GROUND-WATER RESOURCES OF SELECTED HIGH VOLCANIC ISLANDS OF TRUK WITH EMPHASIS ON SMALL VILLAGE SUPPLIES

By Kiyoshi J. Takasaki

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CONVERSION FACTORS AND ABBREVIATIONS

The following table may be used to convert the inch-pound units to metric units.

Multiply inch-pound units	By	To obtain metric (SI) units
Temperature		
degree Fahrenheit (°F)	°C = 5/9 x (°F-32)	degree Celsius (°C)
Length		
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
acre	4,047	square meter (m^2)
square foot (ft^2)	0.09294	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
Volume		
acre-foot (acre-ft)	1,233	cubic meter (m^3)
gallon (gal)	3.785	liter (L)
million gallons (Mgal)	3,785	cubic meter (m^3)
Volume Per Unit Time (includes Flow)		
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter [(L/s)/m]
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06308	cubic decimeter per second (dm^3/s)
gallon per day (gal/d)	0.00004381	cubic decimeter per second (dm^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

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ABSTRACT

The Truk Lagoon, about 800 square miles, is roughly the size of a volcano that once occupied it. The volcano was eroded and also sank with time. The 19 volcanic islands now visible in the lagoon are remnant peaks of this partly eroded and sunken volcano. Coral atolls form the periphery of the lagoon.

The bulk of the islands consists of tight, massive lavas and cemented rock fragments. Although the rocks are saturated, they yield little water to springs or to wells tapping them. Weathering of these rocks causes some increase in permeability and where the weathering is deepest as in valleys and in the flatter slopes, the material in the valleys underlying the flatter slopes comprise the main ground-water reservoirs. Although mostly small and discontinuous, these aquifers store limited quantities of ground water available for development.

Rainfall averages about 140 inches per year and generally is sufficiently persistent to provide water for drinking and cooking from very small rain catchments, springs, and seeps with small storage. This situation is not satisfactory because with rainless periods, even short ones, springs, seeps, and rain barrels quickly go dry.

Water supplies in the villages can quickly be made more dependable by increasing the size of rain catchments and storage. Another alternative, where costs are too high to make these changes immediately, is to dig wells to supply water only for bathing, washing and flushing of toilets. A design for a simple well, to provide drinking and cooking water for long rainless periods, is illustrated.

The water-supply problems in the volcanic islands of Dublon, Uman, Fefan and the Faichuk Islands during the 1982-83 drought were generally similar. Ground water occurs in Pis Island, a coral island, on the north end of the lagoon in a freshwater lens floating on seawater.

The water from wells tapping the freshwater lens had some increase in chloride concentration during the 1982-83 drought.

The day-to-day rain-dependent supply of water was totally inadequate during the 1982-83 drought. During this drought, rain barrels went dry, most streams and springs ceased to flow, and many shallow dug wells went dry. Fortunately, some dug wells in flat coastal areas still had water and these wells provided the only water available for the villages.

INTRODUCTION

Generally high and frequent rainfall throughout most of the year in Truk provides enough water from rain catchments and springs for normal household use in most villages. This condition prevails only because of the high rainfall even though rain catchments are small and the flow from springs and seeps is small after each rainfall. Manmade storage is, in most cases, limited to a few days supply. There are some water shortages, mostly during February when rainfall is lowest for the year. In many villages, water dipped from shallow dug wells provides the supply for bathing and laundering and, more recently, for use as toilet flush water. Because of the high rainfall, ground-water levels generally remain high.

The day-to-day rain-dependent supply of water was totally inadequate during the 1982-83 drought. During this drought, rain barrels went dry, most streams and springs ceased to flow, and many shallow dug wells went dry. Fortunately, some dug wells in flat coastal areas still had water and these wells provided the only water available for the villages.

Purpose and Scope

This report was written primarily to discuss alternatives available to alleviate another such water shortage as occurred in 1982-83. One of the goals is to describe fundamental components of the hydrologic cycle. It is desired that the readers understand the limitations of rainfall, streamflow, and springflow as supply sources with no storage, and their value as supply sources with adequate storage. This report provides an assessment of the water-supply sources in the Truk State so that the villagers can start to improve and expand the existing sources. Emphasis of the report is on village supplies.

A comprehensive program to develop the water resources of 14 volcanic islands in the Truk Lagoon and 24 outer-island coral atolls is included in a recently developed 5-year Capital Improvement Plan for the Truk State. It is hoped that the material in this report will increase the likelihood of success of this task.

An open-file report, "An Evaluation of Geophysical Techniques for Ground-Water Exploration in Truk," was prepared by James Kauahikaua (1987) of the U.S. Geological Survey.

The scope of this report is limited to describing and assessing the supply sources, with emphasis on ground water, of the high islands in the Truk Lagoon and the reef island of Pis. Because the occurrence and development of ground water is so similar from one island to another, no attempt was made to be island-specific. Instead, the occurrence of ground water in the high islands is used as a prototype with examples of wells tapping the different aquifers. The dug wells in the islands that were visited, such as Dublon, Uman and Fefan, are included in this prototype. A summary of water resources for the islands of Dublon, Uman, and Fefan are included in the report. These islands were visited in 1983-84.

Location of Area

The Truk State lies in the western Pacific Ocean at the western end of the Eastern Caroline Islands between latitude 4° to 10°N and longitude 148° to 154°E. It is centered around the islands of the Truk Lagoon (Truk Islands) and surrounded by the outer islands of the State which consist of the Western Islands (Pattiw), Namonuito Atoll, Hall Islands and the Mortlock Islands (fig. 1).

The Truk Islands, located at latitude 7°25'N and longitude 151°47'E consist of 19 high volcanic islands and at least 65 low reef islands (fig. 2). The volcanic islands lie in a roughly triangular lagoon with an area of about 800 square miles enclosed by a barrier reef. The Truk Islands comprise the area to be discussed in this report.

Development Under Japanese Administration

A large and rapid increase in the Japanese population in Truk from about 5,000 in 1940 to nearly 40,000 in 1945 had a significant impact on the development of the water resources in the islands (Father Hezel, written commun., 1983). At the end of World War II, the Japanese population was nearly three times that of the Trukese (fig. 3).

The largest Japanese-constructed water-supply installation was a filtration plant in Dublon Island that was used to supply ships and the needs of the Japanese Navy headquartered there. The plant, with little modification, is still in use today. The Japanese also started to build a 90-foot dam on the island but were not able to finish it before the end of the war.

Hundreds of shallow wells were dug by the Japanese throughout Truk, many equipped with hand pumps and a few with small gasoline-powered pumps. Most of the dug wells were lined and curbed at least a foot above the land surface. Many of these wells are still used today. In addition, many large cisterns and reservoirs were constructed. Some of these have been restored and put to use.

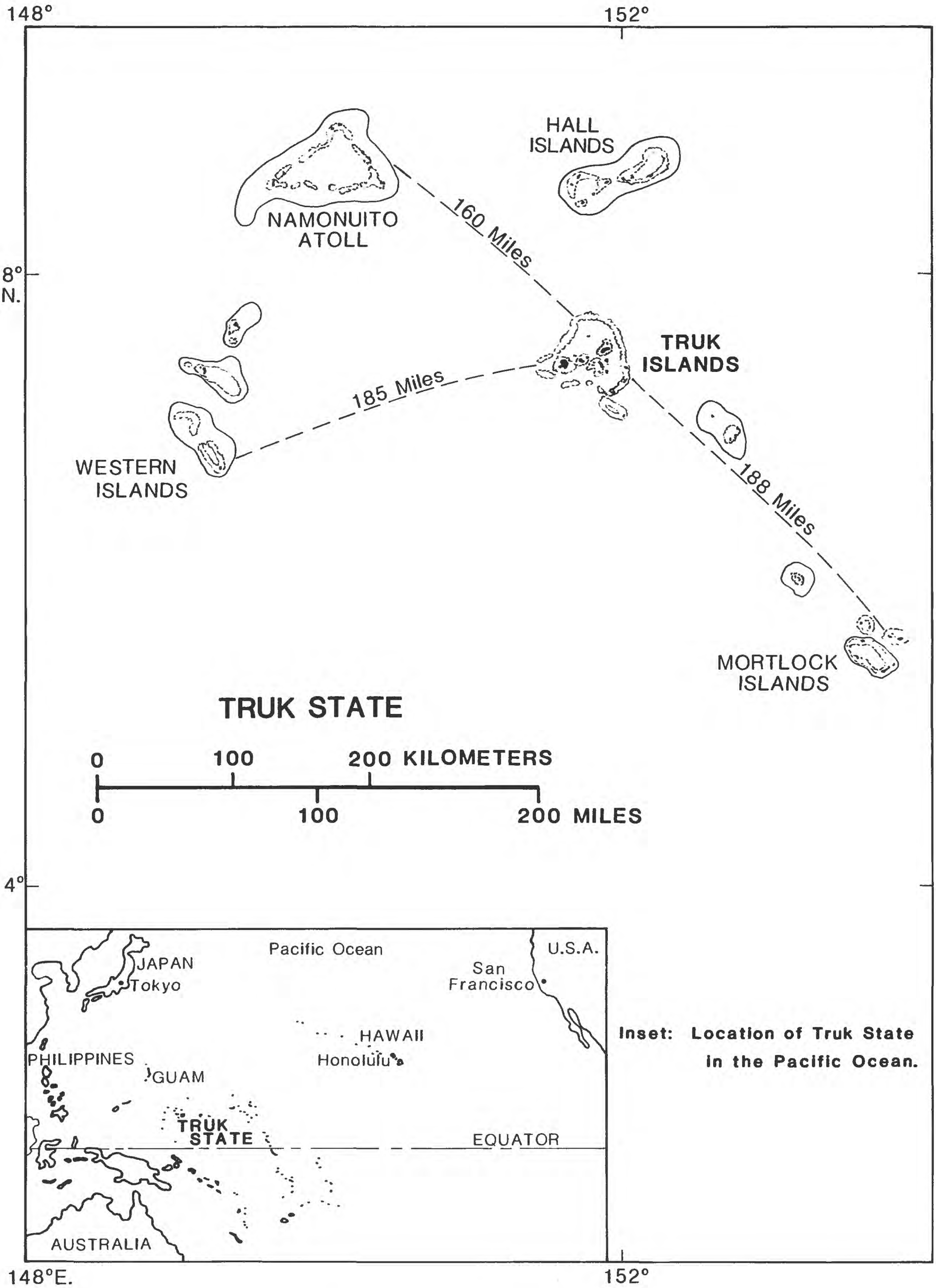
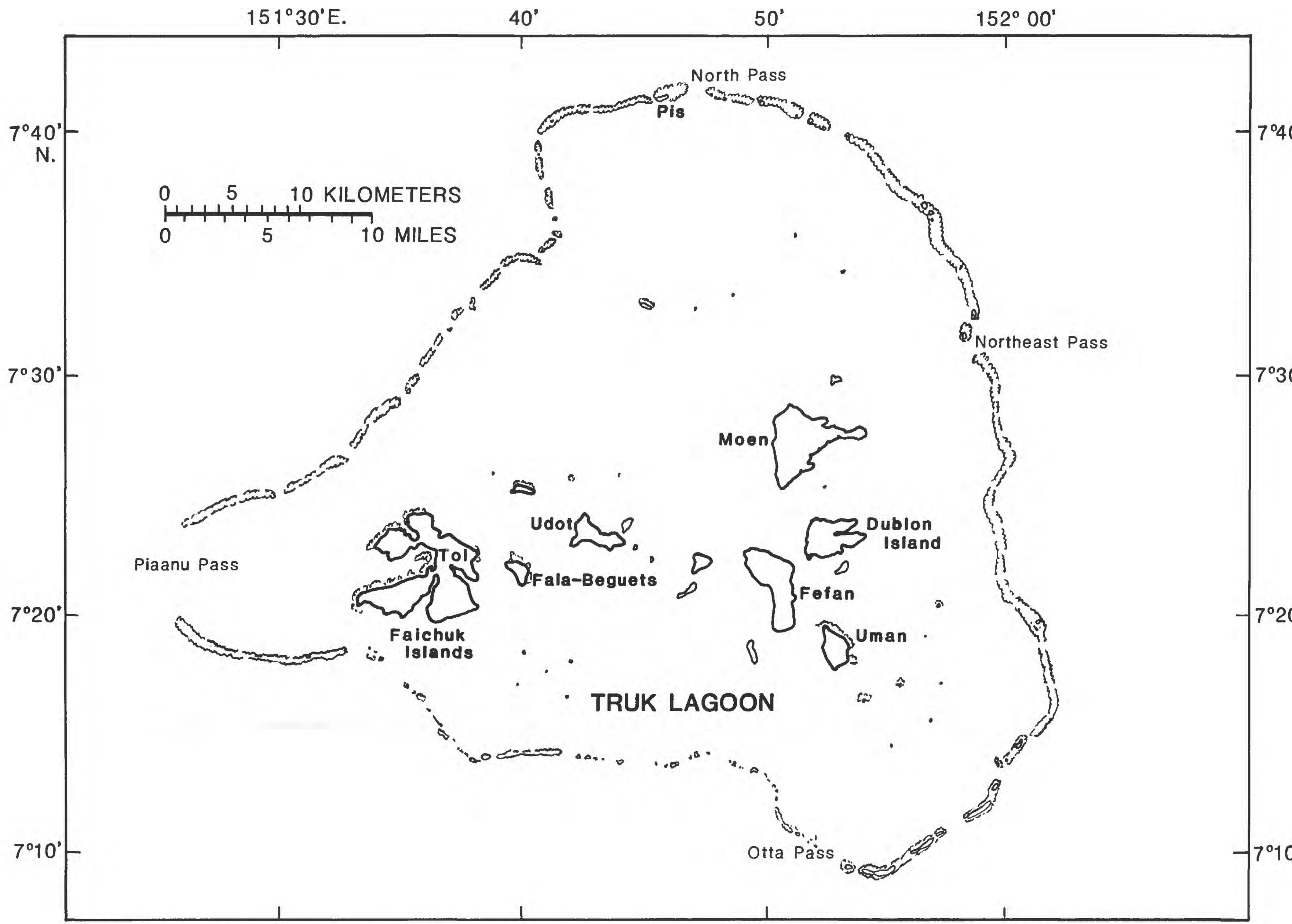


Figure 1. Location of Truk State.



Modified from Austin, Smith and Associates, Inc., 1967.

Figure 2. Truk Lagoon and the Truk Islands.

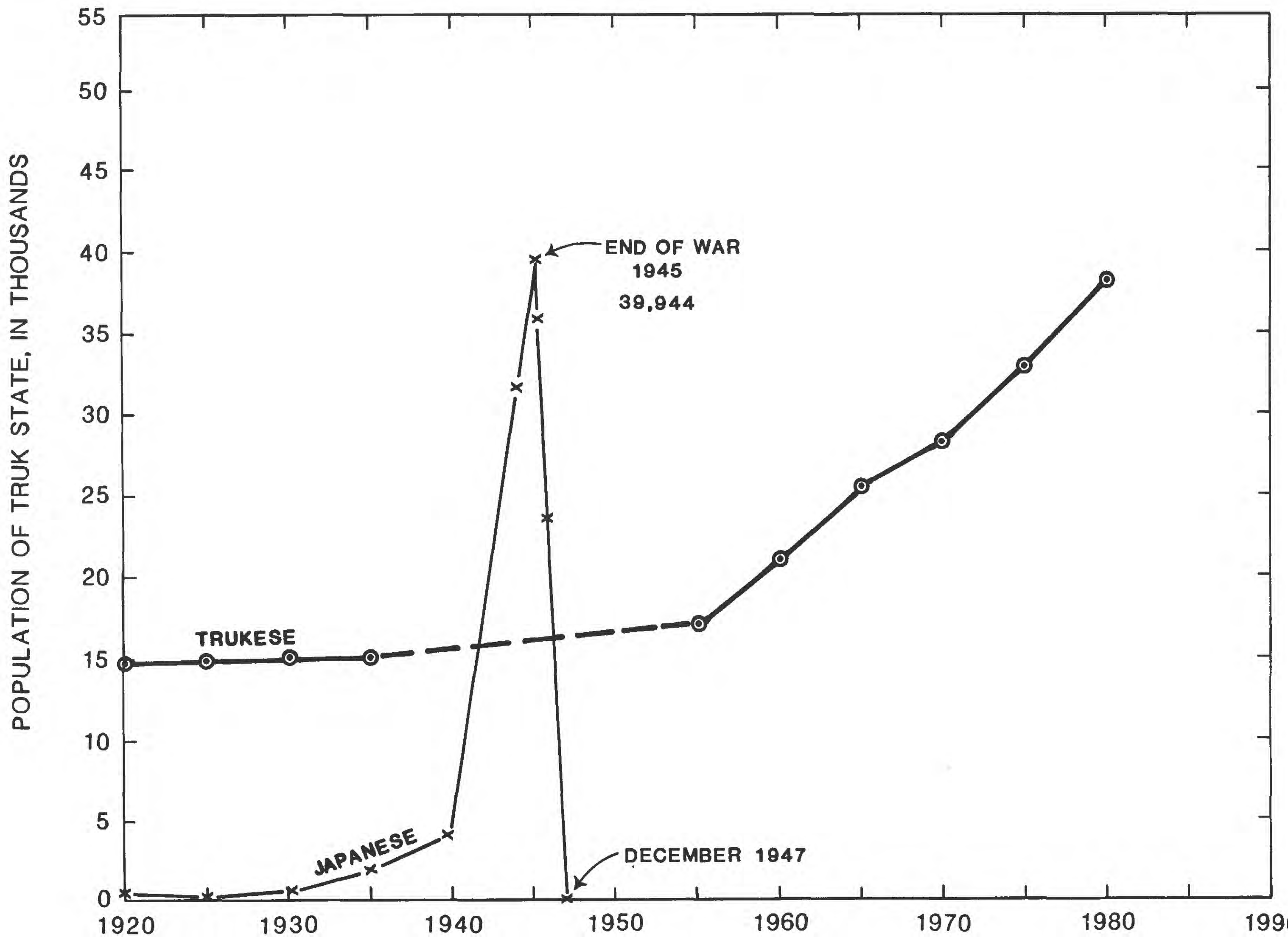


Figure 3. Comparison of Japanese and Trukese populations in Truk State. (Data from unpublished Japanese and Trukese sources).

CLIMATE

The Truk islands are warm and humid. The average annual temperature is about 81°F (27°C) and is uniform throughout the year. Relative humidity ranges from about 55 to 100 percent and is generally more than 75 percent. Relative humidity is the ratio of the amount of water vapor present in the air to the greatest amount possible at the same temperature.

Although typhoons are not common, several have passed near or over the islands. Typhoons have caused loss of life, widespread damage to buildings and crops, and wave damage to shorelines and coastal structures. Much of the discussion of the climate is based on Blumenstock (<u>in</u> Stark and others, 1958) and climatological data and annual summaries of the National Weather Service.

Rainfall

The Truk Islands lie in an elongated high rainfall belt centered about 100 miles south of Pohnpei at about latitude 5°N and longitude 159°E. The belt extends eastward beyond Majuro and westward to Palau for a distance of more than 2,000 miles. It extends north and south for about 200 miles (see fig. 4). Figure 4 was modified from a report by Taylor (1973) that describes the average monthly rainfall for the entire Pacific area.

The average annual rainfall in the Truk Islands ranges from about 100 to 180 inches. Data from rain gage at Moen Airport operated by the National Weather Service for the past 33 years (1952-85), indicates that the area receives a yearly average of about 140 inches of rainfall. Most of the year is wet, except for the period January through March when the monthly rainfall is only about half that of the other months. The average monthly rainfall on Moen are shown in figure 5.

The U.S. Geological Survey water-supply reconnaissance began in April 1983 during one of the periods of lowest rainfall recorded or remembered by the natives in the Truk Islands. From July 1982 to June 1983, the rainfall on Moen was 69 inches, 75 inches below the annual average of 144 inches. The drought started in October 1982 and ended in May 1983. The rainfall during this 8-month period was only 28 inches compared to the long term average of 90 inches. The long-term average monthly rainfall at Moen is compared with the recorded rainfall during the drought in figure 6.

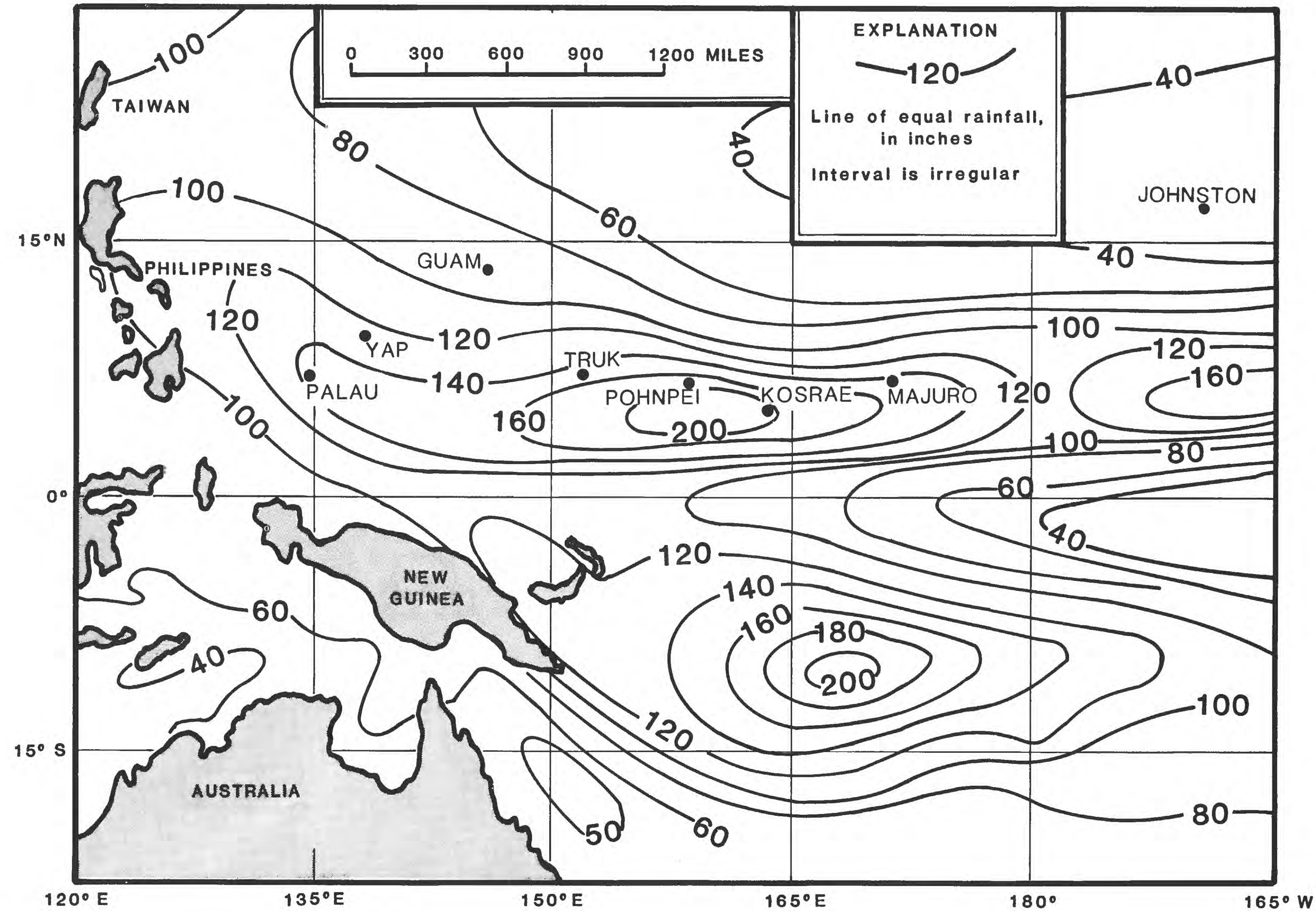


Figure 4. Distribution of average annual rainfall in Western Pacific. (Modified from Taylor, 1973).

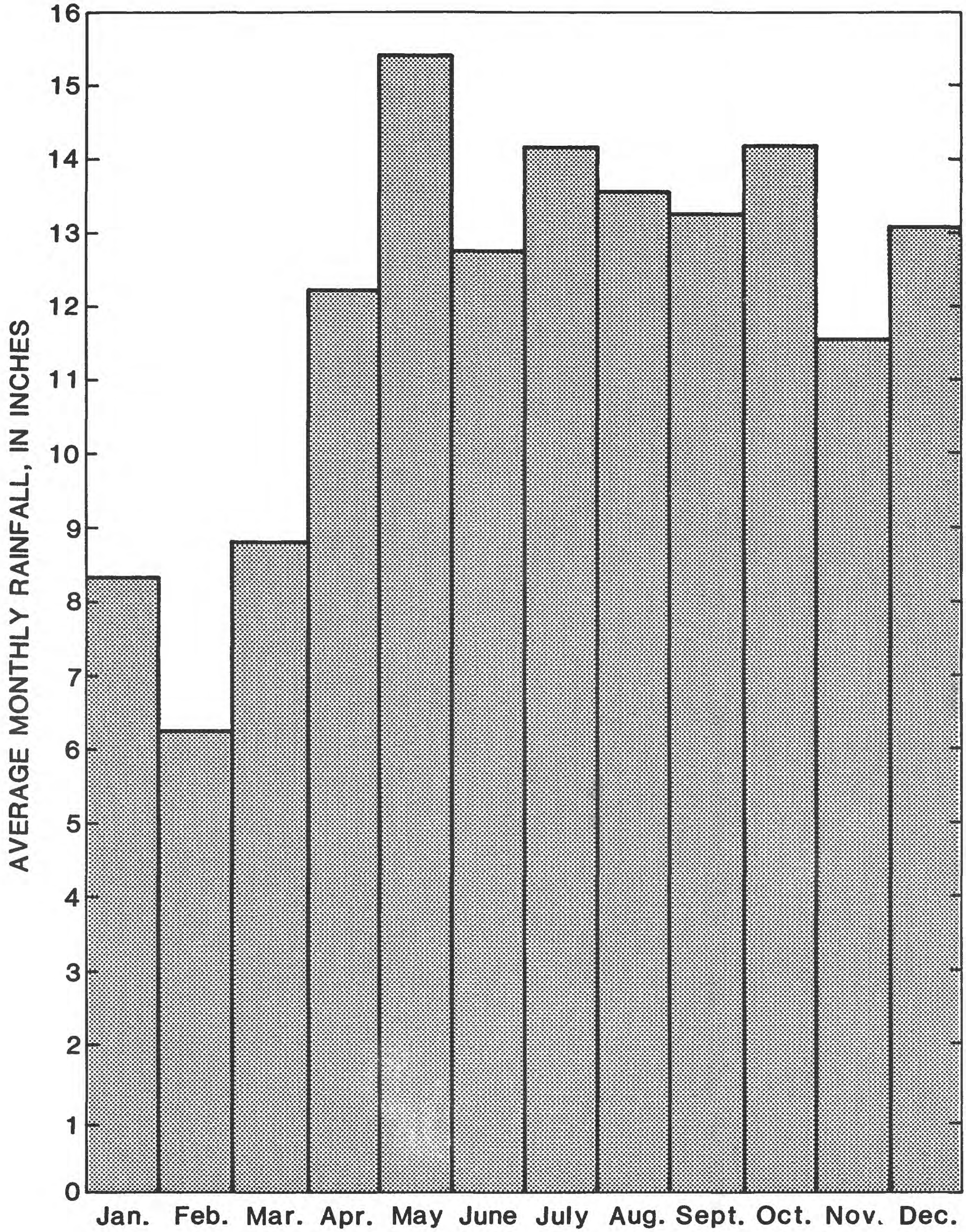


Figure 5. Average monthly rainfall on Moen.

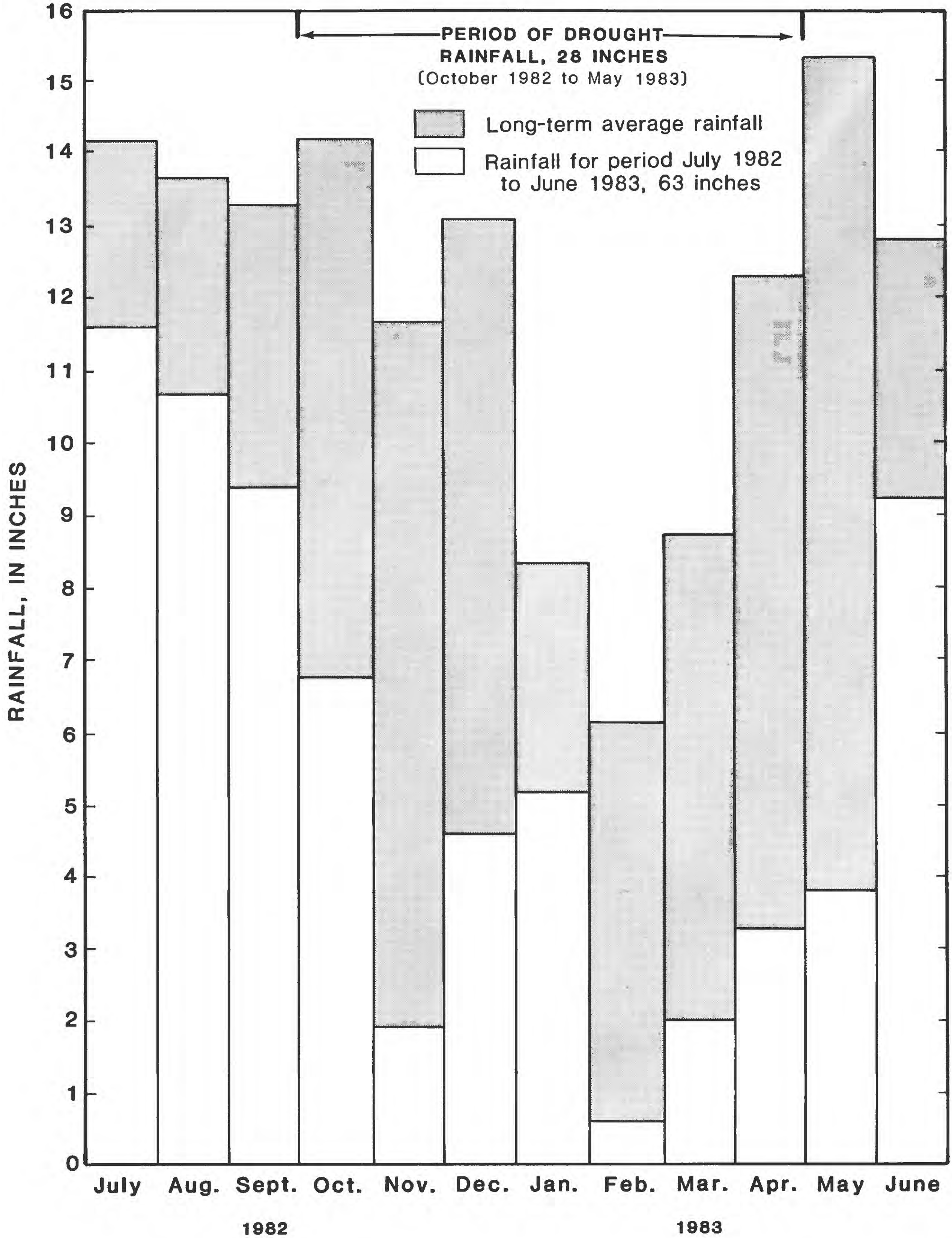


Figure 6. Long-term average monthly rainfall at Moen and rainfall during drought.

Evaporation and Transpiration

Some understanding of evaporation and transpiration is necessary to make reasonable estimates of the water available from rainfall. Part of the rainfall on land returns to the atmosphere as water vapor from free water surfaces, from wet soil by direct evaporation, and from plants by transpiration. These demands for water, commonly combined and referred to as evapotranspiration, must be satisfied before any part of the rainfall can contribute to the water supply. Where water is nearly always available to plants and where the soil is nearly always wet, as in the Truk Islands, the actual evapotranspiration rate approaches its potential or maximum possible rate. Under these conditions, evaporation and transpiration are so interrelated that when there is an increase in the rate of one, there is a comparable decrease in the rate of the other. The sum of the rates of the two never exceeds the potential evaporation rate. Pan evaporation is a measure of the potential evapotranspiration rate, and where the conditions are wet, such as in the Truk Islands, is about equal to the evapotranspiration rate.

Relation Between Pan Evaporation and Rainfall

A common period, 1978-83, was used to obtain a relation between average annual pan evaporation and rainfall at gages in Johnston Island, Guam, and Yap (fig. 7). The relation was extended in the figure to the average rainfall at the gage in Truk for the same period. From this relation, the average pan evaporation at the site of the rainfall gage at Truk was estimated to be 70 inches.

Wind movement is an important factor in the rate of evaporation. The relation between average annual pan evaporation and wind movement, also for the period 1978-83, in Johnston Island, Guam, and Yap are shown in figure 8. An extension of this relation was used to estimate the average wind movement at Truk.

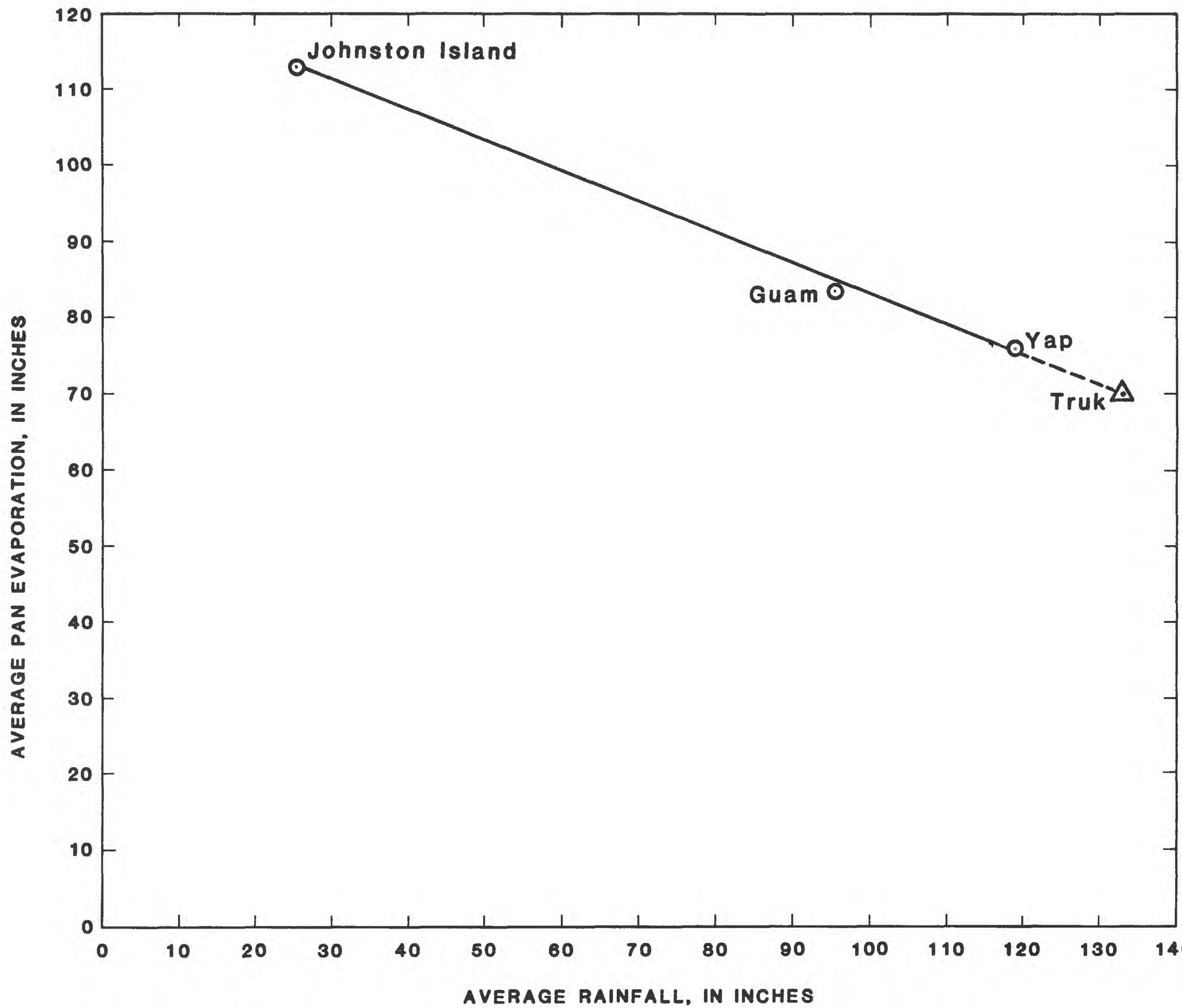


Figure 7. Relation between average annual pan evaporation and average rainfall, for the period 1978-83, in Johnston Island, Guam, and Yap, with extension to include rainfall data for Truk.

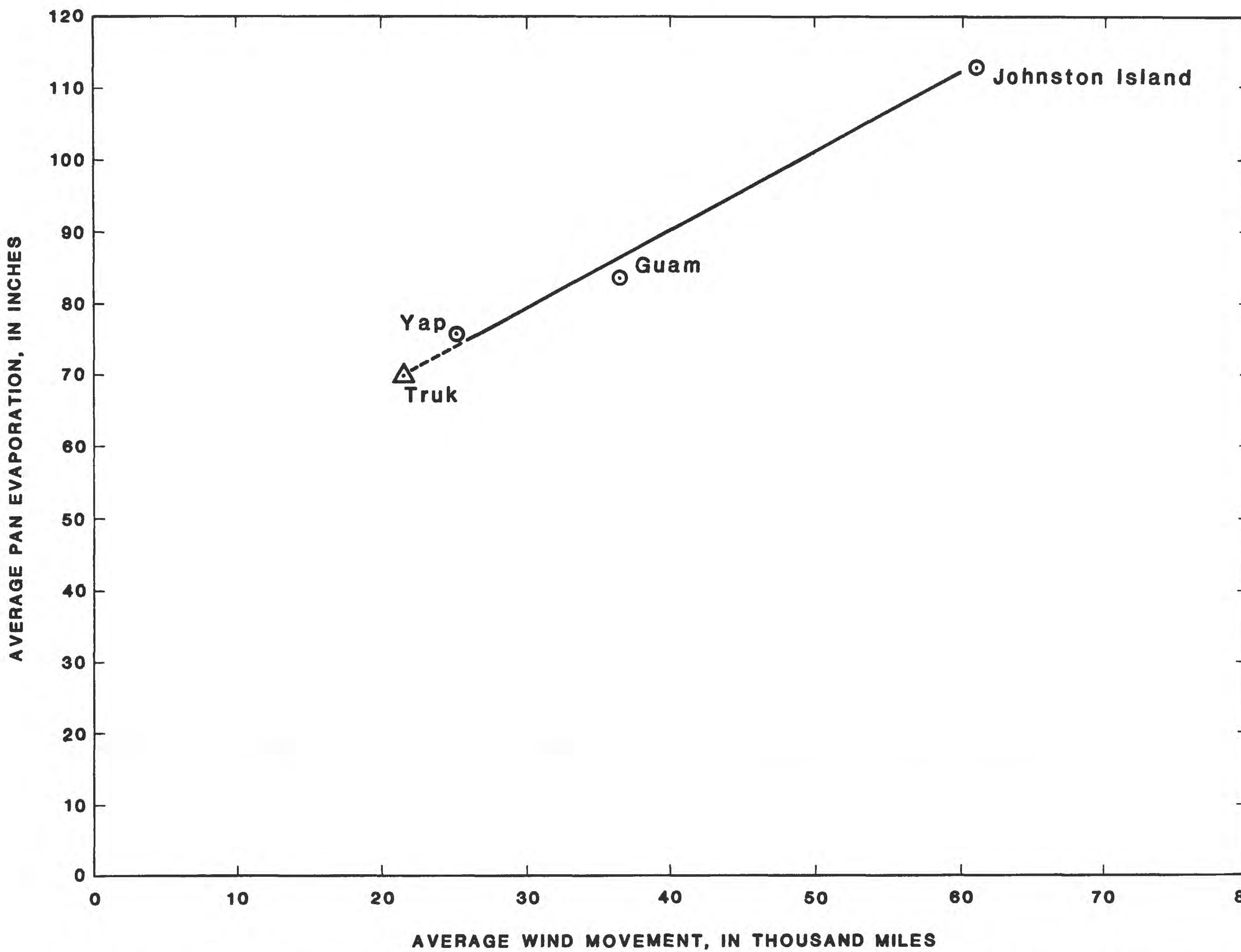


Figure 8. Relation between average annual pan evaporation and wind movement, for the period 1978-83, in Johnston Island, Guam, and Yap, with extension to include data for Truk.

The estimated average annual pan evaporation was prorated into monthly rates based on data available for the island of Yap. The monthly pan evaporation is compared to the monthly rainfall for the common period of 1978-83 in figure 9. This comparison shows that on the average the monthly pan evaporation generally is more than the monthly rainfall only in February and March.

GEOLOGY

The volcanic islands in the Truk Lagoon are the remaining high parts of a large eroded volcano that has partly sunk. These 19 volcanic islands have a total land area of about 35 square miles or less than 5 percent of the area of the original volcano. The size of the Truk Lagoon, about 800 square miles, is roughly the size of the original volcano above sea level. Truk would become a typical atoll, with its lagoon surrounded by a rim of coral islands, if all the volcanic islands should sink below sea level.

The Truk volcano is the oldest and, before it sank, the largest of a group of geologically related islands extending from Truk to Kosrae, 800 miles to the east. According to Keating and others (1984), the volcanoes in this group, which are part of the Eastern Caroline Islands, decrease in age and in size to the east, from Truk to Kosrae.

The Truk volcano extends below sea level nearly 16,000 feet to the ocean floor. The volcano was once at least several thousand feet above sea level. Presently, several peaks rise to an altitude of 1,000 feet or more. The highest peak, at 1,453 feet, is on the island of Tol.

Rock Types

The rocks in the volcanic islands of Truk are the product of the following processes.

1. Mountain-building stage of the volcano.
    a. Mostly extrusion of lava flows and ejecta (explosive materials) and deposition of cemented rock fragments (breccia and conglomerate) mixed or interbedded with the flows.

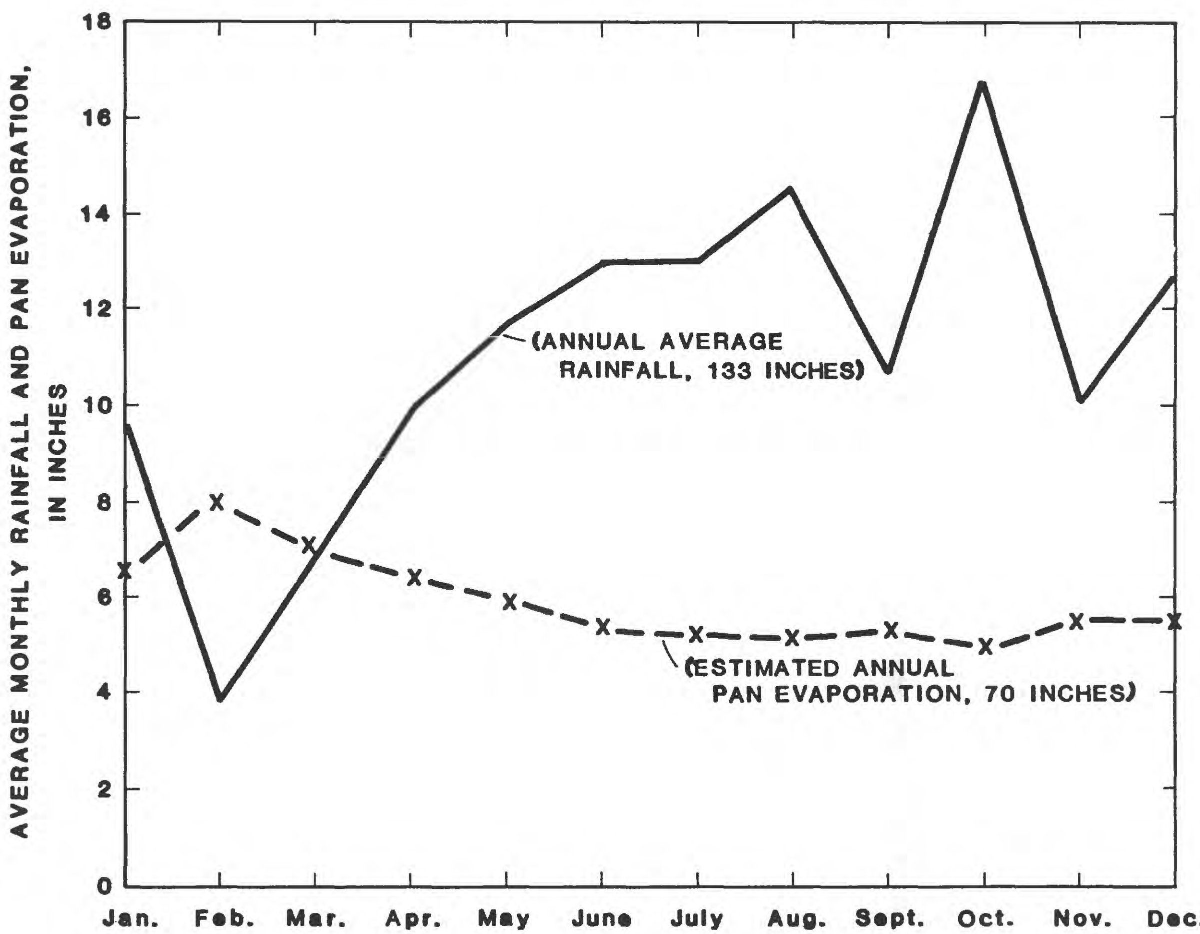


Figure 9. Average monthly rainfall and the estimated average monthly pan evaporation at Moen for the period 1978-83.

2. Erosion after the mountain-building stage.
   a. Deposition of sedimentary rocks such as slope wash, talus at bases of slopes, and alluvium in valleys.
3. Volcanic activity after the erosional period.
   a. Further extrusion of lava flows and explosive materials and deposition of cemented rock fragments interbedded with lava flows.
4. Submergence of the volcano during and after volcanic periods of and erosional activity and rises and falls of sea level.
   a. Deep weathering of the volcano and fragmental rocks.
   b. Formation of talus at bases of slopes.
   c. Deposition of alluvium in valleys and coastal flats.
   d. Deposition of peat and muck in coastal marshes and swamps.
   e. Deposition of calcareous sands and minor amounts of coral limestone along the shores.

For a more detailed discussion of the geology and rocks of Truk, the reader is referred to Stark and others (1958) and Stark and Hay (1963).

Character of the Rocks and Their Ability to Store and Transmit Water

The volcanic islands of Truk consist chiefly of massive lava flows and some interbedded explosive volcanic ejecta and cemented rock fragments. These rocks are in large part saturated with water, but because they are so poorly permeable, they yield little water to wells tapping them. Weathering of the volcanic rocks causes a small but significant increase in permeability. The weathering is shallow on the steep slopes, is progressively deeper as the slopes become flatter, and is deepest in flat areas and in broad stream valleys. Talus and alluvium make up the lower slopes where these rocks overlie the weathered volcanic rocks. These sediments are commonly more permeable than the weathered volcanic rock except when the sediments are extremely weathered. These sediments and the weathered volcanic rocks together make up the main reservoirs of ground water in the areas inland of the coastal flats.

The coastal flats are made up of alluvium and artificial-fill materials with some talus. The artificial-fill materials include crushed fresh volcanic rocks, weathered rock, alluvium, and talus. At and near the shore, the sediments are fronted by coral beach sands except where the land slopes are extremely steep and the flats very narrow.

The most permeable materials are the beach sands. These sands are likely to be saturated with brackish to near saline water near the shore.

STREAMS

The flow of streams is flashy and extremely variable. Because rain is not readily absorbed by the land surface and because of the generally steep slopes and small size of the drainage basins, most streams quickly go dry or nearly so after each rain.

Some of the larger streams were monitored continuously with recording gages. The streamflow data from these streams were compiled and analyzed by Van der Brug (1983). His analysis shows a good correlation between annual streamflow and annual rainfall. Ratios of annual runoff to rainfall for the gaged streams are about 40 percent in Dublon Island, 45 percent in Tol, and 50 percent in Moen. These ratios, where appropriate are used to estimate streamflow for periods of missing record and for the larger ungaged streams in the islands of Truk.

Flow-duration, and low-flow and high-flow frequency curves were constructed by Van der Brug (1983) for five streamflow-gaging stations located in Dublon and Moen. Chemical analyses of the water from all major streams sampled between 1953 and 1982 also are included in Van der Brug's report. Chemically, the stream waters are acceptable for most uses.

GROUND WATER

Occurrence

Most of the recoverable fresh ground water in the volcanic islands of Truk occurs in aquifers (water-bearing materials) composed of weathered rock, talus, and alluvium, or of artificial land fill. Water levels are shallow and generally parallel the slope of the land surface. In the steep sloping upland areas, the water-level gradient is steep and fluctuates widely with recharge. Ground-water flow is to coastal areas or to valleys cutting the uplands. In the lowlands and coastal areas, the gradient is flat and slopes to the sea commonly toward freshwater marshes or to mangrove swamps near the coast. Fluctuation in water levels is small in the lowlands.

In the upland areas, where a surface layer of weathered rock overlies less permeable fresher rock, many small water bodies are perched in the weathered rock. These perched water bodies commonly discharge at the land surface as springs or seeps. Because the water bodies are small, most of the springs and seeps quickly dry after each rain. Some small springs and seeps flow for days and even weeks after rains. Water from many of these longer-lasting springs and seeps is piped to villages for their water supply.

In the lowlands and adjoining coastal flats, most of the ground water occurs in talus and alluvium and in the artificial-fill materials. These low areas are widest near the mouths of valleys and along gently sloping areas. Many freshwater marshes occupy the wider coastal flats. Saltwater mangrove swamps generally occupy the area seaward of the freshwater marshes. Where the coastal flats are narrow, freshwater marshes are generally absent and mangrove swamps occupy the near-shore areas. Much of the areas once occupied by the freshwater marshes and mangrove swamps have been artificially filled to provide land for villages and crops.

Springs and seeps, common in the upland areas, are generally absent in the coastal areas because of the flatness of the land. Natural discharge in the coastal areas is largely by plant use (transpiration from the shallow water bodies) and by evaporation from the wet soil and freshwater marshes. The marshes are fed by rainfall and by ground-water discharge from the surrounding shallow water bodies. Ground water not discharged at the surface by springs or to the atmosphere by evapotranspiration slowly seeps to the lagoon through the beach sands and other sediments at the shore.

The occurrence of ground water in all the high islands of Truk is similar; only the quantity of the water in storage and its availability differ. In general, the larger islands have more available ground water than the smaller islands. Occasionally the shape of the island becomes important, because given an area, the optimal shape for recharge and storage of water is an island with the least shoreline distances.

Because the occurrence of ground water in the high islands is so similar, the occurrence and type of wells needed to develop ground water can be grouped or categorized. This grouping is shown in sketches in figures 10 to 13. The geology, the ground-water bodies, and the wells are described in table 1. The figures and the descriptions in table 1 can be used as guides to describe the occurrence of ground water in all the high volcanic islands of Truk and how to develop the ground-water resources for village supplies.

Use of Ground Water for Village Supplies

More freshwater to increase existing supplies from rain catchments and springs is needed for most villages. The people in the villages prefer spring and rain waters to well water for drinking and cooking. Where these supplies are limited and if costs to develop these sources are too high, development of ground water by shallow wells would be an alternative way to increase the water supply. Ground water so developed would likely be used mainly for bathing, laundering, and for flushing the new type of outdoor toilets that are becoming popular in Truk. During long rainless periods when springs and rain barrels go dry, the water from dug wells can supply all the water needs of a village.

A simply designed dug well that can be used both as a supply source and as an underground storage may be a desirable alternative to building surface storage. Because the aquifers are so tight, the wells need to be wide enough and deep enough below the water table if they are to provide enough water for a day's need. Even though the rocks are tight, the water level in wells of adequate depth will recover overnight and be ready for another day's use by morning.

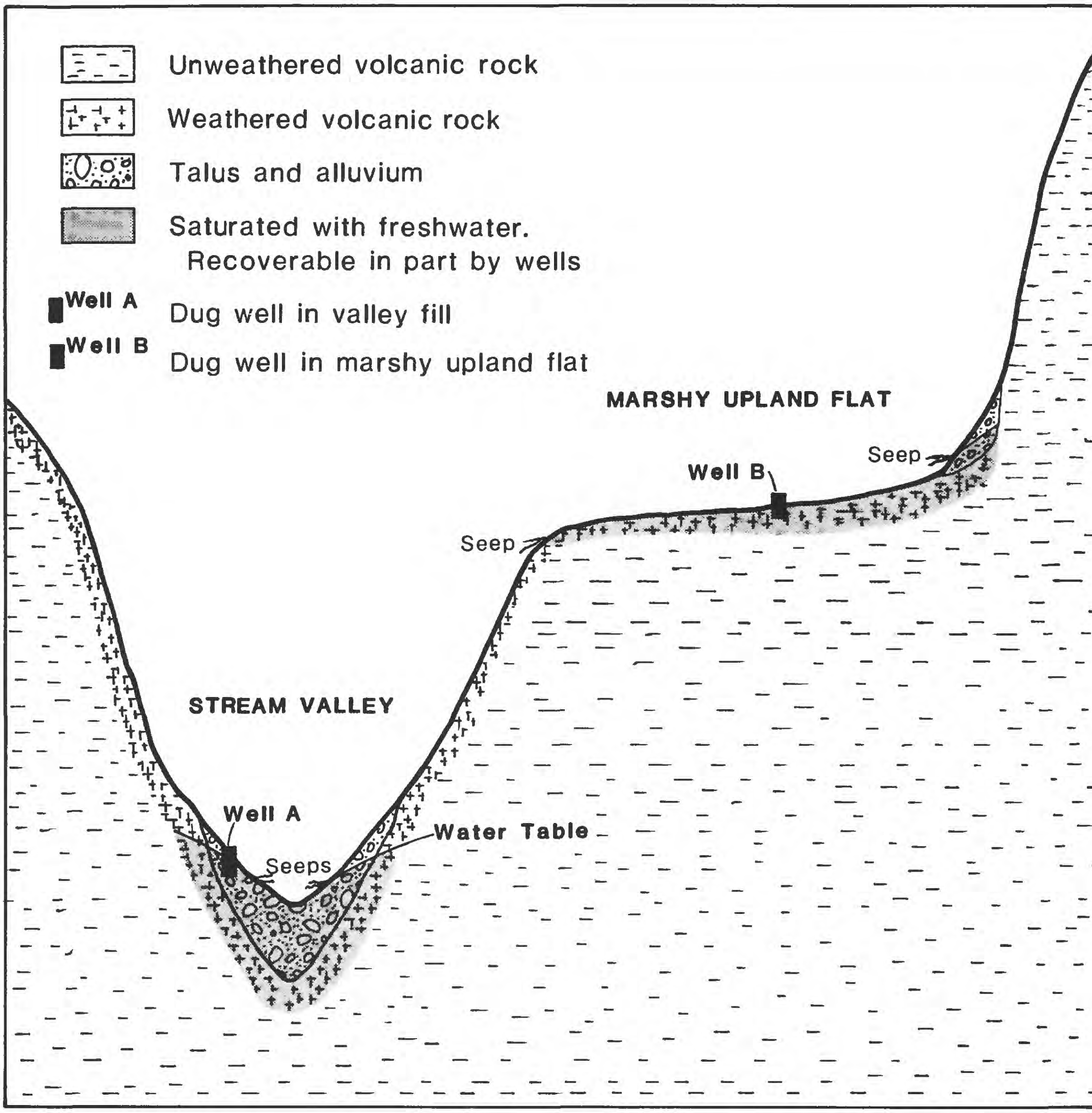


Figure 10. Generalized sketch showing ground-water occurrence in upland areas of high volcanic islands in Truk. Not to scale.

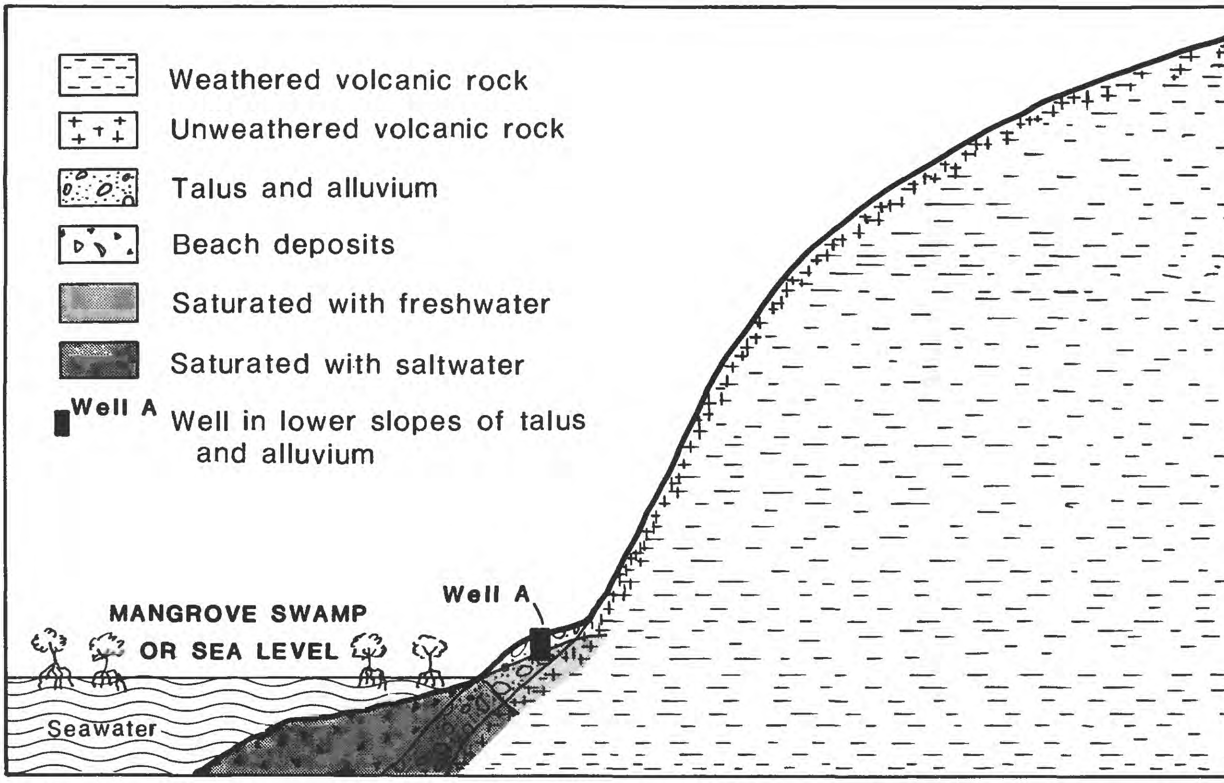


Figure 11. Generalized sketch showing ground-water occurrence in narrow coastal areas of high volcanic islands in Truk with little or no beach deposits. Not to scale.

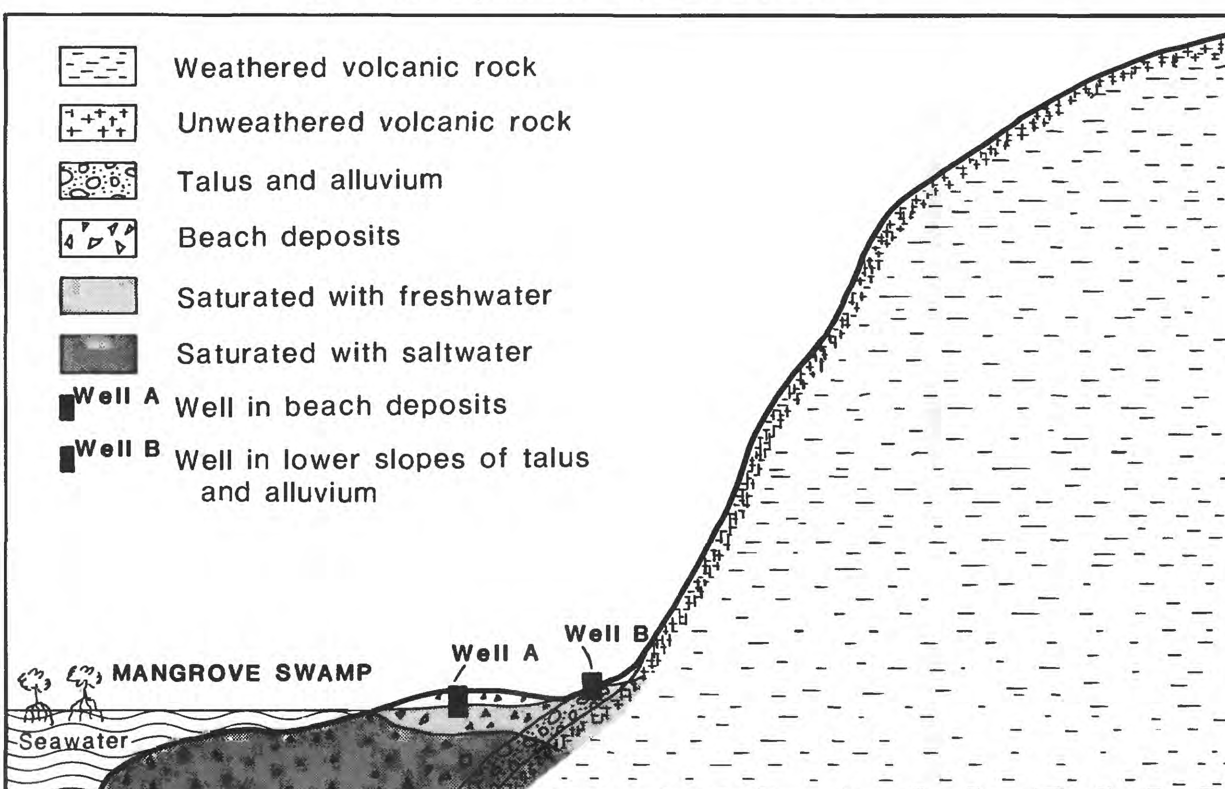


Figure 12. Generalized sketch showing ground-water occurrence in narrow coastal areas of high volcanic islands in Truk with narrow beach deposits. Not to scale.

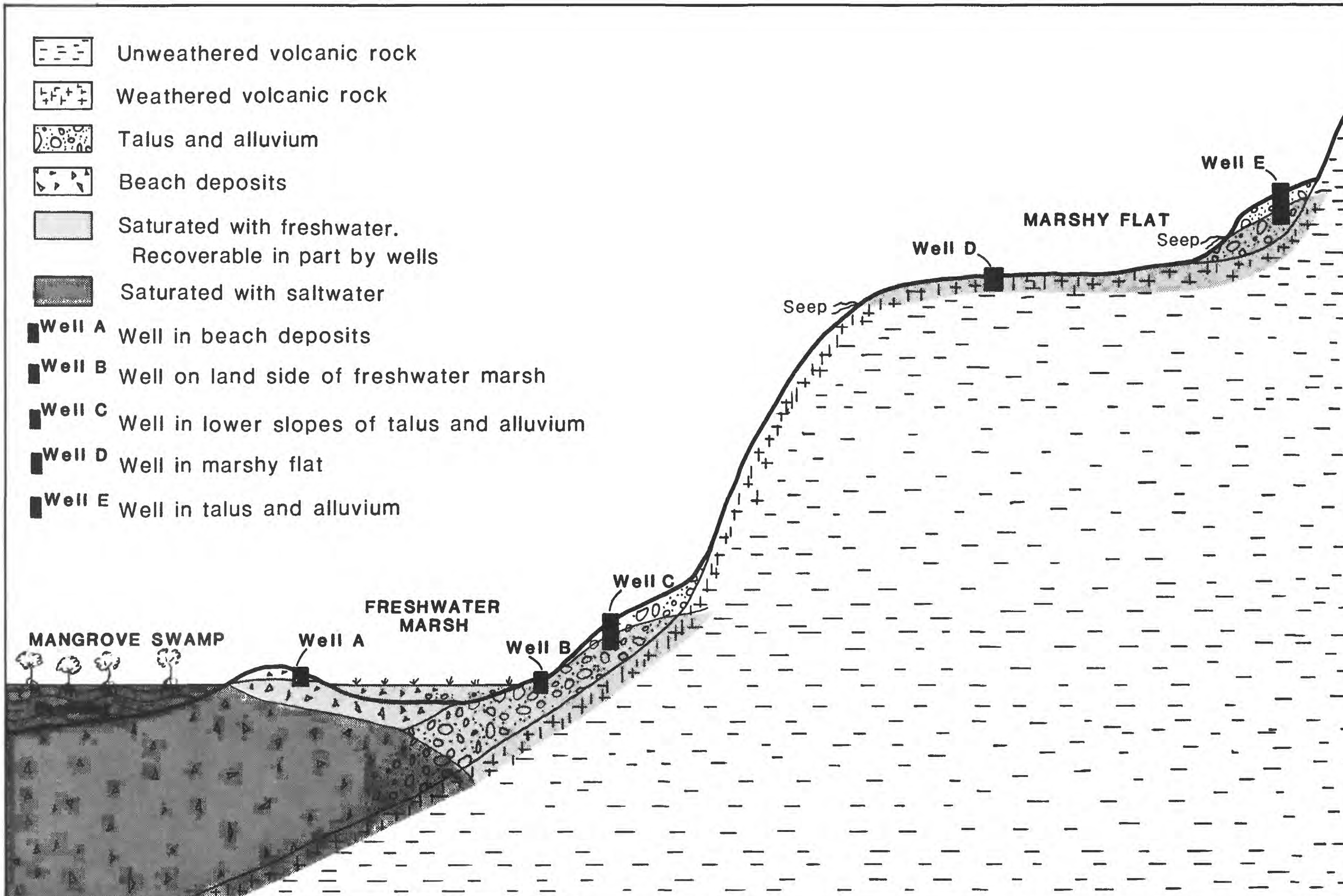


Figure 13. Ground-water occurrence in coastal areas of high volcanic islands in Truk. Not to scale.

Table 1.--Description of geologic setting, occurrence of ground water and dug wells shown in figures 10 to 13

Figure	Dug well	Description and Remarks	Occurrence
10	A	Dug well taps water in valley fill and/or weathered rock. Because yield to wells is small, dug wells need to be as deep as possible below water level and sufficiently wide in diameter for ample storage. Seeps occur where land surface intercepts water table.	Valley in upland areas.
10	B	Dug well taps water in marshy upland flat. Because yield to wells is small, dug wells need to be as deep as possible below water level. Seeps occur where land surface intercepts water table.	Do.
11	A	Dug well taps water in lower slopes of talus and alluvium. Depth to water increases in the higher slopes. Yield to wells is small.	Narrow coastal areas with few or no beach deposits.
12	A	Dug well in beach deposits where freshwater floats on saline water. Chemical quality of water improves with distance from edge of mangrove swamp. Yield to wells is large but subject to saline-water intrusion if pumped heavily. Depth of dug wells needs to be less than 2 feet below the lowest water level determined during the digging to obtain water suitable for human consumption.	Narrow coastal areas with narrow beach deposits.
12	B	Dug well in lower slope of talus and alluvium. Similar to well A, figure 11.	Do.
13	A	Dug well in beach deposits. Similar to well A, figure 12 except that quality of water may be affected by the marsh water if well is too close to the marsh.	Wide coastal areas.

Table 1.--Description of geologic setting, occurrence of ground water and dug wells shown in figures 10 to 13--Continued

Figure	Dug well	Description and Remarks	Occurrence
13	B	Dug well in talus and alluvium on land side of freshwater marsh. Yield to wells is small. Water quality may be affected by the marsh water if well is too close to the marsh.	Wide coastal areas.
13	C	Dug well in lower slopes of talus and alluvium. Similar to well A, figure 11.	Do.
13	D	Dug well in marshy flat. Similar to well B, figure 10.	Do.
13	E	Dug well in talus and alluvium slope. Similar to well A, figure 11. Seeps where land surface intercepts water table. Seeps may go dry after long rainless periods.	Do.

All wells are subject to pollution from the surface because of the shallow water levels. Because of this and the high cost of building materials, a possible alternative is to dig two different types of wells, one specially designed to supply water for drinking and cooking and a simpler one for the other needs. The wells may be alike, except that, the well to be used for drinking and cooking would be constructed to minimize pollution from the surface. These wells would have a cover or concrete platform, raised curbing, cemented or solid casing, and would be equipped with a hand pump, or solar pump. The other well type may be open with no cover, no casing and no pump. However, a raised cemented curbing would prevent the laundering and bathing waste water from flowing back into the well.

Figure 14 illustrates a dug well designed to minimize pollution from the surface. The height of the raised curbing, the extent of the lip away from the well, and the depth of the solid casing below water level likely are minimums, because sizes less than these probably would not be effective in curtailing pollution from the surface.

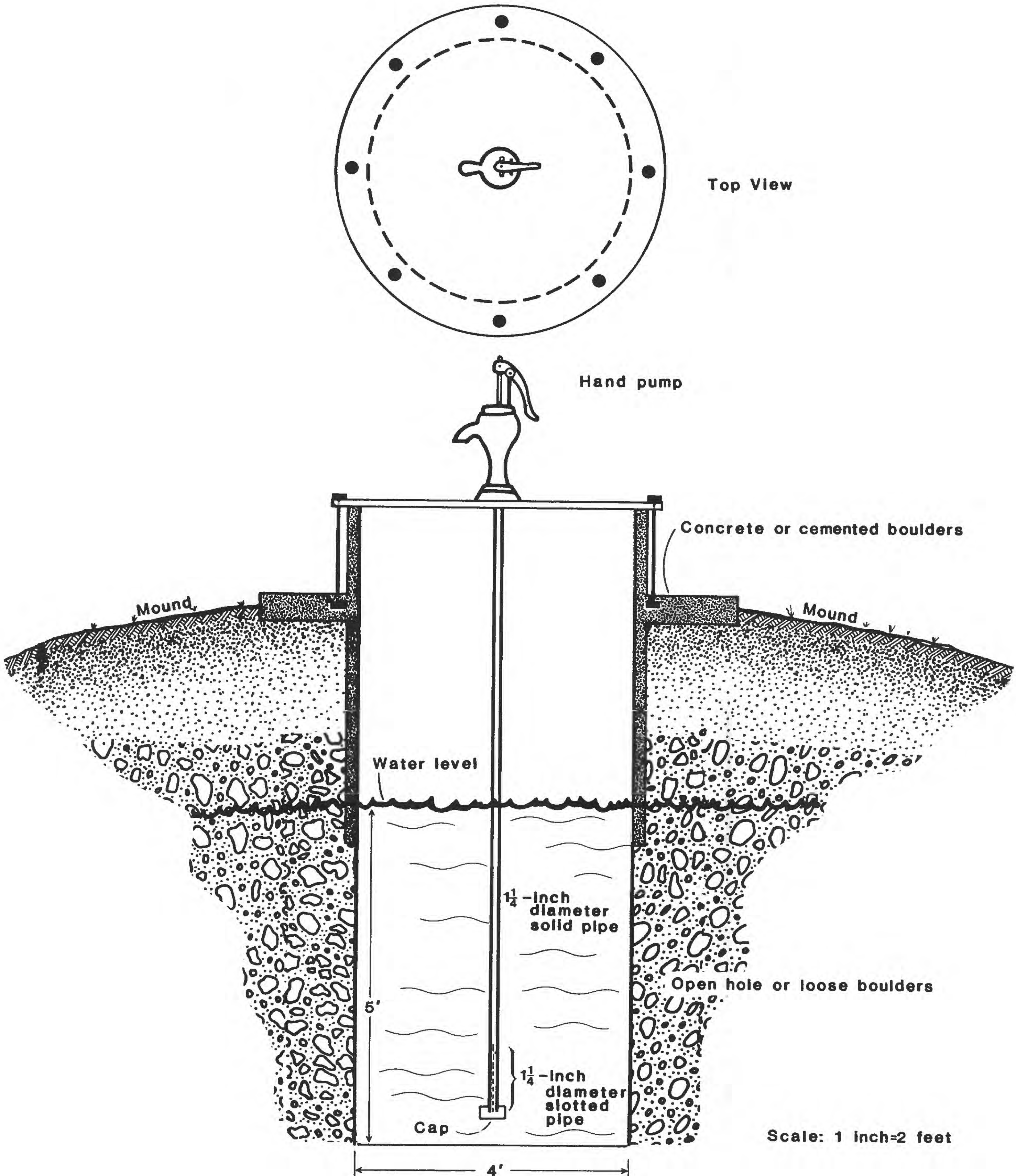


Figure 14. Dug well designed to minimize pollution from surface.

Height of raised curbing, 1 foot

Extent of lip, 1 foot

Depth of solid casing below water level, 1/2 foot

Although the size and depth of the well are optional, the depth of the well below the water table needs to be as deep as practical to allow maximum infiltration and storage. To minimize the potential for pollution, wells need to be sited upgradient or away from the sources of pollution.

A village uses about 5 gallons of water per person per day for drinking and cooking. For example, a village of 300 people would need 1,500 gallons of water every day for drinking and cooking. If there are rain catchments, a single well designed for use as an emergency drinking supply per 75 people would be adequate. The Trukese have been advised to boil the water from wells used for drinking and cooking.

The following table gives the size and depth of well below the water level and the maximum quantity of water that well will hold.

Diameter (feet)	Depth below water (feet)	Number of gallons
3	3	160
3	4	210
3	5	270
4	3	280
4	4	380
4	5	470
5	3	440
5	4	590
5	5	740

For some wells the number of gallons shown may be the maximum daily yield. However, many of the wells may yield several times the number of gallons shown above.

Most of the water in the ground moves toward the Truk Lagoon. This is also true of water leaking from an outdoor toilet or water seeping into the ground from pig pens. To minimize possible contamination of water in supply wells, supply wells need to be upgradient of toilets and pig pens.

A village of 300 people that uses about 1,500 gallons every day for cooking and drinking solely from wells will need at least the equivalent of four dug wells that are 4 feet in diameter and 5 feet deep below the water level. The minimum yield of these four wells from the above table is 470 gallons each, or 1,880 gallons. Any combination of well sizes and depths may be used to develop the quantity of water needed.

Because the water-bearing rocks are tight, the water level will drop when water is pumped or dipped or when there is no rain for a long period. To allow for these drops in the water level, the well needs to be dug as deep as practical. The easiest time to dig the wells generally is in February and March when the water levels are usually lowest.

The water level in most of the wells being dug can be lowered enough and kept low by continuous dipping so that digging is possible below the water level. If the water level cannot be lowered, this indicates that the well is a good producer and need not be as deep.

Once a well is dug, it does not need to be abandoned simply because it dries up during long rainless periods. The well goes dry because of the water-level decline caused by the lack of replenishment by rain. Instead of abandoning the well, it could be deepened at this time. In 1983 many wells in Truk were needlessly abandoned.

WATER-SUPPLY DEVELOPMENT FOR VILLAGES IN TRUK

Alternative Procedures

The villagers like rain water and spring water better than the water from dug wells for their drinking and cooking needs. Because most springs and seeps are small and quickly go dry after rains, the catching and storing of rain water becomes a favorable alternative. The following alternative procedures for developing village water supplies to serve general needs can probably be developed by the villagers themselves.

1. Construct rain gutters on roofs and small storage tanks at individual family homes. Two or more families may share a common installation.
2. Pipe water from springs and seeps to storage tanks in the village.

3. Use shallow wells for drinking and cooking if necessary, otherwise use for bathing, laundry and toilet flush water.
4. Construct rain gutters on roofs and storage tanks at all larger buildings in the village, such as churches and schools when and where affordable.

Rain Catchments

The capacity of the tank necessary to store enough water from a rain catchment depends on the number of people using the water, the roof area available, and the cost. The 55-gallon oil drum commonly used is much too small unless several of them are used so that when one drum fills up, the water will flow into another. For sizing a tank, the following formula can be used.

Number of people x 5 gallons x 15 days.

An example would be:

8 people x 5 gallons x 15 days = 600 gallons

A storage tank twice this size (1,200 gallons) would provide water for 30 rainless days.

The roof area of the catchment needs to be large enough to catch a minimum of 50 percent more rain than the daily family use. This means that for eight people using 5 gallons a day, the minimum rain catch should be 60 gallons a day instead of only 40 gallons.

Figure 15 is a graph that shows a relation between small roof area and rain catch. The dashed line shows the minimum roof area needed to catch 60 gallons a day, using an annual rainfall of 100 inches and a roof area of 350 square feet.

Figure 16 shows the relation between large roof areas and rain catch. This figure provides information useful for large catchments such as the roofs of churches and schools. Because of the generally high rainfall in Truk, the annual rainfall figure of 100 inches can be used for planning purposes without adjusting for roof efficiencies and variations in the annual rainfall.

A good summary on the filter and flushing systems and other methods of quality control of water storage tanks is given in the Proceedings of the International Conference on Rain Water Cistern Systems, 1982. The reader is referred to that report.

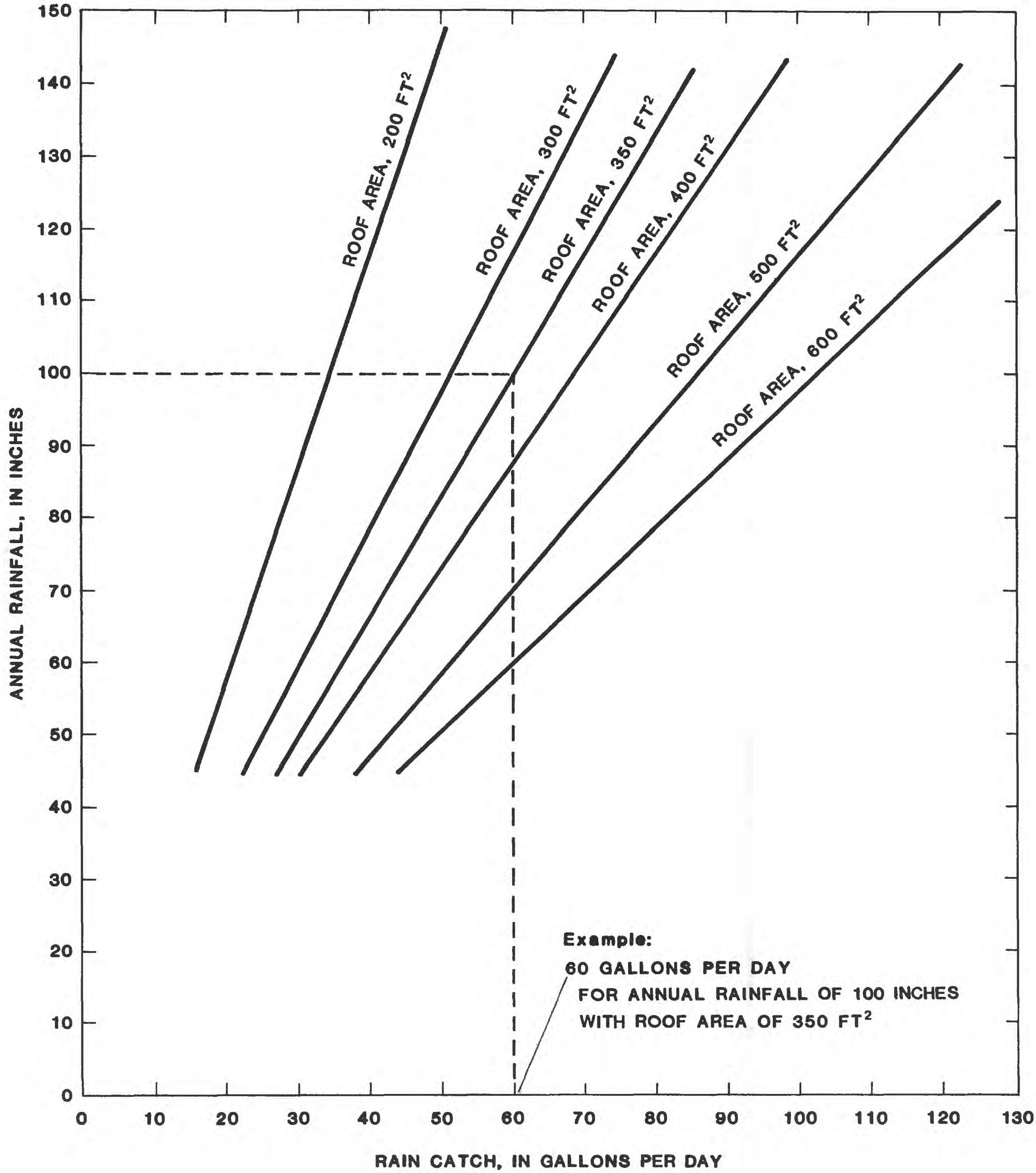


Figure 15. Relation between small roof areas and rain catch.

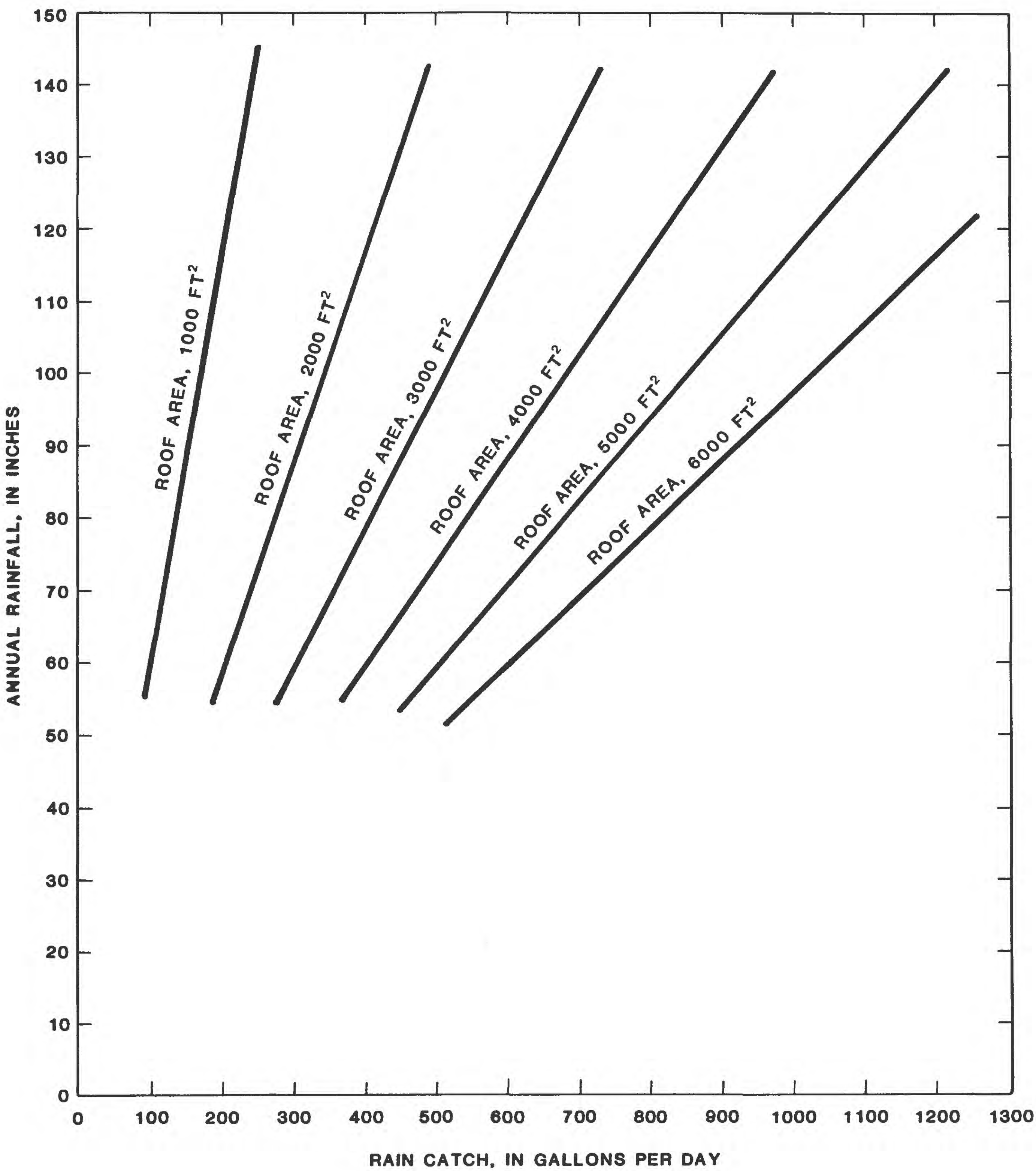


Figure 16. Relation between large roof areas and rain catch.

Two methods of tank construction are described. One method is having tank panels that are light enough to be transported and joined together at the site for erection. The other method is for on-site construction and uses a simple cylindrical mold.

The first method uses a series of panels from which the tank can be assembled and completed by hand plastering the joints. The second method is similar in result but can only be done on site. In this method, an internal liner mold is built and the wire reinforcement for the tank sides is assembled before plastering. The tank walls then are formed in a one stage operation, instead of segmenting them for subsequent joining as in the first method.

HYDROLOGIC CONDITIONS IN THE TRUK ISLANDS IN APRIL 1983

A U.S. Geological Survey reconnaissance team visited the high islands of Moen, Dublon, Fefan, and Uman, and the reef island of Pis from April 1-15, 1983. The visit was made during the drought period that lasted from October 1982 to June 1983 in Truk. The objective of the reconnaissance was twofold: (1) to assess hydrologic conditions during the drought as related to water supply and water quality; and (2) to evaluate the use of surface geophysical techniques to assess the ground-water resource and to delineate geologic structures favorable for the occurrence of ground water.

High Islands

The flow of perennial and near-perennial streams in the high islands visited were the lowest recorded or remembered by the villagers. All small streams were dry. Most small springs were dry, and the flow of larger springs was down to a trickle.

Many of the streams and springs that went dry were the main sources of drinking water in the villages. With these sources and most rain barrels dry, the villagers were using the water from nearby and distant shallow dug wells for drinking and cooking.

The decline in ground-water levels caused many dug wells, especially at high altitudes away from the coastal areas, to go dry, and they were abandoned. In many instances ground-water levels, after the decline, were only a few feet lower than the bottom of the wells. Had the wells been a few feet deeper, they would not have gone dry. Because most of these wells were dug into alluvium with low permeability or deeply weathered rock, the water levels in the wells fluctuate widely with recharge.

The decline in water levels in dug wells in the coastal areas was less severe and most did not go dry. These wells became the principal source of water in the villages during the drought.

Declining water levels in the Administration area in Moen caused as much as a 10-fold increase in the chloride concentration of the water pumped from drilled wells there (fig. 17). The chloride concentration of the water in two of the wells in April 1983, exceeded the maximum permissible limit of 600 mg/L recommended by the World Health Organization (WHO).

Reef Islands

Pis, the only inhabited reef island, was visited by the reconnaissance team on April 11 and 12, 1983. It was difficult to determine what effect the drought had on the quality of the freshwater lens in Pis without adequate prior data. Water from each of two wells sampled in 1955 had a chloride concentration of 62 mg/L. The water from dug wells in approximately the same locations sampled in 1983 had a chloride concentration ranging from about 100 to 200 mg/L. The water from dug wells in other areas of Pis, not sampled in 1955, had chloride concentrations ranging from about 100 to 1,000 mg/L. The drought may have caused significant increases in the chloride concentration of the freshwater lens.

None of the dug wells were covered; consequently they were subject to surface pollution. The U.S. Geological Survey drove two 1-1/4-inch diameter well points and equipped them with hand pumps. This was done to demonstrate how a part of the surface pollution can be eliminated if a well is covered and equipped with a pump.

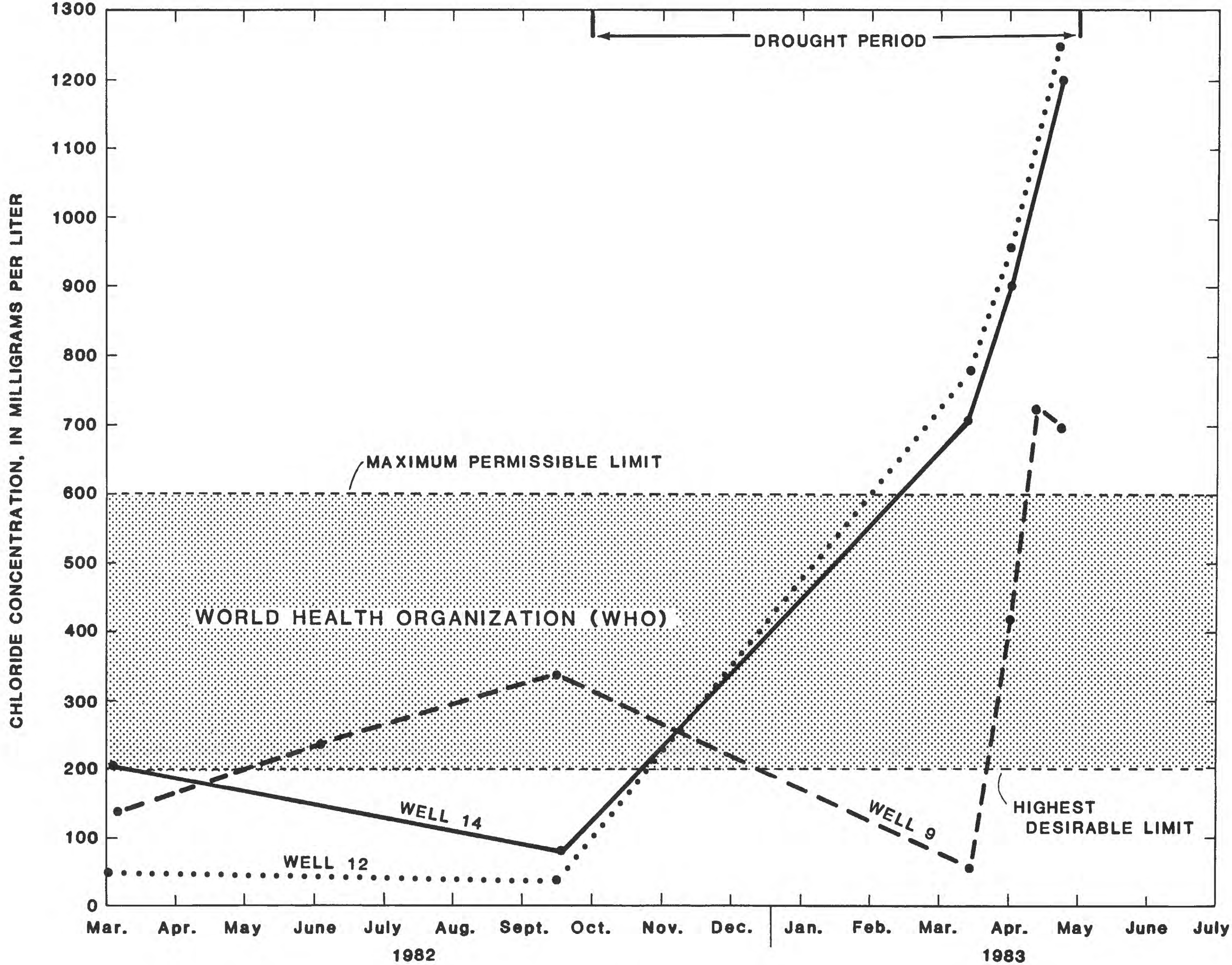


Figure 17. Chloride concentration of water from wells in Administration area, Moen, during drought compared to limits recommended by World Health Organization (WHO).

Assessment of Surface Geophysical Techniques

The following assessment was made by James Kauahikaua (1987) of the U.S. Geological Survey who was a member of the reconnaissance team that visited Truk in April 1983.

During a two week field trip, three different techniques were evaluated for measuring subsurface electrical resistivities in a variety of island environments. The techniques were: vertical electrical resistivity sounding (VES), electromagnetic profiling (Max/min), and very-low radio frequency measurements (VLF). Tests were made in two different types of environments; reef islands and volcanic islands.

VES and Max/min data taken on one reef island (Pis) show that these techniques can determine depth to saltwater saturated material, and that they can also, in combination, determine the average salinity of freshwater within the lens. Depth to saltwater can easily be measured with the Max/min, but the average salinity estimates require both Max/min and VES measurements. Logistically, the Max/min measurements can be done rapidly, but the VES requires up to an hour per site.

VES measurements on three volcanic islands within the lagoon (Moen, Dublon, and Fefan) easily determined the depth to highly resistive rock, which is presumed to be hard basalt beneath a cover of soil, alluvial fill, and weathered basalt.

In either environment, the VLF method was too imprecise to be useful by itself. The VLF signals are weak in that part of the Pacific Ocean, and it was impossible to get measurements precise enough for meaningful interpretation. The geology of Truk also was too complicated for a simple technique like the VLF; however, it may work well on reef islands if the signals were stronger and if the island were not too small. Proximity to the ocean has a great effect on VLF measurements.

VES and Max/min together provide the most hydrologic information of reef islands, and are ideal methods for assessing the ground-water resources of these islands. With only the Max/min technique, thickness of freshwater lenses over an entire island may be mapped rapidly. VES would require several days to map in detail the hydrologic information on a moderate-size island. VES can be used to determine depth to resistive rock, which is presumed to be basalt. VLF is not sufficiently useful in this area of the Pacific.

WATER SUPPLIES IN SELECTED TRUK ISLANDS

Dublon

Topographic and Geologic Features

Dublon Island is similar to the other high islands of Truk in that it is a remnant of a partly submerged much larger volcanic island. Two mountains, Foukenau and Tonomwan, and the saddle between them form the main land mass (fig. 18). The larger streams occur in the saddle area. Two prominent peninsulas project eastward from these mountains to form the deep reentrant bay called Nemwanon Bay.

Talus and alluvium generally make up the lower slopes where they overlie weathered volcanic rocks. During the occupation by the Japanese, much of the coastal lowlands were filled artificially. There are extensive freshwater marshes fronted by mangrove swamps at the head of Nemwanon Bay. The northern coastline is underlain by a narrow strip of unconsolidated beach deposits.

Ground-Water Surveys

All the ground-water surveys in Dublon Island listed below were made by the U.S. Geological Survey. A reconnaissance study of the occurrence of ground water was made by Valenciano and Takasaki in June 1957. Their findings were reported in a Water Resources Supplement to the Military Geology Report of the Truk Islands (1959).

In April 1983, during the prolonged drought, two electrical resistivity traverses were run, the first across the head of Nemwanon Bay and the second near the mouth of Chun Stream (see fig. 18). The first traverse was run to determine the depth of fill material and of weathered rock and the second to determine the depth to saline ground water. The depth of fill and of weathered rock near the mouth of Tumunu Stream at the head of Nemwanon Bay was found to be more than 100 feet. These rocks extended to a depth of at least 70 feet, 800 feet away from the stream. The depth to saline ground water near the mouth of Chun Stream was shallow and indicated, at least locally, the absence of fresh ground water.

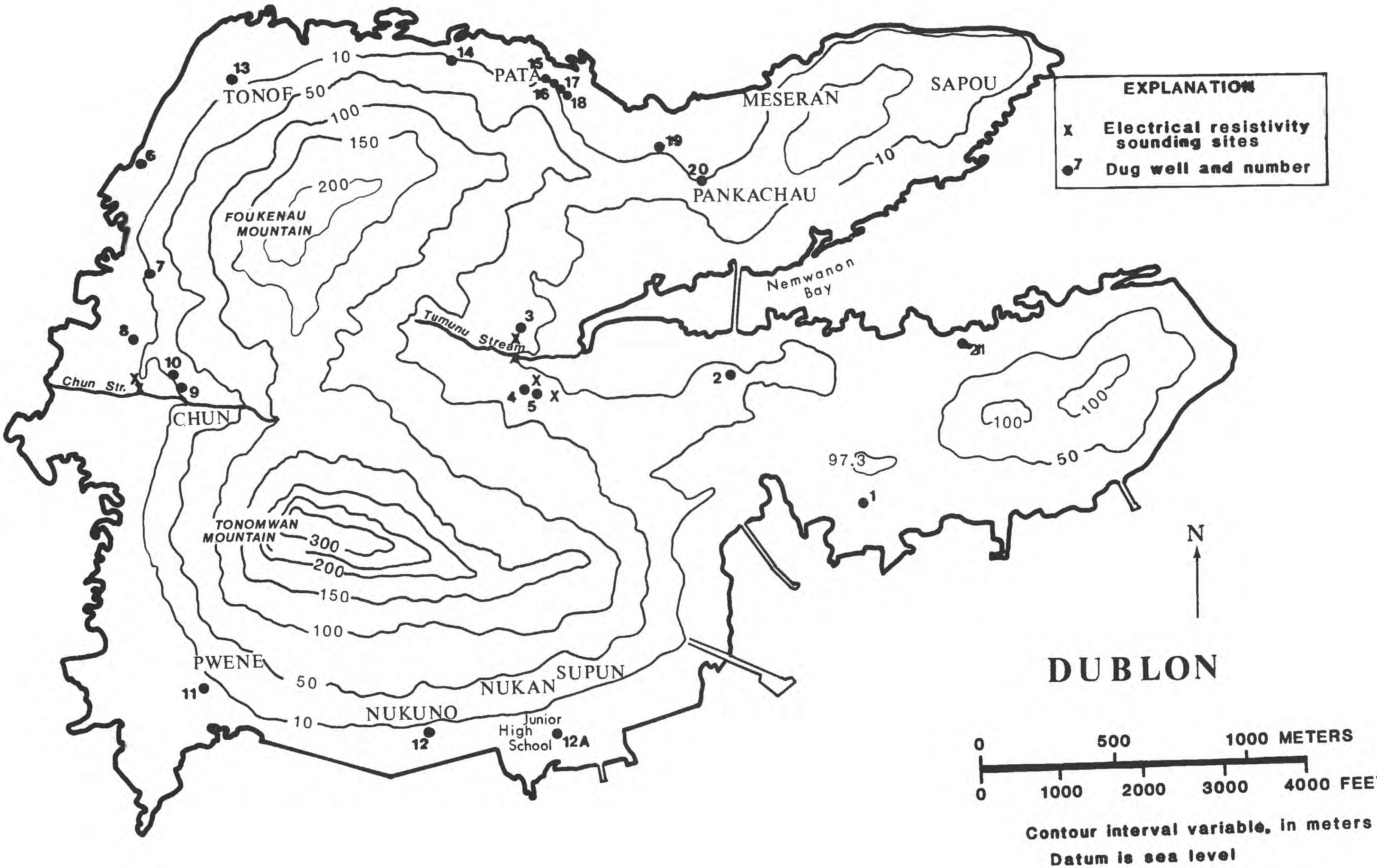


Figure 18. Location of dug wells and electrical resistivity sounding sites on Dublon.

Water levels were measured in several dug wells at or near the resistivity traverses during this time. The sounding sites of the traverses and the selected dug wells measured are shown in figure 18. Depths to water and specific-conductance values determined in April 1983 are compared with those determined in February 1984 in table 2. As shown by these comparisons, the water levels were significantly lower in 1983 during the drought than in 1984, and specific conductance was generally higher.

Table 2.--Comparison of water-level measurements made in Dublon wells in April 1983 and in February 1984

Site	Owner	Specific conductance (microsiemens) April 1983	Feb. 1984	Depth to water (feet) April 1983	Feb. 1984
2	Amara	320	300	11	6
3	Old Japanese well	185	180	6	1
5	Itimmar	125	83	9	2
8	Saiko	300	195	9	4
16	Nachikawa	430	250	10	4
17	Nachikawa	280	180	8	4

Water from these dug wells in the high islands normally is not used for drinking and cooking. Rain-water catchments and springs generally provide sufficient water for these purposes. Dug wells, however, became the main source of supply during the 1983 drought. Many wells were abandoned because they went dry, and people traveled long distances to other wells for drinking and cooking supplies. Most of the wells were abandoned unnecessarily; they had to be deepened only a few feet to be productive once again.

A 3-day survey of the dug wells in Dublon Island was made in February 1984 by K.J. Takasaki and S.N. Hamlin. A summary of their findings is given in table 3. The geologic settings of the wells (as defined and shown in figures 10 to 13, and table 1) are also listed. Unlike the drought period of 1982-83 when many wells were used as sources of drinking water, in February 1984 only one well was so used.

Table 3.--Survey of dug wells in Dublon Island, Truk, February 24, 25, 28, 1984

Site	Owner and description	Approximate altitude (feet)	Diameter or size (feet)	Total depth of well (feet)	Depth to water (feet)	Temperature (centigrade)	pH	Specific conductance (microsiemens at 25°C)	Approximate chloride concentration (mg/L)	Nitrate concentration (mg/L)	Geologic Setting Figure	Example Well
1	Conception: Concrete curbing 1 ft	20	3	7.1	3.9	27.5	5.8	120	10	ND(a)	13	B
2	Amara: Concrete lined, no curbing	30	3	9	6	27	6.1	300	20	--	11	A
3	Old Japanese well in tunnel about 200 ft from portal	30	2x3	8	1	27.5	6.2	180	10	ND	13	D
4	Itimmar: Boulder lined, no curbing	20	2.5	5	1.6	27	5.8	88	10	--	13	C
5	Itimmar: Boulder lined, curbing 1 ft	20	4.5	8	2	27	5.6	83	< 10	--	13	C
6	Sikemenene: Concrete curbing 0.5 ft	5	7	5	3	26.5	6.8	630	70	ND	12	A
7	Sikemenene: Boulder lined, no curbing	40	4.5	5	1	27	6.3	125	< 10	--	13	D
8	Saiko: Boulder lined, concrete curbing 2.6 ft	15	10	9.5	3.5	27.5	6.3	195	10	ND	11	A
9	Peru: Concrete to tunnel in alluvial slope	20	--	--	--	26.5	7.2	110	< 10	--	10	B
10	Peru: Boulder lined, no curbing	30	6	6.5	1	27.5	6.1	120	< 10	--	10	B
11	Saklos: Boulder lined, curbing 0.2 ft	5	5	1	0.2	27.5	5.7	83	< 10	ND	11	A
12	Luke: Concrete lined, curbing 1.5 ft	10	6	5	3.0	--	--	--	--	ND	11	A
12a	High School: open pit in artificial fill	5	--	--	--	28.5	--	340	25	--	12	A
13	Reuben: Boulder lined, no curbing	5	--	2.5	0.5	26.5	5.3	64	10	--	13	B
14	Ukuo: Boulder lined, no curbing	5	4	2.0	1.0	27.5	5.1	90	10	--	11	A
15	Nachikawa: Concrete lined, curbing 2.5 ft	10	3	12.8	5.8	27.5	5.7	175	10	18	11	A
16	Nachikawa: Concrete lined, curbing 1.6 ft	10	3	9	4.0	27.5	6.0	250	20	ND	11	A
17	Nachikawa: Concrete lined, curbing 2.0 ft	10	3	8	3.8	27	6.0	180	10	--	11	A

Site	Owner and description	Approximate altitude (feet)	Diameter or size (feet)	Total depth of well (feet)	Depth to water (feet)	Temperature (centigrade)	pH	Specific conductance (microsiemens at 25°C)	Approximate chloride concentration (mg/L)	Nitrate concentration (mg/L)	Geologic Setting Figure	Example Well
18	Nachikawa: Concrete lined, curbing 0.8 ft	10	4x4	7.5	3.5	27	5.8	130	10	--	11	A
19	Saburo: Concrete lined, curbing 0.5 ft	5	5x5	8	1.8	27	6.2	390	30	--	13	C
20	Fairo: Concrete lined, curbing 0.6 ft	10	15	9	2.5	27	5.9	160	10	ND	13	C
21	Not known: Concrete lined, curbing	10	--	--	2	--	--	75	10	--	11	A

(a) ND - Not detected.

On October 3, 1984, K.J. Takasaki of the U.S. Geological Survey accompanied by Lts. Bruce Reichert and James Walters of OICC, U.S. Navy; Ted Lund, driller; and Son Manas of the Truk Land Management Office selected sites for drilled wells to supply water for a proposed fish processing plant. The sites selected are shown in figure 19. The criteria listed below generally follow the order of importance by which these sites were selected:

1. The saturated thickness of weathered volcanic rock.
2. Position of the site in relation to possible contamination by underlying saline ground water or leachate from village and animal wastes.
3. Proximity to a proposed fish processing plant.
4. Accessibility for drilling equipment.

Existing Water Supplies

A filtration plant on the northeast side of Mount Tonomwan consisting of four 60,000-gallon concrete settling tanks and a 42,000-gallon reservoir, collects water from springs that feed Fansinifo Stream. The principal intake is at an altitude of about 60 feet. The water is chlorinated at the filtration plant before being pumped to two 144,000-gallon concrete tanks on the east flank of Mount Tonomwan. The water is then allowed to flow by gravity to the junior high school area on the south coast. The system was originally constructed by the Japanese.

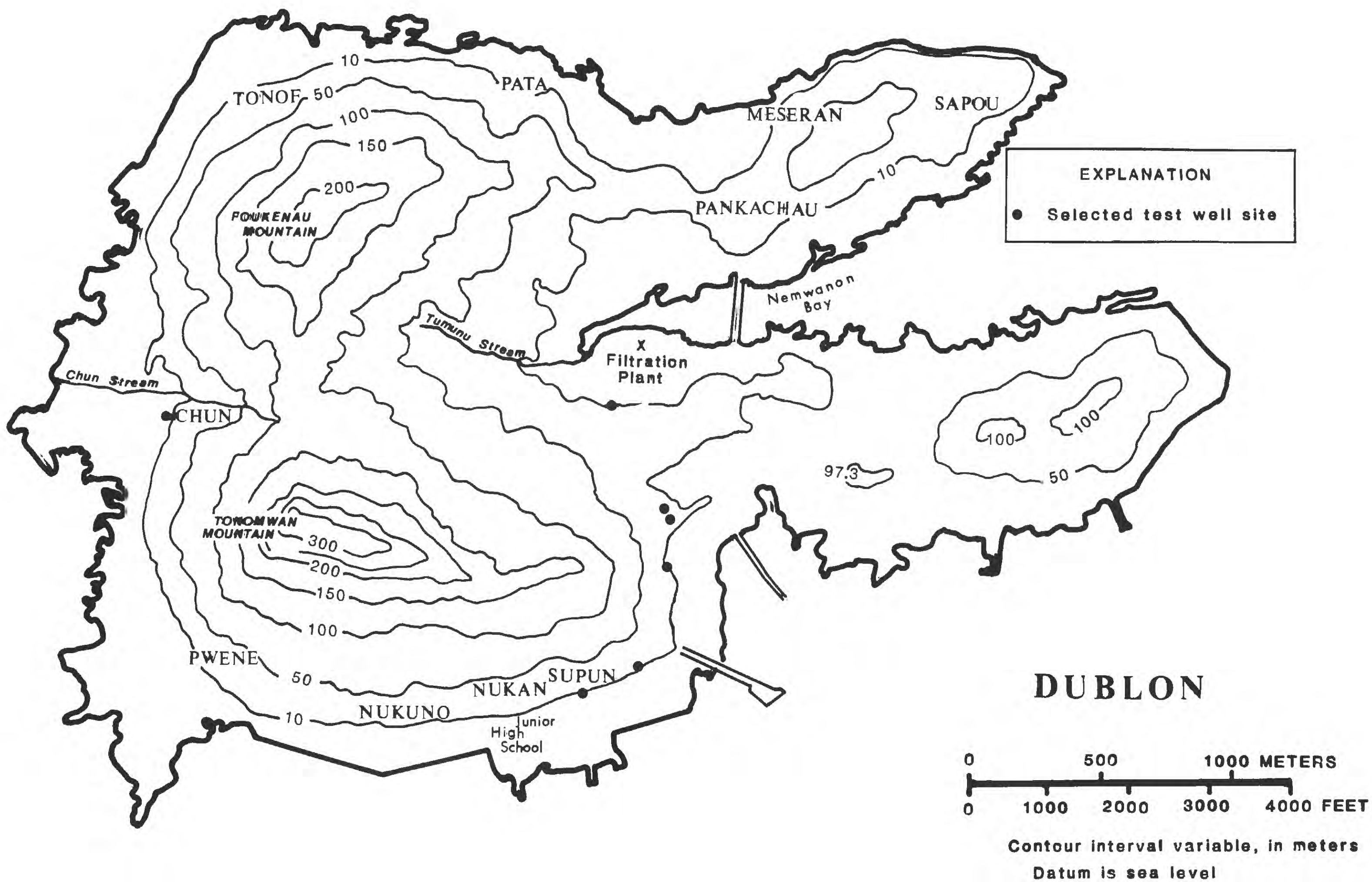


Figure 19. Location of selected test well sites on Dublon.

The principal intake area, consisting of a small holding dam and grated intake, was overgrown and full of debris when it was visited on February 24, 1984. The estimated flow on February 24, 1984, was 100 gallons per minute.

Optimal Water-Development Alternatives

A. Supply for Fish Processing Plant

Requirement: A dependable supply of freshwater delivered at a given head.

Possible sources:

1. Drilled wells

   Advantages

   a) Drilled wells are excellent sources for moderate supplies and they are easy to maintain quality control.

   b) Water from drilled wells require smaller storage than surface-water sources.

   c) Drilled wells can be deeply cased to minimize pollution.

   Disadvantages

   a) Well yield of drilled wells are likely to be very small because of the tight nature of the water-bearing rocks.

2. Battery of shallow dug wells

   Advantages

   a) If supply is not adequate, shallow dug wells in the lower alluvial slopes and in the artificial fill can be developed to augment the supply. The water from these dug wells can be put to lower use, such as washing and cleaning.

   b) Dug wells can be used to augment the freshwater supply from drilled wells if needed.

   Disadvantages

   a) There are likely to be logistic problems in acquiring large areas necessary for source development.

   b) There are inherent pollution problems owing to proximity of the underlying ground water to the land surface.

   c) Wells can be cased only to shallow depths.

3. Streamflow

   a) Improvements are needed in the existing supply and filtration plant.

b) The supply is not dependable unless utilized in conjunction with one or more sizeable surface reservoirs. Likelihood for acquiring reservoir sites are small.

c) There are high costs and logistic problems associated with maintaining quality control.

B. Drinking-water supply for villages not served by the present pressurized water system

Requirement: A water supply that is sufficiently fresh to augment rain catchment and spring supply.

Possible sources:

1. Rain catchments
   a) They are not adequately utilized, needed.
   b) They need simple filter system at reservoir intake.
   c) They need covered reservoirs and spigot to minimize pollution.
2. Stream or spring supplies
   a) Intakes need to be fenced off to keep pigs and other animals out.
   b) They require storage tanks so that flow during the night can be accumulated and stored for day-time use.
   c) They require water taps for reservoirs to reduce pollution.
   d) They require adequate pipe size to accommodate flow.
3. Dug wells that can be utilized as a combination of underground storage and supply (see design in fig. 14).
4. Drilled wells
   a) Development and maintenance costs are high.
   b) Suitable aquifers have not been tested.

Uman

Topographic and Geologic Features

Uman is an approximately conical island bordered by freshwater marshes and narrow beaches in coastal lowlands on the north end and the southeast side (fig. 20). The island is 1.4 square miles in area and has no deep bays.

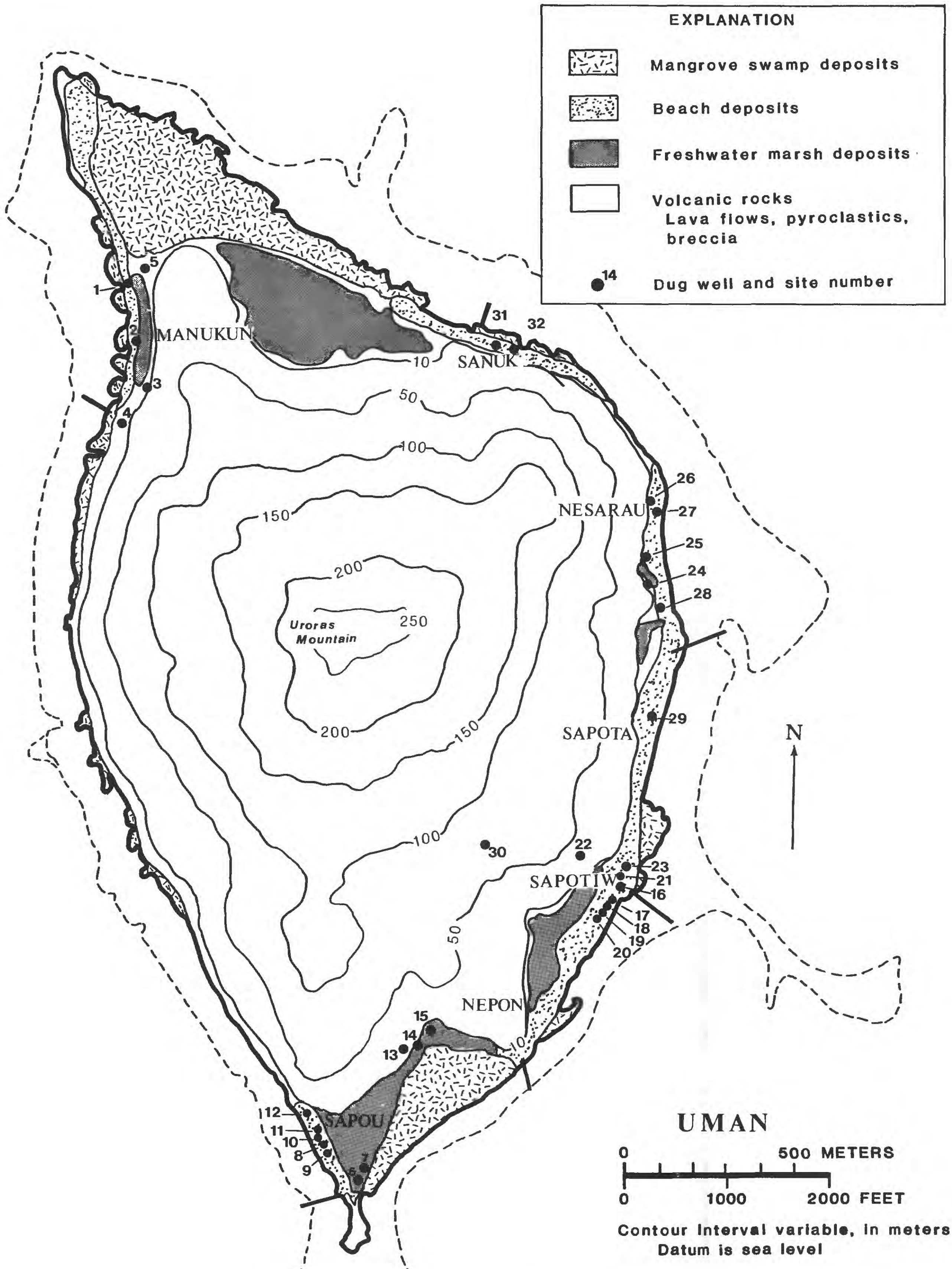


Figure 20. Generalized geology, dug wells, and other measuring points on Uman.

The volcanic rocks have steep slopes that are interrupted at different levels by small areas of more gentle slopes. The rocks are mostly lava flows with a small amount of interbedded cemented broken rock (breccia).

Ground-Water Surveys

Two ground-water reconnaissance surveys were made by Takasaki of the U.S. Geological Survey. The first in June 1957 and the second in April 1983, during the prolonged drought. The findings of the first survey were reported in a Water Resources Supplement to the Military Geology of the Truk Islands (1959). The conclusions reached in 1957 as given in the report follows:

"Practically all the streams on Uman are dry during prolonged periods of no rainfall, and it is not unusual for the streams to go dry even during the rainy season."

Little is known of the ground water in the volcanic rocks on Uman. On the upland slopes numerous seeps flow from slope wash, but only meager quantities of water can be developed from this material at any one locality. In the lowland along the west shore of the island, seeps are rare and no wells were found. On the north and east sides, seeps are common in the talus and alluvium near sea level, and shallow dug wells in these deposits supply meager quantities of water to households. These materials potentially are the most productive sources of ground water in the island. For maximum yields, wells dug in the talus and alluvium need to be as deep as is practical.

The strip of beach deposits extending from the north end of the island probably contains little freshwater. The beach deposits on the southeast side contain water of low chloride concentration, but the concentration will likely increase in wells that are pumped.

In April 1983, many of the streams and springs (seeps) that were the main sources of drinking water in Uman Island were dry or nearly so. With these sources dry, many villages were using water from dug wells in coastal areas for drinking. Many of the dug wells located at the higher upland areas became dry during this period. These wells were abandoned, most of them unnecessarily; they had to be deepened only a few feet to reach water that was at a low level because of the drought. Water levels in wells at the high altitudes are generally subject to wide fluctuations in response to changes in rainfall recharge because they are dug into poorly permeable rocks and generally tap small perched bodies. The decline in water levels in the coastal wells was small, especially where the wells tap freshwater floating on saline water in permeable beach deposits. These coastal wells did not go dry.

A one-day survey of dug wells on Uman at the sites shown in figure 20 was made in April 14, 1983, during a severe drought that began in October 1982. The findings from this survey are summarized in table 4. The northeast area was not included in this survey and data gathered there in a survey in 1957 were substituted for that area.

The water from most of the dug wells measured was generally of low chloride concentration. However, the water from dug wells at site 1, located about 25 feet from shore and at site 14, located near the edge of a mangrove swamp, had chloride concentrations of about 950 and 550 mg/L, respectively.

The bacterial quality of the water from the wells was not measured. Only one of the wells was securely covered, and the water had to be dipped for use. The covered well, located at site 6, was equipped with a hand pump. Most of the wells had no raised curbings, the absence of which allowed waste water and other polluted waters to easily flow into the well.

The following conclusions were reached after the April 14, 1983 survey of Uman.

1. Surface-water flow including streamflows, springs, and seeps is not a dependable source of water during any prolonged rainless period.
2. There are no unused lands suitable for surface reservoirs to store streamflow.
3. Many inland dug wells at high altitudes were dry because water levels had been lowered below the bottom of the well during the drought. These dry wells were abandoned.
4. Most dug wells at low altitudes near the coast did not go dry because they were dug into more permeable rocks and commonly dug a foot or more below sea level. Water from some wells very near the shore or near mangrove swamps was brackish.
5. All water in dug wells is subject to pollution because the wells are not covered. If covered, the wells need to be equipped with hand or windmill (or solar) pumps to be usable.

Table 4.--Survey of dug wells in Uman, Truk, April 14, 1983

Site	Owner and description	Approximate altitude (feet)	Diameter or size (feet)	Total depth of well (feet)	Depth to water (feet)	Temperature (centigrade)	Specific conductance (microsiemens at 25°C)	Approximate chloride concentration (mg/L)	Geologic Setting Figure	Example Well
1	Rectangular dug well, 25 ft from shore. No curbing. Beach deposits.	3	5x4	3.5	2	26.5	3,300	950	13	A
2	Rectangular dug well, 100 ft from shore. No curbing. Alluvium.	10	5x4	2.5	5	26.5	700	95	13	A
3	Rectangular dug well, 300 ft from shore. Boulder curb, 1.2 ft. Alluvium and/or saprolite.	30	6x6	12.5	11.5	26.5	190	15	12	B
4	Rectangular dug well, talus.	20	5x4	8.5	7.5	26.5	220	15	11	A
5	Boulder lining no curbing, owner Yeichi. Round dug well. Alluvium.	15	3	3.8	3	27	200	15	13	B
6	Round dug well, 150 ft from shore. Boulder curb, 1 ft. Equipped with Japanese hand pump, 10 gal/min, owner Ichie Uehara. Beach deposits.	5	5	6	4	29	700	95	13	A
7	Dug well 100 ft north of site 6. Boulder lined, no curb. Beach deposits.	5	--	3.5	2	27	700		13	A
8	Round dug well, 50 ft from shore. Beach deposits.	10	3.5	6.2	4	29	900	145	13	A
9	Dug well, 55-gal. drum curb., 1.3 above ground, 50 ft from shore. Beach deposits.	10	--	3.7	2.5	28.5	725	100	13	A
10	Dug well, 10 ft north of site 8. Boulder curb., 0.9 ft. Beach deposits.	10	--	5.7	3.1	28	1,200	250	13	A
11	Dug well, 10 ft NE of site 10. Boulder lined, no curb. Beach deposits.	10	3	--	3.1	28	625	75	13	A

Table 4.--Survey of dug wells in Uman, Truk, April 14, 1983--Continued

Site	Owner and description	Approximate altitude (feet)	Diameter or size (feet)	Total depth of well (feet)	Depth to water (feet)	Temperature (centigrade)	Specific conductance (microsiemens at 25°C)	Approximate chloride concentration (mg/L)	Geologic Setting Figure	Example Well
12	Round dug well, 75 ft from shore. Boulder lined, no curbing. Beach deposits.	10	4	--	5	30	850	130	13	A
13	Round dug well, boulder lined, curb., 0.5 ft. Alluvium.	50	5	6.1	3.5	28	540	60	13	B
14	Round dug well near salty marsh. Boulder lined. Talus and alluvium.	10	5	--	--	28.5	2,200	550	13	B
15	Round dug well, no curbing. Alluvium and talus.	20	3	4	3	28	430	45	13	B
16	Round dug well, 40 ft from shore. No curbing or lining. Fine beach sand.	5	5	--	3.5	26.5	700	95	13	A
17	Rectangular dug well, 100 ft from shore. No lining. Fine beach sand.	5	3x3	4	3	30.5	600	70	13	A
18	Round dug well, 125 ft from shore unlined. Fine sand mixed with alluvium.	5	4	4.5	3.5	26.5	650	80	13	A
19	Round dug well, 150 ft from shore. Dirty fine beach sand.	5	3	4.7	4	27	600	70	13	A
20	Round dug well, 150 ft from shore, unlined. Dirty beach sand.	5	3	--	3.5	29	700	95	13	A
21	Round dug well, 300 ft from shore. Dirty beach sand.	10	3	5.5	4	30	550	65	13	A
22	Chief's well, concrete curbing. Perched water in talus.	75	--	3.0	1.6	29	170	15	13	E
23	Round dug well, 100 ft from shore, open, unlined. Beach deposits.	5	6	4.5	3	29	790	105	12	A
24	Round dug well, boulder lined, no curbing. Alluvium.	15	3.5	6.0	4.5	28.5	230	15	13	B
25	Rectangular dug well, 150 ft from shore. No lining. Alluvium.	15	6x4	5.5	4	28	380	40	13	B

Table 4.--Survey of dug wells in Uman, Truk, April 14, 1983--Continued

Site	Owner and description	Approximate altitude (feet)	Diameter or size (feet)	Total depth of well (feet)	Depth to water (feet)	Temperature (centigrade)	Specific conductance (microsiemens at 25°C)	Approximate chloride concentration (mg/L)	Geologic Setting Figure	Example Well
26	Round dug well, 100 ft from shore, unlined. Alluvium and talus.	10	4	--	4.5	28	230	15	12	A
27	Round dug well, 40 ft from shore, unlined. Dirty beach sand, some boulders.	5	4.5	4.5	3	28	900	145	12	A
28	Round dug well, 75 ft from shore, boulder lined, no curbing. Talus and alluvium.	10	--	--	3	28	650	80	12	A
29	Dug well, 100 ft from shore, concrete curb., 1.1 ft. Near edge of beach deposits.	10	--	6.3	4.3	28.5	360	35	12	A
The following sites were surveyed in 1957:										
30	Seep, trickle from talus.	200	--	--	--	--	--	--	13	E
31	Dug well, boulder lined. Talus.	5	--	3	1	--	--	15	12	A
32	Dug well, boulder lined. Talus.	5	--	3	1	--	--	--	12	A

6. The dug wells used to supply drinking water need to be covered and equipped with pumps. Most of these wells need to be modified to handle the pumps. Most need to be deepened and curbed. If the wells designated for drinking water are susceptible to pollution by nearby homes and pig pens, it would be safer not to use these wells as a source of drinking water or cooking water. New wells away and upslope from these areas need to be dug. A model dug well is shown in figure 14.

Existing Water Supplies

There are no pressurized water systems in Uman. Water for the villages is provided by roof rain catchments, springs and seeps, and by dug wells. A survey in April 1983 determined that at least 30 wells were being used. During the drought when most springs and seeps went dry, many of the dug wells were used as sources of water for drinking and cooking.

Optimal Water-Development Alternatives

A. Drinking-water supply for villages

Requirement: To increase existing rain catchment and spring supplies.

Possible source:

1. Rain catchments
    a) They are not used enough in Uman; more are needed.
    b) They need simple filter at storage tank intake.
    c) They need covered storage tank and water tap to minimize pollution.
2. Streamflow, springs and seeps
    a) Most streams go dry quickly after rains and there are no suitable sites for reservoirs.
    b) Springs and seeps are small and many go dry after rains. Fencing off the intake of larger ones would minimize pollution. Providing adequate storage would enable flow to be accumulated at night.
3. A simply designed dug well that can be used as a combination of underground storage and supply (see fig. 14).
4. Drilled wells
    a) Not feasible at present.

Fefan

Topographic and Geologic Features

Fefan consists of a mountainous ridge with four prominent peaks. Mangrove swamps lie along most of the coast, and locally, areas of freshwater marshes and sandy beaches occur (fig. 21). Most of the volcanic rocks are lava flows with some rocks resulting from explosive eruptions (pyroclastics).

Ground-Water Surveys

Surveys of the water resources of Fefan were made by the U.S. Geological Survey during the following periods. The first in June 1957 by Valenciano and Takasaki (1959). The area near Mesa village on the northeast coast was briefly visited by Takasaki and Kauahikaua in April 1983 during the drought. On February 8, 1984, Takasaki and Hamlin made a one-day reconnaissance of the dug wells along the west coast. Their findings are summarized in table 5.

As in the other islands, many of the streams and springs in April 1983, which were the main sources of drinking water in Fefan, were dry or nearly so. Water dipped from dug wells was the main source of drinking water. Many of the wells at the higher altitudes inland from the coast had become dry. Some of the wells along the east coast had become salty.

Existing Water Supplies

A survey in February 1984 found at least 17 dug wells along the west coast of the island. It is likely that there are at least as many wells along the east coast. Except for some seepage flows piped to individual homes, there is no pressurized water system in Fefan. Water dipped from dug wells is mostly used for bathing and laundering.

Optimal Water-Development Alternatives

A. Drinking-water supply for villages

Requirement: To increase existing rain catchment and spring supplies.

Possible sources:

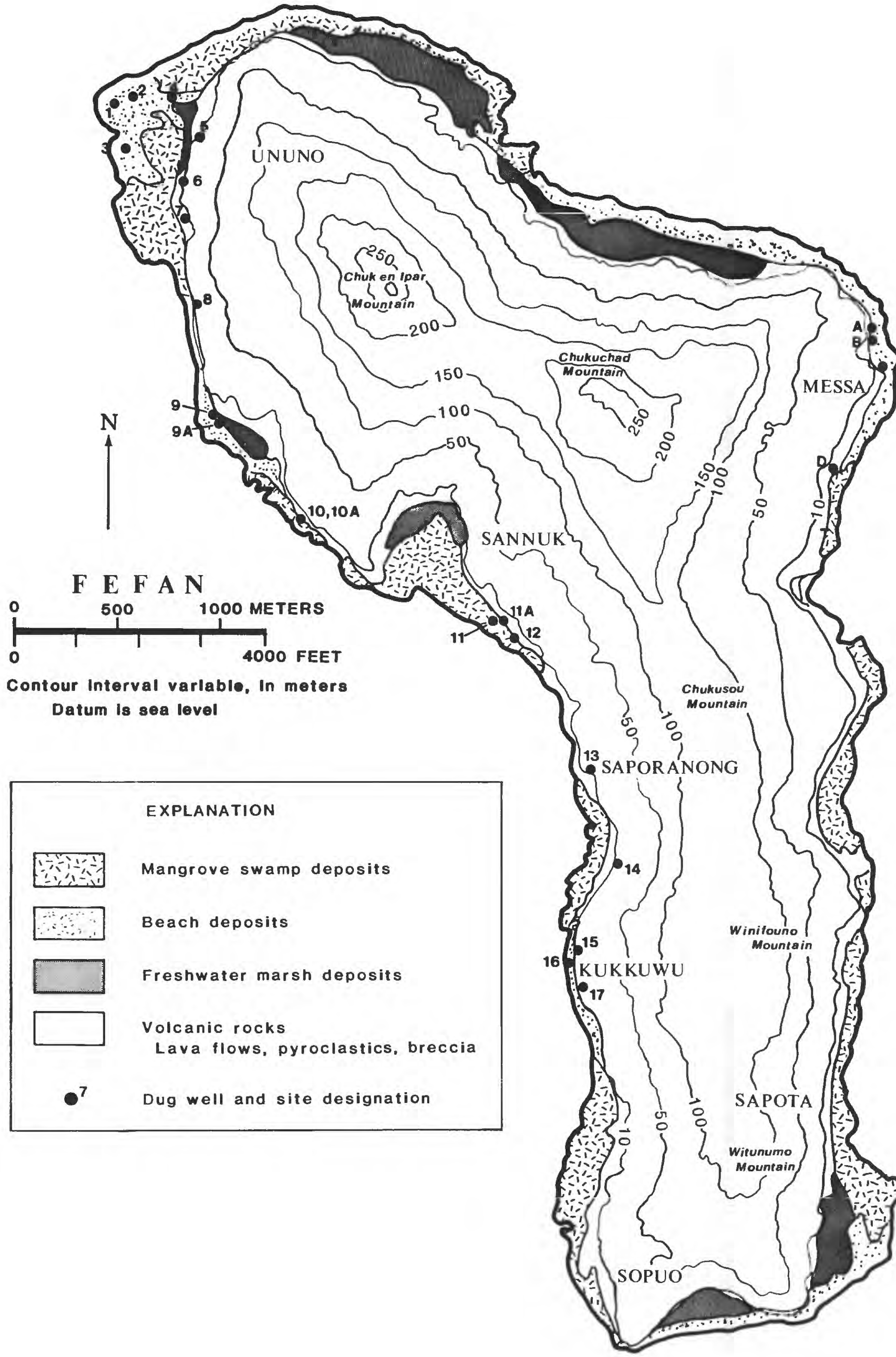


Figure 21. Generalized geology, dug wells, and other measuring points on Fefan.

Table 5.--Survey of dug wells in Fefan, Truk, wells 1 to 17, February 8, 1984; Wells A to D, April 8, 1983

Site	Owner	Description	Diameter or size (feet)	Total depth of well (feet)	Depth to water (feet)	Temper-ature (centi-grade)	Specific conductance (microsiemens at 25°C)	Approx-imate chloride concen-tration (mg/L)	Nitrate concen-tration (mg/L)(a)	Geologic Setting Figure	Example Well
1	Rewein	Concrete lined and curbed, 2 ft above ground	2	2.9	0.9	26	290	20	--	13	A
2	Manawan	55-gal drum, 1 ft above ground	--	2.5	1.5	26	750	60	--	13	A
3	Esekio	Boulder lined, no curbing	4	4.7	1.7	27	480	20	--	13	A
4	Enacio	55-gal drum, 1.2 ft above ground	--	3.3	1.3	26.5	680	40	--	12	A
5	Pacidio	Not lined or curbed, open pit	10	--	--	27	270	20	--	11	A
6	Umiko	Open hole	5	--	--	27	65	20	--	11	A
7	Filo	Not lined or curbed, open hole	7	--	1.5	27.5	75	20	--	11	A
8	Amanisio	Boulder curbed, 20 ft from shore in alluvium	4	2.5	1.5	27.5	70	20	ND	11	A
9	Joseph	Boulder lined, algae in water	5	2.5	1.0	27	50	20	9	12	B
9a	Joseph	Open hole along taro patch	--	--	--	--	--	--	--	12	B
10	Caspara	Boulder lined, concrete curbed 1.5 ft above ground	3x3	2.8	2.3	27.5	60	20	--	11	A
10a	Caspara	Not lined or curbed, overflows to sea 1-2 gal/min	4	--	--	--	60	20	ND	11	A
11	Sino	Not lined or curbed	6	2.0	0.5	27	55	20	ND	11	A
11A	Sino	Overflow from open hole less than 1 gal/min	--	--	--	--	--	--	--	11	A
12	Marcelino	Overflow from alluvium, 3 to 5 gal/min	--	--	--	28	80	20	--	11	A
13	Yino	Boulder lined and curbed, went dry during drought	4	11	3	27.5	50	20	ND	13	D

Table 5.--Survey of dug wells in Fefan, Truk, wells 1 to 17, February 8, 1984; Wells A to D, April 8, 1983--Continued

Site	Owner	Description	Diameter or size (feet)	Total depth of well (feet)	Depth to water (feet)	Temperature (centigrade)	Specific conductance (microsiemens at 25°C)	Approximate chloride concentration (mg/L)	Nitrate concentration (mg/L)(a)	Geologic Setting Figure	Geologic Example Well
14	Nemonan	Spring flow 1-2 gal/min; dry during drought	--	--	--	28	50	20	ND	12	B
15	School	Boulder lined, concrete curbed	5	5	2	27.5	75	20	ND	12	B
16	Edgar	Boulder lined and curbed, 0.2 ft above ground	3	2.3	0.8	29.5	200	20	ND	11	A
17	Raphael	Boulder lined, no curb; not dry during drought	5	3.0	1.5	28	80	20	ND	11	A
A	--	--	--	--	4	27	7,000	2,000	--	12	A
B	Luter	--	--	--	--	27	470	20	--	12	B
C	Church	Water draining from talus slope	--	--	5	28	130	20	--	12	B
D	--	--	4x5	4.5	3	--	320	20	--	12	B

(a) ND - Not detected.

1. They need rain catchments with simple filter systems to minimize pollution.
2. Possible sources are flow of streams, springs, and seeps. If flows do not go dry after rains, sufficient storage needs to be provided so that flow at night can be saved for day use.
3. They need simply designed dug wells that are a combination of storage and supply (see fig. 14).
4. Drilled wells are not feasible at present.

Faichuk Islands

Mink made a survey of the water resources of the Faichuk Islands in March 1983. His findings are given in a consultant's report by Barrett, Harris and Associates (1983). In this report, Mink describes the major problems and needs with respect to the development of water supply and waste-water disposal systems in the Faichuk Islands.

Highlights of his summation include:

a) The need to better identify potential water-supply sources.

b) The water-supply sources are limited during dry months of January, February, and March.

c) The existing practice of water collection and waste-water disposal systems are not sanitary.

His major recommendations include:

a) They need multiple sources of water supply to cope with dry periods.

b) They need to increase use of rain catchments.

c) They need exploratory well drilling to indicate that areas show potential for ground-water development.

d) They need dug wells for bathing, washing, and toilet flushing where ground water is brackish.

Pis

Pis is a low (reef) island located on the northernmost part of the barrier reef that encircles the Truk Lagoon. The island lies on the edge of the barrier reef on the lagoon side.

The chloride concentration of two dug wells were 62 mg/L in February 1955. Takasaki and Kauahikaua of the Geological Survey revisited the island during the drought on April 11 and 12, 1983. During this visit, a reconnaissance of the dug wells and two north-south electrical traverses were made by Kauahikaua. The well locations are shown in figure 22 and results of the dug-well survey are summarized in table 6. The electrical resistivity traverses indicated the presence of a thicker freshwater lens on the lagoon side of the island than on the ocean-side.

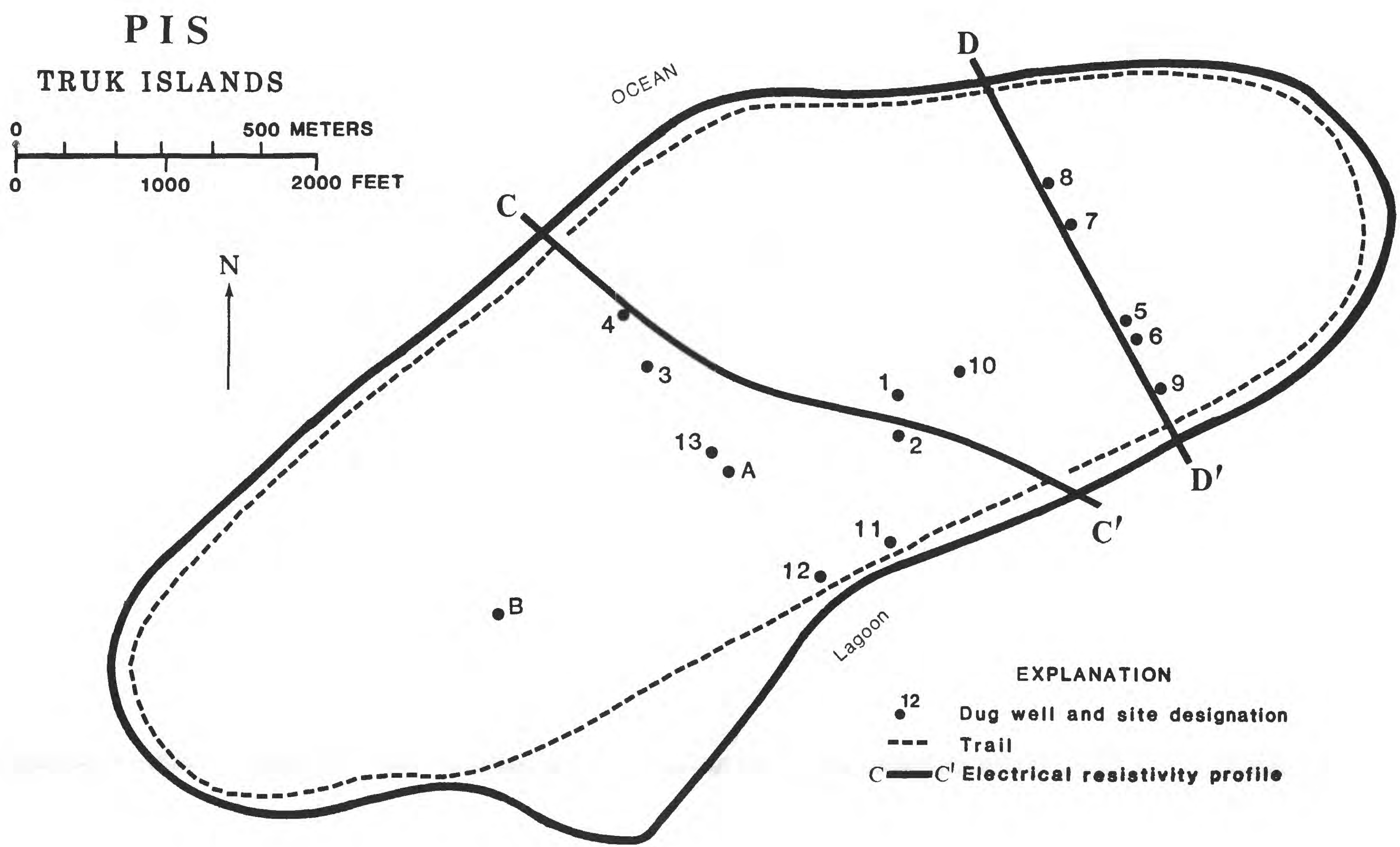


Figure 22. Locations of dug wells and electrical resistivity profiles on the island of Pis.

Table 6.--Survey of dug wells in Pis, Truk, April 11, 12, 1983

Site	Description	Total depth of well (feet)	Depth to water (feet)	Temperature (centigrade)	Specific conductance (microsiemens at 25°C)	Approximate chloride concentration (mg/L)
1	Top of well 3.6 ft below ground	6.3	4.2	31	1,800	300
	Top of well 3.5 ft below ground	7.6	4.8	30	1,000	120
3	-------------------------	--	5.5	29	560	25
4	Well point and hand pump installed. Pumps 4 gal/min.	8.0	5.0	--	650	40
5	Chief's well. Concrete curb 1.7 ft above ground	--	3.7	28	1,400	240
6	Benito's well	5.6	4.1	27	630	40
7	Tionis well	--	3.0	28	2,000	400
8	Marino well, 300 ft from ocean 55-gal drum from lining	3.8	2.8	27	2,200	440
9	Andrews well, 150 ft from lagoon	6.3	4.5	27	1,100	140
10	-------------------------	--	--	29	3,000	700
11	100 ft from lagoon	5.5	4.5	27	1,200	160
12	60 ft from lagoon	6.0	3.5	26	730	60
13	-------------------------	--	--	29	950	110
A	Measured in Feb 1955	--	--	--	--	62
B	Measured in Feb 1955	--	--	--	--	62

CONCLUSIONS

The general lack of natural and manmade storage is the principal water problem in the high islands of the Truk State. The bulk of the islands is made up of tight, massive lavas and cemented rock fragments that allow only a small part of the rainfall to infiltrate or allow large quantities of the infiltrated water to be stored below the ground surface. Thus, even with a rainfall that averages 140 inches per year, streams are flashy and short-lived and water levels in wells fluctuate widely.

The small size of most of the islands and the reluctance of the natives to give up precious family-held lands for reservoir sites are the biggest constraints to the construction of surface reservoirs. The high cost of constructing roof catchments and cisterns large enough to store adequate supplies of water is a real problem. The Truk government has recently initiated a plan to solve this problem whereby the villagers would participate by paying only for the materials needed. This plan, if widely practiced, will do much to ease water-supply problems, especially in the small villages.

For water uses other than drinking and cooking, shallow dug wells are development alternatives. Water from these wells can be used for washing, bathing, and toilet flush water, and when required for the other household uses during long rainless periods when the other sources go dry.

Many dug wells in the high islands went dry during the 1982-83 drought and were abandoned. In many instances, the ground-water levels were only a few feet deeper and the wells need not have been abandoned, only deepened.

Ground water in Pis Island, a coral island, is a freshwater lens floating on seawater. The water from wells tapping the freshwater lens showed some increases in chloride concentration during the 1982-83 drought.

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