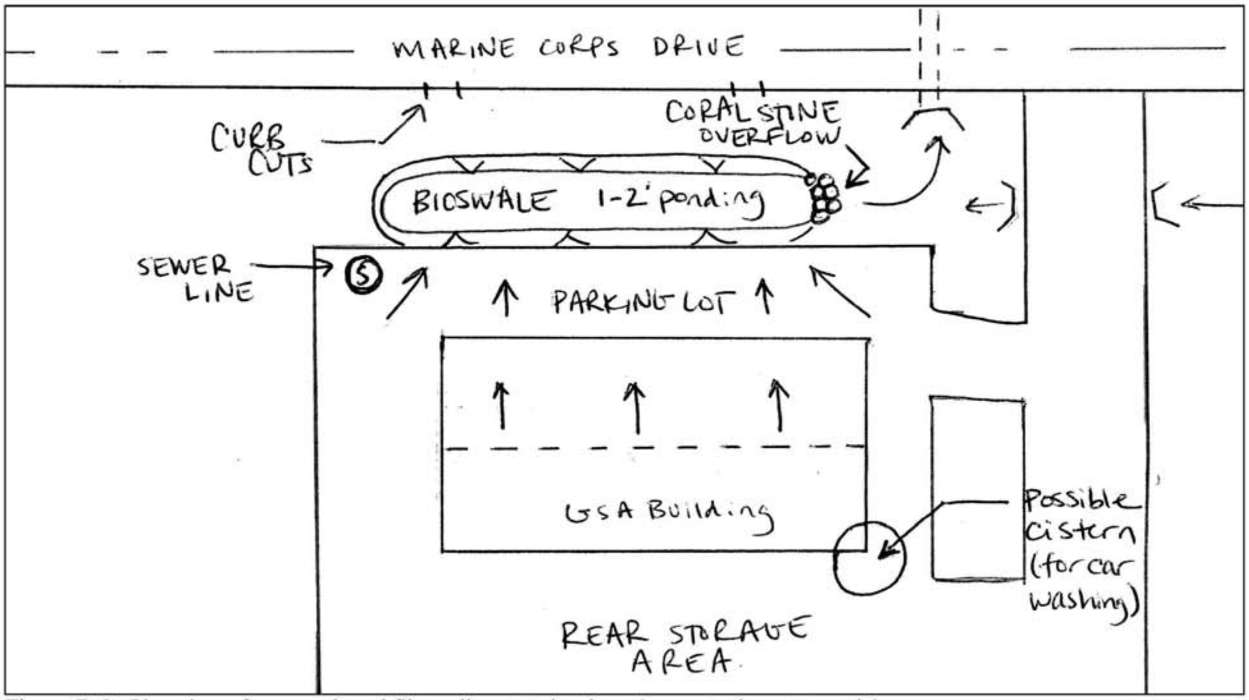

Figure D-2. Plan view of proposed sand filter adjacent to bus loop (conceptual – not to scale).

Design Consideration

A sewer manhole was located in the front parking lot. The exact location of the sewer line and other utilities (i.e., electric) must be confirmed and avoided in the final design.

Example Projects

Figures D-3 and D-4 show examples of various bioretention areas and rain gardens.

Figure D-3. Example of a parking lot bioretention area in Guam.

Figure D-4. Example of a rain garden treating parking lot runoff in Saipan.

JOSE L.G. RIOS MIDDLE SCHOOL

Trench drain conveyance to rain garden, site stabilization retention area to treat roof and parking lot runoff

Project Summary

Project Rank	High
Estimated Cost	$$$

Site Description

The proposed retrofit concept is located in a grassed area adjacent to the dirt teacher parking lot at RIOS Elementary School in the Piti Watershed. The school has two courtyard areas, both of which contain large trees but lack adequate or stable ground cover. Both courtyard areas serve as a playground area for the school children and receive heavy compaction from foot traffic.

Existing Conditions

During rainfall events, runoff from the school rooftop and the lower courtyard area is conveyed to a surface channel, into a trench, and then out across the front paved parking lot. From the parking lot, the runoff is conveyed offsite and enters the stormwater conveyance system. Sediment from the bare courtyard areas is picked up and transported in stormwater runoff, as evidenced by the opaque water shown in Figure D-5. During heavy rain events, runoff from the courtyard backs up and floods lower classroom areas.

Proposed Concept

In order to reduce stormwater sediment loads, the courtyard areas should be stabilized with mulch (Figure D-6). Construct a drainage channel with a grate top to convey runoff out of the courtyard and around the front of the school. Continue this trench around to the large grassed area adjacent to the dirt parking lot. Construct a rain garden with 1-2 feet of ponding depth to capture and treat the conveyed runoff. Additionally, replace the dirt parking lot with grassed permeable pavement (Figure D-7).

Figure B-5. Sediment in runoff is conveyed over the courtyard, into a channel then trench, and continues out across the parking lot. Runoff leaves the site and enters the street conveyance system (ditch), carrying sediment to the bay.

Site: Rios Middle School

Figure D-6. Existing site conditions and proposed location of the retrofit.

Design Considerations

Explore methods to keep sediment, mulch, and debris out of trench drain and bioretention area; options may include adding sumps at strategic locations along trench and a sediment forebay in bioretention area that can be easily maintained. Check dams installed along the roadside ditch may be an alternative back up to help trap sediment. Maintenance of this system will be a long-term commitment for the school.

While utility constraints are expected to be minimal, detailed utility mapping should be obtained before completing the final project design.

The underlying soils will need to be evaluated to determine if an underdrain is needed to provide adequate drainage If the soil infiltration rate is less than 0.5 in/hr, include an underdrain in the design.

Site: Rios Middle School

In addition to solving a flooding problem, this project is a good demonstration and educational opportunity. The design can be incorporated into an environmental curriculum.

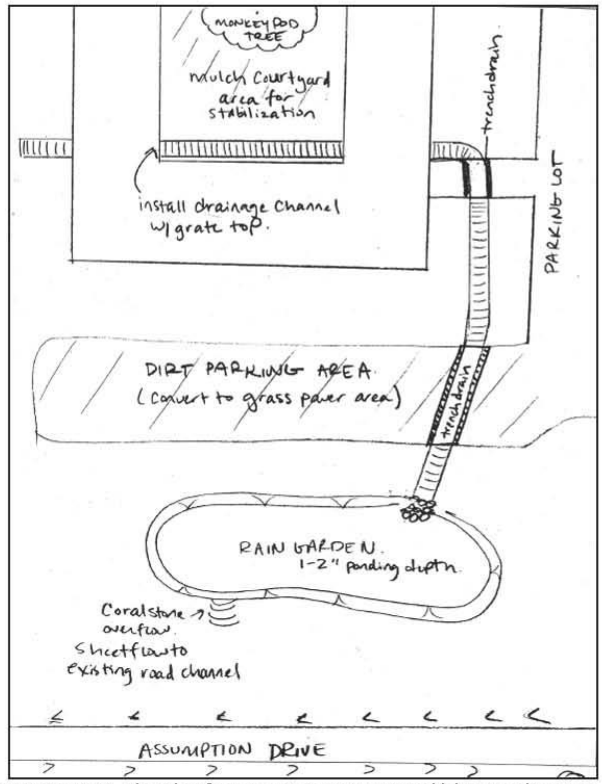

Figure D-7. Sketch of conveyance system and bioretention area at Rios Middle School (conceptual – not to scale)

Example Projects

Figure D-8. Example of a rain garden in Saipan.

FISH EYE PUBLIC PARK PARKING LOT

Wetland to treat runoff from flooded parking lot

Project Summary

Project Rank	High
Estimated Cost	$$$

Site Description

The parking lot services the Fish Eye Public Park, which is located along the Piti Bay. The adjacent Fish Eye Marine Park receives many visitors and is a highly visible location for demonstrating stormwater management practices.

Existing Conditions

Runoff from the parking lot and adjacent roadway collects and ponds in a low spot of the parking lot, causing major issues for parking and for traffic flow through the lot. The site lacks adequate drainage, but during high flooding events, some runoff will eventually spill out to an adjacent grassed area. This area was very wet and muddy during the site investigation. Adjacent to the site is a roadway outfall that conveys runoff from Marine Corps Drive out to the Bay (see Figure D-9).

Proposed Concept

In order to alleviate parking lot flooding problems and provide for water quality treatment prior to discharge into the bay, we propose constructing a stormwater wetland to capture parking lot runoff and roadway runoff in the open space adjacent to the parking lot. Use curb cuts and a stabilized channel to allow drainage to flow from the parking lot into the wetland. The wetland area can be excavated 1-2' below grade to provide positive drainage to the proposed area. The wetland overflow should connect with the existing outfall channel (see Figure D-10).

Figure D-9. Images of the flooded parking lot area (top), adjacent open space for a proposed wetland (middle), and the roadway outfall channel (bottom photo).

Site: Fish Eye Public Park

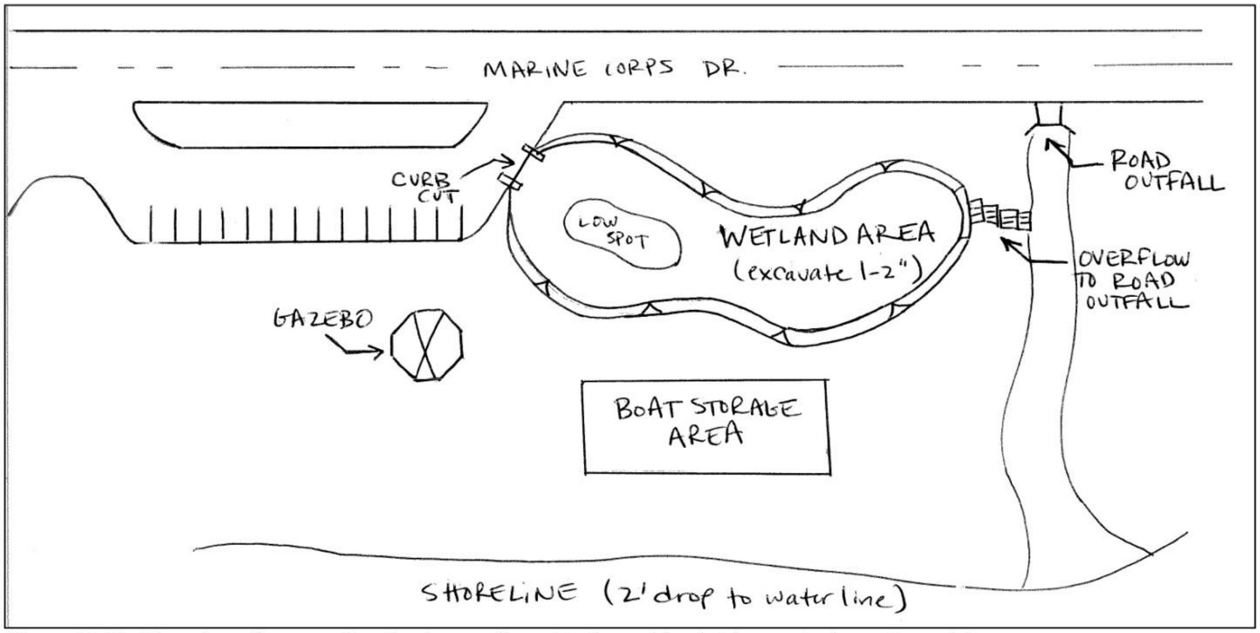

Figure D-10. Plan view of proposed wetland area adjacent to the parking lot (conceptual – not to scale).

Design Considerations

The land at this site is owned by parks and recreation, which makes implementation and maintenance more feasible.

A partnership with Fish Eye and the sand filter project should be considered.

Interpretative or educational sign explaining the function of the wetland should be considered, since this lot is adjacent to a highly visible and heavily used site.

The proposed location is adjacent to a boat storage area, which should be avoided.

Some improvements to the parking lot may also be needed to ensure positive drainage to the wetland.

Project examples are shown in Figure D-11.

Figure D-11. Example of a wetland treating parking lot runoff in (upper photo) and wetland plantings in a stormwater channel (lower photo) in Saipan.

Site: Fish Eye Public Park

FISH EYE PUBLIC PARK BUS LOOP

Wetland to treat runoff from flooded parking lot

Project Summary	
	
Project Rank	High
Estimated Cost	$$$

Site Description

Fish Eye Marine Park receives many visitors via buses that pull into the concrete bus loop to drop off and pick up passengers.

Existing Conditions

Runoff from the concrete bus loop and parking lot drains directly to the beach and water. There are several grooves in the concrete that drain runoff through slots in the concrete curb. There are many oil stains in the area, and the bus exhaust also deposits pollutants onto the concrete. There is currently no filtering or treatment mechanism for the pollutants (see Figure D-12).

Proposed Concept

To provide some treatment of the runoff prior to discharge to the water, the concept is to construct a perimeter sand filter adjacent to the concrete bus loop. A retaining wall would be built approximately four feet from the curb, and the area between the existing curb and the retaining wall would be partially excavated and filled with sand. An underdrain would keep the sand filter area dewatered. The sand filter can be covered with a layer of coral stone and a removable grate (see Figure D-13).

Example Projects

Figures D-14 and D-15 show examples of two types of sand filters.

Figure D-12. Runoff from the concrete bus loop is conveyed across the concrete pad via grooves and sheetflow, and discharges through square notches in the curb to the nearby beach and water. There are oil stains on the concrete pad and bus exhaust deposits other pollutants on the concrete.

Site: Fish Eye Bus Loop

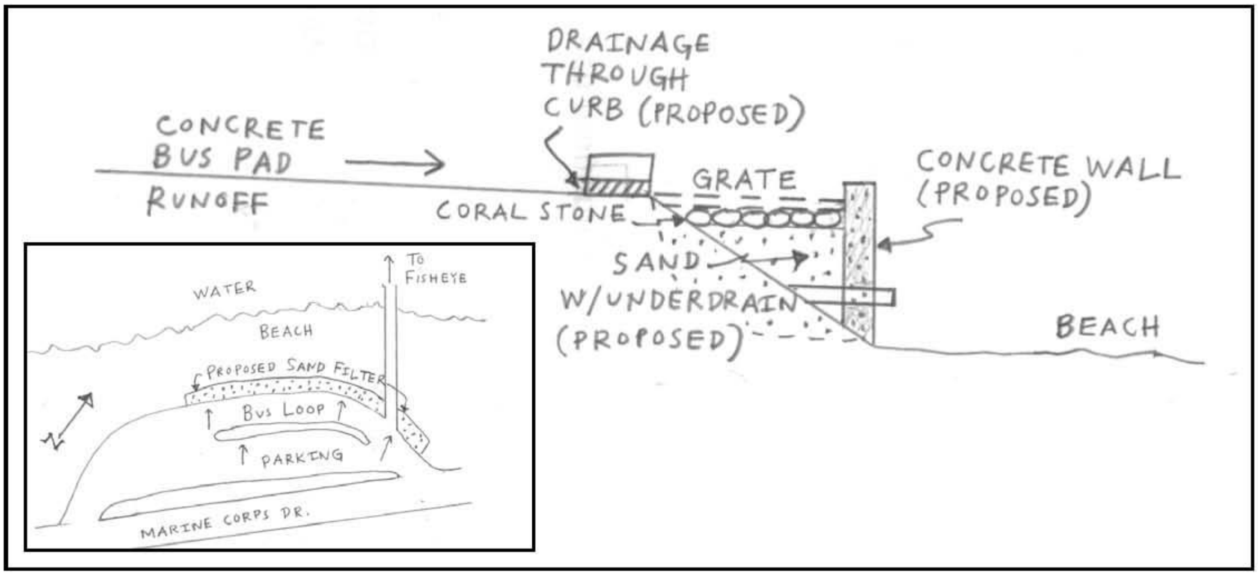

Figure D-13. Plan view (inset) and cross-section view of proposed sand filter adjacent to bus loop (conceptual – not to scale).

Design Considerations
Further design work is needed for the retaining wall and materials to be used.

Maintenance is a major consideration. The top layer (2 to 3 inches) of coral stone and sand will have to removed periodically and replaced with clean material.

An interpretative or educational sign explaining the function of the filter should be considered, since this is highly visible and heavily used site.

Figure D-14. Example of a surface sand filter treating parking lot runoff.

Figure D-15. Example of sand filter with grate top. The grates provide maintenance access.

Site: Fish Eye Bus Loop

ASAN RIVER AT LIMTIACO CUL-DE-SAC

Community bioretention/ rain gardens and native planting

Project Summary

Project Rank	High
Estimated Cost	$$

Site Description

The site is an undeveloped, vegetated lot between the cul-de-sac at the end of Limitaco St. and Jose Leon Guerrero St., which is the main road in the Asan Village. This area is adjacent to the Asan River, and is a highly visible location for demonstrating community stormwater management practices.

Existing Conditions

Runoff from Limitaco St., residential driveways, and rooftops collects along the street curb and flows down the hill into the cul-de-sac and jumps the curb into a grassy lot. This area was very wet and muddy during the site investigation. Adjacent to the site is the Asan River, which lacks a properly vegetated riparian buffer along this reach (see Figure D-16).

Proposed Concept

In order to demonstrate innovative stormwater practices, restore a native stream buffer, and improve aesthetics, we propose constructing a community rain garden/bioretention facility and planting native trees at this site. Curb cuts along the cul-de-sac can be used to convey runoff from the curb to the biorentention via a stabilized conveyance structure such as a paved flume (Figure D-17).

Runoff will enter a pretreatment forebay to remove sediment and debris before flowing into the bioretention cell. Overflow volumes will spill out as sheet flow into the stream buffer (see Figure D-18). .

Figure D-16. Open space area for community bioretention (top). Plant native trees and buffer vegetation along Asan River (middle). Notice turbid flow in stream. Runoff to cul-de-sac is generated on Limitaco St. and includes residential driveways and, in some cases, rooftops (bottom).

Site: Asan River at Limtiaco Cul-de-sac

Figure D-17. Plan view of proposed bioretention/community rain garden (conceptual – not to scale) adjacent to the cul-de-sac (top photo) and small rain garden at house up the hill (bottom photo).

Further up the hill is a location at a private residence that is a good candidate for installation of a rain garden in an existing depression between two houses. Installation of gutter and downspouts can direct rooftop runoff to the rain garden, which can be used to grow harvestable species such as taro, banana, white lily, or kang kung.

Design Considerations

The land at this site is a privately owned, undeveloped parcel. Ownership and potential land acquisition should be investigated.

This is a good site for educational signage explaining the function of the practice and the link between residential lawn care, automotive repair, and pet waste management on stormwater quality and the Bay. Residents should be engaged in native tree planting, and rain garden construction.

Example Projects

Figure 18 shows examples of a bioretention facility at the end of a parking lot and educational signage. While these are examples from mainland US, they can be adapted for Guam.

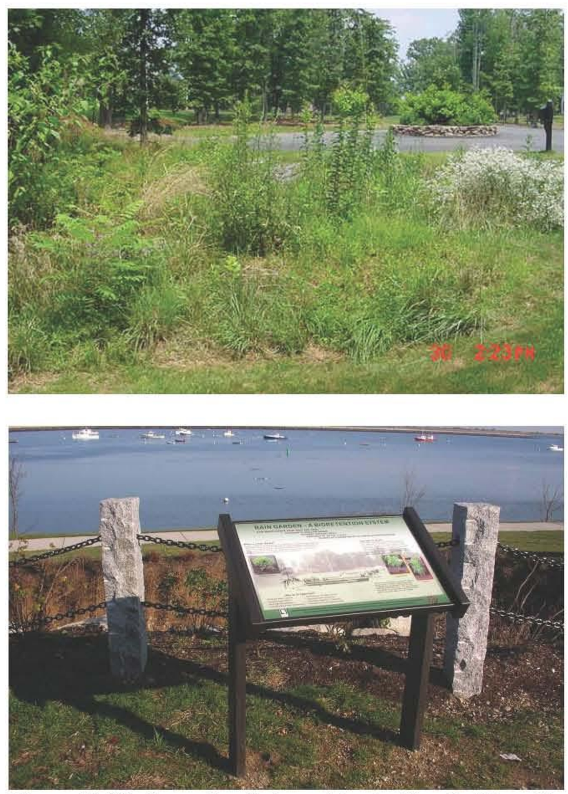

Figure D-18. Example of a large bioretention facility collecting runoff from a cul-de-sac and educational signage describing a rain garden along the waterfront (bottom).

ASAN MAYOR'S OFFICE/ COMMUNITY CENTER

Community bioretention/ rain gardens and native planting

Project Summary

Project Rank	High
Estimated Cost	Vaires ($ to $$)

Site Description

The proposed retrofit is located at the Asan Village Community Center/Mayor's Office on the corner of Nino Perdido and Jose Leon Guerrero Streets. There are a number of restoration opportunities here, including trash cleanup in the adjacent wetland and stream buffer, rain garden demonstration, native tree planting, and municipal pollution prevention.

Existing Conditions

Currently, there is no stormwater management on the site. Rooftop runoff is directed to the parking lot and road out front and into grassed areas in the back through internal roof leaders and below grade downspouts. When the facility is washed/cleaned, soaps and cleaning products are rinsed directly onto the parking lot (Figure D-19).

Between the river and the building is a drop off center for tires and other goods. The collection bin is self-contained; however there are piles of trash and debris in the riparian buffer (Figure D-20).

The small parking lot by the basketball court floods during rain storms, often leaving a large puddle near the exit. A swale running alongside the basketball court collects and conveys drainage from the surrounding area to a small wetland in the back, which ultimately outlets into an unnamed tributary. The wetland area is full of trash (Figure D-21).

Upslope from the ball court, there is an open area with no canopy cover and three large concrete pads.

Figure D-19. Rooftop downspout through curb and onto parking lot. Washwater drains to parking lot, which drains to river (top). Proposed rain garden location in rear where roof leaders open into grassed area (lower).

Figure D-20. Debris piles along river buffer.

Figure D-21. Water collects in small side parking lot. Install trench drain to convey water to existing swale (top photo). May need to excavate swale to appropriate depth for trench drain invert to achieve positive drainage. Enhance swale with vegetation (middle). Trash in wetland area (bottom).

Proposed Concept

A variety of opportunities exist at this location:

- Install a rain garden in the grassed area behind the building to capture rooftop runoff and serve an educational demonstration (Figure 19).
- Clean up trash in wetland area and along riparian buffer (Figure 20).
- Excavate and created an enhanced bioswale at the existing swale location along the basketball courts. Install a trench drain in side lot to convey runoff under the sidewalk and into the area. The bioswale should be enhanced with local vegetation (Figure D-22).
- Plant native trees in open area beyond ball court.
- Evaluate staff cleaning behaviors and waste/materials storage for any potential practices that may pollute stormwater (i.e., washing bleach water onto parking lot, having uncovered waste containers or collection bins without secondary containment).

Design Considerations

Grade and elevations of side lot may make getting runoff into swale difficult. Trench drain can have reverse slope, but swale may require additional excavation to obtain proper invert. The design should consider an appropriate method for crossing the existing sidewalk.

Install educational signage at rain garden and bioswale.

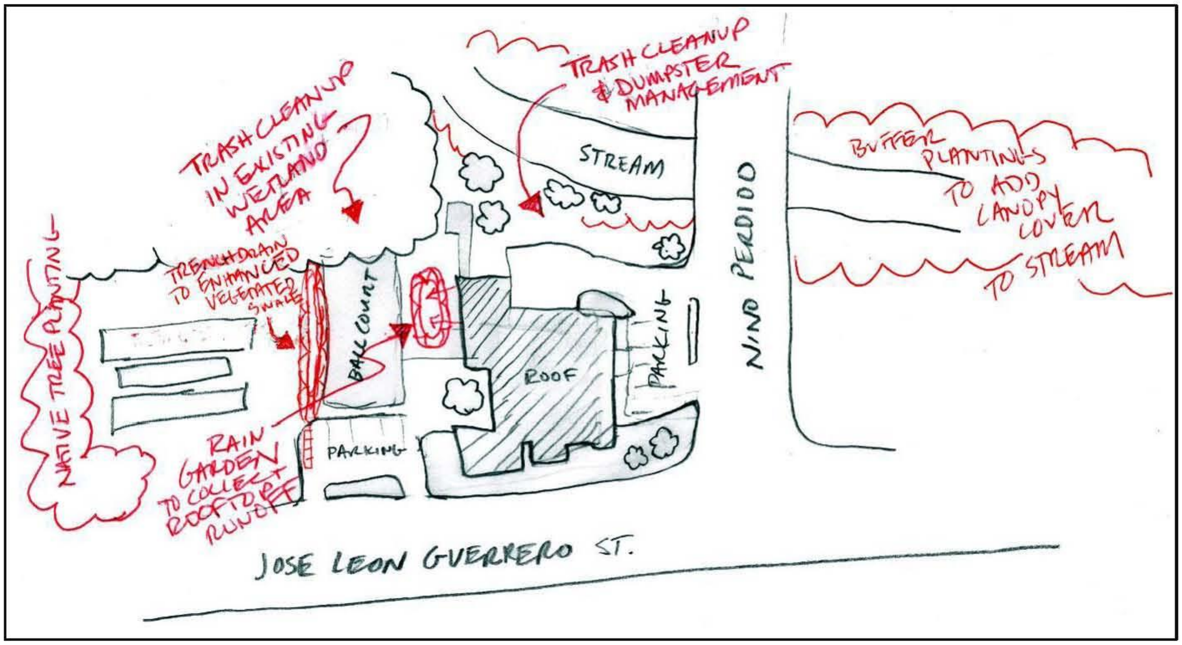

Figure D-22. Plan view sketch of various restoration opportunities at Asan Mayor's Office (conceptual – not to scale).

Example Projects

Figures D-23 and D-24 show examples of a rain garden and a trench drain. The rain garden for the Asan Community center should use local plants.

Figure D-23. Example of a small rain garden collecting rooftop runoff and accompanying signage explaining the benefits of this type of on-site stormwater management.

Figure D-24. Example of a trench drain that can be used to convey runoff from parking area to bioswale.

E: Best Management Practices *(Source: Minton, 2006)*

Table E-1. Best Management Practices (BMPs) to reduce erosion and soil loss in the Asan sub-watershed proposed by Minton (2006). The BMPS are relevant to the entire Piti-Asan watershed. The BMPs are ranked by environmental effectiveness (EE), cost, difficulty to install and maintain, political will to support, and public will to support as high (H), medium (M), and low (L). The total score was derived by assigning values H=5, M=3, and L=1 to EE, political will to support, and public will to support; and values H=1, M=3, and L=5 to cost and difficulty to install and maintain.

BMP	What it is/ What it does	Environ. Effect	Cost	Difficulty	Political Will	Public Will	Total Score
Fire Education	Educate on the impacts of fire, highlighting the environmental damage in a way meaningful to the public and lawmakers. This may convince the public to stop setting fires, to support other BMPs, or to seek legal action against those that burn. Eliminating all fires would lower erosion by ~7%.	M	M	H	L	L	17
Reforestation	Convert badlands to forest. The Guam Fire Department is currently attempting this in the Ugum watershed. This is a long-term project. Converting to Acacia trees is not a viable option for the National Park. Restoration of all badlands in the Asan sub-watershed would lower soil loss by ~18%. This is a long-term solution to badland erosion.	H	M	M	M	M	17
Enforcement of Construction Regulations	Developers and contractors are required to use environmentally sound practices, such as installation of sediment fences. These regulations are often ignored and are poorly enforced. Enforcement to ensure compliance would reduce erosion associated with construction sites	L	L	L	L	H	17
Restore Burned Savanna	Using well-established fire rehabilitation techniques, burned areas can be treated to reduce erosion rates and restore vegetation. While not a long-term solution to burning, this BMP would lower erosion rates associated with the burned savanna.	M	M	L	L	H	17
Coconut Fiber/ Erosion Cloth	Install erosion cloth over burned and badland areas to reduce soil erosion, This technique has been used with limited success to reduce erosion in the Fena watershed. This is not a long-term solution to badland erosion.	L	L	L	L to M	L to M	13-17
No Wet-Season Building	Erosion is highest during the wet season. Activities that remove vegetation or break ground should not be permitted to occur during the wet season. Construction permits should not be issued for any project that disturbs soil with a start between June and December.	L to M	L	L	L	L to M	13-17
Put Out All Fires	All fires will be aggressively pursued and extinguished. This will reduce the area of burned savanna and lower watershed soil loss by ~7%.	M	L	L	L to M	H	11-13
Ponding Basins	Ponding basins are essentially sediment basins installed at various locations within the watershed, wherever topography is appropriate. These slow water movement and reduce the likelihood of streambank erosion.	H	H	M	L	L to M	11-13
Install Anti-Erosion Vegetation	Revegetate badlands with anti-erosion plants such as vetiver grass. Restoration of all badlands in the Asan sub-watershed would lower soil loss by ~18%. This may be a long-term solution to badland erosion.	M	M	M	L	L	11
Ban Off-Road Vehicles/ Enforce	Off-road vehicles (ORV) contribute to erosion by destroying vegetation. Restricting the use of ORVs to appropriate areas would reduce their environmental impacts. Off-roading is not a significant issue in the Asan watershed but it is in other areas.	L	M	M	L	L to M	9-11
Badland Anti-Restoration	Convert badlands to native savanna vegetation. Methods do not currently exist. Restoration of all badlands in the Asan sub-watershed would lower soil loss by ~18%. This is a long-term solution to badland erosion.	M	M to H	H	L	L	7-9

Table E-2. BMPs to reduce sedimentation on Asan's coral reefs as proposed by Minton (2006). The BMPs are relevant to the entire Piti-Asan watershed. The BMPs are ranked by environmental effectiveness (EE), cost, difficulty to install and maintain, political will to support, and public will to support as high (H), medium (M), and low (L). The total score was derived by assigning values H=5, M=3, and L=1 to EE, political will to support, and public will to support; and values H=1, M=3, and L=5 to cost and difficulty to install and maintain.

BMP	What it is/ What it does	Environ. Effect	Cost	Difficulty	Political Will	Public Will	Total Score
Rainwater Catchment	Installing catchment systems on all buildings in Asan would capture stormwater before it entered streams and other drainages. Because of the watershed's steep terrain, land runoff could be captured in a large municipal tank for use as an emergency supply. This has the additional benefit of providing water to the village.	M	L	L	M	H	21
Sedimentation Education	Educate the public on the impacts of sedimentation on Guam's coral reefs. Use education to highlight the environmental damage in a meaningful way to the public (*e.g*., declining coral reef impacts on fisheries) and to teach about ways to reduce runoff and sedimentation.	M	M	H	L	L	17
Permeable Surfaces	All paved surfaces could be replaced with permeable materials or re-paved using techniques that enhance permeability. This would slow runoff water in urban areas and reduce laminar sheet flow. Less water would enter the drainage ways.	M	M to H	L	M	M	15-17
Install Asan River Sediment Basin	A sediment basin at the mouth of the Asan River would slow water movement and collect sediment. Basin would need continual maintenance dredging that should be conducted at the end of the dry season. Finding a suitable area to create the basin might be problematic.	H	H	M	M	L to M	13-15
Re-channel Storm Drainage on Route 1	The drainage system on Route 1 near Adelup Point should be re-designed so that water does not cascade down the cliff and directly into the ocean. Water should be channeled in a permeable canal to a sediment basin. Basin would need continual maintenance dredging that should be conducted at the end of the dry season.	L	M to H	L to M	M	M	11-15
Green Roof	Installing environmentally friendly green roofs slow runoff waters in urban areas and reduce laminar sheet flow. Less water enters the drainage system from Asan village.	L	L to M	L	L	L	11-13
Ponding Basins	Ponding basins are essentially sediment basins but they would be installed at various locations within the watershed, wherever topography is appropriate. These slow the movement and collect sediments. These would require maintenance dredging.	H	H	M	L	L to M	11-13
Remove impermeable channels	Riprap and concrete-lined drainage ditches should be replaced with permeable (*e.g*., green) surfaces. Storm drains should be replaced with green filter systems to slow the transport of rainwater. Systems should be developed to be effective with large storm events.	M	H	H	L	L	9
Create wanders in Asan River to slow water flow	Engineer additional bends in the Asan River to slow water movement and allow sediment to settle before reaching the ocean. Needs to be used in combination with the sediment basin which would need continual maintenance dredging that should be conducted at the end of the dry season.	M	H	H	L	L	9

F: Examples of Signage

Example of a watershed awareness billboard on the side of the road in Kolonia, Pohnpei. A similar billboard could be made for Guam, perhaps in coordination with the Guam Environmental Education Committee Public Outreach Campaign.

The environmental awareness signs recently popping up all over the island are eye-catching, attractive, and convey good messages. Marine Mania, an environmental club at George Washington High School, created the signs as part of a national competition. Similar signs could be made for watershed awareness in collaboration with Marine Mania or other school clubs such as Guam Community College's Eco-Warriors. This way the making of the billboards would also be educational.