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TEST WELL SITES AND PRELIMINARY EVALUATION OF GROUND-WATER POTENTIAL IN TORTOLA, BRITISH VIRGIN ISLANDS. 1926.

Test Well Sites and Preliminary Evaluation of Ground-Water Potential in Tortola, British Virgin Islands

by

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U.S. Geological Survey

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Administrative Report

Work Done in Cooperation with the Government

of the Virgin Islands,

Ralph M. Paiewonsky, Governor

October 1966

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Test Well Sites and Preliminary Evaluation of Ground-Water Potential in Tortola, British Virgin Islands

SUMMARY

Moderate supplies of potable ground water are believed to be available in the Roadtown and Paraquita Bay areas, and small, possibly brackish supplies in the Long Look and West End areas of Tortola. Two water-bearing units of the same hydrologic system have the potential of yielding water to wells: 1) alluvial deposits, possibly as thick as 60 feet and locally containing beds and lenses of gravel 1 to 5 feet thick; and 2) fractured and jointed bedrock, especially where it is overlain by alluvium.

The most productive ground-water areas are expected to be the lower reaches of the larger valleys. Here the alluvial deposits are thickest and the valleys often follow the trace of fault or fracture systems in the bedrock. A potential yield of 195,000 gpd (U.S. gallons per day) is estimated to be available in the Road Bay area, 55,000 gpd in the Long Look area, and 8,000 gpd in the West End area.

Sites are suggested for test and monitoring wells in the lower courses of six of the valleys on the south coast.

OBJECTIVE

A reconnaissance of potential ground-water areas in Tortola, British Virgin Islands, was made August 9 through 11, 1965. The reconnaissance was undertaken to select sites for test wells to determine the feasibility of obtaining ground water for the communities of Roadtown, Long Look, and West End. Six areas on the south coast of Tortola were investigated (figure 1). In general, each area was given a brief inspection principally from roads and trails. Stream courses in areas 1 and 2 were walked out. Hydrologic interpretations are based on the transfer of data from St. Thomas, U.S. Virgin Islands.

CURRENT SITUATION

Public water supplies currently are obtained from a few dug wells scattered about the Island of Tortola. Water supply generally is an individual endeavor. Nearly all residences, public buildings, and commercial establishments have facilities for collecting rain on rooftops and storing it in cisterns. A small hillside rain catchment at Roadtown is inoperative (1965). Current water use probably is less than 10 gpd (gallons per day) per capita--probably a reflection of the water available rather than of the demand.

Figure 1.--Location of watersheds investigated, Tortola, B.V. I.

PROJECTED WATER NEEDS

If more water becomes available, the per capita consumption can be expected to increase from the present estimate of 10 gpd to about 50 gpd within a few years. To supply the present population of the Roadtown area, which is about 1,500, an initial water supply of about 45,000 gpd will be required. To supply the projected population of 5,000 in 1975, additional water supplies totaling about 350,000 gpd will have to be developed concurrently with the population increase.

The community of Long Look has an estimated population of about 500 within the central core of residences. Initial water needs for the central core will be about 15,000 gpd. Population is expected to triple by 1975 and per capita demand will increase as well. The estimated water requirement for Long Look by 1975 is about 150,000 gpd.

Only a few hundred people were living in the West End area in 1965. The recently constructed all-weather road should cause some relocation of population to this area. Initial water needs are probably no more than 5,000 gpd. A possible doubling of the population and greater per capita water demand will increase water use to an estimated 25,000 gpd by 1975.

SOURCE AND OCCURRENCE OF WATER

Rain is the only source of surface and ground water on Tortola. Of the rain which falls on the Island, about 90 percent returns to the atmosphere by evapotranspiration. About half of the remainder is recharged to the ground water and half is discharged to the sea as storm runoff.

Rainfall near sea level at the Bontanic Station in Roadtown averages about 53 inches per year; whereas rainfall in the eastern and western ends of Tortola is estimated to be about 35 inches per year; and on Mt. Sage is estimated to be about 80 inches per year. For the purpose of this report rainfall of 53 inches per year is used for watersheds 1, 2, and 3; 35 inches per year for watersheds 4, 5, and 6 in figure 1.

Ground water

Rain water will move from its point of entrance into the earth to the water table and then down gradient toward the sea. The surface of the water table, which indicates the top of the water-saturated zone in the earth, follows the general contour of the land surface. Ground water thus moves toward the center of a valley, much the same as surface-water flow. The result is that the ground-water discharge of a watershed is more or less funneled to the sea through the relatively small area of the lower part of a valley.

Ground water occurs in the alluvial deposits and bedrock of the Island. The alluvium and the bedrock are treated herein as individual, hydraulically interconnected water-bearing units of an aquifer whose limits are the boundaries of the watershed in which it is located.

Alluvium

Alluvial deposits are confined to the lower reaches of the valleys where they form relatively flat alluvial fans adjacent to the sea. The alluvium exposed along the stream courses is a poorly sorted mixture of sediments, ranging from clay to boulders with occasional lenses of sand and gravel.

Drilling in alluvium on St. Thomas has penetrated beds of sand and gravel as much as 3 feet thick lying on or near the bedrock surface. As the depositional environment is the same, similar sand and gravel deposits should be present in the alluvium on Tortola. The sand and gravel beds are the remnants of former stream channels now buried by more recent alluvium.

The clayey to bouldery alluvium has an estimated porosity of as much as 30 percent by volume, and so is capable of storing large volumes of water. Because the material is fine-grained, however, it transmits water slowly.

The lenses and beds of sand and gravel, while having about the same porosity, have a much higher permeability than the bulk of the alluvium and transmit water readily. Wells which penetrate the sand and gravel should yield 10 to 20 gpm, compared with less than 1 gpm for wells in the fine-grained alluvium. In effect, the gravel acts as a very large-diameter gravel-walled well presenting an extensive surface area to the finer-grained alluvium from which water can infiltrate.

Bedrock

Water in the volcanic and associated sedimentary rocks is confined to open fractures and joints. Many of the fractures and joints which once were open are now filled or partly filled with secondary calcite or quartz. Other fractures and joints, although open, are not interconnected; thus they are not capable of transmitting water except locally within the fracture.

The number and extent of interconnected openings form a very small part of the total volume of the rock. Data obtained on St. Thomas indicate the porosity of the bedrock ranges from 0.5 to 5 percent in areas considered to have a good potential for the development of water supplies. The greatest density of fractures and joints generally is in areas where the rocks have been subjected to faulting or to some type of shearing stress. Fracture zones may range in width from a few to many tens of feet and are most extensive where two or more faults or fracture zones cross or join.

Fracturing and jointing tend to weaken the bedrock, making it more susceptible to weathering and erosion. Thus, valleys are often topographic indications of extensive fracturing and jointing of the bedrock.

Yield of wells tapping the bedrock will be highly variable, ranging from less than 1 to as much as 100 gpm, depending upon the number, extent, and interconnection of fractures encountered.

Recharge

Each valley is essentially a self-sustaining hydrologic unit, although it has hydrologic continuity with the adjoining valleys. The larger valleys with their greater area consequently have a greater exposure to recharge from rainfall and consequently have a greater potential for ground-water yield than the smaller valleys.

Soil thickness and porosity, degree of rock weathering, slope of land surface, soil moisture, vegetal cover, and exposure are some of the factors affecting recharge to the ground-water reservoir.

Data from St. Thomas indicate that recharge to the bedrock may occur but once or twice a year from rains that exceed 2 to 3 inches in 24 hours. Lesser rains are dissipated by minor runoff and by the requirements of soil moisture and evaporation.

The alluvial deposits in the valleys, however, are rehcarged by any rain which results in storm runoff. Recharge occurs by rainfall on the surface of the alluvial deposits and also by infiltration of surface flow along the stream channels. Storm runoff in varying amounts can be expected to occur about 6 times in a year of average rainfall.

Information on the amount of recharge to the ground water in the islands is limited. Preliminary data indicate recharge to the bedrock is about 1 to 2 inches per year, while that to the alluvium is on the order of 5 inches per year. The bedrock aquifer, where overlain by alluvial deposits benefits from the more frequent recharge to the alluvium

Surface water

Flow in the streams of the Island is essentially confined to storm discharge following rains of 1 inch or more. Runoff is controlled to a large extent by the topographic and geologic features of the watershed. Watersheds with steeply sloping upper valleys and alluviated relatively flat lower valleys, common on Tortola, will yield 4 to 8 percent of the average annual rainfall of 53 inches as storm runoff. The runoff is derived principally from the steeply sloping part of the watershed. Most of the rain falling on the alluviated part of the watershed filters directly into the alluvium, with very little being contributed to storm runoff.

Figure 2 shows the rainfall-runoff relationship for Bonne Resolution Gut on St. Thomas. The curves in the figure indirectly show the effect of soil moisture upon runoff. In the lower curve major rains which satisfied, or nearly satisfied, soil moisture requirements occurred 12 days or less before the storm resulting in runoff. In the upper curve the antecedent storm occurred 25 days or more before the storm resulting in runoff. Rains of 1.0 to 1.75 inches are required to produce significant runoff (1 million gallons per square mile). Rainfall-runoff characteristics probably are similar for watersheds on Tortola.

Quality of water

The quality of the ground water probably is similar to that of ground water in St. Thomas. Ground water in the perennially fresh parts of the aquifer probably has a chloride content ranging from 200 to 600 ppm and a dissolved solids content of 1,000 to 1,500 ppm. Nitrates and fluoride probably are high, 8 to 15 ppm, and 0.6 to 1.2 ppm, respectively. Four analyses of ground water from St. Thomas, which are believed to be representative, are given in table 1.

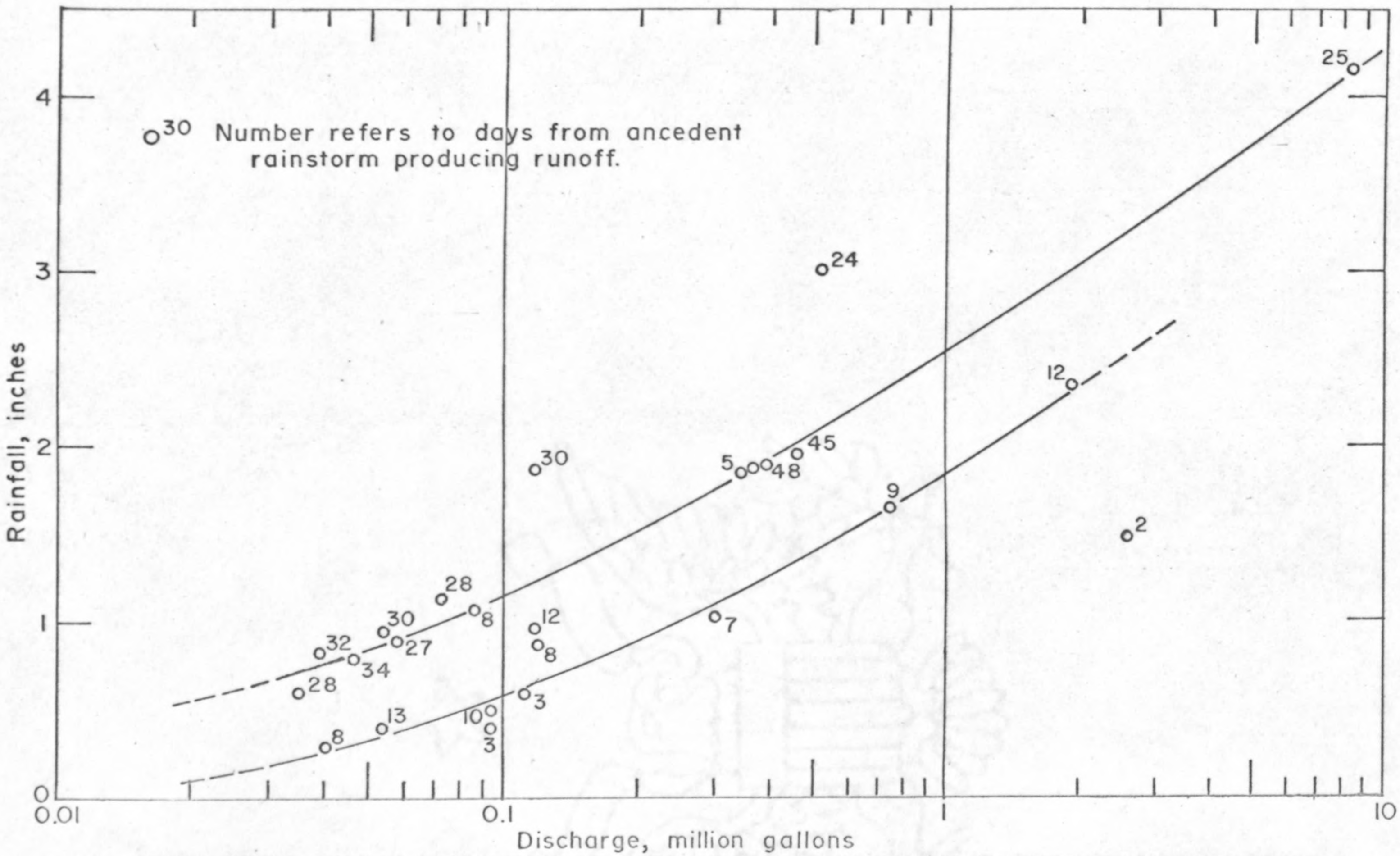

Figure 2.--Rainfall-storm runoff relationship of Bonne Resolution Gut, St. Thomas, from a watershed of 0.5 square miles.

Salt-water encroachment

On Tortola, where recharge to and subsequent discharge from an aquifer is limited, salt-water encroachment can occur readily in an aquifer. The fresh water discharged to the sea under natural conditions generally is sufficient to prevent salt water from moving into the aquifer (figure 3A). During periods when there may be no recharge to the aquifer for several months, ground-water discharge to the sea will practically cease and the interface between salt water and fresh water will move inland until equilibrium is reached (fig. 3B).

Pumping a well will depress the water table and cause a movement of water toward the well. Fresh water removed from a coastal aquifer will be replaced by fresh water from the landward side, salt water from the seaward side, and by brackish and salt water beneath the well (fig. 3C).

It is possible to prevent salt-water encroachment when a coastal aquifer is pumped by achieving a balance between the fresh water entering and being removed from the aquifer. This can be accomplished by careful monitoring of water quality and ground-water levels and controlled pumping from individual wells and the aquifer as a whole.

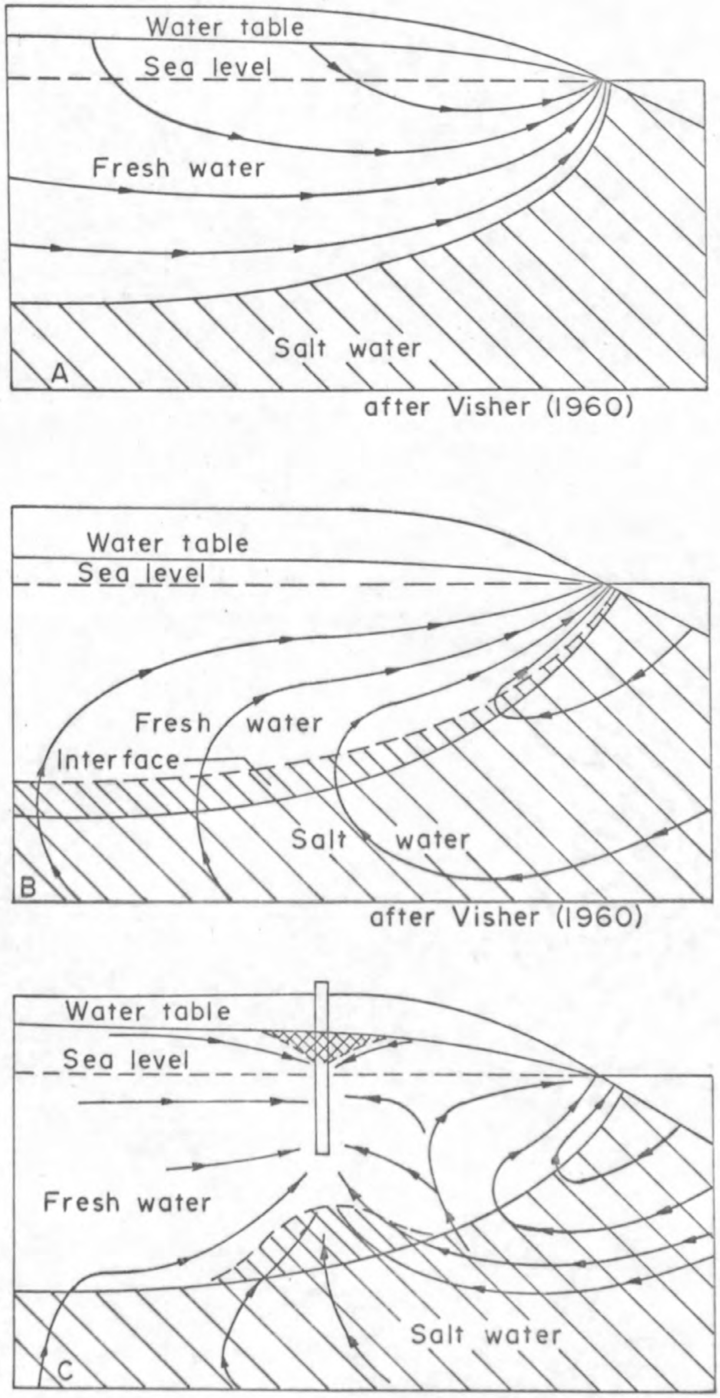

Figure 3.--Cross sections of an idealized coastal aquifer, show direction of flow. (Not to scale.) A) Steady state condition of constant uniform rate of fresh water recharge. B) No recharge, fresh water lens shrinking. Dashed line is new position of interface. C) Effect of controlled pumping, discharge not exceeding recharge. Upward movement of salt water in equilibrium with lowering of water table.

RECOMMENDATIONS

The development of water supply for the communities on Tortola should be gradual. The greatest ground-water potential in all areas lies in the alluvial parts of the valleys, where wells may tap sand and gravel zones in the alluvium and fractured zones in the bedrock. The alluviated parts of the valleys also have the greatest potential for both natural and artificial recharge which is necessary for the development of a water supply. The construction of reservoirs and retention structures in the streambeds in order to utilize more of the storm runoff for recharging the aquifers is recommended. Although not of immediate need for the development of water supplies, greater utilization of storm runoff will increase the yield of the aquifers.

The monitoring wells will be used to detect changes in water levels and quality of the ground water which may indicate salt water encroachment in those parts of the aquifers between the sea and the production areas. The data obtained from these wells will determine the quantity of water which can be safely produced from the aquifers. Water levels in the wells should be measured weekly to determine fluctuations in the ground-water table. Quality of water profiles of the chloride content of the water in the aquifer at each well should be made at least monthly by taking water samples at established depths with a thief type sampler. The depth intervals of sampling will depend upon the distribution of permeability in the aquifers as indicated by test drilling.

Roadtown area

Alluviated valleys adjacent to Road Bay have excellent potential for the development of ground-water supplies. These valleys are separated by bedrock ridges into three groups--Long Bush and Huntum Guts, Jackass and Purcell's Guts, and Belle View Gut (areas 1, 2, and 3, figure 1).

Long Bush and Huntum Guts

The lower valleys of Long Bush and Huntum Guts join to form a common alluvial fan with an area of about 90 acres (figures 4 and 5). The alluvium is a poorly sorted mixture of sediments ranging from clay to boulders as seen in exposures along Huntum Gut. Near the bay, the alluvium may be interfingered with beach sands and the remains of mangrove swamps. Beds of sand and gravel are most likely present where the alluvium is thickest. The topography indicates that the thickest alluvium, estimated to be 60 feet thick, lies generally along the stream courses.

Huntum Gut follows the trace of a major fault that strikes northwest across the Island. This fault is intersected by a fault, striking west-northwest, in the vicinity of the upper limit of the alluvial deposits. Minor faults are present in the vicinity of Long Bush Gut and the valley may follow the strike of several small faults.

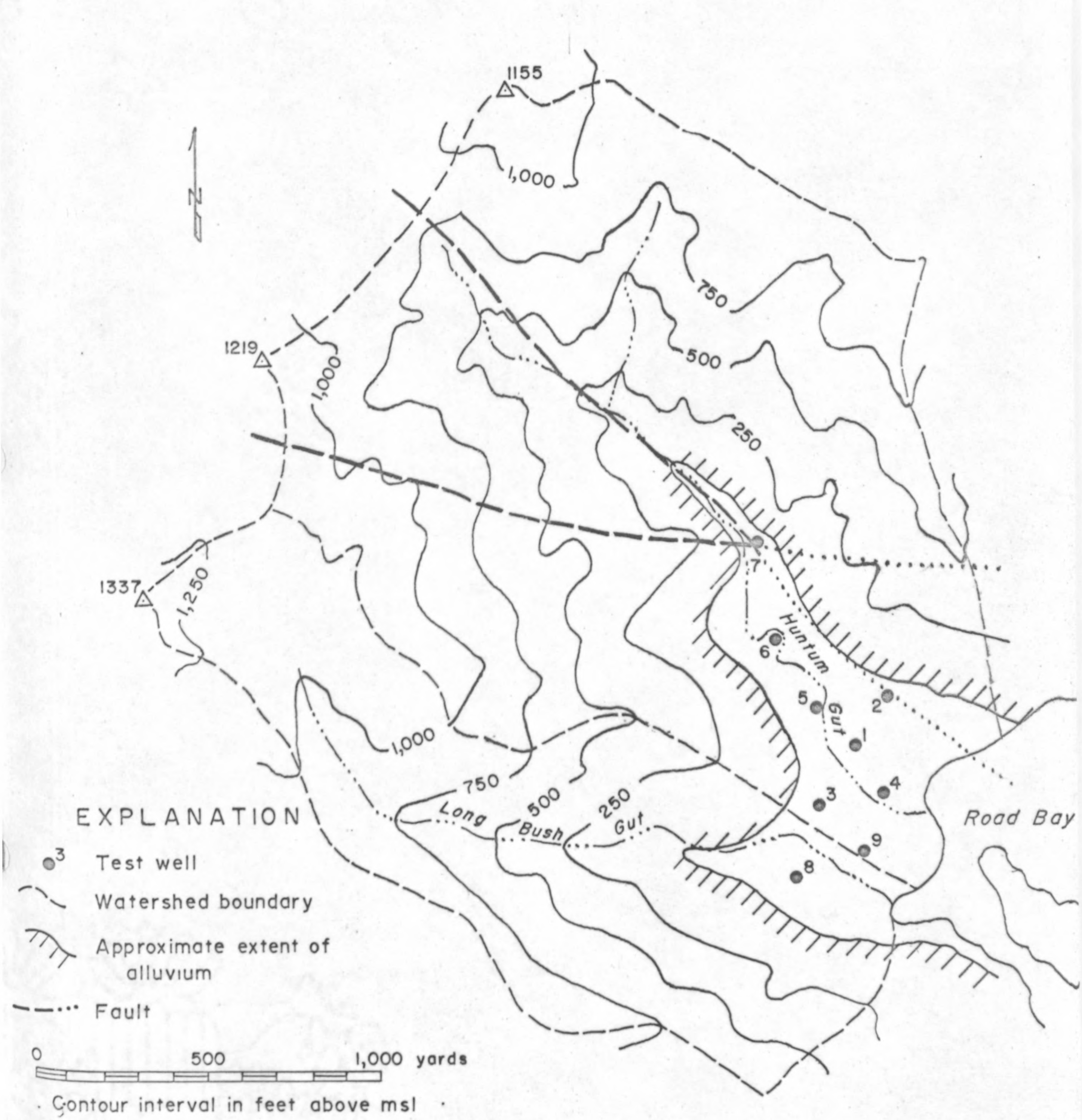

Figure 4.--Watershed and test well locations, Huntum and Long Bush Guts.

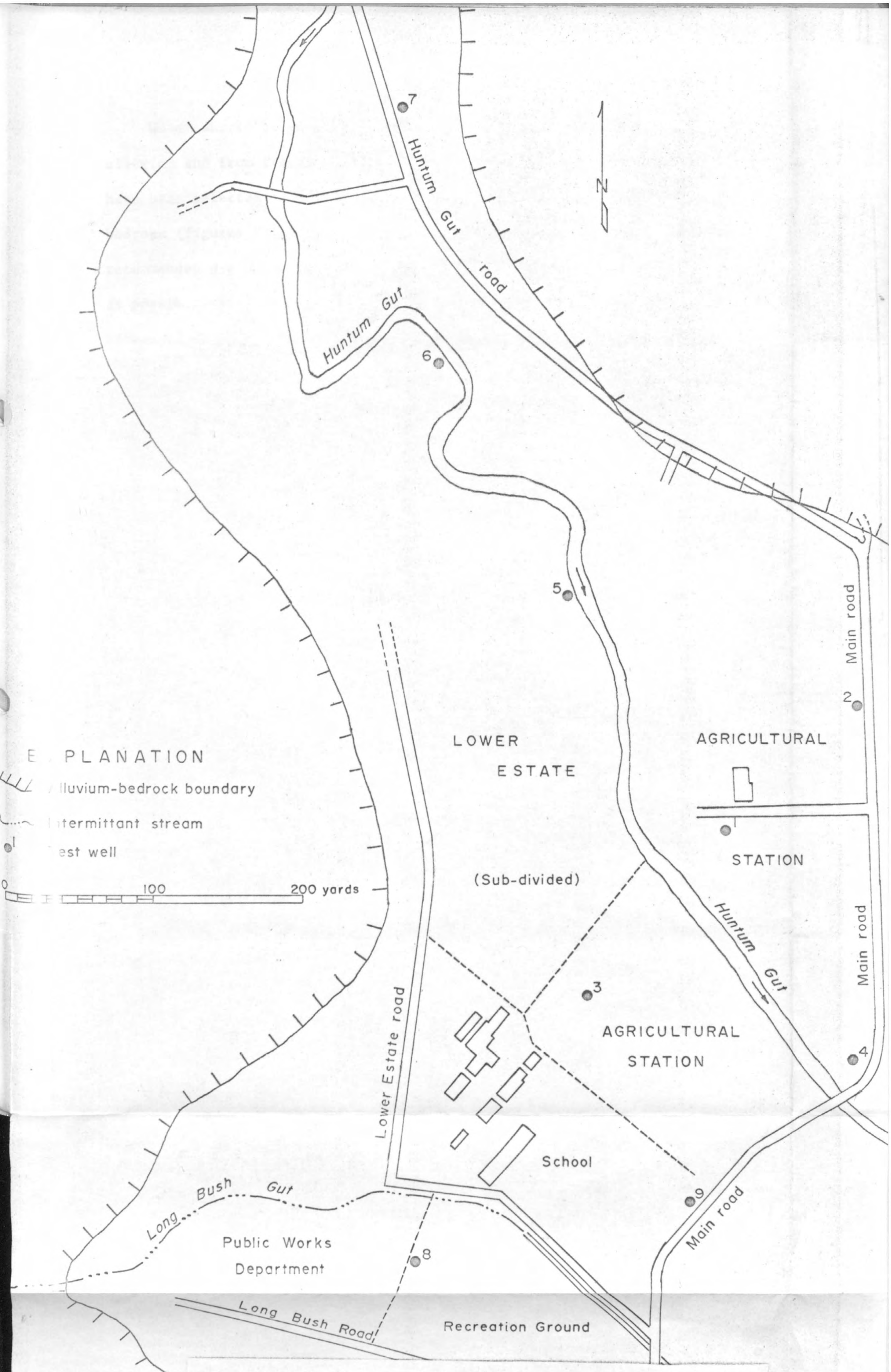

Figure 5.--Detail of lower Huntum and Long Bush Guts.

Water should be obtainable from sand and gravel zones in the alluvium and from fractured bedrock associated with faulting. Sites have been selected accordingly to test for water in both alluvium and bedrock (figures 4 and 5). The relatively large number of test wells recommended are to serve several purposes: 1) to explore as thoroughly as possible the ground-water potential of the area; 2) to spread the effect of pumping throughout the water-bearing units if the test wells are converted to production wells; 3) to use some wells as observation wells to monitor water levels and salt-water encroachment.

The test wells are numbered in the suggested order of drilling. Test wells 1, 3, 5, and 6 have the greatest potential for striking water-bearing sand and gravel zones in the alluvium. The estimated thickness of the alluvium ranges from about 40 feet in test well 6 to about 60 feet in test well 1. If no sand and gravel zones are encountered, the test wells should be drilled at least 80 feet into bedrock. Test well 2 is located near the projection of the major fault followed by Huntum Gut. Regardless of what zones may be present in the alluvium, this well should be drilled into the bedrock to a depth of 150 feet to test for fractured water-bearing rock associated with the fault. Test well 7 is approximately at the intersection of two major faults, and it offers an excellent possibility of being a very productive bedrock well. The well should be drilled to a minimum depth of 150 feet.

Sand and gravel zones may not occur in the alluvium at test well 8; it should be drilled at least 80 feet into bedrock. Test wells 4 and 9 are observation wells to be used solely for monitoring water levels and salt-water encroachment. These wells should be drilled into bedrock at least 60 feet.

Jackass and Purcell's Guts

The lower reaches of Jackass and Purcell's Guts flow across coalesced alluvial fans (figure 6). The deposits are similar to other alluvial deposits on Tortola being a poorly sorted mixture ranging in size from clay to boulders. The alluvium covers an area about half a mile long by a quarter of a mile wide and probably has a maximum thickness of 60 to 70 feet. Buried gravel-filled channel deposits may be present in the alluvium, especially in the vicinity of Purcell's Gut.

Two major faults cut the area. One trends north-south through the valley of Purcell's Gut and the other northeast-southwest, intersecting the first near the upper limits of the alluvial deposits.

Water should be obtainable from sand and gravel zones in the alluvium and from fractured zones associated with faulting in the bedrock. Ground water near the salt pond near Fort George probably is contaminated by salt water.

The test wells are numbered in the suggested order of drilling. Test well 1 is in a good position to tap a water-bearing sand and gravel zone and also to intersect fractured rock associated with the fault paralleling Purcell's Gut. This well should be drilled to a depth of at least 150 feet, whether or not water is obtained in the alluvium. Test well 2 is located at the approximate intersection of the two faults that cross the area. Twenty to thirty feet of alluvium may be penetrated in this well, but as the object is to test for fractured bedrock, the well should be drilled to a minimum of 150 feet.

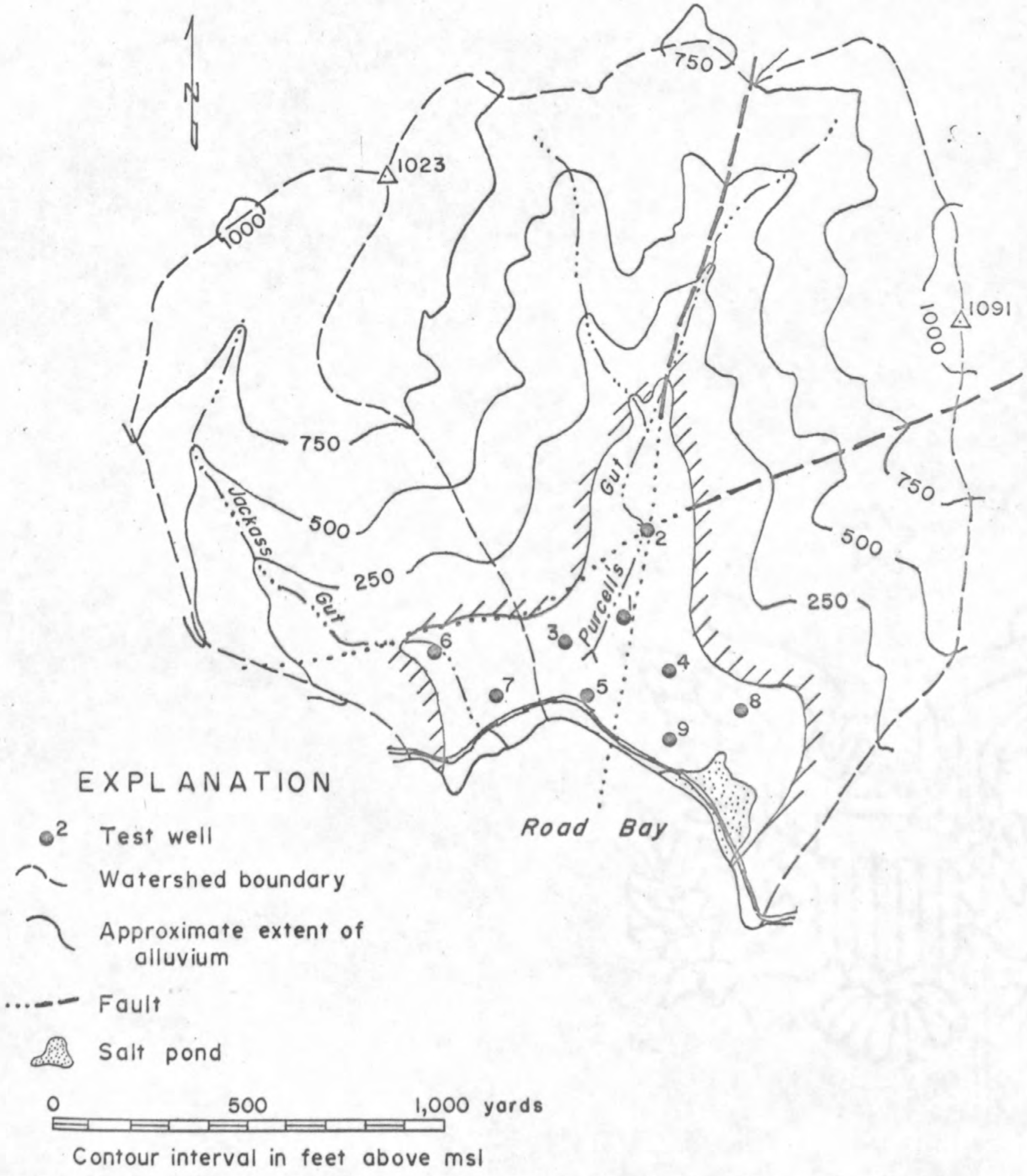

Figure 6.--Watershed and test well locations, Jackass and Purcell's Guts

Test wells 3, 4, 6, and 8 may encounter water-bearing sand and gravel zones in alluvium ranging from 30 to 50 feet in thickness. If no water-bearing sand and gravel zones are penetrated, the wells should be drilled about 80 feet into the bedrock. Test wells 5, 7, and 9 are observation wells to monitor water levels and salt-water encroachment and should be drilled into the bedrock at least 60 feet.

Belle View Gut

The lower reaches of Belle View Gut valley contain a well developed alluvial fan about 50 acres in extent (figure 7). The alluvial deposits are similar to those in the other valleys and should contain some sand and gravel zones. No known faults cut the valley, but some may exist. Water should be available in sand and gravel zones and, in limited amounts, from the bedrock.

Test wells are numbered in suggested drilling order. Test well 1, the only well intended to test the bedrock aquifer, should be drilled to 150 feet. It is located on the approximate center line of the valley and may tap water-bearing sand and gravel at a depth of about 30 feet. If the gut is eroded along the trace of a fault, the well may penetrate fractured rocks. Test wells 2 and 3 are an attempt to tap sand and gravel zones. These wells should be drilled through the alluvium and into the upper 10 feet of the bedrock. Test well 4 is an observation well for monitoring water levels and salt-water encroachment. Total depth of the well should be about 100 feet.

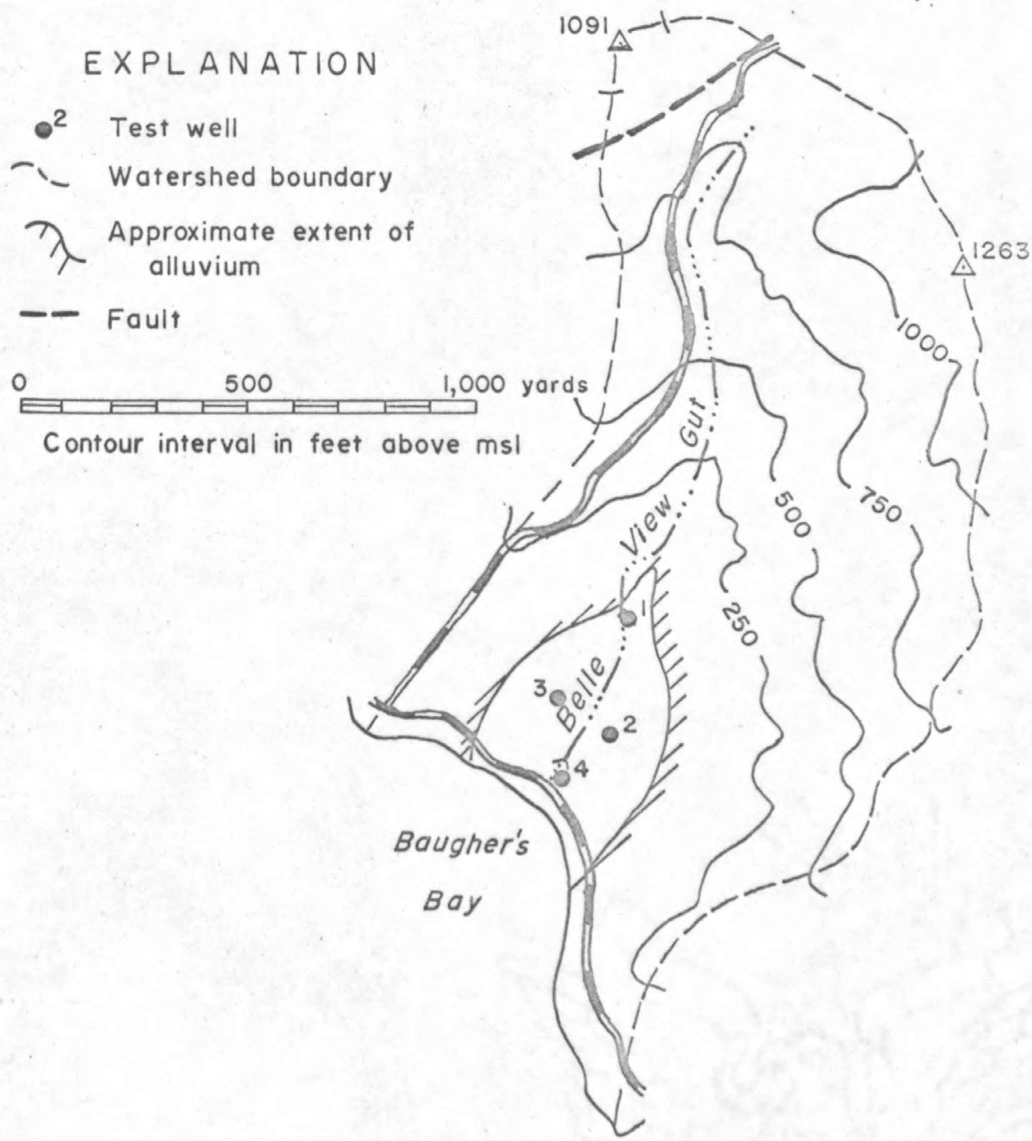

Figure 7.--Watershed and test well locations, Belle View Gut.

Long Look Area

Long Look

Sufficient local ground water may not be available to supply the present (1965) needs of the Long Look settlement.

An alluvial fan covers about 80 acres in the Long Look valley (figure 8). However, the valley lacks the watershed area necessary to supply large amounts of recharge to the aquifers. In addition, the southern half of the watershed, including about half of the alluvial fan is occupied by housing. Sanitation facilities generally are primitive and the ground water may be polluted.

The northern half of the watershed is underlain by well-jointed granitic rock; weathering may extend to depths of about 50 feet. Granitic rocks often are water-bearing where severe weathered has enlarged joints and created pore spaces between the crystalline grains of the rock. Where unweathered, these rocks will yield little or no water. The weathering residue from granitic rocks is generally coarse grained and alluvial deposits formed from such detritus are often quite permeable.

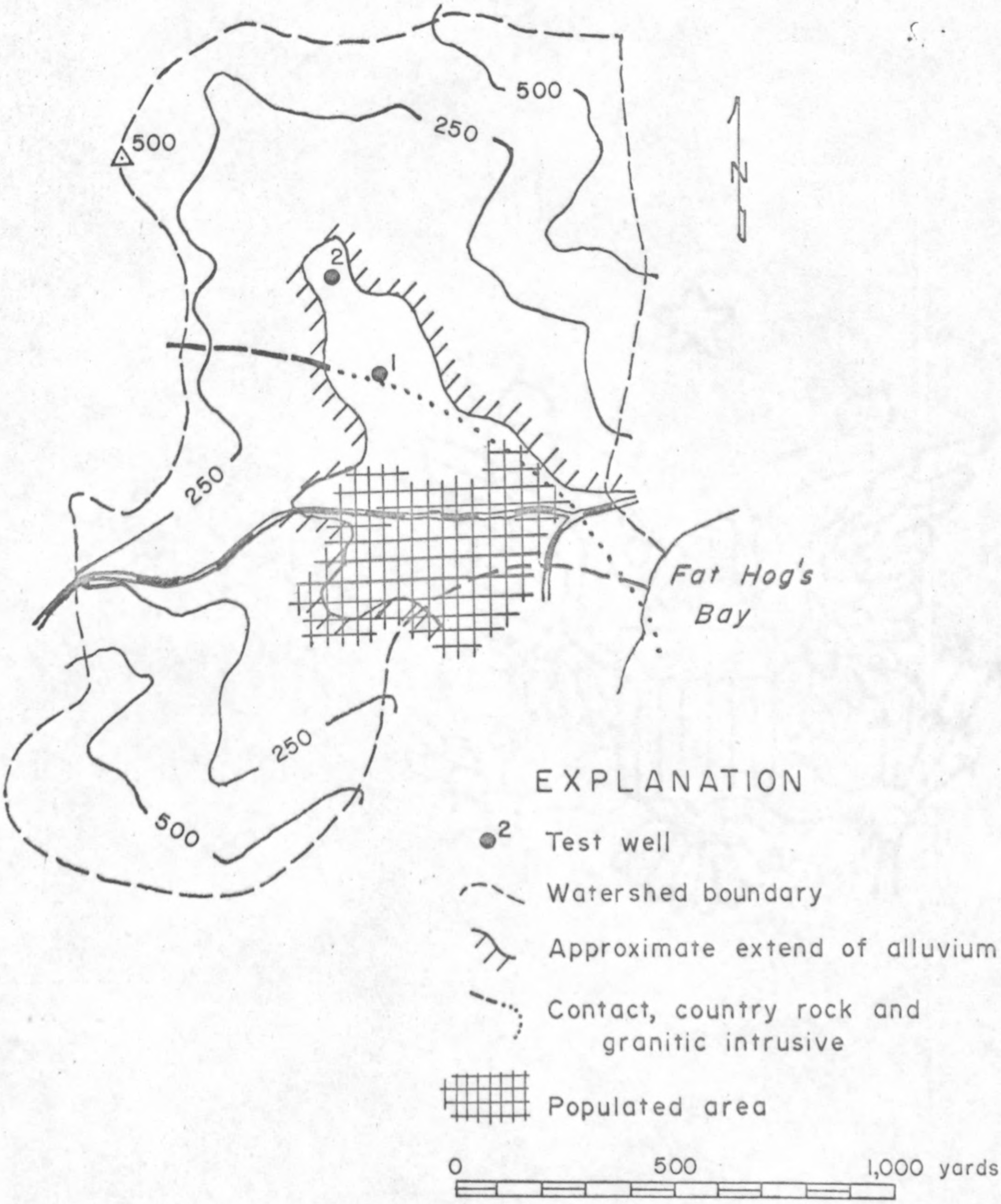

Figure 8.--Watershed and test well locations of the Long Look area.

Because of possible pollution, only about half of the watershed at Long Look is considered suitable for ground-water testing. Two test wells are located in the northern half of the valley. Test well 1 is approximately on the contact of the granitic intrusion and country rock. The intention is to drill the granitic rock where it is most apt to have the largest number of water-bearing joints and fractures. The well will also penetrate alluvium derived from the granitic rock. The depth of the well should be about 100 feet, penetrating about 30 feet of alluvium and 70 feet of weathered rock. However, the well should be drilled to whatever depth necessary to fully penetrate the weathered granitic rock. Test well 2 is principally to test a possible 50 to 80 feet of weathered granitic rock that may be overlain by up to 20 feet of alluvium.

Paraquita Bay

The Paraquita Bay valley is marked by a gently sloping alluvial flat a quarter of a mile in width and over half a mile in length (fig.
The extensive alluvium should contain water-bearing sand and gravel zones. Even if it does not, it forms an excellent recharge area for the underlying bedrock aquifer. No faults are known to occur in the valley, but faults may be hidden by alluvium.

Figure 9.--Watershed and test well locations Spring Gut, Paraquita Bay area.

The ground-water potential of this valley warrants extensive testing. Test wells 1, 2, and 3 should penetrate both the alluvium and the bedrock. The alluvium is expected to be about 60 feet thick at well 1, decreasing in thickness to about 30 feet at well 3. Well 1 should be drilled to a depth of 100 feet; well 2 to 125 feet; and well 3 to 150 feet. If only 5 gpm is obtained in well 2 at 125 feet, it should be continued to 175 feet.

Test wells 4 and 5 are monitoring wells and should be drilled to depths of 100 feet. Test wells 6 through 9 are principally for testing the alluvium. However, if no water-bearing sand or gravel is present, wells 6 and 7 should be drilled at least 75 feet into the bedrock, and wells 8 and 9 should be drilled 50 feet into the bedrock.

West End

VanterPool Gut

The only likely area where a dependable ground-water supply may be obtained for West End is the valley drained by VanterPool Gut (figure 10). Because of the possible presence of brackish water in the lower reaches of the valley, test wells should be located in the upper part of the valley. The alluvium is thin in this part and may not be water-bearing.

Two test wells are suggested, both to be drilled into the bedrock. Test well 1 probably will penetrate about 25 feet of alluvium. Total depth of the well should be about 125 feet. Test well 2 probably will penetrate but 5 to 10 feet of alluvium. Total depth of the well should be about 150 feet.

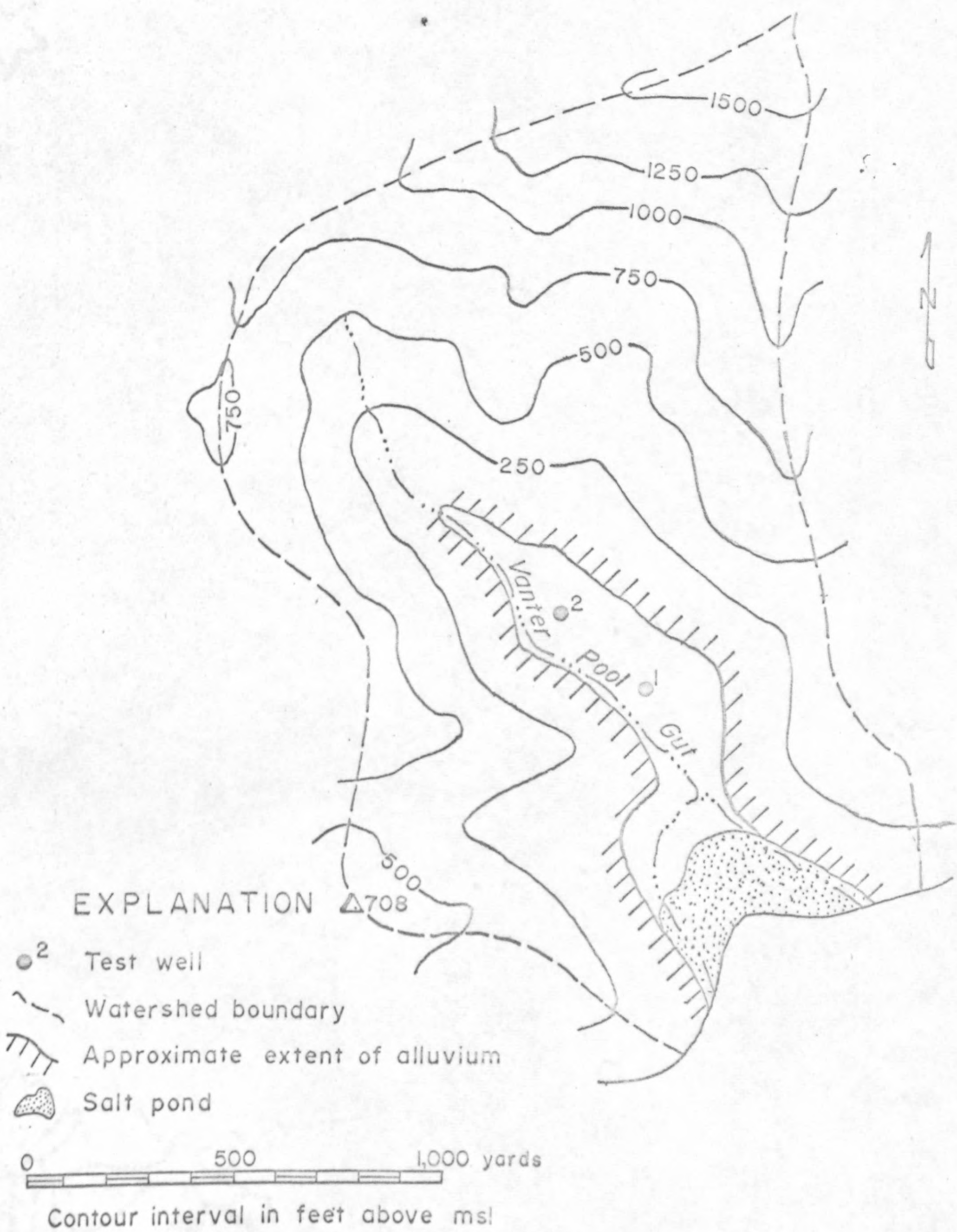

Figure 10.--Watershed and test well locations at VanterPool Gut.

CONCLUSIONS

The recommendations for test drilling are based upon data obtained on the source, occurrence, and movement of ground water in similar climatic, topographic, and geohydrologic conditions on St. Thomas, U.S. Virgin Islands. The difference in these conditions between St. Thomas and Tortola are not great and reasonable comparisons can be made.

Ground-water supplies can be developed in both the alluvium and the bedrock of the individual valleys, which are essentially independent hydrologic units. Nearly all of the more productive wells on St. Thomas obtain their water from the bedrock, but in most of these wells the bedrock is overlain by 20 to 50 feet of fine-grained alluvium. Available data indicate that the alluvium absorbs rain and storm runoff and then slowly releases it to the underlying bedrock.

In Tortola, the areas where the ground-water potential is greatest are small and scattered. Fortunately, several of the potentially more productive areas are near Roadtown, a major population center. However, depending upon sanitation facilities, the population concentration can be a source of pollution to the ground-water supplies.

The potential yield of the aquifers is based on the assumption that approximately 1.5 inches of the rainfall on a watershed can be recovered by wells drilled in the alluvium and bedrock of the valleys. Annual rainfall is less in the eastern and western ends of the Island. As a result, potential yield from these areas is estimated to be about one inch of rainfall on the watershed. Since each valley is essentially an independent hydrologic unit, the potential yield of a valley is to some extent in direct proportion to its area.

Listed below are estimates of the potential yield for the areas in which test drilling is recommended.

Area	Yield, gpd (U.S.)
Long Bush and Huntum Guts	90,000
Jackass and Purcell's Guts	70,000
Belle View Gut	35,000
Long Look	5,000
Paraquita Bay	50,000
VanterPool Gut 1/	8,000

1/ Recharge is assumed to be about one-half inch.

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Table 1.--Analyses of representative ground water, St. Thomas, U.S. Virgin Islands.

Well 1 is in alluvium periodically recharged by streamflow and runoff; well 2 is in bedrock overlain by about 40 feet of fine-grained alluvium which serves as a source of recharge; wells 3 and 4 are in bedrock overlain by a thin soil cover through which recharge is directly to the bedrock.

CHEMICAL ANALYSES

Number of well	Depth of well (feet)	Date of collection	Parts per million											Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH	Temperature °F
			Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Calcium, magnesium	Non-carbonate			
1			20	0.00	48	39	355	798	37	255	0.4	0.0	1,080	280	0	1,870	7.8	80
2			40	.02	82	78	314	640	53	385	.6	10	1,440	525	0	2,360	7.8	--
3			23	.00	48	45	464	726	90	432	1.2	17	1,440	305	0	2,490	8.0	--
4			43	.00	58	46	244	698	26	180	1.0	10	965	334	0	1,650	7.9	--