



INDIGENOUS FRESH WATER MANAGEMENT TECHNOLOGIES

OF TRUK, POHNPEI
AND KOSRAE,
EASTERN CAROLINE ISLANDS,
AND OF GUAM,
MARIANA ISLANDS, MICRONESIA

by

Rosalind L. Hunter-Anderson



WERI

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ABSTRACT

The indigenous fresh water management technologies of Truk, Pohnpei, and Kosrae, the Federated States of Micronesia, and of Guam, a U.S. Territory in the Mariana Islands, were investigated at the reconnaissance level through a combination of archaeological and ethnographic field methods and library research. More intensive field studies in the coral islands and remote parts of the high islands of the Carolines can yield additional information on native fresh water management which can help guide the introduction of appropriate modern technologies.

It was found that a well-developed series of indigenous techniques for managing fresh water for domestic uses and in agriculture once existed on all the islands studied. These include provision of clean drinking water by various rainwater catchment devices, and by the development of shallow wells, seeps, and springs. Freshets emerging from the sand were sources of bathing water at low tide in some settings. Where surface water is abundant, such as on Truk, Pohnpei and Kosrae, streams and rivers were used for both drinking water and bathing. Where surface water is less abundant, such as on Guam and the atolls of Namoluk and Ant, rainwater catchment for drinking and shallow wells for bathing were more common. In such islands rainwater was preferred over ground water for drinking. Boundary channels within the large interior taro patches of Namoluk Atoll provided drinking and bathing water. Large canals occasionally were dug to drain these taro patches of salt water after typhoon-related flooding. In addition to technical documentation, customs and folklore related to the origins and socially appropriate uses of fresh water were recorded.

Fresh water management in high island agriculture included the construction of stone retaining walls, elevated garden plots, and dirt- and rock-lined channels to prevent soil loss during intense tropical storms. In Namoluk Atoll perimeter channels were built around smaller taro patches to drain excess runoff. Natural seepage in upland settings (Pohnpei) and fluvial flows and freshets within mangroves (Kosrae) were used in the production of fermented breadfruit in underground storage pits. As modern technologies replace indigenous ones, especially the use of ferro-cement catchment tanks in Namoluk and piped water systems on the high islands, customary water management practices related to drinking and bathing are rapidly disappearing. However, native agricultural uses and management of fresh water are still common in the high islands studied except Guam, where subsistence farming has all but disappeared.

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INTRODUCTION

Fresh water management technology in Micronesia is as old as the advent of man in these islands some five thousand years ago. Ironically the variety and sophistication of this regional cultural legacy is being recognized by Western science just as intensive contact with modern industrial systems threatens to erase it from the islands. It is important both from a documentary perspective and from a practical viewpoint that we understand the traditional technologies, habits, and associated attitudes on which these changes are being superimposed. In short, we need to know "where people are coming from" -- particularly their cultural background with its native traditions of technical competence -- in order to help predict which modern introductions can work and which cannot.

As did the study undertaken last year in Yap (Hunter-Anderson, 1986), the present project documents some of the native solutions to basic hydrological problems presented by the physical and social settings of the Eastern Caroline Islands: Truk, Pohnpei and Kosrae, in the Federated States of Micronesia (FSM) and on Guam, a U.S. Territory. A brief comparison of findings of the two studies will be found in the Conclusions.

Gaps in present knowledge of indigenous fresh water management technologies in Guam and the Eastern Carolines are apparent from the study. Some of this knowledge has been lost irretrievably, the result of intensive foreign contacts associated with colonial administrations that have operated continuously since the late 19th century in the FSM States and from the late 17th century on Guam. Not surprisingly, the longer foreign administrations have been present in an island, the more losses there have been, Guam's case being the most extreme. Nonetheless this study found an interesting array of appropriate technical and social devices for coping with the various hydrological conditions of the Eastern Carolines and the Southern Marianas. Examples include methods for rainwater catchment, storage, and conveyance; stone-lined wells and seeps; and the creation or diversion of channels, ditches and streams to redirect excess water.

In addition to the Yap project (Hunter-Anderson, 1986) and that presented here, WERI researchers have conducted the following studies of traditional fresh water uses, customs, and beliefs: Stephenson, 1979; Stephenson and Moore, 1980; Winter and Stephenson, 1981; O'Meara, 1982; Stephenson and Kurashina, 1983; Stephenson, 1984; Dillaha and Zolan, 1983; and Stephenson, 1987.

STATEMENT OF RESEARCH PROBLEM

This study was undertaken in response to the need for accurate baseline information about variations in indigenous fresh water management systems in Micronesia. Such information is necessary in order to anticipate the impacts of rapid population growth on the developing economies of these islands, particularly the agricultural sector.

Presently farming land is relatively abundant on the high islands of the FSM. Overall densities are low but population is growing rapidly throughout the region (U.S. Dept. of State, 1984). Farming on Guam is becoming mechanized and population is relatively high, increasing

steadily since World War II through intrinsic growth and in-migration. Farming land on the coral islands of the FSM, particularly for growing taro, has always been relatively scarce. In recent decades the populations of many of these small islands have risen to intolerably high levels. This has prompted internal migration within the state to the district center and beyond.

As the Micronesian islands' populations continue to grow and their economies develop, there will be a rising demand for high quality water for drinking as well as a greater need for food produced locally. This study investigated whether future farming uses of fresh water are likely to conflict with or impinge upon drinking water delivery systems already in place. Information obtained in the project could be useful in evaluating the potential of existing indigenous water conveyance systems for increased usage and projected demographic increase in the islands.

METHODS

Prior to the present study it was not known whether fresh water management technologies still existed on all the study islands nor the range of variation among them. Thus, the fieldwork was conducted on a reconnaissance level. In addition to providing some information about indigenous technologies, such an approach can determine the feasibility of more intensive research and can significantly aid in its successful design. Approximately two weeks were spent in the states of Truk, Pohnpei and Kosrae, and one week on Guam. Interviews and archaeological survey including photo-documentation were conducted in the field, and archival research was carried out before and after the fieldwork.

Archival reviews of ethnographic documentation of indigenous fresh water management in the study locations were conducted at the libraries of the Community College of Micronesia in Pohnpei and the University of Guam's Micronesian Area Research Center.

FIELD STUDY LOCATIONS

Fieldwork was conducted in three of the Federated States of Micronesia: Truk, Pohnpei, and Kosrae, and in Guam, an unincorporated US Territory (Figure 1). The FSM study locations include Moen Island in Truk Lagoon and Namoluk Atoll, Mortlock Islands, in Truk State; Pohnpei Island, Param Island, and Ant Atoll in Pohnpei State; and Kosrae Island; Kosrae State.

While field research took place mainly on the high islands of the FSM states, limited investigations on Guam and the coral islands of Namoluk and Ant provided instructive ecological and cultural contrasts.

GEOGRAPHIC SUMMARIES OF THE STUDY LOCATIONS

Geographic summaries of the study locations and major study sites are presented below. The localities of features manifesting the indigenous management of fresh water which were seen in the field are indicated on the island maps (Figures 2-9. It should be remembered that the number and

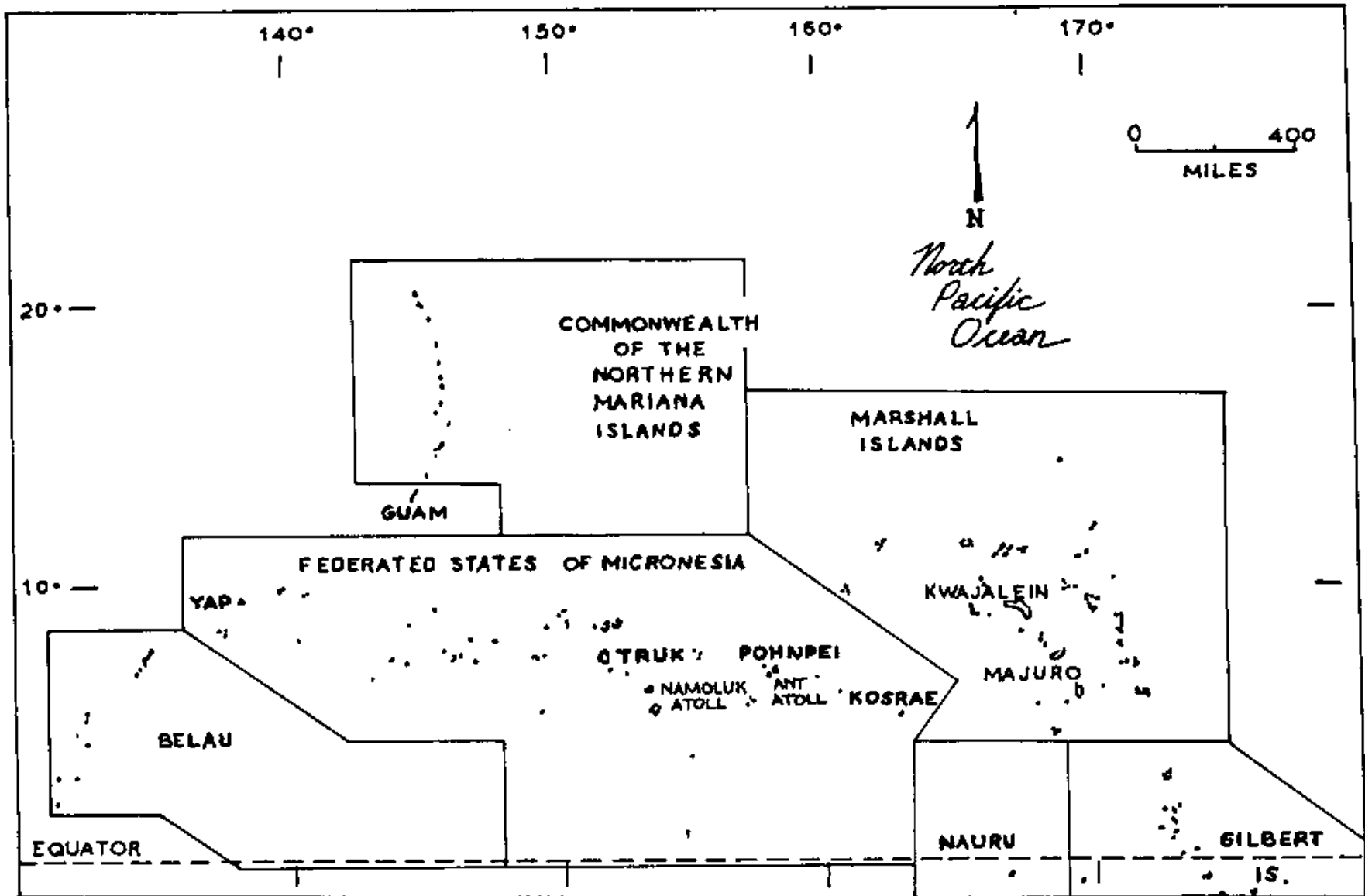


Figure 1. Island Study Locations: Guam; Moen, Truk Lagoon, Namoluk Atoll; Pohnpei, Ant Atoll; Kosrae.

distribution of these localities do not necessarily reflect the complete range nor actual frequency of particular types of features.

Guam (Figure 2)

Guam, southernmost island in the Marianas chain, is the largest island in the western Pacific, with a land area of 212 sq mi. Guam is approximately 30 mi long, and its width varies from four to over eleven mi. The northern half of the island is a raised limestone plateau, heavily faulted, with steep cliffs and solution caves along the coast. The southern half of Guam is volcanic, with pronounced relief. Several narrow river valleys debouch into small bays. Guam is almost completely surrounded by fringing reefs or limestone benches. Off the southern tip of the island is the Cocos Island barrier reef and associated atoll development (Tracey et al, 1964).

Guam's climate is marine tropical; a pronounced dry season occurs from November through June. Temperatures vary from 75 to 95 degrees F, rainfall averages around 100 in per year, and destructive typhoons occur fairly frequently (van der Brug, 1986).

Formerly Guam's northern plateau supported a unique limestone forest which post-World War II land uses, primarily military in character, have all but destroyed except along the northern coastline. This forest included Calophyllum inophyllum, Cycas circinalis, Intsia bijuga, breadfruit, Hibiscus, banyan, Pandanus, Guamia, Premnia, Neisosperma, Macaranga, Mannea, and Aglaia. The rolling southern hills present a savannah appearance; dominant grasses include Miscanthus, Pennisetum, and Demeria. The volcanic soils of the south also support the club moss (Lycopodium) and Myrtella, and on highly eroded areas can be seen pure stands of Gleichenia ferns. Riparian vegetation, confined to narrow strips within the savannah, includes Pandanus, betel nut palm, Nipa palm, coconut palm, Cyathea, and various herbs and ferns. Coastal strand species include Calophyllum, Hibiscus, Pandanus, Messerschmidia, Pluchea, Wedelia, Scaevola, Ipomoea pes-caprae, Barringtonia, Vigna marina, Thespesia, coconut, and Pemphis acidula (Fosberg, 1960; Stone, 1970; Moore and McMakin, 1979).

As the vegetative patterns reveal, Guam's soils can be grouped into those which are shallow and excessively well drained derived from limestone (on the plateau and sandy beaches), those of poor drainage but with high organic content in lowlands and coastal swamps, clay soils of volcanic origin that occur in river valleys, and the red lateritic soils, widespread in the south, of low nutrient quality (Russell, 1965, cited in Karolle, 1978a).

Guam's population is over 120,000 persons; unlike the other islands in this study many of them are non-natives. Human settlement is densest in the central and northern parts of the island and is related to military and modern commercial activities. The southern part of the island is more rural in character, supporting small commercial and subsistence farming and fishing communities located along the coast. The common Guam cultigens are coconut, breadfruit, betel nut, bananas, papaya, yams (Dioscorea esculenta, D. alata), Terminalia catappa (which does not grow to the size found in

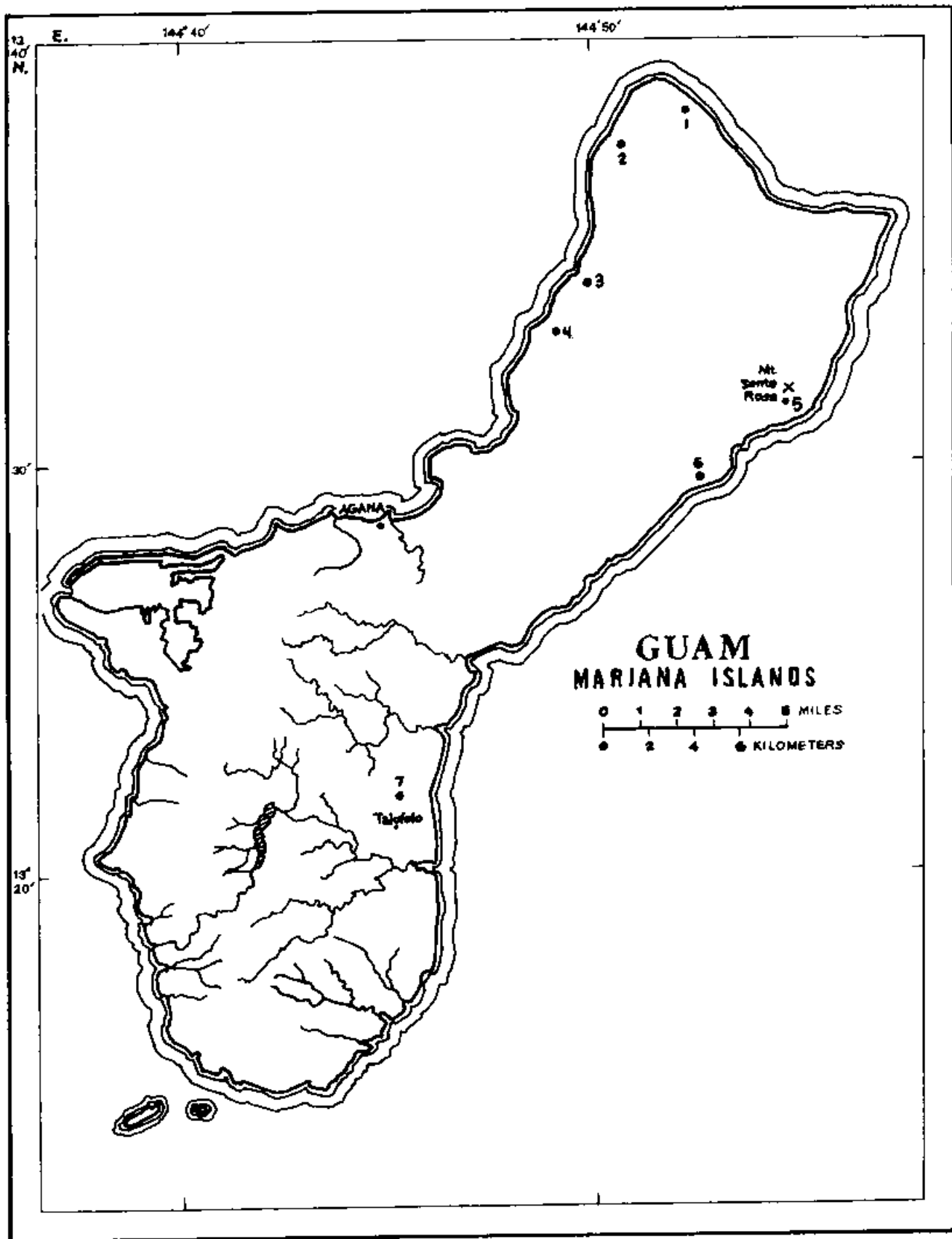


Figure 2. Guam; major streams and study sites: (1) Ritidian Cave (2) Uruno Beach (3) Haputo Beach (4) Hilaan (5) ranch at base of Mt. Santa Rosa (6) ranch at Pagat (7) ranch at Talofoto.

Kosrae), Ipomoea aquatica, Bixa, Colocasia, Alocasia, various species of Annona, mango, Cananga odorata, tapioca, Pangium edule, sugarcane, guava, Averrhoa bilimbi, starfruit, pepper leaf, various species of Citrus, and Capsicum (Karolle, 1978a).

Surface water on Guam is confined to the central and southern parts. Rainfall (hanum fresku, hanum sinaga) rapidly percolates through the northern limestone. In addition to perennial and intermittent streams (hanum saduk), there are waterfalls (manutu), seeps, and springs (bo'bo') in the southern mountains. Freshets emerge along the coast throughout the island, and the karstic substrate in the north contains a number of fresh water pools within a few meters of the shore (Stephenson, 1979).

Truk State (Figure 3)

Truk State consists of a cluster of volcanic islands surrounded by a single barrier reef 125 miles long, forming a lagoon about 40 miles wide, and 24 inhabited outer island atolls to the northwest and southwest of Truk Lagoon. The lagoon islands are the erosive remnants of a partly submerged, large shield volcano located 500 miles north of the equator and approximately 600 miles southwest of Guam. Total land area in the state comprises about 45 sq mi, most of it inside the lagoon (Stark et al., 1958).

The soils of Truk's volcanic islands can be classified into those of relatively poor drainage in coastal mangroves, on coastal strands, and on bottom lands and those of moderate to good drainage which occur in upland settings amid basaltic rock outcrops (Laird, 1983a).

Rainfall averages about 140 inches per year, falling mainly between May and September, and temperatures range between the mid-80s and mid-70s F. Major typhoon tracks lie well to the north and west of Truk but severe storms occasionally cause widespread damage to buildings and crops (van der Brug, 1986).

Surface water is relatively abundant although during the dry season (December through May) or occasional droughts, stream and seep flows markedly lessen (van der Brug, 1986). In Truk, rivers are chonun pupu; springs and seep are nik e miror; and water falls, as flowing water, are chonun pupu. Rain and fresh water are called konik.

Study Site: Moen (Figure 4)

Triangular-shaped Moen Island is 7.3 sq mi in area. It is the second largest of the nineteen lagoon islands. Moen is the state capital and a major port of entry by sea and air. The population is concentrated along the narrow coastal flats, a modern settlement pattern related to the coastal road and commercial development but also reflecting indigenous preference for proximity to the sea and to the swampy lowlands where taro can be grown. The eastern side of Moen is densely inhabited (roughly 13,000 persons) while the western and northern sides are sparsely settled.

Behind Moen's shoreline of alternating segments of coconut strand and mangroves, particularly on the western side of the island, are extensive

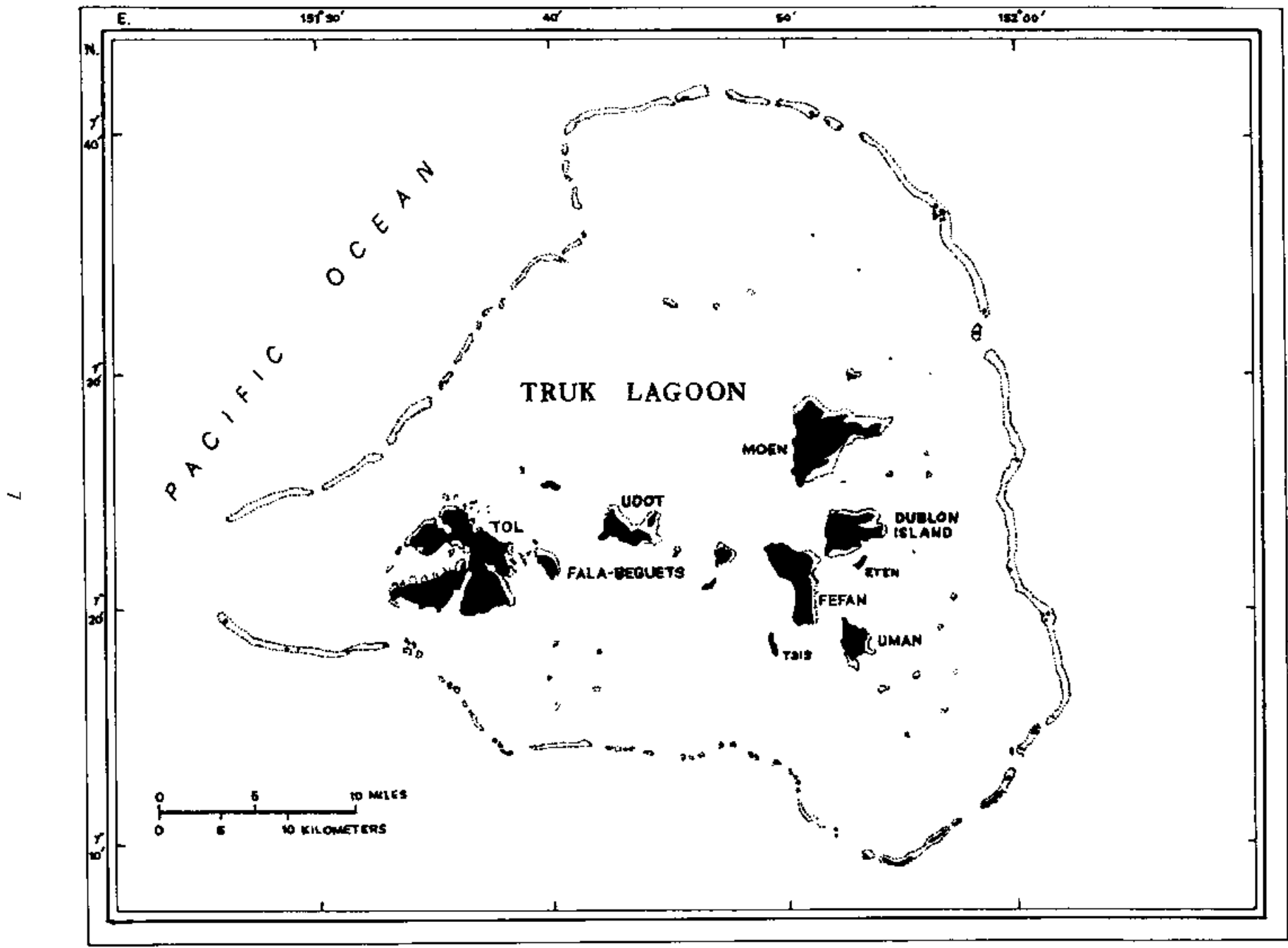


Figure 3. Truk Lagoon

agricultural swamps once planted to Cyrtosperma chamissonis and to a lesser extent Colocasia sp. These swamps are now largely unused and have become overgrown with Phragmites karka. On Moen's nearshore slopes rise dense agroforests of coconuts (Cocos nucifera), bananas (Musa spp), and breadfruit (Artocarpus spp). The rocky interior hilltops such as Mt. Tonaachaw (elevation 748 ft) support mainly grasses such as Miscanthus floridulus and Gleichenia ferns (Fosberg, 1960).

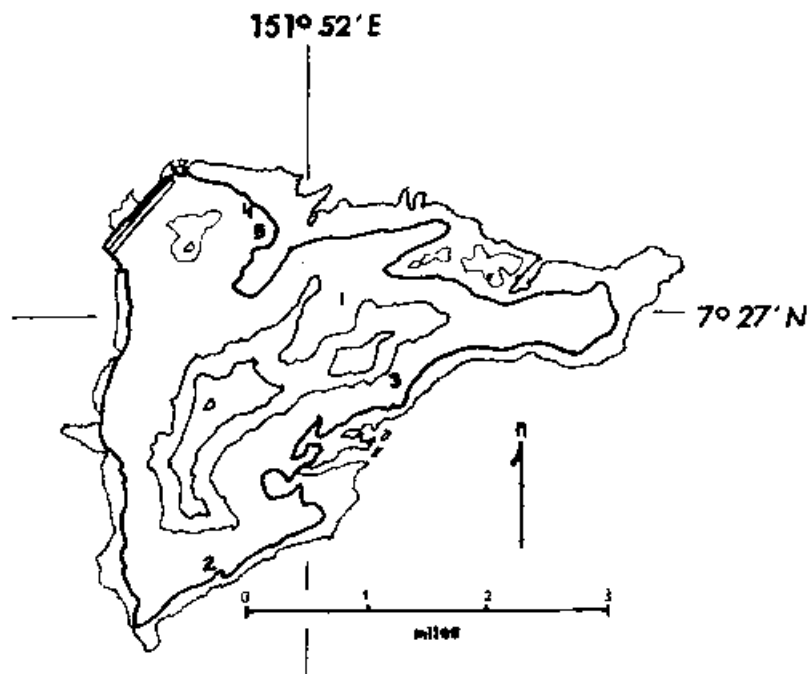
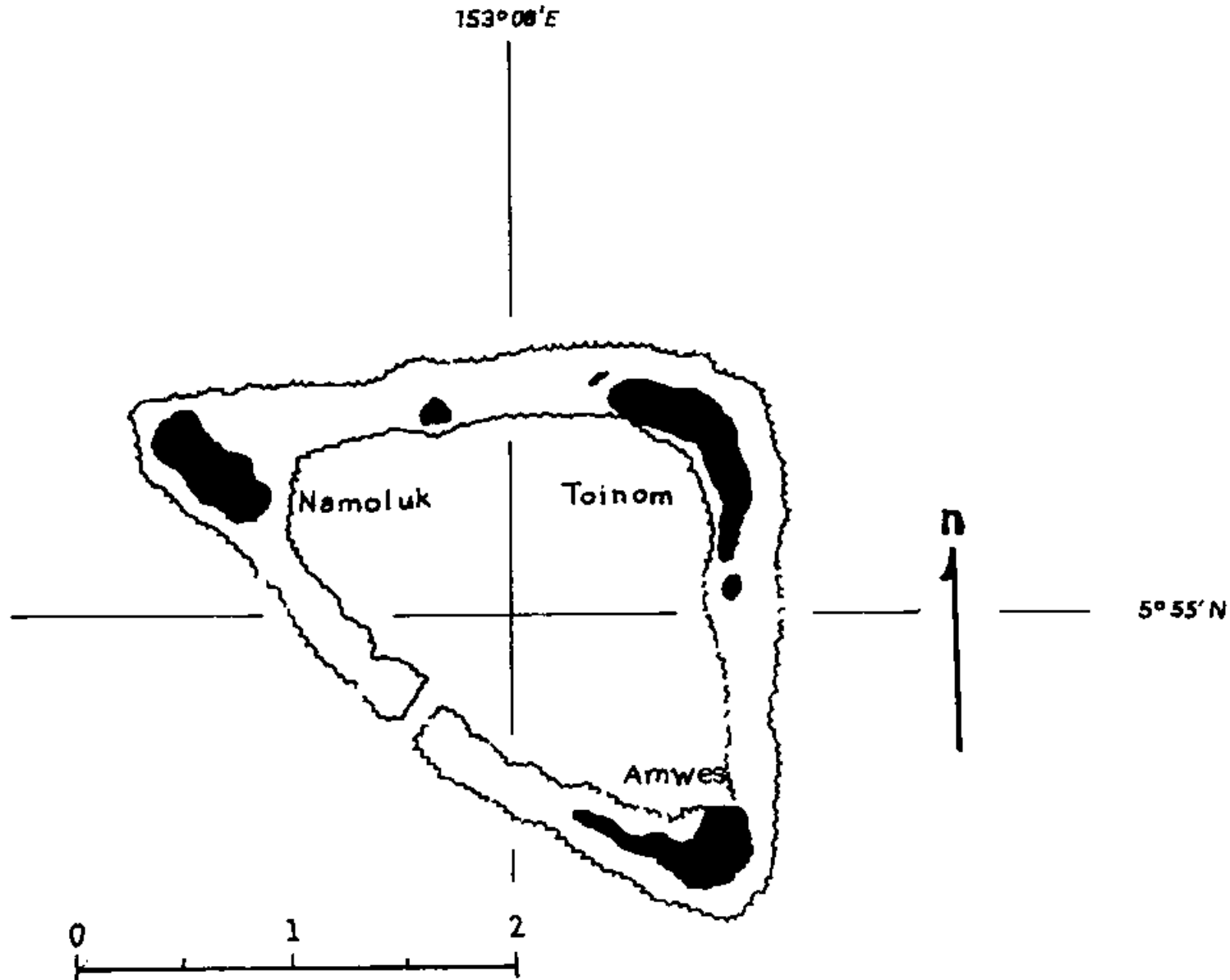


Figure 4. Moen Island, Truk Lagoon, study sites: (1) Wichen River (2) Nounen (3) Petiw (4) Neewutumas Spring (5) Winikachaw Spring.

Moen's surface water sources are the Wichen River and various smaller streams, seeps and springs. Fresh water is also available by catchment and in shallow wells in lowlying swampy areas. Presently a modern piped water system serves the urbanized part of Moen (Heitz, 1986).

Study Site: Namoluk Atoll (Figure 5)

Namoluk Atoll, in the middle Mortlocks, contains three major and two minor islets ringing a lagoon about three sq mi in area. Total land surface is a third of a sq mi. The soils are coralline and are thus sometimes excessively well drained. Fewer plant species can thrive in them in comparison with the volcanic soils of the lagoon islands. In the interior of the larger islets of Namoluk are the man-made organic soils which require constant maintenance for the successful cultivation of taro.



Namoluk Atoll

Figure 5. Namoluk Atoll, Truk State.

As in Moen, in Namoluk annual rainfall averages 140 inches, and maximum and minimum daily temperatures average 91 and 78 degrees F, respectively. The atoll lies outside the normal typhoon belt but occasionally experiences tropical storms which severely damage crops by high winds and/or salt-water intrusion.

Most of the population (ca. 600 people) live on the eastern half of Namoluk Islet (Figure 6). A chiefly family stays on Amwas Islet; the other islets in the atoll are uninhabited on a permanent basis but are used intermittently for gardening and marine resource collecting. Sandy, lagoon-facing portions of Namoluk's three main islets (Amwas, Toinom, and Namoluk) are fringed with coconut palms. Behind the rocky berm of the seaward sides, only salt-tolerant strand vegetation such as Hibiscus tiliaceus, Pandanus tectorius, Scaevola sp and Pemphis acidula can be seen. A small mangrove forest, the only example of this kind of plant community in the atoll, occurs on the lagoon side of crescent-shaped Amwas (Marshall, 1975).

Namoluk and Amwas have large interior taro patches made possible by the presence of a sufficiently extensive underground fresh water lens and the continuous efforts of the people to create and replenish the taro patch soil with organic matter. Only small taro patches occur on Toinom, and none exists on the two smallest islets. Cyrtosperma chamissonis is the staple crop grown in all these taro patches.

In contrast to Moen, where taro patches have been neglected in spite of rising population, on Namoluk Islet the area under taro cultivation (approximately 20 acres) is currently under expansion in response to continuing population growth since World War II. Breadfruit (Artocarpus sp) is another important cultigen; the large trees, forming dense groves in the interior of the larger islets, are harvested seasonally. Bananas (Musa sapientum), and coconuts (Cocos nucifera), dryland taro (Alocasia sp), true taro (Colocasia esculenta), Citrus, chili peppers, sugarcane, papayas, and a variety of other minor crops and ornamentals are planted throughout residential areas.

Surface water does not exist on Namoluk although there are many stone-lined wells (chonutu) dug into the fresh water lens and numerous modern catchment systems of cement and tin. The word for fresh water in Namoluk is chon.

Pohnpei State (Figure 7)

Pohnpei State consists of the large, rugged, volcanic dome island of Pohnpei (formerly Ponape), about 130 sq mi in area; and the small coral islands of Ant, Kapingamarangi, Ngatik, Oroluk, Pakin, Mokil, Nukuoro, and Pingelap, which together amount to less than three sq mi of land.

Surrounding Pohnpei Island is an extensive barrier reef system containing several sandy islets, and inside the reef occur several smaller volcanic islands, some of which are inhabited. The population (about 20,000 persons) tends to be distributed along the islands' perimeter. The highest density is found in Kolonia, the port town and administrative center located on the northern coast of Pohnpei.

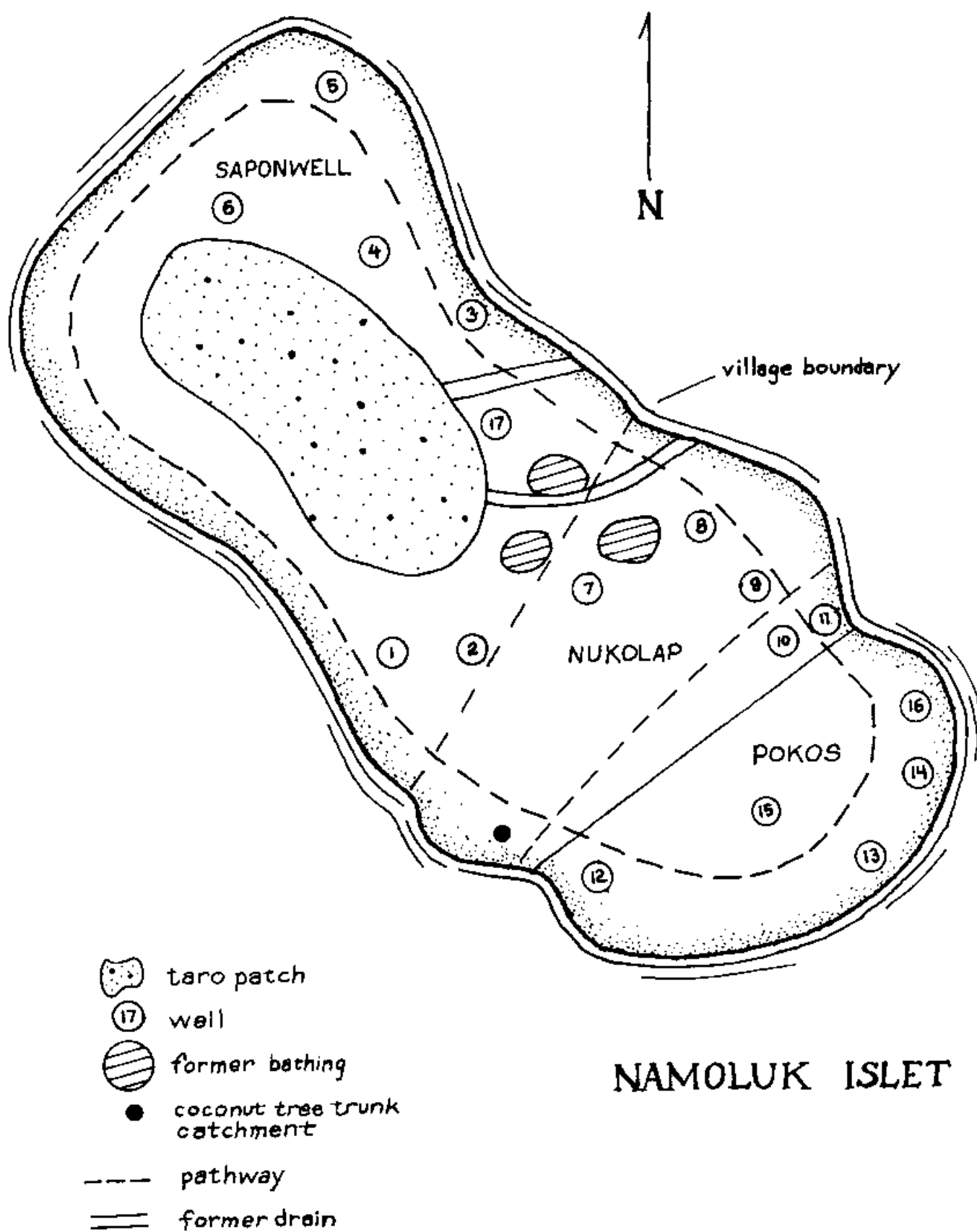


Figure 6. Namoluk Islet, Namoluk Atoll.

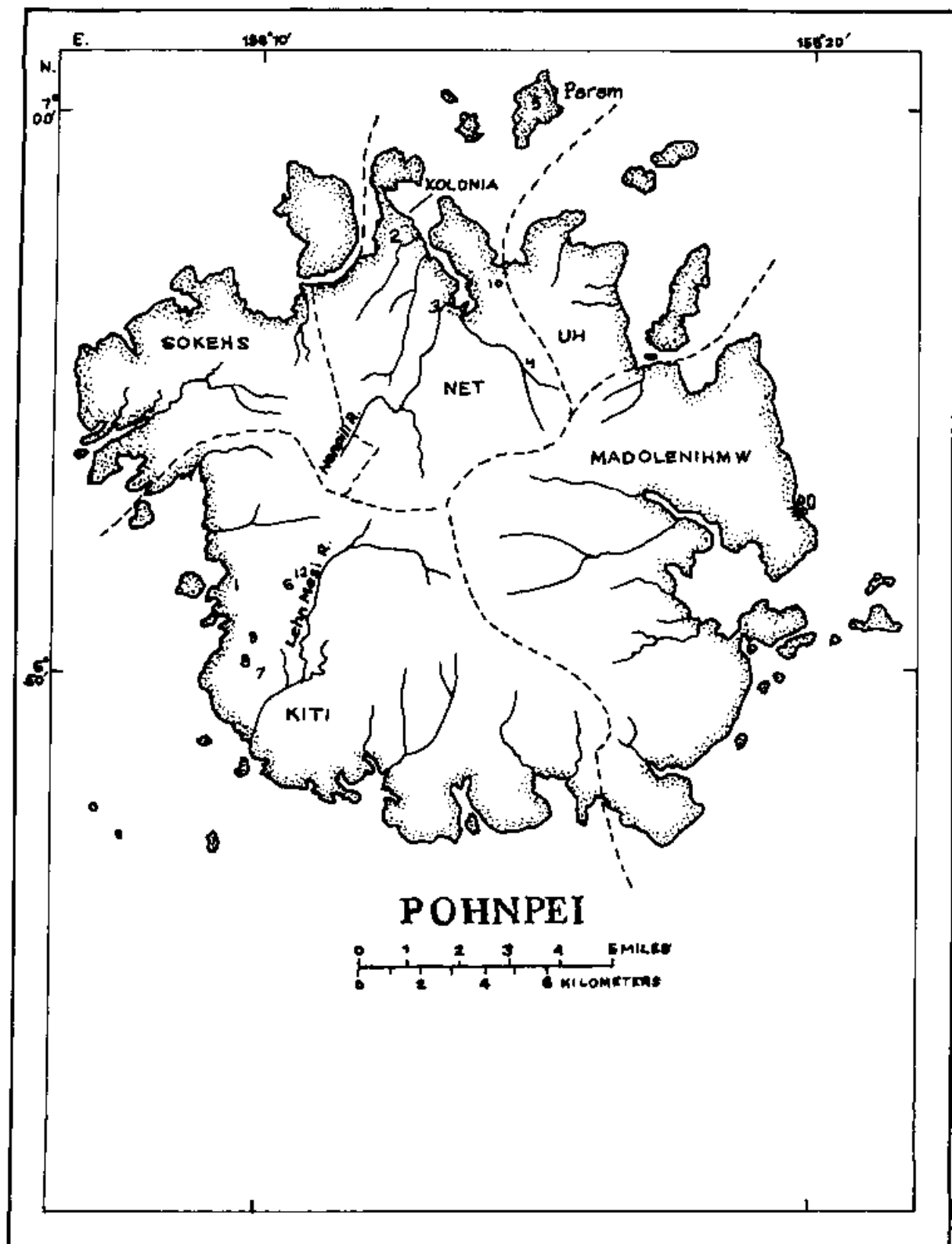


Figure 7. Pohnpei Island; study sites: (1) Kapin Mwoamwi, Kiti (2) Ohmine Road, Kolonia (3) Kamar River, Net (4) Pilenmeitik River, Net (5) Param Island, Net (6) Sahrwtakai, Kiti (7) Poatopoot, Kiti (8) Pan Matew, Kiti (9) Pilen Nan Snaip, Kiti (10) Pilen Sakaralap, Net (11) reef islands, Kiti (12) Sawarlap, Sawartik waterfalls Kiti.

Pohnpei Island is less than 500 miles north of the equator and enjoys year-round moist tropical conditions. Annual rainfall averages around 200 in at the mangrove-fringed coast and an estimated 350 to 400 in in the steep, forested interior (the highest point is 2,595 ft). The driest period is January-February, when monthly rainfall averages around 20 inches. Temperatures vary little throughout the year; highs are in the mid- to upper 80s F, lows in the low to mid-70s F. Major typhoon tracks lie well to the north and west although destructive storms can occur, causing extensive damage to crops and buildings. Droughts are rare; however in 1983 a region-wide drought resulted in reduced harvests and several destructive fires in the interior of Pohnpei as the hydrophytic vegetation had become extremely dry (van der Brug, 1986).

Like Truk's volcanic islands, Pohnpei's soils can be classified into those which are poorly drained, in bottomlands and coastal tidal marshes; and those of better drainage in upland settings. Some of the latter occur on extremely steep slopes and include old lava flows, terraces and benches (Laird, 1982).

Surface water on Pohnpei is plentiful. There are several large rivers (pil lap) and waterfalls (teniher) and numerous smaller streams (pil li chig), springs, and seeps (pil pwank). Freshets emerge from the sandy soil of some of the reef islets, and seeps and small streams occur on the small volcanic islands inside the reef such as Param.

Study Site: Nukuoroan Residence in Kolonia, Net Municipality

A quasi-urban settlement of about 6,000 people, Kolonia and its environs contain a number of ethnic enclaves, for example, neighborhoods of Pingelapese, Kapingamarangians, Nukuorans, and others. Traditional fresh water management was investigated in a Nukuoroan residential and garden area on Ohmine Road in upper Kolonia. This residential site is now served by the municipal water system but contains an old well and several drainage canals of traditional Nukuoroan design which guide runoff through a series of small taro patches.

Study Site: Net municipality, Pohnpei Island

Net is the most urbanized of the five municipalities of Pohnpei Island, containing the administrative and commercial center (Kolonia), a deep water port, and the airport. The majority of Net's population of 4,000 live and/or work in Kolonia. Param (see below), Lenger, and Sapwtik -- small islands off the north coast of Net but within the barrier reef -- are also part of this municipality. Major rivers in Net are the Nanpil, Dauen Neu, Lewi, Meitik, and Kiepw, which all flow northward, into the west side of Dausokele Bay.

Outside of the town, most of the land is forested, particularly along the river valleys and their tributaries; however, on some ridges open grass- and fernlands occur. Residences and homesteads are dispersed along the main road as well as in more remote, hilly locations only accessible by foot or four wheel drive vehicle. Mixed gardening of (Cyrtosperma chamissonis, Colocasia esculenta, yams (Dioscorea spp), breadfruit (Artocarpus spp), Cocos nucifera, and various ornamentals, such as Cananga

odorata is carried out near homesteads, along streams, and on valley slopes. On the higher elevations, sakau (Piper methysticum) is cultivated (Glassman, 1952).

Study Site: Param Island

Param is a volcanic island of approximately .7 sq mi, located within Pohnpei's lagoon some three miles northeast of Kolonia. Its port of Net. The highest point on Param is 74 m. The island is almost entirely surrounded by mangroves, which are most extensive on the western side. Param's steep slopes are forested (breadfruit, coconuts, mango, and various hardwoods). A few bare areas on the eastern side of the island expose a rocky substrate. Settlement is dispersed mainly along the lower slopes and coast in the central part of the island. Kitchen gardens and interior farming areas are similar to those on Pohnpei Island. There are no permanent rivers. Fresh water seeps emerge at the mangrove/shoreline interface and on the hillside of the interior.

Study Site: Kiti Municipality, Pohnpei Island

Kiti is a large municipality on the southwest side of Pohnpei Island. The Lehn Mesi is the largest river, and there are numerous other perennial streams which originate in the mountainous interior and flow southwest, into extensive mangrove forests along the coast. Field investigations were concentrated in the lower elevation Sewihso area near the west coast and in upland Sapwtakai and Salapwuk, near the origin of tributaries of the Lehn Mesi River. As elsewhere in Pohnpei, in addition to rivers, fresh water seeps occur on the coast and in the interior of Kiti.

The population of Kiti (about 4,000 persons) is dispersed among numerous homesteads which tend to be located near present roads. Some breadfruit, yam and sakau farming is done in remote plots. Kitchen gardens contain yams, sweet potatoes, tapioca, sugar cane, various fruit and nut trees, and ornamental shrubs. Cyrtosperma and Colocasia are planted along small streams. The destructive rooting of wild pigs in the interior necessitates the building of protective walls of stone and other materials as barriers around garden areas.

Study Site: Ant Atoll (Figure 8)

Located about seven miles west of Pohnpei Island and traditionally part of Kiti Municipality, Ant Atoll contains 17 islets distributed mainly along the southern portion of the reef. Ant's total land area is about .7 sq mi. Presently only one family resides in Ant, on Nikalap Aru Islet, producing copra for sale. Interior portions of the main islets (Nikalap Aru, Panemuk) contain large taro patches where Cyrtosperma chamissonis has been cultivated in the past.

The typical geomorphological and vegetative differences between lagoon-facing and ocean-facing sides of atoll islets, as described above for Namoluk, can be seen at Ant. The corraline soils support a limited vegetation, and the fertility of interior taro patches has depended upon constant human effort at replenishment. There is essentially no surface water on Ant; wells, however, have been dug and yield water at shallow depths.

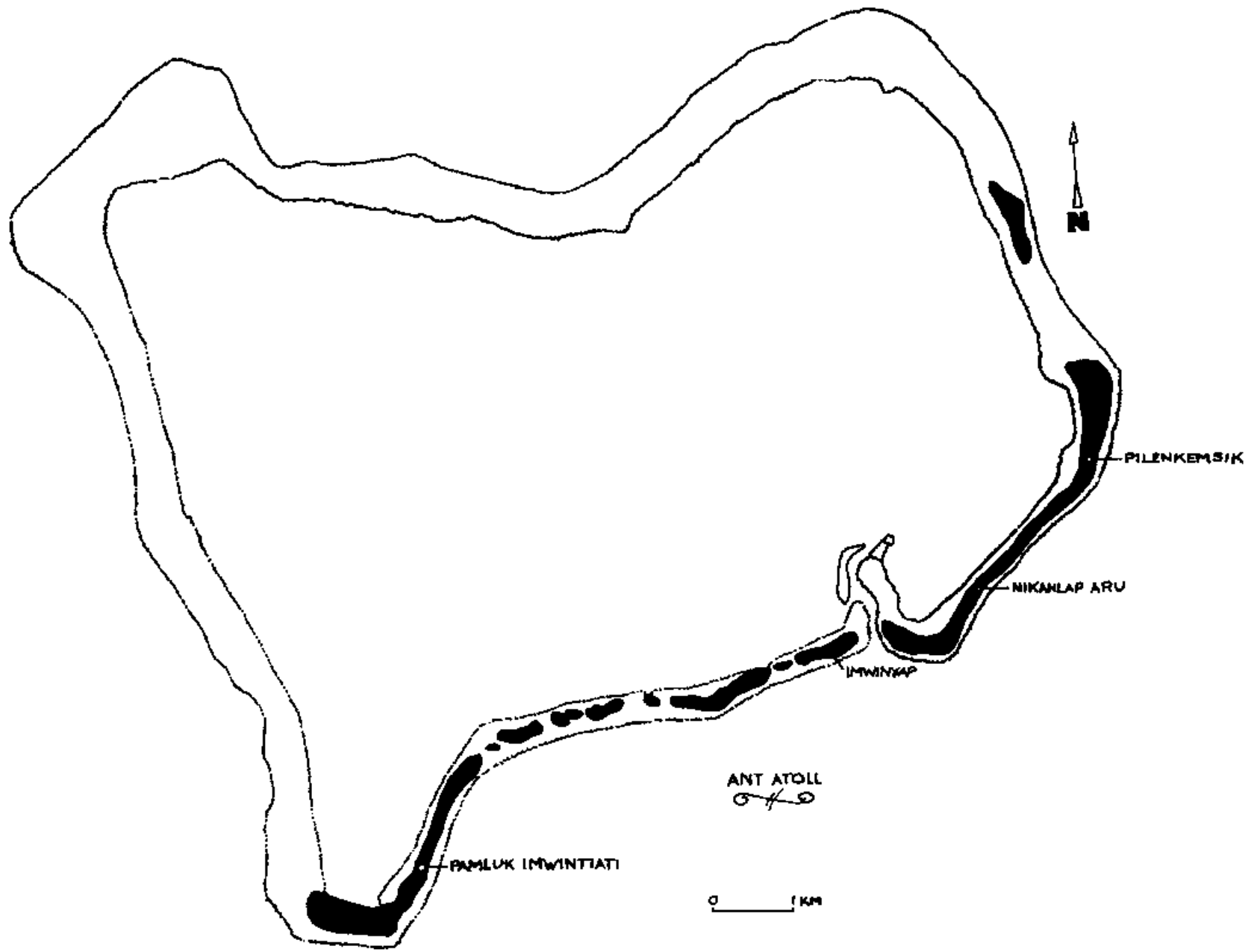


Figure 8. Ant Atoll, Pohnpei State.

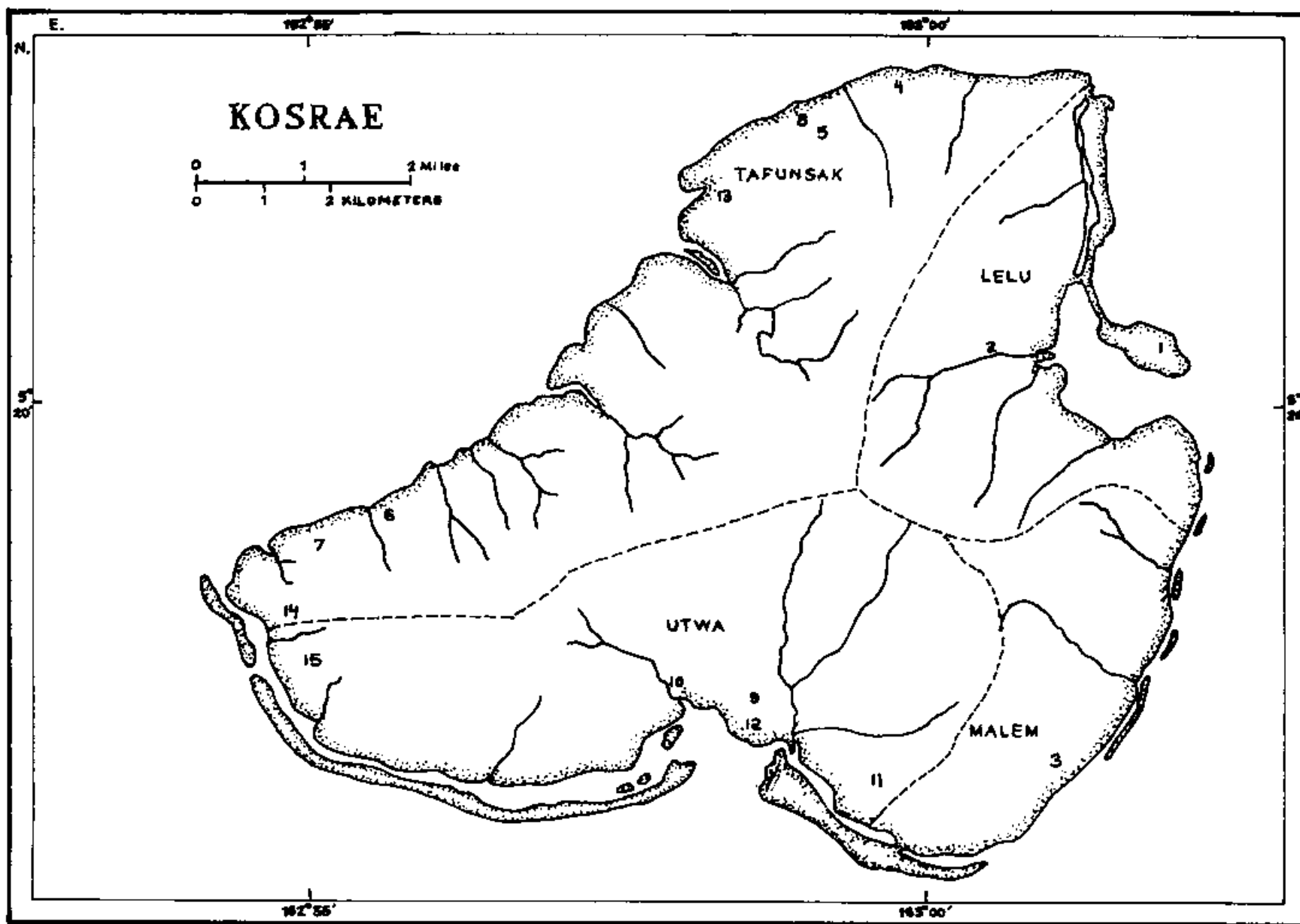


Figure 9. Kosrae study sites: (1) Lelu Island, including Salahtu, Kik, Isokelekel's Well, Medais (2) Innem Valley, Lelu, including Kolong Stream, Innem Srisrik (3) Mutunsoktar, Malem (4) Tafunsak Beach (5) Srupunyot, Tafunsak (6) Mwot, Welung (7) Leahp, Welung (8) Inkoanong, Tafunsak (9) Yawal Valley, Utwa (10) Utwa River, Utwa (11) Finsrem Stream, Inyaa seep, Utwa (12) Yot Mula Rock, Utwa (13) Loal, Tafunsak (14) Likihnhluhlwem, Tafunsak (15) Yemilil, Utwa.

Kosrae State (Figure 9)

The state of Kosrae consists of one volcanic island approximately 30 sq mi in area, surrounded by a fringing reef. Kosrae's coastline is lined with mangroves and sandy beaches. Roads are few, and travel to various parts of the island is still more easily accomplished by paddling canoe than by car, using the salt water canals which run parallel to the shore behind a sandy barrier.

Kosrae's climate is like Pohnpei's: evenly distributed high annual rainfall (about 300 in) and monthly average temperatures varying one or two degrees from 80 F. At 500mi north of the equator, Kosrae is situated well to the south and east of major typhoon tracks but is subject to occasional drought (van der Brug, 1986).

The roughly triangular-shaped island is geologically similar to Pohnpei and Truk but relatively younger. The interior is characterized by steep, jagged mountains and deep valleys. The population, about 5,000 persons, is dispersed among four municipalities. Settlement is mainly along the coastal road which nearly encircles the island. Prior to the advent of cars, people lived dispersed along Kosrae's many river valleys. A quasiurban concentration occurs on Lelu Island, formerly a sacred, high status precinct similar to Pohnpei's Nan Madol. Lelu Island is connected to the northeast coast by modern causeway.

Vegetation on Kosrae's lower slopes is secondary agro-forest (coconut, breadfruit, mango, Inocarpus, bananas); Cyrtosperma and Colocasia are grown in lowland swamps and along streams in the interior. An important hardwood is Terminalia catappa, which grows to a great height. Mangroves are highly developed and diverse, forming the dominant coastal plant communities. Primary rainforest occurs on the highest ridges and peaks, several of which rise over 600 m (Fosberg, 1960).

The soils of Kosrae can be grouped into three major types, the poorly drained coastal strands and tidal marshes, the poorly drained bottomlands of the coast and river valleys, and the well drained upland soils (Laird, 1983b). Areas of soil slumping from water-saturation are seen on the steepest slopes of the interior, constantly creating bare soil which however is quickly invaded by early successional species and later by trees.

As in Pohnpei, Kosrae's surface water is plentiful; there are numerous large and small perennial streams (infal, infal srisrik), seeps, and springs (unon). Freshets (also known as unon) emerge at the mangrove shoreline and along the island's sandy beaches.

FINDINGS

Rainwater Catchment, Storage, and Conveyance

As a rule, natural resources available for development and use in indigenous technologies are more diverse on high islands than on low islands, and people tend to adapt the materials locally at hand to their

needs. This study found that the occurrence of given technological devices and the variety in raw materials used in the catchment, storage, and conveyance of fresh water in different environmental settings corroborate these generalizations. For example, on coral islands like Namoluk, where there is no naturally occurring clay, a ceramic technology did not develop. Instead, coconut shells and large folded leaves served as containers, and cooking was done mainly in the earth oven. On Guam, a high island with naturally abundant clay sources, ceramic vessels were traditionally made and used, along with coconut shells and bamboo logs, to store and transport water, as well as in cooking.

Situated within the monsoon belt, Guam, Truk, and Namoluk experience a definite dry season. In northern Guam and in Namoluk, the lack of surface water, creates the need for catchments and reliance on ground water. In contrast, in Pohnpei and Kosrae, abundant surface water makes such practices unnecessary, and indeed they were not developed as part of these islands' indigenous water management technologies. Truk is intermediate in this respect; while seeps and streams are the main sources of fresh water, some catchment has always been practiced and wells were occasionally used.

Stephenson (1979) reports that in northern Guam, tree catchment using ceramic vessels (tinajan hanum = ceramic ware containers for water) and water storage in scooped-out coconut tree trunk basins (tok-no) were practiced. During the present project an elderly informant from the Mt. Santa Rosa area in northern Guam, said that tok-no were very common there at one time. Whereas in Namoluk tree catchment the coconut frond tied to the tree guided rainwater into the suspended coconut shell, in Guam this kind of tree catchment consisted of two downward-pointing grooves cut directly into the tree trunk. They guided the water into a large ceramic container resting on the ground. This same informant said bamboo piping was used to bring water from a seep called Meme Awguka' ("eagle's pee") to a garden area over fifty meters away.

When they became widely available on Guam after World War II, steel drum cans replaced the large ceramic containers (tinaja) (Figure 10) in household catchment systems (Photo 1). Large subsurface cement catchment tanks also came into use as people gained access to concrete. In Truk, under the Japanese administration (1914-1945), cement catchment tanks were built in the urban areas, enabling larger quantities of water to be stored. These were mainly used by foreigners. After the war, as in Guam and much of Micronesia, drum cans became common in Truk. Currently large capacity ferro-cement catchment systems, many built after the cholera epidemic in the early 1980s, have replaced them throughout the state.

Also reported for Guam in the past is the use of bamboo logs (Figure 10), with septa removed (Stephenson, 1979). The logs served as storage vessels and as rainwater catchment devices in conjunction with a tree trunk. Slung across the shoulders, bamboo logs were useful for carrying water from a catchment site or a surface source such as a spring or stream. Each segment of the large diameter bamboo used individually could hold over a gallon of water. A hole would be made in the upper side of the log, plugged with coconut husk fibers.

One catchment system used in the past by individual families on Namoluk involved suspending from a tree trunk a coconut shell from which

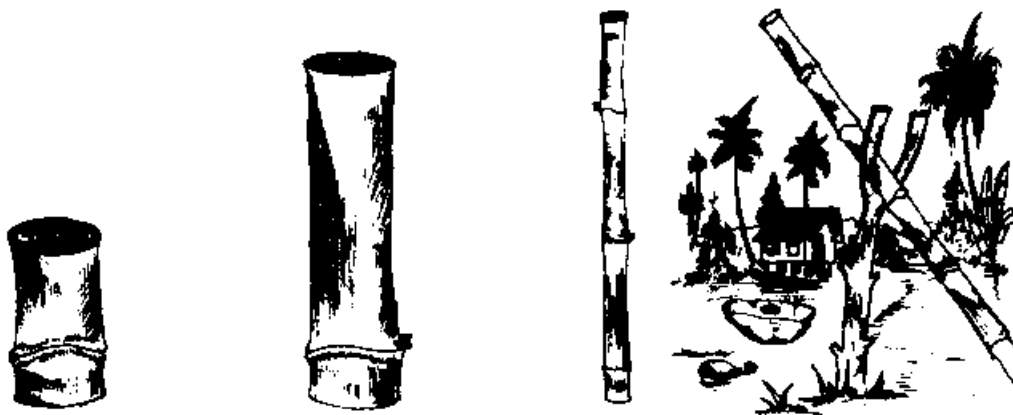


Figure 10. Rainwater catchment and storage, Guam. A. Grooved coconut tree with ceramic container B. Bamboo vessels; from Stephenson (1979).



Photo 1. Coconut tree/drumcan catchment, abandoned campsite, Oruno, northern Guam. Drumcan catchments became common on Guam after World War II and still used in remote areas.



Photo 2. Deteriorated coconut tree trunk catchment basin, Namoluk Islet, Namoluk Atoll, Truk State. This technique has been replaced by large ferro-cement catchment systems near households.



Photo 3. Alocasia taro leaf catchment basin, Namoluk Islet, Namoluk Atoll, Truk State. The water in these catchments is preferred for drinking over well water.



Photo 4. Alocasia taro leaf containers for storing and carrying water, Utwa municipality, Kosrae State. These large leaf containers can hold more than a gallon.

the ripe meat had been removed and a small hole cut out of the top (see Hunter-Anderson, 1986). A coconut frond was attached to the tree trunk above the hanging coconut shell with its hole side facing up. The midrib of the frond pointed into the opening in the coconut shell. The leaves of the frond, which were spread around the tree trunk, collected the rainwater as it coursed down the trunk, and directed it towards the lower end of the frond. The water flowed by gravity into the shell. During a moderate rain shower, a liter-sized coconut shell suspended from a young coconut tree about 10 ft tall and 25 in around fills up in less than five minutes. In Namoluk this catchment device is call pur, which is also the word for the coconut shell itself. Rain is ut, fresh water, chon.

Another catchment device used on Namoluk, as on Guam, involved hollowing out a portion of the top of the base of a coconut tree, creating a small basin. Rainwater would fall directly into the basin and sheet runoff from the trunk would flow into it as well. This method, called appwang (pwang = hole), used to be common on Namoluk. We observed only one deteriorated example on Namoluk Islet, which measured 21 by 33 cm and was 22cm deep (Photo 2). Over the past few decades roof catchment systems have replaced such traditional forms on Namoluk.

A third catchment device formerly used on Namoluk is the land taro (Alocasia; kaa in Namolukese) leaf-lined shallow basin built directly on or scooped slightly into the ground at the base of a coconut tree (Photo 3). Rainwater and runoff from the tree flow into the basin, call chonefuro (chon = water, furo = catching). The basin was uncovered, any sediment settling to the bottom. Water obtained by this method was considered very clean and was preferred for drinking to that from wells (see below).

Rainwater in these small capacity catchments was scooped up for drinking and food preparation with hollowed-out coconut shells and cups made from the folded and tied leaf of land taro (kaa) or swamp taro (Cyrtosperma chamissonis; pula in Namolukese) or breadfruit (Artocarpus spp.; mai in Namolukese). Such leaf containers, called wutewit, were also used in bathing and for temporary storage and to convey water over short distances.

In Trukese households on Moen there would be one coconut shell catchment per tree, and several such containers (pur) would be kept for short periods in the house. Coconut shell catchments for men and post-partum women were kept separate. Similarly, men and women drank from separate cups. Coconut half-shell scoops (sok; peisok) were used for drinking and to scoop water for bathing.

In Pohnpei rain is pilenketeu, and fresh water is pil. Coconut shell cups (isoak) as well as land taro and breadfruit leaf containers (ngke and chon mai, respectively) were used to scoop water and to carry it short distances from springs or other surface water sources. The water in taro leaf containers stayed cool and tasted good. Some ngke could hold over a gallon. Coconut shell scoops are called pohndal. In Param Island, two types of ngke were made; one type was used for scooping water for washing and cooking and the other, having an inside flap, was for drinking. The globular fruit of the pwile vine found in the interior of Pohnpei (unidentified, from a family of vines called salap in Pohnpeian) was used as a container for transporting water as well.

No information was obtained regarding traditional water catchment and storage on Ant Atoll in Pohnpei State but it is likely that the technology was similar to other coral islands.

In Kosrae, rain is ahf, and fresh water is kof. Containers were made from the land taro leaf (mwe nenyuk kof, lah) (Photo 4). Coconut shells (alu kosrae) were used to scoop and to carry water from seeps and streams. These containers would be suspended from Hibiscus fiber rope hangers for storage in the house or for transporting. On a large labor project where no drinking water source was close by, it was the women's job to bring water in bunches of taro leaf containers on a pole, for use by workers. Like the Pohnpeians, Kosraeans preferred taro leaf cups over coconut shells because the leaf imparted no taste to the water and therefore it did not become "spoiled."

High status persons were provided drinking water by lower status servants, from sacred sources designated for this. During droughts when stream flows lessened considerably, people avoided drinking stream water, as they believed it contaminated. At such times the reliable seeps became the main sources of drinking water.

Bamboo water conveyance structures were observed in Pohnpei, on Param Island, and in Kiti municipality (Photo 5). These elevated pipelines, supported by forked wooden sticks, carried water from a seep, downhill to residential areas. Bamboo conveyance was not traditional on Kosrae, according to informants.

Wells

As was found in this project with rainwater catchment, wells tend to be a prominent part of native technologies where surface water is scarce. Thus most wells were observed on Namoluk and few or none on the high islands of the Eastern Carolines. In northern Guam, where surface water is essentially absent, there are several large, circular, partially stone-lined depressions which have been interpreted as prehistoric walk-in wells (Reinman, 1977). They occur in north-coastal archeological sites, in the sandy soil a few meters behind the beach berm, where broken pottery and other habitation debris are common. The depressions we visited averaged 11.3m in diameter (5 cases) and averaged an estimated 1.9m in depth (2 cases). Detailed archaeological excavations and analyses of microscopic remains in the soil fill of these features may settle the question of their former function.

Stephenson (1979) records the traditional use of shallow wells on Guam, called topo, apparently dug into naturally wet soils in taro patches. They were lined with smooth rocks and provided drinking and bathing water to households. It is not indicated whether these features occurred throughout Guam, but it is likely that they would have been limited mainly to the southern part, given the island's geology. Safford (1910:38), who lived on Guam in the early 20th century, mentioned obtaining water from such a shallow well, dug at the edge of a swamp. Referring to a settlement in Agana or Tamuning, he also stated "all the houses have wells near them" (Safford, 1910:38) but did not describe the wells.



Photo 5. Portion of hillside bamboo conveyance for seep water leading to house site, Kiti municipality, Pohnpei Island, Pohnpei State.



Photo 6. Limestone slab-lined well shaft with cement paving around opening, Namoluk Islet, Namoluk Atoll, Truk State.

On Namoluk, wells (chonutu; chon = water, tu = digging) were dug into the sandy soil with coconut shell scoops, penetrating the fresh water lens which underlies the large islands of the atoll. Fresh water was also obtained from shallow basins scooped into the wet, organic soils near the large taro patch on Namoluk Islet. Such water was generally used only for bathing, not drinking.

The wells dug into the sandy substrate (see Table 1) on Namoluk Islet vary in total depth from .95m to 3.26m, averaging 2.24m. Most were carefully lined with coral slabs and cobbles. The well shaft was either rectangular or round in cross-section. Informants indicated that when making a rock lining, a square shaft is easier to produce than a round one.

Table 1. AVERAGE MEASUREMENTS OF WELLS AT NAMOLUK ATOLL

| A. Namoluk | No. of Wells - 17 | |
|-----------------------------------|-------------------|-----------|
| | Average | Range |
| Area of Opening (m ²) | 1.52 | .47-3.35 |
| Total Depth (m) | 2.24 | .95-3.26 |
| Water Depth (m) | .37* | .08-.61* |
| Depth to Water (m) | 1.89* | .83-2.71* |
| B. Amwas | No. of Wells - 3 | |
| | Average | Range |
| Area of Opening (m ²) | 1.63 | .95-2.47 |
| Total Depth (m) | 1.33 | 1.05-1.47 |
| Water Depth (m) | .59 | .45-.71 |
| Depth to Water (m) | .74 | .6-86 |

* NOTE: average and range for these were from 14 wells because 3 wells were dry.

Three wells on Namoluk Islet are said to be ancient: #2, #6, and #7. One, #12, is also supposed to be old but not as old as the first three (Figure 6). All the other wells were dug within the last twenty years. Most have coral rock and/or cement pavements .75m wide around the opening and a cement lining extending .25-.50m down the sides of the shaft from the surface pavement (Photo 6). These mostly abandoned wells provided domestic water prior to the early 1980s, when several large ferro-cement catchment systems were built. Presently every household on Namoluk Islet has at least one, often two, of these modern devices. They provide water for water-seal toilets in addition to water for clothes washing, bathing, drinking and cooking.

On Amwas Islet there were three wells, one an old well with the shaft recently cemented and two with the traditional coral stone lining (Photo 7). All of them were located within 40 to 60m of the shore. They averaged 1.33m deep (Table 1), about a meter shallower than the average depth of the wells on Namoluk Islet. These features are abandoned and reused, as land owners periodically visit or reside on the islet.



Photo 7. Limestone slab-lined well shaft, paving around opening, Amwas Islet, Namoluk Atoll, Truk State.



Photo 8. Shallow dirt-lined well, Toinum Islet, Namoluk Atoll, Truk State. This feature was used for bathing; it could also be used for soaking coconut husks prior to making coir.

On Toinum Islet one shallow, unlined well was observed some 40m from the shore (Photo 8). Now it is filled in with organic debris. Sometimes it is cleaned out by temporary residents on the islet, providing bathing and drinking water during their stays. Such a shallow well is called chonetu when used for drinking and bathing; with little modification, it could be converted into a chonetur, which is a soaking pond for coconut husks prior to making coconut fiber rope. The water in a chonetur is called lipuakenkoch.

According to an older Namoluk informant, traditionally wells were located close to the taro patch, because the digging is easier in the softer soil there, and water is closer to the surface. The tools used for digging wells were coconut shells and Cassis shells. Only a few wells (chonlap = big well) were used on an islet. These were dug only by the men though a woman might dig a small well for herself. Bathing at these communal chonlap was segregated by sex, hence an occupied islet would have at least two. On Namoluk Islet there were three bathing places, called Sakunganei, Raiwall, and Wenup (Figure 6). Sakunganei was for women and Raiwall for men; Wenup, also used by women, was constructed in the Japanese era and hence is not ancient like the other two. These three bathing places were converted into taro patches after the disastrous Typhoon Pamela in 1976 flooded the main taro patch on the islet.

Other fresh water customs in Namoluk include those which involved post-partum women. For example, they should not bathe near men nor drink from a man's cup (and vice versa); the result of a violation of these rules would be bad luck in war. From drinking from a post-partum woman's cup a man would become woinaukis -- unable to act -- unable to obey a captain's command, for instance. It is believed that the water in a drinking cup can be the medium for magic; without the separation of drinking cups, one sex would be vulnerable to the other's magic (auwar). Another fresh water custom is that a pregnant woman's drinking water should be collected only during daylight hours and brought to her. During delivery and for at least two months after, she should drink only coconuts, not water. The juice of the young drinking coconut is considered superior to water, helping to make mother's milk.

In the Truk Lagoon islands such as Moen, wells (chonetu = pool or water that stands) were not important sources of fresh water (konik, pweke) since surface water was usually abundant and rainwater (ran) catchment was also practiced. However, an aged informant said that 10-12 ft deep, rock-lined wells were dug and used as sources of bathing water. To dig out these structures, people used a digging stick like a pick, made from the engii tree (Pemphis acidula). To remove the dirt they would scoop it from the bottom and sides of the shaft into a coconut leaf basket (chug) suspended from a rope. The work was done by both men and women. In a finished well, coconut shells were used to scoop up the water. For bathing, the well water would be scooped and then poured into a large wooden bowl or small tub (seprien tutu = bowl/plate for shower). This container was then carried to the appropriate bathing site (separate for men and women) located 10-15m from the well. The mouth of the well was paved all around with small corals forming an apron about 2 meters wide; the opening was round as was the shaft. According to the same informant some of these wells can still be seen Udot Island while none remains on Moen.

Wells (pwarer) on Pohnpei were rare. We observed a former well in a residential section of Kolonia, at the Ohmine Road site. This well probably dated to the Japanese period and was the main source of bathing and cooking water for a Pohnpeian household until the municipal water system was extended to this area about ten years ago. Part of the well opening is visible in an outdoor shower area built to use piped water. As it is always full of water, this well serves as a backup supply when the city water is turned off for several hours per day. The opening measures 1.1m in diameter and the circular, stone-lined shaft is 1.6m deep.

In Ant Atoll, Pohnpei State, a traditional well and nearby bathing areas, called Pilenkemsik ("well of the hill"), were recorded on Nikalap Aru Islet (Figure 8). Reflecting close political and social ties between Ant and Pohnpei, the water is said to have been brought to the site a long

time ago from the old chiefly district of Madolenihmw in eastern Pohnpei (see the Appendix for this legend). Pilenkemsik was used for both bathing and drinking water; presently clothes washing is done in the bathing places.

The circular, stone-lined well at Pilenkemsik is 1.1m in diameter and 1m deep (Photo 9). The depth to water from the surface measured .6m; the water was very clear. It is believed that an eel has always lived in this well, ensuring that the water remains clear. The traditional manner of taking water from the well was to approach at one's clan's designated place along the circular opening. It was the responsibility of one particular clan (the eel clan) to maintain the well.

In the bathing area at Pilenkemsik, two shallow, conjoined basins have been fashioned by piling coral blocks and cobbles around pools of standing water. The larger pool measured 4.3m by 1.9m and was about .3m deep. The smaller pool measured 2.8m long by 1.6m wide; water depth was about the same, .3m.

Wells were not traditionally used on Kosrae. An exception is Isokelekel's Well, a sacred bathing place for the chiefs of Lelu Island. Later it became a major fresh water source for the entire island of Lelu. In one informant's memory as a boy, the well had been several feet deep and the shaft was about three feet in diameter; the opening margin was paved with coral slabs; and the water, very clear and clean, had come right up to the ground surface. Originally the stone-lined shaft was square in cross-section, later it was made round. Traditional access to Isokelekel's Well was by canoe; the landing was located about 25m away. Presently it is covered with sand and coral gravel but the owners say they intend to dig it out again.

Seeps, Springs, Pools, and Freshets

Springs and seeps developed for drinking and bathing are common on the high islands in this study and absent on the coral islands and in northern Guam. Northern Guam's karstic substrate contains a number of caves and sinkholes, some of which contain fresh water (Photo 10). According to Stephenson (1979:3), some of these features show evidence of pre-contact Chamorro use as sources of drinking water. Stephenson (1979:4) located the



Photo 9. Sacred well dug into sand, paved around opening and lined with coral slabs, Nikhalap Aru Islet, Ant Atoll, Pohnpei State.

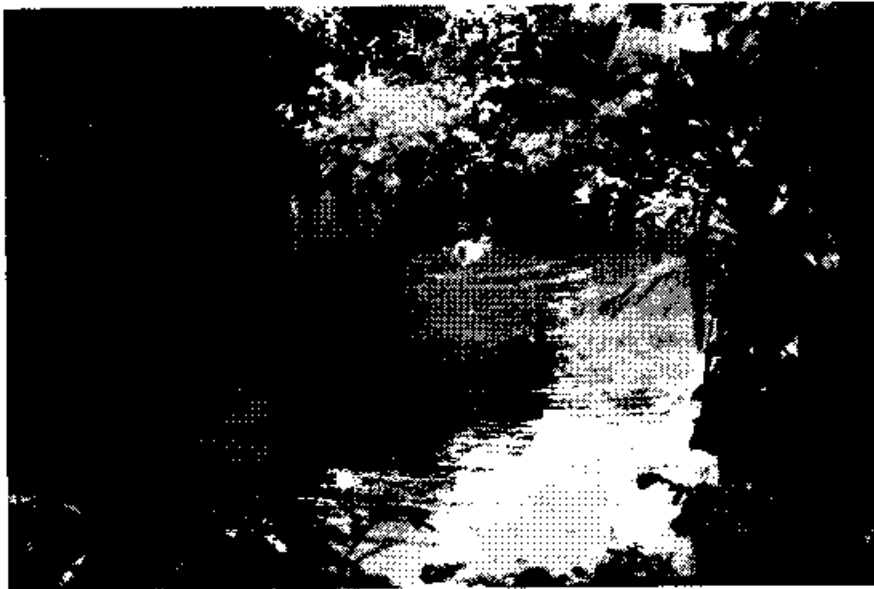


Photo 10. Large fresh water pool in limestone, Hilaan archaeological site, northern Guam.

major fresh water sources on Guam, which include two natural ponds and twenty-three natural caves with water (nine in the north). We visited a large subterranean fresh water pool at Ritidian Point and one at Pagat, and a large open pool at Hilaan (near "Sharks Hole"). All three are associated with archaeological habitation sites (Reinman, 1977).

Safford (1905:52) stated that in northern Guam a number of sinkholes call lupong were important water sources. He also described the source of the Agana River, about a mile inland, as a "fine large spring or lake (Matanhanom) from which a copious supply of water issues all the year round." At that time the channel of the river had been diverted from its original course and artificially lengthened for about a mile, running parallel to the coast in the settlement of Agana. The purpose of these historic period modifications was to provide water for washing clothes.

Freshets definitely used as a source of domestic water were found during our survey only on Kosrae. Those seen along the sandy beaches of northern Guam, for example, at Oruno, in pre-contact times may have served this purpose. This site contains extensive archaeological deposits indicating residential activities. Spanish Governor De La Cortes (cited in Mink, 1976:2) wrote of several abundant freshets along Guam's northern shoreline during the period 1855-1866.

Some of the reef islands on Pohnpei's lagoon margin have abundant freshets which were regularly tapped by whaling ships during the historic period. These water sources may occasionally have been used by Pohnpeian fishermen as well.

There is a considerable amount of folklore associated with springs and seeps, with the fresh water eel as a prominent element in stories about particular sites. In general, the eel was not eaten in the high islands of this study as it was regarded as sacred. The Appendix contains some of the traditional stories collected during fieldwork which involve seeps and springs.

On Moen, Truk, following a footpath along the southern side of the island we saw one seep, in the Petiw Village area, which had been improved by piling rocks to form a shallow basin. This seep area is used for washing clothes. At Nefow in Neiwe Village, we observed two springs on the margin of a large swamp taro patch. They have been developed as drinking and bathing water sources and are being used by a family living nearby. One of these springs was circular and had been lined with rocks, .9m in diameter. The other was rectangular, had been lined with cement, and measured 1.9m by 1.5m at the opening (Photo 11).

Winter and Stephenson (1981) report a number of "wells" in the village of Nemwen, on the Sapuk peninsula of Moen. These shallow fresh water sources actually appear to be seeps or springs. The largest, known as "Ekipekin," is used for drinking, cooking, and washing dishes and clothes. Because it never dries up, Ekipekin is the principal fresh water source for the village during the dry season when rainwater catchment supplies are low. It also provides bathing water, which is piped from the spring to an enclosed bathing place about 50 ft away. Other bathing places located within this village are the small springs called "Fanifou" and "Fanmei."

Each is surrounded by rocks forming a shallow basin and have flat, paved margins around this basin which prevent muddiness.

Customs associated with these fresh water sites in Nemwen include unrestricted access by villagers, in accordance with long-standing informal agreements between land owners where the sources are located and relatives living elsewhere in the village. It is considered appropriate and desirable by the Trukese to bathe several times daily; average per capita fresh water usage in Nemwen was estimated by Winter and Stephenson at about 19 gallons a day.

Seeps and springs in Pohnpei occur in three geographic contexts: at the interface between the volcanic shoreline and the landward edge of mangrove forests; on the barrier reef islands, where the fresh water lens emerges through the sandy ground surface; and on hillsides, flowing from rock outcrops or between non-permeable clay layers.

On Param Island we observed three mangrove forest-edge seeps, called pilentutu. Only usable at low tide when the salt water has receded for a few hours, these seeps are contained in oval or round rock-lined basins which also catch rainwater. They provide water for bathing and washing clothes. Basins ranged in area from 1.4 to 2.5m² and in depth from .3 to 0.7m. The largest one had a cobble pavement on the mangrove side of the seep (Photo 12).

Also on Param we observed a large hillside seep called "Pilenweliran" or "Pilentele". This seep has been separated into two drinking places and one bathing place. The latter consists of a boulder and cobble basin with a cobble pavement around it. The two drinking places are rock-lined and covered with pieces of tin. One has been tapped by a PVC pipe which runs downhill from the seep, to join an elevated bamboo piping system debouching into a drum can by a house near the shore. This is an ancient seep that is legendarily associated with Toluh Mountain in Kiti, Pohnpei. It is said to have been brought to Param along with the mountain; later the mountain was returned to Kiti (see the Appendix).

Other ancient seeps on Param which we did not visit but learned of in an interview are: "Malaule", said to have been obtained from Awak (a traditional district in northern Pohnpei, Uh municipality) as a gift from a titled leader named Soulikenawak; "Pilenpoatoik", one of the original three seeps on Param (Param is said to have become a separate island when a giant pushed it off the reef toward Pohnpei), and part of which seep (also called "Pilenpoatoik") remained on the reef; "Pilenwelirau", another of Param's original seeps, which has two parts (one at the mangrove/shore interface and one inland); "Pilenohp", the third of Param's original seeps; and "Pilenteleu" (see the Appendix).

On Pohnpei, Kiti municipality, we visited two hillside seeps, one in the high elevation Sahptakai area (Photo 13) and one in coastal Sowihso, called "Riliosoun". The latter has two parts; the lower seep is used for bathing and washing clothes, and the upper seep is for drinking water. The rectangular washing area measured .9 by 1m and was .3m deep. The drinking area, also rectangular, measured .5 by 1m and was .6m deep. Water depth, .07m and .04m, respectively, was considerably less than the capacity of the



Photo 11. Cement-lined seep on edge of large taro patch, Moen Island, Truk State.



Photo 12. Seep at shore used for bathing and clothes washing, Param Island, Pohnpei State.



Photo 13. Seep used for drinking water, Sahpwtakai, Kiti municipality, Pohnpei Island, Pohnpei State.



Photo 14. Seep emanating from basalt outcrop, Lelu Island, Lelu municipality, Kosrae Island, Kosrae State.

basins of these seeps. Informants pointed out a small flowering plant (not identified) that grows near perpetual seeps. The presence of eels is also considered a sign that a seep or stream is reliable and tends not to dry up during droughts.

Bathing and washing on Pohnpei also took place in pools at the base of water falls, such as those at the heads of the Sawarlap and Sawaratik rivers in interior Kiti. At the Sawarlap water fall we observed a low rock wall holding soil away from the pool on the southeast side of the nearby stream. These spectacular falls are said to have been created in mythological time by two brothers for whom the falls are named (see the Appendix).

As was found in Pohnpei, seeps and springs in Kosrae occur in three main settings: on hillsides where they emerge from cracks in rock outcrops (Photo 14); along the sandy beach in the intertidal zone, as freshets only usable during low tide (Photo 15); and at the mangrove forest/volcanic shoreline interface.

Another geographic setting for seeps, seen only in Kosrae, is in or near fresh water swamps which occur fifty to a hundred meters inland from the shore. These swamps, fed by inland streams, have developed behind the sand bars and mangrove forests encircling most of the island. The sand bars and mangroves buffer the fresh water swamps from regular salt water intrusion. Fresh water is obtainable at the surface in some places within and on the edge of these swamps, forming pools. Archaeological features associated with such fresh water sources are stone platforms, pavements, and enclosures (Bath et al., 1983; Ueki, 1984). Hambruch's plan view of a Kosraean residence (in Sarfert 1919-1920:278), which may have been situated in such a setting, shows holes in the stone pavement which are identified as bathing places.

A series of wide salt water canals dug just behind the sand bars, connected with some open lagoon areas where no sand bars are present, once served as a major transportation route for paddling canoes on Kosrae. Parts of the present perimeter road are built in this zone of sand bars and canals. In other parts of the island, road building has obliterated an unknown number of hillside seeps, while it has made some of the more remote farming areas more accessible. Other seeps have been destroyed by smaller scale land modifications such as house constructions and new pathways. Their loss is apparently offset by the availability of piped water to most residential locations.

On Lelu, a small artificial island adjacent to the main island of Kosrae and now connected to it by a causeway, we observed the site of a former hillside seep called "Salahtu". The seep was filled in when an adjacent pathway was widened and so is no longer visible. It is said to have been about a foot across and at least a meter deep. The water was very cool and clear, never running dry. When the seep was last in use a few years ago, access was not restricted. However, our informant suggested that prehistorically this seep may have served as a drinking water source exclusively for the high chiefs living on Lelu in the sacred precinct also called Lelu.



Photo 15. Freshet emanating from sand at low tide, Tafunsak municipality, Kosrae Island, Kosrae State.



Photo 16. Seep emanating from volcanic outcrop in Mt. Santa Rosa area, northern Guam.

In the same general area is the site of another seep, also no longer visible due to recent activities. This seep apparently was located inside the hill, at the end of a short tunnel. The tunnel walls were high enough to stand up inside so people walked in to obtain the water, which was plentiful. On the sandy beach just below these two seeps, where basalt outcrops dominate, we observed a former bathing and clothes-washing site. Fresh water trickles out of the rocks which form the base of the hill, into many natural basins and pools formed by the rocks protruding from the sand. The natural crevices at ground level tend to fill up with sand but were kept clear when the site was in use. The water is easily tapped by using a narrow leaf or other light conveyance to guide the trickles into a waiting vessel or basin area. The complex of seeps at Salahtu seems to indicate a large subterranean water source on the south side of Lelu Island.

Another hillside seep on southern Lelu Island is called "Lik". It is now enclosed by a cement tank and has corrugated tin for conveying rainfall into a series of drumcans. The water from this seep is said to have been used by the high ranking residents of Lelu Island. At the Medais site not far from "Lik" in Lelu is a very productive seep. According to our informants it was used during the Japanese era to supply the entire island. When the Americans took over, it supplied the nearby hospital and served as a bathing place for island residents as well. Several concrete holding tanks have been built at the site.

On mainland Kosrae, on the inland side of the road running between mangrove forest and a steep rocky hillside, we observed a hillside seep called "inyaa". Said never to go dry, it is regarded as a kind of "fountain of youth" which can make one young again.

According to one informant bamboo pipes were once used to convey water from such hillside seeps to more convenient locations for collecting the water. Bamboo is thought to have been brought into Kosrae during the last 50-100 years from Pohnpei, which would make this practice relatively modern.

At the Myot site in Welung municipality, is a seep emerging from the rocks at the base of a hill. The seep has been enclosed by a U-shaped cement wall, and cement has been poured to form a 'floor' as well. Formerly the pool was larger than the present cement tank and had only basalt boulders for bottom and sides. It drained downward into a large taro swamp which supplied the mission school built on the hill above. The tank is 3.4m wide, 4.4m long, and just under a meter deep.

Isokelekel's Well on Lelu Island (see the discussion in the "Wells" section above) more accurately may be described as a seep developed on the edge of a fresh water swamp. Another seep in a fresh water swamp was seen at Leap, in Welung. This seep, set in the middle of the swamp, was used until recently for bathing. It is considerably silted in and no longer usable.

In order to reach the Leap seep, we had to cross an almost desertic area of former swamp, now composed of stagnant salt water and mud, and dying trees. The current deterioration of the fresh water swamp is attributed to salt water intrusion that began about 10 years ago, when the

landowner widened the formerly narrow, rock-lined fresh water stream that drained the swamp into the ocean. The stream widening destroyed a protective sea wall, and erosion by wave action permitted large quantities of salt water to enter the taro-growing areas of the swamp. Now another sea wall is being constructed in hopes of preventing further damage and allowing the damaged area to recover.

Three freshets were observed along the sand beach in Tafunsak municipality. The Kosraean name for seeps in the sand is unon (Photo 15). The three freshets are spaced fifty and one hundred meters apart in a line parallel with the shore. Prior to the availability of piped water, they were used for bathing and washing clothes and dishes during low tide. Drinking water for the residents of this area was obtained from a river inland, not from these sources. Two of the freshets are called "Kiokat", and one is called "Kalo". The latter has a considerable amount of coral rubble associated with it, whereas the other two flow in pure sand. During the 1983 drought these seeps did not go dry.

Ditches, Canals, and Stream Modifications

In general, the indigenous use of ditches and canals was found to be more common in coral islands than on high islands in this study. Conversely, stream modifications, particularly stonework which slowed stream flow or altered a river's course, were found only on high islands, such as Pohnpei and Kosrae, where perennial streams are common. Some of the stream modifications were made in conjunction with earth terracing and retaining walls that were parts of residential and horticultural sites. In both of these islands taro is grown, sometimes along with bananas, in stream beds and adjacent banks, without ditches or canals.

It can be noted in passing that salt water canals used for paddling canoe travel were conspicuous parts of the elaborate architectural complexes built on artificial islands near the coasts of Pohnpei (the Nan Madol site) and Kosrae (the Lelu site). At the Lelu site during low tide, the canals fill with fresh water from a stream. This would have provided a convenient source for the many residences that once were occupied at the site. As mentioned earlier, salt water canals were also constructed for canoe travel along the coast of Kosrae. These canals are rapidly deteriorating from lack of regular maintenance and use.

On Guam, pre-contact farming methods involving fresh water management can no longer be observed. Modern subsistence farming, utilizing many of the native cultigens, includes some stream modifications which may reflect older techniques. In the Mt. Santa Rosa area in northern Guam, which is a prominent volcanic remnant within the limestone plateau, we visited a ranch whose owner a few years ago diverted the only perennial stream in the area (fed by a seep), in order to water his bananas and land taro. Formerly this stream had flowed through a swampy area mainly used for growing Cyrtosperma; now, partially filled in, it supports the former crops. The owner built a series of small concrete "dams" along the stream, which slow the flow of water without inhibiting the growth of the highly esteemed fresh water shrimp, oohang (Macrobrachium; see Amesbury et al, 1986). The Meme Awguka seep from which the stream derives is an important water source during typhoons if the modern water system fails from a lack of power

(Photo 16). It appears that this stream has long been a reliable water source during droughts.

Archaeological evidence for ditches, canals, and stream modifications on Guam is extremely slight. Excavations in the Asan area near the coast of central Guam revealed remains of a large cultivated swamp, fed by several underground springs in the limestone substrate behind the site. Wet rice was cultivated in the Asan swamp prior to World War I, using carabao as draft animals. Taro probably was a major crop at the site in prehistoric times (Hunter-Anderson, 1983a). Graves and Moore (1986) found a possible buried channel in the Asan swamp deposits, which may have functioned as a drain; prehistoric food shells and pottery were found inside the channel.

On Moen, Truk, ditches and canals were apparently rarely used in agriculture. Informants said that now there is no need for such features in the growing of taro, mainly Colocasia and Cyrtosperma, since these cultigens are generally planted directly in streams along stream banks. Sometimes they are individually anchored by rocks. Taro is also planted in wet depressions on hillsides, where the soil is appropriate, and in lowland swamps. It is in the latter setting that canal features were recorded.

We observed two cement-lined canals leading under the seaside road to the lagoon, emanating from the large taro swamp at Neauo in southwestern Moen. They drain excess water from the swamp. Responsibility for maintaining these features is now seen as the government's but local residents acknowledged that prior to the building of the road and the addition of cement siding, their repair was carried out by the villagers. Rocks had been used to line parts of the outer edge of the Neauo taro patch, presumably to stabilize the soil, which also served as a pathway.

Informants stated that ditches and canals designed to control the flow of runoff were not necessary in the agroforests on steep slopes and in the upper river valleys. Torrential rainfall can do limited erosional damage as long as the ground is perpetually covered with vegetation, which is characteristic of this island as well as Pohnpei and Kosrae.

Rock lining of the banks along the lower reaches of the Wichen River in Moen was observed (Photo 17). The purpose of such stonework apparently is to stabilize the banks. It was most elaborate where the river passes under the road, flowing into the lagoon, and near the houses built near the river, also near the road. There were linear arrangements of large cobbles across this river, at various points along its course (Photo 18). These features facilitate foot crossing and slow the flow of water.

The Wichen originates in a large seep several hundred meters inland. Along the sides of the river, where a new road has been cut paralleling the river and providing convenient access to its banks, new taro plantings have been made and a few residences built. It is not known whether such usages were also characteristic in the prehistoric past.

On Namoluk Atoll, ditching is a conspicuous part of soil management in the large inland taro swamps (Photo 19). There are two types of ditches. Perimeter ditches (kinel) are dug completely around the smaller taro



Photo 17. Stone-lined bank on lower Wichen River, Moen Island, Truk State.



Photo 18. Stone alignments slow water flow and provide a way across upper Wichen River, Moen Island, Truk State.

patches (mach) in order to drain excess water away from the plants growing in the slightly raised central area (Photo 20). Linear, grid-like ditches (also kinei) mark land plot boundaries within the larger taro patches and drain excess water away from the plants inside each demarcated land plot (Photo 21).

A perimeter ditch around a small taro patch on Amwas (approximately 9m by 6m) averaged .5m wide and .2m deep. The large inland taro patch on Amwas is about 100m by 50m. Lengthwise it is divided by a gridwork of kinei into nine sections and across into three sections.

Whereas the perimeter ditches in the smaller taro patches do not always contain water, the boundary ditches in the larger taro patches usually do, especially during high tide when the fresh water lens is high. The water in these ditches can be quite clear and is sometimes drunk from a taro leaf container (wutewit) made on the spot. Ditch water was used for clothes washing and bathing while people worked in the taro patch (now in the era of large cement catchments these practices have decreased). Sometimes water is scooped out of the ditches and used to water individual taro plants during the dry spells.

Informants stated that ideally, there should be a perimeter ditch completely surrounding the large taro patches in addition to the internal boundary ditches. Actually the perimeter ditches on the large taro patches in Namoluk are not maintained frequently enough to keep them from becoming temporarily obscured by roots. About once every two years all the ditches are cleaned out and repaired. Every year, generally after new plantings, a protective and fertile mulch of dried ferns, coconut leaves, and other plant matter is applied. In this way taro patch soil is continuously being created and improved.

Typhoons sometimes bring large waves which inundate the taro patches of Namoluk, killing the taro and spoiling the soil with salt. The people respond to such disasters by digging deep drainage channels leading from the large taro patches to the sea (see Figure 6). The aim is to get rid of the salt water washed in by the storm and to facilitate rainfall flushing of the soil, prior to eventual replanting after four or five years. The last time such a drainage channel had to be dug was after Typhoon Pamela in 1976.

As in Moen, Truk, ditches and canals associated with draining soils for taro growing on Pohnpei, as in Moen, Truk, are rare or absent; we observed none which could be said to have been features of traditional Pohnpeian farming. Both Cyrtosperma and Colocasia are casually planted in stream beds and wet depressions on hillsides; fresh water flows through the plantings with no apparent guidance from man. However, on Ohmine Road in Kolonia, we visited a Nukuoroan residence where systematic ditching of hillside taro plots reflected the Nukuoroan method of growing Cyrtosperma. The ditches formed a grid which demarcated three small plots within the family's holdings (Photo 22). Flowing toward a larger drainage canal paralleling the road, the water from the smaller ditches debouched into a small stream draining the hillside. The seven taro plot ditches observed at this residence averaged .5m wide and .3m deep.

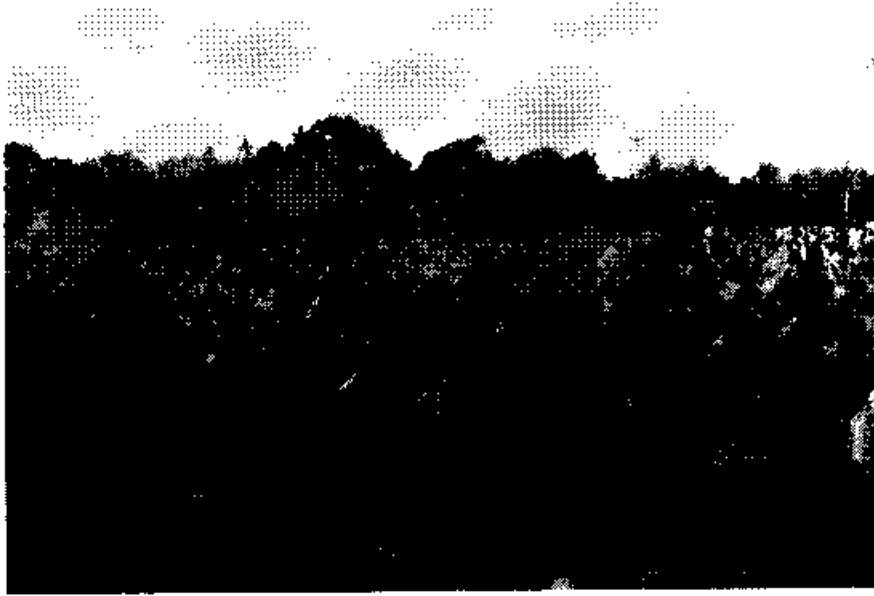


Photo 19. View across large interior taro patch, Namoluk Islet, Namoluk Atoll, Truk State. This taro patch is subdivided into nine sections by a gridwork of shallow ditches.



Photo 20. Portion of dry perimeter ditch around small taro patch, Amwas Islet, Namoluk Atoll, Truk State.

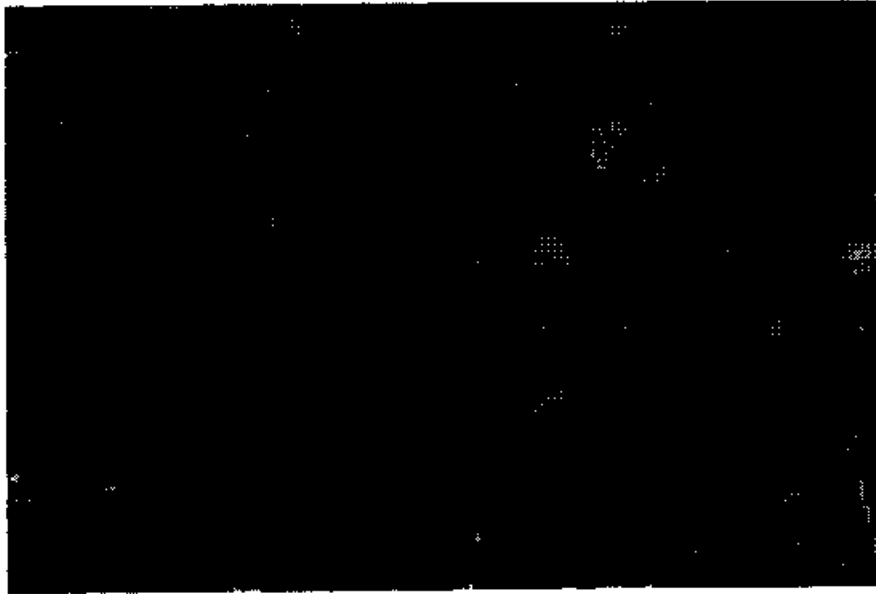


Photo 21. Internal boundary ditch in large interior taro patch, Amwas Islet, Namoluk Atoll, Truk State.



Photo 22. Rock-lined drainage channel in a taro patch complex, at a Nukuoran family's residence on Ohmine Road, Kolonia, Pohnpei Island, Pohnpei State.

Cobble lining of stream sides, apparently to stabilize the banks, was observed in Pohnpei, as on Moen, Truk. The lining of a streambank with rocks is called koskosok in Pohnpeian. It is done only at the lower reaches of a stream, where the channel is wide and the water is slow-moving. We also saw cobbles and boulders placed in streams -- along the banks of wide rivers and completely across smaller streams -- to form shallow pools (lehnpil) (Photo 23). These pools are used for bathing and clothes washing. On Pohnpei heavy showers causing the larger rivers to overflow can completely destroy such rock features but they are relatively easy to rebuild.

Stream-pool areas at four pool sites were calculated. At the Pilenkaren River in Kiti, five pools ranged from 1.8m^2 to 9.8m^2 , with an average of 4.2m^2 . At the Pilen Nan Sraip River in Kiti, five pools ranged in area from $.5\text{m}^2$ to 17.9m^2 , with an average area of 8.4m^2 . At Pilen Sakaralap, along the Kamar River in Net, five pools ranged in area from 4.8m^2 to 16.6m^2 , with an average area of 12.5m^2 (Photo 24). One pool was measured along the Pinmeitik River in Net, yielding an area of 4.2m^2 .

Generally the size of rock-formed pools is correlated with the width of the river in which they are built. The tendency for such features to be washed away during heavy rainstorms and river swelling is less in the smaller streams, greater in the larger rivers draining more area, as would be expected.

Archaeological investigations in Awak municipality, Pohnpei, indicate the use of stone-lined, steep sided ditches (Ayres et al., 1981:61-64). They have been interpreted as either for drainage or as defensive. We did not visit these sites.

As in Pohnpei, in Kosrae the construction and maintenance of drainage ditches and canals associated with subsistence farming are not typical. Agroforestry, on the other hand, especially hillside cultivation of breadfruit, which does not require water diversion, is an important component in the farming system. However, we observed one rock-lined channel, approximately 50m long, running down a terraced hillside in Lelu municipality, apparently to direct runoff downward between the terraces. This terrace complex is not in use today but may once have supported cultigens such as bananas and taro. In the field we frequently observed taro (Colocasia and Cyrtosperma) plantings in shallow perennial streams and in swampy coastal areas with no artificial drain features.

Some stonework was observed in streams near archaeological sites formerly used for residence, which could be interpreted as attempts to slow down the flow of water and to facilitate crossing. At some of these sites, rock-lining of stream banks was evident, as was the formation of shallow pools in streams using river cobbles.

Nine rock-formed pools along the stream at the Srupuyot site in Tafunsak municipality were measured. They ranged in area from $.9\text{m}^2$ to 4.1m^2 with an average of 1.9m^2 . At a site along the stream called Finsrem in Utwe municipality, three pools ranged in area from $.7\text{m}^2$ to 2.8m^2 , averaging 1.5m^2 . One pool in the Inem Srisik River in Lelu municipality was 5.4m^2 in area.



Photo 23. Bathing pool formed by placing rocks across stream, Kiti municipality, Pohnpei Island, Pohnpei State.



Photo 24. Bathing and clothes washing pools formed by rocks along side of Kamar River, Pohnpei Island, Pohnpei State.

As in Pohnpei, in Kosrae the size of rock-formed pools in streams tends to correlate with stream size. The rivers in Kosrae are relatively short, narrow, and steep, in comparison to those on Pohnpei, such as the Kamar. This is reflected in the fact that the average area of pools constructed in streams and rivers in Pohnpei (7.6m², 17 cases) is over three times that of such pools in Kosrae (2.1m², 13 cases).

According to informants, in Kosrae streams were diverted in order to bring water to farming areas where taro and bananas were grown. Streams were also diverted away from residential areas to keep them from being flooded. Such drainage channels were built of rocks and dirt walls.

Terraces, Retaining Walls, and Mounds

Terraces, retaining walls, and mounds which functioned to control or minimize the adverse effects of excess runoff were frequently observed by us in Pohnpei and Kosrae and were rare or absent in Moen, Truk, and on Namoluk and Ant Atolls. Thus in this study the occurrence of these features is correlated with volcanic soils, lushly forested steep slopes, and relatively high and evenly distributed annual rainfall. Guam, averaging only 100 in of rain per year which falls in a highly seasonal pattern and with the mountainous southern half of the island composed mainly of infertile lateritic soils, is perhaps not as likely to have had such devices, particularly for farming purposes.

Unfortunately, Guam's inhabited land surface has vastly changed over the last century, making present detection of ancient terraces, retaining walls, and mounds difficult, if not impossible. Our limited field trips did not yield evidence of these kinds of features but this does not mean they did not exist in the past. A review of the literature pertaining to Guam and the Marianas during the pre-industrial era on Guam, as well as archaeological reports, indicate native Chamorro knowledge and limited use of such technologies.

In Rota, a series of stepped terraces and water diversion ditches for growing rice was recorded by Governor Fritz, whose observations pertain to the late 19th Century (Fritz, 1984). He also stated that was rice grown on Guam in swampy low areas. According to Thompson (cited in Karolle, 1978a:36), rice was planted in the southern river valleys of Guam in the 1930s. However, as Karolle (1978b:11) pointed out, "Wet rice was cultivated in Spanish times, but no evidence of a pre-contact irrigation system exists, nor evidence that the (prehistoric) wet rice system required a plow and draft animals to pull it". The question of prehistoric rice cultivation in the Marianas remains a topic of debate in anthropology (Craib and Farrell, 1981).

The archaeological record of Guam includes evidence for native terracing not for crop cultivation but for house sites on slopes. Reinman (1977) recorded prehistoric platforms and stone walls at habitation sites in northeastern Guam. For example, at two coastal sites situated between the base of the limestone cliff and the sandy beach, low retaining walls were observed near the remains of native Guamanian pre-contact houses. The retaining walls apparently functioned to prevent water erosion of the house sites.

Reinman (1977) also recorded several archaeological settlements in inland river valleys, which showed evidence of water control techniques. Such house sites tend to be dispersed along both sides of the stream. On Guam's intermittent streams, house sites were fairly close to the water whereas along the larger streams they were set well above the floodplain. An example is the Pulantat site along a tributary of the Pago River. The houses at Pulantat had been built on a series of descending terraces, which appear to have been modifications of the natural landscape in order to stabilize the sloping soils in the area.

We observed no terraces, retaining walls, or mounds in Moen, Truk, nor in Namoluk Atoll. Namoluk's soils afford no accumulation of surface water, and Moen's native farming system is essentially agroforestry with some lowland swamp taro cultivation. Many of the higher hills and ridges are in uncultivable swordgrass savanna, and rainfall is considerably lower, and more seasonally distributed, than on Pohnpei and Kosrae. Based on the pattern of distribution of the features in question on the other islands in this study, it is perhaps unlikely, then, that such features were ever much in use on the Moen or the other lagoon islands of Truk. However, archaeological and ethnohistorical studies indicate that the control of excess water at residential sites in low land settings was probably accomplished through such means.

At the coastal village of Iras, Moen during the 1920s, one lineage house was situated "on a small bit of land practically surrounded by taro swamp" (King and Parker, 1984:231). Unfortunately the site was damaged beyond recognition prior to archaeological investigations which were carried out in the late 1970s. It seems likely that a house in a swamp setting would have required techniques of site elevation and substrate stabilization such as earth-fill and stone retaining walls. At this house site in Iras there had been breadfruit pits and burial areas, indicating a relatively large land area to be protected from fresh water inundation. LeBar (1963:60) reports that Trukese houses were built on stone or log foundations.

The Trukese did not lack knowledge of the effectiveness of stone walls to control water in swamps. A traditional technique is to build stone walls within mangroves near the shore, which prevent the tidal flow of salt water. This kills the salt-adapted mangrove trees and enables the area so enclosed to be converted to a fresh water swamp for taro cultivation (Ismael Mikel, personal communication, 1987); similar techniques have been used in Yap (Hunter-Anderson, 1983b).

In Pohnpei, elongated earthen mounds without stone buttressing were built up in flat, open areas and planted with bananas, coconut trees, and various other cultigens. Two or three of these slightly elevated features might be aligned in one area, separated by V-shaped ditches. Such a mound system could extend for several hundred meters. We learned of this traditional gardening technique, apparently designed to minimize the water-logging and supersaturation of the soil, in an interview. We were shown the remnant of one mound on the informant's property in Kolonia, Net municipality.

An example of stone work in conjunction with earth fill, observed in rural Net municipality, was an elevated stone walkway (al koskosok) (Photo 25). This feature originated on a sloping hillside and led from a residential area to a small bridge across the Pilenmeitik River. The walkway was about 2m across, .8m high at the hillside and .4m above the river. It extended for 6m. At this site stone retaining walls defined an ancient rectangular burial ground (called pei, the Pohnpeian term for any high stone platform imbued with sacredness).

Pohnpeian archaeological sites exhibiting numerous stone platforms, retaining walls, ramps, and stone-faced terraces have been documented in various surveys (e.g. Ayres et al., 1981; Ayres and Haun, 1980; Bath, 1984). Ayres et al. (1981:42) have interpreted such features in the Awak Valley as concerned with controlling the downslope movement of stones and soil, both for agriculture and to stabilize the substrate for residential and sacred structures and activities. Bath's (1984) work in the large, high elevation, interior site of Sapwtakai, Kiti municipality, has revealed similar features, interpreted similarly.

In Awak municipality, terraces with one or more retaining walls or facings ranged in area from 5m² to 100m² (Ayres, 1981:35). The smaller terraces tended to occur at the higher elevation sites; some were still in use when recorded. The cultigens grown on these features most commonly were the sakau plant (Piper methysticum) bananas, and land taro (Alocasia). The larger terraces, in the 10m² to 100m² range, sometimes were paved, suggesting non-agricultural uses at lower elevations.

One elongated mound feature, about 90m long and 8m wide, was recorded at Sapwtakai in interior Kiti municipality. Bath (1984:Fig.52) suggested it was a "raised roadway." However, it seems similar to the raised garden mounds described by our informant in Kolonia, except for the low stone facings. The straight alignments of stones partially embedded in sloping soils seen in Awak also should be mentioned, as devices facilitating foot travel in wet and slippery areas; some of these "stepping stone paths" are still in use (Ayres et al., 1981:43).

Finally, the Pohnpeian practice of growing yams in shallow pits encircled and covered by stones can be noted in connection with water and soil erosion control. It is said that this method of growing yams serves to protect the tubers from marauding wild pigs (similar reasons are given for the building of stone and wire fencing of gardens in remote areas). Other possible functions of the piled stone circles are to hold the soil in place on sloping ground while still allowing plenty of water to be absorbed by the tuber, and to provide a cooler soil temperature for the young vines -- a kind of "hydroponic stone minigarden". If these functions were indeed important in the design and use of these features, the piled rock yam-growing technique could be prehistoric, contrary to received opinion. Pigs (Sus scrofa) were introduced during the historic period whereas the conditions of Pohnpei favoring it (high year round rainfall, sloping ground, large water need for large tubers) were present prehistorically.

Traditional Kosraean uses of terraces, retaining walls, and mounds, particularly for residential and ceremonial activities, and to some extent for farming, are no longer capable of being observed directly. However,



Photo 25. Raised earth and stone pathway leading to bridge over Pilenmeitik River, Pohnpei Island, Pohnpei State.



Photo 26. Small stone-faced terrace and stone-lined drainage channel (arrow), Innem Srisrik area, Lelu municipality, Kosrae Island, Kosrae State.

the ethnographic, ethnohistoric, and archaeological literatures, as well as our field work on Kosrae, indicate the consistent use of such features in the past.

Early travelers' accounts (see Ritter and Ritter, 1982) and ethnographies (e.g., Sarfert 1919-1920; Wilson, 1968) describe the use of stone garden walls, platforms, retaining walls and terraces which minimized the adverse effects of excess rainfall. For example, von Kittlitz, writing of his stay on Kosrae in the 1820s, visited a residence which

consisted of seven buildings connected by courtyards. The entrance through a small lane formed by garden walls is one of the corners of the square formed by the whole. It is so laid out that the moisture drains off from all sides, a precaution that is also always carefully observed with single houses... (translated in Ritter and Ritter, 1982:204).

The garden walls were of stone, as were those of the entire complex.

Sarfert (1919-1920) reported that each farm on Lolo (Lelu Island) was surrounded by "a wall of coral plates." On the main island, small, dispersed, hillside farms (taro, breadfruit, coconuts, seka (Piper methysticum), bananas, yams) were irregularly laid out except for sugar cane stands. By this time many such sites had been abandoned after Kosrae's post-contact population decline. Sarfert was referring to the ruins of rock enclosures for gardens on the main island.

Archaeological surveys (e.g., Cordy et al., 1985; Cordy, 1981; Bath et al., 1983; Andrew, 1980; Ueki, 1984) have recorded stone platforms, platform-terraces, rectangular alignments, retaining walls, and pavings along rivers, in valley slopes and along the coast. These have been interpreted as related to domestic, ceremonial and farming activities.

We observed low, stone-faced terraces on a hillside near the Innem Srisrik (mentioned above in connection with a 50m long drainage ditch), which were probably agricultural (Photo 26). The height of the stone facings or retaining walls for the terraces averaged .5m.

Stone retaining walls were observed along both shallow banks of the Yawal River, which was approximately 6m wide at that point. These walls were about a half meter high and varied in length from 18m to 34m. Their purpose seemed to be prevent the soil on the sides of the stream from sloughing off into the water. Remnants of small rock pools were apparent on the east bank. Another retaining wall about 8m away, which paralleled the stream for some 30m, was two courses thick and averaged 1.7m high (Photo 27). It was designed to prevent soil loss from a flat farming area that had been created at the base of a hill. A segment of slightly elevated paved pathway about 10m long was also seen at this site.

A presently occupied archaeological site called Yemlilil, in Utwa municipality, exemplifies the traditional Kosraean streamside settlement preference. A small stream runs along one side of the residential complex and is used for bathing, washing clothes and drinking water. For these activities, shallow pools have been formed using streamside rocks. Small



Photo 27. Stone and earth retaining wall near Yewal River, Utwa municipality, Kosrae Island, Kosrae State.



Photo 28. Rock-lined breadfruit fermentation pit; pile of rocks in center covers fruit, Kiti municipality, Pohnpei Island, Pohnpei State.

garden plots planted in a flat area near the house structures have been enclosed by a low stone wall. There is an abundant seep that emanates from the steep, rocky hillside about 20m away. Should the stream dry up during a severe drought, as happened in 1983, this abundant seep provides the family with good quality water.

Breadfruit Fermentation Pits

The traditional preservation of breadfruit by pit fermentation is still commonly practiced in the Eastern Carolines. Breadfruit pit features are relevant to this study because they represent a native technological solution to the problem of food storage in tropical settings which involves fresh water management. In the low islands, such as Namoluk Atoll, the preference is for "dry" preservation. The fermenting fruit is not allowed to become wet from the fresh water lens, as only rainwater percolates into the silage held in wide, shallow pits.

On the high islands of Truk, Pohnpei, and Kosrae, "wet" fermentation is preferred. Deeper pits are dug into hillsides and others are placed along streams within mangrove swamps so that the silage is nearly always moist. Runoff and subsurface water flows through the hillside pits, sometimes routed downward by a channel. Dug into clayey soil, hillside pits are generally not completely lined with stones. In Kosrae, alternating fresh water and salt water flows through the pits that are dug along streams within the mangroves. These streamside features are formed by rocks, which exclude animals and keep the contents intact despite moving water.

We did not observe breadfruit fermentation pits on Moen, Truk, but were told of the existence of the hillside type. On Pohnpei these features are called kahnlipw. One was seen at the Sapwtakai archaeological site in Kiti municipality. A drain at the lower end led to a nearby stream. The roughly circular pit was .2.6m across and 2.2m deep. Another hillside breadfruit fermentation pit, partially rock-lined, was seen in Kiti at Poatapoat (Photo 28). It measured 4.5m long, 2.9m wide, and 1.3m deep. A shallow pool of water 8cm deep could be seen at the bottom of the pit.

On Kosrae breadfruit fermentation pits (furoh) along a stream at the edge of a mangrove swamp were observed at Won Utwa (Photo 29). One of these pit features, presently not in use, measured 1.5m by 1m. It was formed by one course of coral rocks and basalt cobbles arranged in a U shape, opening toward the stream. A second pit on the same side of the stream was in use. It consisted of a circular area of coral rocks two courses thick and measured 1m by 1.3m. Across the stream from these two pit features were two more, not measured. At Likenlulem in Tafunsak municipality, seven rock features for breadfruit fermentation were found on both sides of a small seep-fed stream. This stream is at the edge of mangrove forest and fresh water wetlands (Photo 30).

CONCLUSIONS

This study has documented some indigenous Micronesian solutions to the basic hydrological problems presented by the physical and social settings of Truk, Pohnpei, Kosrae, and Guam. Contrasting geographic characteristics, such as volcanic vs. corraline soils, and seasonal vs.

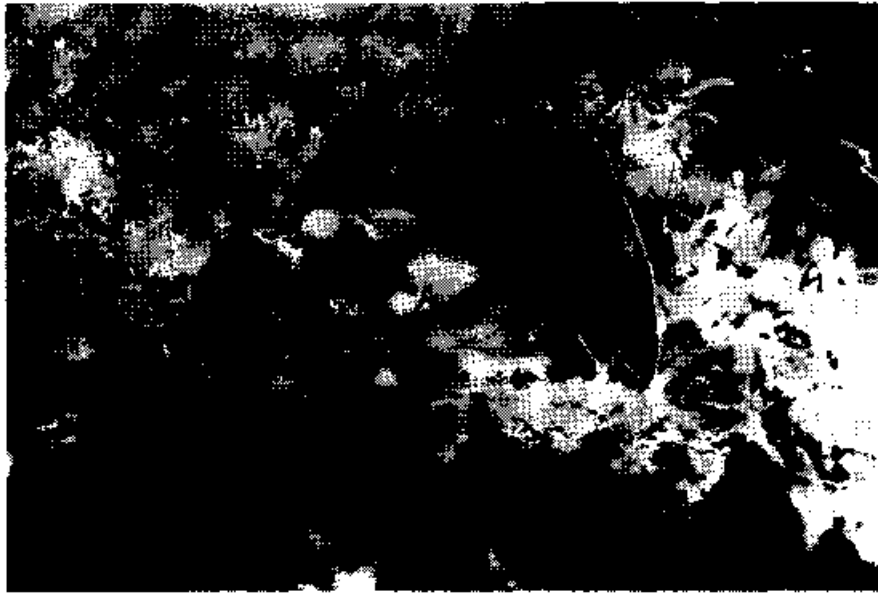


Photo 29. Rock-lined breadfruit fermentaion pit at edge of stream in mangrove, Utwa municipality, Kosrae Island, Kosrae State.

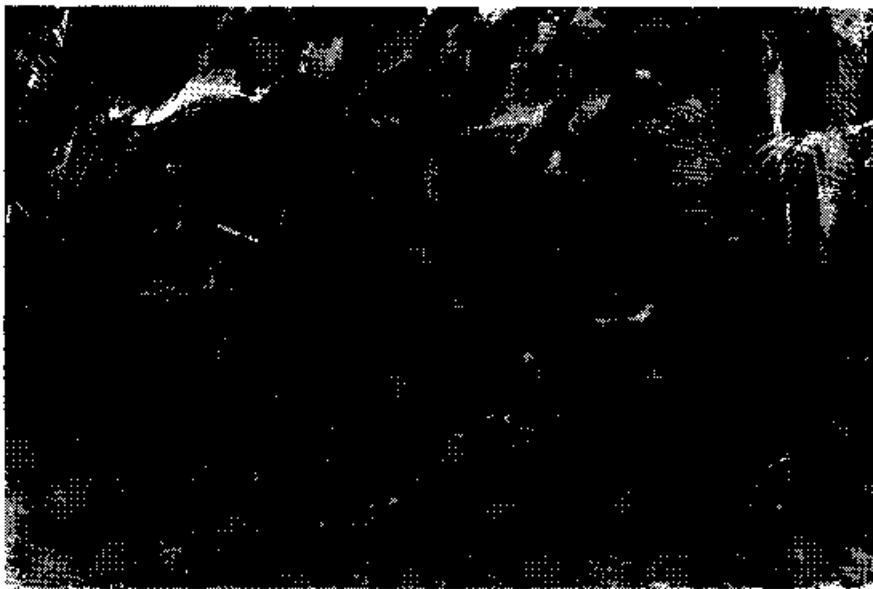


Photo 30. Intersection of three streams fed by seeps within mangrove; rock-lined breadfruit fermentation pits on both sides of main stream, Likinlulum, Kosrae Island, Kosrae State.

non-seasonal climates, have elicited contrasting adaptations. There are corresponding variations in the design and use of water catchment, storage, and conveyance devices, in wells, terraces, retaining walls, seeps, and springs, in agricultural mounds and stone yam protectors, and in breadfruit storage pits.

Rainwater catchment devices were more common on coral islands and on northern Guam. They were less important or absent in high islands, where surface water is plentiful. In Pohnpei and Kosrae, islands with ample annual rainfall, various earth and stonework features redirected excessive surface flows and prevented soil loss. Stone-lined wells for domestic use were strikingly more common on coral islands and on Guam -- where there is a pronounced dry season -- whereas perennial seeps, springs and streams were the usual sources of drinking and bathing water in Pohnpei and Kosrae.

For agricultural purposes, ditches and canals which drain agricultural soils were more frequent on coral islands and less frequent on high islands. Earthen mounds and stone-faced terraces which ensured the accumulation of soil at the base of hills were seen only in Pohnpei and Kosrae, where these features permit gardening in relatively well-drained soils in spite of heavy rainfall. The circular stone features built on steep hillsides to protect yam tubers, also seen only on these islands, may be an adaptation to periodically intense surface water flows as well as to the threat from wild pigs.

Traditional attitudes and behavior toward fresh water in islands with plentiful surface water differed from those with none, or where droughts are common. The preferred locations for households in the Eastern Carolines are near perennial streams, enabling frequent daily bathing and other domestic activities involving fresh water. This contrasts with the findings of last year's study on Yap, where surface water is scarce or absent during the annual dry season. In Yap, most settlements are in the coastal areas and there is a strong conservation ethic with regard to fresh water available in interior seeps. The regulation of access to fresh water sources is part of the traditional ideology and social organization which assigns differential rank and status to individuals and to land.

Fresh water sources, particularly hillside seeps, have been carefully managed through such cultural conventions. In contrast, in the high islands of the Eastern Carolines the naturally abundant surface water -- a result of year round high rainfall and a volcanic substrate -- is viewed as an "unlimited free good". Concomitantly, there is no complex cultural regulation of access. Legendary associations between fresh water sources and human activities emphasize political relations among corporate units within the islands of the Eastern Carolines, not individual rank and status as in Yap.

The study found that increasing the traditional agricultural uses of fresh water in the islands studied is not likely to impinge on or conflict with increased demand for drinking water as populations grow. In the high islands, fresh water management techniques in agriculture have been designed to minimize soil erosion. Excess water is diverted away from vulnerable plantings, into normal stream outlets. Streams and seeps are preferred for bathing and drinking, and catchment is rare.

On the high islands a potential conflict between intensified agriculture and increased fresh water demand is from chemical pollution. For example, runoff diverted from hillside plots into streams used as drinking water sources could contain harmful pesticides, fertilizers, and residues from fossil fuels mechanized farming, should these chemicals be introduced in order to increase crop production or to enable non-traditional crops to be grown.

In the coral islands, rainfall-derived ground water, in the form of the fresh water lens, provides water for growing staple crops (taro and breadfruit) and to a limited extent, for bathing and cooking. Large capacity household rainwater catchment systems are becoming the main source of domestic water in these islands, and wells are decreasing in use. It is possible that the increased amounts of domestic water provided each household by the new catchment systems will encourage higher household consumption rates. Should flush toilets, inside plumbing, washing machines, etc., become common, however, then chemical and bacteriological pollution of the fresh water lens is a potential hazard for ground water-fed crops (see Ayers et al., 1984:112).

Other Implications

The design of new technologies for the islands could be improved by knowledge of the information gathered in this study. In some cases, such as Kolonia, Pohnpei, which has developed into a small town, modern utilities are necessary but still need to be adjusted for local conditions. For example, it appears that the consumer demand for water is higher in Kolonia than in many American cities (Khosrowpanah and Hunter-Anderson, 1987). This may be a manifestation of traditional attitudes and behavior toward an abundant and freely accessible resource, as well as habits formed during recent times when short "water hours," leaking pipes, and a flat rate for household water usage encouraged waste. To insure the success of a modern water supply system, it's management must incorporate a change in consumer behavior through, say, technical upgrades and rate-structure incentives, or it must be designed to provide larger than usual amounts of water per household with all the additional expenses that would entail.

Similar facts recently were not taken into account by the designers of a desalinization plant on Ebeye, Kwajalein Atoll, in the Marshall Islands where water hours were regularly imposed and wasteful habits had developed. The new water supply system immediately collapsed under unanticipated high demand and could not be reactivated until the many household service lines lacking shut-off valves had been repaired or replaced (D. Ballendorf, personal communication, 1987).

Another practical implication of this study involves anticipating the local effects of a change in water use, say, for industrial or commercial purposes. If the traditional management of fresh water includes the use of hillside seeps during drought or when the power goes out and pumps stop, then destroying or diverting such family "back up" water supplies when a new facility such as a cannery is built can create serious hardships and may ultimately result in the failure of the new enterprise, from public resentment and non-cooperation. Such a problem occurred in Truk when a small seep-fed water distribution system was installed behind a village,

destroying an area that had been a popular meeting place for young people. The system has been vandalized repeatedly. There were other problems related to the failure of this project yet some of them could have been anticipated had customary behavior been taken into account (see Winter and Stephenson, 1981).

Finally, the study shows that where fresh water has been successfully managed by indigenous methods for centuries, there seems no compelling reason for replacing traditional technologies by possibly inappropriate modern ones. Currently fostering such replacements are trends away from subsistence farming and fishing toward wage work and dependence on imported food and clothing. Population migration from outlying islands to the district centers, and part-time residence by non-land owners in these quasi-urban areas are additional factors. Modern technologies (paved roads, electricity and piped water, and large appliances like washing machines and freezers) are being extended from the district centers to outlying, rural households. But along with these introductions have come the consequences of using inappropriate and incomplete technological systems, such as soil and ground water pollution from inadequate sewerage and unsightly accumulations of metallic waste from lack of adequate collection and disposal facilities.

Micronesian islanders and their newly formed governments do not have the technical background and experience with modern technologies which would enable them to better cope with these problems. Yet they do possess a legacy of technical competence in managing their natural resources in traditional ways. The challenge for water supply professionals who are involved in technology transfers in these islands is to integrate a knowledge of these traditional attitudes and behavior into the design in modern systems.

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APPENDIX

Published sources of water-related Micronesian folklore include Hambruch (1931), Mueller (1917), Grey (1951), (Poignant, 1967) Uag (1968), Lee (1968), Mitchell (1973), Ashby (1985), Van Peenan (1974), Stephenson and Moore (1980), Bath (1984), Hunter-Anderson (1986) and Lessa (1961, 1980). Several unpublished sources can be found in Trowbridge's (1986) review of water myths of Micronesia.

The following materials related to fresh water were collected during this project's fieldwork. They all pertain to Pohnpei State.

1. Interview with the late Joseph Ligorio, of Param Island, Pohnpei, July 21, 1986.

Mr. Ligorio related that there are five ancient seeps on Param which are called Malaule, Pilenpaotoik, Pilenwelirau, Pilenohp, and Pilenteleu. The seep called Pilenpaotoik was split into two parts when a giant pushed Param Island off the reef towards the main island of Pohnpei. Regarding the origin of Pilenteleu, people brought a mountain with this seep in it to Param. Some people took the seep from the mountain. Other people found that there was no more seep in that mountain so they threw the mountain away to Kiti. This mountain is called Toluh. The seep called Malaule originated when a man called Soulikenawak liked the people of Param and offered them a present with this seep.

2. A story about the ancient well on Nikalap Aru Islet, Ant Atoll, related in an interview with Lucius Sakh, July 25, 1986.

An eel brought the water here from a seep in Aru, Madolenihmw, on Pohnpei. The seep water became a well. The name was given by the female eel to commemorate the place where it came from. When she first brought the water she stayed inside the well. Whenever someone would come to get water, the eel would react to him or her. If she liked the person she would stay still and the water would remain calm. If she did not like the person she would make the water rough. Finally she got homesick for Aru in Madolenihmw and returned home.

Mr. Sakh said that the custom on Aru Islet at the site on the well was that only those who lived near the well, where the eel knew them, should take water from it. This was true also in Pohnpei at wells there. The eel of a well or seep knew the local people. At Aru in Ant, the people there still believe the eel is in there because the same things happen now as they did in the past. Formerly there were specific places designated around the circular opening of the well for people to obtain the water, according to their clan.

3. Regarding the two waterfalls in Kiti, called Sawarlap and Sawartik, on July 27, 1986 Mr. Mikel Tomsin related that they were formed by two brothers. The older was named Soamoanpwoailapalap and the younger was named Soamoanpwoaitikitik. The brothers stopped a giant who was trying to dig across Pohnpei at the place of the falls. They also created three mountains, one each in Kiti, Madolehihmw, and Uh. These legendary brothers have other names in other districts of Pohnpei, for example,

they are called Olsipa (the younger) and Olsopa (the older) in Madolenihmw.

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