3-3 Groundwater Development Plans

1) Present conditions and problems on groundwater intake

(1) Methods to obtain domestic water in the project areas

The project areas are not served by a central water supply system, and people obtain water for domestic uses by the following means.

a. To obtain groundwater from hand-dug wells with the depth 15 m or less.

b. To obtain good quality water from creaks at some remote points from villages.

c. To collect rain water by roof catchment systems

(2) Problems of currently used water sources

The water sources listed above have at present same problems as listed below, and improved means are desirable for more stable supply.

a. Shallow aquifers, surface water and rain water are all directly affected by rainfalls. In particular, shallow wells often dry up during dry seasons.

b. As development proceeds toward hinterlands, small rivers tend to be exposed to pollution. Also these rivers become muddy, and often unfit for use in cases of heavy rainfalls.

c. Shallow wells near the shoreline face salt water intrusion problems during dry seasons.

(3) Urgent countermeasures

When it becomes difficult to take water from hand-dug wells or roof-catchment systems during a dry year or a dry season, peple receive emergency supply of water by water tanks from Labasa water works. In the Vunika area, a simple storage tank made of steel panels is set up on a road near the village, considering negative effects of salt water.

These supply measures for emergency cases are primarily for areas around Labasa, and in the case of extended drought, many communities suffer from inconvenience.

2) Rural water works development plans in the Vanua Leve island

(1) Procedure for development planning

The rural water works development plans are under way based on each community and groundwater as sources, in view of the facts that communities are widely dispersed and that the local ground water can be used as relatively stable supply sources.

The Public Works Department (PWD) is undertaking local water works improvement in cooperation with Mineral Reserves Department (MRD). More specifically Water and Sewerge section of PWD and Mapping and Hydrogeology section of MRD are in charge.

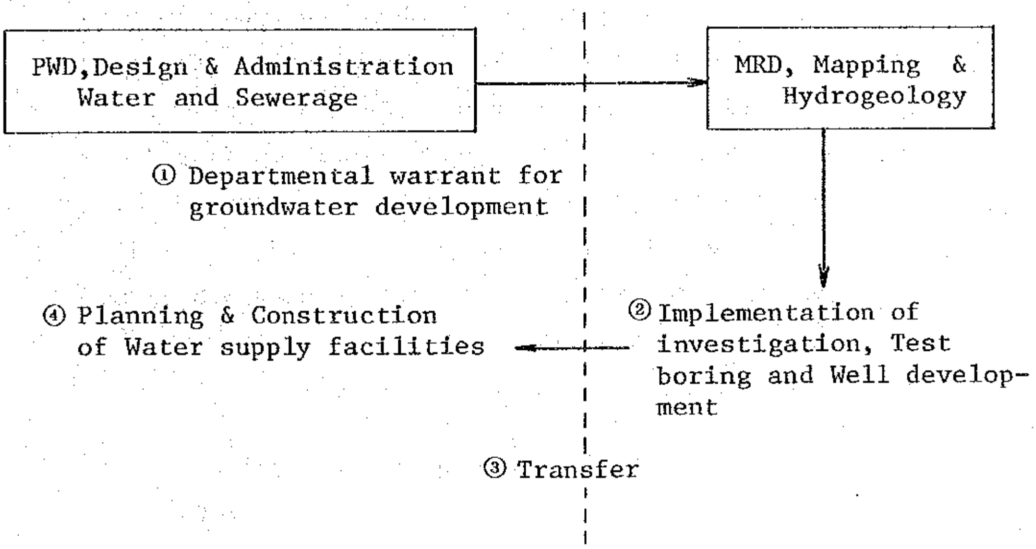
After project areas for rural water works improvement are selected, PWD entrusts MRD with construction of production well for intaking groundwater. MRD in their turn determines sites for exploratory wells, after existing data on local hydrogeology at the areas are analyzed, field survey is conducted base on it and the results are comprehensively evaluated as to areas of high potential for groundwater, existing comunities, accesses and other factors. If exploratory wells are found feasible in terme of both quantity and qualify of water, they will be completed for production well and delivered to PWD.

If it is judged that the well diameter needs to be enlarged, necessary works will be done delivery.

After the completion of production wells, PWD determines the service area corresponding to the total water quantity available and draft a facility plan to be allowed by construction.

The procedure for the rural water works development planning is illustrated by the following figure.

<Rural Water Supply Development>



(2) Potential sites for development

To improve living conditions by securing more stable and reliable water sources in the Vanua Levu Island, Ministry of Works instructed to investigate methods for utilizing surface water. Unfortunately the results of the investigation indicate that it will induce a large amount of investment, since water sources of good quality are located at remote places from areas of uses, also, to intake water near the demand areas require expensive water treatment facilities such as sedimentation, filtration and others.
Therefore, PWD entrusted MRD with making a list of high priority areas for rural water works improvement and also with investigations for feasibility of groundwater development.

The investigation was carried out by A. Rahiman and A.S. P. Green who visited Vanua Levu between the 17th and 27th of October, 1979. The results were reported in "Preliminary Investigation of the Groundwater Resources around Labasa, Seaqaqa and Vunivau in Bua".

This report designates as priority areas the settlements of Vunicuicui, Vunimoli, Waidamudamu and Nabekavu located in sugar cane farm areas adjacent to the southern part of the Labasa water works serving district, south of the town of Labasa, the settlement of Vunika east of Labasa, the settlement of Seaqaqa located in a large-scale sugar cane farm development area about 30 km west of Labasa, and the Vunivau Bua area at the western end of the Vanua Levu island.
The report describes results of investigation for the groundwater resources in each area and concludes that there exist a good possibility for groundwater reserves in these areas. The report also specifies potential sites for water intake and reservoirs for all the areas except Seaqaqa. These areas for possible water works development are listed below.

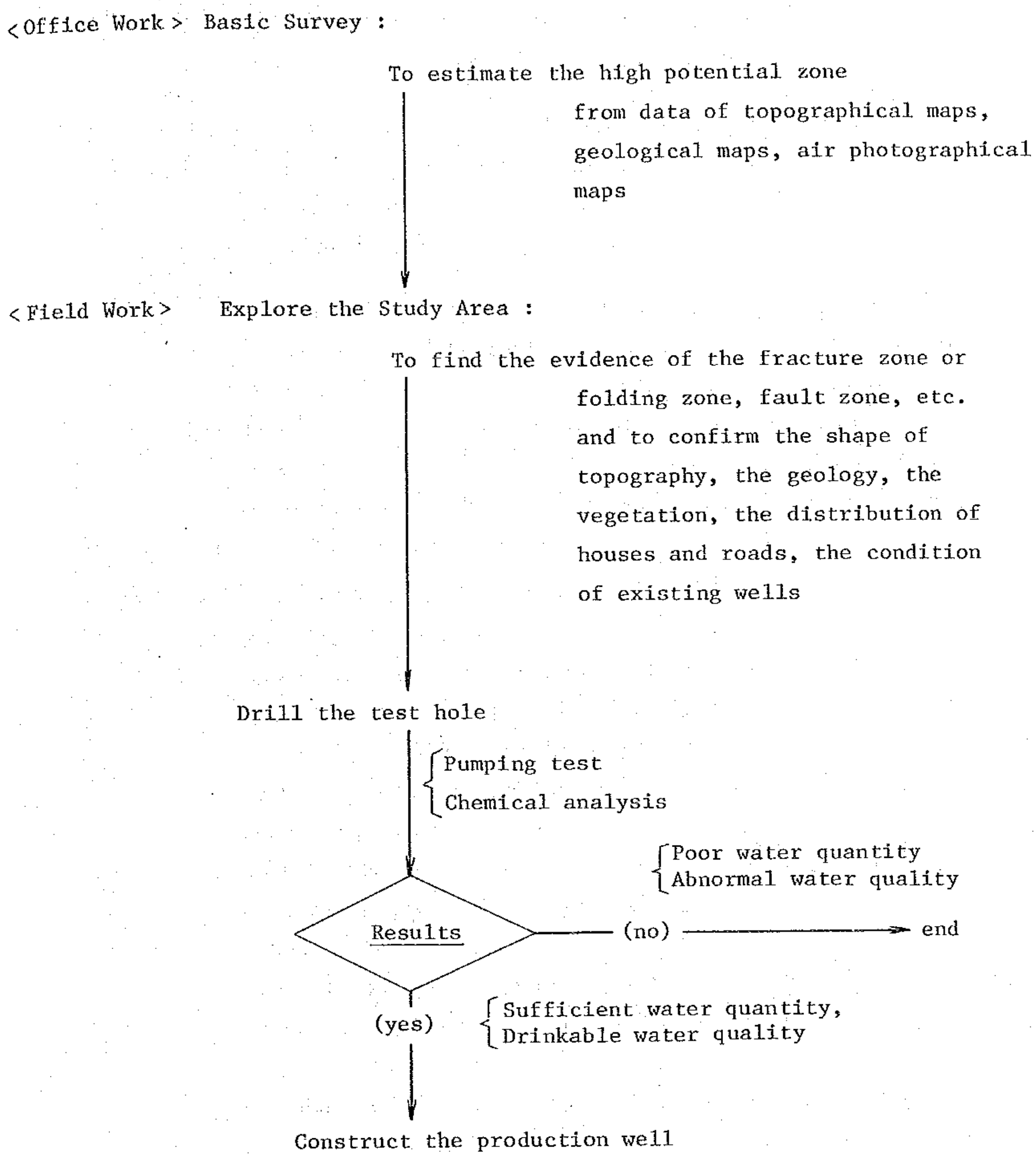
Vunicuicui	Settlement
Vunika	"
Vunimoli	"
Waidamudamu	"
Nabekavu	"
Vunivau Bua	"
Seaqaqa	"

Note: No mention is made in the 1980 report of specific plans for village water works projects.

(3) Methods of groundwater development by MRD

Persons at MRD in charge of groundwater development make inference on fractured zones around faults and weak zones created by foldings, using air photos and topography maps in addition to geological maps of the areas in 1 to 50,000 scale and other references. A field survey is conducted after these works. Faults and foldings are confirmed by observations of geological structure, topographic characteristics, vegetation and exposed water crops and judgement on the existence of weak zones. On the other hand, population distribution, other social condition including existing road networks, and water quality of existing wells are investigated. The final decision of the site of exploratory boring is done on the basis of hydrogeological conditions, water supply conditions and water quality conditions.

The cased hole method has been adopted for exploratory boring. This is a method by which the barry proceeds with insertion of a casing material to prevent collapsing of geological strata. After boring is completed, promising location of aquifer is supposed by the data of drilling log and a position for a tentative strainer is determined. At this time, results of minar pumping tests conducted with bailers during the drilling operation are of course used, too. After setting up the temporary casing with a strainer inside the casing, the exterior pipe is pulled out to predetermined position. Then the well is completed by air-lift and pumping tests and water quality analyses are made. If the results turn out to be favorable, the exterior casing is pulled out, and the space between the bare outer wall and the interior casing is filled with gravels from a predetermined depth up to the surface and the part about the ground surface is filled with cement. Finally the well casing is covered up. If the test results are unfavorable, the casing is completely pulled up, and the drilled hole is filled up.


<Office Work> Basic Survey :
To estimate the high potential zone from data of topographical maps, geological maps, air photographical maps
<Field Work> Explore the Study Area :
To find the evidence of the fracture zone or folding zone, fault zone, etc. and to confirm the shape of topography, the geology, the vegetation, the distribution of houses and roads, the condition of existing wells
Drill the test hole
Pumping test
Chemical analysis
Poor water quantity
Abnormal water quality
Results
(no)
end
(yes)
Sufficient water quantity,
Drinkable water quality
Construct the production well

With the method outlined above, production wells are completed. The steps of the method are illustrated above.

There is no absolute standard for the amount of water required for each well to be satisfactory as a supply source. It is only judged by whether the well can serve the population of a particular project area.

Fiji does not have its own water quality standards, but follows the WHO standards. However, in the case of rural water works, that are to be operated and maintained by local inhabitants themselves, usually only those wells that yield water of such a good quality that it can be served without any specifical treatment or even without chlorination are considered suitable for practical use.

(4) Progress of groundwater development

a. Existing deep wells

There are fourteen existing deep wells on the Vanua levu island (Refer to Figure 2-5 and Table 2-3). The first one was sunk in 1970. A main purpose of well development during 1970 - 1972 was to perform exploratory boring and to construct supplementary sources for the Labasa water work. Those wells with high specifc yield, as estimated by exploratory boring, were used as water sources for schools, settlements and others with installation of pumps (Examples are wells with No. 5, 7, 8, 9 and 10). These wells, however, were neglected after the pumps failed except the No.10 well which is still in use. No. 10 well was dug in 1972 and equiped with a hand pump. This well also had been neglected following a break-down of the pump until 1978, when a new headmaster of the school determined to revitalize it. This well is currently supply 2000 gallons per day of water while the school is in session. This well is the best of all the well developed in the Vanua Levu island by MRD and considered capable of supplying the water required by the Vunicuicui settlement all by itself, according to the 1980 report

by A Green and A Rahiman. Carr (1974) estimated that 5,600 gallon the water can be pumped up at the rate per hour.

The No. 6 well was abandoned and buried as a results of performance in pumping tests. Other wells numbered 1, 2 3 and 4 are collapsed and not used at present.

The groundwater development reinitiated in 1980 is ran under way at the sites of potential sources within the project areas as planned in the groundwater development report on rural water works improvement projects mentioned in subsection 3-3-2)-(2). As of today, four wells have been completed in the Vunivau Bua area, and drilling is going on in the Seaqaqa area. The No.13 well in Vunivau Bua can not be used due to inflow into the casing of cement during the finishing stage of the well.

b. Number of deep wells expected to be developed

Number of wells to be developed in the Seaqaqa area has not been determined, but for other areas the following has been planned.

Number of wells expected to be developed

Vunicuicui	3 wells
Waidamudamu, Vunimoli	2 wells
Nabekavu	3 wells
Vunika	2 wells
Seaqaqa	not specified

* Source: A Green and A. Rahiman (1980)

Table 3-1 Water Quality Data for Deep Well

		Vunicuicui VAN 6/7				Vunivau Bua						Vunivau Bua		Vunimoli-Village	Vunicuicui VAN 6/7	Nakama
						CDH/W/80/22		CDH/W/80/23		DH/W/80/24		CDH/W/80 123	CDH/W/80 142			
	WHO Water quality requirement	(27/3/72) Well depth 175 ft.	(18/4/72) after 4 hr. pumping	(19/4/72) after 20 hr. pumping	(19/10/79)	(1/5/80)	(22/5/80)	(7/7/80)	(8/7/80)	(9/8/80) before pump closed	(2/9/80) after second development	(16/10/80)	(16/10/80) before casing	Surface Water (17/10/80)	(17/10/80)	Hot Spring (18/10/80)
Ca (p.p.m)	75 (200)	1	20	20	14	5.5	5.2					5.9	5.5	25	32	154
Mg (p.p.m)	50 (150)	2	4	4	0.25	0.73	0.88					0.84	1.3	2.9	8.4	0.01
Na (p.p.m)	-	5	13	14	10	9.8	9.1					12	8	6	16	175
K (p.p.m)	-	< 1	1	1	1.5	1.2	1.5					2.4	0.7	0.6	1.8	4.2
Mn (p.p.m)	0.1 (0.5)	< 0.01	< 0.01	< 0.01	< 0.02	<0.02	<0.02	<0.04	<0.08	0.54	0.38	<0.02	0.66	<0.02	<0.02	<0.02
Fe (p.p.m)	0.3 (1.0)	0.07	< 0.02	< 0.02	< 0.3	0.04	0.8	0.4	0.24	12	14	<0.02	8.7	<0.02	<0.02	<0.02
HCO_3 (p.p.m)	-	10	88	107	89	40	68					44	17	54	146	15
CO_3 (p.p.m)												nil	nil	nil	nil	9.6
SO_4 (p.p.m)	200 (400)	2	0	0	3	<2	2.7					< 2	< 2	< 2	< 2	504
Cℓ (p.p.m)	200 (400)	9	8	8	6.3	3.6	6.3	4.9	4.9	5.4	74	4.4	4.9	4.9	6.9	7.4
NO_3 (p.p.m)	40 (80)				0.06							nil	nil	nil	0.54	
as $CaCo_3$ Total Hardness(p.p.m)	100 (500)	11	66	66	36	17	17					18	19	74	83	385
Total Solids (p.p.m)	-	49	124	164	118	103	118					120	50	72	172	1,010
Conductivity(micromho/cm)	-				175							(93)*	(59)*	(98)*	(258)*	(1,250)*
pH	7.0 - 8.5 (6.5 - 9.2)	5.5	7.0	7.0	6.25		7.10					(6.8)* 7.2	(6.4)* 6.55	(8.0)* 7.5	(7.1)* 7.2	(8.4)* 8.35

( )* analyzed directly at sampling site.

c. Quantity and quality of water to be pumped up

It has been confirmed from the results of pumping tests for existing wells for eleven wells except No. 6, 7 and 13 wells, water can be pumped up at the rate of 100 to 600 m^3 per day, with draw-down of groundwater level being 5 to 17 m.
The wells of No. 6, 7 and 13 are considered unfit for practical uses, since the water level drops to the bottom of each well during pumping.

As seen from the results in Table 3-1 of water quality analysis, high concentration of iron is observed in the water from No. 13 and 14 wells. The values are 12 - 14 ppm for the No. 13 well and 8.7 ppm for No. 14.

(5) Problems associated with groundwater development

a. Lack of drilling equipments

MRD presently owns seven drilling rigs as listed in Table 3-2. Four of these are Churn Drill or Universal type and capable of drilling production wells. Others are used only for exploration of mineralized zones.
Of all the drilling rigs for groundwater development one is being checked up, and two rigs are devoted to the rural water works imprevement projects in Vanua Levu.

Table 3-2 Drilling Rigs in Operation

No.	Type	Machines	Capacity	Diameter	Got Year	Remarks
1	Churn Drills	Bourne	500'	6",8",10"	1978	available for constructing of productive well
2		Hydromaster	400'	6",8"	1968	ditto
3		Hydromaster	1,500'	6",8"	1970	ditto (under over hole)
4	Universal	Auger	225'	6"	1972	ditto
		Auger	100'	8"		
		Down hole hammer	300'	6"		
5	Diamond Drills	10L	1,500'	3"	1965	
6		F52A	1,500'	3"	1968	
7		Portable Minor	1,500'	2"		

Labor efficiency of well development in Vanua Levu is indicated by Table 3-3. As shown in the Table, No. 11 well in Vunivau Bua took 41 day from April 24, through June 4, 1980 for completion with the finished well diameter of 150mm and the depth of 46.34m; the efficiency corresponding to 1.13m per day.
Similarly, the efficiency for No. 12 well is 1.43m/day, 1.24 m/day and 1.04m/day respectively for No. 13 and No. 14 wells.

Table 3-3 Labor efficiency of well completion

No.	Construction stand on	Construction finished on	Finished Well diameter ϕ mm	Well depth D m	Days required Day	Labor efficiency m/Day
11	80.4.24	80.6. 4	150	46.34	41	1.13
12	80.6. 9	80.7.10	150	45.73	32	1.43
13	80.7.16	80.9. 3	150	60.98	49	1.24
14	80.9.11	80.10.30	150	51.83	50	1.04

Number of deep wells to be developed for use as water supply sources on the Vanua Levu island in the future will amount to 20 to 30 in total including the ten wells for which their sites have been already determined and others in the Seaqaqa area and villages.

Suppose 20 wells will be developed hereafter then almost two years will be required if one drilling rig is to be used. Addition of another drilling rig is desirable for more prompt implementation of the rual water works improvement projects to procure sufficient quantity of water.

b. Lack of technical experts

It is recommended that experts who can take charge of facility planning for water supply systems and specialists on hydrogeology who can select potential sites for water sources be educated and trained as well as technical experts who can operate boring equipments

c. Necessity to investigate techniques for well development

Areas under groundwater development at present are situated at the foot of volcanoes, and no geophysical exploration such as electric prospecting has been undertaken.

Reasons for this include the following. First quantity of water expected is not large; second resistivity data obtained by electrical prospecting can not be easily compared with geology of corresponding areas due to lack of data on geological columnar section. In the future, considerable well logging data can be collected from explorating (or production) wells being developed by the rural water supply development projects.
These data (geological columnar section) can be compared with values of resistivity to determine eventually the resistivity specific to each geologica structure of the Vanua Levu island. This information in turn will serve for determining potential sites for groundwater resources.

Well drilling proceeds with pushing in a protective tube against collapsing, and after a strainer is set up inside the protective casing, the tube is pulled out and gravels are filled into the space. The location of the strainer is determined based on records on boring taken on the site and boring logs, but no well logging - typically electric prospecting - has been undertaken. Well logging would enable to make more objective judgements on location of good aquifers without being affected by arbitrary judgements.

When the groundwater in fractured zones of rocks (what is called fissure water) is investigated, caliper measurements method are suitable, which is based on the fact that the diameter of drilled hole is enlarged when the hole reaches the fractured zones. To identify unsolidified coarse sand or clay layers such as clastic rocks in sedimentary layer, electric logging which is based on the difference in resistivity is effective, and the self-potential (SP) method and electric conductivity logging can be used to catch salt intrusion in coastal areas, or temperature logging are useful for identifying hot springs and other phenomena.

Thus by using these methods, the most favorable positions of aquifer in the drilling site can be identified, and casing programs can be formulated in such a way to set up strainers in the best positions and finish the wells in a most effective way.

Strainers used for wells in Vunivau Bua are polyvinyl chloride pipes of 150mm diameter processed for slits, but this type is unfavorable in terms of strength and drainage efficiency due to uneven opening and opening ratios. Strainer processing should be standardized hereafter.

For pumping tests, air-lift pumps presently used for well development are diverted to conduct successive and recovery tests. This type of pumps is not easily adoptable to changing pumping rates and thus makes it difficult to find out the most economical pumping rate of wells. It is desirable therefore that submersible pumps with electric generator be provided to carry out pumping tests, and results of stepwise pumping should be used to make judgements on the capacity of a particular well and to determine the most appropriate pumping rate to be used thereafter. Use of the appropriate pumping rate would make it possible to utilize the well for a

long period of time by preventing drawdown of groundwater level coused by increasing well losses due to clogging.

Methods adopted at present for groundwater development are generally appropriate, but they can be further improved if more data are accumulated. For this purpose, it is not sufficient to dig wells but every effort should be made to organize data obtained during well drilling and those data should be compared with results of electric logging and pumping tests to be introduced in the future in order to fully understand the hydrogeological conditions of each geological section in all areas. This will facilitiate the groundwater development, and if, in addition, a monitoring system is introduces, management of aquifers will become possible to prevent various problems which may accompany the groundwater development.

3) Hydrogeology of the project areas

Potential sites for water sources have been determined by the method described in subsection 2-3-2). Drilling has been completed in Vunivau Bua area with sufficient quantity of water yield.

In this subsection, hydrogeological conditions of the potential sites for water sources primarily in settlements including Vunivau Bua are summarized based on available reference materials and data on deep wells.

The project areas are grouped as follows according to geological classification.

Natewa Group : Vunicuicui,Vunimoli,Waidamudamu
Nabekavu, Seaqaqa(settlements)
Namoli,Korowiri,Vunimoli (villages)
Valebasoga (school)

Undu Group : Vunika (settlement)
Matai Labasa, Vuo (villages)
Thonggeloa (school)

Mbua Group : Vunivau Bua (settlement)
Lekutu Junior, Lekutu Bhartiya (schools)

* Underlined settlement and schools already have deep wells.

Hydrogeological conditions of each area are described below

(1) Water sources for settlements

a. Vunicuicui

The principal geological structure constituting this area is Wailebu Formation of Natewa Group, and its surface is covered with alluvial layers. Shallow hand-dug wells are set up in these alluvia. Of these wells, those with four to five meter depth in the upstream of Vunavuna creek are superior and not affected by meteorological conditions.
The thickness of the alluvial layers is considered less than 10 meters, Wailebu Formation under these layers presumably consists primarily mud stones, sand stones, greywackes and grits, and aquifers may exist in coarse unsolidified layes of grits, sand stones and greywackes.

There exists a deep well developed in March 1972 in the site of Vunicuicui India Primary school in the Vunicuicui area. Specific data during pumping tests are as follows (refer to Table 2-3).

Depth	57.91m
Length of Strainer	19.20m
Natural water level	3.00m
Pumped water level	7.88m
Pumping rate	363.6 m^3/day
Specific capacity	74.47 m^3/day/m
Transmissivity	94.2 m^2/day

Only the upper portion is provided with casing and the lower part is left as a bare hole.
A hand pump was installed after drilling, but the well had been neglected until 1978 after the pump broke down. A new headmaster of the school installed a small pump to provide 2,000 gallons water to be used at school every day during school terms. Carr (1974) estimated that water can be pumped up at the rate up to 5,600 gallons per hour. A Green and A Rahiman (1980) conducted that this well is capable of providing water for the entire settlment of Vunicuicui.

In accordance with the above, A, Green and A Rahiman, in their report (1980), recommended three wells as water sources, but if a new well is drilled near the existing well at Vunicuicui India Primary school, this will enable to pump up 200 to 300 m^3 water per day.

b. Vunimoli, Waidamudamu

The Vunimoli area has the same geological structure as the Vunicuicui area.
Waidamudamu lacks alluvial layers and Wailebu Formation of Natewa Group, the principal geological structure of the Vunicuicui and Vunimoli areas, is

exposed on the surface. This implies that about 200 to 300 m^3 water can be expected per day from single well. A Green and A Rahiman (1980) specified two locations for water sources considering distribution of communities.

c. Nabekavu

The Nabekavu area also consists of Wailebu Formation, and three sites have been selected by a Green and A Rahiman (1980) as potential water sources.

Of these, one located near the Labasa Airfield is geologically slightly different from those described before, being primarily covered with sedimentation of re-worked andestic breccia with possible aquifers in coarse unsolidified or fractured zones existing in its rock matrices. Within this same geological strata, two deep wells corresponding to No. 4 Nakama and No. 2 Nanduna Savenakai in Table 2-3 have already been developed. The Nakama well was dunk to 64.62m depth and the natural water level at 5.18m (b.g.l) and a pumping rate at 180.1 m^3/day have been recorded. The well, however, underwent collapsing after pumping tests and is not in use at present. It is judged that water can be taken from this geological strata at about 100 m^3/day.

d. Vunika

This is the area consisting of Malau Breccias of Undu Group. Malau Breccias consist of pumiceous epiclastic breccias containing acid and intermediate clasts.

They are found in the form of massive rocks dipped in some place toward north.

Shallow and dug wells in the Vunika area face problems of salt water intrusion and water exhaustion during dry seasons. Therefore as water sources, these areas should be selected, which are situated a far from the coastline as possible and have high potential for groundwater recharge with wide watershed area. A Green and A Rahima (1980) selected areas of the foot of mountains in the south-east of Vunika. Fissure water is possibley found in this area within boundary zones between massive breccia and other rocks. These zones deserves exploratory boring, although large yield can not be expected. Within the geological structure classified in Malau Breccias of Undu Group, a deep well corresponding to No. 13 Nanging in Table 2-3 was drilled in 1970 with the following specifications.

Depth	85.34m
Length of strainer	36.58m
Natural water level	2.14m
Pumped water level	10.64m
Pumping rate	222.2 m^3/day
Specific capacity	26.09 m^3/day/m
Transmissivity	11.52 m^2/day

No. 9 well at Coqeloa in Nasavu Dacite of Undu Group was also developed in 1972 and recorded the pumping rate of 109 m^3/day. These data an existing wells indicate a pumping rate of almost 100 m^3/day for each well is quite feasible. However, watershed area around the potential site for groundwater development is approximately 3 km^2 and extensive recharge can not be expected. Therefore pumping tests

shoud be carefully carried out after well drilling to determine the most appropriate pumping rate to prevent over extraction. One criterion to determine pumping rates is that drawdown during pumping should not exceed the see level. If the total quantity of water secured by these schemes of groundwater development is found short of requirements for the whole Vunika area, extension of the Labasa water works should be considered.

e. Seaqaqa

The Seaqaqa area is constituted by Natua Formation of Natewa Group. This formation consists of sedimentary rocks made of reworked tuff and lapillistones lithified oozes, basic andesite lava flows, pillow lavas, sills.
A deep well is developed as of September, 1980 in the area with the same geological structure. Judging based on geological conditions, zones with high potential for aquifers are fissure zone in lava streams or in contacts between different geological strata such as sedimentary rocks and lava streams.
Existence of a large recharging area due to wide watershed area is another important consideration in selecting sites for groundwater development.

Development of sugar cane farms is now under way in this area, but as for groundwater development, even the number of wells required has not been determined although two sites have been selected as potential water sources.

f. Vunivau Bua

This area consist of Mbua Basalts of Mbua Group and is made of olivine basalt and subordinate breceia. Drilling at deep well has beem completed at potential sites for water sources. These wells correspond to No. 11, 12, 13 and 14 in Table 2-3 with confirmed pumping rates of 608,375, 181 and 428 m^3/day, respectively. Typical well structures are represented by wells No. 11 and 12 as illustrated in Figure 3-2 and Figure 3-3.

The hydrogeological conditions of each settlement areas are summarized in Table 3-4. Potential sites for deep wells in each area are shown in geological maps (Figures 3-4-a,-b,-c,-d and -e).

(2) Water sources for villages

The project areas for villages were selected by the survey conducted this time. Households are more concentrated in villages than in settlements. Therefore a single water source needs to be located for each village.

a. Vunimoli, Korowiri

This area is constituted with Wailebu Formation of Natewa Group and 100 to 300 m^3/day water is expected per well.

b. Korowiri

This area is covered by Koroutari Andesites of Natewa Group, consisting of andesite lavas, clastic rocks and reworked breccias. Concentration of faults is expected in the area within Korotini Breccias made of reworked andeste breccia, and thus aquifers in fractured zones are expected.

Fig. 3-2 Well Structure

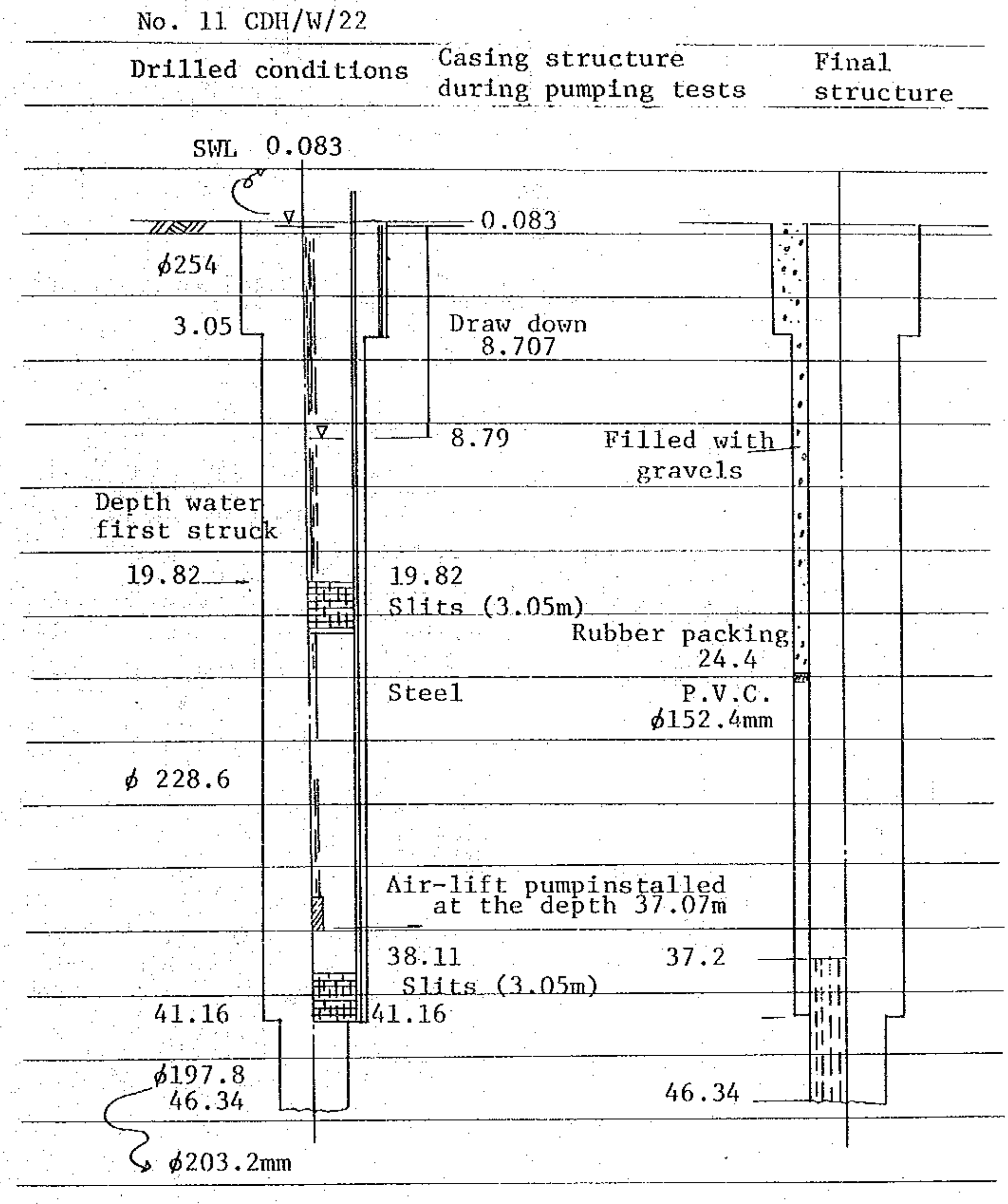


Fig. 3-3 Geological Columnar Section and Well Structure

No. 12 CDH/W/80/23

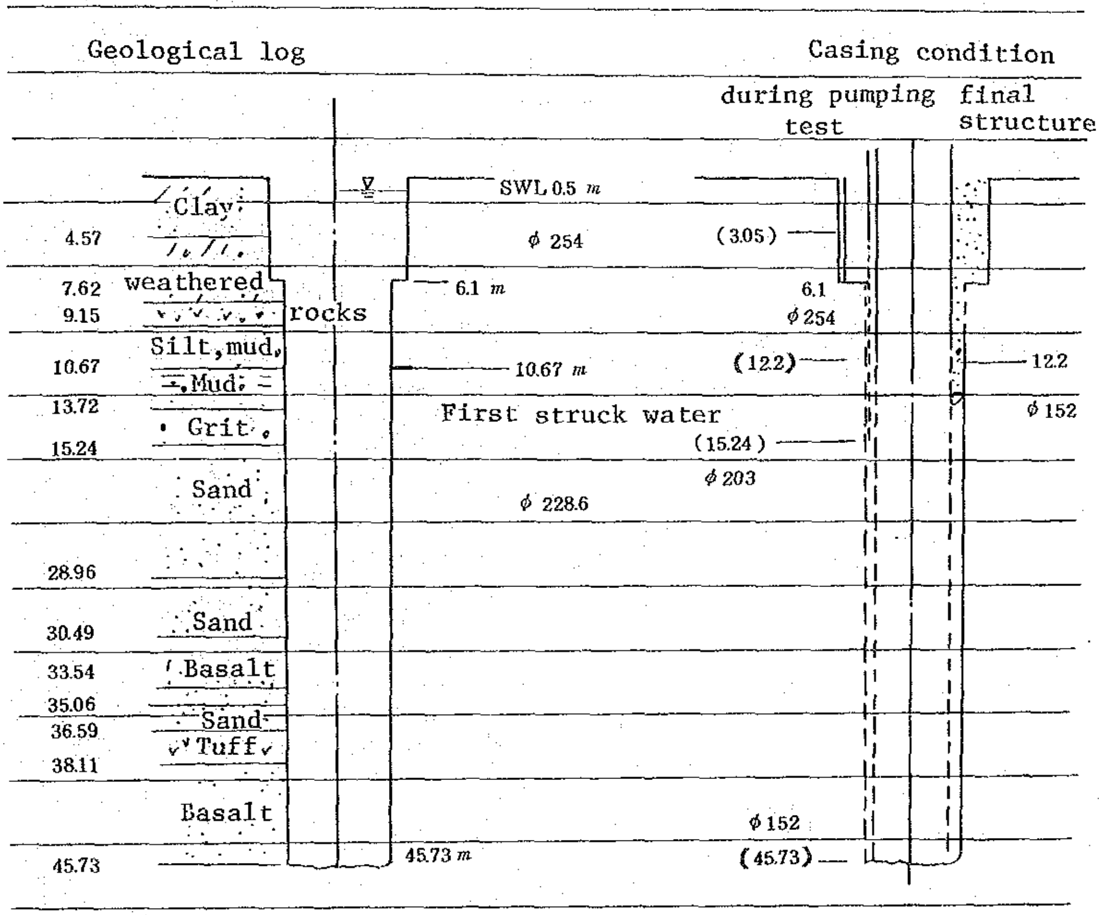


Table 3-4 Summary of Hydrogeological Conditions in Each Settlement Area

Area	Geological Structure	Principal Aquifers	Existing Deep Wells	Reference
Vunicuicui, Vunimoli	Wailebu Formation of Natewa Group is covered with alluvial layers on the surface. Thickness of alluvia is estimated from data on to be less than 10 m.	Wailebu Formation is sedimentary stratum consisting of rich mud stones, sand stones, greywackes and grits. Principal aquifers exist in coarse unsolidified zones of sand stones, greywackes, grits and etc.	The well (No.10 in Table 2-3) used for Indian School in the Vunicuicui area was sank into 57.91 m depth and was excellent record on a pumping rates of 363.6 m^3/day and specific capacity of 74.47 m^3/day/m during pumping tests. It is presently used for the school and other purposes. Carr (1974) estimated that water can be extracted at the rate 5,600 gallons per hour.	Figure 3-4-a, -b.
Waidamudamu	Wailebu Formation with no cover of alluvia.			
Nabekavu	Wailebu Formation	The potential development sites No.2 and No.3 has geological structure remarked above. The No. 1 site primarily consists of andesitic epiclastic breccias in Wailebu Formation. Coarse unsolidified zones and fractured zones in rock matrices constitute potential aquifers.	No well has been developed at No. 2 and 3 sites. No. 1 site is expected to take advantage of hot springs from fractured zones near the site. No. 4 Nakama and No. 2 Nanduna Savenakai in Table 2-3 represent wells in the same geological formation as the No. 1 site. At No.4 site, pumping rate of 180 m^3/day was recorded. These wells, however, have been neglected for about 10 years and collapsed as a result.	Figure 3-4-a, -b
Vunika	Malau Breccias of Undu Group	Malau Breccias are acidic secondary breccias of pumice and clastic rocks. These rocks are massive but in same paces dip toward northern direction. Aquifers are expected in bordering zones with fault between massive rocks and other geological strata.	No.3 Nangingi and No.9 Thonggelda wells in Table 2-3 exist in Undu Group, with pumping rate of 222 and 109 m^3/day, respectively, No. 3 well is considered to be in the same geological formation as a new development site selected this time.	Figure 3-4-c
Seaqaqa	Natwa Formation of Natewa Group.	Natwa Formation sedimentary rocks consisting of secondary sedimentary tuffs, volcanic conglomerates, mud stones and basic lava flows of dacite columnar and intruding rock bodies. Possibilities for aquifers are in contact zones between sedimentary rocks and lava flows as well as joints in lava flows.	As of September , drilling is under way.	Figure 3-4-d,-e
Vunivau Bua	Mbua Basalts of Mbua Group	Mbua Basalts consist of olivine basalts and their breccias. Principal aquifers are joints in basalty and unfolidified strata between lavas.	At potential sites No.11,12,13 and 14, drilling and pumping tests were completed with pumping rate of 508, 375, 181, 428 m^3/day respectively.	

Fig. 3-4-a Proposed Sites for Deep Wells
Vunicuicui, Waidamudamu & Vunimoli, Nabekavu

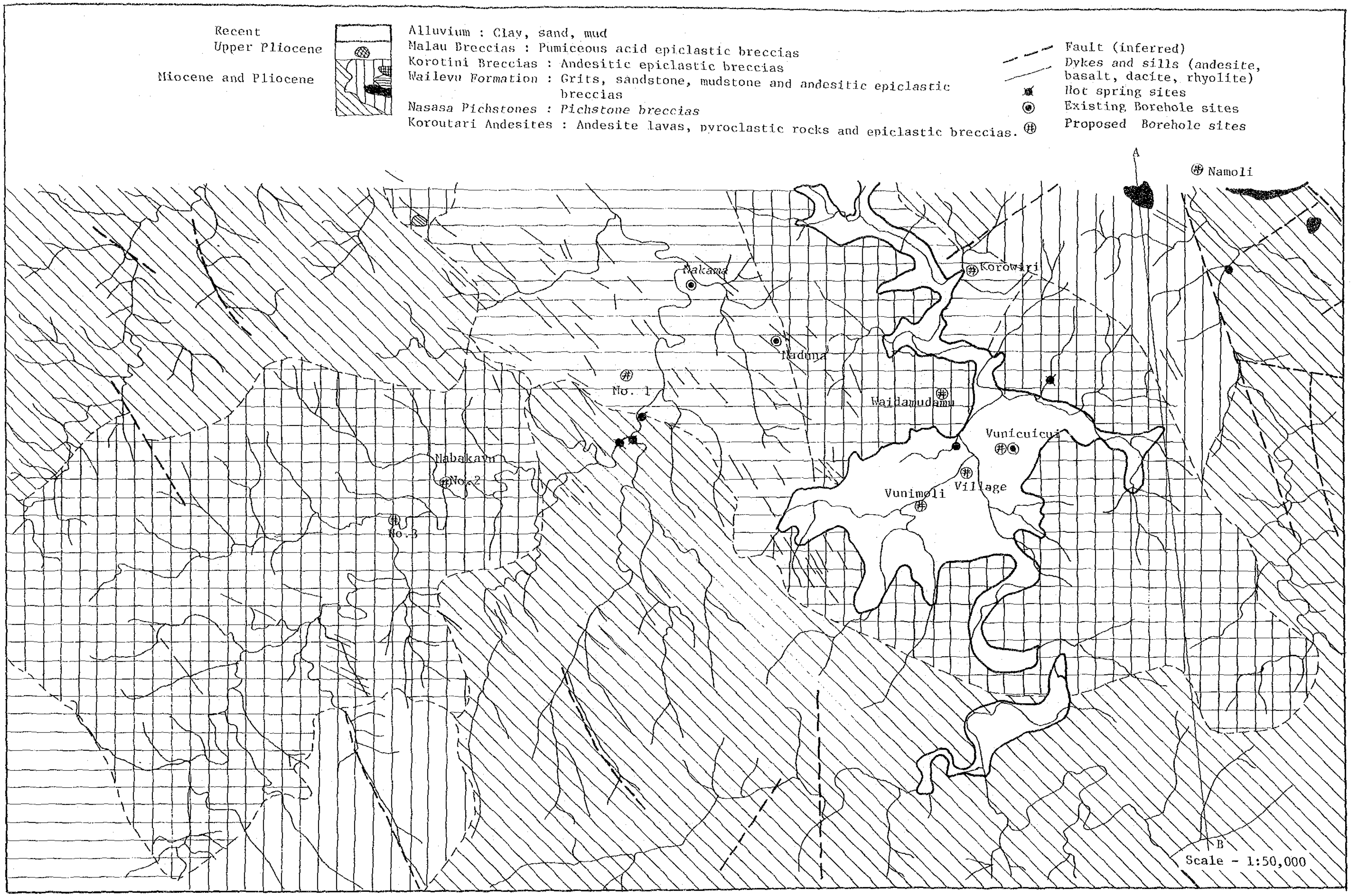
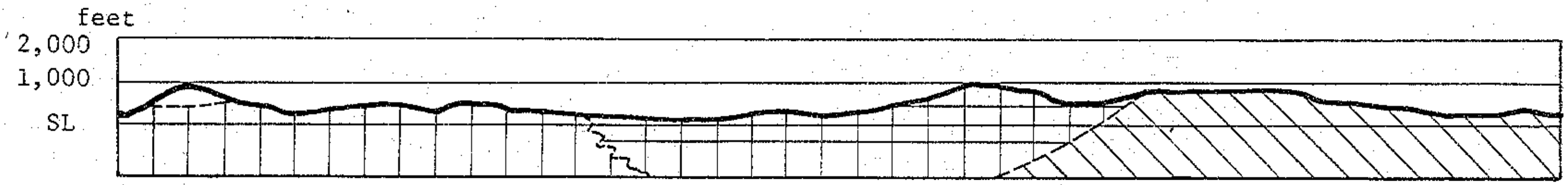


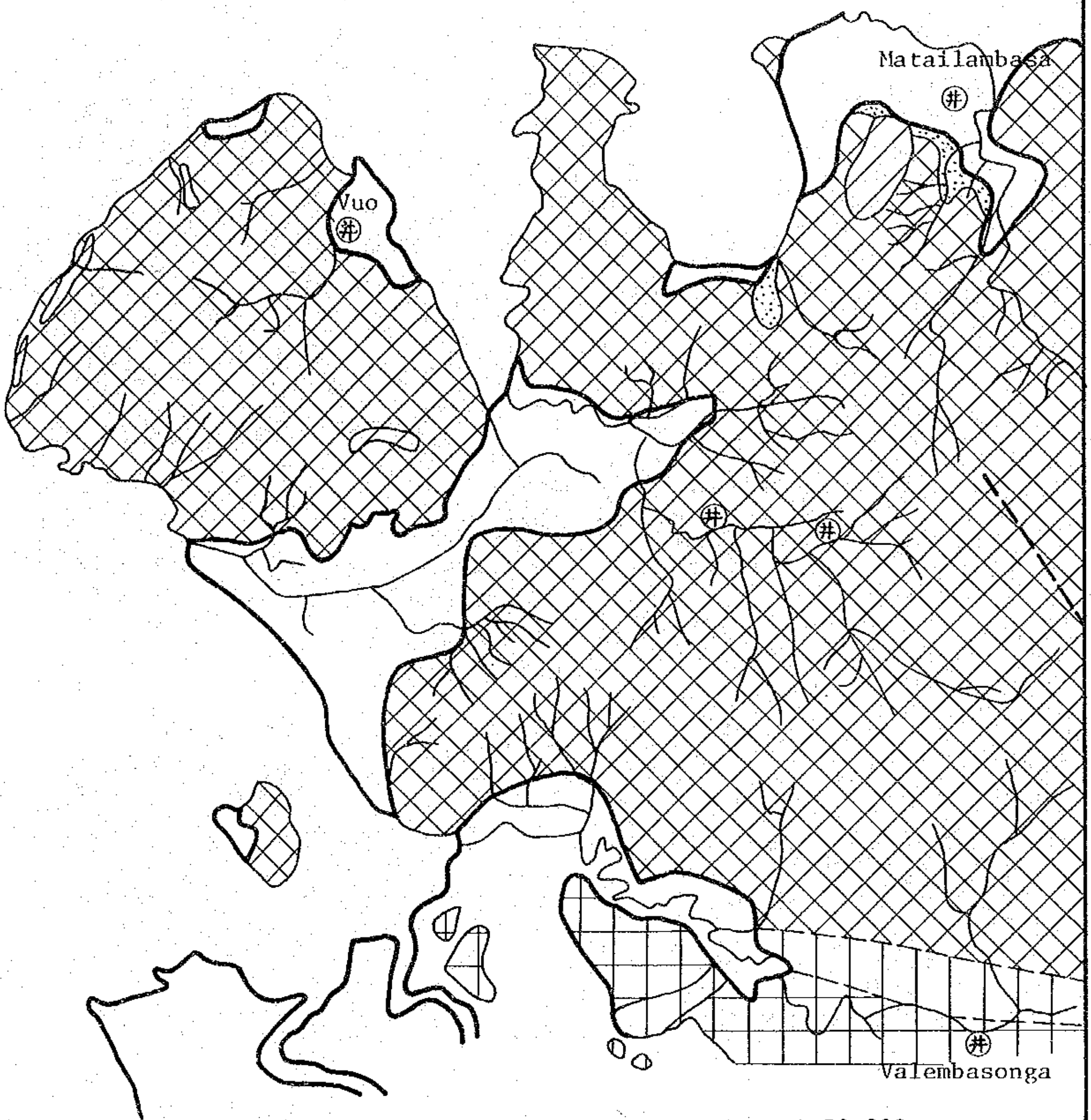
Fig. 3-4-b Section A - B

Section A - B



Vertical Scale 1:48,000 Horizontal Scale 1:50,000

Fig. 3-4-c Proposed Sites for Deep Wells (Vunika)



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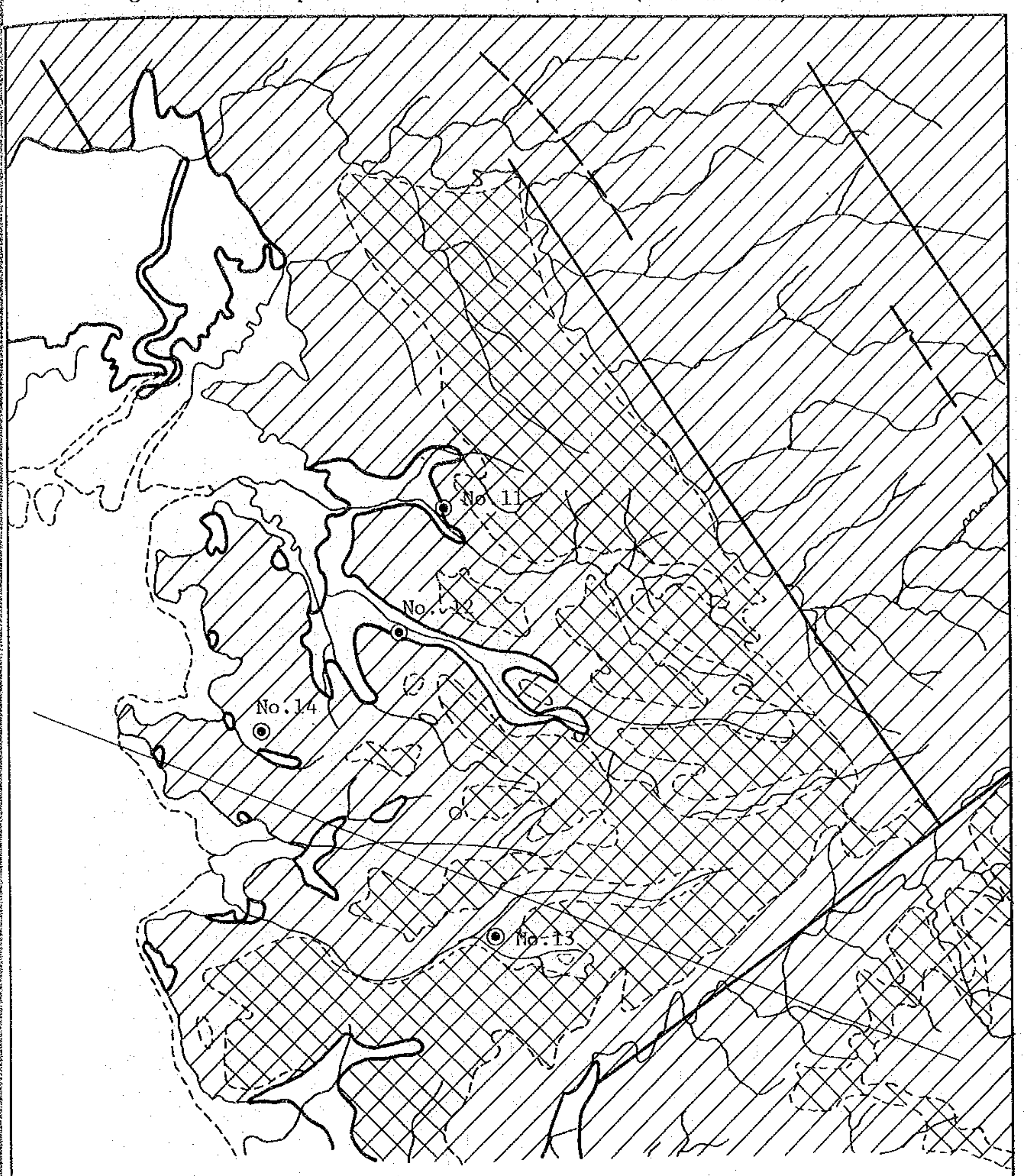
Recent	Alluvium : Clay, sand, mud
Post Upper Pliocene	Matailambasa Novaculites : Fine-grained silliseous rocks passing laterally into grits
Upper Pliocene	Korovatu Andesites : Sheets and dykes in Malau Breccias
"	Malau Breccias : Pumiceous acid epiclastic Breccias
Miocene and Pliocene	Korotini Breccias
"	Wailevu Formation

Fig. 3-4-d Proposed Sites for Deep Wells (Vunivau Bua)

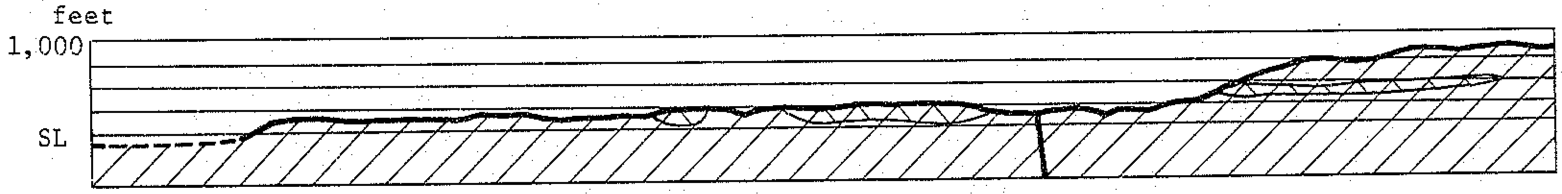


Recent		Clay, sand, gravel	
Pliocene		Narunai Conglomerates : Basalt conglomerate Mbua Basalts : Olivine basalt, subordinate breccia	Mbua Volcanic Group

Scale - 1:50,000

Fig. 3-4-e Section A - B

Section A - B



Vertical Scale 1:24,000 Horizontal Scale 1:50,000

c. Matai Labasa, Vuo

These areas consist of Malau Breccias of Undu Group. In the area around Matai Labasa the No. 3 well existing at Nangingi serve as reference data on given in Table 2-3. Specific data during pumping tests given in subsection 3-3-3)-(1)-d shown the pumping rate at 222.2 m^3/day and the specific capacity of 26.09 m^3/day/m. Judged based on these, water is expected to be extracted at the rate 200 m^3/day for each well in Matai Labasa.
The Vuo area is along the shoreline just like Vunika possibilities, aquifers in fissure zone of basement rocks or contacts of different geological strata are expected. When aquifers are found, a necessary condition for pumping is that drawdown of groundwater level does not exceed the sea level to prevent salt water intrusion

(3) Schools

Four schools were selected, deep wells exist in three schools, and one school has no well.

a. Valebasoga

The school is located in the area where Wailebu Formation at Natewa Group contacts Malau Breccias of Undu Group. Specification at the existing well is as follows.

Depth	56.1m
Length of strainer	unknown
Natural water level	0.4m
Pumped water level	depletion
Pumping rate	80.81 m^3/day

Specific capacity	-	unknown
Transmissivity	-	unknown

The well water was dried up when pumping test proceeded at the pumping rate of 80.81 m^3/day. It has not been used after failure of the pump installed. To determine whether this well can serve for water uses at the school, stepwise pumping tests should be carried out by using a submersible pump. If the most appropriate pumping rate thus determined satisfied the requirements of the school, it will be necessary only to install a new pump. Otherwise a new well has to provided.

b. Thonggeloa

The area is covered by Nasavu Dacites of Undu Group, consisting of dacite and rhyolite lavas, valcanic ashes and breccia. A deep well in Thonggeloa corresponds to the No. 9 well in Table 2-3, specification is as follows.

Depth	45.73m
Strainer length	unknown
Natrual water level	6.86m
Pumped water level	20.33m
Pumping rate	109.2 m^3/day
Specific capacity	8.11 m^3/day/m
Transmissivity	9.72 m^2/day

This well has also been neglected after the initially installed pump failure and is not presently used. The similar pumping tests described above for Valebasoga is necessary before it is used again.

c. Lekutu Junior, Lekutu Bhatiya

This area is covered by Lekutu Mudstones of Mbua Group consisted of mudstones and gravel strata. A deep well (No. 8 Korokandi in Table 2-3) exists in Lekutu Bhartiya, but is not used due to failure of the pump initially installed. Specific data at the time of pumping tests are as follows.

Depth	45.72m
Strainer length	39.23m
Natrual water level	0.56m
Pumped water level	16.77m
Pumping rate	269.8 m^3/day
Specific capacity	16.72 m^3/day/m
Transmissivily	11.33 m^2/day

The pumping test described above should be conducted before the well is used again.

It is expected that water can be taken from a new well in Lekutu Junior at the rate 100 to 200 m^3/day.

3-4. Facility Planning

3-4-1. Factor of Design

1) Design criteria

The basic design of the water supply facilities shall be in accordance with the Design Guideline adopted by PWD of the Government of Fiji as included in the Appendicies hereto, with necessary modifications. The design criteria which serve as the basis for planning were determined as follows on the basis of the said Design Guideline and information obtained through field survey.

(1) Unit water demand

For settlements : 150 l/c/d (with some individual house connections)

For settlements and villages:
50 l/c/d (without individual house connections)

(2) Water source

Type of water source : Ground water (intake by deep well)

Casing program : To be determined for each area based on the geological data obtained.

Location of well : Each well, as a rule, shall be located at a site indicated in the following report of investigation which was undertaken by MRD: "A PRELIMINARY INVESTIGATION OF THE GROUNDWATER RESOURCES AROUND LABASA, SEAQAQA, AND VNIVAU IN BUA" (By A. Green and A Rahiman)

(3) Intake facilities

For settlements : Vertical shaft turbine

pump for deep well (driven by diesel engine) or mono type well pump (driven by diesel engine)

For villages : Foot operated well pump

(4) Water conveyance and distribution piping system

The project, as a rule, shall use deep well water as the water source, potable without purification or chlorination by chlorine, and be based upon the basic system concept of intake → conveyance → storage → distribution → service tap.

Water shall be directly conveyed by the well pump through pipe, the diameter of which shall be determined according to the daily operating hours of the intake facilities.

Distribution shall be by the gravity flow, and the pipe diameter is determined on the basis of the peak flow which is assumed to be 2.5 times the daily average water demand.

The pipe, as a rule, shall be rigid PVC pipe which is locally produced.

(5) Water storage facilities

a. Storage capacity

Case 1 : 30 % of the daily average water demand (in case where the well pump is operated more than 20 hours a day and the facilities are placed under the control of PWD.)

Case 2 : Equivalent to 16 hours of daily average water demand (in case where the well pump is operated 8 hours a day and the facilities are placed under the control of each community.)

Case 3 : Tank with 2.5 m^3 effective capacity (for village supply)

b. Type of water storage

Case 1 : Hume's tank (for settlements)

Case 2 : Panel tank or corrugated sheet tank (for villages)

2) Served population

The served population shall be as shown on Tables 3-5-a and -b, which was estimated for 1990 based on the population statistics as of 1976. As a rule, the proposed project shall deem the entire population within the project area as the population to be served, but this may become difficult depending on the piping system design, topography and other reasons. We are therefore making the special notation that houses to which water supply is difficult under the proposed project shall be taken care of by PWD in future.

3) Water demand

The water demand is as shown on the same Table 3-5-a and -b on the estimated population.

The water demand for settlements was calculated on the basis of 50 l/capita/day as a rule, but for Vunicuicui where the installation of a water meter is scheduled in the near future and also for Vunika, which is close to Labasa and abounds in development potentials with the possibility of having its water distributed from the Labasa waterworks or of developing its own water sources, the water demand was calculated on the basis of 150 l/capita/day.

Table 3-5-a Served Population and Water Demand for Settlements

DISTRICTS	PREDICTED 1990		WATER DEMAND (1)		WATER DEMAND (2)	
			50ℓ/c/d (12.5 Gal./c/d)		150ℓ/c/d (37.5 Gal./c/d)	
	NO.OF HOUSEHOLDS	POPULATION	m^3		m^3	Gallon
VUNICUICUI	142	880	-	-	132	29,700
VUNIKA	292	1,670	-	-	251	56,700
VUNIMOLI	61	380	19	4,200	-	-
WAIDAMUDAMU	50	360	18	4,000	-	-
NABEKAVU	324	1,980	99	22,200	-	-
VUNIVAU BUA	81	540	27	6,100	-	-
SEAQAQA	1,055	6,440	322	70,800	-	-
TOTAL	2,005	12,250	485	107,300	383	86,400

[NOTE]

WATER DEMAND (1) For Non-Metered Water Supply - 50ℓ/Capita/day

WATER DEMAND (2) For Metered Water Supply - 150ℓ/Capita/day

Table 3-5-b Served Population and Water Demand for Village and School

DISTRICT		PRESENT POPULATION 1980	PREDICTED POPULATION 1990	WATER DEMAND	
				m^3	Gallon
VILLAGE	VUNIMOLI	120	150	8	1,760
	NAMOLI	71	90	5	1,100
	KOROWIRI	164	200	10	2,200
	VUO	471	570	29	5,370
	MATAI LABASA	911	1,110	56	12,310
SCHOOL	COQUELOA (THONGGELOA) SANGAM SCHOOL	142	170	4	880
	VALEVASOGA PRIMARY SCHOOL	311	380	10	2,200
	LEKUTU JUNIOR SECONDARY SCHOOL	420	510	13	2,860
	LEKUTU BHARTIYA SCHOOL	118	140	4	880
TOTAL		2,728	3,320	139	30,560

[NOTE] Water demand is based on per capita demand of 50ℓ/d for village and 25ℓ/d for School.

3-4-2. Basic Policy on Groundwater Resources Development

1) Drilling rig

Two typical drilling rigs are the percussion type and the rotary type.

In the areas where rural water supply development programs are being implemented, the percussion type churn drills and the rotary type universal machines are currently being used in constructing the production wells. The churn drill type Bourne rig began to be used since 1978 and is capable of drilling holes with 6, 8 and 10 inch diameters to the maximum depth of 500 feet. The Universal type auger machines in capable of drilling both 6 inch diameter hole to the maximum depth of 225 feet and the 8 inch diameter hole to the maximum depth of 100 feet, while the down hole hammer is capable of drilling 6 inch diameter hole to the maximum depth of 300 feet, all being in use since 1972.

The churn drill type drilling rig is suitable for drilling of alluvium and soft rocks. Of the universal type drilling rigs, the auger is suitable for drilling alluvium which does not contain rolling stones and such, while the down hole hammer is suitable for drilling medium to hard rocks.

However, geological condition of the investigated areas has revealed that the foundation is mainly composed of hard rocks like lava flows and breccias or of alluvium containing rolling stones, for which neither the churn drill type nor the Universal type auger drilling rig can demonstrate very good drilling efficiency. The Universal type down hole hammer is considered suitable for such geological conditions, but the diameter of its bit seems somewhat small for completing a production well.

The suitable drilling methods for each type of lithology are listed in tabular form (Table 3-6), and individualities are described as bellow.

Table 3-6. Suitable Drilling Methods by Lithology

Lithology	Cable Tool Method	Rotary Method		
		Normal Circulation		Reverse Circulation
		Mud	Air Hammer	
Collapsible soil	o	o	x	o
Soft	o	◎	x	◎
Semi-hard	Δ	◎	o	Δ
Hard	x	o	◎	x
Very hard	x	Δ	◎	x

◎ Best suited o Suited Δ Tolerable x Unsuited

(1) The advantage of the cable tool (percussion) method lies in its low cost. It is suitable for drilling shallow soft ground where work water is hard to obtain, or where lost circulation water loss and collapse frequently occur. It is also used in cases where winch is frequently used, such as for installing of pump or cleaning of old well.

This method, however, is gradually being abandoned because of its poor work efficiency, unsuitability for very hard rocks and soft elastic clay stratum and also because of its extremely poor efficiency compared to the rotary percussion type in drilling semi-hard rocks.

(2) Rotary drilling methods include the mud circulation type, the air hammer type and the reverse circulation type.

(3) The mud circulation type rotary drilling method is suitable for almost all types of lithology, from soft to very hard rock.

(4) The air hammer type is not suited to collapsible type of ground or soft and weak ground. However, the air percussion type in particular can be expected to drill hard to very hard rocks with 3 to 10 times the efficiency of the mud circulation type and from 10 to 20 times that of the cable tool method. Since a large borehole diameter requires much more air, it is usually recommended that the relatively soft section close to the ground surface be drilled with the mud circulation type, then when the hole becomes deeper and intersects with hard rocks, to make the hole diameter smaller and drill with the air hammer type. As a result, the hydraulic top hard driven type rotary rig which is suited to both of these methods is becoming popular of late.

(5) The reverse circulation type is suitable for drilling large borehole diameters of 600 mm or more in soft and weak ground, such as for large capacity wells for farming in the alluvial plain. It is also used for drilling holes for foundation piles in civil engineering works.

When all of the above described characteristics of each drilling rig and the geological structure of the drilling sites are taken into consideration, it is judged that the air percussion rotary (down the hole) type is most suited for the project area since it can cope with a wide range of lithology, from soft and weak ground to very hard rock.

2) Drilling and development of well

The following is the general procedure in drilling and the development of well.

(1) Drill hole with a diameter of 254 mm to a depth of about 5 m in the topsoil, making sure that the bottom of the hole has arrived at the relatively stable, unconsolidated sediments.

(2) After inserting a steel pipe (conductor pipe) with an inner diameter of 200 mm, drive it in or push it in using hydraulic power of the rig into the unexcavated earth for about 10 to 20 cm in order to prevent collaps at the pipe end.

Holding the steel pipe vertically, inject cement milk around it to stabilize the pipe.

(3) While circulating the drilling mud, drill the borehole with a diameter of 194 mm straight down to the predetermined depth.

(4) Conduct electrical logging and whatever other logging of the borehole that is necessary, and prepare a casing program based upon an overall judgement of the logging results, analysis of sampled columner log and the report submitted by the boring personnel.

(5) For preliminary pumping test to confirm the groundwater reserves, install a ϕ150 mm N.D. steel casing in the borehole in accordance with the casing program. (perforate slots in three of the lowest pipes with a drill.)

(6) Bail out the muddy water in the pipe with a bailer. After confirming that some groundwater is seen to infilterate into the pipes, descend the D.P. in the pipe and cleanse the pipe by feeding fresh water by pump.

(7) Descend an air lift device, then cleanse the pipe, after which conduct a preliminary pumping test by air lift pump.

(8) After confirming that the yield is sufficiently large to be utilized.

(9) Pull out the ϕ150 mm N.D. casing. Confirm that there is no collapsing in the borehole with a bailer, and if there is, remove caved substance.

(10) Insert ϕ150 mm N.D. PVC screen and casing pipe.

(11) Thereafter, develop the well by air lift pump. At the same time, fill formation stabilizer around the screen to prevent caving.

(12) Conduct pumping tests - continuous, recovery, and stepwise drawndown test - by means of a pump with submarine motor.

(13) Place concrete slabs around the surface section, plug the well temporarily and mount a cap on top, with which the work is completed.

(14) Prepare a written report on the well drilling work according to the style described later.

(Note) When a hard rockbed is intersected during drilling and further drilling becomes difficult, perform processes (4), (5) and (6) at this depth, and then drill by 6" N.D. air hammer from inside the 6" N.D. pipe. When the well starts to yield groundwater, this can be recognized during drilling by air lift. When an adequate amount of water is produced, stop drilling. Thereafter, follow the same processes from (9) through (14), providing however, the PVC screen in process (10) shall be used only when the water is produced from the upper section. If the water is not produced from the upper section, insert a plain pipe and perform cementing and back-filling around the pipe.

3) Report on the well drilling work

As well drilling work will increase hereafter, the reports thereof will serve as an important source of information for investigating hydrogeology and managing groundwater. The items which ought to be covered by the reports are enumerated below as reference.

1. Name and reference No. of each well
2. Location of well, to be entered on a S = 1/50,000 map.
3. Ground hight
4. Description of work

   (1) Work schedule (outline) - attach the record of well drilling log as an appendix and term is from time of access to the site, to withdrawal.

   (2) Type of machinery used

   (3) Geologic columnar section, well logging

   (4) Casing program (final well structure)

5. Description of pumping test

   (1) Year, month and date tested

   (2) Equipment used

   (3) Conditions of casing

   (4) Analytical results of pumping test - attach the record of pumping test and analytical graph as appendices.
   Static water level
   Pumped water level
   Pumping rate
   Specific capacity
   Transmissivity
   Limits pumping rate (stepwise drawdown test)

6. Description of chemical analysis

7. Summary

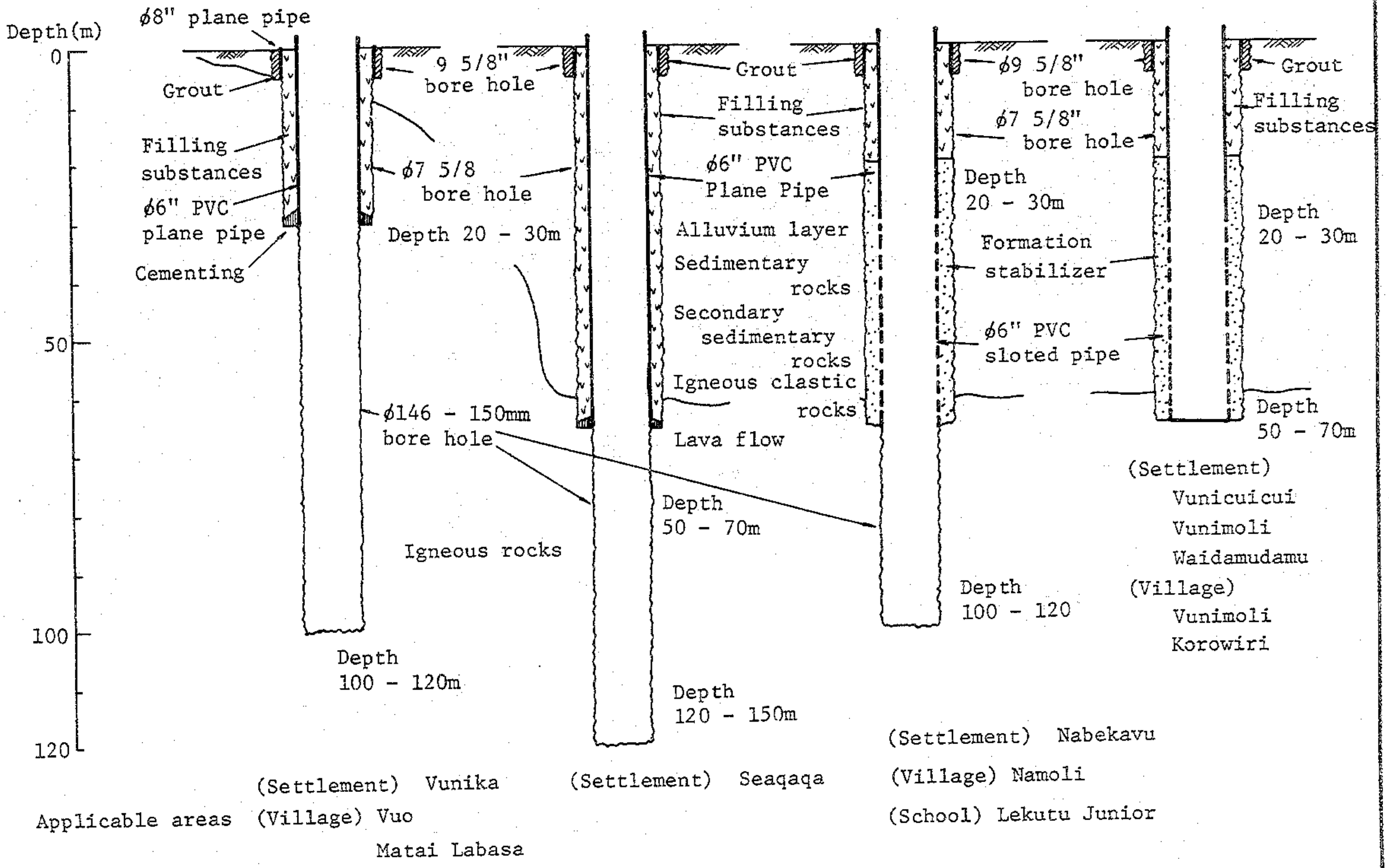
4) Structure of production wells in the project areas

The structures of the production wells are hypothesized on the basis of the geologic composition in each project area. They can be broadly classified into the four types of I to IV as illustrated in Fig. 3-5.

① Type I

Wells of this type directly intersect with igneous rocks in areas where alluvium or other sedimentary layers are not distributed at all or hardly exist if any, and the upper section comprises a weathered zone which is relatively soft. As the depth increases, the ground becomes harder and requires drilling by air hammer type. After the top section of well is drilled with a diameter of 9 5/8"(245 mm), an 8" (200 mm) casing is inserted and the pipe end is sealed by cementing. Then boring is continued to a depth of about 30 m with a borehole diameter of 7 5/8" (194 mm). A preliminary pumping test is then conducted by air lift, and if the amount of water produced is insufficient or non-existent, a 150 mm N.D. flash joint pipe is installed and drilling by air hammer is continued. The maximum depth is tentatively assumed to be up to 120 m. If fissure zone are intersect and groundwater starts to fill the borehole, this can be confirmed by air lift while drilling. If a sufficient amount of water is seen to spurt, the drilling operation is stopped and the water level is measured along with other measurements. If it is seen to satisfy the initially planned amount of water, then drilling is terminated and the well is developed to completion. The 150 mm N.D. flash joint pipe is pulled out, and the inside of the borehole cleaned by means of air lift pump or otherwise. If water is produced from the upper section, a slotted PVC pipe is installed, but if the upper section is a non-producing zone, a plain PVC pipe is installed and the pipe end sealed by cementing. Then the interstices between the borehole wall and the pipe are filled with sand, clay and the like to stabilize

Fig. 3-5 Type of Well Structure



the pipe. This type of well seems applicable to Vunika settlement and Vuo village.

② Type II

Type II is different from Type I in that the plain PVC pipe which is installed in the upper section and must be made longer because of the thick accumulation of impermeable alluvium layers and tuff breccia, etc. This type of well is considered applicable to the settlement of Seaqaqa.

③ Type III

Type III is different from Type II in that although groundwater is also produced from the upper sedimentary rocks, the amount is insufficient so that groundwater in the cracks of the lower rockbed is also exploited to increase the amount of water produced.

In practical terms, this is the case where Type IV produces insufficient water, and after temporary casing work, the borehole is cut by air hammer. During this process, the utmost care must be paid where possibilities of collapsing exist due to the large depth of the casing.

This type of well is considered applicable to Navekabu settlement, Namoli village and also the Lekutu Junior Secondary School.

④ Type IV

Most of the wells in the plains south of Labasa are expected to be of this type. This type of well is bored with fresh water or thin mud straight down through alluvium layer and sedimentary rocks as far as the weathered zone of the bed rock. A plain PVC pipe and slotted screen are installed to reach the bottom of the borehole, with the plain PVC pipe provided at the part that intersects with

the weathered zone at the bottom to withstand sedimentation. Formation stabilizer or coarse filter sand of uniform grain size is filled around the screen. The interstices in the upper section may be filled with filling substances instead, provided however, about 10 m from the upper end of the screen must be filled with filter sand. As for the topsoil part, cement grouting is carried out around the temporary casing while pulling it out, but it is more desirable to bury the temporary casing in situ from the standpoint of protecting the well mouth and preventing it from becoming contaminated from the ground surface.

This type of well is considered applicable to the settlements at Vunicuicui, Vunimoli, Waidamudamu and the villages at Vunimoli and Korowiri.

3-4-3. Basic Design for the Model Areas

1) Settlement water supply

The basic plan for Vunicuicui, which was selected as the model area for settlement, is as follows.

(1) Intake facilities

Water will be taken from the deep well which MRD is scheduling to bore at a site across the street from the Indian School. For well pump, a heavy duty vertical shaft turbine pump driven by a diesel engine will be used. The daily operating hours of the pump will be 20 hours on condition that PWD will undertake its operation and maintenance. Since the amount of groundwater stored in this area are expected to be more than in other areas as stated previously, all of the water demand as shown on Table 3-5-a is planned to be pumped from this single well. Basic data for the well pump are as follows.

a. Basic data and specifications of the well pump

Elevation of the proposed well site : + 15.0 m

Pumping water level : -5.0 m (GL - 20 m, considering future draw-down of water level.)

Actual head : 72.5 m (67.5 - (-5), assuming HWL of the distribution tank to be 67.5 m)

Friction losshead due to conveyance pipe : 4 m

Pipe diameter ϕ75
Flow rate 1.83 l/sec.
Flow rate coefficient C = 110
Length of pipeline 800 m

From these :
Velocity of flow 0.41 m/sec.
Hydraulic gradient 4.4%
Loss of head 4.4 x 800/1,000
= 3.52 m
approx. 4 m

Total head : 80.0 m (72.5 + 4.0 + other losses)

Specifications for pumping equipment

Type :	Heavy duty vertical shaft turbine pump for deep well
Performance :	Total head 80 m Discharge 110 l/min. Revolution 1,800 rpm No. of stages 17 stages
Dimensions :	Bawl diameter 145 mm length 3,300 mm Column pipe diameter 80 mm length 20 m

Strainer   diameter 80 mm
            length 3,000 mm

Lubricating system : water lubrication

Output :   6.5 Hp

Prime mover: Diesel engine (water cooled 4 cycle)
    Revolution 1,800 rpm
    Output 15 Hp

b. Specifications for intake facilities

Well pump :   As above

Casing :   Rigid PVC pipe, ϕ150, 70 m

Strainer :   Of the total 70 m length of casing, slits will be provided for 40 m.

Well construction:
    Refer to Par. 3-4-2, 4)

Pump room :   Floor area 2.55 x 5.05 m
    Structure concrete block
    Details refer to the Drawings

(2) Water conveyance facilities

This is the pipeline facilities for conveying water from the intake pump to the distribution tank that will be constructed in the flank of the hill. With a view to prevent water hammer pressure caused sudden start-up and shut-down of the pump and sudden valve operation, it shall be provided with an automatic valve which is actuated by the changes in water pressure and water level.

a. Specifications for water conveyance facilities

Water conveyance pipe: Rigid PVC pipe, ϕ75, L=800 m,
    Class D, Maximum head 120 m

Strainer :   FCD ϕ75   1 unit

Maximum service pressure 10 kg/cm^2

Mesh size   12

Hydraulic primary pressure regulating valve (safety valve):

FCD ϕ50 1 unit

Type	Diaphragm safety valve
Maximum service pressure	
	10 kg/cm^2
Range of pre-set pressure	
	5 - 10 kg/cm^2
Accessories	Pilot valve, pressure gage, etc.

Hydraulic surge relief valve :

FCD ϕ75 1 unit

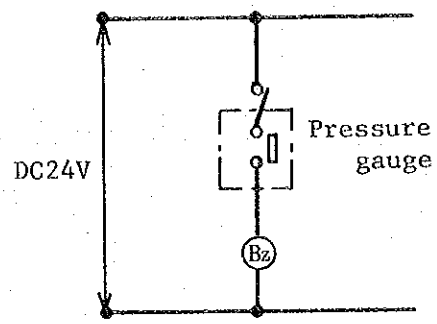
Maximum water pressure	
	10 kg/cm^2
Minimum working pressure	
	0.3 kg/cm^2

Sluice valve for waterworks :

FCD ϕ75 and ϕ50 1 unit each

Pressure gauge with alarm device : 1 set

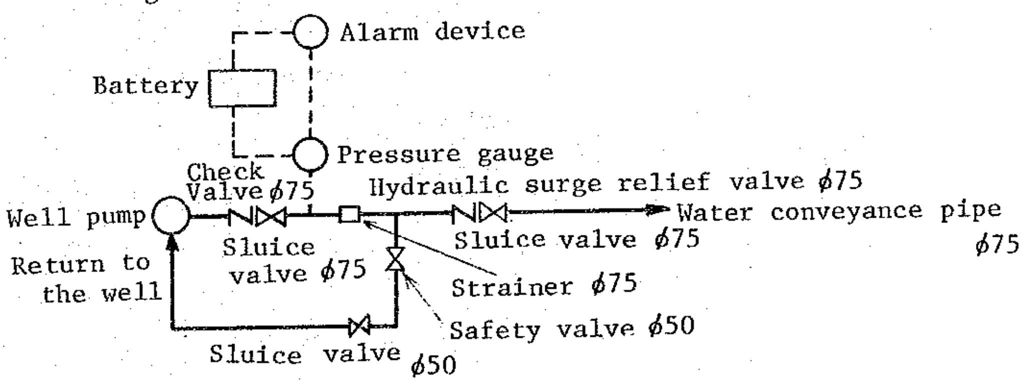
Type of pressure gauge	
	Bourdon tube with micro-switch, JM21
Scale	0 - 15 kg/cm^2
Alarm contact	at one location
Gauge diameter	150 mm
Buzzer box	wall type
Power	DC 24 V
Schematic diagram	
	as presented below



b. Piping of well pump delivery pipes

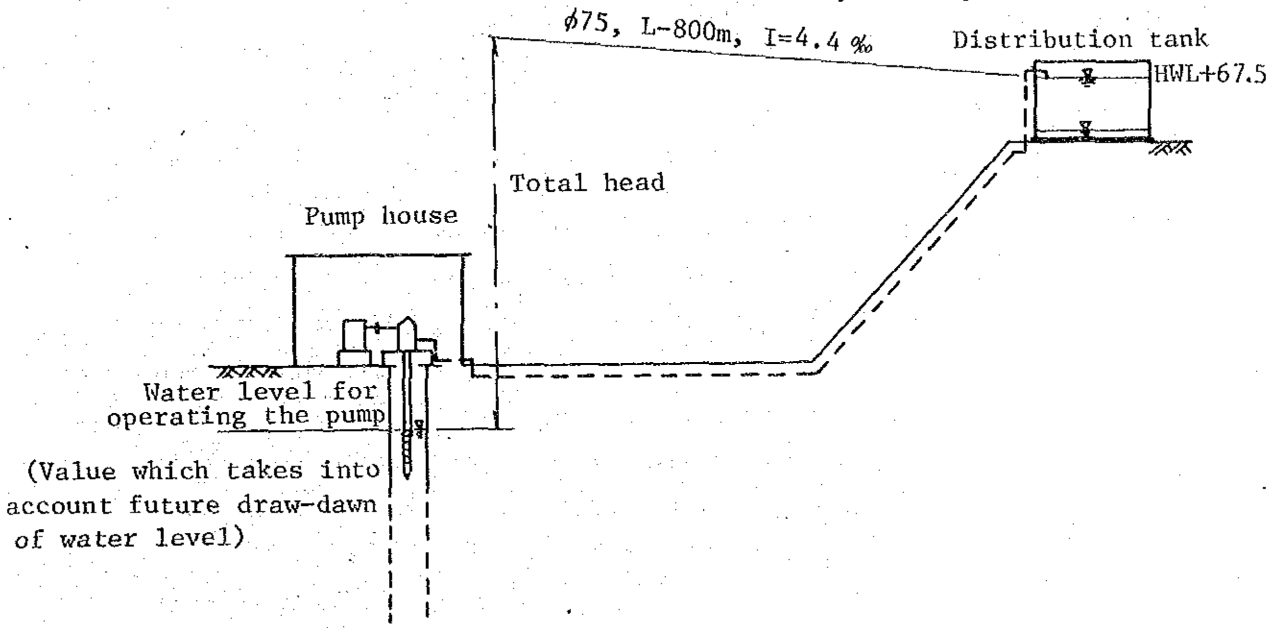
The piping on the discharge side of the well pump, in relation to its start-up and shut-down operation which is actuated depending on the water level of the distribution tank, shall be as illustrated in Fig. 3-6. When the water level in the distribution tank reaches HWL and the water level control valve closes, the pressure within the water conveyance pipe rises since the well pump is in operation at this time. The system is designed so that the rise in pressure is detected by the pressure gauge (pressure switch) which in turn actuates the alarm buzzer. It is by this alarm that the operator will know when to stop the pump.

Fig. 3-6 Piping for the Discharge Pipe



c. Study of the water conveyance pipe

Fig. 3-7 Illustration of Loss Head in the Water Conveyance Pipe (Vunicuicui)



The total head of the pump as shown in Fig. 3-7 was figured out by adding the loss of head in the water conveyance pipe, etc. to the actual head as follows:

Quantity of water pumping :

$$132\ m^3/day \times \frac{24\ hours}{20\ hours} = 158.4\ m^3/day = 1.83\ l/sec$$

Conveyance pipe: Pipe diameter ø75, length 800 m

Friction loss head : Q = 1.83 l/sec., c = 110, resulting in a hydraulic gradient of 4.4 %, from which the friction loss head (F. Loss) is calculated to be :

F. Loss = 4.4/1,000 x 800 m = 3.52 m

Pumping water level : -5.0 m

H.W.L. of distribution reservoir : +67.5 m

Total head of the pump : 67.5 - (-5) + 4.0 + other losses = 80 m

(3) Distribution reservoir

A distribution reservoir with a capacity equivalent to 30% of the daily water demand will be built at a place 68.5 m in elevation (HWL). The structure shall be a Hume tank which has already proved well in the locality. The water level control valve shall be installed so that when the water level in the tank has been detected to have reached the high water level (HWL) due to pumping from the well, the valve on the inflow side will be closed and control any further rise of the water level.

a. Basic data of the distribution reservoir

Capacity :	39.6 m^3 or more (132 m^3/day x 30 %)
High water level :	+67.5 m
Low water level :	+65.9 m

b. Specifications for distribution reservoir

Structure :	RC silo stave tank 1 unit
Dimensions :	ϕ6.0 m x 1.6 m (effective water depth)
Built-up height :	2.1 m (3 tiers)
Bracing :	Steel bar ϕ13

Detail of distributing reservoir: as per drawings.

Hydraulic altitude control valve (water level control valve) : FCD ø75 1 unit

Type : Bar float pilot type
Maximum service pressure : 10 kg/cm^2
Minimum water depth : 1.0 m
Accessories : Pilot valve, pressure gauge, etc.

Valve chamber : RC built 1.42 (W) x 2.35 (L) x 1.47 (H) m

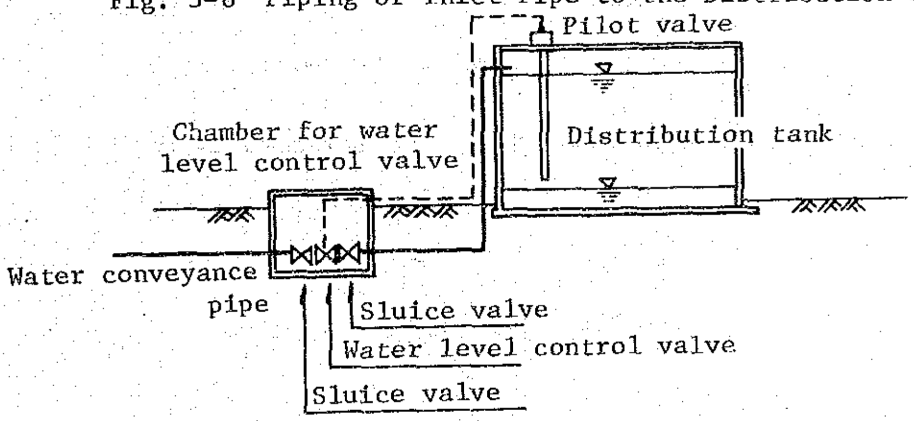
Gate valve for waterworks : FCD ø75 2 units

Piping around the reservoir :
SGP ø75 to ø100 1 set

c. Piping of distribution tank inlet pipes

A water level control valve is installed to the inlet pipe (conveyance pipe) leading to the distribution tank and a pilot valve is installed to the distribution tank so that when the water level in the distribution tank is detected to have reached HWL, the water level control valve is closed by the water pressure and stops the inflow of water into the distribution tank. Piping which enables this action to be taken is as illustrated in Fig. 3-8.

Fig. 3-8 Piping of Inlet Pipe to the Distribution Tank



(4) Distribution facilities

The distribution main will be laid from the distribution tank to the principal public roads within the settlement. The pipe diameter shall be ϕ100 to ϕ50, with standard earth covering of 0.8 m. Sluice valve, blow off pipe, fire hydrant, river crossing, air valve, pipe anchoring, etc. will be provided as necessary so that the entire facility will adequately function as a pipeline. As for pipe material, the locally produced rigid PVC pipe will be used. Steel pipe and ductile iron pipe may also be used as necessary. The distribution will be made by the gravity flow system. The pipeline network will be as shown on the drawing.

a. Specifications for the distribution facilities

Distribution pipe:
(Class C, Maximum head 90 m)

Rigid PVC pipe	ϕ100, L = 2,500 m
	ϕ 75, L = 3,500 m
	ϕ 50, L = 4,900 m
Galvanized steel pipe	ϕ 75, L = 49.5 m

Sluice valve :	FCD ϕ100	4 ea.
	ϕ 75	14 ea.
	ϕ 50	12 ea.

Blow off pipe : ϕ50 x 3 places (pipe length 10 m ea.)

Air valve : Single hole ϕ13 m x 4 places

Fire hydrant : Above ground type x 12 places

River crossing : ϕ75 x 3 places (pipe length 10 m ea.)

Special pipe anchoring :
Tees ϕ100, ϕ 75 x 12 places
90 bend ϕ100 x 1 place

Common water tap: ϕ 13 x 4 taps x 36 places

b. Study of the distribution pipe

In order to function as a distribution pipeline sluice valves, air valves, blow off pipes and fire hydrants shall be installed as indicated on Fig. 3-9.

Sluice valves, as a rule, were placed in the downstream of pipe branching, at both sides of the pipeline where it crosses the river, and in the downstream side of the blow off pipes. Fire hydrants should desirably be installed on a pipeline with 150 mm or larger pipe diameter, but because the largest diameter of the distribution pipes under the proposed plan is 100 mm, the fire hydrants were installed only where the pipeline was 100 mm in diameter at intervals of 200 to 300 m.

The section laid across the river is overpassed and installed with a air valve. Also, blow off pipes are installed in the upstream side of the river crossings to remove sediments in the pipe.

In calculation, it is determined that the pipe diameter should secure more than 20 m (2.0 kg/cm^2) of residual head at the far end of the distribution pipe, and as a result, the residual head is estimated to be approximately 22 m as shown in Fig. 3-10. The trial calculation is made according to William Hazen's formula on the assumption that the peak flow is 2.5 times the average daily flow. A study involving the fire water demand was omitted.

Fig. 3-9 Details of Distribution Pipe System in Vunicuicui

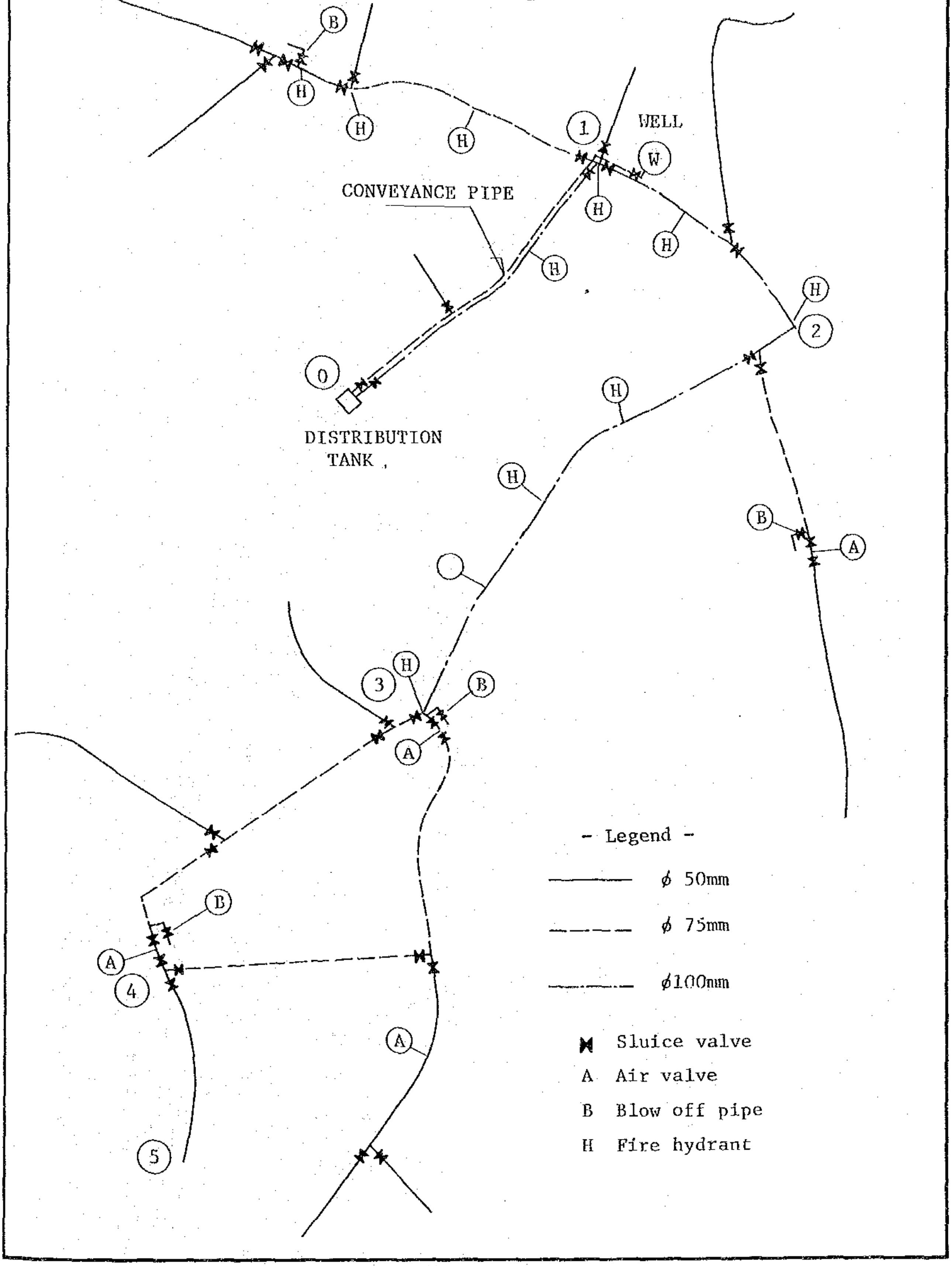
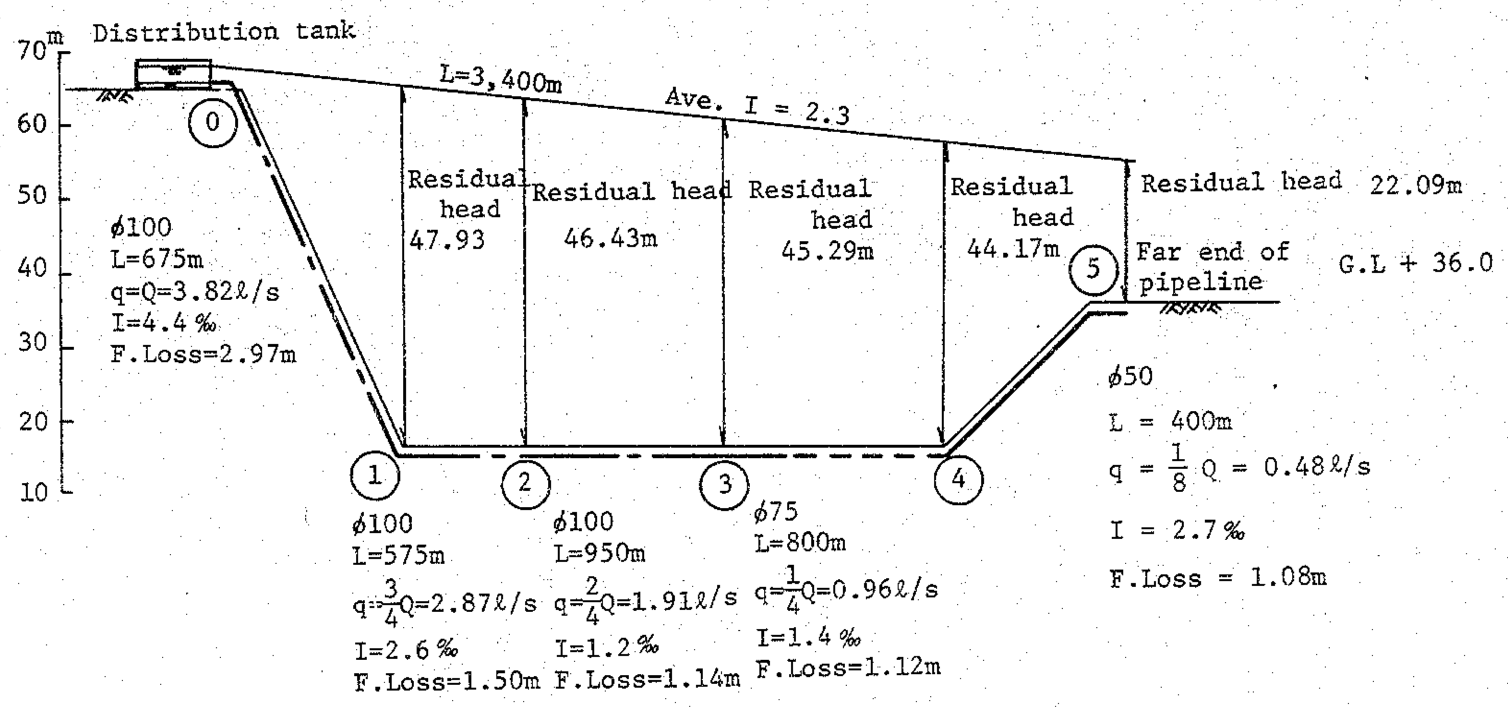


Fig. 3-10 Approximate Loss Head in the Distribution Pipe (Vunicuicui)



Residual head at the far end of pipe

= L.W.L. in the distribution tank − (G.L. at the far end of pipe + F.Loss)

= 65.9 − (36.0 + 2.97 + 1.50 + 1.14 + 1.12 + 1.08)

= 22.09m

(Note) The peak flow is assumed to be 2.5 times the average daily flow.
Calculated according to William Hazen's formula at C=110.

2) Village water supply

The basic design for Vunimoli which was selected as the model village is as follows.

(1) Intake facilities

A deep well will be bored within the village from which water will be taken by foot-operated pump. The water demand is assumed to be 8 m^3/day, and the pumping facilities are determined on the basis of a supposed case that water is consumed during 8 hours in a daytime.

a. Basic data and specifications for well pump

Type of pump : Foot-operated pump

Working mechanism:

When the pedal of the plunger pump, on the ground, is pushed by foot and pressure water is fed to the pump installed in the lower part of the well, the flexible baloon in the pump body inflates, and by the same working mechanism as the diaphragm pump, water in the pump barrel is pushed up through the water lift hose. When the pedal is let go, the baloon automatically deflates and groundwater is induced from the well into the pump barrel. Repetition of this process pump up water.

Lift head : 30 m

Flow rate : (Discharge) 1 to 1.5 m^3/hour

Borehole diameter: 150 mm

Pump body :	Total length	1.42 m
	Weight	6.5 kg
	Caliber	92 mm
Sleeve :	Length	750 mm
	Caliber	65 mm
	Elongation percentage	40 %
Superstructure :	Height	1.38 m
	Weight	16.5 kg
	Pedal stroke	250 mm
Command pipe :	Polyethylene 23 x 32	
Delivery pipe :	Polyethylene 26 x 32	
Pump mound :	Built with concrete 1.5 (W) x 1.5 (L) x 0.15(H) m	

(2) Water conveyance and distribution facilities

Water pressure fed by means of a foot-operated pump is conveyed to the distribution tank adjacent to the well through a ϕ25 polyethylene pipe, then from the tank distributed through ϕ25 rigid PVC pipes to the common water taps and shower huts.

a. Specifications for water conveyance and distribution facilities

Water conveyance pipe :

Polyethylene pipe	ϕ25, L = 9.0 m

Service pipe:

Rigid PVC pipe	ϕ25, L = 18.0 m
Galvanized steel pipe	ϕ25, L = 6.0 m
Galvanized steel pipe	ϕ13, L = 12.0 m
Fittings	ϕ25 to ϕ13 1 set
Valve	ϕ25 5 ea.
Water tap	ϕ13 2 ea.
Shower head and valve	ϕ13 2 ea.

Distribution tank :

Effective capacity 2.5 m^3, made of FRP, with mounting frame, 1 unit each

Shower hut : Zinc plate walled, 2.4 (W) x 2.4 (L)m, 1 place

Washing chamber: Made of concrete, 1.5 (W) x 1.8 (L)m, 2 places

Catch basin: Made of concrete, 0.4 (W) x 0.4 (L)m, 2 places

Drain pipe:

Rigid PVC pipe,	ϕ 75, L = 6.0 m
	ϕ100, L = 12.0 m
(for drainage)	ϕ150, L = 12.0 m

Details : As per the Drawings.

3-4-4. Plans for Other Areas

The plans for the model settlement and village are as described in the preceding paragraph. Outline of the plans for other areas and schools are mentioned here in this section.

1) *Plans for other settlements*

The estimated water demand was obtained by multiplying the average water demand per capita per day by the served population for each settlement as shown in Table 3-5-a. The figures are cited below.

Vunika	251 m^3/day
Vunimoli	19 "
Waidamudamu	18 "
Nabekavu	99 "
Vanibau Bua	27 "

The following is an outline of the plan for each settlements.

(1) Vunika

As the area is not only close to the coastal line but has mountains right in the hinterland, it is an area that can not afford any potential site of the well at an adequate distance any potential site of the well at an adequate distance from the coastal line, therefore, always be considered the possibility of sea water introsion by pumping the well. In this light, it would be difficult to supply all of the water demand from the 'porposed well, and that it would be recommended to plan on reducing the quantity of water to be pumped from the proposed well by receiving a part of the water supply from the Labasa waterworks.

Although the planned discharge is not determined accurately unless a test borehole is drilled and a pumping test is conducted first, the basic frame-work of the plan is drafted on the assumption that it will be feasible to intake all of the water demand from the proposed well. Only one well is planned as the production well in the area.

a. Well pump

Vertical shaft turbine pump for deep well 1 unit

Operating hours :	20 hours a day
Discharge :	210 l/min.
Diameter :	75 mm (3 inches)
Total head :	60 to 80 m
Output :	8.5 Hp
Prime mover :	
Diesel engine	15 Hp x 1,800 rpm, 4 cycle

b. Water conveyance pipe

Rigid PVC pipe (Class D, 120 m hd)

ϕ100, L = 3,200 m

Q = 3.5 l/sec., V = 0.44 m/sec.,

I = 3.7 ‰

c. Distribution tank

Hume's tank — 1 unit

Required capacity :	251 m^3 x 30 % = 75.3 m^3
Dimensions:	ϕ7.8 m x 1.6 m (effective water depth)

d. Distribution pipes

Rigid PVC pipe (Class C, 90 m hd.)

ϕ150, L = 4,800 m
ϕ100, L = 1,400 m
ϕ 75, L = 3,700 m
ϕ 50, L = 2,800 m

Common water tap: ϕ13 x 4 faucets x 73 places

(2) Vunimoli and Waidamudamu

These areas extend along the Labasa River with a large catchment area. The water requirement therefore can be easily met since the planned quantity of water pumping is small. Some places already have water supply facilities of their own while others are in the stage of planning, but the proposed plan should aim at providing improved facilities and services to the entire area inclusive these places. The plan calls for one producing well for each settlement.

a. Well pump

Mono type deep well pump — 2 units

Operating hours :	8 hours a day
Discharge :	40 l/min. (per each system)
Diameter :	ϕ50 mm (2 inches)
Total head :	60 to 80 m
Output :	3 Hp
Prime mover :	Diesel engine, 4 Hp x 2,000 rpm x 4 cycle

b. Water conveyance pipe

Rigid PVC pipe (Class D, 120 m hd.)

ø50, L = 4,100 m

Q = 0.66 l/sec., V = 0.34 m/sec.,

I = 4.9 ‰ (per each system)

c. Distribution tank

Hume's tank — 2 units

Required capacity: $19\ m^3 \times 16/24 = 12.7\ m^3$

Dimensions: ø3.3 m x 1.6 m (effective water depth)

d. Distribution pipe

Rigid PVC pipe (Class C, 90 m hd.)

ø75, L = 13,000 m

ø50, L = 7,400 m

Common water tap : ø13 x 4 faucets x 28 places

(3) Nabekabu

Although the planned quantity of water intake by pumping is relatively large, it will be sufficiently met the water demand by just one well judging from the pumping test results of the existing well. However, since the extended length of the distribution pipe system would have to be made excessively long in this case, with the result that the working water pressure at the far end of pipe may possibly become too low, the plan is prepared on the basis of intaking water from two production wells.

a. Well pump

Heavy duty vertical shaft turbine pump for deep well — 2 units

Operating hours : 8 hours a day

Discharge : 110 l/min. (per each system)

Diameter :	75 mm (3 inches)
Total head:	60 to 80 m
Output:	6.5 Hp
Prime mover:	Diesel engine, 15 Hp x 1,800 rpm x 4 cycle

b. Water conveyance pipe

Rigid PVC pipe (Class D, 120 m hd.)
ϕ 75, L = 4,300 m
Q = 1.72 l/sec.
V = 0.39 m/sec.,
I = 4.0 ‰ (per each system)

c. Distribution tank

Hume's tank 2 units

Required capacity :	99 $m^3/2 \times 16/24 = 33$ m^3
Dimensions :	ϕ5.2 m x 1.6 m (effective water depth)

d. Distribution pipe

Rigid PVC pipe (Class C, 90 m hd.)
ϕ100, L = 6,500 m
ϕ 75, L = 5,300 m
ϕ 50, L = 7,900 m

Common water tap: ϕ13 x 4 faucets x 81 places

(4) Vunivau Bua

As this area has low precipitation, the recharge of groundwater per unit land area is smaller than other areas. The potential intake quantity by pumping per well is therefore also small. But since the planned water quantity to be supplied is small, it can be obtained from a single well. Yet, because of the disadvantage to extend long pipeline and also for other reasons,

the plan is made having two production wells. Among the wells that have already been developed, there are some wells which show poor water quality, such as containing particularly high iron and manganese content. Threfore, before to utilize these as the producing wells, careful water quality test shall be necessary.

a. Well pump

Mono type deep well pump 2 units

Operating hours :	8 hours a day
Discharge :	30 l/min. (per each system)
Diameter :	ϕ50 mm (2 inches)
Total head :	60 to 80 m
Output :	3 Hp
Prime mover :	Diesel engine, 4 Hp x 2,000 rpm, 4 cycle

b. Water conveyance pipe

Rigid PVC pipe (Class D, 120 m hd.)
ϕ50, L = 3,000 m
Q = 0.47 l/sec.,
V = 0.24 m/sec.,
I = 2.6 ‰ (per each system)

c. Distribution tank

Hume's tank 2 units

Required capacity :	27 m^3/2 x 16/24 = 9 m^3
Dimensions :	ϕ3.0 m x 1.6 m (effective water depth)

d. Distribution pipe

Rigid PVC pipe (Class C, 90 m hd.)
ϕ 75, L = 8,000 m
ϕ 50, L = 7,300 m

Common water tap : ϕ13 x 4 faucets x 21 places

(5) Seaqaqa

Except where the existing water supply facilities are provided, the houses are spaced wide apart. The method of supplying water to these houses by piping is not advisable because the pipeline extension would become too long. A recommended plan is providing similar facilities as the ones that were planned for Vunimol village, that is dig a well for each or every few houses and install foot pumps. As the insufficient data to work on during the current investigation, it is difficult to map out a specific plan for Seaqaqa settlement. Then, it is confined to merely recommending, as a directional guide, to provide the kind of water supply facilities that have been planned in the villages as stated before.

2) Plan for other villages

This paragraph covers the basic framework of the plans for villages other than Vunimoli which has been planned as for the model village. The design water demands are tabulated in Table 3-5-b, also shown in the following.

Namoli	5 m^3/day
Korowiri	10 "
Vuo	29 "
Matai Labasa	56 "

The design water demands of the villages have a wide variance of more than 10 times between the smallest of 5 m^3/day and the largest of 56 m^3/day. This is because the values for Vuo and Matai Labasa, in particular, are estimated on the basis of the total population of several communities of which the villages are composed. Since the basic idea of the investigation is to plan one water supply facility for each community, it means that the two villages mentioned above will require several water supply facilities.

The conceived water supply system plan for each village as a single community is as outlined below.

Typical village population: 150 to 200 people

Design water demand for a typical village:

8 to 12 m^3/day

(50 to 60 l/capita/day)

When the water supply system is planned on the basis of a design water demand ranging between 8 to 12 m^3/day, water will be supplied to the villagers by a system similar to the one that was planned for Vunimoli, the model village, the standard design of which is as outlined below.

(1) Standard design of village water supply system

a. Well pump

Foot-operated pump, made of stainless steel

1 unit

Borehole diameter :	ϕ150
Lift head :	30 m
Discharge :	1 to 1.5 m^3/hour
Pump diameter :	92 mm
Diameter of drive hose:	26 x 32
Diameter of discharge hose :	26 x 32
Pump mound :	Made of concrete 1.5 (W) x 1.5 (L) x 0.15 (H)m

b. Water conveyance and distribution facilities

Water conveyance pipe :	Polyethylene pipe ϕ25, L = 9.0 m
Service pipe :	Rigid PVC pipe, ϕ25, L = 18.0 m

	Galvanized steel pipe ϕ25, L = 6.0 m ϕ13, L = 12.0 m Valve ϕ25 5 ea. Faucet ϕ13 2 ea. Shower head & valve ϕ13 2 ea.
Distribution tank:	Effective capacity 2.5 m^3, made of FRP, with mounting frame 1 unit
Shower hut :	Zinc plate walled, 2.4(W) x 2.4(L)m, 1 place
Washing chamber :	Made of concrete, 1.5(W) x 1.8 (L)m, 1 place
Catch basin :	Made of concrete, 0.4(W) x 0.4 (L)m, 2 places
Drain pipe :	Rigid PVC pipe, (for drainage) ϕ 75, L = 6.0 m ϕ100, L = 12.0 m ϕ150, L = 12.0 m

3) Water supply plan for schools

Schools taken up as objects of this study are shown below along with the estimated water demand of each school based on the number of pupils.

Coqueloa (Thonggeloa) Sangam School	4 m^3/day
Valebasoga Primary School	10 "
Lekutu Junior Secondary School	13 "
Lekutu Bhartiya School	4 "

The design water demand is classified into 4 m^3/day and 10 to 13 m^3/day. Assuming that the indicated water demand is to be pumped up during 2 hours in the morning, the capacity of the well pump was determined as follows:

Description	Case 1 (4 m^3/day)	Case 2 (10 - 13 m^3/day)
Type of pump	Mono type deep well pump	Mono type deep well pump
No. of pumps	2	2
Borehole dia. of well	ϕ150	ϕ150
Operating hours	2 hours a day	2 hours a day
Dischrage (pumped intake)	40 l/min.	110 l/min.
Total head	30 m	30 m
Output	1.5 Hp	2 Hp
Prime mover	Diesel engine 4 Hp x 2,000 rpm 4 cycle	Diesel engine 4 Hp x 2,000 rpm 4 cycle

Three of the above schools have water supply facilities which are not used now due to failure of the pumps. It is considered that, by installing well pumps, these facilities can be restored to function as water supply systems.

3-5. Estimated Construction Costs

The construction costs for the water supply systems in six settlements, five villages, and four schools covered by the present survey were estimated, based on the present (December 1980) levels of prices. Estimated results are presented in Tables 3.9.a - 3.9.i.

The construction costs are divided into construction material costs and labor costs, and further into foreign currency components and local currency components.

The main parts of the foreign currency components consist of casing and screen for well construction materials, pipes, Hum's tanks (Fiji-made but counted as foreign component) and FRP panel tanks for water distribution materials and pumping equipment. The foreign components of well drilling machines and ancillary equipment, and ocean freight are presented by a separate item. Regarding the local currency component, cement, aggregates, steel bars, crushed stone etc. as raw materials, and labor costs are included. In addition, estimation of labor costs is based on the wage rates of the Fiji government and the required manpower for each work is based on the references from Japan's government - subsidized construction works of environmental and sanitary facilities.

The estimates of construction costs are presented in Tables 3.9.a - 3.9.i. A summary of these figures are shown in Table 3.8.

Table 3-8 Foreign and Local Components of Total Construction Cost

	Foreign Component	Local Component			Total
	Material	Materials	Labor	Temporary work	
In million of yen	173.0	59.7	66.7	15.8	315.2
As percentage of total construction cost	55	19	21	5	100

According to Table 3.8, the total construction cost was estimated at 315 million yen, of which 55 % or 173 million yen is the foreign component and 45 percent or 142 million yen is the local component. Included in the local component are material cost (60 million yen), labor cost (67 million yen) and temporary works cost (16 million yen).

On the other hand, according to the Eighth 5 Year Development Plan (1981 - 85) of Fiji, the total budget for rural water supply development plan for settlements and villages is expected 4.44 million Fiji dollars or about 1240 million yen. Therefore, the estimate of total construction cost of the present project shares some 25 percent of the Fiji government's budget for rural water supply development plan.

In addition to the drilling rig, the equipment and materials estimated in the construction cost above will be mentioned later in connection with the cooperation objects and their effects.

The foreign exchange rates used in this estimation are :

1 F$ = 280 ¥ = 1.33 US$

Table 3.9.a. ESTIMATED CONSTRUCTION COSTS : ALL PROJECT AREAS

ITEMS	DETAILS	MATERIAL			LABOR	TOTAL			REMARKS
		FOREIGN COMPONENT	LOCAL COMPONENT	SUB-TOTAL	LOCAL	FOREIGN	LOCAL	TOTAL	
SETTLEMENTS		¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	
VUNICUICUI		17,610	6,359	23,969	7,510	17,610	13,869	31,479	
VUNIKA		41,275	13,060	54,335	11,315	41,275	24,375	65,650	
VUNIMOLI & WAIDAMUDAMU		28,648	11,912	40,560	15,790	28,648	27,652	56,300	
NABEKAVU		38,878	13,932	52,810	18,108	38,878	29,722	68,600	
VUNIVAU BUA		22,179	9,083	31,262	11,938	22,179	21,021	43,200	
SUB-TOTAL		148,590	54,346	202,936	62,293	148,590	116,639	265,229	
VILLAGE									
VUNIMOLI		1,822	473	2,295	395	1,822	868	2,690	
OTHERS (9 VILLAGES)		16,398	4,257	20,655	3,555	16,398	7,812	24,210	
SUB-TOTAL		18,220	4,730	22,950	3,950	18,220	8,680	26,900	
SCHOOL (4 SCHOOLS)		6,225	585	6,810	420	6,225	1,005	7,230	
SUB-TOTAL		6,225	585	6,810	420	6,225	1,005	7,230	
TOTAL (Direct Construction Cost)		173,035	59,661	232,696	66,663	173,035	126,324	299,359	
TEMPORARY WORKS							15,841	15,841	5% of direct Construction Cost
TOTAL		173,035	59,661	232,696	66,663	173,035	142,165	315,200	

Table 3.9.b. ESTIMATED CONSTRUCTION COST : VUNICUICUI SETTLEMENT

ITEMS	DETAILS	MATERIAL			LABOR	TOTAL			REMARKS
		FOREIGN COMPONENT	LOCAL COMPONENT	SUB-TOTAL	LOCAL	FOREIGN	LOCAL	TOTAL	
		¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	
1. Well Construction Works									
1-1 Well construction	ϕ150 x 70m x 1 well	625	20	645	205	625	225	860	
1-2 Pumping equipment Installation	Vertical shaft pump with heavy duty diesel engine ϕ75 x 6.5HP x 1 set	2,000		2,000	40	2,000	40	2,040	
1-3 Pump house construction	(W) (L) 2.55 m x 5.05 m x 1 dwell		565	565	175		740	740	
SUB-TOTAL		2,625	585	3,210	420	2,625	1,005	3,630	
2. Laying of Conveyance Pipe									
2-1 Material cost	PVC, CLASS D, Rubber ring ϕ75 x 804 m	3,137	113	3,250		3,137	113	3,250	
2-2 Laying Pipes	"		249	249	511		760	760	
SUB-TOTAL		3,137	362	3,499	511	3,137	873	4,010	
3. Distribution Tank Construction Works	Hume's Tank (H) DIA. 6.0 x 2.1 m x 1 reservoir	367	535	902	327	367	862	1,229	
4. Laying of Distribution Pipes									
4-1 Pipe material cost	PVC, CLASS C, Rubber ring ϕ100 x 2,500 m	4,879		4,879		4,879		4,879	
	ϕ75 x 3,500 m	3,906		3,906		3,906		3,906	
	ϕ50 x 4,900 m	2,696		2,696		2,696		2,696	
	Other material costs		2,689	2,689			2,689	2,689	

Table 3.9.b ESTIMATED CONSTRUCTION COST : VUNICUICUI SETTLEMENT (Cont'd)

ITEMS	DETAILS	MATERIAL			LABOR	TOTAL			REMARKS
		FOREIGN COMPONENT	LOCAL COMPONENT	SUB-TOTAL	LOCAL	FOREIGN	LOCAL	TOTAL	
		¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	
4-2 Laying Pipes	PVC, CLASS C, Rubber ring ϕ100 x 2,500 m				1,338		1,338	1,338	
	ϕ75 x 3,500 m				1,705		1,705	1,705	
	ϕ50 x 4,900 m				2,352		2,352	2,352	
	Other Setting and Construction Costs		2,188	2,188	857		3,045	3,045	
SUB-TOTAL		11,481	4,877	16,358	6,252	11,481	11,129	22,610	
TOTAL (Direct construction cost)		17,610	6,359	23,969	7,510	17,610	13,869	31,479	
TEMPORARY WORKS							1,621	1,621	5% of direct construction cost
TOTAL		17,610	6,359	23,969	7,510	17,610	15,490	33,100	

Table 3.9.c. ESTIMATED CONSTRUCTION COST : VUNIKA SETTLEMENT

ITEMS	DETAILS	MATERIAL			LABOR	TOTAL			REMARKS
		FOREIGN COMPONENT	LOCAL COMPONENT	SUB-TOTAL	LOCAL	FOREIGN	LOCAL	TOTAL	
		¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	
1. Well Construction Works									
1-1 Well construction	ϕ150 x 70m x 1 well	625	20	645	205	625	225	850	
1-2 Pumping equipment Installation	Vertical turbine pump with heavy duty diesel engine ϕ75 x 8.5 Hp x 1 set	2,000		2,000	100	2,000	100	2,100	
1-3 Pump house construction	(W) (L) 2.55 m x 5.05 m x 1 dwell		535	535	165		700	700	
SUB-TOTAL		2,625	555	3,180	470	2,625	1,025	3,650	
2. Laying of Conveyance Pipe									
2-1 Material cost	PVC, CLASS D, Rubber ring ϕ100 x 3,200 m	10,340	760	11,100		10,340	760	11,100	
2-2 Laying Pipes	"		1,112	1,112	2,288		3,400	3,400	
SUB-TOTAL		10,340	1,872	12,212	2,288	10,340	4,160	14,500	
3. Distribution Tank Construction Works	Hume's Tank (H) DIA. 7.8 m x 2.1 m x 1 reservoir	628	914	1,542	558	628	1,472	2,100	
4. Laying of Distribution Pipes									
4-1 Pipe material	PVC, CLASS C, Rubber ring ϕ150 x 4,800 m ϕ100 x 1,400 m ϕ75 x 3,700 m ϕ50 x 2,800 m Other material costs	27,682	6,918	34,600		27,682	6,918	34,600	

Table 3.9.c. ESTIMATED CONSTRUCTION COST : VUNIKA SETTLEMENT (Cont'd)

ITEMS	DETAILS	MATERIAL			LABOR	TOTAL			REMARKS
		FOREIGN COMPONENT	LOCAL COMPONENT	SUB-TOTAL	LOCAL	FOREIGN	LOCAL	TOTAL	
		¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	
4-2 Laying Pipes construction cost	PVC, CLASS C, Rubber ring ϕ150 x 4,800 m								
	ϕ100 x 1,400 m								
	ϕ75 x 3,700 m		2,801	2,801	7,999		10,800	10,800	
	ϕ50 x 2,800 m								
	Other Setting and Construction Costs								
SUB-TOTAL		27,682	9,719	37,401	7,999	27,682	17,718	45,400	
TOTAL (Direct construction cost)		41,275	13,060	54,335	11,315	41,275	24,375	65,650	
TEMPORARY WORKS							3,350	3,350	5% of direct construction cost
TOTAL		41,275	13,060	54,335	11,315	41,275	27,725	69,000	

Table 3.9.d. ESTIMATED CONSTRUCTION COST : VUNIMOLI & WAIDAMUDAMU SETTLEMENTS

ITEMS	DETAILS	MATERIAL			LABOR	TOTAL			REMARKS
		FOREIGN COMPONENT	LOCAL COMPONENT	SUB-TOTAL	LOCAL	FOREIGN	LOCAL	TOTAL	
		¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	
1. Well Construction Works									
1-1 Well construction	ϕ150 x 70 m x 2 wells	1,250	40	1,290	410	1,250	450	1,700	
1-2 Pumping equipment Installation	Mono pump with diesel engine ϕ50 x 3 Hp x 2 sets	2,800		2,800	100	2,800	100	2,900	
1-3 Pump house construction	(W) (L) 2.55 m x 5.05 m x 2 dwells		1,147	1,147	353		1,500	1,500	
SUB-TOTAL		4,050	1,187	5,237	863	4,050	2,050	6,100	
2. Laying of Conveyance Pipe									
2-1 Material cost	PVC, CLASS C, Rubber ring ϕ50 x 4,100 m	5,802	298	6,100		5,802	298	6,100	
2-2 Laying Pipes	"		1,308	1,308	2,692		4,000	4,000	
SUB-TOTAL		5,802	1,606	7,408	2,692	5,802	4,298	10,100	
3. Distribution Tank Construction Works	Hume's Tank (H) DIA. 3.3 m x 2.1 m x 2 reservoir	209	305	514	186	209	491	700	
4. Laying of Distribution Pipes									
4-1 Pipe material	PVC, CLASS C, Rubber ring ϕ75 x 13,000 m								
	ϕ50 x 7,400 m	18,587	4,613	23,200		18,587	4,613	23,200	
	Other material costs								

Table 3.9.d. ESTIMATED CONSTRUCTION COST : VUNIMOLI & WAIDAMUDAMU SETTLEMENTS (Cont'd)

ITEMS	DETAILS	MATERIAL			LABOR	TOTAL			REMARKS
		FOREIGN COMPONENT	LOCAL COMPONENT	SUB-TOTAL	LOCAL	FOREIGN	LOCAL	TOTAL	
		¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	
4-2 Laying Pipes	PVC, CLASS C, Rubber ring ϕ75 x 13,000 m								
	ϕ50 x 7,400 m		4,201	4,201	11,999		16,200	16,200	
	Other Setting and Construction Costs								
SUB-TOTAL		18,587	8,814	27,401	11,999	18,587	20,813	39,400	
TOTAL (Direct construction cost)		28,648	11,912	40,560	15,740	28,648	27,652	56,300	
TEMPORARY WORKS							2,800	2,800	5% of direct construction cost
TOTAL		28,648	11,912	40,560	15,740	28,648	30,452	59,100	

Table 3.9.e. ESTIMATED CONSTRUCTION COST : NABEKAVU SETTLEMENT

ITEMS	DETAILS	MATERIAL FOREIGN COMPONENT	MATERIAL LOCAL COMPONENT	MATERIAL SUB-TOTAL	LABOR LOCAL	TOTAL FOREIGN	TOTAL LOCAL	TOTAL TOTAL	REMARKS
		¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	
1. Well Construction Works									
1-1 Well construction	ϕ150 x 70 m x 2 wells	1,250	40	1,290	410	1,250	450	1,700	
1-2 Pumping equipment Installation	Vertical turbine pump with heavy duty diesel engine ϕ75 x 6.5 HP x 2 sets	4,000		4,000	100	4,000	100	4,100	
1-3 Pump house construction	(W) (L) 2.55 m x 5.05 m x 2 dwells		1,147	1,147	353		1,500	1,500	
SUB-TOTAL		5,250	1,187	6,437	863	5,250	2,050	7,300	
2. Laying of Conveyance Pipe									
2-1 Material cost	PVC, CLASS D, Rubber ring ϕ75 x 4,300 m	10,160	640	10,800		10,160	640	10,800	
2-2 Laying Pipes	"		1,537	1,537	3,163		4,700	4,200	
SUB-TOTAL		10,160	2,177	12,337	3,163	10,160	5,340	15,500	
3. Distribution Tank Construction Works	Hume's Tank (H) DIA. 5.2 m x 2.1 m x 2 reservoir	568	827	1,395	505	568	1,332	1,900	
4. Laying of Distribution Pipes									
4-1 Pipe material	PVC, CLASS C, Rubber ring ϕ100 x 6,500 m ϕ75 x 5,300 m ϕ50 x 7,900 m Other material costs	22,900	5,800	28,700		22,900	5,800	28,700	

Table 3.9.e. ESTIMATED CONSTRUCTION COST : NABEKAVU SETTLEMENT (Cont'd)

ITEMS	DETAILS	MATERIAL			LABOR	TOTAL			REMARKS
		FOREIGN COMPONENT	LOCAL COMPONENT	SUB-TOTAL	LOCAL	FOREIGN	LOCAL	TOTAL	
		¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	
4-2 Laying Pipes	PVC, CLASS C, Rubber ring ϕ100 x 6,500 m ϕ 75 x 5,300 m ϕ50 x 7,900 m Other Setting and Construction Costs		3,941	3,941	11,259		15,200	15,200	
SUB-TOTAL		22,900	9,741	32,641	11,259	22,900	21,000	43,900	
TOTAL (Direct construction cost)		38,878	13,932	52,810	15,790	38,878	29,722	68,600	
TEMPORARY WORKS							3,400	3,400	5% of direct construction cost
TOTAL		38,878	13,932	52,810	15,790	38,878	33,122	72,000	

Table 3.9.f. ESTIMATED CONSTRUCTION COST : VUNIVAU BUA SETTLEMENT

ITEMS	DETAILS	MATERIAL			LABOR	TOTAL			REMARKS
		FOREIGN COMPONENT	LOCAL COMPONENT	SUB-TOTAL	LOCAL	FOREIGN	LOCAL	TOTAL	
		¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	
1. Well Construction Works									
1-1 Well construction	ϕ150 x 70 m x 2 wells	1,250	40	1,290	410	1,250	450	1,700	
1-2 Pumping equipment Installation	Mono pump with diesel engine ϕ50 x 3 Hp x 2 sets	2,800		2,800	100	2,800	100	2,900	
1-3 Pump house construction	(W) (L) 2.55 m x 5.05 m x 2 dwells		1,147	1,147	353		1,500	1,500	
SUB-TOTAL		4,050	1,187	5,237	863	4,050	2,050	6,100	
2. Laying of Conveyance Pipe									
2-1 Material cost	PVC, CLASS D, Rubber ring ϕ50 x 3,000 m	5,050	250	5,300		5,050	250	5,300	
2-2 Laying Pipes	"		948	948	1,952		2,900	2,900	
SUB-TOTAL		5,050	1,198	6,248	1,952	5,050	3,150	8,200	
3. Distribution Tank Construction Works	Hume's Tank (H) DIA. 3.0 m x 2.1 m x 2 reservoir	179	261	440	160	179	421	600	
4. Laying of Distribution Pipes									
4-1 Pipe material	PVC, CLASS C, Rubber ring ϕ75 x 8,000 m								
	ϕ50 x 7,300 m	12,900	3,300	16,200		12,900	3,300	16,200	
	Other material costs								

Table 3.9.f. ESTIMATED CONSTRUCTION COST : VUNIVAU BUA SETTLEMENT (Cont'd)

ITEMS	DETAILS	MATERIAL FOREIGN COMPONENT	MATERIAL LOCAL COMPONENT	MATERIAL SUB-TOTAL	LABOR LOCAL	TOTAL FOREIGN	TOTAL LOCAL	TOTAL TOTAL	REMARKS
		¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	
4-2 Laying Pipes	PVC, CLASS C, Rubber ring ∅75 x 8,000 m								
	∅50 x 7,300 m		3,137	3,137	8,963		12,100	12,100	
	Other Setting and Construction Costs								
SUB-TOTAL		12,900	6,437	19,337	8,963	12,900	15,400	28,300	
TOTAL (Direct construction cost)		22,179	9,083	31,262	11,938	22,179	21,021	43,200	
TEMPORARY WORKS							2,200	2,200	5% of direct construction cost
TOTAL		22,179	9,083	31,262	11,938	22,179	23,221	45,400	

Table 3.9.g. ESTIMATED CONSTRUCTION COST : VUNIMOLI VILLAGE SETTLEMENT

ITEMS	DETAILS	MATERIAL			LABOR	TOTAL			REMARKS
		FOREIGN COMPONENT	LOCAL COMPONENT	SUB-TOTAL	LOCAL	FOREIGN	LOCAL	TOTAL	
		¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	
1. Well Construction Works	ϕ150 x 70 m x 1 well	625	20	645	205	625	225	850	
2. Casing and Screen Stopcock Construction	ϕ13 x 2 Stopcocks		37	37	16		53	53	
3. Panel Tank Construction Works	FRP-made; effective capacity : 2.5 m^3	618	328	946	64	618	392	1,010	
4. Shower House Construction Works	(W) (L) 2.4 m x 2.4 m	11	50	61	35	11	85	96	
5. Distribution Pipe Installation Works	Polyethylene Pipe ϕ25 x 9 m PVC ϕ25 x 18 m SGP ϕ25 x 1 m SGP ϕ13 x 12 m	12		12	6	12	6	18	
6. Drainage Equipment Installation Works	For Sewage PVC ϕ75 x 6 m PVC ϕ100 x 12 m PVC ϕ150 x 12 m	56	30	86	23	56	53	109	
7. Foot Operated Pump Installation Works	H = 30 m Q = 1 - 1.5 m^3/hr	500		500	5	500	5	505	
8. Miscellaneous Works			8	8	41		49	49	
TOTAL (Direct Construction Cost)		1,822	473	2,295	395	1,822	868	2,690	
TEMPORARY WORKS							210	210	5% of direct construction Cost
TOTAL		1,822	473	2,295	395	1,822	1,078	2,900	

Table 3.9.h. ESTIMATED CONSTRUCTION COST : FOUR OTHER VILLAGES (9 WELLS)

ITEMS	DETAILS	MATERIAL			LABOR	TOTAL			REMARKS
		FOREIGN COMPONENT	LOCAL COMPONENT	SUB-TOTAL	LOCAL	FOREIGN	LOCAL	TOTAL	
		¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	
1. Well Construction Works	ϕ150 x 70 m x 9 wells	5,625	180	5,805	1,845	5,625	2,025	7,650	
2. Casing and Screen Stopcock Construction	ϕ13 x 2 stopcocks x 9sets		333	333	144		477	477	
3. Panel Tank Construction Works	FRP-made; effective capacity : 2.5 m^3 x 9 sets	5,562	2,952	8,514	576	5,562	3,528	9,090	
4. Shower House Construction Works	(W) (L) 2.4 m x 2.4 m x 9 dwells	99	450	549	315	99	765	864	
5. Distribution Pipe Installation Works	Polyethylene Pipe ϕ25 x 9 m x 9 PVC ϕ25 x 18 m x 9 SGP ϕ25 x 1 m x 9 SGP ϕ13 x 12 m x 9	108		108	54	108	54	162	
6. Drainage Equipment Installation Works	For Sewage PVC ϕ75 x 6 m x 9 PVC ϕ100 x 12 m x 9 PVC ϕ150 x 12 m x 9	504	270	774	207	504	477	981	
7. Foot Operated Pump Installation Works	H = 30 m Q = 1 - 1.5 m^3/hr 9 sets	9,500		4,500	45	4,500	45	4,545	
8. Miscellaneous Works			72	72	369		441	441	
TOTAL (Direct Construction Cost)		16,398	4,257	20,655	3,555	16,398	7,812	24,210	
TEMPORARY WORKS							1,890	1,890	5% of direct construction cost
TOTAL		16,398	4,257	20,655	3,555	16,398	9,702	26,100	

Table 3.9.1. ESTIMATED CONSTRUCTION COST : SCHOOLS (4 SCHOOLS)

ITEMS	DETAILS	MATERIAL			LABOR	TOTAL			REMARKS
		FOREIGN COMPONENT	LOCAL COMPONENT	SUB-TOTAL	LOCAL	FOREIGN	LOCAL	TOTAL	
		¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	¥1,000	
1. Well Construction Works	ϕ150 x 70 m x 1 well	625	20	645	205	625	225	850	3 wells already constructed
2. Mono Type Pump	ϕ40 x 3 KW x 4 sets	5,600		5,600	40	5,600	40	5,640	
3. Pumphouse Construction Works			565	565	175		740	740	
SUB-TOTAL		6,225	585	6,810	420	6,225	1,005	7,230	
TEMPORARY WORKS							370	370	
						6,225	1,375	7,600	

CHAPTER 4 JAPANESE COOPERATION

CHAPTER 4. JAPANESE COOPERATION

4-1. Outline of Proposed Assistance

The objective of the present study is, on the other words, to search for efficient measures of financial aid that Japan can cooperate to assist the Fiji Government in the rural water supply development plan through a groundwater development project in Vanua Levu Island. As financial assistance is considered most efficient, the present study was focussed on estimation of construction costs and listing of necessary materials and equipment for the objected higher priority area in Vanua Levu, through the basic design of water supply system for the area, also, on identification of major important points associated with the fulfilment of the project.

The study finally comes to a conclusion that if the project is undertaken by the Public Works Department (PWD) of the Fiji Government, the total construction cost for the water supply facilities planned for six settlements, five villages, and four schools covered by the present study would be about 315 million yen, of which 173 million yen is estimated as the foreign cost component for imported materials and equipment.

Regarding the major items suggested for financial assistance, one set of well drilling machine is considered to be the highest priority. Since pumps and water distribution materials are indispensable to the establishment of the water supply systems, their foreign component also presents a prior item for financial assistance.

If assistance is finally determined as Japanese cooperation to the request for assisting the rural water supply development plan at Vanua Levu, financial assistance for the purchase of materials and equipment required for the project seems most adequate and efficient.

4-2. Materials and Equipment Suggested for Aid Scheme and Cost Estimation

4-2-1. Materials and Equipment Suggested for Aid Scheme

(1) Water well drilling rig, air compressor, test pump, tender vehicles and tents for well drilling and pumping test.

(2) Pipes for water distribution.

(3) Well pumps.

(4) Water distribution materials for the model settlement (Vunicuicui) and distribution materials and tanks for village areas.

(5) Spare parts and supplies for two years.

4-2-2. Decisive Factors in the Selection of Materials and Equipment

(1) Well drilling rig and ancillary equipment

The choice of well drilling rig of proper type and capacity was made with careful consideration of the topographical and geological conditions of the project area, as well as the experiences and request of the Fiji Government and local officers.

Geology of Vanua Levu Island is mainly composed of volcanic rocks and sedimentary rocks, and its topography is characterized by the existence of numerous hills. The investigated area is located near coasts in the south and northeastern parts of the island, which covers an alluvial plain of lowland river basin in the center part, and dominated mainly by inter-hill basin. Under these circumstances selected machines should be sufficiently powerful type suitable for mountainous area. In addition, the rig shall be able to move in a limited site of comparatively small area. For these reason, it is suggested that the drill rig shall be mounted on a 4 x 4 wheel drive truck as carrier.

As for the method of drilling, the hydraulic rotary method using direct mud circulation system is considered safe and most appropriate. However, to cope with the volcanic rocks that are often encountedred in the area, the air percussion drilling method is recommended to supplement the above-described rotary method. To enable the above two drilling methods, it is recommended to specify hydraulic top-head drive drilling rig. This type of rig has a property that the sizes and combination of drill strings can be easily adjusted to fit the desired drilling method. The number of bit rotation, feed pressure, and feed speed can be freely adjusted for the utilization of air hammer in rocky conditions.

For air-hummer drilling, bit rotation should be freely adjusted in the range of 10 - 30 r.p.m., and fine adjustment of feed pressure and speed should be feasible. Thus, instead of hydraulic motor, hydraulic cylinder type feed system was chosen. In order to avoid overload of truck, a separated trailer mounted air compressor was selected. This type of air compressor can be placed away from the rig, so that negative effects of excessive noise and consequent danger can be substantially reduced.

The Universal rigs presently used in Fiji which were donated by the Government of Australia have different functions but similar operation method with the above-described rigs. Fijian engineers, thus, can easily get used with the recommended rig. This choice of rig is also in accord with a strong request by the senior engineering officer of MRD. The following ancillary equipment is also chosen with careful consideration of geographical conditions and existing experiences from the Fijian engineers. Efforts were made to select and design two types of drill pipes of 3-meters long, one is suitable for air hammer and the other for mud rotary method, in order to minimize impediments of the air hammer operation.

Regarding the mud circulation method of rotary drilling, three cutter rock bits of sizes 146 mm, 194 mm, 245 mm and 311 mm are recommended so that operation can be made on geological conditions ranging from soft to medium hard formations. In the case of hard limestones and hard volcanic rocks where the drilling is difficult, temporary casing of superficial strata is recommended before changing to air hammer method.

The air-drilling method has an advantage in that the condition of ground water can be detected during drilling. The TC insert type are recommended to cope with extremely hard rocks. Besides, a dumper sub is suggested to fit under the drill head to reduce shocks caused by air hammer. On the other hand, regarding pump for testing, submersible type with diesel generator is proposed in response to a request from the Fijian engineers.

Considering high possibility of salt water penetration in a number of sites in Vunika and hot spring areas, a simple single-channel well logger with resistivity and spontaneous potential modules was chosen. Additional module for the temperature log is also included.

The completion of wells is carried out mainly by air lift method. However, as jettling has shown considerable results in Fiji and in response to a request from the Fijian engineers, high pressure pump of duplex type is recommended for jetting development in this project.

Proposed tender vehicles are to meet the minimum requirement. Cargo truck with HIAB type crane is for transportation of machinery, pipes and water for construction use. The main reason for the choice of HIAB type crane is that by using arms instead of winches in hoisting, this type is less dangerous and easy to handle according to Fijian practices in the past. Pickup truck is recommended, first, for the transportation of drilling and construction crew and daily supplies and, second for the reason that Fijian department has seriously shortage of vehicles.

Sheets are to protect PVC and other supplies in the project field from direct sun light. Tents will be used as shelters for temporary mobilization. Locally produced shelters can be used instead of mobil-houses at work.

(2) Well construction materials

Recommended well construction materials consist mainly of temporary casing for caving formation, PVC slotted well screen and PVC pipes. Among these materials, Fiji-made PVC pipes may be prepared to meet the demand of 20 wells planned for construction. These estimates were made by assuming 120 m of depth for an average well. Approximately 50 m of depth for wells will be uncased because of hard rocks, but 30 m of blind pipe and 40 m of slotted pipes are assumed to be used in an average well constructed in unconsolidated formation.

The demand of well in Vanua Levu Island is forecasted to be largely increased in future when the development of Seaqaqa is realized. For this reason, 20 units of well construction materials are planned for assistance to this project.

It is desirable that Fiji can produce PVC screen in the near future. For this purpose, the slotted pipes donated by Japan must be used as the sample so that local facility can process slots in future, and for this purpose a simple sloting machine from Japan, if available, would contribute greatly to this achievement.

(3) Well pumps

The choice of pumps was made with consideration for the quantity of water, water level, and maintenance. From the Fiji's side, the first priority is in principle for gravity water supply, and the Fiji Government tends to consider pumped water supply of the second priority

It is the engineers view that at the small village level foot-operated pumps are adequate. And for populated settlement areas where operation and maintenance will be undertaken by

local inhabitants, pumps with diesel engines are recommended. Specially, for such settlements like Vunicuicui where population and pumping water quantity is large, the deep well turbine pump with appropriate diesel power unit is suitable; while for settlements with smaller water demand, Australian made Mono pumps are chosen. Mono pumps which have been effectively used in Fiji have small capacity but high pumping head. Fiji authorities strongly requested the adoptation of these Mono pumps for convenience in maintenance, in addition to the popularity of the Mono pumps in Fiji.

Mono pumps are submersible but of positive displacement type and can run at low speed and lift water to high level, due to constant amount of water is displaced in each rotation. Owing to these properties, this type of pump has been widely used in projects of developing countries. These pumps are also made in England, but associated price and maintenance costs of Australian-made ones are more reasonable in Fiji.

Foot operated pumps are considered suitable to village water supply systems for the following properties. First, their submersible pumping part does not require preservation. Second, their on ground drive piston not only can be maintained by exchanging a few parts each year but the part replacement can be easily handled by village inhabitants. Besides, the installation of these pumps does not require sophisticated equipment. These pumps can be set at 30 m in depth from the land surface and can lift water to the elevated tank.

(4) Water distribution materials

Regarding water distribution materials, PVC pipes and Hume's tank sufficient for the establishment of the system in model area at Vunicuicui settlement are recommended. This decision was based on limited budget scale and expectation of movement towards self-help in the settlement. Except a small portion of special valves, recommended distribution materials consist mainly of Fiji-made items.