Draft Environmental Impact Statement

Infrastructure Improvements at the Yap International Airport and the Yap Seaport

Yap State, Federated States of Micronesia

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Appendix O
Wetland and Mangrove Study (2026)

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Wetland Delineation and Mangrove Assessment for Proposed Infrastructure Improvements on Yap Island, FSM

Jacob F. Berkowitz, Krystyna Powell, Daniel M. Savercool, Joney Rengiil, Matt Blanchard, Jaybus Price

April 2026

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Abstract

Wetland delineations identify the locations of wetlands and document wetland boundaries. Delineation data can help prioritize areas for conservation and restoration and guide the development of roads, buildings, and other infrastructure. The following wetland delineation utilized a combination of offsite data analysis and field data collection at over 20 locations to delineate wetlands within five priority areas and lands near the Yap International Airport. The wetland study identified an estimated 32.62 acres of wetlands, including 28.78 acres of wetlands with connections to permanent or semipermanent surface waters. The study identified opportunities to increase wetland functions through management activities including restoration of areas subject to stream incision and head cutting, vegetation management, and other actions.

In addition to the wetland delineation, mangroves were assessed at several priority mangrove areas in the vicinity of the airport and seaport. Mangrove assessments include quantitative, semi-quantitative, and qualitative evaluations of mangrove species composition and indicators of forest maturity and health. Results indicate that a range of mangrove conditions is present within the priority areas, including mature and robust mangrove forests near the airport as well as areas of very sparse mangrove density in some locations near portions of the proposed seaport project footprint. Mangrove forest data is presented to provide a baseline for potential future monitoring and adaptive management. Collectively, the wetland delineation and mangrove assessment inform potential activities associated with infrastucture improvements under consideration in the study area, including the development of National Environmnetal Policy Act (NEPA) documents.

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Preface

This study was conducted for the US Army Corps of Engineers (USACE), under MIPR W58Y7V53085787. The technical monitor was Ms. Michelle Ogman, Project Manager, USACE Honolulu District. Rhonda Lucas and Justine Kmiecik (USACE Honolulu District), Matthew Welsh and Jason Stolfer (Environmental Planning/Natural Resources Program Supporting AFIMSC DET 2/CEV), and Dwayne French (U.S. Army Engineering and Support Center Huntsville) assisted with field data collection and logistics.

The work was performed by the Wetlands and Coastal Ecology Branch of the Ecosystem Evaluation and Engineering Division, US Army Engineer Research and Development Center–Environmental Laboratory (ERDC-EL). At the time of publication, Mr. Bobby McComas was branch chief; Mr. Will Jones was acting division chief. The deputy director of ERDC-EL was Dr. Brandon Lafferty, and the director was Dr. Edmond Russo.

LT COL Joshua Haynes was commander of ERDC, and Dr. Elizabeth Fleming was the director.

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1.0 Background and Objectives

Engineer Research and Development Center (ERDC) staff conducted a wetland delineation and mangrove assessment of priority areas associated with the airport and seaport on Yap Island, FSM in support of the United States Army Corps of Engineers (USACE) Honolulu District, the Naval Facilities Engineering Systems Command Marianas, and the Airforce Installation and Mission Support Center (Figure 1). The following report provides a description of the sampling and analysis approach, a summary of findings, maps of sample locations depicting the spatial extent of wetland features, field data, representative site photographs, and other supporting information. The report is organized in two sections, the first of which addresses the wetland delineation and the latter of which presents the results of the mangrove assessment.

The wetland delineation is designed to support land use planning-level analyses and to inform potential additional wetland and natural resources surveys. The mangrove assessments provide baseline data in support of potential future monitoring and adaptive management.

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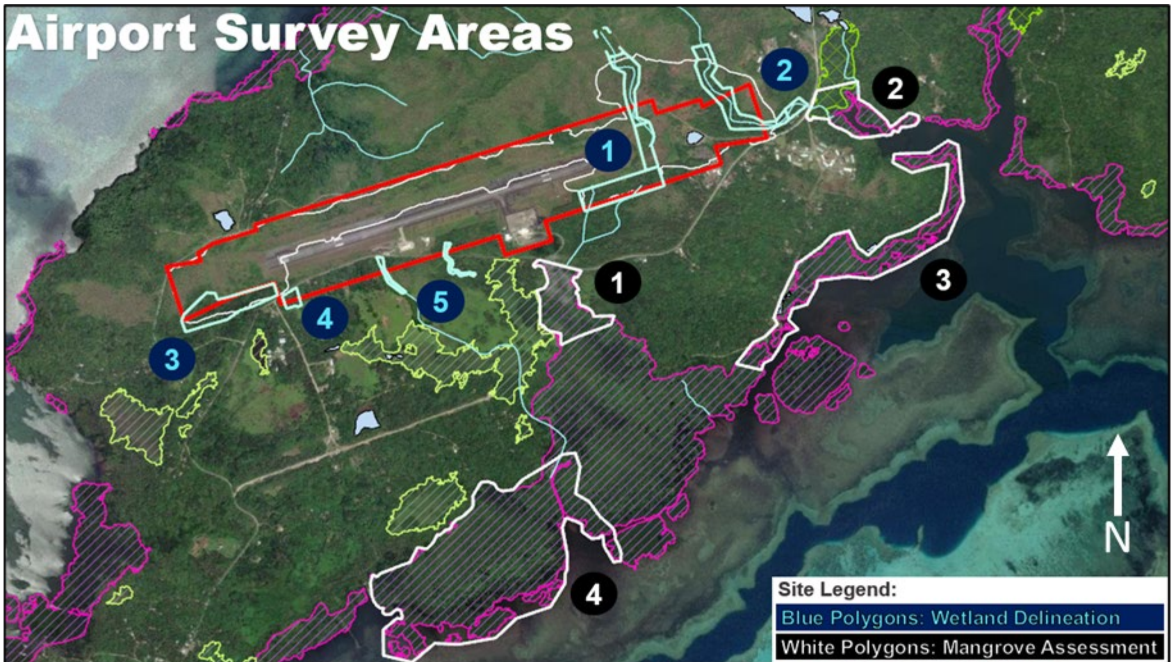
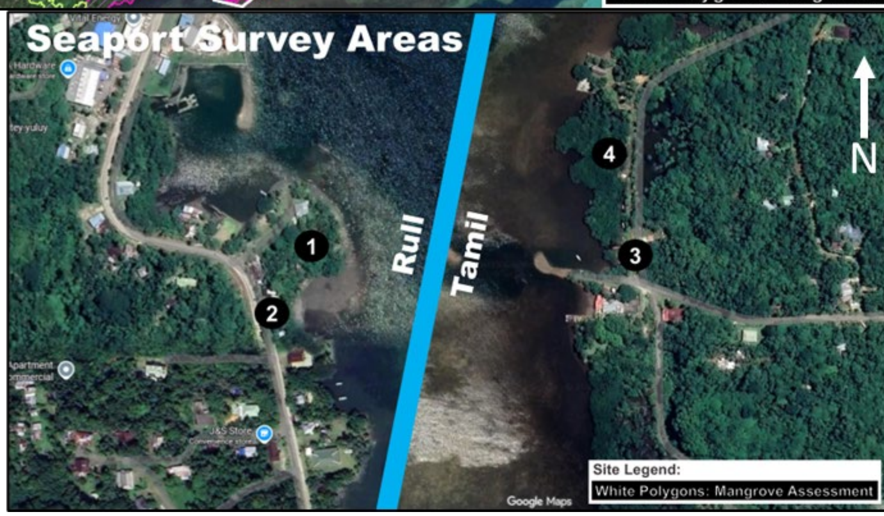




2.0 Approach - Wetlands

The team conducted field investigations during November 2025 to document wetland conditions within the limits of the priority areas and adjacent areas. Thirty locations were evaluated for the presence of hydrophytic vegetation, wetland hydrology, and hydric soils as described in the USACE *Wetland Delineation Manual* (Environmental Laboratory 1987) and the *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Hawaii and Pacific Islands Region* (Version 2.0; USACE 2012). This included the application of Field Indicators of Hydric Soils based on depth of soil layers, soil color, texture, and the presence of redoximorphic features; observation of primary and secondary indicators of wetland hydrology such as the presence of standing water, water stained leaves, and geomorphic position; and evaluation of plant indicator status ratings of dominant species as defined in the 2022 National Wetland Plant List (USACE 2023). All data sheets and representative site photos are provided in the Appendix. The field data, in combination with analysis of offsite information, was used to delineate the estimated spatial extent of wetlands within the priority areas and surrounding lands. Additionally, isolated wetlands were mapped near a borrow area and an area behind a berm near the end of the runway.

Off-site sources of information and data were reviewed prior to the initiation of all field investigations to identify target areas for on-site data collection and increase efficiency of the delineation. Data included the Natural Resources Conservation Service Web Soil Survey (Soil Survey Staff 2026) and a variety of open-source aerial photographs and images. Imagery and maps including publicly available sources and Unmanned Aerial Survey collected in and around the project area were reviewed to locate areas of standing water, areas displaying saturated soil conditions, and vegetation characteristic of riparian areas and floodplain wetlands.

The following materials were used to conduct the field investigation:

- USACE Wetland Delineation Manual (Environmental Laboratory 1987)
- Regional supplement to the Corps of Engineers Wetland Delineation Manual: Hawai‘i and Pacific Islands Region (Version 2.0; USACE 2012)
- Munsell Color Chart (Munsell Color 2000)
- Field Indicators of Hydric Soils in the United States, Version 9.2. (USDA 2025)
- Web Soil Survey (Soil Survey Staff 2026)
- National Wetlands Inventory (NWI) (USFWS 2018)
- The National Wetland Plant List (USACE 2020)

Wetland mosaics are areas where wetland and non-wetland components are too closely associated to be easily delineated or mapped separately (USACE 2012). These areas often have complex microtopography, with repeated small changes in elevation occurring over short distances. Tops of ridges and hummocks are often non-wetland but are interspersed throughout a wetland matrix having clearly identifiable hydrophytic vegetation, hydric soils, and wetland hydrology. Examples of wetland mosaics in the project area include ridge-and-swale topography on floodplains; areas that exhibit alteration from agricultural or silvicultural operations (including taro operations); areas containing numerous connected pools; areas where wind-thrown trees have created microtopographic relief, pit-and-mound, or cradle and knoll topography. Notably, a number of wetland mosaics associated with impact craters were encountered during field data collection and are included in the mapping results detailed below. Due to the potential for impacts to wetlands in areas exhibiting wetland mosaics, the maps generated with the priority areas were conglomerated into contiguous wetland features for the purposes of this report.

Wetland delineations can be impacted by both anthropogenic activities that alter environmental conditions (i.e., altered wetlands) and by naturally occurring conditions that pose challenges to determining wetland boundaries (i.e., problematic wetlands). The procedure for conducting delineations under these difficult wetland scenarios was applied in accordance with the guidance outlined in chapter five of the regional supplement (USACE 2012). Landscape disturbances from agricultural practices, silvicultural operations and historic impact craters (and other World War II activities) were the most commonly altered wetland situations encountered during the field investigations (Figure 2). Additionally, stream incision and head cutting were observed in some areas, potentially altering wetland hydropatterns (Figure 3). Most of these stream channel degradations were likely associated with some anthropogenic activity or feature (i.e., road crossing). Some disturbed and altered areas may not reflect the normal circumstances with regards to the plant community composition or wetland hydrology. However, the extent and severity of disturbances observed within the priority area did not alter the outcomes of the wetland delineation.

Figure 2. Altered wetland vegetation embedded within an active Taro patch.

Figure 3. Example of incised channel with head cut area within a narrow wetland and stream network.

2.1 Results – Wetlands

The following describes the wetland types (i.e., classes) and characteristics encountered during the delineation, and reports information on the vegetation, soils, and hydrology of the project area. Additionally, maps of each priority area are presented in addition to summary information about the estimated spatial extent of wetlands within the priority areas. All wetland delineation data forms are provided in the Appendix, along with representative photos of each data collection location.

2.2 Results – Wetland classification

Various wetland classification schemes have been developed to communicate similarities and differences across wetland types, assess wetland functions and conditions, and support a variety of management activities such as restoration, conservation planning, and land-use. For example, the hydrogeomorphic (HGM) approach to wetland classification has proven useful, because it integrates landscape position, hydrology, and hydrodynamics with structural indicators of ecological functions (Smith et al. 2013). The approach designates wetlands as riverine, depressional, slope, flat, or fringe classes, all of which were encountered during the delineation. The National Wetland Inventory (NWI) classification system is also applicable in the project area and can be readily linked with the NWI mapping tools where available (Cowardin et al. 1979). To communicate the general findings of the wetland delineation, the subsequent paragraphs detail the wetland NWI classes observed during the on-site evaluation. Additionally, the ecological functions and characteristics associated with each wetland class are described by integrating elements of both the HGM and NWI wetland classification systems.

Riverine wetlands—The observed riverine wetlands in the project area were found in floodplains adjacent to small rivers and streams. The river channels and adjacent floodplains are inundated following large rain events when water overflows the banks, or when downstream discharge capacity is exceeded inducing backwater flooding (Figure 4). These wetlands may become dry during low rainfall and runoff portions of the year especially during periods of drought. Riverine wetlands in the survey area, occurring across a gradient of headwater streams, creeks, and larger rivers. The ecosystem functions provided by riverine wetlands are described below.

- Habitat—Many fish and animals use floodplains as sources of food and shelter; they are critical rearing habitat for sport fishes, amphibians and waterfowl.
- Water quality—Floodplains help to remove excess nutrients and pollutants from waterways, reducing the transport of harmful compounds downstream.
- Groundwater recharge—Floodplains facilitate the transport of surface water into the water table, supporting base flow conditions and contributing to aquifers and groundwater used for drinking water and agriculture.
- Flood risk reduction—Riverine wetlands decrease the velocity of water and provide temporary storage of precipitation and floodwater. This decreases flood severity and extent to downstream areas. As a result, areas with healthy, intact floodplains experience less flood damage than areas in which the floodplain has been altered.

The following details are general characteristics of the riverine wetlands encountered during the wetland delineation.

- Landscape setting—Riverine wetlands in the project area exhibited relatively flat to gently sloping topography and occur adjacent to small river, and stream networks.
- Water sources—A combination of precipitation, flooding, and localized runoff support these wetlands and the ecosystem functions they provide.
- Hydrodynamics—When high flows occur, surface water moves out of a river's banks and across the floodplain. This can result from backwater or headwater flooding. Riverine wetlands lose water via the return of floodwater to the channel after flooding, through surface flow during rainfall events, by groundwater discharge to the channel, by water moving into deep groundwater storage, and through evapotranspiration. Some riverine wetlands in the project area may lack flowing surface water during dry periods.
- Ecological setting—Riverine wetlands in the project area included forested, shrub-scrub, and emergent wetlands that occur within the active river floodplain. However, the majority of riverine wetlands encountered were associated with forested areas. Vegetation types varied widely in these dynamic ecosystems, but several of the riverine wetlands evaluated were characterized by mature forests that provide habitat for a wide array of other species.
- Threats—Channel alterations, roads and other infrastructure have impacted riverine wetlands in the project area.

Figure 4. Example of a riverine wetland within the project area.

Depressional and fringe wetland habitats—These wetlands occur in low lying depressions and fringes along the border of pools and ponds. These habitats are saturated or inundated by water that accumulated in areas of lower topographic relief than the surrounding landscape where runoff accumulates (Figure 5). Some depressional and fringe wetlands stay saturated most of the year, but these ecosystems may also become dry during drought periods or when seasonal drawdown occurs as the result of evapotranspiration. The ecosystem functions provided by depressional and fringe wetland habitats are described below.

- Habitat—Many fish and animals use wetlands in depression and fringe wetlands for shelter and food. These areas can be dominated by herbaceous vegetation (often in fringes) but may also contain woody trees and shrubs (many depressions). They are important rearing habitat for fishes, birds, amphibians, and reptiles such as turtles.
- Water quality—Depressional and fringe wetlands are important for nutrient cycling, and these areas remove or retain excess sediment, nutrients, and pollution from the environment to improve water quality.
- Flood risk reduction—Depressional and fringe wetlands intercept runoff from the surrounding landscape, providing temporary storage of precipitation and floodwaters. This decreases flood severity and extent to downstream areas. Communities that maintain healthy depressions, lake and pond ecosystems store more water and experience less flood damage than areas with altered depressional and fringe wetlands.

The following details are general characteristics of the depressional and fringe wetlands encountered during the wetland delineation.

- Landscape setting—Depressional and fringe (lacustrine) wetland habitats in the project area are found in low-lying areas and adjacent to pools and ponds.
- Water sources—The water elevation of the pool/pond maintains the water table in fringe wetlands. Precipitation, flooding, and runoff are supplemental water sources in fringes and provide the dominant sources of water to depressions.
- Hydrodynamics—Surface water flow is bidirectional, usually controlled by water-level fluctuations induced by runoff from the surrounding area. Depressional and fringe wetlands lose water via groundwater infiltration and evapotranspiration.
- Ecological setting—Depressional and fringe wetland plant community types vary and can be dominated by emergent wetland species or flood tolerant woody species. In some cases, the composition of depressional and fringe wetland vegetation changes during the year as water elevations increase during high precipitation periods followed by progressively lower water tables during drier periods.
- Threats—Development of infrastructure that places fill materials into depressional and fringe wetlands, sedimentation, and pollution from urban and agricultural runoff are the primary threats for these wetland types.

Figure 5. Examples of emergent (borrow area; left) and forested (impact crater; right) depressional wetlands within the project area.

Forested wetland habitat—Forested wetlands are abundant across a variety of landforms in the project area. The observed forested wetlands in the project area were found on floodplains, slopes, and depressional areas (Figure 6). The ecosystem functions provided by forested wetland habitats are described below.

- Habitat—These productive ecosystems are inhabited by a diverse assemblage of plants and animals that use the forests as a source for nourishment, shelter, and as breeding and rearing areas.
- Water quality—Forested wetlands help remove excess nutrients and pollutants from water, reducing the transport of harmful compounds into groundwater, and surface waterways.
- Flood risk reduction—Forested wetlands decrease the velocity of surface water, retain sediments, and provide temporary storage of precipitation and floodwater. This decreases flood severity and extent to downstream areas.

The following details are general characteristics of the forested wetland habitats encountered during the wetland delineation.

- Landscape setting—Forested wetlands in the project area exhibit relatively flat to gently sloping topography and occur in floodplains, flats, depressions, and headwater slope systems. These wetlands are found in areas of low topography that receive floodwaters, runoff from local precipitation, and groundwater inputs from the larger surrounding area.

- Water sources—A combination of precipitation, runoff, groundwater discharge, and flooding support these wetlands and their ecosystem functions.
- Hydrodynamics—Forested wetlands in the project area are diverse, spanning a wide range of landscape features. As a result, hydrodynamics can be driven by headwater seepage, accumulation of direct precipitation in areas with limited topography, or flooding.
- Ecological setting—Vegetation types vary widely in these dynamic ecosystems, but forested wetlands are characterized by woody species that develop into forests in the absence of disturbance, that provide habitat for many species.
- Threats: Alteration to wetland hydrology, development (infrastructure and agricultural), roads and other infrastructure have impacted forested wetlands in the project area.

Figure 6. Examples of forested wetland habitats within the project area.

2.3 Results - Hydrophytic vegetation

The following section describes common wetland plant communities observed during field investigations. These descriptions are not designed to be exhaustive, but to provide general context for the wetland delineation. Most of the wetlands encountered in the priority areas were characterized by dense vegetation, with canopy cover commonly higher than 75% and often approaching or exceeding 100% due to overlapping foliage (Figure 7). Woody vegetation was dominated by the tree and sapling strata, with lower abundances of herbaceous plants on the forest floor. Hydrophytic vegetation communities were identified using the Dominance Test, wherein greater than 50% of vegetative cover was composed of dominant plant species with wetland plant indicator status ratings of Facultative, Facultative Wetland, or Obligate (Table 1). Prevalence Index scores were also calculated but did not alter any hydrophytic vegetation outcomes.

Figure 7. Examples of hydrophytic vegetation communities in the wetland delineation area.

Table 1. Summary of hydrophytic vegetation, wetland hydrology†, and hydric soils†† indicators observed within the wetland delineation area. *Hydrology indicators in italics are secondary indicators.

	Hydrophytic vegetation Indicators			
	Dominance test score	Prevalence index score	Wetland hydrology indicators	Hydric soil indicators
Wetland 1	80	3.2	A1, A2, B9, *B10*, *D2*	F3, F8
Upland 1	65.2	4.62	B8	NIM
Wetland 2	66.7	3.85	A2, A3, B1, B2, B5, *B8, B10, D2, D5*	F3, F8
Upland 2	66.7	3.43	NIM	F3
Wetland 3	50	4.07	A2, A3, B1, B3, B9, C4, *B10, D2*	A11, F3, F8
Upland 3	50	4.12	NIM	NIM
Wetland 4	40	4.06	A2, B9, *B10, D2*	F3, F8
Upland 4	37.5	3.5	NIM	NIM
Wetland 5	100	2.78	A1, A2, A3, B4, C4, *B10, D2, D3, D5*	F3, F8
Wetland 6	100	2.62	A3, B3, B9, *B10, D2, D5*	
Upland 6	71.4	2.97	NIM	NIM
Wetland 7	100	3	A1, A2, C4, *B10, D2*	F3, F8
Wetland 8	66	3.16	A1, A2, A3, B9, C4, *B10, D2*	F3, F8
Wetland 9	100	1.3	A1, A2, A3, B5, C4, *B10, D2, D5*	F3, F8
Wetland 10	0	3.63	A1, A2, A3, B4, B7, C4, C7, *D2, D3*	A8, F3, F8
Wetland 11	100	1.95	B2, *B10, D2, D5*	F3
Upland 11	100	2.32	*D5*	NIM
Wetland 12	100	1.06	A2, A3, *B10, D2, D5*	F3, F8
Wetland 13	100	2.56	A2, A3, B9, *B10, D2, D5*	A11, F3, F8
Upland 13	75	2.86	NIM	NIM
Wetland 14	75	2.29	A2, A3, B5, B9, C4, *B10, D2, D5*	F3, F8
Upland 14	62.5	3.3	NIM	NIM
Wetland 15	40	3.57	B2, B3, *B10, D2*	F3
Ephemeral upland drainage	50	4.11	*B10*	NIM
Wetland 18	75	2.63	A2, A3, B1, B3, B5, B9, C4, *B10, D2, D5*	F3, F8
Wetland 19	0	4	A2, A3, B1, B3, B5, B9, C4, *B10, D2*	F8
Wetland 20	100	1	A2, A3, B9, C4, *B10, D2, D5*	A11, F3, F8
Wetland 21	60	3.35	A2, A3, B9, *B10, D2*	F8
Wetland 22	42.9	3.06	B1, B2, B3, B9, *B10, C3, D2, D5*	F3, F8

†Surface water (A1), High water table (A2), Saturation (A3), Water marks (B1), Sediment deposits (B2), Drift deposits (B3), Algal mat or crust (B4), Iron deposits (B5), Inundation visible on aerial imagery (B7), Water stained leaves (B9), Oxidized rhizospheres along living roots (C3), Presence of reduced iron (C4), Thin muck surface (C7), Sparsely vegetated concave surface (B8), Drainage patterns (B10), Geomorphic position (D2), Shallow aquitard (D3), FAC neutral test (D5)

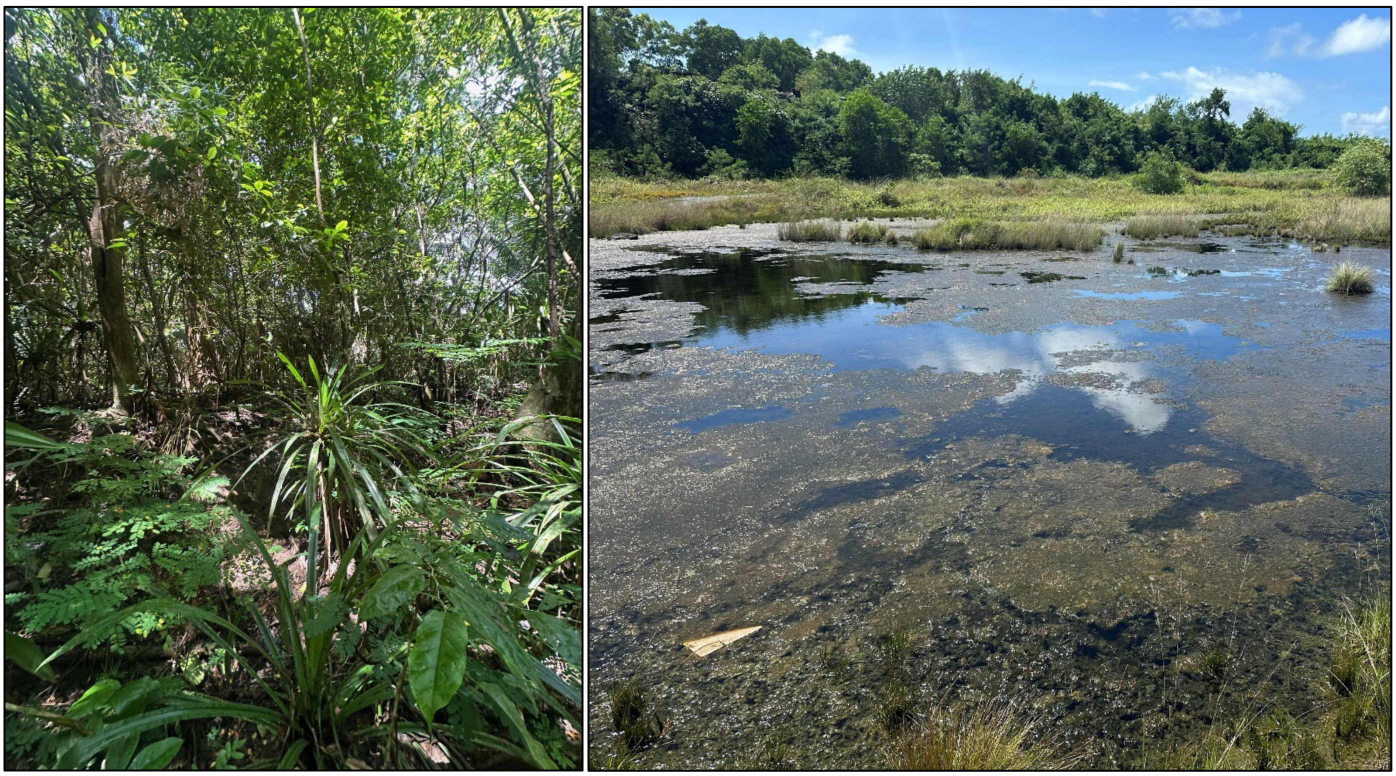
††Depleted Below Dark Surface (A11), Reduced Matrix (F3), Redox Depressions (F8), Muck Presence (A8)

Frequently encountered dominant species observed in wetlands included *Pandanus tectorius*, *Hibiscus tiliaceus*, *Campnosperma brevipetiolata*, *Bruguiera gymnorrhiza*, *Cyrtosperma merkusii*, and *Scleria polycarpa*. Note that six wetland areas (Wetlands 3, 4, 10, 15, 19, and 22) failed to meet a hydrophytic vegetation indicator but were determined to be wetlands based on the presence of wetland hydrology and hydric soils in conjunction with appropriate landscape positions, and the presence of upland vegetation occupying higher elevation 'hummocks' (small, raised areas) interspersed within several wetland areas (Figure 8). This approach aligns with the "Difficult Wetland

Situations" portion of the wetland delineation guidance which recognizes that some non-wetland species occur in wetlands. Wetlands 3 and 4 included *Trichosperma ikutai*, Wetland 15 included *Pandanus yapenis*, Wetland 19 included *Centotheca lappacea* and *Elephantopus mollis*, and Wetland 22 included *Cocos nucifera* as non-wetland dominant species. The vegetation community surrounding Wetland 10 was a heavily disturbed managed plant community surrounding a roadside borrow area or gravel pit (Figure 8).

Full descriptions of wetland plant communities are provided in the data forms within the Appendix, including the identification of dominant plant species used to document the presence of hydrophytes within each wetland boundary. Additional detailed information regarding wetland vegetation on Yap Island can be found in Falanruw et al. (1987).

Figure 8. Examples of wetlands that failed to exhibit hydrophytic vegetation due to the presence of dominant non-wetland plants or disturbance.



2.4 Results - Hydric soils

Hydric soils within the wetland delineation priority areas exhibited depleted matrices, common to many redoximorphic features, and other hydromorphic features associated with wetland soils elsewhere in the Pacific Basin (Figure 9). The soils were predominantly composed of loamy/clayey textures. Organic soil horizons were infrequent, and when encountered were restricted to thin surficial layers within the wetland delineation area. However, thick organic layers did occur in the mangrove assessment areas described in subsequent sections of this report. Field indicators of Hydric Soils, identifiable soil morphologic patterns indicative of anaerobic conditions, were readily observable within each wetland area evaluated. The most commonly encountered field indicators included F3 - Depleted Matrix and F8 – Redox Depressions (USDA-NRCS, 2025). Additionally, indicators A11 Depleted Below Dark Surface was documented at three locations and A8 – Thin Muck Surface were observed at one heavily disturbed area with compacted soils (Wetland 10).

No problematic hydric soil situations were encountered during the study, and the application of the Field Indicators of Hydric Soils (USDA 2025) proved effective for identifying hydric soils on Yap Island. One location (Upland 2) exhibited hydric soil indicator F3 – Depleted Matrix, but lacked all indicators of wetland hydrology. While soils in that location appear to have formed under anaerobic conditions, changes in local stream channel morphology and hydrodynamics (i.e., incision and downcutting) likely disconnected the area from contemporary inundation or saturation. Additionally, Upland 2 was dominated by Facultative plants suggesting a potential shift towards drier conditions near the wetland-upland boundary.

Figure 9. Examples of hydric soils observed in the study area.

The U.S. Department of Agriculture, Natural Resources Conservation Service, Web Soil Survey is available within the project area (Figure 10). Mapped soil series classified as hydric soils within the areas evaluated included the Gitman very gravelly silty clay loam and the Dechel mucky silt loam. While the presence of wetlands generally corresponded to the extent of mapped hydric soils, inclusions of wetlands with hydric soils were observed in some areas mapped as Gagil silty clay loam, likely as the result of limitations related to the scale of the available soil maps. The hydric soil rating by map unit data is presented in Figure 11.

Figure 10. Soil survey data for the wetland delineation area (Soil Survey Staff 2026).

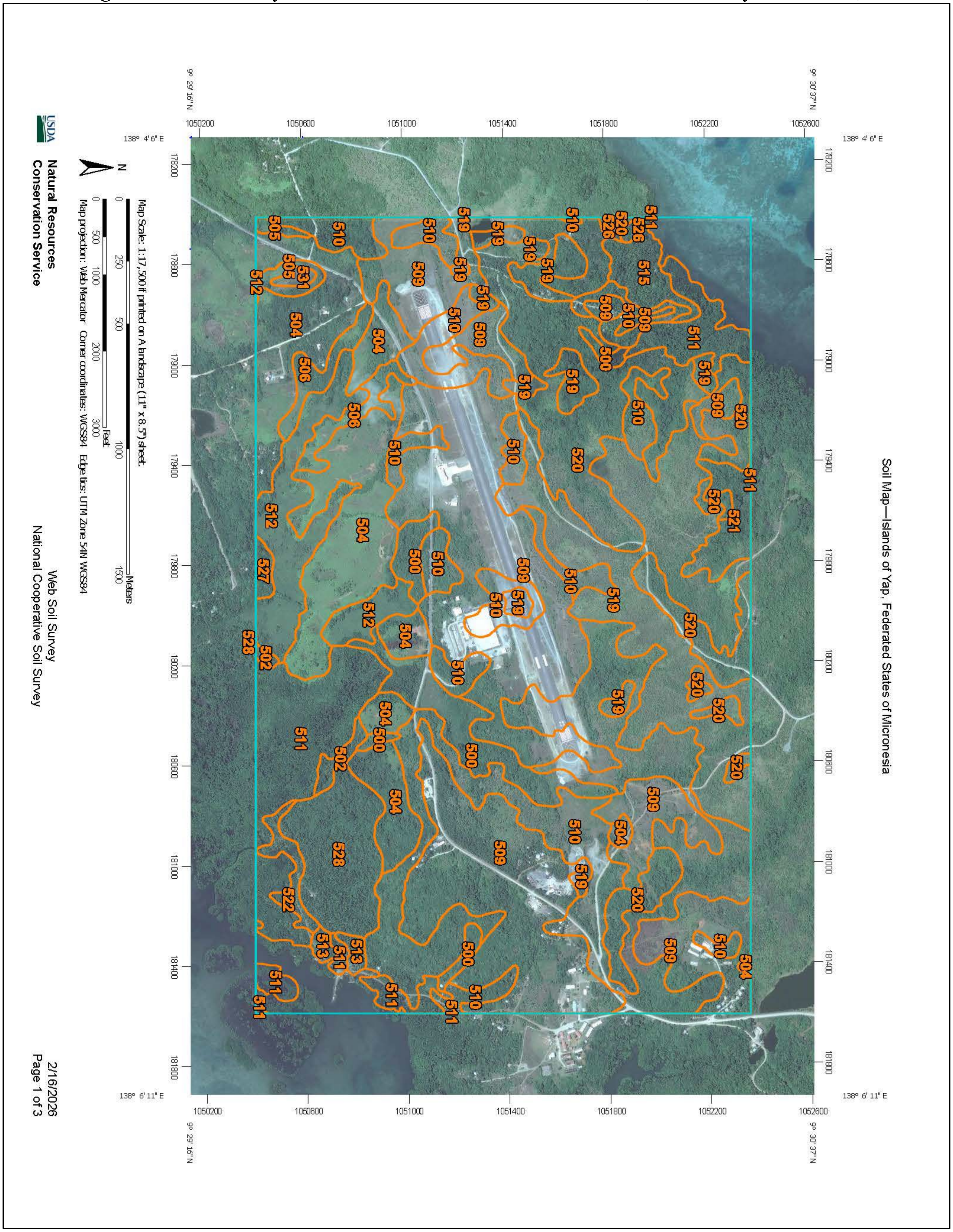
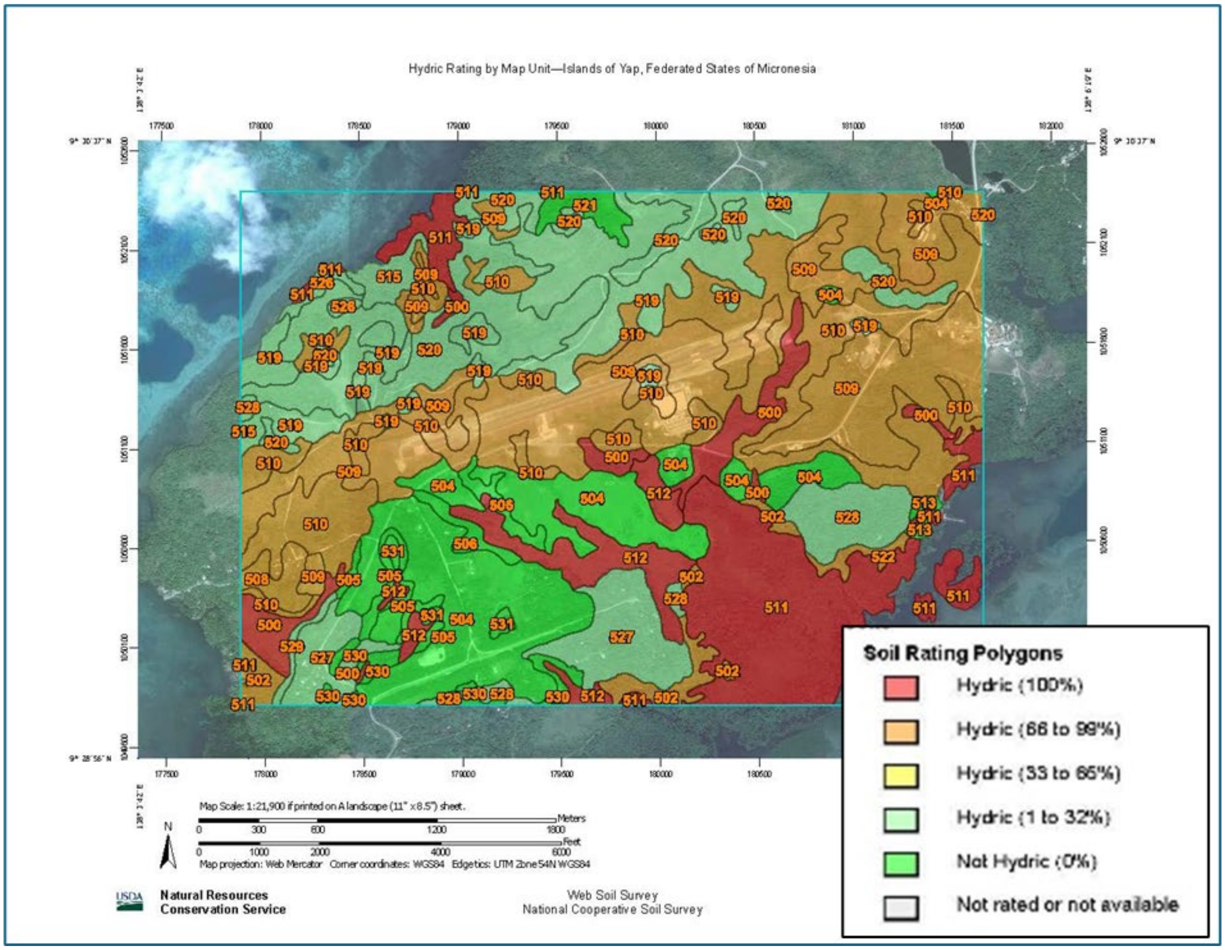


Figure 10. Continued.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
500	Dechel mucky silt loam, 0 to 2 percent slopes, frequently flooded	49.0	3.2%
502	Dublon taxadjunct sandy clay loam, 0 to 4 percent slopes, occasionally flooded	5.7	0.4%
504	Gagil silty clay loam, 2 to 6 percent slopes	167.7	10.9%
505	Gagil silty clay loam, 6 to 12 percent slopes	7.0	0.5%
506	Gagil silty clay loam, 12 to 30 percent slopes	21.0	1.4%
509	Gitam very gravelly silty clay loam, 2 to 6 percent slopes	362.0	23.5%
510	Gitam very gravelly silty clay loam, 6 to 12 percent slopes	277.9	18.0%
511	Ilachetomel peat, 0 to 1 percent slopes, frequently flooded	100.3	6.5%
512	Mesei mucky peat, 0 to 1 percent slopes, frequently flooded	56.9	3.7%
513	Ngedebus sand, 0 to 4 percent slopes, occasionally flooded	5.2	0.3%
515	Ngersuul silty clay loam, 2 to 8 percent slopes, rarely flooded	16.0	1.0%
519	Rumung-Weloy complex, 12 to 30 percent slopes	177.7	11.5%
520	Rumung-Weloy complex, 30 to 50 percent slopes	164.5	10.7%
521	Rumung-Weloy complex, 50 to 75 percent slopes	16.5	1.1%
522	Sonahnpil variant extremely gravelly silt loam, 0 to 4 percent slopes, occasionally flooded	8.3	0.5%
526	Weloy-Rumung complex, 2 to 12 percent slopes	2.4	0.2%
527	Yap silty clay loam, 0 to 2 percent slopes	3.5	0.2%
528	Yap silty clay loam, 2 to 6 percent slopes	46.9	3.0%
531	Water	2.3	0.1%
Totals for Area of Interest		**1,541.7**	**100.0%**

Figure 11. Hydric soil rating by map unit for the study area.



2.5 Results - Wetland hydrology

Indicators of wetland hydrology include observations of surface water or saturated soils, evidence of recent inundation, evidence of current or recent soil saturation, and other site conditions indicative of wetland hydropatterns (USACE 2012). Eighteen wetland hydrology indicators were documented within the priority areas, including at least one primary or two secondary indicators within each wetland delineation area (Figure 12). High water tables, soil saturation, and water-stained leaves were most commonly observed primary indicators, along with secondary indicators such as drainage patterns, geomorphic position, and the FAC neutral test (Table 1, 2).

Wetland hydrologic conditions were considered normal during the data collection period, because the site visits occurred near the end of the wettest season when antecedent soil moisture levels are anticipated to be high. Most surface water features (including stream channels, depressions, and ephemeral drainages) contained water during the site visits and soil saturation was documented at the majority of the wetland locations.

Figure 12. Examples of wetland hydrology indicators observed in the study area including: Surface water (A1), High water table (A2), Saturation (A3), Presence of reduced iron (C4), Drainage patterns (B10), and Geomorphic position (D2).

Table 2. Frequency of wetland hydrology indicators observed within wetland delineation areas

Surface water (A1)	6
High water table (A2)	16
Saturation (A3)	14
Water marks (B1)	5
Sediment deposits (B2)	4
Drift deposits (B3)	6
Algal mat or crust (B4)	4
Iron deposits (B5)	4
Inundation visible on aerial imagery (B7)	1
Water stained leaves (B9)	10
Oxidized rhizospheres along living roots (C3)	1
Presence of reduced iron (C4)	7
Thin muck surface (C7)	1
Sparsely vegetated concave surface (B8)	1
Drainage patterns (B10)	20
Geomorphic position (D2)	20
Shallow aquitard (D3)	2
FAC neutral test (D5)	12

2.6 Wetland Boundary Delineation

The on-site investigations verified the presence of wetlands, which occupied a total of 32.62 acres including areas of wetland mosaics. The spatial extent and percent coverage by wetlands, including wetland mosaics, is shown in Table 3. Within the priority areas, the delineated extent of wetlands occupied 28.78 acres.

Areas delineated as wetland mosaic occupied approximately 5.87 acres of priority area 3 and included areas of high microtopographic relief where distinct wetland boundaries were difficult to establish. These features are sometimes described as “hummock and hollow” in other regions where convex features that lack one or more wetland indicators are embedded with concave features that meet all required wetland criteria. In particular, the presence of extensive cratering within priority area 3 resulted in the decision to delineate the mosaic features as wetlands. Wetland maps for each priority area are shown in Figures 13-18.

Table 3. Summary of wetland documented extents within the study area.			
Priority area identifier	Area surveyed (ac)	Wetland extent (ac)	Percent of priority area (%)
1*	26.75	12.82	47.9
2	14.92	7.53	50.5
3	14	5.87	41.9
4	1.77	1.06	59.9
5**	2.46	1.5	61.0
Priority area totals	59.9	28.78	48.1
Non-priority areas			
5`	NA	0.35	NA
Borrow area	NA	2.04	NA
End of runway area	NA	1.8	NA
Non-priority area totals	NA	4.19	
Grand total		32.97	

*Priority area 1 includes two wetland features, a smaller 1.37 acre wetland to the south of the runway and a larger 11.45 acre wetland on the east side of the runway.
**Priority area 5 includes two wetland features, a larger 1.05 acre wetland to the west and a smaller 0.46 acre wetland to the east.

Figure 13. Overview of connected wetlands (green polygons) and isolated wetlands (pink polygons) identified within the project area. Priority survey area boundaries are denoted with red outlines.

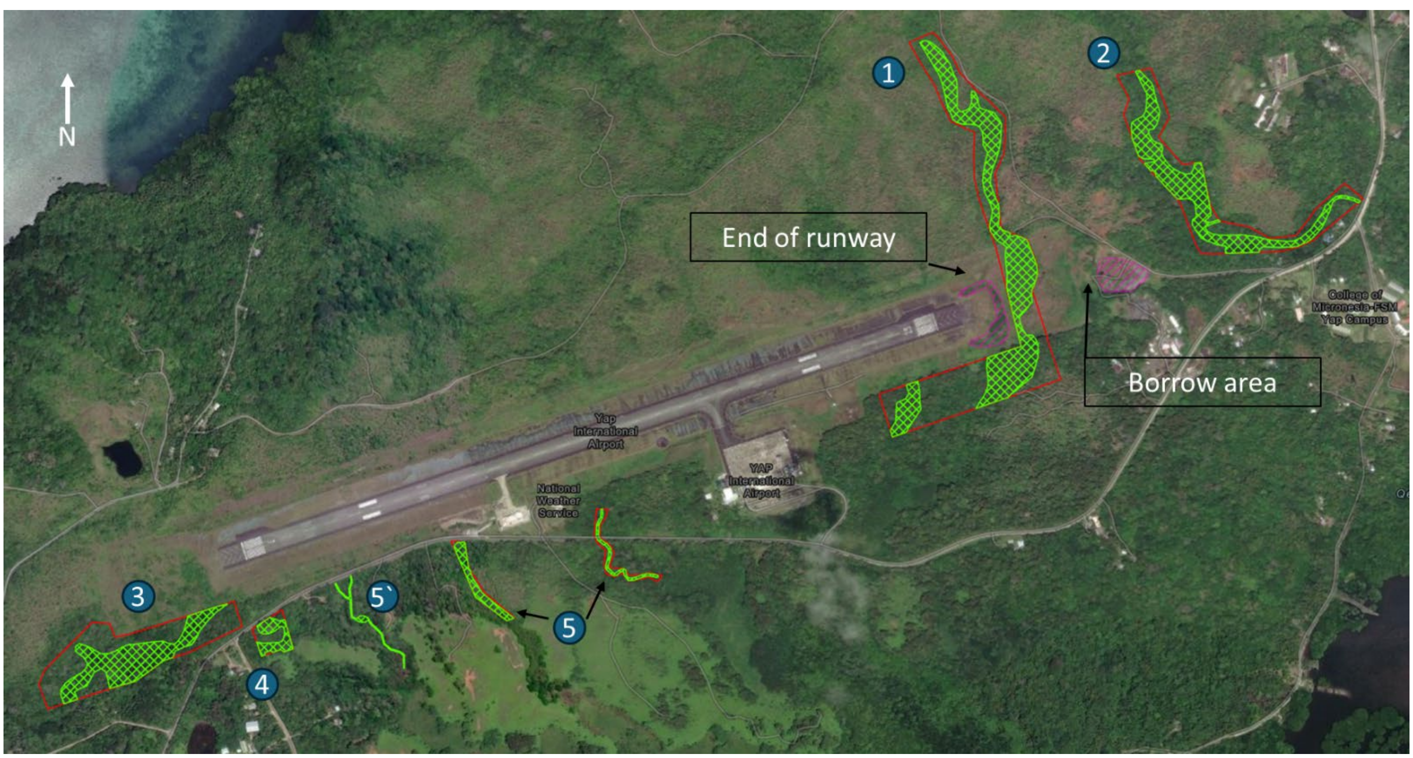


Figure 14. Connected wetland areas (green polygons) identified within priority area 1. The area includes two wetland features, a smaller 1.37 acre wetland to the south of the runway and a larger 11.45 acre wetland east side of the runway. Priority survey area boundaries are denoted with red outlines. An isolated wetland (pink polygon) also appears in the image).

Figure 15. Connected wetland areas (green polygons) identified within priority area 2. Priority survey area boundaries are denoted with red outlines.

Figure 16. Connected wetland areas (green polygons) identified within priority area 3. Priority survey area boundaries are denoted with red outlines.

Figure 17. Connected wetland areas (green polygons) identified within priority area 4. Priority survey area boundaries are denoted with red outlines.

Figure 18. Connected wetland areas (green polygons) identified within priority area 5. The area includes two wetland features, a larger 1.05 acre wetland to the west and a smaller 0.46 acre wetland to the east. Priority survey area boundaries are denoted with red outlines.

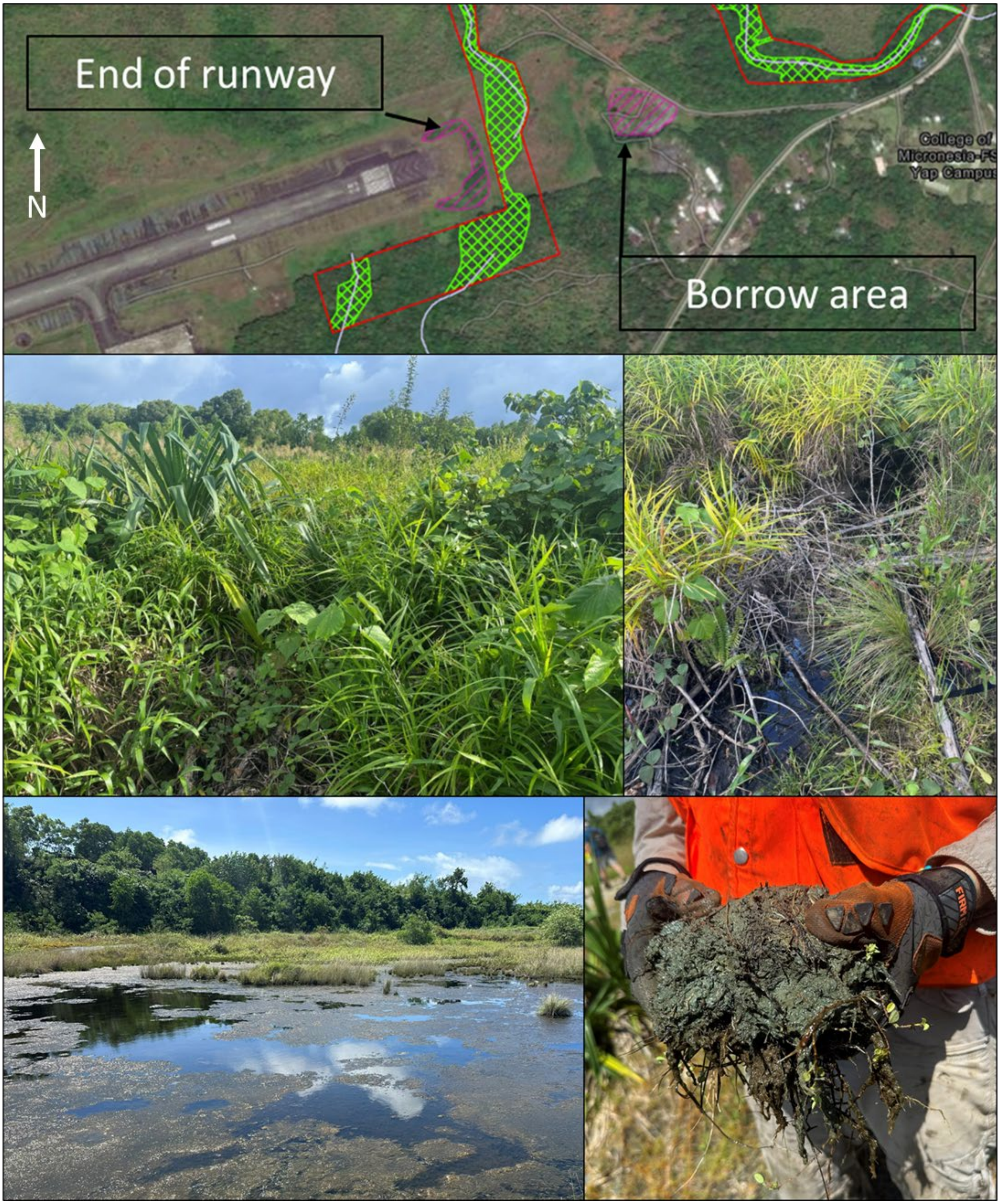
Wetland boundaries were abrupt in most areas, characterized by readily distinguishable changes in landform topography and slope (Figure 19). Most wetlands were associated with active stream channels, which provided the major source of hydrology to riverine floodplain wetlands, as well as most of the depressions and fringe wetlands observed in the project area. Small headwater slope wetlands occurred adjacent to larger first and second order channels. As a result of the landscape position, all wetlands within the priority areas (including wetland mosaics) were considered to maintain connectivity with surface water features at least during portions of the year (Figure 20). Additionally, a small (0.35 acre) wetland feature was identified between priority areas 4 and 5 (denoted 5`), the wetland was connected with a headwater stream feature (Figure 21). Alternatively, two areas located at the end of the runway berm and in a borrow area (Table 3) appeared to be isolated features disconnected from other wetlands or surface water bodies (Figure 22).

Figure 19. Examples of wetland boundaries displaying clear topographic breaks at transitions to upland areas.

Figure 20. Examples of continuous surface water connections with wetlands in priority areas to larger drainage features.

Figure 21. Location and representative photos of a small 0.35 acre wetland feature (denoted as 5`; green polygon) associated with a small drainageway east priority areas 4 (outlined in red).

Figure 22. Location and representative photos of geographically isolated wetlands (pink polygons) associated with the berm at the end of the runway (Wetland 5 – middle photos) and a borrow area (Wetland 10 – bottom photos). Portions of connected wetlands within priority areas 1 and 2 are also shown (green polygons within red outlines).



2.7 Wetland delineation summary and recommendations

In general (details below), the wetlands in the priority areas posed few challenges to wetland delineation and appear to provide the suite of habitat, hydrologic, and biogeochemical functions associated with wetland ecosystems. The results of the wetland delineation are intended to guide decision-making related to project design, implementation, and management. The location and extent of wetlands support alternative analysis, helps identify restoration opportunities, and establishes a baseline for future surveys of wetland resources within the context of the NEPA process (see Appendix). Following the guidance in the 2008 Mitigation Rule (USACE, USEPA 2008), activities should avoid or minimize activities that impact wetlands, including the placement of fill. When unavoidable impacts occur, mitigation activities should seek to offset impacts through environmental restoration, enhancement, and preservation or other remedies.

Several opportunities exist to improve the function of wetlands and aquatic resources in the project vicinity. These include:

1) efforts to reduce erosion, stream channel incision, and head cutting,

2) vegetation and hydrology management,

3) the improvement of wetland hydrology in the vicinity of road crossings, culverts, and other water control structures, and

4) the incorporation of constructed wetlands into the proposed airport expansion where Bird/wildlife Aircraft Strike Hazards can be effectively managed.

Multiple head cuts were observed in priority areas 1, 2, and 5 that could be addressed using a variety of techniques. Large head cuts can be effectively remedied using structures such as drop pipes, weirs, sills, and other grade control features. In particular, large head cuts occur in the vicinity of the area denoted 5`, wetlands 18 and 19, that could be included in a mitigation strategy. Smaller head cuts can be addressed using deliberately placed and maintained check dams, debris jams, root balls, and/or rock structures that stabilize channels and maintain the riffle and run morphology typical of the lotic features encountered during the site visits. Many opportunities to reduce erosion and stream channel incision were observed in the project area and elsewhere in the vicinity of the airport property to assist with wetland impact mitigation (Figure 23). Reducing head cuts precludes additional channel incision, promotes floodplain connectivity, and enhances wetland hydroperiods, all of which improves functions of the wetland classes evaluated in the study area. Additionally, these approaches reduce channel bank and bed erosion, decreasing sediment loading to downstream environments and improving habitat for a variety of wetland and aquatic species. Streambank stabilization using vegetation re-establishment, geotextiles, or other erosion reduction strategies would likely also provide appropriate mitigation opportunities given the interconnectivity of wetland and stream features within the project area.

Figure 23. Examples of erosion and stream incision in the vicinity of area 5`, providing opportunities for erosion control and wetland restoration/enhancement.

Vegetation and hydrology management provides additional opportunities to improve wetland functions within the project area. In particular, wetlands in the vicinity of Wetland 20 (priority area 4) have undergone alteration and appears to be dominated by *Hymenachne amplexicaulis* (West Indian marsh grass) a species native to Mexico, South and Central America, and the Caribbean Islands (Figure 24). The species readily occupies disturbed areas and often thrives as near monocultures that reduce native species diversity by invading marshes, river edges and wet pastures (Florida Natural Areas Inventory 2026). Wetland restoration in the identified areas would include removal of the invasive species and restoration of native plant communities. Additionally, opportunities exist to improve wetland hydrology in this portion of the project area, including settings conducive to water management in support of agroforestry such as additional taro cultivation (Figure 25). Restoration activities would include channel improvement to ensure connectivity between the channel and the floodplain. This could be accomplished using weir and baffle structures allowing the community to manage water levels in support of forested wetland crop cultivation, to maintain surface water during dry periods for aquatic species, habitat, and to provide for sediment entrapment to benefit downstream environments.

Figure 24. Area of potential vegetation restoration dominated by non-native *Hymenachne amplexicaulis*.

Figure 25. Wetlands within the vicinity of priority area 4 that could be targeted for hydrologic restoration and potential taro cultivation.

Opportunities exist to improve wetland and aquatic health through additional water management activities south of the airport property. A number of culverts, water control structures, bridges and road crossings, and other infrastructures can be evaluated to enhance sediment retention, nutrient assimilation and transformation, and habitat and water quality (Figure 26). Target areas would include culverts, drainage features, and other conveyances that channelize flow, increase erosive force, and alter stream-wetland floodplain dynamics. Examples of these opportunities can be found in all priority areas but are most evident south of the airport fence line, where drainage structures have induced hillslope erosion, and south of the main roadway where culverts and other structures have become partially buried with sediment, coarse gravels predominate, and bank erosion becomes more extensive.

Lastly, the incorporation of constructed wetland features as part of the proposed airport expansion has many potential benefits that can provide mitigation for unavoidable impacts to wetlands while yielding positive project outcomes. These activities can take many forms, but the incorporation of wetland ecosystem components into borrow areas, storm water retention features, drainage systems, and other green infrastructure is recommended. For example, wetland fringe features can be established along water conveyances, and because most wetlands naturally experience water level fluctuations, extended periods of inundation are not required as long as soil saturation persists for periods exceeding several weeks. Constructed wetland designs can maximize sediment retention, habitat creation, or other goals. Notably, incorporating constructed wetlands into project designs must consider Bird/wildlife Aircraft Strike Hazard assessments. The USACE Engineering With Nature® program, along with the International Guidelines for Natural and Nature-Based Features provide additional resources for incorporating wetland features into project designs (https://ewn.erdc.dren.mil/).

Figure 26. Examples of water control structures where wetland hydrology management could be applied as potential mitigation measures.

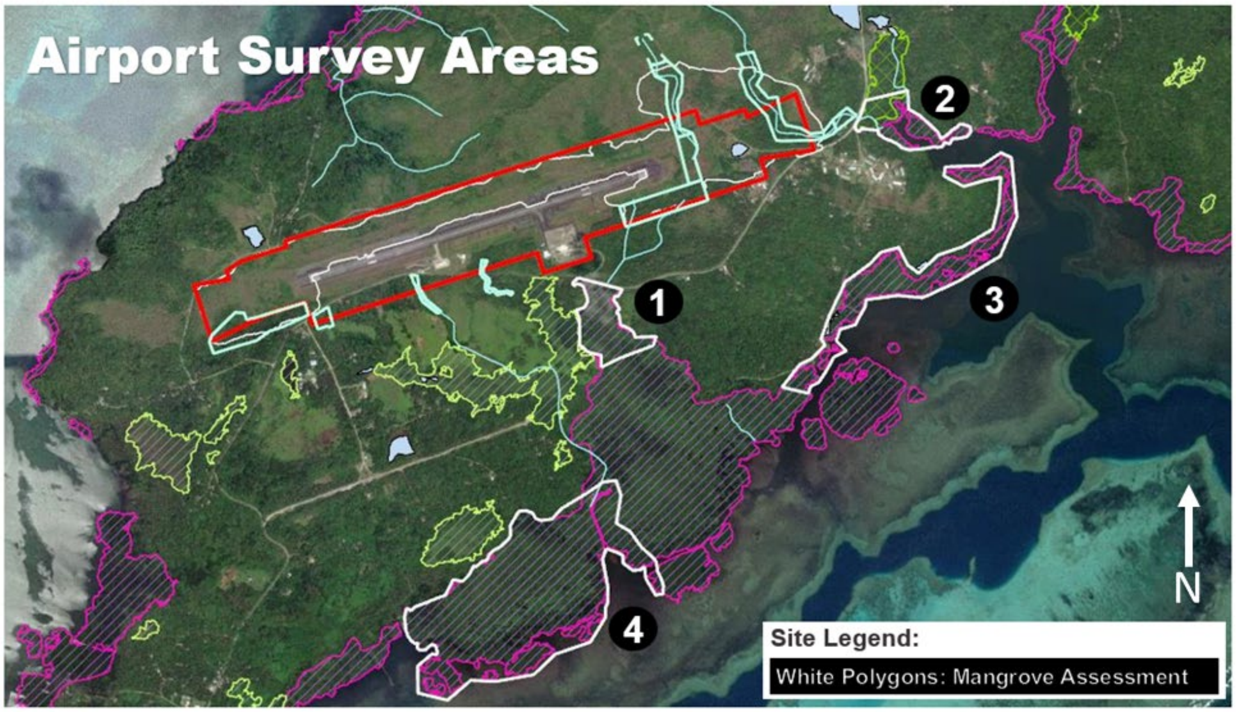
In conclusion, the wetland delineation applied standard protocols to identify wetland features in the project area and document their boundaries. The wetland classes observed were described, highlighting linkages between the wetlands in the project area and the wetland functions they provide. Descriptions of hydrophytic vegetation, hydric soils, and wetland hydrology are summarized in the text, and all detailed field data collection information is provided in the Appendix. Maps of the wetland extents are provided for each priority area, totaling 28.78 acres of wetlands and accounting for 48% of the total area identified for evaluation. Additionally, a small, 0.35-acre wetland feature (denoted 5`, Figure 21) was found between priority areas 4 and 5. This resulted in a total of 29.13 acres of wetlands with clear connection to other surface water bodies. Two small areas of geographically isolated wetlands occurred outside of the priority areas, totaling 3.84 acres.

Four potential wetland mitigation strategies were introduced, including opportunities to 1) reduce stream incision and improve floodplain connectivity and water quality, 2) address invasive species and enhance wetland hydrology and/or support taro farming, 3) evaluate water control structures and conveyances to advance water quality objectives while ensuring wetland hydropatterns remain intact, and 4) incorporate constructed wetland features into the proposed airport expansion.

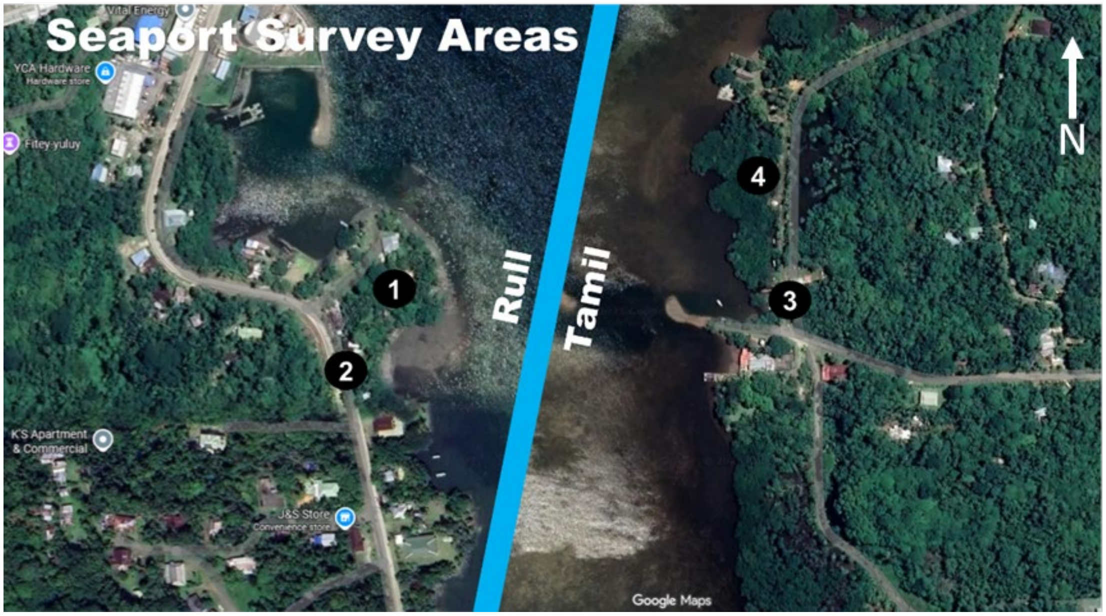
3.0 Mangrove assessment – Introduction

This assessment evaluated mangrove ecosystems within priority areas identified in the vicinity of the proposed airport and seaport projects. The assessment documented mangrove forest composition and structure to inform planning and management decisions. Seven areas were surveyed using quantitative sampling or qualitative observations to document current conditions. The study locations included Mangrove priority area 1 near the airport footprint; Mangrove priority areas 2 and 3 along the coast, which were assessed by boat (Figure 27); Tamil mangrove areas 3 and 4, and the small clusters of mangrove trees near the Rull community coastline (Figure 28).

Figure 27. Airport survey mangrove priority areas.



28. Seaport survey mangrove priority areas.



3.1 Mangrove assessment – Approach

Quantitative assessment

Four mangrove forest inventory plots were established in Mangrove priority area 1 near the airport, and one plot was located in Tamil Area 4. Plots were fixed area circles with a radius of 7.3 m. Each woody stem ≥ 2.5 cm (1 in) was identified to species level, determined to be alive or dead, and the diameter at breast height (DBH), height to live crown (live stems only), total height, and decay class (dead stems only; 1-3 scale with 3 being most degraded, Howard et al. 2014) were recorded.

Subplots were nested inside each plot to document regeneration dynamics. Subplots had a 2.07 m (6.08 ft) radius and located 3.65 m (12 ft) from plot center at North, Southeast, and Northwest directions. The number of woody stems < 2.5 cm (1 in) DBH within each subplot were categorized in three height classes; < 50 cm, 50 – 100 cm, > 100 cm. Pneumatophore (or knee root) density of Bruguiera gymnorrhiza was quantified within 1-m subplots nested inside each main plot.

Tree basal area (square meters), live wood volume (cubic meters), and live wood biomass (kg) were calculated for each sample location. Volume and biomass calculations used equations from Yap mangroves published by Kauffman and Cole (2010) (Table 4). Forest attributes were scaled to the hectare (where appropriate). A tree expansion factor was also calculated based on the area of the sample plot.

Table 4: Equations to determine components of above ground biomass of mangrove forest in Yap, Federated States of Micronesia. Adapted from Kauffman and Cole 2010.

Species and plant part	Equation
Tree basal area (m^2)	$BA = 0.00007854 * DBH^2$
Live wood volume (m^3)	
Bruguiera gymnorrhiza	$V_{wood} = 0.0000754*(DBH)^{2.50}$
Sonneratia alba	$V_{wood} = 0.0003841*(DBH)^{2.10}$
Rhizophora spp.	$V_{wood} = 0.0000695*(DBH)^{2.64}$
Live wood biomass (kg)	$AGB_{wood} = V_{wood}*Sg*1000$[a]
Bruguiera gymnorrhiza	$AGB_{wood} = V_{wood}*0.84*1000$
Sonneratia alba	$AGB_{wood} = V_{wood}*0.78*1000$
Rhizophora spp.	$AGB_{wood} = V_{wood}*0.96*1000$

Definitions for symbols used in the equations are BA = Tree basal area, AGB_{wood} = aboveground biomass (kg), V_{wood} = live wood volume (m^3), Sg = specific gravity (g/m^3)

[a] Specific gravities (Sg) to convert volume to wood biomass by species are: *Bruguiera* = 0.84, *Sonneratia* = 0.78, and *Rhizophora* = 0.96

Triplicate Russian peat auger samples were collected at each of the four sampling locations in Mangrove priority area 1 to determine bulk density and soil organic matter content (measured by loss on ignition). Cores were separated into intervals of 0-2.5 cm, 5-7.5 cm, 10-15 cm, 20-25 cm, and where possible 30-35 cm, and 40-45 cm sections. Additionally, soil samples for isotope analysis (Pb210 and Cs137) were collected at each study plot in Mangrove priority area 1 to a depth of between 36 and 50 cm by inserting a cylindrical core vertically into the substrate (Figure 29). Isotope cores were sectioned into 2 cm depth increments and placed into labeled containers for laboratory analysis. Isotope activity profiles reveal how fast sediment accumulates, enabling accurate estimates of sedimentation rates. Soil analyses for organic carbon content and isotope composition are currently underway, and some results are not yet available at the time of this preliminary report.

Figure 29. Soil samples were collected using a peat auger (left) and soil core (right) for organic matter and isotope analysis, respectively.

Rapid Assessment

A rapid assessment was used in locations where full plot installation was not feasible due to limited mangrove extent and/or restricted access. The rapid assessment documented species presence and estimated species abundance within two size classes: trees ≥ 2.5 cm DBH and woody stems < 2.5 cm DBH. It also categorized into three height classes (< 50 cm, 50 – 100 cm, > 100 cm). In Mangrove priority area 2 and 3, an approximate 7 m shoreline plot on both sides of the channel was assessed from the boat, and canopy composition, salinity, and water depth were recorded. At Tamil Site 3, a 7 m plot was estimated from within the mangroves, with an additional 4-m shoreline assessment where direct access into the stand was not possible. The Rull Area contained less than 10 ft of mangrove shoreline, allowing only limited qualitative data collection where species presence and size classes were recorded.

3.2 Mangrove assessment – Results

Forest Inventory Results

Five forest inventory plots across 2 survey areas (four at Mangrove priority area 1 and one at Tamil Area 4) were sampled using the quantitative assessment. Forest attributes were scaled to one hectare (where appropriate). Mangrove priority area 1 represents a basin mangrove ecosystem with four mangrove species present: *Bruguiera gymnorrhiza, Rhizophora mucronate, Rhizophora apiculata, Lumnitzera littorea, Scyphiphora hydrophylacea,* (Figure 30 and 31). A total of 126 stems were measured across, which included only 4 dead stems (3.2% of total). Across all stems in Mangrove priority area 1 plots, *B. gymnorrhiza* and *R. mucronata* had the largest median DBH values (Figure 32) and tended to be the tallest species based on median values (Figure 33). Notably, we measured an individual *R. mucronata* with a DBH of 63.2 cm, one of the largest stems recorded in the survey. *B. gymnorrhiza* had the highest biomass and basal area values across the four Mangrove priority area 1 plots, indicating dominance near the airport (Table 5).

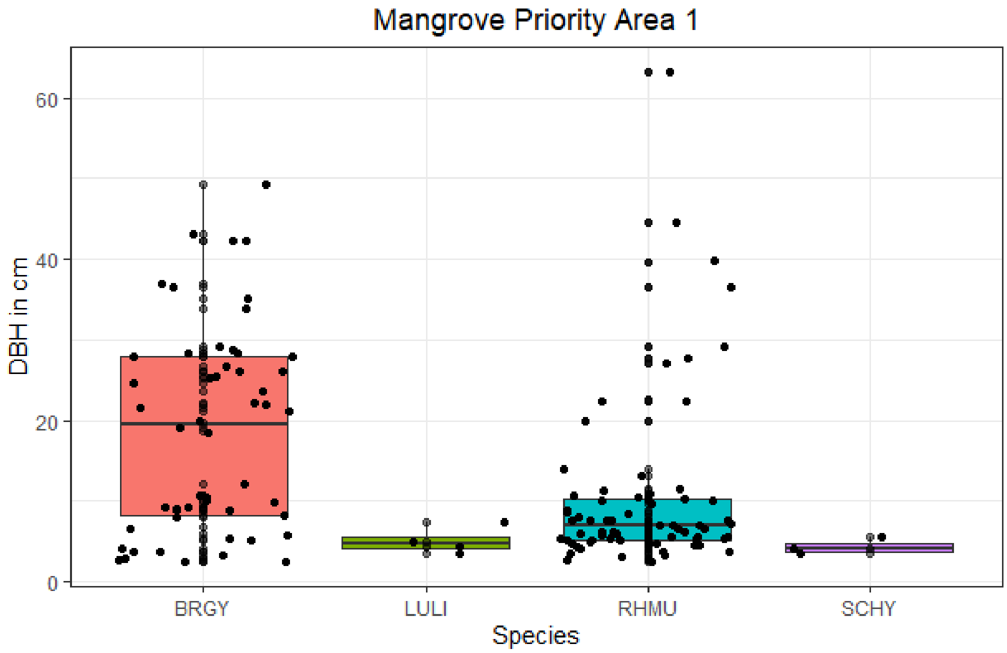
Tamil Area 4 represents coastal fringing mangroves, with three species present: *Sonneratia alba, Rhizophora apiculata,* and *Bruguiera gymnorrhiza*. A total of 18 stems were measured at this site, and no dead stems were recorded. *S. alba* was the dominant species in Tamil Area 4. Across all stems, *S. alba* and *B. gymnorrhiza* had the largest median DBH values (Figure 32), and *S. alba* tended to be the tallest species based on median values (Figure 33). *S. alba* also had the highest biomass and basal area values in the Tamil Area 4 plot, indicating dominance along that portion of the Tamil coastline (Table 5).

After summing across species and scaling attributes to the plot, we calculated site level estimates for total live tree biomass (Figure 34), total density (Figure 35), and total basal area (Figure 36).

Figure 30. Examples of documented mangrove species including (from left) *Lumnitzera littorea*, *Rhizophora sp*., and *Bruguiera gymnorrhiza*.

Figure 31. Examples of mangrove forest structure from Mangrove priority area 1 near the airport (top row) and Tamil Area 4 (bottom row).

Figure 32. Distribution of DBH (cm) by species in Mangrove priority area 1 and Tamil Area 4. BRGY = *Bruguiera gymnorrhiza, LULI = Lumnitzera littorea,* RHAP = *Rhizophora apiculata,* RHMU = *Rhizophora mucronate, SCHY = Scyphiphora hydrophylacea,* SOAL = *Sonneratia alba.*



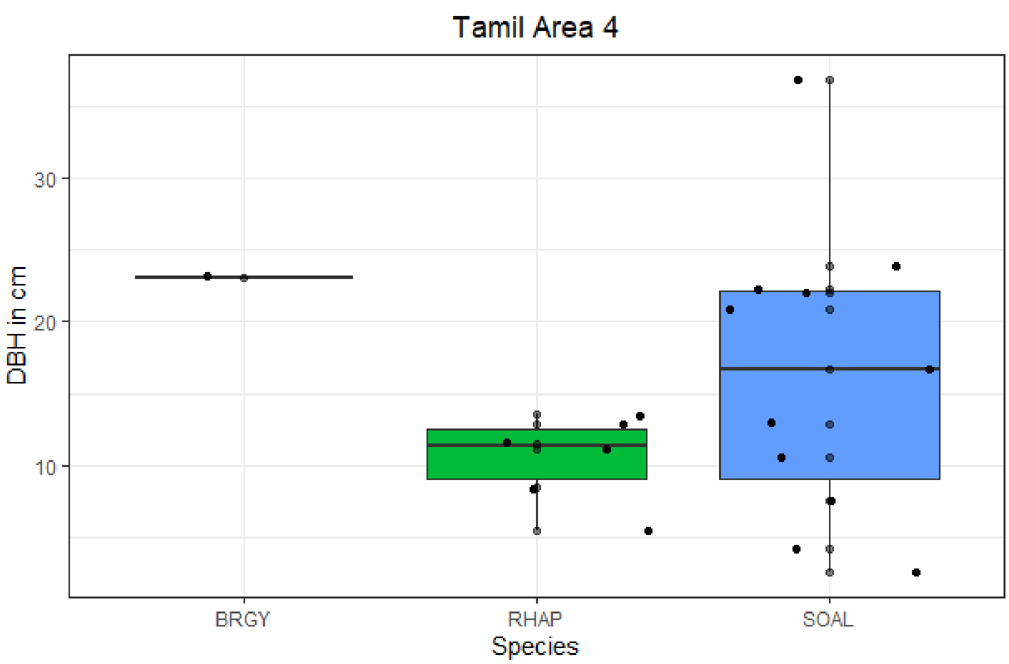
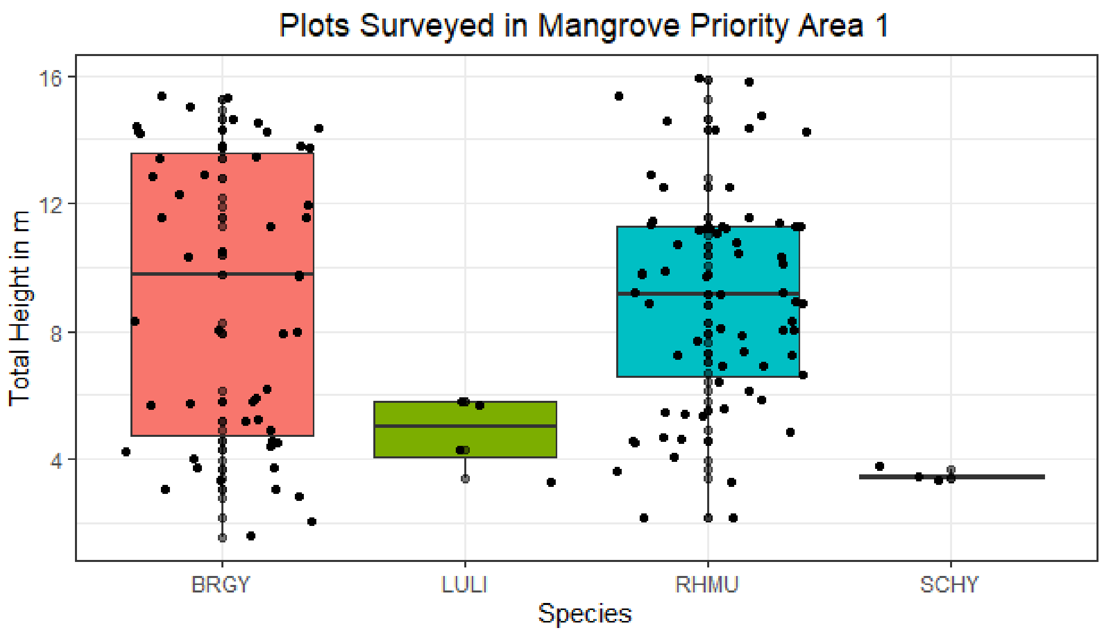


Figure 33. Distribution of total tree height (m) by species in Mangrove priority area 1 (top) and Tamil Area 4 (bottom). BRGY = *Bruguiera gymnorrhiza,* LULI = *Lumnitzera littorea,* RHAP = *Rhizophora apiculata,* RHMU = *Rhizophora mucronate,* SCHY = *Scyphiphora hydrophylacea,* SOAL = *Sonneratia alba.*



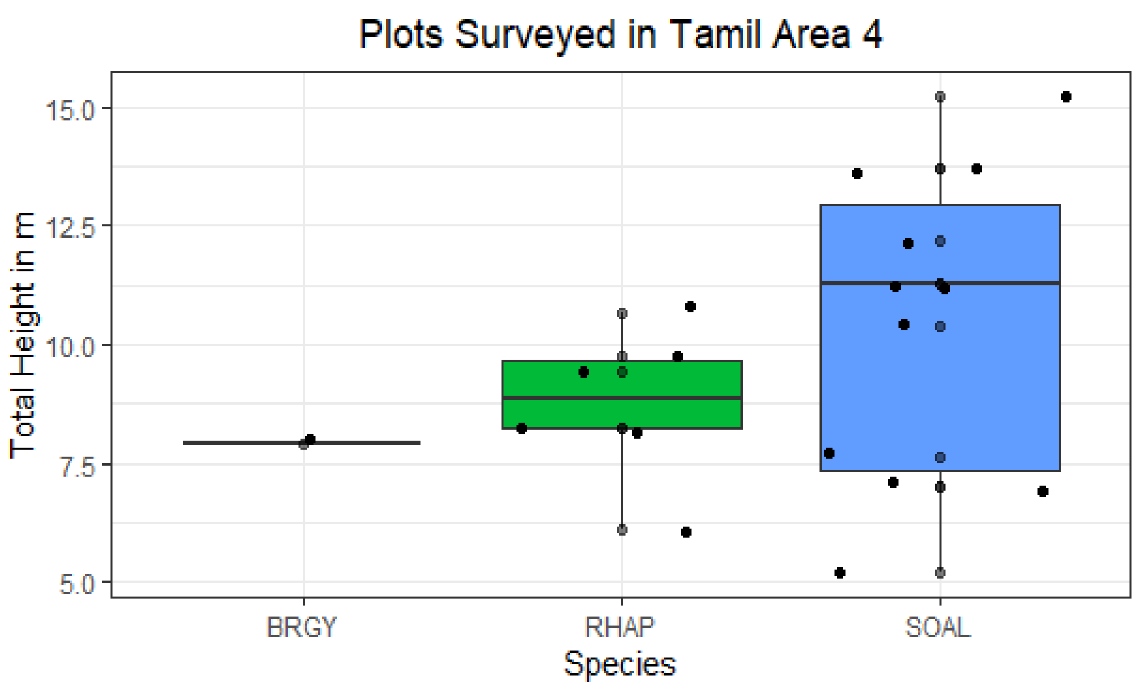


Table 5. Tree density (trees per hectare), live tree biomass (Mg/ha), and basal area (m^2) by plot and species. Biomass for species without direct calculations from Kauffman and Cole (2010) denotes as NA.

Plot number	Species	Tree Density	Biomass (Mg/ha)	Basal Area sum (m^2)
Mangrove 1_p1	*B. gymnorrhiza*	892.3	240.7	49.7
Mangrove 1_p1	*R. mucronata*	297.4	9.4	2.5
Mangrove 1_p2	*B. gymnorrhiza*	475.9	29.5	8.4
Mangrove 1_p2	*L. littorea*	237.9	NA	0.5
Mangrove 1_p2	*R. mucronata*	832.8	300.1	36.6
Mangrove 1_p2	*S. hydrophylacea*	178.5	NA	0.3
Mangrove 1_p3	*B. gymnorrhiza*	713.8	109.3	27.4
Mangrove 1_p3	*R. mucronata*	1903.5	53.4	12.0
Mangrove 1_p4	*B. gymnorrhiza*	1070.7	287.6	57.4
Mangrove 1_p4	*R. mucronata*	892.3	11.1	3.3
Tamil 4_p1	*B. gymnorrhiza*	59.5	9.7	2.5
Tamil 4_p1	*R. apiculata*	356.9	13.4	3.3
Tamil 4_p1	*S. alba*	654.3	97.8	18.6

Figure 34. Total aboveground live tree biomass (Mg/ha) by plot.

Figure 35. Total density (trees/ha) by plot.

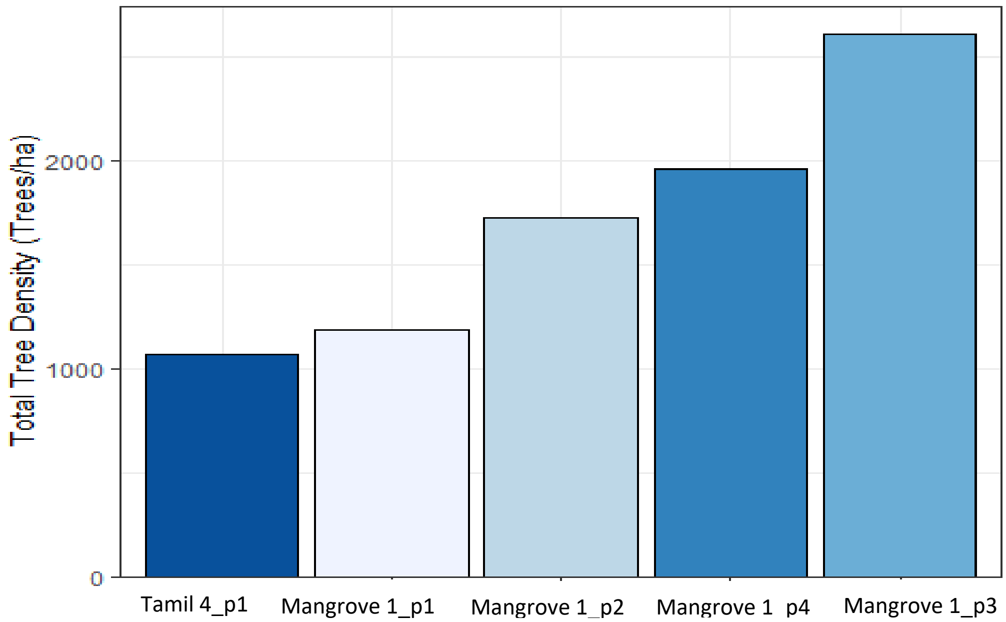
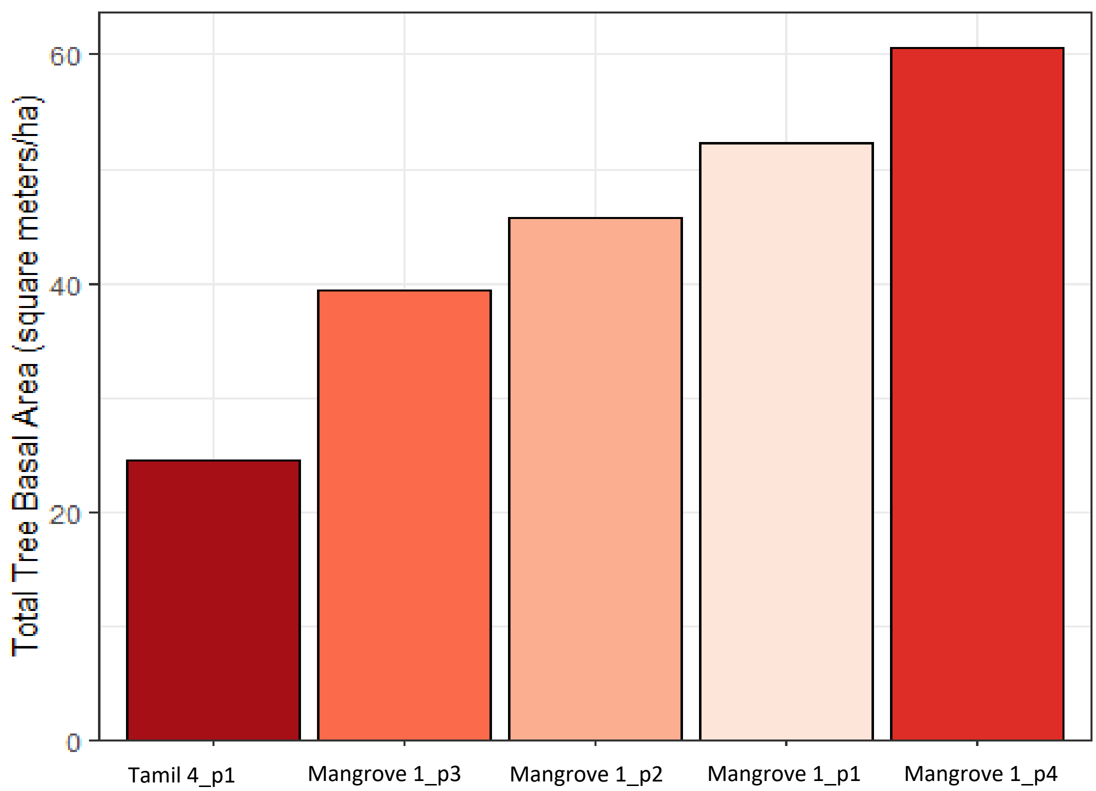


Figure 36. Total basal area (m^2/ha) by plot.



Forest Regeneration Results

Woody stem regeneration was sampled in 3 nested subplots within each forest inventory plot. Each subplot was 13.5 m^2; the collective area of 3 subplots in each plot was 40.5 m^2. Total regeneration density was higher in Mangrove priority area 1 plots than the Tamil Area 4 site, with the highest total in Mangrove 1, plot 2 (Figure 37; Table 6).

Figure 37. Examples of forest regeneration near the airport Mangrove priority area 1.

Plot number	Count	Density
Mangrove 1_p1	25	0.6174775
Mangrove 1_p2	31	0.7656721
Mangrove 1_p3	14	0.3457874
Mangrove 1_p4	8	0.1975928
Tamil 4	2	0.0493982

Table 6. Regeneration density in number stems/square meter.

Pneumatophore Density Results

Knee roots of *B. gymnorrhiza* density were sampled in the Mangrove priority area 1 plots, with the highest observed density in Mangrove priority area 1, plot 4 site (Table 7). Due to the sparse presence of pneumatophores and the dense network of prop roots at Tamil Area 4, pneumatophore density measurements were not collected (Figure 38). Prop roots are aboveground aerial roots used for stability and some gas exchange (characteristic of Rhizophora spp.) while pneumatophores are breathing roots that stick up from the soil used for gas exchange (characteristic of B. gymnorrhiza and S. alba). S. alba produces true pneumatophores, vertical pencil like projections, while B. gymnorrhiza forms knee roots – horizontal roots that bend upward and back down, creating a “knee” that protrudes above the soil and are used for support and aeration.

Table 7. Total site-level pneumatophore density in number structures/square meter.		
Plot number	count	density
Mangrove 1_p1	134	3.3096793
Mangrove 1_p2	23	0.5680793
Mangrove 1_p3	103	2.5440073
Mangrove 1_p4	138	3.4084757

Figure 38. Examples of knee roots, prop roots, and pneumatophores (left to right).

Rapid Assessment

During the rapid assessment conducted in Mangrove priority areas 2 and 3, seven survey plots were established in Mangrove Area 2. Mangrove Area 2 represents a riverine mangrove system. The plots began at the interior basin—where the roadside culvert discharges into the mangrove forest—and continued outward toward the ocean. Due to weather and time constraints, only one survey plot was completed in Mangrove Area 3, a coastal fringing ecosystem. All observations made at these locations were from the boat. Five mangrove species were identified during the surveys: *Bruguiera gymnorrhiza, Rhizophora mucronata*, *Rhizophora apiculata, Sonneratia alba*, and *Xylocarpus granatum*. *B. gymnorrhiza* was the dominant species across abundance and size classes, particularly among trees with DBH > 2.5 cm and stems in the > 100 cm and < 50 cm categories (Figure 39).

Environmental conditions varied along the survey transect. In the interior basin of Mangrove Area 2, water depth remains <1 m with a salinity of 0 ppt during data collection. This area also contained noticeable debris, including trash, abandoned boats, and automobile parts. Moving outward through the channels toward the ocean, salinity increased to 15 – 23 ppt in the channels to 33 ppt along the coast and water depth ranged from 2-3 m. Very few snags or dead trees were observed within the basin or channels of Mangrove Area 2. Midway along the channel, a sunken vessel was documented, and at the channel opening, evidence of blowdown—trees uprooted or leaning—was observed.

Additional field observations included the presence of *Excoecaria agallocha* (milky mangrove) along the outer coastline of Mangrove Area 2, although it was not quantified in the surveys. *S. alba* was observed flowering with abundant propagules, and *X. granatum* was fruiting. At the channel entrance of Mangrove Area 2, R. *mucronata* and *B. gymnorrhiza* were the dominant species, and along the coast of this area *S. alba* and *B. gymnorrhiza* dominated. On the fringing coast of Mangrove Area 3, *R. apiculata* and *R. mucronata* were the dominant species (Figure 40). Mangroves in Micronesia tend to flower and fruit throughout the year, with species-specific peak periods that often align with the wet season but no seasonal reproductive cycle (Duke 1998, Duke 2002). Therefore, it is common to observe overlapping reproductive phases, meaning flowers and propagules can be present at the same time. Observations for this study were made in mid-November, following the end of the typical wet season (Falanruw et al 1987, Kauffman and Cole 2010).

Figure 39. Species distribution of individuals in Mangrove priority areas 2 and 3, across four size classes, highlighting variation in recruitment and mature stem abundance among species. BRGY = *Bruguiera gymnorrhiza,* RHAP = *Rhizophora apiculata,* RHMU = *Rhizophora mucronata, SON = Sonneratia alba, XYLO = Xylocarpus granatum.*

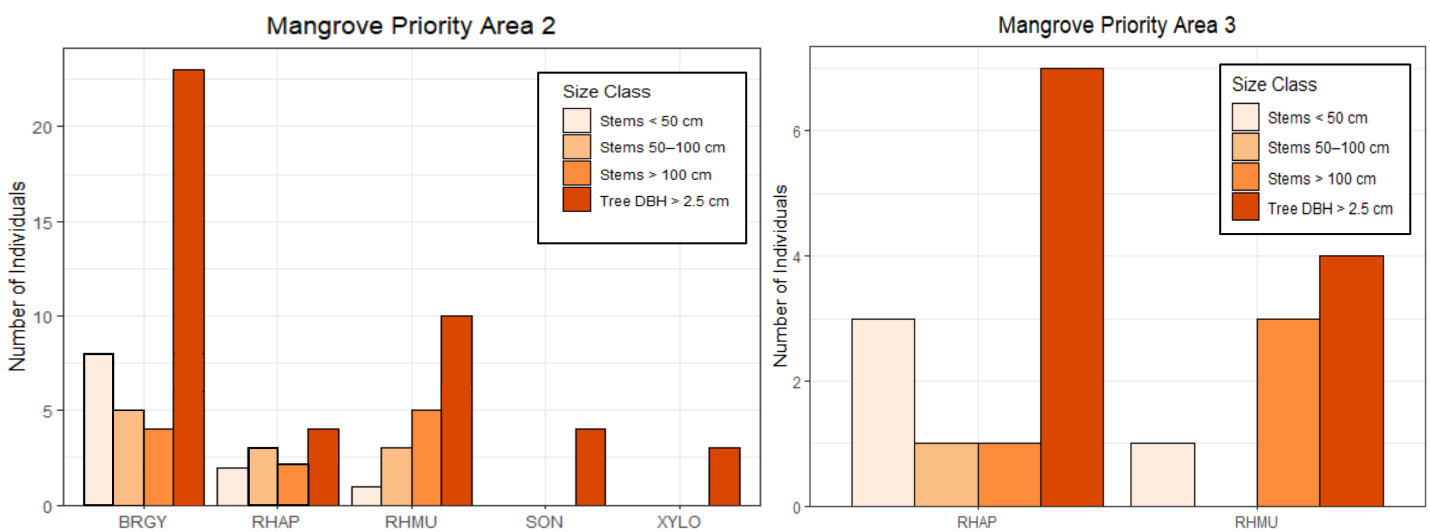
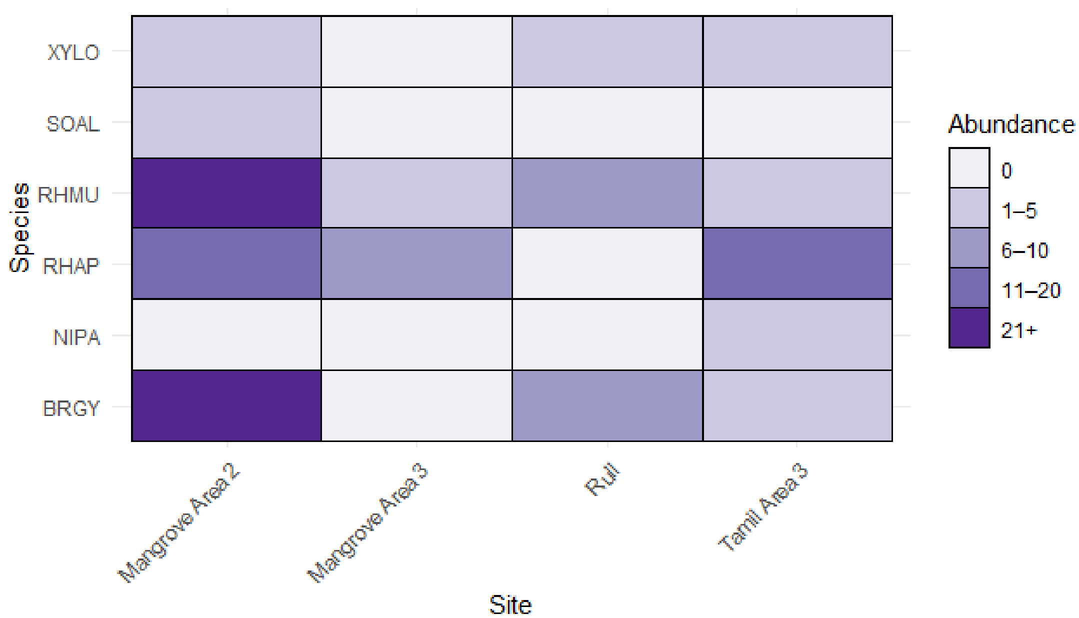


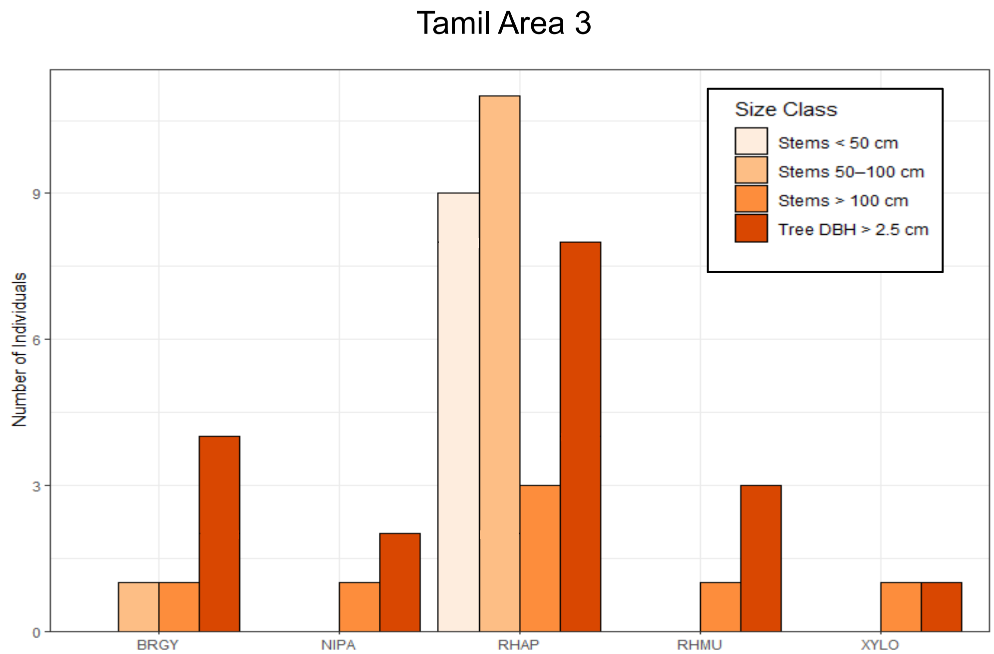
Figure 40. Heat map showing the abundance of six mangrove species across four sampling sites. Colors represent binned abundance categories, highlighting differences in species presence and relative density among sites. BRGY = *Bruguiera gymnorrhiza,* RHAP = *Rhizophora apiculata,* RHMU = *Rhizophora mucronata, SOAL* = *Sonneratia alba, XYLO* = *Xylocarpus granatum.*



The rapid assessment approach at Tamil Area 3 was selected due to limited access into the forest. Observations were made at three locations: the north and south sides of the mangroves surrounding the culvert, and the mangrove stand on the opposite side of the road adjacent to the same culvert. Tree height at this site ranged from approximately 5-10 m, with the tallest individuals occurring on the landward side of the culvert. The height to live canopy ranged from 2 to 6 m. Average DBH across the three observation points ranged from 2 to 5.5 cm. Notably, a large *R. apiculata* on the landward side measured approximately 50 cm DBH and about 16 m in height. *R. apiculata* was the dominant species across abundance and size classes (Figure 41).

Both *S. alba* and *X. granatum* were observed along the outer edge of the mangrove forest near the road on the north side of the culvert. On the landward side of the road, near the culvert, the coastal tree, *Heritiera littoralis*, was also documented. Additional individuals of *Nypa fruticans* and *R. apiculata* were observed further inland but were not included in the rapid survey.

Figure 41. Species distribution of individuals in Tamil Area 3, across four size classes, highlighting variation in recruitment and mature stem abundance among species. BRGY = *Bruguiera gymnorrhiza, NIPA = Nypa fruticans,* RHAP = *Rhizophora apiculata,* RHMU = *Rhizophora mucronate,* and *XYLO = Xylocarpus granatum.*



The rapid assessment was conducted along the Rull coastline due to the limited extent of mangroves in the area (Figure 42). Three species were observed: *Bruguiera gymnorrhiza, Rhizophora mucronata*, and *Xylocarpus granatum*. A total of 15 mangrove trees were recorded, including six *B. gymnorrhiza,* eight *R. mucronata*, and one *X. granatum*. Average tree height ranged from 3 to 7 m, height to live canopy ranged from 2-4 m, and average DBH ranged from 5 to 18 cm. The *X. granatum* and several *R. mucronata* located south of the Men's House were smaller, measuring approximately 1-2 m in height with DBH values around 2.5 cm.

Figure 42. Photos of the sparse mangroves in the Rull community.

Approximately 35 mangrove saplings under 50 cm in height were also observed along the Rull community coastline, the only location where natural regeneration was documented in the vicinity of Rull. Mangroves were absent along the shoreline directly in front of the Men's House; instead, narrow bands of mangrove stand—less than 3 m wide—were present to the north and south. Additional observations included large rocks, cement blocks, and scattered debris along the shoreline.

3.3 Mangrove assessment – Preliminary soil results

The soils within the vicinity of the airport and Mangrove priority area 1 consisted of low density, organic rich substrates typical of many mangrove forests due to anaerobic conditions and high primary productivity rates that exceed rates of microbial decomposition. Bulk density averaged 0.103 g/cm^3 (range = 0.028-0.148 g/cm^3) and soil organic matter averaged 36.6 % (range = 23.3-55.9 %) (Table 8). Bulk density generally increased with depth and soil organic matter generally decreased with depth, as expected. These data are designed to document baseline conditions and to inform potential future monitoring or adaptive management initiatives. Notably, the available data does not suggest that recent shifts in mineral soil content or organic matter accumulation have occurred within the depth intervals examined.

Table 8. Summary of mean soil bulk density and soil organic matter content at four sample locations within Mangrove priority area 1.

Plot number →	1	2	3	4
Depth interval (cm)	Bulk density (g/cm3)			
0-2.5	0.028	0.092	0.098	0.113
5-7.5	0.070	0.120	0.143	0.086
10-15	0.085	0.084	0.146	0.088
20-25	0.093	0.080	0.145	0.136
30-35	0.105	0.092	0.117	0.093
40-45	0.088	0.112	0.148	0.115
	Soil organic matter content (%)			
0-2.5	55.9	35.5	31.6	25.3
5-7.5	45.4	36.2	34.5	34.8
10-15	34.3	38.8	30.6	34.6
20-25	40.8	39.3	30.4	29.8
30-35	39.8	37.3	39.2	39.4
40-45	42.3	37.0	31.8	34.3

3.4 Mangrove assessment – Summary and conclusions

Overall, this assessment documented mature mangrove stands across the surveyed areas near the airport and Tamil, with tree heights ranging up to 16 m in Mangrove priority area 1. Evidence of regeneration and pneumatophore development was also prevalent in this area. *Bruguiera gymnorrhiza* was the dominant species in Mangrove priority areas 1, 2, and 3; *Rhizophora mucronata* dominated along the Rull community coastline; *Rhizophora apiculata* was most abundant in Tamil Area 3; and *Sonneratia alba* dominated in Tamil Area 4. All surveyed areas supported at least two mangrove species, with some plots containing as many as five. During data collection, flowering and propagule production were observed in *Rhizophora* species, and several other mangrove species were noted to be fruiting.

Although little evidence of degradation was observed within the Mangrove priority areas surrounding the airport, localized trash and debris were present in mangrove stands closer to the coast. Along the Rull community coastline, substantial anthropogenic disturbance was documented, and mangrove stands were sparse, with only one small area showing observable regeneration. Tamil Area 4, the section furthest from the culvert, supported dense mangrove stands composed of three species, while areas closer to the culvert showed greater impacts from docks and other human activities. Tamil Area 3 also exhibited a high density of trash and debris.

Collectively, the surveyed sites represent a mosaic of healthy stands, areas under stress, and locations with active regeneration. Soils near the airport within Mangrove priority area 1 were characterized by low-density organic rich substrates. Available data does not indicate recent changes in mineral content or organic matter accumulation. This assessment provides baseline conditions to inform potential future monitoring efforts to support the long-term management of these mangrove ecosystems. Additionally, opportunities exist to conduct restoration or rehabilitation in several areas. This could include propagule introduction to expand mangrove areas, removal of debris, or other actions to promote mangrove forest health. Further, the incorporation of mangrove replanting efforts into future project designs that facilitate mangrove establishment are recommended if project features will directly impact (i.e., fill) mangrove areas during construction.

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