the method of analysis used for geophysical prospecting and the analysis results, and to certify the hydrogeological conditions of aquifer.

3.3.1 Geophysical Prospecting

Two types of geophysical prospecting, such as vertical electrical sounding of electrical resistivity and electromagnetic sounding, have been implemented in this study.

Vertical electrical sounding (Schlumberger method) was carried out to cover most parts of the Project Area (487 points), while electromagnetic sounding (EM method) was to cover the area thinly-overlain by superficial sediments (996 points).

These points were selected from the results of remote sensing analysis , aerophotographic interpretation, geologic and hydrogeological investigation; and special attention was paid to geologic structure and sediment materials, as well as village distribution and water demand.

3.3.2 Results of Geophysical Prospecting Works

1) Figures 3.8 (1) and 3.8 (2) show the allocations of traverse lines in this study, while, Figure 3.9 (1)~(4) provide geological structural interpretations along traverse lines.
   Approximate ranges of apparent specific resistivity values, in accordance with the rock facies shown in drill log sheets, are listed in Table 3.3.
   Apparent specific resistivity values of Tertiary beds are estimated to be generally low, and extremely low at 3 to 7 Ω. m in mudstone beds. Apparent low resistivity values of Tertiary beds are estimated to be caused by ground water with variable salinity.

2) Llano de Yaque del Norte
   Based on the results of the stations, T-1 to K-3 (Figure 3.9 (1) to (2)), traversely lined on the low land at about 15 m above sea level, the flat lowland of Rio Yaque del Norte generally shows a relatively constant distribution of specific resistivity values as stated below:

   (1) In general, the lowland shows a 2-layer-structure with continuity, i.e., overlying high specific resistivity layer of 9 to 23 Ω. m and underlying low specific resistivity layer of 2-8 Ω. m.

   (2) Overlying high specific resistivity layer is locally intercalated by low specific resistivity layer of lenticular form.

(3) Overlying high specific resistivity layer is estimated to be thick, reaching about 80 m in the lowland and further south. However, the overlying layer is considered to be thin nearby the southern bank of Rio Yaque del Norte, the central lowland, while the surface of the underlying layer is estimated to be remarkably elevated.

These geophysical estimations have been interpreted by two drill holes, No.3 and No.4, operations in central part of the flat land and associated geophysical hole logging works to show the occurrence of overlying high specific resistivity layer and underlying low specific resistivity layer.

3) Stations of K-1 to W-3 (Figure 3.9 (2)) are extended to the south from the above traverse lines in b), showing the following geophysical characteristics:

(1) 2- or 3-layer-structure, with an intricate distribution of specific resistivity values, is observed in the Project Area.

(2) Distributions of identical specific resistivity values are discontinuously shown.

(3) Remarkable rises in high specific resistivity values, which are close to the maximum "unlimitedly high" values up to nearby ground surface, are shown in two locations.

The Project Area is widely covered by Tertiary beds with rock exposures on ground surface. Sandstone or calcareous sandstone beds are estimated to represent specific resistivity values of 10 to 50 Ω. m. Based on the results by drill holes operation, Holes 5 and 9, sandstone beds near stations E and G (Palo Blanco), and calcareous sandstone beds deeply below stations F and K, are clearly observed to carry aquifers.

4) Stations Ep-4 to Ep-9 (Figure 3.9 (3)) are traversed in the northern half of San Juan Basin. Measurement results show the following geophysical characteristics:

(1) A 6-layer-structure with intricate distributions of specific resistivity values;

(2) General continuity of respective specific resistivity values are considered to be disrupted in connection with the variation in the elevation of land lay;

(3) Extremely high apparent specific resistivity values are not observed in the Project Area.

Discontinuities of respectively identical specific resistivity values on profile are shown in connection with the variation in the elevation of the land lay of river terraces developed on both banks of the Rio Macasia basin. Discontinuities in the values are observed at the topographical turning of highly elevated, medium elevated and lowly elevated river terraces, while a relatively constant valued layer with relatively invariable thickness is observed in connection with the occurrence of any of the above elevated river terraces.

River terraces on both banks of Rio Macasia show similar values of specific resistivity at every elevated area, while highly elevated river terraces on both banks commonly show 5- to 6-layer-structures with a remarkably variable distribution of specific resistivity values. From these, we can assume a geological possibility that the Project Area had been repeatedly subjected more than twice to erosions and sedimentations, while the eroded surfaces might provide discontinuous causes for specific resistivity value distribution.

The apparently high specific resistivity values range from 13 to 36 in accordance with the evolution of sand-gravel beds with abundant quantity of pebbles. The sand-gravel beds are thick in Rio Macasia basin and further north. The beds are about 100 m thick nearby station Ep-5 (Las Rosas) to provide an aquifer.

Apparent low specific resistivity values are chiefly represented in accordance with the mudstone beds.

5) Stations Ep-3 through Ep-11 (Figure 3.9 (4)) have been allocated in the southern half of San Juan Basin in the west to show the geophysical characteristics stated below:

(1) Low specific resistivity value distributions are generally extremely-thickly and widely observed.

(2) High specific resistivity value distributions are thinly observed to be close to the ground surface.

(3) Apparent specific resistivity values in the Project Area are rather shown in a relatively low range.
Mudstone bed exposures are widely observed in the Project Area to provide a geological accordance with the results by current vertical electrical sounding.

Occurrences of groundwater deep underground in the Project Area are estimated to be unlikely possible on the bases of geologic and geophysical studies, while drill operation results in the district show dry holes. High specific resistivity value distributions nearby the ground surface are thin as observed, and the above values are evaluated to be within the range of relatively low apparent specific resistivity, possibly cemented by fine-grained clay and silt.

6) Electromagnetic sounding operations have been implemented in the area covered by basement rocks. Electrical conductivity values are to be determined in connection with the variations in intercoil spacing which is about 15 m deep for 10 m spacing and about 30 m deep for 20 m spacing.
Faults and fracture zones are estimated as high conductivity zones with low specific resistivity features, particularly in areas of granitoids and Cretaceous volcanic rocks where weathered and unweathered parts are remarkably observed. The electromagnetic sounding operations in the area of mudstone beds or alternations of mudstone-sandstone beds showed obscure results.
Figures 3.10 (1) and 3.10 (2) show the operation results in El Cajuil and Piedra Blanca.
Remarkable variations in conductivity values along the possible locations of deep-seated weathered parts along faults or joints in tonalite body are observed. The conductivity values in volcanic rock areas of Cretaceous age vary abruptly nearby station 1300 in Piedra Blanca and may cause the development of faults. Groundwater of good quality are currently produced through hand pumps in the district.
Electromagnetic sounding operations are considered effective in specifying deep-seated weathered parts in the basement rock area.

3.3.3 Test Drilling

The Test drilling consists of drilling and pumping test work.

1) Drilling sites
27 sites were selected for drilling; 24 sites based on the geophysical prospecting results and 3 sites in need of the groundwater survey and water supply. These sites are shown in Figure 3.11 (1)~(2).

2) Pumping Test
Three kinds of transmissibilities of all the drilled holes (wells) were calculated with data from the pumping tests. Transmissibilities were based on the Theis's and Jacob's nonequilibrium formulas and on the formula for recovery method, and the results are listed on the Tables 3.4 (1)~3.4 (2).

Specific capacity is calculated by using the discharge quantity and the maximum drawdown during the constant method test (Q/s), and this value is used to determine the reasonable discharge quantity of the future project in the Groundwater Development Plan within about 15 to 20 m on the drawdown. The Hydrogeologic Provinces to be mentioned later are divided based on this reasonable discharge quantity, depth, and lithofacies of the aquifer.

3.3.4 Classification of the Project Area and Groundwater Quality

1) Classification based on the lithofacies
The geology of the Project Area consists of the formations from the Cretaceous to the Quaternary period as mentioned previously. The major lithofacies of these formations can be described as follows:

(L1) alternation of mudstone, sandstone, and marl with limestone and few sand and gravel .... (O'Mce, Mice)
(L2) fine sand, silt, clay, intercalated by sand and gravel ......(Qal)
(L3) siltstone ....(Mscm)
(L4) calcareous sandstone and marl ....(Mmca)
(L5) alternation of sandstone and siltstone, or sandstone and/or silty sandstone ....(Mice)
(L6) sandy siltstone or siltstone ....(Mice)
(L7) weathered granite, tonalite or granodyorite ....(Intrusive)
(L8) slate, andesite, tuff and tuff breccia ....(Ksvts)
(L9) limestone ....(Ec)

(L10) calcareous conglomerate, calcareous sand and gravel .....(Mg)
(L11) mudstone ....(Pcmg)
(L12) limestone, calcareous mudstone ....(Oce, Ec)
(L13) sand and gravel ....(Qlac)
(L14) conglomerate or alternation of conglomerate and sandstone....
..............(Mpg, Mpc)
(L15) limestone ....(Oc, Ec)

2) Classifications based on the Results of the Drilling Test and Pumping Test

The result of the drilling and pumping tests were classified to divide aquifers of the Project Area into the under-mentioned 13 categories excluding the data area and the saltmarsh and/or mangrove area.

(Unit: 1/min/m)

(D1) Super-high productive aquifer (Q=300, partly Q>500)
existing between 60 - 120 m in depth
(D2) High to Super-high productive aquifer (200>Q>100, partly Q>3000)
existing between 30 - 60 m in depth
(D3) High productive aquifer (Q>100, partly Q>1000)
existing between 60 - 90 m in depth
(D4) Intermediate to High productive aquifer (Q=100, partly Q>500)
existing at shallow part of less than 60 m in depth
(D5) High productive aquifer (Q=100)
existing between 60 - 90 m in depth
(D6) Low to moderately productive aquifer (60>Q>10)
existing between 30 - 60 m in depth
(D7) Low productive aquifer (20>Q>5, partly Q>300 - 500)
existing between 80 - 60 m in depth
(D8) Lack of available aquifer up to the basement situated at 60 m in depth (5>Q)
(D9) Lack of available aquifer up to the basement situated at 90 m in depth (5>Q)
(D10) Lack of available aquifer within 120 m in depth (5>Q)
(D11) Lack of available aquifer within 150 m in depth (5>Q)
(D12) no data area
(D13) saltmarsh or mangrove area

3) Classification of the Hydrogeological Provinces

The Project Area was classified into the 8 major provinces as Ⅰ~Ⅷ referring to the aforementioned two kinds of classifications and the hydrological data. And province Ⅲ was divided into the 4 sub-provinces Ⅲ-1, Ⅲ-2, Ⅲ-3, and Ⅲ-4; province Ⅳ into the 3 sub-provinces Ⅳ-1, Ⅳ-2, and Ⅳ-3; province Ⅴ into the 2 sub-provinces Ⅴ-1, and Ⅴ-2; and province Ⅶ into the 3 sub-provinces Ⅶ-1 and Ⅶ-2 (see Fig. 3.12, and Tables 3.5 (1)~(3)).

(1) Hydrogeological province Ⅰ: Cordillera Septentrional

The geology of this province consists of Oligocene or Miocene. It is topographically very mountainous at the northern part and hilly at the southern part. The large and small flat intra-mountain basins are scattered in the mountain side and the residential areas are restricted to these places.

Most of the areal rivers or streams are dry except immediately after a rainy day.

a: altitude: 0-200-500 m

b: annual rainfall potential:
600-700 mm, very seasonal

c: surface water resources potential:
very low and very seasonal

d: groundwater resources potential:
very low and very salty

e: correlation to the classification:
L1 / D11

(2) Hydrogeological province Ⅱ: Llano Rio Yaque del Norte

This province is mainly represented by the alluvial plain, formed by the sediments transported by Rio Yaque del Norte. The recharging place is estimated to be located outside of the Project Area upstream of Rio Yaque del Norte.

The major tributaries flow down with high rainfall figures from Central Mountains located from the south of the Project Area to the north.

a: altitude: Less than 50 m

b: annual rainfall potential:
700 mm

c: surface water resources potential:
very high from the Rio Yaque del Norte

d: groundwater resources potential:
very high with locally floating material

e: correlation to the classification:
L2 / D4

(3) Hydrogeological province Ⅲ: Southern Rio Yaque del Norte

The general geology consists mainly of the Tertiary beds of sandstone-mudstone, calcareous mudstone-limestone, and mudstone-conglomerate.

Flat lands and hilly regions to the south of Hydrological Province Ⅱ extend to this province.

The major streams flow to the north down from the Central Mountains located south of this province, but seasonally, only few surface water or none at all can be observed downstream because water is stored in a dam for agricultural use.

This province, based on its lithofacies, is divided into the 3 sub-provinces like the aforementioned. All of the sub-provinces have comparatively high potential discharge capacity, therefore, this province would be regarded as the proposed area highly prioritized for groundwater development, especially the Ⅲ-4 sub-province. However, it has been detected to have high concentration of SO_4^{2-} in limited areas.

a: altitude: 50-300 m

b: annual rainfall potential:
700-1000 mm

c: surface water resources potential:
low and very seasonal from the Rio Chacuey, Maguaca, Gayubin

d: groundwater resources potential:
very high, partly with high SO_4^{2-} contents

e: correlation to the classification:

Ⅲ-1	L3 / D5
Ⅲ-2	L4 / D3
Ⅲ-3	L5 / D1
Ⅲ-4	L6 / D7

(4) Hydrogeological province Ⅳ: Cordillera Central

The geology consists of the Cretacious beds and submarine volcanic products and the granitic rock (tonalite) that intrudes

slightly later into the Cretaceous formation. Therefore, the Cretaceous metamorphoses into hornfels, slate, and phyllite.
This province is classified into 3 sub-provinces (Ⅳ-1, Ⅳ-2, Ⅳ-3). Ⅳ-1 sub-province consists of granitic rock. The rock bodies are heavily weathered to form the uneven rugged appearance of ground surface occurrence.
In the Ⅳ-1 sub-province where a number of inhabitants live, topographically, the typical dendritic drainage is formed at the upstream of the tributaries of Rio Yaque del Norte.
The Ⅳ-2 sub-provinces are symmetrically situated on both sides of the north and the south of the granitic rock body. Geologically, both sides are generally of Cretaceous beds, elevated to 100-300 m at the north side and 500-1000 m at the south side.
In the Ⅳ-2 sub-province, the inhabitants live on the gently inclined part and on the intra-mountainous partly cultivated or farmed flat land. In the south Ⅳ-2 sub-province, the high lands, the inhabitants live only on small scale intra-mountainous flat land. The drainage system consists of a deep valley with sufficient water. The inhabitants rely on these surface water sources.
The Ⅳ-3 sub-province is situated closely in the south of the Ⅳ-2 sub-province and the geology consists of massive limestone.
In the Ⅳ-3 sub-province, the inhabitants live only on the western hilly zone.

a:	altitude:	Ⅳ-1	300-500 m
		Ⅳ-2	north: 100-700 m
			south: 500-1000 m
		Ⅳ-3	200-1700 m
b:	annual rainfall potential:		
		1000-2000 mm	
c:	surface water resources potential:		
		Ⅳ-1	intermediate to high
		Ⅳ-2	north: very low to intermediate
			south: low because of steep and deep valley
		Ⅳ-3	high

d: groundwater resources potential:

Ⅳ-1	intermediate to high
Ⅳ-2	north: low south: intermediate
Ⅳ-3	low

e: correlation to the classification:

Ⅳ-1		L7 / D6
Ⅳ-2	north:	L8 / D9
	south:	L8 / D8
Ⅳ-3		L9 / D12

(5) Hydrogeological Province Ⅴ: Valle de San Juan Basin

Valle de San Juan Basin, extended on an approximate altitude of 300 to 400 meters high above sea level, shows a general land lay of gently undulated hills and tablelands. The Province, which is geologically featured by a running of the NNW-SSE directional anticlinal axis plunging toward NNW, is consequently divided into two sub-provinces: Ⅴ-1 sub-province, chiefly geologically covered by upper formation units, and Ⅴ-2 sub-province, chiefly covered by lower formation units. Ⅴ-1 sub-province chiefly consists of mudstone beds associated with overlying unconsolidated calcareous conglomerate beds while Ⅴ-2 sub-province lacks geological association with the overlying bed.

Macasia River, which flows down west in the central part of the basin, has its riverheads in the Central Mountain area to the north and in the Neiba Mountain area to the south. It is ramified by many large-scale tributaries with substantial water quantities due to a relatively heavy annual rainfall. Water for human consumption in Ⅴ-1 sub-province is available from the water sources in superficially weathered parts of calcareous conglomerate or mudstone beds. However, quantities are small and salinity is high.

a: altitude:

Ⅴ-1	300-500 m high
Ⅴ-2	300-500 m high

b: annual rainfall potential:

1500-1750 mm

c: surface water resources potential:

Ⅴ-1	intermediate to high
Ⅴ-2	very low to intermediate

d: groundwater resources potential:

Ⅴ-1	intermediate
Ⅴ-2	low

e: correlation to the classification:

Ⅴ-1	L10 / D7
Ⅴ-2	L11 / D10

(6) Hydrogeological Province Ⅵ: Sierra de Neiba

Sierra de Neiba is located between Ⅴ-2 sub-province and Lago Enriquillo. The Province is situated along the northern coast of Lago Enriquillo and is featured by a mountainous area extending in an east-west direction with gentle slopes to the north, and steep ones to the south, forming a relative height difference of 2000 meters from the Lago Enriquillo water level. In the central part of the mountain area, residential areas in the water system and intramountainous lowland zones are structures in the east-west direction parallel to the mountainous ridges. Ephemeral streams of small-scale, downstreams of those are generally attenuated, and dolines are largely developed on the top of flat lands.

Geologically the province consists chiefly of limestone beds of Tertiary age, associated with occurrences of folding axes of N70° to 80°W directions. Small and large inferred faults and lineaments on air-photographs of NW directions are largely developed in the province to cause a localized geological blocking of the Sierra de Neiba body. The annual rainfall figure in the province reaches 750 to 2000 mm, the highest in the Republic of Dominica. Abundant surface water provides sufficient supply of water for human consumption in the northern part of the mountainous ridges in the province. Inversely, only a few surface water flows are observed in the southern part, as they move directly into sinkholes of karst topography. However, an abundant number of scattered water springs are observed in marginal alluvial fans abundantly developed at the hill feet.

a: altitude: -40 - 1700 m

b: annual rainfall potential:

750 - 2000 mm

c: surface water resources potential:

north	high

south high at marginal fans

d: groundwater resources potential:

medium

e: correlation to the classification:

L12 / D7

(7) Hydrogeological Province Ⅶ: Lago Enriquillo

Lago Enriquillo forms a graben-like lay centered between the northern side of Sierra de Neiba and the southern side of Sierra de Baoruco. The confluent fans in Sierra de Neiba stand between minus 40 to 100 meters high above sea level and are located in the northern coast of Lago Enriquillo (sub-province Ⅶ-1). Fault valleys extended in a NE-SW direction are well-developed in the southern lake coast forming an altitude averaging minus 20 to 20 meters high above sea level. However, some scattered areas can go as high as 100 to 400 meters above sea level due to intense erosion.

Geologically, the province chiefly consists of limestone, calcareous conglomerate and marl beds.

Surface water flow in the northern coast of Lago Enriquillo solely originates from large springs in the marginal alluvial fans at the skirt of Sierra de Neiba. Surface water flow in the southern lake coast, behind which is Sierra de Baoruco with a large annual rainfall, is not perennially caused by the significant permeation of rain water into the underground of Sierra de Baoruco body. Large quantities of ground water below the limestone beds are observable sometimes, however, the selection of water yielding sites of the same type is not easily done. Some of the province's spring water were found to have relatively high sulphate ion contents, while groundwater in clastic-rocks-covered area of lower elevation tends to be very salty. Drill site locations of water well development are restricted to the southern-area where rock salt beds are being mined on a large scale in eastern La Salina.

a: altitude: Ⅶ-1 -40 - 100 m

Ⅶ-2 -40 - 400 m

b: annual rainfall potential:

500 - 750 mm

c: surface water resources potential:

Ⅶ-1 high at marginal fans

Ⅶ-2 low

d: groundwater resources potential:

Ⅶ-1 high at fans

Ⅶ-2 intermediate

e: correlation to the classification:

Ⅶ-1 L13 / D12

Ⅶ-2 L14 / D2

(8) Hydrogeological Province Ⅷ: Sierra de Baoruco

To the south, Sierra de Baoruco is adjacent to sub-province Ⅶ-2, and confines the southern end of Sierra de Baoruco mountainous ridges. The province has an altitude of 100 to 2100 meters above sea level and shows similar geological characteristics and land lay to those in Province Ⅵ, i.e., well-developed geological blocking by N70° to 80°W-directional faults and of karst topography.

Although the annual rainfall record shows a significant figure, surface water flows are not perennial.

The existence of large quantities of ground water underlying limestone beds is likely possible. However, the selection of similar water yielding sites will be difficult.

a: altitude: Ⅷ 100 - 2100 m

b: annual rainfall potential:

750 - 2000 mm

c: surface water resources potential:

Ⅷ low

d: groundwater resources potential:

Ⅷ high at alluvial fans

e: correlation to the classification:

Ⅷ L15 / D12

(9) Classification of (D1) through (D13) show that smaller figures designate a more productive aquifer. Consequently, (D1) through (D7) would designate an operative potential of groundwater by submersible pump operations in aquifers; (D8) and (D9) by manual pump operations. It is unlikely, however, that (D10) and (D11) would hold aquifers for groundwater development; (D12) lacks sufficient information, while the possible mixture of sea water and water or sea water itself is detected in (D13).

The aquifers delineated in the upper positions are assessed to be more productive, while those in more left-sided positions would be more shallow-seated.

4) Groundwater Quality

Groundwater test samples collected before the completion of continuous pumping test were analysed in INAPA's laboratory.

Chemical values exceeding the allowable limitation values of groundwater quality stipulated by the INAPA are shown in the following table:

Assay results of water quality,
exceeding allowable limitation values by INAPA

Drill hole No.	Hydro-geological province		Total solid	Na^{+}	Ca^{2+}	Mg^{2+}	SO_4^{2-}	Cl^{-}	Total Hard-ness
		Allowable limitation value in ppm	1500	-	500	600	400	800	500
1	I		3032	1311	-	-	850	1500	-
2	I		6731	3213	-	-	4750	2500	771
3	I		1859	-	-	-	883	-	510
4	I		-	-	-	-	500	-	-
13	Ⅳ2		-	1610	-	-	1400	-	-
25	Ⅶ2		-	49151	3209	3668	18500	67250	6877

The general propensities of ion content values of hydrogeological provinces are shown in Figure 3.13 to set up standards of the areal selections for groundwater development purposes. The figures of Province Ⅶ and Province Ⅷ are not shown because of a dispersed result of value distributions in the former and a lack of assay values in the latter. Table 3.6 shows the estimated volume of good quality water yields highly possible in provinces Ⅲ, Ⅳ and Ⅵ.

3.3.5 Ground Water Potential in Each Hydrogeological Province

1) General Groundwater Potential

The Project Area has been initially divided into eight hydrogeological provinces, and parts of the provinces have been further sub-divided into sub-provinces. Table 3.6 shows the estimated potential quantities of groundwater development in the Project Area.

Estimated potential quantities of groundwater development are shown on the results of pumping tests of test well drill operations. By referring to the specific capacity values obtained from the pumping tests, the potential quantities were estimated on an assumption that, as a rule, the water level drawdown values after a 24-hour period of continuous pumping operation should range from about 15 to 20 meters. Drill depth values shown in Table 3.6, show the total of the depths toward aquifers specified by test water wells taking into account the variations in electrical conductivity values observed in the pumping tests. Depths of 20 meters each are added for the disposals of fine sand materials that infiltrate the wells through water screens.

2) Groundwater Potentials in the Respective Hydrogeological Provinces
Table 3.6 establishes the interpretations of groundwater development potentials according to the category of respective hydrogeological provinces. The figures under the item "Quality" in the Table are specified in compliance with the lower categories according to the chemical contents previously shown in Figure 3.13.

a: a shows the field chiefly covered by Hydrogeological Province Ⅳ. Groundwater in this area is of good quality.

b: b shows the field chiefly covered by Hydrogeological Province Ⅲ. Groundwater in this area is of good quality.
Qualitative potentials with values close to the allowable limit established by INAPA are variedly included. Hydrogeological Provinces Ⅰ and Ⅳ are included in this field.

c: c shows the field chiefly covered by Hydrogeological Province Ⅵ. It is characterized by high contents of Na^{+} and Cl^{-}, therefore, is below the allowable upper limit values established by INAPA.

(1) Hydrogeological Province Ⅰ: Cordillera Septentrional
Available aquifers are estimated to be unlikely potential within the depth of 150 meters in this province.
Underground geology chiefly consists of alternations of mudstone, sandstone and marl beds of Tertiary age. Static water level averages 10 to 20 m deep, the water recharge potential underground is estimated to be 10 liters per min. leading to an estimated drawdown value of 50 to 80 m. The Cl^{-} and SO_4^{2-} contents are so high reaching more than 1500 ppm and 850 to

5000 ppm, respectively. Groundwater development is not considered possible in this area.

(2) Hydrogeological Province Ⅱ : Llano de Yaque del Norte

Aquifers in Province Ⅱ, chiefly located in fine-grained sand and clay beds of Quaternary age and in intercalated sand and gravel beds, is estimated to be seated within a depth of 60 m. Groundwater in this area is unconfined, with a water quality that is comparable to the values of the upper limitation stipulated by the INAPA. Abundant suspension of solid substances is locally observed and static water level is seated about 5 m deep, while water yield potential is expected to be 100 liters per min. A highly-available aquifer with a potential water yield of 500 liters per min and a drawdown value of about 10 m is locally observed.

(3) Hydrogeological Province Ⅲ1: Southern Rio Yaque del Norte

Aquifers in Province Ⅲ are estimated to be formed in the alternations of siltstone and fine-grained sandstone beds of Tertiary age and to be seated 60 to 90 m deep, while groundwater is estimated to be weakly confined. General static water levels are still obscure in this study, although through the execution of a water well drill test the availability of confined groundwater about several meters deep was revealed. Province Ⅲ shows similar water quality properties, water quantity, and drawdown value range as in Province Ⅱ.

(4) Hydrogeological Province Ⅲ2: Southern Rio Yaque del Norte

Aquifers in Province Ⅲ2 are estimated to be formed in calcareous sandstone and marl beds of Tertiary age and to be seated 60 to 90 m deep. Groundwater in this area is estimated to be of confined type, while water quality itself generally resembles that of Province Ⅱ. However, an abundant quantity of water recharge under geological control with a high content value of SO_4^{2-} has been observed. Static water level in the Province is generally estimated to be seated 20 m deep underground, while the potential water yield is estimated to be more than 100 liters per min. The water yield under a particular geological structure, as shown in the above, is inferred to be about 1000 liters per min., while the drawdown value during pumping operation is estimated to be about 5 m.

(5) Hydrogeological Province Ⅲ3: Southern Rio Yaque del Norte

Aquifers in Province Ⅲ3 are estimated to be formed in the alternations of arkose and massive sandstone and siltstone beds of Tertiary age. They sit 60 to 120 m deep underground. Groundwater in this area is estimated to be of confined type. The Province appears to have the greatest potential for groundwater development in the Project Area and the highest groundwater yield as in Chacuey and Canderon. General water quality in the Province resembles that of Hydrogeological Province Ⅱ. Static water level is generally estimated to be seated 15 m deep, however, it is 50 m deep in Palo Blanco. The potential water yield is generally estimated to be 300 liters per min., and possibly 500 liters per min. locally.

(6) Hydrogeological Province Ⅲ4: Sur del Yaque del Norte

Aquifers in Province Ⅲ4 are estimated to be formed in calcareous sandstone beds of Tertiary age and to be seated at a depth of 30 to 60 m. Groundwater in the Province is of confined type. Water quality generally shows a resemblance to that in Province Ⅱ, however, the $C\ell^-$ content is slightly high. Static water level is generally estimated to be seated at a depth of several to ten and several meters. The potential water yield is estimated to be about 5 to 20 liters per min.

(7) Hydrogeological Province Ⅳ1: Cordillera Central

Aquifers in Province Ⅳ1 are estimated to be formed in weathered granitoid body (tonalite) of Cretaceous age and to be seated at a depth of 30 to 60 m. Groundwater in the Province is unconfined while the water quality, in terms of $Ca(HCO_3)_2$ content, is considered to be the best in the Project Area. Potential water yields vary in connection with the variations of thickness of weathered parts of tonalite body, indicating that water yield in nearby mountain ridges should be small and inversely, it should be large in less-undulated hilly areas. Static water level is estimated to be seated at a depth of 5 to 15 m, and the potential water yield appears to be about 10 to 60 liters per min.

(8) Hydrogeological Province Ⅳ2: Cordillera Central

Province Ⅳ2 is dividedly situated northerly and southerly, between where Province Ⅳ1 is located. Aquifers in the Province, both in the north and in the south, are formed in mudstone, calcareous sandstone and sandstone beds of Cretaceous age. The potential yield of groundwater is estimated to be 10 liters per min.

The possibility of the existence of aquifers in the bed rocks within 80 m deep is low in the northern side. Static water level in the north is estimated to be sharply variable as it ranges from a depth of 8 to 50 m. The possibilities of the groundwater containing high conconcentrations of SO_4^{2-} and Cl^- should be examined.

The availability of aquifers in the bed rocks within the depth of 60 m deep are estimated to be low in the southern side. Static water level in the south is estimated to sit at a depth of about 14 m, and $Ca(HCO_3)_2$ is detected from the quality of the water.

(9) Hydrogeological Province Ⅳ3: Cordillera Central

The general geology of Province Ⅳ3 chiefly consists of limestone beds. Information on groundwater in the Province has not yet been available.

(10) Hydrogeological Province Ⅴ1: Valle de San Juan

Aquifers in Province Ⅴ1 are said to be formed in calcareous conglomerate and muddy-calcareous sandstone beds of Tertiary age. They are found 30 to 60 m deep underground. Groundwater in the province is specified to be unconfined in loosely consolidated calcareous conglomerate beds which spatially extend up to the ground surface, and confined in calcareous sand-gravel beds overlain by aquiclude siltstone beds. It is also rich in Cl^- content, without exceeding the allowable upmost limitation value stipulated by the INAPA. Static water level is estimated to be seated within the range of 20 m deep underground, while potential water yield is inferred to be from 5 to 20 liters per min.

(11) Hydrogeological Province Ⅴ2: Valle de San Juan

Aquifers within the range of 120 m deep underground are hardly observed in Province Ⅴ2. The geology of the area generally consists of calcareous mudstone beds of the Tertiary Age.

(12) Hydrogeological Province Ⅵ: Sierra de Neiba

Aquifers in Province Ⅵ are estimated to be formed in calcareous sandstone layers intercalated in calcareous mudstone beds. Groundwater quality in the Province resembles Hydrogeological

Provinces II and III. Static water level is estimated to be seated about 20 m deep underground, and potential water yield is inferred to be 5 to 20 liters per min.

(13) Hydrogeological Province VII-1: Cuenca de Enriquillo
The Province is generally made up of sand-gravel beds. Groundwater information in the province is not yet available.

(14) Hydrogeological Province VII-2: Cuenca de Enriquillo
Aquifers in Province VII-2 are formed in calcareous conglomerate bed or in alternations of conglomerate and sandstone beds of Tertiary age. Rock salt beds are distributed in the environs of the province, causing the groundwater to have very high contents of $C\ell^-$ and SO_4^{2-}. The selections of water well drill sites should be cautiously made and these sites should be as far as the southern part of the Province where groundwater of $Ca(HCO_3)_2$ type should be supplied under normal circumstances. Static water level is estimated to be seated about 20 m deep underground, while potential water yield is inferred to be 100 to 200 liters per minute, and locally up to 300 liters per min.

(15) Hydrogeological Province VIII: Sierra de Baoruco

Province VIII chiefly consists of limestone beds and is hydrogeologically identical with Province VI I. Groundwater information in the Province is not yet available.

3) Examination of Influences by Pump-up Operations
A sphere, where influence by drawdown of water level by pumping takes place, is referred to as the "influence sphere". Two wells are at least substantially required for the estimation of the value of the above; one for pumping and the other to determine water level. An outlined estimation of the above value is made using a single well for greater accuracy. The value of "r", which is normally designated as the distance between two wells is the radius value of the above single well.

The extensions of the "influence sphere", estimated in the current Project Area, assuming that potential yield quantity should be continuously operated for 24 hours, are inferred to be less than 100 meters. This would lead to the conclusion that drawdown effects of water level is impossible when the distance between wells for groundwater development in the Project Area is more than 200 meters.

Holes 9 through 12, operated in III_3 sub-province, are categorized under "D1", while Hole 13 is categorized under "D9" in IV_2 sub-province and Hole 16 under "D6" in IV_1 sub-province.

4) Summary

The specific capacity values and potential water yield evaluated for each hydrogeological province are shown in the next page.

Province	Depth of Aquifer (m)	Specific Capacity Values (m3/day/m)	Potential Water Yield (Q (ℓ/min)		Potential
Ⅰ	–	–		Locally	Very low
Ⅱ	Unconfined<60	13~72	Q=100	≧500	High
Ⅲ1	Weakly confined 60~90	22	Q=100		H
Ⅲ2	Confined 60~90	303	Q=100	≧1,000	H
Ⅲ3	Confined 60~120	26~83	Q=300	≧500	H
Ⅲ4	Confined 30~60	10	20>Q≧5	≧300~500	H
Ⅳ1	Unconfined30~60	2~12	60>Q≧10		Medium
Ⅳ2_N	Weathering zone 30~60	1.1	–		L
Ⅳ2_S	Rocks –	1.6~1.9	15>Q≧5		L
Ⅳ3	Rocks –	–	–		
Ⅴ1	Unconfined50~70	2.8~51.6	20>Q≧5	≧300~500	Medium
Ⅴ2	– –	–	–		L
Ⅵ	Limestone 50~70	3.0	20>Q≧5	≧300~500	Medium
Ⅶ1	Salty –	–	–		Spring
Ⅶ2	Salty –	418	200>Q-≧10 0	≧3,000	Medium
Ⅷ	Limestone –	–			Spring

To sum up the above, classification of groundwater in the proposed Area can be as follows:

① Unconfined Groundwater, 30 m deep
② Unconfined Groundwater, 60 m deep
③ Unconfined Groundwater, 60~120 m deep
④ Unconfined Groundwater, in weathering zones of basement rock body (Provinces Ⅳ-1, Ⅳ-2)
⑤ Water confined in fissures of the basement rock (Ⅳ-2)

⑥ Spring water passing through limestone body (Province Ⅵ, Ⅷ)

Characteristics of the above classified groundwater:

① Groundwater was drawn up by hand pump and windmill pump from the existing wells, it is mostly unsuitable for drinking, however, due to salinity content and turbidity.

② There are no problems concerning groundwater quantity, quality is rather the problem, especially in Province Ⅶ where high salinity content is observed.

③ With regard to quantity and quality, this groundwater has the highest potential.

④ Potential is inferred to vary in accordance with depth or location of the weathering zones, but the quality and quantity of the water are considered suitable for consumption.

⑤ Though inferred to have potential, specification of the sites is difficult.

⑥ Utilization of spring water rather than water from wells is more profitable, and proper development is already ongoing.

Water balance estimation from a regional standpoint of potential view has been made, however, the meteorological observatory stations are currently in operation with an insufficient coverage of the current Project Area demarcated as crossing the general topographical configuration in oblong mode. What is more, some basic data are not available. For instance, conditions of the upstream recharging place are likely unknown, while basic discharge of the rivers cannot be stated due to storage of water and water intake for irrigation operated in the upstream basin. Besides, very few of the existing wells implemented in the Project Area are more than 100 m deep, and all data on groundwater level fluctuation are not available. This explains why hydraulic gradient and discharge of ground water was not strictly evaluated. Though accuracy of the estimations is considered barely satisfactory, tentative water balance estimation by the Phase- I work has been revised in line with the divisions of water Province-subprovince. Annual possible recharge of groundwater and possible water yield per day per square kilometer respective to hydrogeological provinces are summarized in Table 3.7.

Considering the above described conditions and the urgent need for domestic water in the Project Area, in addition to an expected quantity value of more than 10ℓ/min, attention was paid to the presence of other effective water sources and to topographical conditions, and 8 of the Hydrogeological Provinces (Ⅱ, Ⅲ-1~4, Ⅳ-

1~2, V-1 Northern part of VI) were selected for groundwater development formulated in the present Project.

3.4 Surface Water

3.4.1 Present Conditions of Surface Water Development

The rivers of the Project Area have been highly developed by local population for ages, for irrigation or domestic water use. Recently, a systematic water supply development has been undertaken on a large scale under the supervision of INDRHI, INAPA and other Governmental Agencies. The situation is detailed below.

1) Domestic Water Supply

According to INAPA, though water supply systems and levels vary widely, 34.6 milliom tons of water is supplied annually to about 100,000 local inhabitants by 30 existing water supply systems using the running water of rivers located in the Project Area.
The water supply volume by river system, including spring waters of the Lago Enriquillo Basin, is listed below (1990 estimates).

	Annual Water Supply Volume (hm^3)
Rio Dajabon (Rio Masacre/Capotillo)	1.4
Rio Guarabo, Lag. Saladillo	1.6
Rio Yaque del Norte	23.4
Rio Artibonito	3.3
Lago Enriquillo Basin's springs/rivers	4.9
Total	34.6

Besides the aforementioned supply resources, the flow water of mountain streams will be developed and used as domestic water. However, there are no data on water volume.

2) Irrigation Water

According to the INDRHI's data, reservoir ponds for irrigation water are implemented in rivers like Gurabo, Mao, Cana, Chacuey, Maguaca, Masacre rivers. Several pump stations are settled in the Yaque del Norte river, for instance at Represa de Concreto. Besides

this, permanent or temporary private pump stations of different scales were installed by plantation owners, although only restricted to irrigation use.
Annual volume of irrigation water used by means of drainage system, is as follows (INDRHI statistics of 1986).

Rio Yaque del Norte, Dajabon, Guarabo	660 hm^3
Artibonito	50-80
Enriquillo	35~82
Total	745-822

Moreover, the development of irrigation by private farmers is increasing yearly. For this reason, it is estimated that irrigation water use exceeds 900 hm^3 per year.
The estimate of the return flow of irrigation water in rice crop-low lands is estimated to be more than 50% to 60%.

3.4.2 Development Potential of Surface Water

1) Objective Water Resources

Stream, lake, and spring waters have been used since olden days as domestic water. These water resources are considered to have the potential for present and future domestic water use.
The development of the lake and spring waters as domestic water is limited to their location, but the river stream water presents high development potential for domestic water.
Consequently, the stream water will be examined as an alternative water resource for development.

Evaluation Method
Development Potential of the river water as water resource for the proposed Project was evaluated as follows:

$$D_P = D_T - D_E - D_M$$

where:

D_P	:	Available River Water (Useful Water)	m^3
D_T	:	Average Annual River Discharge	m^3
D_E	:	Existing Water Use	m^3
D_M	:	River Maintenance Discharge	m^3

3) Average Annual River Discharge (D_T)

The average annual river discharge was estimated from precipitation and other meteorological and hydrological recollected datas. The discharge was estimated with 80% of return frequency for the annual runoff of each river.

(1) Areal Rainfall

Areal rainfall in the respective hydrological basins was estimated according to the Arithmethic Average Method, the Thiessen Method, and the Isohyetal Method. In this Study, the volume of the annual precipitation, 10356.9m^3, was calculated using the arithmetic average method.

If the areal rainfall value calculated from arithmethic average method is estimated at 100, the value of the Thiessen method is 95 and the value of Isohyetal method is 107.

(2) Evapotranspiration

According to the data collected by evapometers, evaporation amounts to 200~300% of the annual rainfall.

The mean annual evapotranspiration was examined for the purpose of estimating the runoff discharge of every hydrological basin.

The calculation of evapotranspiration were based on data collected from INDRHI dealing with rainfall pattern, topographic features, vegetation, land use, cultivation and other relevant factors in the Project Area.

The following estimations are experimental values:

Humid and semi-humid area : 65-70% of annual rainfall

Arid and semi-arid area : 85-90% of annual rainfall

(3) Runoff Discharge

Collected data on specific discharge, runoff coefficient and coefficient of river regime for each river are shown in Table 3.8.

The annual base runoff percentage is 80% for Rio Amina and Rio Mao (left bank tributary stream of Yaque del Norte), 80% for Rio Masacre, and around 30% for other rivers. Rio Macasia and Cana runoff percentage is 10~12% (Rio Artibonito system) and for the other rivers of this system, 30~35%.

The precipitation pattern in the Area is classified by heavy rains of short duration. The discharge pattern is correlated with peak discharge and decrease in discharge within a short period of time.

The discharge of each river is correlated with monthly or seasonal distribution of rainfall. Most of the rivers have 70% of total annual discharge for a period of six months (April, May, June, September, October and November). In February and March the monthly total discharge is 3.7% or 4% of the total annual discharge.

The range of the variation of water level in upstream Rio Artibonito is 12m in a short period of time and 10~15m in other rivers.

Daily, monthly, and annual base run-off of Rio Guayubin and Rio Masacre were analysed.

The runoff percentage with respect to annual base rainfall measured during a 12 year period (from 1973 to 1984) reveals the following values: maximum ratio - 215.4%, minimum ratio - 12.7%; and mean ratio - 49.1%.

Discharge measurement reveals the drought period in January, February, and March, where monthly discharge is 0 and rainfall is 30 to 40 mm. An average of 342% in January, 137% in February, and 57% in March was observed.

The daily base correlation with the rainfall of Rio Masacre (1985 to 1988) is shown in Fig. 3.14.

The correlation rate in monthly base (discharge/rainfall) indicates a maximum rate of 15.9, a minimum rate of 1.98 to 0, and 2.86-0.614 of the mean annual rate. In Rio Guayubin a correlation ratio of 5.62 to 1.6 was observed.

Results expected from the above mentioned daily base discharge analysis could not be obtained for the following reasons:

- The distribution pattern of precipitation is diversified locally, and it is difficult to cover this distribution pattern with existing stations;

- There is no available daily rainfall data on the river headstreams located in the humid zone;

- Many occurrences of intermediate runoff of groundwater are observed, and ground water base flow is important;

- It is estimated that the diversion water from the reservoir is included in the discharge data of the drought period.

4) Available Water (D_P)

(1) Discharge with a return probability of 80% was estimated for each river as shown below.

unit: hm^3

Hydrological Basin	Gauge Point	Annual Discharge (hm^3)
Yaque del Norte	Ranchadero	1064
Chacuey	La Expensa	150
Guarabo	Confluence	65
Dajabon	Don Miguel	360
Artibonito	Pedro Santana	1000
Total D_T		1639

※ source: INDRHI

(2) Existing Water Use (D_E)

Volume of water used for irrigation or water supply in each hydrological basin is indicated below:

unit: hm^3

Basin Name	Irrigation Water	Domestic Water	Total
Rio Yaque del Norte Dajabon, Guarabo, Chacuey	700	30	730
Rio Artibonito	80	4	83
Lago Enriquillo Basin*	(35~82)	(5)	(39.9~87.0)
Total	780	34	814

(3) Maintenance Flow (D_M)

In order to maintain the river course and the supply of domestic water for the inhabitants living downstream, 30% of the annual discharge is estimated to be necessary for flow maintenance (D_M).

(4) Available Water (D_P)

Estimated available water is summarized below:

unit: hm^3

Basin Name	D_T	D_G	D_M	D_P
Rio Yaque del Norte Dajabon, Guarabo, Chacuey	1639	−730 <1	−491.7	417.3
Rio Artibonito	1000	−84	−300.0	616.0
Total	2639	−814	−791.7	1033.3

<1 : Including the existing diversion water in the downstream of Ranchadero gauging point

5) Development Potential

As above-mentioned, the possible surplus water for river development in the Project Area, except for the river system of Lago Enriquillo basin, is approximately 1033 hm^3.
According to ONAPLAN, the surface water development potential is estimated to be 3936 hm^3 (including Enriquillo basin with 25 hm^3).

The above mentioned value was examined only in annual terms. 60 to 70% of the available discharge is observable in April, May, June, September, October, and November.
Accordingly, the implementation of dams for the use of surface water as a stable domestic water source is required.
If these conditions of development are not fulfilled, the development potential of these resources is inferred to be very low or negligible.

3.5 Present Condition of Water Supply Development

3.5.1 Proposed Villages

In 1988 the Dominican Republic requested the Government of Japan for technical cooperation for the study on groundwater potential and for preparation of rural water supply for the four provinces along the Western Border (See Fig. 3.15).
The number of villages to be covered in the water supply plan is 154 (4 villages were subsequently added and total number amounts to 158), as proposed by INAPA.

Province	Villages
Monte Cristi	37
Dajabon	55
Elias Piña	55
Independencia	11
Total	158

3.5.2 Present Water Supply conditions

During the field study period, socio-economical surveys were conducted in the 158 proposed villages with respect to water supply conditions, to evaluate the urgency and potential of water supply development and its implementation (for details, refer to the Data Book).

The domestic water supply conditions, existing available water sources, structure and dispersion of villages, and social infrastructure in the proposed villages were examined, according to the results of the survey. Finally, the villages subject to the water supply development plan were selected.

Based on the various local conditions correlated to the water supply development plan, the 95 villages selected in each province are presented in the following table.

Province	Dissolved Villages	Villages with Existing Water Supply System	Villages in Need of Water Supply Plan	Total
Monte Cristi	8	5	24	37
Dajabon	5	23	27	55
Elias Piña	3	13	39	55
Independencia	2	4	5	11
Total	18	45	95	158

In addition, among the 95 villages, 15 villages (3 Dajabon and 12 in Elias Piña) are inaccessible by vehicle.

The general conditions related to water supply in each of the proposed villages are detailed in Tables 3.9 (1) to 3.9 (9).

CHAPTER IV

THE PROPOSED PROJECT

CHAPTER IV

THE PROPOSED PROJECT

4.1 Objectives of the Project

1) The main objectives of the Project are to provide the proposed rural villages of Monte Cristi, Dajabon, Elias Pina, and Independencia, the four western provinces of the Dominican Republic, with a stable supply of safe water for domestic use in sufficient quantity to promote health, sanitation and the improvement of the residents' living conditions.
The Project is set within the framework of the specific policy and target of the country concerning water supply and the promotion of health and sanitation.

2) The implementation of this Development Project is accorded top priority among the basic Water Supply projects formulated for the resolution of water shortage which becomes more critical every year in the frontier zone.

4.2 Basic Concept of Development

The proposed Project is to be implemented to fulfill the previously described objectives on the basis of the optimum plan formulated in line with the following basic concepts (see Fig. 4.1):

1) The plan shall be formulated for the 95 villages assessed to be in need of water resource development.

Socio-Economic Conditions	:	Population and its variations; Village Structure and Form; Industrial Structure
Water Supply Conditions	:	Effective Water Sources; Water Supply Method; Existing Water Service Facilities
Potential Development of Water Resources	:	Reliable Water Resources and their Development Potential; Water Quality; Difficulties in Development; Alternative Water Resources and their Development Potential

Access and other Developmental Constraints

2) Proposed Villages in need of Development

Basically, the exclusion of some villages from the implementation plan under the proposed Project shall be based on the following:

- Can be covered by the existing urban water supply system;

- Inaccessibility;

- Water resources only limited to mountain stream water; and

- Poor groundwater development potential.

Among the 5 villages of Independencia Province, 2 are located in the west, and 3 in the east. Both of these areas are undulated mountain slopes of Sierra de Neiba with an elevation ranging between 800 and 1300 m above sea level. The degree of village dispersion is observed to be relatively high.

These villages are situated in a humid area with more than 1500 mm of annual rainfall, and blessed with dependable mountain streams or springs. However, it is considered that the formulation of an economical water distribution plan is unlikely, judging from the topographical conditions and dispersion of villages.

Moreover, located in remote places far from the 95 other project villages, it seems that many difficulties hinder work implementation and O/M of this Project. For instance, the 3 eastern villages can not be reached by car.

Accordingly, these villages are excluded from the proposed Project as the separate execution of an independent project or a plan which shall include the components of the integrated regional socio-infrastructure development project such as roads, is considered important.

The implementation of the proposed development plan shall be carried out in some of the northern villages of Monte Cristi Province, however, due to serious water shortage resulting from sole dependence on rain water.

3) Basic study items for planning

- Water resources development : A long term stabilization, Quantitative and qualitive technical soundness, Economic viability
- Water production/Supply Systems : Minimization of construction and O/M costs, Simplicity/easiness of O/M

4) Improvement and reinforcement of the O/M systems

5) Introduction of the self-imposed O/M to the beneficiary community

4.3 Components of the Project

Delay in the development of the water resources poses as a constraint for the development of the water supply system in the proposed villages. The proposed Project, therefore, shall be mainly focused on water resources development.

Accordingly, the proposed Project plan shall consist of the following:

- Domestic Water Development Plan : Assessment of available resources, estimation of groundwater development potential, safe yield, drilling measure of well, estimation of availability of surface runoff water
- Water Production Plan : Establishment of target year, service population estimate, estimation of water demand and unit yield
  Water production measures
- Water Supply/System Plan : Formulation of produced water distribution/supply methods and water production/supply systems
- Facility Plan : Planning of required facilities, preliminary design

- Implementation Plan : Formulation of construction schedule, executive organization

- Cost Estimation : Estimation of construction, O/M and unit water production cost

- Operation/Maintenance Plan: Formulation of water production control and operation/maintenance plan, establishment of O/M organization

4.4 Ground Water Development Plan

4.4.1 Basic Approach

1) Highly Prioritized Water Resources

The scale of the villages in the Project Area, spatial distance between respective villages, population, general water demands, seasonal fluctuation magnitudes of surface water or groundwater quantity, development cost and etc., are considered to be significant factors in the priority ranking evaluation of domestic water resources. These factors have been cautiously studied in the preceding chapter and led to the conclusion that the development of ground water is to be given first priority as domestic water resource.

2) Procedures of groundwater development programming

Feasibility of groundwater development in the Project Area has been implemented in accordance with the procedures shown below:

(1) Demarcations of hydrogeological provinces and their features

a) Demarcations of hydrogeological provinces have been implemented on the bases of the results of the Phase I and Phase II works of the current program, while interpretation of existing information related to the respective hydrogeological provinces has also been considered.

b) Depths of respective aquifers underground have been investigated. The successful development of aquifers possesses economic significance in respect to the possible construction of water supply facilities.

c) Groundwater quality in respective hydrogeological provinces was investigated.

(2) Areal evaluations of priority ranking for groundwater development program

Following items concerning the respective hydrogeological provinces have been studied for the areal evaluation of priority ranking for ground water development.

a) Evaluation of groundwater reservoirs and groundwater development potential.
b) Technological and financial feasibility of groundwater development and water supply systems.
c) Assessment of the environmental effects of groundwater development in the Project Area.

(3) Supplementary water resources

Alternative water resources have been studied under the following conditions :

a) In the occasion that initial development cost, sustenance and maintenance costs, possible long-term sustainability of certain quantity of water, etc., are evaluated to be hardly feasible or if ground water development is estimated to be more costly than that of other water resources.
b) In the occasion that other type of water resources are evaluated to be more effective in terms of development.

3) Programming of groundwater development

(1) Groundwater development program should be established in compliance with characteristics of development area, aquifer properties, basin reserve, groundwater level, village structure general landform, geological structure of aquifers, etc.

Location and structure of water wells are to be determined in accordance with estimated quantity of water demand, while water yield programs are to be studied cautiously.

Evaluation of water quality is to be examined cautiously in line with the development sites to be decided.

(2) Attention should be paid to the following in connection with the results of the current works.

a) Two types of aquifers are observed in the Project Area.

The "unconfined aquifer" is generally observed in weathered basement rock bodies or Tertiary-aged beds near the ground surface. Groundwater resources in unconfined aquifers are considered to be reasonably technologically modern in development, although they are estimated to be not sufficiently stable domestic water sources. The banks along Rio Yaque del Norte are excluded though, since they are considered to be mostly affected by seasonal changes. Unconfined aquifers are observed in the Hydrogeological Provinces Ⅱ, Ⅳ-1, Ⅳ-2, and northern part of Ⅵ.

Consequently, the development of unconfined aquifers was properly implemented and was given first priority in areas where such issues as social situations, seasonal change in water quality, etc., can be reasonably settled.

b) Another type of aquifer, the "confined aquifer", is observed in the Tertiary-aged beds in the Project Area.

   The potential development of this type of aquifer is evaluated to be high in Hydrogeological Province Ⅲ and Ⅴ. Attention should be paid to the development of confined aquifers since they frequently indicate high Cl^- and SO_4^{2-} contents.

   Confined aquifers are generally found more than 20m deep underground. The development of confined aquifers in the Project Area is, therefore, estimated at a maximum depth range of about 120 meters, since $C\ell^-$ and SO_4^{2-} contents in Tertiary-aged beds show a general propensity to increase with depth.

c) Groundwater in unconfined aquifers can be developed in the region occupied by the sediments of late stage along Rio Yaque del Norte. However, it is necessary to further examine the general thickness of the above sediments and to continuously monitor water quality.

4.4.2 Aquifer and Development Scale Magnitude

The general characteristics of aquifers in the proposed groundwater development area and water yield potentials are stated below (see Table 4.1):

1) Hydrogeological Province Ⅱ : Llano de Yaque del Norte

Aquifers in Province Ⅱ, is estimated to be seated within the depths of 60m. Groundwater in the Province is unconfined. Static water level is seated about 5m deep, while water yield potential is expected to rate 10 liters per min. A highly-available aquifer, with a potential water yield of 500 liters per min. and a drawdown value of about 10m was locally observed.

2) Hydrogeological Province Ⅲ-1: Sur Yaque del Norte

Aquifers in Province Ⅲ-1 are estimated to be seated 60 to 90 m deep, while groundwater is estimated to be weakly confined.

General static water level elevations have not been confirmed yet, while a water well drill test has revealed the existence of confined groundwater about several meters thick. Province Ⅲ-1 shows similar water qualities, water quantity and drawdown value range as in Province Ⅱ.

3) Hydrogeological Province Ⅲ-2: Sur del Yaque del Norte

Aquifers in Province Ⅲ-2 are estimated to be seated 60 to 90m deep. Groundwater in the Province is estimated to be confined, while the water quality is generally similar to that in Province Ⅱ. However, an abundant quantity of water recharge under possible geological control, with high $SO_4 2$-content has been observed. Static water level in the Province is generally estimated to be seated 20m deep, while the potential water yield is estimated to be more than 100 liters per min. The water yield under a particular geological structure, as shown above, is inferred to be about 1000 liters per min., while the drawdown value during the pumping operation is estimated to be about 5m.

4) Hydrogeological Province Ⅲ-3: Sur del Yaque Norte

Aquifers in Province Ⅲ-3 are estimated to be in siltstone beds of Tertiary age seated 60 to 120m deep. Groundwater in this Province is estimated to be confined. Groundwater development in the Project Area is considered to be highly possible in this Province. It is also considered to have the highest potential of groundwater yield with high $Ca\ (HCO_3)_2$ content. the same situation is also observed nearby Chacuey and Canderon. Water quality in the Province is generally similar to that of Hydrogeological Province Ⅱ. Static water level is generally estimated to be seated 15m deep, and 50m deep in Palo Blanco.

The potential water yield is generally inferred to be 300 liters per min, and possibly 500 liters per min, locally.

5) Hydrogeological Province Ⅲ-4: Sur del Yaque del Norte

Aquifers in Province Ⅲ-4 are estimated to be seated 30 to 60m deep. Groundwater in the Province is confined. Water quality is generally similar to that in Province Ⅱ, although the Cl quantity is slightly high. Static water level is generally estimated to be seated several to ten and several meters deep, and the potential water yield is inferred to be about 5 to 20 liters per min.

6) Hydrogeological Province Ⅳ-1: Cordillera Central

Aquifers in Province Ⅳ-1 are estimated to be seated 30 to 60m deep. Groundwater in the Province is unconfined and the $Ca(HCO_3)_2$ content in the water quality is evaluated to be the highest in the Project Area. Potential water yields are estimated to vary according to the thickness of weathered parts of tonalite bodies, which consequently led to the estimation that the water yields from the wells allocated nearby the ridges of mountainous hills must be small, and must be large in wells in less-undulated hilly areas. Static water level is estimated to be 5 to 15m deep and the potential water yield is inferred to be about 10 to 60 liters per min.

7) Hydrogeological Province Ⅳ-2: Cordillera Central

Province Ⅳ-2 is situated in the north and south area between Province Ⅳ-1. Potential water yield of groundwater in this Province, both in the north and south, is estimated to be 10 liters per min.

If is unlikely possible to observe aquifers in the bed rocks within 90 m deep in northern Province Ⅳ-2. Static water level in the north is estimated to vary sharply from 8 to 50 m deep. The possibility of high SO_4^{2-} and $C\ell^-$ contents in the water quality should be cautiously examined.

It is unlikely possible to observe aquifers in the bed rocks within 60m deep in southern Province Ⅳ-2. Static water level in the south is estimated to be seated about 14m deep while water quality contains high Ca $(HCO_3)_2$ concentrations.

8) Hydrogeological Province V-1: Valle de San Juan

Aquifers in Province V-1 are estimated to be seated about 30 to 60m deep. Groundwater in the Province is specified to be unconfined in loosely consolidated calcareous conglomerate beds which spatially extend up to ground surface, and confined in calcareous sand-gravel beds overlain by aquiclude siltstone beds. Groundwater is relatively rich in Cl^- content and does not exceed the limitation value stipulated by the INAPA. Static water level is estimated to be seated within the range of 20m deep and potential water yield is inferred to be 5 to 20 liters per min.

9) Hydrogeological Province VI: Sierra de Neiba

Groundwater quality in the Province is similar to that of Hydrogeological Provinces II and III. Static water level is estimated to be about 20m deep and potential water yield is inferred to be 5 to 20 liters per min.

4.4.3 Standard Drilling Techniques

Drill well operations are typically composed of such works as hole opening, drill for work casing, infixing, and drill in the lower portion below the casing-infixing-portion.

1) Well Location, Depth and Borehole

The groundwater production method to be adopted in this Project is the hand pump system, in consideration of its advantages, that is, low construction cost, easy O/M and time saving. In case 2 or 3 hand pumps are operated simultaneously in a village, drawdown of water level will be prevented by keeping a suitable distance (more than 200 m) between wells.

Drill hole will be 6 inches in diameter to prevent drawdown of pumping efficiency.

Given a relatively low design production, the same drill hole aperture of 6 inches, which is more economical, will be applied to wells equipped with a motor pump.

Well location, depth and drilling method must be determined based on comprehensive hydrogeological survey. Detailed hydrogeological structure shall be studied by electric prospecting, if required, after reviewing seasonal variation of groundwater level, water quality, yield and hydraulic information of existing wells.

As for the target depth of bore holes in connection with groundwater quality, it was found that 30 m deep groundwater contains salt and suspended matter and is, therefore, unsuitable for drinking. Besides, according to the results of the survey, ground water quality shows a propensity to higher content value of $C\ell^-$ and SO_4^{2-} in accordance with deeper depth. Consequently, drill hole depth was fixed between 60 and 120 m at the most, with due regard to critical pumping depth of hand pump-equipped wells.

An additional 20 m depth will be added to the target depth for the small particles such as fine-grain sand penetrating in the well through the water screen, to avoid water pollution.

2) Standard Drilling Method

Drill operations are to be implemented by rotary mud drilling, percussion by air-hammer and/or cable percussion methods in compliance with the anticipated underground geological situation of program drill sites. Rotary method and percussion method by air hammer are to be conveniently turned to any choice when drilling holes, while a choice of cable percussion method is to be made in advance before the selection of the drill rig is to start.

Cable percussion method is evaluated to be more effective in areas covered by unconsolidated sand beds, such as in Hydrogeological Province II (Llano de Yaque del Norte). On the other hand, air-hammer percussion method is effective in areas covered by granitic bodies, such as in Hydrogeological Province IV-2 (Cordillera Central).

Rotary method is evaluated to be less effective in areas where groundwater level is deep and where upper beds from water surface are formed from porous substances.

Generally, the drill hole depths, depending on the selected techniques, shall be as follows:

Rotary method: about 120 meters deep

Percussion method by air-hammer:

about 80 to 100 m deep

Cable Percussion Method:

about 60 to 80 m deep

In order to identify the aquifer and decide on the screen position and length, spontaneous logging, resistivity and natural gamma ray logging is to be carried out after drilling.
During drilling, particularly in the case of rotary mud drilling, slime must be carefully observed for a complete geologic log.
Air-hammer percussion method allows the rapid detection of aquifers and geological conditions during drilling.

3) Completion of Water Well

Completion works of water well are comprised of infixing of screens for well, casing pipes and packing of gravels.
Infixing of screens for well and casing pipes are carried out by using a drill rig. Packing of gravels is carried out after the completion of infixing screens. Size of gravels to be used has to be adjusted to an optimum scale by mixing coarse-grained sands to prevent infiltration of fine-grained sands into water screens of wells, as the aquifers in Dominican Republic chiefly consist of fine-grained sand beds.
A highly resistant pipe is recommended for well screen, with a 5% opening ratio and a slot size of 1.0 mm (horizontal slot screen).
A layer of gravel is recommended as a filter to keep the fine-grained sand observed in many aquifers in the Project Area out of the well, and grain sized gravel of less than 9 mm is to be used. Gravel is introduced around the screen casing.
Installation of a cement grout is carried out extending from the surface to a depth of several meters, to prevent any dirty water or material from flowing into the well and give the upper end of the casing firm support.
Drilling plan is as follows:

Province	Rock beds of Aquifers	Thickness of Aquifers (m)	Expected Water Yield per Borehole ℓ/m	Designed Depth (m)	Borehole Diameter (Inch)	Drilling Method
II	Fine-grained sand, Unconfined	20~30	100	60~90	6	C.P.
III-1	Extremely fine-grained, sand weakly confined	20	100	70~80	6	C.P., R
III-2	Calcareous sandstone, confined	20~30	100	70~80	6	C.P., R
III-3	Sandstone silstone alternation, confined	10~60	300	80~150	6	R.
III-4	Calcareous sandstone, weakly confined	5~20	5~20	70~80	6	C.P., R
IV-1	Weathered granitic body, unconfined	20~40	10~60	60	6	A.H.
IV-2	Weathered Mesozoic sandstone unconfined	10~40	5~15	70~90	6	A.H.
V-1	Calcareous conglomerate sandstone, unconfined~confined	20~30	5~20	50~70	6	C.P., R.
VI	Calcareous sandstone, unconfined	20~30	20	50~70	6	C.P.

C.P. = Cable Percussion, R = rotary, A.H. = Air Hammer

4.5 Surface Water Development Plan

Surface water development plan shall be formulated as the water source development plan for the 7 villages located in the northern part of Monte Cristi Province depending on rain water for domestic use.

The proposed development plan shall examine the collectible amount of surface runoff water and the designed storage water to be reserved in order to meet the local water demand.

1) Design Precipitation

The areal rainfall estimate was based on data recorded in Monte Cristi, in Villa Vasquez, in the Papayo rainfall gauge stations installed by JICA, and the Isohyetal Map of monthly rainfall provided by the ≪Servicio Meteorologico National≫.

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
mm												mm
62	39	40	69	75	44	20	37	44	80	125	115	750

Little runoff percentage and low collecting efficiency are observable in areas where monthly rainfall amounts to less than 45 mm. Only monthly rainfall exceeding 45 mm was retained as effective rainfall. Consequently, design precipitation is evaluated based on 6 months data (Apr., May, Oct., Nov., Dec., Jan.), that is, months with more than 45mm rainfall, and total design precipitation amounts to 526 mm.

2) Surface Runoff

(1) Runoff water (R) can be correlated as:

$$R = KP$$

where,

R : Runoff water

K : Runoff Coefficient

P : Rainfall

The physical characteristic, cropping pattern and related factors were taken into consideration in obtaining the design runoff (R). A 0.4 value was decided after the examination of the various R values obtained in reference to the rational or empirical formula.

(2) Available Surface Runoff Water and Demand Water

The location of the reservoirs, the catchment area of the proposed reservoirs, and the design water demand in the proposed villages are as follows:

Name /Village	Location of Reservoirs	Catchment Area of Reservoirs	Design Demand Water
		km2	m3
Sabana Cruz El Cayal La Conucos	El Cayal	3.1	26,645
Las Canas La Brigada Las Aguitas Buen Hombre	La Brigada	2.5	25,185

Sometimes runoff channels are artificially obstructed even in the village area. Given that surface storage is possibly due to road construction, the collecting efficiency of surface runoff water was assumed to be 70%.

Evaporation of water stored in reservoirs is estimated at 1,307 mm.

Reservoirs Name	Catchment Area	Effective Rainfall	Collectible Water *	Effective Storage Water		
				Demand	Evaporation **	Total
	(km2)	(mm)	(m3)	(m3)	(m3)	(m3)
El Cayal	3.1	526	456,568	26,645	26,140	52,785
La Brigada	2.5	526	368,200	25,185	26,140	51,325

* : Qc=P. A. K. E.

where ; Qc=Collectible water

P=Rainfall K=Runoff Coefficient: 0.4

A=Catchment Area E=Collecting Efficiency: 0.7

** : Estimated reservoir surface area in high water level: $200 \times 100 = 20{,}000 m^2$

Strictly speaking, it is difficult to think that both reservoirs will be used in the same physical and socio-economical conditions. However, the collectible water volume will fully satisfy the design water requirement and constitute a stable water source for the proposed water supply plan.

4.6 Water Supply Plan

4.6.1 Basic Approach

The proposed water supply plan consists of a water production and water supply plan. The plan shall be formulated for the proposed 95 villages on the basis of the following basic policies.

- The proposed plan shall be made practical and realizable in connection with the dependable water resources and water demand of the respective selected villages.

1) Planning Criteria

(1) Target Year

The planned target year is 2000 in consideration of the future expansion of water demand.

(2) Service Population

The 1990 population of some areas of the regions surveyed has more than doubled (203%) since the 1981 census, while other areas had decreased or even dispersed altogether (-100%). In order to accommodate these changes, the project will, therefore, be based on the following standards.

- Present population : The population as of the 1990 survey
- Population Growth Rate: The rate will be based on the 1981-1990 growth rate. Service population of villages where population decrease is evident will be based on the 1981 census.

(3) Water Consumption

Proposed water consumption per capita is a realistic quantity in reference with the INAPA's standard. Designed water consumption for each proposed supply system is indicated in the following table.

Water Supply System	Reference	Consumption
Hand Pump	Walking distance more than 500m	40 ℓ/c/d
Hand Pump	Walking distance less than 500 m	60 ℓ/c/d
Motor Pump	Communal faucet, walking distance more than 500 m	60 ℓ/c/d
Motor Pump	Communal faucet, walking distance less than 500 mm	100 ℓ/c/d

Daily maximum demand = Service Population × Average Water Consumption × 1.2

Hourly maximum demand = Service Population × Average Water consumption × 1.8

(4) Water Quality Standard

The INAPA water quality standard is applicable to all INAPA operated water supply facilities and is similar to the WHO standard (see Table 2.10).

4.6.2 Development Plan for the Target Villages

The feasibility of the implementation of the development plan for the 95 villages assessed to be in need of a water supply plan was evaluated according to the following:

1) In accordance with the water shortage conditions, urgency for water supply development, and the difficulties in water development works, the (95) target villages were categorized into 3 classes.

A: Villages with grave water shortage conditions and very urgent need for water development.

B: Villages with a relatively low demand for water development in comparison with (A).

C: Villages covered by the existing urban water supply services; with inaccessible roads; with mountain stream water as their sole water source; with a household population of less than 20; with small groundwater development potential; and those located at the northern mountains of Independencia.

2) The villages were divided into two groups according to dependable water resources.

G: Villages which can depend on groundwater as their source.

S: Villages depending on surface water as their source.

The classification of the villages is shown in the following Table (see details in Table 4.2 (1 - 7)).

4.6.3 Target Villages

The classification of the (95) evaluated villages is as shown below.

	Monte Cristi	Dajabon	Eliás Piña	Indepen-dencia	Total
Class A Villages	14	6	12	-	32
Class B Villages	5	15	6	-	26
Class C Villages					
Inaccessibility	-	3	12	-	15
Existing Water Supply	3	2	-	-	5
Small Ground-water Dev. Potential	2	1	9	5	17
Total	24	27	39	5	95

Based on the above evaluation, it was determined that the water production and water supply development projects should be implemented in the 58 villages under Class A and B.

The population of these villages is 25,627, 64.4% of the overall population of the 95 target villages.

Regarding the development plan which should be carried out as soon as possible, present conditions of available water for domestic use and potentiality of groundwater development for the 37 villages of class C excluded from the proposed Project implementation plan are as shown in Table 4.3 (1)~4.3 (2).
5 of the 37 villages located in the surroundings of a town with existing water supply system, can likely be connected to the same system by improvement and extension works.
The formulation of individual projects or wide area cooperation project including mountain stream water development is recommended for the remaining 32 villages, because of available mountain streams or spring. However, data on the discharge water required to assess development potential and stability of water resources for domestic use are not available.
Accordingly, observation of discharge water shall be systematically carried out over a period of more than one year to obtain the necessary discharge data, then to evaluate the viability of water resources.

4.6.4 Water Production Plan

The water resources plan shall involve groundwater for 47 villages and run-off water for the remaining 11 villages located in the province of Monte Cristi.

1) Design Yield

The design yield of each production system was estimated based on the water supply standard. With the inclusion of the water intake and conveyance losses, the design yield was calculated as 120% of the standard water supply. The design yield of a different system plan are as follows:

- Manual Pump System	48 liters/daily maximum water demand
- Motor Pump System	72 - 120 liters/daily maximum water demand
- Reservoir, filtrated water, Booster Pump Station	48 liters/daily maximum water demand
- Tank Lorry System *	15 liters/daily maximum water demand

*: Drinking Water Distribution

2) Production System

(1) Groundwater Production System

Hand pump and motor pump production systems were chosen for groundwater production method in terms of the groundwater aquifer properties, groundwater level, lifting head variations, required drilling depth, and service population.

Of the 47 villages having groundwater as their source, 40 were installed with hand pump systems and 7 were installed with the motor pump system.

The required number of hand pump facilities in the 40 villages was determined based on the safe volume of pumped water and water supply yield in each area, and is shown in the following table:

Province	Number of Villages	Wells Hand Pumps
Monte Cristi	2	5
Dajabon	20	72
Elias Piña	18	54
Total	40	131

(2) Surface Water Production System

According to the topography and the mechanism of surface water run-off of the target villages, the villages were again classified in terms of surface water intake, and the easiness and difficulties in storing water.

The target villages involved here are the 11 villages located at the north coast and hills of Monte Cristi. The 3 villages along the north coast and one village at the west-north end of the hills shall be provided with treated water through the tank lorry.

(3) Water Supply System

The water supply system was determined in accordance with the water production system, village structure, and service population.

a) Independent Production and Procurement System
Independent production and procurement of water through the hand pump facilities; this system shall be limited to approximately 20 households to minimize transportation distance.

b) Motorized Pumping, Communal Faucet, Water Supply System
With motorized pumping, pumped water is stored in an elevated water tank, then distributed through gravity conveyance to communal faucets. The maximum conveyance distance is 500 m.

c) Reservoir Ponds, Purifying Plant, Booster Pumps, Communal Faucet Water Supply System

d) Purified drinking water treated from the purifying plant under INAPA's jurisdiction is transported to the water tanks installed in each village through a tank lorry. Water distributed to each tank shall undergo chlorination again.

The Water supply network system of each system is shown in Figure 4.2.

Only 1 pump well shall be constructed in one farming village, in 6 Monte Cristi villages, and in one Dajabon village.
Storing and purification, to make it drinkable, and conveyance of surface water was proposed for the remaining 7 villages. Nevertheless, the construction of a reservoir pond was proposed.
Surface water shall be collected, stored, purified and treated. In order to curtail the construction and operation and maintenance costs of the water production system, 2 systems, one in the 4 villages and 3 villages, were installed.

CHAPTER V

FACILITY PLANNING

CHAPTER V

FACILITY PLANNING

5.1 Basic Policy

The plan for the facilities required in this development project will be formulated based on the proposed water production and supply plan.

1) Required Facilities

The required facilities and materials for each plan proposed are as follows :

System	Required Facilities
Hand Pump System	131 wells, hand pump, base floor
Motor Pump System	7 wells, motor pumps, generation source, engine and control room, elevated water tank, pipelines, communal faucets
Reservoir Pond, Purification, Booster Pump System	Ponds in 2 places, water intake equipment, filter, equipment for water treatment, motorized booster pump, pipelines, elevated water tank, communal faucets
Water Conveyance System	Conveyance or distribution vehicle, water supply tank

Aside from the above, the facility and machinery plan shall, therefore, entail the operation and maintenance of the facilities, monitoring of groundwater, and improvement of roads for accessibility.

2) Norms of the Plan

(1) Hand Pump System

a) Wells

- Standard drilling method and diameter

Upon comparison with the results of the boring test conducted during the study period, the method , i.e., mud rotation method (more than 80m) and cable percussion method (less than 80m), to be used shall be determined according to the geological structure and rock features of the drilling area. The drilling diameter for both methods shall be 10 5/8 inches.

- Standard Cross Sections

The standard cross section is as shown in Fig. 5.1. Wells of 10 5/8 inches in diameter shall have a finishing pipeline hole of 6 inches. The maximum and minimum depth shall be 150m and 70m, respectively, according to the properties of the groundwater aquifer at the designated point. Further, the depth of the sand deposits is considered to be 20m.

- Casing and Strainer

With due consideration of the comparatively large Cl and SO4 content in the groundwater properties, highly durable FRP materials (strengthened glass fiber plastic) shall be used for the casing and the strainer.

The opening ratio of the strainer must be 5%, and although it is more favorable to regulate or adjust the opening, the length shall be about 30% of the excavation length based on the study results.

b) Hand Pump

Hand pumps shall be installed in deep wells and the pipe diameter shall be 3-2/3 inches.

c) Pump Installation

The base of the pump shall be of concrete and structured to make water leakage and drainage of dirt possible.

(2) Motorized Pump System

a) Wells

The drilling method, diameter, casing, strainer, depth, etc., shall be similar to those decided for the well of the hand pump system.

The standard arrangement is shown in Fig. 5.2.

b) Motor Pump

- A submersible motor pump, considered to be most suitable for pumping large volume of groundwater, shall be used in areas where groundwater volume is thought to decline in the dry season and if the required amount of pumped water is large.

- The submersible motor pump shall be of stainless material with a switch that would temporarily stop the production of water when water level is low.

- A power engine shall be installed in a generator house to supply electric power to the submersible motor pump. An electric and control room shall be constructed too. The motor pump capacity shall be designed to accommodate the peak demand, and the maximum production shall be 180% of the standard production plan. The required power shall be determined in comparison to the windmill and solar electric system. Refer to the following sections for further details.

c) Elevated Water Tank

- The capacity of the elevated water tank shall accommodate 10 hours worth of the maximum demand /day. The height of the elevated water tank shall be determined by making the hydraulic pressure from the ground surface not less than 7m and the terminal hydraulic pressure of the distribution pipe at approximately 5m.
- The elevated water tank shall be made of reinforced concrete to prevent corrosion, rusting, and contamination of stored water.

d) Distribution Pipes

The distribution pipes, both inside and outside, must be strong, strongly resistant to corrosion, and made of steel with lead gilding. The pipe line friction coefficient shall be C=130, based on the William and Hazen formula.

e) Communal Faucet

Communal faucets shall be constructed as terminal water facilities. The standard rule would be the installation of one unit per 20 - 30 households at a maximum distance (for independent intake and conveyance) of 500m. Two 25mm tap mouths made of concrete shall be installed.

(3) Reservoir Pond, Purified Water Booster Pump System

This system shall consist of a surface water runoff collecting duct, reservoir, water intake facilities, filter, facilities for sterilization, booster pump facilities, conveyance pipes, distribution tanks and communal faucets.

This system covers (7) seven villages. Aside from the reservoir, however, there is another water production plan employing two systems.

Facilities for Surface Water Development

a) Location of Reservoir

The location shall be determined based on geographical features, water intake possibilities, safety of surplus water discharge, required water conveyance distance, and preservation of water quality. Through these observations, the reconstructed and newly constructed reservoirs shall be compared. El Cayal and Las Brigadas were chosen on the basis of the following:

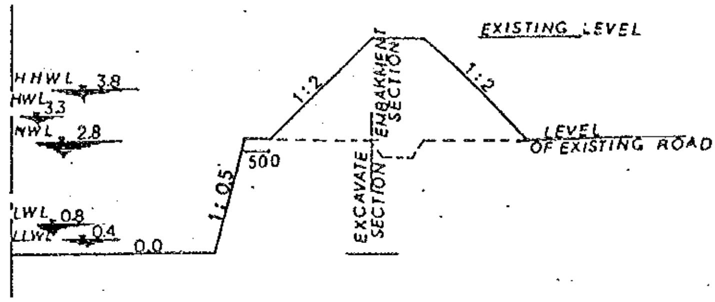
- they are both located at the natural catch line of surface water run-off;
- the headstream of the former is Arroyo Blanca and that of the latter is Canada Los Corbanos. Surplus water discharge is considered to be possible and safe in these areas;
- the comings and goings of livestock animals can be easily obstructed in these areas, and preservation of water quality can be easily attained;
- the juxtaposition of water treatment facilities is easy;
- accessible since they are both located facing the passable rural road.

b) Structure and Formation

The reservoir plan was basically studied for the reconstruction plan of the existing reservoirs. Accordingly, the dam type reservoirs shall be made into homogeneous or earth dam in type with an embankment-excavation compound structure.

- Standard Section

The height of the embankment shall be equal to the top level of the existing dam, and the standard section of the embankment body is as shown in the graph below. The existing embankment body shall be repaired and strengthened.



- Reservoir Area and Storage Capacity

  In normal water level, the reservoir area measures 20,000m2. Considering the large monthly and yearly rainfall variations, the groundwater level was adopted as normal water level, in order to ensure a safe domestic water source and to be able to cope with the variations in rainfall distribution. In addition, this was also meant to prevent the back water from affecting the upper reaches.

- Half of the annual evaporation consists of surface water in high water level, while the other half is surface water in normal or low water level. It is assumed, however, that surface water in normal water level evaporates more.

c) Water Intake Works

A concrete water intake tower, where surface water intake activities are to be conducted, shall be constructed. Water shall be pumped up to the filtration basin through the jetty.

d) Spring Water Sterilization Equipment

The use of a sand filter will enable the production of raw water with less than 30 NTU for turbidity. Water shall be chlorinated in consideration of the safety and easiness in the beneficiaries' administration of water production. The filter shall be changed at least once a month and the rate of filtration shall be 4 m/day.

e) Water Distribution and Conveyance Facilities

- The produced water shall be conveyed to the elevated water tanks installed in each villages through booster pumps and the pipeline.

- After the elevated water tank, water shall be transmitted up to the communal faucets through the gravity system. Motor pumps shall be used.
- The standard section of water intake works, filter basins, reservoir tanks, conveyance pipe, communal faucet, etc., is shown in Fig. 5.3 and Fig. 5.4.

(4) Water Distribution System through the Tank Lorry

- The capacity of the tank lorry was determined as 8m3 based on the domestic water demand per day and operational efficiency and the economical feasibility of the tank lorry;
- Water shall be distributed up to the location of the supply tanks in each village. The capacity of the tanks in each village shall be uniformed at more than 100 m3. Based on this development project, water to be supplied is treated and purified at the nearest filtration plant. To prevent water quality contamination after distribution, therefore, a small water supply tank shall be constructed in accordance with the water volume of the conveyance and distribution plan. Besides, to prevent water quality contamination during the storage period, water will be simply sterilized after distribution by introducing solid chlorine in each water distribution tank.

(5) Comparative Study of the Motorized Pump System

The power of the motor pump can be provided by a generator, windmill, solar batteries, etc. This project will use, however, a diesel engine according to the following reasons:

a) Windmill System

Groundwater is pumped up through the rotating energy of the windmill which is proportional to the cube of the wind velocity and the cross section of the windmill. This energy is, therefore, dependent on the velocity of the wind. Past data indicate a standard wind velocity of more than 3.0m/sec.

The annual data of each area within the project area is not available, while the monthly data of the neighboring area mostly showed a wind velocity of less than 3.0m/sec. Moreover, the state of the existing windmills indicate frequent break down of the pumping machine of deep wells, the need for technology and a maintenance system, and an extremely low ratio of operation.

Consequently, a future plan was made, that is, to conduct reinvestigations after sufficient data on wind velocity are gathered.

b) Solar Battery System

This system transmits power by saving up irradiation energy. Efficiency is assessed through the duration of sunshine hours and amount of solar heat. The majority of the project areas are located in mountains and hills and a less than 80% decline in efficiency is particularly estimated in December.

The data of Madagascar shows the month of May, from 9 am to 4 pm, to effect 0.6 - 0.6KW/m2, the largest amount of solar heat. Since the capacity of the water supply plan's motor pump is 1.5 - 2.2KW, only more than 5.0m2 of sunlit area is estimated to be required even with an all year round pumping. Further, the possibility of this system as a power source is considered low, based on the expected decrease in efficiency during rainy and cloudy days and contamination from birds' droppings. This system is also considered to be non-economical as its construction shall cost approximately 10 times more than that of the diesel engine, and technologically ineffective in terms of operation and maintenance.

5.2 Facility Plan

Based on the norms of the project, the facility plan was formulated as shown below. The facilities planned for each village is shown in Table 5.1 (1)~(4).

1) Type I (hand pump system)

Province	Number of Villages	Total Borehole Length	Number of Hand Pumps
Monte Cristi	2	350 m	5 pcs.
Dajabon	20	6,340	72
Eliás Piña	18	3,880	54
Total	40	10,570	131

2) Type II (motor pump system)

Province	Number of Villages	Total Borehole Length	No. of Motor Pumps	No. of Elevated Tank	No. of Faucet Unit
Monte Cristi	6	480 m	6	6	23
Dajabon	1	80	1	1	2
Total	7	560	7	7	25

3) Type III (reservoir, booster pump)

The existing reservoirs in La Brigada and El Cayal shall be used.

Treatment Plant	Service Population	Treatment Capacity (m^3/d)	Intake Pumps (kw)	Sand Filter Area (m^3)	Distribution Pumps (kw)
La Brigada	1,455 (4)	69.0	0.4 × 2	25.6 × 2	3.7 × 2
El Cayal	1,554 (3)	73.0	0.4 × 2	25.6 × 2	5.5 × 2
Total	3,009 (7)	142.0			

4) Type IV (tank lorry)

Water supply for the 4 Monte Cristi villages shall be conducted through the tank lorry.

5) Access Road

Repair works	4 villages	total length of 6.5 km
River Crossing works	14 places	
Construction of New Roads	5 villages	total length of 14.5 km

5.3 Operation and Maintenance Facilities

The operation and maintenance facilities shall include an O&M office, vehicles and respective materials, etc., enumerated below.

(1) O&M Office

Monte Cristi Office	1	
Elias Pina Office	1	

(2) Vehicles and Materials

Water Wagon	2	
Crane Truck	2	
Pick-up	1	
Motor Bicycle	2	

(3) Spare Parts

Hand Pump	13	1.5 kw × 1, 2.2 kw × 1
Submersible Pump	2	approximately 10% of the
Pipe, Valves	1	facility material

5.4 Summary of the Major Project Facilities

Items	Unit	Nos/ Quantity	Remarks
1. Preliminary Works	Lump	1	
2. Land Acquisition	ha	14.33	
3. Water Production/Supply Facilities			
Hand Pump Systems		131	40 villages
Well	No	131	D=6'
Drilling	m	10.570	D=10-5/8 inches
Hand Pump	Set	131	
Motor Pump Systems	No	7	7-villages
Well	No	7	D=6'
Drilling	m	560	D=10-5/8
Submersible Motor Pump	Set	7	1.5 kw - (5) 2.2 kw - (2)
Engine Generator	Set	7	7.7 kva - (6) 6.3 kva - (1)
Engine room	No	7	
Water Tank	Set		2.5×2.5×2.0H (H:7m) (reinforced concrete)
Faucet	Set	16	0.9×2.1 w (reinforced concrete)
Pipe-line	m	7,100	$\phi50 \sim \phi100$
Reservoir/Treatment System	No	2	7-villages
Reservoir	No	2	A-20,000 m^2
Treatment Plant	Set	2	69 m^3/day, 73m^3/day
Booster Pump	Set	2	3.7kw (2) 5.5kw (2)
Generator	Set		13.6 kva (2) 18.74 kva (2)
Water Pipe	m	13,100	$\phi50 \sim \phi100$
Water Distribution Tank	No	4	Reinforced concrete C:6~24m^3
Tank Lorry System	Unit	2	4-villages
Water Wagon	No	2	C:8m^3
Water Distribution Tank	No	4	4.0×4.0×1.0 (1) 4.0×4.5×1.5 (2) 4.0×5.0×1.5 (1)

Items	Unit	Nos/ Quantity	Remarks
4. O/M Facilities			
Office Building	No	2	60 m^2
Work Shop	Lump	1	
Patrol Service Car	Lump	1	4t-truck crane (2) etc.
5. Access Road			
Improvement	km	6.5	
New Construction	km	14.5	
River Crossing	No	14	
6. Monitoring Facilities			
Well	No	7	Dia. 150 mm
Groundwater Level Meter	Set	7	Depth 100~150 m

CHAPTER VI

COST ESTIMATION

CHAPTER VI

COST ESTIMATION

6.1 General

The implementation of this Project shall entail direct construction expenses, operation and maintenance expenses, land acquisition expenses, general management expenses, and contingencies concerning consultation services with respect to work load and price fluctuations. The financial cost estimation of the project was, therefore, performed based on the following.

1) Financial evaluation was based on the December, 1991 price rate.

2) The following exchange rate was applied:
US$1 = 12.45 Dominican Republic Pesos

3) The construction works are to be implemented on the basis of competitive bidding between international and domestic contractors.

4) The expenses of the material for the construction work are to be directly purchased by INAPA, the implementing body, and are to be procured and supplied to the contractors.

5) The construction cost is divided into foreign and local costs. The classification of foreign and local costs is shown below.

(1) Foreign costs
- Galvanized steel pipe
- Hand pump and submersible pump with accessories
- Chlorinator and accessories
- Generator and operation board
- Casing pipes, strainer
- Drilling work for the wells
- Engineering service cost of foreign consultants

(2) Local costs
- Labour forces
- Reinforcement bars
- Cement, sand and gravel
- Fuel, oil etc.
- Inland transportation costs
- Engineering service costs for local consultants

6) Physical contingencies were estimated at 10% of the total cost, and includes direct construction expenses, land acquisition expenses, operation and maintenance equipment and general management expenses, and consultation services.

7) Considering future price fluctuations, the contingencies for local cost were estimated at 30% of the total local costs.
   - The main facilities and equipment proposed in the Project are listed below.

	Monte Cristi	Dajabon	Elias Pina	Independencia	Total
1) Manual Pump System					
Pump & Well	5	72	54	–	131
Drilling length					10,570m
2) Motorized Pump System					
Pump & Well	6	1	–	–	7
Drilling length					560m
Water Tank	6	1			7
Communal Faucet	23	2			25
Pipeline	6900m	200m			7,100m
3) Reservoir-Booster Pump System					
Reservoir	2				2
Filtration Plant	2				2
Water Tank	4				4
Communal Faucet	17				17
Pipeline	18,100m				18,100m
4) Water Wagon System					
(Water Wagon)	(2)				(2)
Communal Water Tank	4				4
5) O/M Office	1	–	1		2
6) Travelling Workshop	1				1
7) Monitoring Well	3	3	1		7
8) Access Road					

6.2 Project Cost Estimation

Accordingly, the project cost for the draft final facility plan is estimated for the urgent water supply plan intake for 58 villages.
The financial cost of the proposed Project is summarized in the Table below.

(Unit : RD$)

Items	Foreign Currency	Local Currency	Total
1 Water Production / Supply System			
Type-Ⅰ Manual Pump System	48,465,177	7,915,913	56,381,090
Type-Ⅱ Motorized Pump System	5,782,382	5,510,303	11,292,685
Type-Ⅲ Reservoir Filtratim Booster Pump System	4,278,484	6,684,503	10,962,987
Type-Ⅳ Water Wagon System	1,145,739	658,574	1,804,313
Sub Total	59,671,782	20,769,293	80,441,075
2 O/M Facilities / Equipment	3,649,750	684,250	4,334,000
3 Monitoring System	1,137,000	1,643,000	2,780,000
4 Access Roads	190,600	1,715,000	1,905,900
5 Preparatory Works	—	744,355	744,355
Sub Total	64,649,132	25,556,198	90,205,330
6 Spare Parts	1,704,971	—	1,704,971
7 Administration / Engineering service	10,818,263	4,523,447	15,341,710
8 Land Acquisition	—	143,000	143,000
Total	77,172,366	30,222,645	107,395,011
9 Physical Contingencies	7,717,236	3,022,264	10,739,500
10 Price Contingency 30% of Local costs	—	9,066,793	9,066,793
Grand Total	84,889,602	42,311,702	127,201,304
			≒127,201,000

6.2.1 Direct Construction Costs

The breakdown of the direct construction cost by work items are presented in the following table.

FINANCIAL CONSTRUCTION COST

(Unit : RD$)

Item	Foreign Currency	Local Currency	Total
1. Water Production / Supply Systems			
(1) Type- I Manual Pump System			
Drilling	30,996,525	5,469,975	36,466,500
Casing / Strainer works	14,075,883	1,739,717	15,815,600
Pump / installation	3,392,769	419,331	3,812,100
Concrete Basefloor Works	—	286,890	286,890
Sub Total	48,465,177	7,915,913	56,381,090
(2) Type- II Motorized Pump System			
Drilling	2,051,560	362,040	2,413,600
Casing / Strainer	620,980	76,780	697,760
Equipment / Installation	1,561,800	203,000	1,764,800
Pump House	80,000	324,000	400,400
Elevated Water Tank	722,400	2,889,600	3,612,000
Pipe Line	745,642	1,409,358	2,155,000
Faucet	—	245,525	245,525
Total	5,782,382	5,510,303	11,292,685
(3) Type-III Reservoir Filtration Booster Pump System			
Reservoir	—	1,216,000	1,216,000
Intake works / pump	226,130	233,088	459,218
Treatment Plant	1947,050	817,510	2,764,560
Elevated Water Tank	157,380	629,520	786,900
Pipe Line	1,915,924	3,621,428	5,537,352
Faucet	—	166,957	166,957
Motor bicycle<1	32,000	—	32,000
Sub Total	4,278,484	6,684,503	10,962,987
(4) Type-IV Water Wagon Distribution System			
Water Wagon<2	(1,420,000)<2	—	—
Water Tank	1,145,739	658,574	1,804,313
Sub Total	1,145,739	658,574	1,804,313
Total	59,671,782	20,769,293	80,441,075

2 O/M Facilities / Equipment			
(1) O/M office Building	105,000	595,000	700,000
O/M office Furnitures	15,750	89,250	105,000
Sub Total	120,750	684,250	805,000
(2) O/M Equipment			
truck crane/vehicles	988,500	—	988,500
Water Wagon	1,420,000	—	1,420,000
Work-shop Car	1,120,500	—	1,120,500
Sub Total	3,529,000	—	3,529,000
Total	3,649,750	684,250	4,334,000
3 Access Road Improvement / Construction Works			
Improvement Works	97,500	877,500	975,000
Construction Works	520	4,700	5,220
River Crossing Works	92,580	833,100	925,680
Sub Total	190,600	1,715,300	1,905,900
4 Monitoring System			
Monitoring Well	1,087,000	1,643,000	2,730,000
Automatic Water Level Meter[<3]	50,000	—	50,000
Sub Total	1,137,000	1,643,000	2,780,000
5 Preparatory Works (3% of local portion)	—	744,355	744,355
	64,649,132	25,556,198	90,205,330

<1 : Separated from the official O/M equipment
<2 : Included in the official O/M equipment
<3 : Only one level meter estimated, because 6 meters will use existing ones.

CHAPTER VII

IMPLEMENTATION PLAN

CHAPTER Ⅶ

IMPLEMENTATION PLAN

7.1 General

The Proposed Project aims to solve the water service problems in 58 villages of 3 border provinces (Monte Cristi, Dajabon and Elias Piña). These villages need potable water services to improve their standard of living, and the early implementation of the Project is urgently required. Project implementation will be under the responsibility of INAPA.

The main facilities are as follows:

Water supply system		Province	Number of villages	Main Facilities	
				unit	m
Type Ⅰ	Hand pump	Monte Cristi	2	Boreholes 5, Total length	350
		Dajabon	20	Boreholes 72, Total length	6,340
		Elias Piña	18	Boreholes 54, Total length	3,880
		Sub-total	40	Boreholes 131, Total length	10,570
Type Ⅱ	Motorized pump	Monte Cristi	6	Borehole, Submersible pump, Elevated tank and pipelines and common water faucets	
		Dajabon	1	Borehole, Submersible pump, Elevated tank, pipelines and common water faucets	
		Sub-total	7	Total pipeline estimate ϕ50~ϕ100 7.1 km	
Type Ⅲ	Water treatment plant	Monte Cristi	4	Improvement of reservoir water treatment facilities, distribution pipeline, common faucets	
		Monte Cristi	3	Improvement of reservoir water treatment facilities, distribution pipeline, common faucets	
		Sub-total	7	Total pipeline estimate ϕ450mm~ϕ100 13.1 km	

Water supply system		Province	Number of villages	Main Facilities
Type IV	Tank car supply	Monte Cristi	4	Tank car 2 units, drainage reservoirs 4 units
		Sub-total	4	Total driving distance estimate: 80 km
Drilling	Access road	Dajabon	4	Repairing: 1 km
	Rehabilitation	Elias Piña	19	Repairing: 5.5 km New Road : 14.5 km River Crossing: 14 places
		Sub-total	23	
O/M	Groundwater Monitoring	Monte Cristi	2	Test well drilling including implementation of water level recorders
		Dajabon	3	
		Elias Piña	2	
		Sub-total	7	

7.2 Implementation Organization

INAPA will be responsible for the execution of the entire project including the following works:

- Procurement of finance for the proposed project
- Detailed design of required facilities
- Formulation of implementation plan
- Planning and supervision of the construction works
- Tender, contract and other required matters and procedures for the commencement of construction works
- Enforcement of tender; choice of Contractors; contract
- Land acquisition
- Procurement and supply of main materials and equipment
- Procurement and provision of funds

For overall execution, INAPA will appoint a project manager under the Deputy Director for implementing the design and construction works.

The appointed Project Manager will be directly responsible for implementing the Project and for coordinating the activities of all concerned sections within INAPA.

The proposed Organization Chart for the construction stage is presented in Fig. 7.1.

It is proposed that facility detailed design, preliminary works (tender document preparation, selection of contractors, etc.), and supervision of implementation be carried out through consultant engineering services.
The project manager of INAPA will establish in each Province a Coordinating Committee, composed of local and police authorities for the smooth and secure implementation of the Project.

7.3 Implementation Schedule

The implementation period was determined based on the scale, cost and number of proposed Project facilities, ability of contractors, procurement of materials and labor, and INAPA's capability to finance construction, etc.
Preparatory works such as preliminary design, land acquisition and construction of access roads will be completed within the first year to expedite commencement and completion of construction works.
Although funding capability of INAPA, as well as financing cooperation from Japan, other countries, and international financing agencies will have to be studied before final decisions are made, a total implementation period of 3 years, that is, 1 year for preliminary works and 2 years for construction is tentatively proposed.
In consideration of the Project objectives, the construction of facilities will be completed within the scheduled year, and implementation will be divided into phases to maximize efficiency.
Moreover, each construction phase will be made to meet the quantitative and geographical demands projected for the corresponding time periods.

It is proposed that the facility detailed cost, preparation of tender documents, and partial construction of access roads will be implemented in the first year. In addition, a field survey including electric prospecting will be carried out in the sites of the 15 villages, where available groundwater is relatively low (safe yield : 10 l/mn), previously selected for well drilling.

The main construction works will be implemented within a 2 year-period, as shown in the following table. However, as indicated above, the principle is to complete the construction within the same year it commenced.

Total implementation period scheduled is 3 years. If preliminary works are executed in the final year, 1993, the works shall be achieved before the end of the 1995 fiscal year. The tentative outline of the work schedule is as follows:

Implementation Schedule

I st year (1993)	II nd Year (1994)	III rd Year (1995)
Preliminary Operations	Construction	Works
Detailed Study, Planning	Access Road Const./ Improvement Works	Water Production/ Distribution Works
Detailed Design Tender Contract Documents Preliminary Works Preparation/Procedures	Preliminary Works (Detailed Design/Survey)	Type I - system : 81 Type III - system : 1 (El Cayal) Type IV - system : 2
O/M Office Installation	Water Production/ Distribution Works	O/M Facilities / Equipments Works (≒60%)
Land Acquisition	Type I -system : 50 Type II -system : 7 Type III -system (Las Aqüitas) : 1	Monitoring System (=40%) Spare parts
Access Road Const./ Improvement Works	Monitoring System (=60%) O/M Facilities/Equipment Works (≒40%)	

7.4 Material Procurement and Construction Work

The main materials and equipment for the Project facilities will be directly procured under the responsibility of INAPA and will be supplied to the contractors. The construction works will be executed by international or local contractors contracted through competitive tendering.
The yearly acquisition of land for the required facilities and power line arrangements will be the responsibility of INAPA.

To prevent delay in the work schedule because of overdue material provision, INAPA must make all the required discretions and assign the personnel necessary for material procurement in compliance with the implementation schedule.

It is also necessary to gain as much cooperation from the local residents during the execution of the works and to increase local employment opportunities.

7.5 Disbursement Schedule

The disbursement schedule for the proposed plan, in accordance with the implementation schedule and project cost, is presented in the following table.

Item	1st year (1993)	2nd Year (1994)		3rd Year (1995)	
Land Acquisition	143,000				
Detailed Design/Administration	5,634,400		4,853,855		4,853,855
Preliminary Works	447,000		297,000		-
O/M Facilities/Equipment	-		2,374,000		1,960,000
Road Works	-		1,906,000		-
Type I (Hand Pump)		Dajabon (50 places)	23,308,000	Monte Cristi (5 places)	1,878,000
				Elias Piña (54 places)	20,939,000
				Dajabon (22 places)	10,256,000
Type II (Motorized pump)		Monte Cristi (6 places)	10,324,585		
		Dajabon (1 place)	968,100		
Type III (Reservoir, Filtration, Booster Pump)		Las Aguitas	5,151,000	El Cayal	5,622,000
Type IV (Tank Lorry)					1,804,313
Monitoring System	-		1,560,000		1,220,000
Spare parts	-		-		1,704,971
Sub-total	6,224,000		50,743,000		50,428,000
Physical Contigencies	622,400		5,074,300		5,042,800
Total	6,846,400		55,817,300		55,470,800
Price Escalation	525,460		4,283,974		4,257,370
Total	7,371,860		60,101,274		59,728,170

CHAPTER VIII

OPERATION AND MAINTENANCE

CHAPTER Ⅷ

OPERATION AND MAINTENANCE PLAN

8.1. Basic Approach

The Objectives of the proposed Project will be fulfilled with the appropriate and systematic Operation/Maintenance of the presented facilities/equipment and overall systems. The effective functioning of the Project facilities/equipment depends on properly organized operations and maintenance system.

Accordingly, the proposed O/M programs and recommendation on the overall O/M practices were made in accordance with the following basic policies.

- Daily maintenance of the facilities and water production control shall be performed by the beneficiary community organized into a system unit base.

- Regular inspection, improvement of the O/M facilities and equipment, and practical guidance on the O/M shall be conducted under INAPA's supervision.

- The reinforcement of INAPA staff and systems by employing skilled technicians for the workshop, patrol service and the administration, etc., for the effective and timely execution of INAPA's duties.

- Regular and concentrated operations shall be introduced to check the daily water production by the common water production/distribution systems to minimize the O/M Cost. A 24 - hour water production/supply will not be planned, but in consideration of emergent demands, 25% of the water tank capacity under the proposed Project shall be reserved any time.

- A coordination committee, which consists of representative members of the beneficiary community units of the proposed water supply system, shall be established in order to perform a reasonable and efficient management of the proposed reservoir system. The committee shall take care of the daily water production/distribution activities and the overall management of the reservoirs, such as, control of water storage, and preservation of the water quality.

- Water distribution by tank lorry shall be meticulously managed to minimize water transportation expenses and maintain the quality of distributed water.

- In principle, the cost for daily water production and maintenance of the facilities/equipment, such as spare parts, easy repair, etc., shall be shouldered by the beneficiary community members. INAPA should properly advice and guide these beneficiaries on reasonable water charge estimates and its collection measure.

- A groundwater monitoring system shall be established in terms of groundwater conservation measures, to prevent a drop in the efficiency of the water production equipment and to improve operation control programs.

- INAPA shall systematically train the beneficiaries on the operation and checking practices and management points, etc., in pursuit of the appropriate execution of daily O/M and efficient control of water production/supply. One of the aims of the training is to orient people with problems on water pollution and sanitation, and the effective water utilization measures to be taken.

8.2 Water Production Control

Water production control involves quantity and quality control.

1) Quantity Control

The production quantity control will ensure the supply of the required volume of water to consumers within the specified time. This control program shall be applied in both normal and emergent circumstances.

Daily water production will be planned for a concentrated and limited period and will correspond with the supply period fixed after mutual consultation with the beneficiaries. An effective water production will be planned to avoid excessive production and storage, considering the fluctuation in water demand according to rainfall distribution and temperature. Besides, records on essential matters such as daily conveyance time and fuel consumption volume and cost will be collected for the implementation of the future production control.

Large area water production control will be required as an emergency counter measure to stem water shortage arising in the neighboring community, or occurence of water shortage due to decreasing groundwater levels or stored water levels in the reservoir caused by drought.

2) Quality Control

The main purpose of water quality control is to satisfy the water quality standards required by the consumers.

Given that raw natural water, as in groundwater, is directly supplied, water quality analysis shall be regularly conducted just after completion of facility construction and for daily measurements of changes in the quality produced.

Routine verification, disinfection and cleaning shall be carried out to prevent pollution in reservoir tanks. Further, taps shall be diligently kept clean, and preventive measures shall be taken against ponding and pollution sources in the vicinity, for instance wash places or drain ditches.

The above items for production control (quantity and quality) should be duly incorporated into the operation and maintenance program.

8.3 Operation and Maintenance of the Project Facilities

1) The water production and supply facilities and machinery proposed in the present works will be handed over to INAPA and their maintenance will be the organizations responsibility. Daily and general operation and maintenance program will be carried out through the maintenance system under INAPA. As a basic policy, daily checking and maintenance will be independently operated by the beneficiary community with special regard to the objectives of the construction works and scale of facilities.

   In return, INAPA will conduct technological transfer on inspection and maintenance, and guidance, too. Moreover, besides routine or timely inspections, INAPA will control the actual conditions of joint control by beneficiaries, carry on guidance on improvement measures, aim for an improved water production and a more effective maintenance system, and work for prolonging the life of the facilities and machinery. For this purpose, the formulation of an operation and maintenance organization for effective and smooth conduct of the study is proposed.

2) Groundwater Monitoring
To devise the preservation and effective O/M of groundwater and to establish reliable documents for the prospective formulation of similar development projects, 7 wells will be constructed to observe groundwater level.

Checking of water level observation wells and preservation of records will be INAPA's responsibility. Suitable guidance for groundwater production and maintenance in respective related systems will be carried out by INAPA in accordance with the monitoring results.

3) Staff Training
A training program concerning general maintenance and maintenance of water production, facilities and clean water is urgently required for the maintenance staff as well as substitute staff of each community, for the rational and effective management of domestic water and facilities independently undertaken by the beneficiaries.

Prior to the completion of the designed facilities, INAPA shall systematically plan a personnel formation, which will be continued after the works are implemented, too. Formation shall be provided to get community residents, especially women, involved in the solution of sanitation problems and water use. Besides, after the water supply facilities are installed, residents will benefit from time saving. Educational programshall be devised to promote the effective use of time saved.

8.4 Annual Operation, Maintenance Cost and Water Production Cost

1) Operation and Maintenance Cost
Annual operation and maintenance cost covers staff salaries, cost of materials and labor wages for the repair and maintenance of project facilities, and the operation and maintenance cost of equipment. Breakdown unit price per m^3 and per household are shown in Table 8.1.

2) Water Production Cost
Equipment cost for maintenance use shall be depreciated on the base

of life span of machines, and the annual water production cost as well as unit price per m^3 and per household are shown in Table 8.2.

Table 8.1 Annual Operation, Maintenance, and Water Production Cost (Unit = RD$)

Items	Personnel Expenses		Fuel Exp. of Car Maintenance Chlorine, sand, water charge		Miscellaneous	Total
	INAPA	Beneficiaries	INAPA	Beneficiaries	Beneficiaries	
1. Manual Pump System					1310	1,310
2. Motorized Pump Production/Supply System		112,800	–	124,308	700	237,808
3. Reservoir·Filtration ·Booster Pump System		115,200		354,327	300	469,827
4. Water Wagon System		<:1		25,369 22,863 <:2	100	48,332
INAPA	414,600		370,236		2410	784,836
Beneficiaries		228,000		526,867		757,277
						1,542,113

<:1: Driver employed by INAPA

<:2: Water charge at RD$3/$m^3$, including solid chlorine for water sterilization in distribution tank

Operation and Maintenance Cost per m^3 and per household

System	RD$/$m^3$	RD$/Household/Month
1. Manual Pump System	0.005	0.044
2. Motorized Pump System	0.88	12.26
3. Reservoir, Filtration Booster Pump System	8.91	58.09
4. Water Wagon System	6.34	18.06
INAPA	1.38	65,403.0

Table 8.2 Production Cost

	No.	Life Span yr	Initial Cost RD$	Annual Cost RD$	RD$/ Household/ Month	RD$/m3
Manual Pump	131	8	3,394,210	424,276.25	14.27	1.77
Submersible Motor Pump	7	15	592,421	39,494.73	2.04	0.15
Centrifugal Pump (0.45kW)	4	15	54,400	3,626.67	0.44	0.07
Centrifugal Pump (3.7kW)	2	15	44,600	2,973.33	0.75	0.21
Centrifugal Pump (5.5kW)	2	15	118,800	7,920.00	1.55	0.21
Generator	7	15	1,127,000	75,133.33	3.87	0.28
	2	15	506,800	33,786.7	8.51	0.06
	2	15	540,000	36,000.0	8.80	0.68
Chlorinator	2	15	300,000	20,000.0	2.47	0.30
Water Wagon	2	8	1,420,000	177,500.0	66.33	23.29
Truck with crane	2	6				
Pick-up	2	6	988,500	164,750.0	2.75	0.29
Motor cycle	2	6				
Travelling Workshop Car	1	15	1,120,500	74,700.0	1.25	0.13

	RD$/Household/Month	RD$/m^3
Manual Pump System	17.7	2.2
Power Pump System	11.8	0.9
Reservoir Filtration, Booster Pump System	15.1	2.4
Water Wagon System	67.5	23.7

CHAPTER IX

PROJECT EVALUATION

CHAPTER IX

PROJECT EVALUATION

9.1 Introduction

In general, water supply projects in rural communities are difficult to justify in numbers, due mainly to the problems encountered in quantifying the benefits. The difficulties are compounded in dispersed rural communities, as in most of the objective villages of this project along the Haitian border.

INAPA does not charge rural communities on water supply, but charges "urban" communities in rural areas, that is, the head town of an administrative district. In practice, however, even in these "urban" communities INAPA faces problems on the collection of supplied water charges. A vicious circle appears to frequently set in, whereby water users claim unsatisfactory service as a reason for not paying, and INAPA finds itself unable to improve the services because of the low collection rate, which is estimated at less than 49%.

Despite the above mentioned difficulties, some quantification is expected in the evaluation of this Project which will be based on criteria such as health improvement of local population owing to the prevention of diseases related to drinking insanitary water.

9.2 Beneficiary Villages

The Government of the Dominican Republic has accorded high priority to the development of the border area, as reflected in the preparation of the integrated development plan in 1987 by ONAPLAN with the assistance of OAS. Moreover, as water supply and sanitation are regarded as essential elements of socio-economic development, a more specific Groundwater Development Project in the Western Region was designed to deal with the urgent water supply needs of four western provinces.
Implementing this project would increase provision of safe water supply to beneficiary villages by 1,363 m^3 per day.

Of the 158 villages proposed by INAPA, the implementation stage will include 58 villages (37% of the previously proposed villages). In terms of population, this project will benefit the 25,630 inhabitants of these villages, and will extend the water supply services up to around 7% of the population of the four provinces by the target year 2000. In practice, however, the number of beneficiaries will be considerably larger if proper account is taken of people passing through the villages and of residents from nearby communities without water supply facilities.

9.3 Willingness to Pay

Already mentioned above is the vicious circle consisting of the apparent unsatisfactory service provided by INAPA and the apparent unwillingness of water users to pay. Prevalence of this situation is unknown among the water supply facilities operated by INAPA. In any event, this situation need not arise, as proven during the study on Groundwater Development Project in the Western Region.

As a matter of fact, a pilot water supply facility was constructed in 1991 by the JICA in Palo Blanco, near the city of Dajabón. The facility consisted of a deep tubewell equipped with a submersible motor pump operated by a diesel generator, an elevated tank and public faucets. Before the construction of the pilot water supply facility, the community of Palo Blanco depended on river water. Some local people found business opportunities in selling river water transported by donkeys with special saddles modified to accommodate water containers.

Response from Palo Blanco residents was very positive from the outset, favored by the existence of local volunteer groups in the community. On their own initiative, Palo Blanco residents made a decision to contribute RD$30 per family per month toward the operation and maintenance of the water supply facilities, with the participation of 75 families out of the total 100 families. As described in Chapter 8, the operation and maintenance costs of the water supply facilities are estimated as follows:

Water Production System	O/M Cost RD$/$m^3$	RD$/household/ Month (average)
Manual Pump	0.005	0.044
Motorized Pump	0.88	12.26
Reservoir Filtration	8.91	58.09
Water Wagon	6.34	18.06

Therefore, the contribution decided by Palo Blanco residents, if well managed and precluding a sudden jump in fuel prices, is enough to cover not only the recurrent costs but also part of the replacement costs.

However, if every village is looked at individually, there will be communities unable to cover operation and maintenance costs. A subsidy, therefore, from