UNITED NATIONS DEVELOPMENT PROGRAMME (SPECIAL FUND)

WORLD HEALTH ORGANIZATION - UNITED NATIONS

GOVERNMENT OF SURINAM

PUBLIC WATER SUPPLIES AND SEWERAGE

INTERIM TECHNICAL REPORT

VOLUME 1

DETAILED REPORT

MARCH, 1971

INTERIM TECHNICAL REPORT

PART I: INTRODUCTION AND BASIC DATA

(Section I - Introduction)

I.I.1 - HISTORY OF PROJECT

The initial request for UNDP(SF) assistance in the field of water supply and sewerage in Surinam was submitted through the Regional Representative, UNDP, in December 1967, with the Ministry of Public Works and the Ministry of Health designated as the responsible government agencies. Titled: "Master Plan for Development of Public Water Supplies and Sewerage in Surinam", the request was reviewed by several of the United Nations specialized agencies and subsequently was re-submitted in September, 1968. Further amendments were effected prior to another submission in December, 1968. As a result of a UNDP/WHO Agency Review Meeting, agreement was reached to provide a joint WHO/UNDP Preparatory Assistance Mission which was charged with the following responsibilities:

(a) the assessment of the Government's interest in the project and their potentialities to provide counterpart contributions and staff;

(b) the evaluation of possibilities of follow-up investment, including local funds and external assistance;

(c) the assessment of the Government's resources to carry out the project and their views on the content and extent of the Netherlands assistance in this respect;

(d) the evaluation of the impact of the project on general development of the country;

(e) the review and amendment, as appropriate, of the Government's request, and preparation of a work plan for the project;

(f) the evaluation of the need to initiate the project by preliminary operations;

(g) determination of the availability in Surinam of technical and other information on the present and potential water supplies, usage and management.

The mission accomplished the above tasks during March, 1969 and reported its findings (in draft) to the UNDP Administrator during April, 1969. A revised request for the 3-year project and an application for approval of a preparatory work program were also prepared by the Mission.

The UNDP allowed project operations to start through a partial allocation in August, 1969 under "pre-project activities" and officially authorized project operations in October, 1969, the Project Manager having arrived at the project site in September, 1969. The Governing Council gave its approval to the project in January,1970. Subsequent to official signature of the Plan of Operations on 30 October, 1970, the project was declared operational as of 3 November, 1970.

I.I.2 - ORGANIZATION OF PROJECT

The UNDP(SF) project provides assistance to Government in carrying out the investigation, planning and design of piped water supply and sewerage systems for communities in the Lower Surinam river basin (excluding the city of Paramaribo) and the heavily populated coastal area, as well as selected inland communities. The following results were expected:

(a) The Government would have an overall plan of phased development of water supply and sewerage systems, on the basis of which future detailed planning could be carried out and budgetary decisions made within the context of national development plans;

(b) The Government would also have the necessary financial and technical documentation for mobilizing investment capital for those water supply and sanitary sewerage construction projects identified as most urgent.

The principal operations and methods of achieving the objectives of the UNDP(SF) projects are listed in the following paragraphs.

I.I.2.1-PREPARATION OF THE PROGRAM OF LONG-TERM DEVELOPMENT of water supplies and sewerage in the UNDP(SF) project area including:

(I) Studies of existing water supply and sewerage installations, and organizational and management institutions;

(II) Projection of long-term water demands through year 2001 for domestic and industrial needs; and forecast of proposed sewage discharges;

(III) Evaluation of available and potential sources of groundwater and surface water, including hydrological studies of data available for the whole area and hydrogeological investigations in the Lower Surinam River Basin and coastal area;

(IV) Water balance study in appropriate areas;

(V) Determination of main features of the proposed water supply and sewerage systems and identification of priority of their implementation.

The program of development would consist of two stages as follows:

(a) Interim Stage: This stage comprised works to be completed during the proposed development period of 1971 through 1981. Certain high priority construction works would be expedited in advance of other projects.

(b) Ultimate Stage: Works in this stage would be expected to be fully operational by the year 2001.

Engineering and Economic planning of the water supply and sewerage systems in the Lower Surinam River Basin and coastal area identified in the phased programme as most important, including; topographic surveys and geological investigations; alternative outline designs and preliminary estimates, as well as financial and organizational studies and economic evaluations needed for loan applications;

Detailed designs of those water supply and sewerage systems identified during preliminary planning mentioned in paragraphs (2) and (3) as being required for Interim Stage development. Detailed designs would include preparations of documents required for construction, namely; detailed drawings, specifications, material lists, etc. Model designs of water supply systems would be adopted for small inland communities;

Organizational and Managerial Studies in connection with proposed water supply and sewerage development. These studies would lead to the preparation of recommendations on modification or strengthening of management, legislation, operating and financing practices to meet the future needs of the country;

Training of Local Staff, providing for fellowships for advanced training of professional personnel in the specialized fields of sanitary engineering, public utility organization and management and hydrogeology.
The areas included in the project were initially defined as follows:

Supply Group I. The metropolitan area surrounding, but not including the city of Paramaribo; consisting of;

Kwatta Leidingen	Nieuw Amsterdam & Voorburg	Koewarasan
Marienburg	Uitkijk Jarikaba	Alkmaar
Houttuin	Spieringshoek	Meerzorg
Tamanredjo	Jagtlust	Domburg

and, the industrial centres including: Paranam, Billiton (Onverdacht) and Smalkalden.

Supply Group II. The provincial centres of population principally in the coastal areas of the districts of Nickerie, Coronie, Saramacca, Marowijne and in the northern extremity of Brokopondo, including:

Groningen and Tambaredjo	Corantijnpolder	Calcutta and
Brokopondo	Hildesheim	Tijgerkreek
Kampong Baroe	Brownsweg	Klaaskreek
Alliance	Wageningen	Totness
Groot en Klein Henar	Albina	Moengo
		Paradise

Supply Group III. The smaller remote communities in which future development is expected.

Scope Work for the Various Groups of Communities.

	Supply Group I	Supply Group II	Supply Group III
Investigations:			
Full investigation and evaluation of water resources	x	x	-
Reconnaisance only	-	-	x
Considerations (minimal analysis only)	-	x	x
Projection of water demands	x	x	x
Water balance: (a) full	x	-	-
(b) tentative	-	x	x
Survey and Planning Water Supply and Distribution Systems	x	x	-
Topographic and geological engineering surveys	x	x	-
Preparation of alternative outline preliminary designs and preliminary estimates	x	-	-
Detailed designs: (a) those that will be in service by 1975	x	-	-
(b) type design and model specifications	-	x	x
(c) those that will be directly connected to the projected Paramaribo city systems	x	-	-

	Supply Group I	Supply Group II	Supply Group III
<u>Survey and Planning Sewerage Systems</u>			
Topographic and geological engineering surveys	x	-	-
Study of possible systems, including experiments and tests for:			
(a) main urban areas	x	-	-
(b) other selected urban settlements	-	x	-
Preparation of outline designs and preliminary estimates	x	x	-

* might be incorporated on a small scale, if warranted.

Detailed designs(for only those sewerage systems that will be connected to the projected Paramaribo sewerage system)	x	-	-
Reconnaisance survey of surface drainage, Paramaribo peripheral area	x	-	-

Subsequent to a field visit by the representative of the Community Water Supplies unit, WHO, HQ Geneva, the Project Activity Plan was revised (See Appendix I-1). Based on observation and experience obtained in the field, the definition of Supply Group I areas was also revised to reflect actual conditions existing or anticipated for the areas. The comparison of projects areas is shown as follows:

I.I.2.2 COMPARITIVE GROUPING OF PROJECT AREAS

Supply Group I

P.A.M. Report Grouping

A. Paramaribo Metropilitan

S.W.C. Present and Potential Areas of Supply

Leidingen Kwatta

Koewarasan

Uitkijk (+Jarikaba)

Houttuin

Meerzorg

Jagtlust

New Amsterdam(+Voorburg)

Marienburg

Alkmaar

Spieringshoek

Tamanredjo

Domburg

Actual(SF)Project Grouping

A. Paramaribo Metropolitan

S.W.C.Zones,including West Paramaribo and South-east Paramaribo.

Kwatta-Leidingen,including

Jarikaba Wooncentrum

Uitkijk extension(?)

Koewarasan Augmentation

Pad van Wanica West no.1

Pad van Wanica West no.2

Commewijne Service Area, including

Meerzorg

Jagtlust

Nieuw Amsterdam

Marienburg

Alkmaar

Spieringshoek

Tamanredjo (?)

Note: All above communities will be included in final design phase, with possible exceptions shown as(?)

Total 1987 design population (excluding S.W.C.Zones = 100,000).
Studies only for:Domburg and Houttuin.

P.A.M. Report Grouping

B. Surinam River Industrial Area

Paranam

Billiton(Onverdacht)

Smalkalden

Actual(SF)Project Grouping

B. Surinam River Industrial Area.

Studies only for Paranam

Onverdacht and Smalkalden

since the industrial complexes have provided for all future expansion.

I.I.3- INTERNATIONAL AND GOVERNMENT STAFFING STRUCTURES

Designated as the Executing Agency was the World Health Organization, and the United Nations was named Participating Agency. The participating agency was given the specific responsibility for the groundwater and hydrological elements in the project following signature of the Letter of Agreement between UN and WHO.
(See Appendix I-2 attached).

International staff assignments were as follows:

Expert	Nationality	Agency	Specialised Field	Arrival Dates
S.G.Serdahely	U.S.A.	W.H.O.	Project Manager	3-9-69
C.K.Stapleton	U.K.	U.N.	Drilling Superintendent	12-3-70
V.R. Dixon	Canada	U.N.	Senior Hydrogeologist	16-4-70
R.Pitters	U.S.A.	W.H.O.	Water Supply and Wastewater engineer	27-6-70

As shown in the conformed Plan of Operation, the project did not include the services of a consulting firm for assistance in the various operational tasks. This departure from usual practice in UNDP(SF) projects executed by WHO had not been previously attempted. The inherent advantages and disadvantages of this approach will be discussed in the final reports for the project.
Short-term consultative services were provided by W.H.O.consultants in the following fields: Management and Industrial Waste Pollution.

The findings of the Management consultants are attached as Appendix I-3. The report of the consultant in industrial wastes has not been released by PAHO/WHO for distribution at this time.
For Government, the Ministry of Rural Government and Decentralization was given the responsibility for the project's administration and implementation. Specifically, counterpart assistance was provided by the Water Supplies Section, with the Surinam Water Company also contributing as necessary. The groundwater exploration program received assistance from the Geological and Mining Survey of the Ministry of Development.

Other Ministries, including Health, General Affairs, Finance and Public Works also provided assistance as required. Administrative Coordination with UNDP was through the Liaison Officer of the Plan Bureau.

Project Administration by the Executing Agency was channeled from the Project Manager level through the office of the Country Representative of Pan American Health Organization. The PAHO Country Representative was responsible to the Chief, PAHO Zone I, whose office is in Caracas, Venezuela. The Zone Office, in turn, answered to the Director PAHO/WHO Regional Office in Washington, D.C. U.S.A. The Regional Office worked through the Director, Division of Environmental Health, World Health Organization Headquarters, Geneva, Switzerland, which was the office responsible for official contact with the International Agencies.

The Participating Agency's channel was through the Chief, Section for Latin America, Office of Technical Cooperation, United Nations, with advising service provided by the Water Resources Division, Department of Resources and Transport, United Nations.

Representation by UNDP on the project level was through the Regional Representative, UNDP, Trinidad.

Close communications were maintained with the staff organizations of the Executing and Participating Agency. Distribution of monthly project staff meeting minutes provided up-to-date information for those agencies. Field visits by the PAHO/WHO Zone Engineer, a review visit by the substantive officer of WHO,HQ, and also a review visit by the substantive officer of UNOTC, provided staff guidance.

Administrative functions such as personnel actions, fellowships implementation, equipment procurement, etc. were handled separately by the Executing Agency and Participating Agency. No conflicts occurred at the project level.

I.I.4. - METHODS AND OBJECTIVES

Numerous conferences, meetings and discussions were held between project staff and principals of government agencies and also organizations in the private and military sectors with regard to the problems, procedures and views connected with various aspects of groundwater exploration, water supply, sewerage and related fields. By incorporating these activities with direct observations, study of local conditions and procedures, together with review and evaluation of a number of reports and documents, it was possible to formulate proposals and reach conclusions which are specifically related to local conditions.

The overriding objective was, of course, to organize the project tasks so that the findings, recommendations, feasibility study, reports and designs could be coordinated to a maximum extent with existing facilities and programs, while keeping the institution-building aspects in view as well.

Following determination of basic criteria, approximate boundaries were delineated in order to establish logical areas for groundwater investigations and water supply and sewerage service zones. Concurrently, preliminary planning commenced; and special emphases was placed on those areas where investigation and/or improvements were most urgently needed. This approach allowed for preparation of final designs and documentation without waiting for preparation of comprehensive plans or master plans, although consistency with these plan concepts was maintained.

Special emphasis should be made concerning the rationale for development of comprehensive plans and related documents. The need was continually recognized to provide a reasonable level of services essential for the promotion of sound community growth, including protection of health and provision of bases for community development. Further the most economic solutions were sought, taking into account the applicable technological aspects, availability and limitations of manpower and materials, and existing desirable local practices. This was done in order to meet basic needs at the least cost, commensurate with Surinam's available financial resources.

I.I.5.-STRUCTURE OF THE INTERIM TECHNICAL REPORT

The report represents an interim statement covering the available comprehensive planning aspects as well as the general project status at the mid-point in the 3-year project life. Further, the report assesses the major problem areas, evaluates progress to date, and views the potential of meeting proposed goals during the second half of the project.

This report consists of the following two volumes:

(I) Volume I. This volume encompasses the written text of the Interim Report.

(II) Volume II. This Volume contains the drawings, tables and other appendices considered necessary to supplement the written text.

Metric system units have been used in the report wherever applicable. However, standard practice in the design of water systems in the country has been to express pipe sizes in inches and to express pump capacities in gallons per minute. Accordingly, these units have been used in designs and in this report. Some of the background material is also expressed in English equivalent units of measurement.

PART I : INTRODUCTION AND BASIC DATA

(Section 2 - Basic Data)

I.2.1 - INTRODUCTION

The inclusion of certain basic data about Surinam and the project areas is considered to be of interest and value, particularly as these effect water supply and sewerage considerations. The data covers general data; history; climate; geography, topography; economics; and population and industrial growth. Data covering geology is covered in Part II.

I.2.2 - GENERAL DATA

Surinam is one of the three autonomous and co-equal parts of the Kingdom of The Netherlands, a sovereign state comprising The Netherlands, Surinam and The Netherlands Antilles. Surinam by itself does not consitute a sovereign state, and the same holds true for The Netherlands and The Netherlands Antilles individually. The Charter for the Kingdom of The Netherlands, which was ratified on December 15, 1954, allows each of the three countries to conduct its own internal interests autonomously and independent. Consulation of the other two countries is required only in matters of common interest. The head of state is Her Majesty Queen Juliana of the House of Orange Nassau.

Kingdom affairs are carried out by a Council of Ministers of the Kingdom, composed of the Ministers appointed by Her Majesty the Queen and the Ministers Plenipotentiary appointed by the Governments of Surinam and The Netherlands Antilles respectively. The latter have a right of veto. In such cases, matters are referred to a special Council of five Ministers including the Prime Minister of the Council of the Kingdom, the Minister Plenipotentiary and a Minister or other representative of the Government concerned.

Surinam is a parliamentary democracy. A Governor is appointed by Her Majesty the Queen as her personal representative. An Executive Council of Ministers is headed by a Minister President and is responsible to a Parliament (Staten van Suriname") of 39 members, elected by universal suffrage every four years. Minimum voting age is 23 years. Surinam has its own Constitution and Laws, an independent Judicial System, its own monetary and fiscal system, its own budget and independent financial responsibility.

Compulsory education is required for all children up to 12 years of age. All primary education in public or denominational schools is free. Literacy rate of the country's population is 70%. In the capital the rate is 90%. There are about 400 schools of which 40 are established to educate Amerindians. Schools can be divided into the following categories: high schools, private schools, junior colleges (administration), teachers training colleges, university with judicial and medical faculties(the latter being affiliated to the University of Leiden, the Netherlands), technical schools, and agricultural schools.

Dutch is the official language, but English is widely spoken and Spanish, French, and German to a lesser degree. Vernaculars are spoken as a means of interracial communications.

There is freedom of religion in Surinam. The Protestant and Roman Catholic religions predominate amongst the Creole population, Hinduism amongst the Hindustani; Muslim amongst the Hindustani and Indonesians.

Communications are provided as follows:

Telephones	:	over 8000
Press	:	4 daily, 3 non-daily newspapers. Several periodicals. ANP(Netherlands News Agency).
Radio	:	Government-operated radio station connects with all parts of the world. Telex and telephone communication with Western Europe, the U.S.A. and some Caribbean Countries.
Broadcasting	:	Total 5 stations (in Paramaribo 3).
Television	:	one station

In connection with transportation there are approximately 1,000 miles of paved and all weather roads; and 700 miles of rural roads, as well as 750 miles of navigable rivers and canals.

I.2.3. - LOCATION OF PROJECT STUDY AREA

A location map showing the study area is included as Appendix I.4

I.2.4. - GEOGRAPHY AND TOPOGRAPHY

The country of Surinam is situated on the North-East coast of South America, between 2° and 6° N latitude and 54° and 58° W longitude, bordered by the Atlantic Ocean to the north, French Guiana to the east, Guyana to the west; and the watershed of the Acarai Mountains, the Boundary Mountains and the Toemak Hoemak Mountains separates the country from Brazil to the South. The total area of Surinam is 62,000 square miles, with approximately 215 miles of coastline and a distance from the coastline to the Brazilian Border of 310 miles.

The coastline of Surinam stretches almost east to west, directly south of 6°N between 54° and 57°W. It is bound by the estuaries of the two major rivers, Marowijne and Corantijn, which form the limits of the Surinam territory. The total coastline distance of 215 miles is subdivided into three parts of 90 miles, 50 miles and 75 miles by the mouths of the two other large rivers, the Suriname and the Coppename.

In 1947-1948 the Aerial Survey of Surinam made available an accurate map of the coastal area, and other photo reconnaissances of the coast were made in 1956-'57 and in 1966. These data permit an accurate assessment of the location of the coast. From older surveys only the data concerning the inhabited parts of the coast are reliable. In all other cases the cartographic description gives an impression of the state of the coast but not of its position.

About 30% of the country's area, including a 60 mile wide coastal plain proper rises only a few meters above mean sea level. The southern mountain range and some mountainous areas in the center of the country, covering about 20% of the area, rise above 200 meters with only small areas more than 500 meters high. A few peaks exceed 1000 meters; but the remainder of the country (about 45%) has altitudes between 100 meters and 200 meters.

A mangrove forest covers the low muddy coast; but a few sandy ridges or beaches are found, mainly in the eastern part of the coast. Apart from some temporary settlements of fishermen, the only inhabited coastal area is around the village of Totness in the district of Coronie between the Coppename and Corantijn Rivers. Former plantations border the coast east of the Suriname Rivier, where the Warappa, Matapica and Toeripa canals intersect the coast, east of the Nickerie River.

The coastal area (8,000 sq. miles) between the estuaries of the rivers consists of vast swamps, extends approximately 15 miles inland in the east and 40 miles inland in the west, and includes some higher sandy ridges. South of this plain a slightly higher zone (3,000 sq.miles) across the country is covered with a savannah-like vegetation on a sandy soil. The rest of the country is covered with a dense tropical forest.

The swamps, the dense forest and the numerous rapids and waterfalls in the rivers have greatly hampered penetration into the country. Of the total population roughly 75% lives in the capital of Paramaribo and the surrounding districts of Suriname and Commewijne. Another 15% are living in the coastal plain with concentrations near Albina, along the Saramacca River, in the district of Coronie and around Nieuw Nickerie. Only 5 to 10% have settled further inland along the Marowijne, Suriname and Saramacca Rivers.

In the proximity of its mouth each of the four main rivers is joined by a smaller one. Three of these, the Commewijne, Saramacca, and Nickerie, flow generally south to north in the inland but at approximately 10 miles from the coast they develop a sudden bend and run parallel to the coast in their lower reaches. They combine with other small rivers such as the Cottica and the Maratakka.

The sources of the Marowijne and Corantijn Rivers and their tributaries are mainly located in the southern half of the country which is divided into two halves by the Eilerts de Haan Mountains. Three other rivers, the Suriname, Saramacca and Coppename, spring in the central mountains to flow northward between the two border streams. The smaller Commewijne and Nickerie Rivers rise in the north-eastern hills and in the Bakhuis Mountains respectively. The Commewijne and Saramacca Rivers join with the larger Suriname and Coppename rivers to form combined mouths across the coast.
In a similar way the Nickerie River flows into the mouth of the Corantijn River.

Catchment areas of the main rivers are as follows:

Corantijn	- 26,500	sq.	miles
Nickerie	- 3,700	"	"
Coppename	- 7,700	"	"
Saramacca	- 4,600	"	"
Suriname	- 6,200	"	"
Commewijne	- 2,600	"	"
Marowijne	- 27,000	"	"
Mana	- 4,400	"	"

Approximately 25% of the catchment area of the Corantijn River is situated in Guyana, and 40% of the Marowijne area (plus the whole of the Mana River) in French Guiana.

More than 55% of the country is drained by the Corantijn and Marowijne Rivers. Their catchment areas are mainly situated south of the central mountains at a latitude of 4°45'N, about 160 miles from the coast. The remaining 40% of the area is divided up in the elongated SSW - NNE catchment areas of the other rivers in the northern half of the country.
(See Appendix I - 5).

Characteristic of the Surinam Rivers are the great number of rapids and falls. Their geological origin appears to lie in the differences in hardness of the bedrock, faulting and the occurence of hard basic intrusives. In general the falls are low, forming dams in the rivers which limit tidal intrusion, with stretches of deeper water in between.

In the coastal plain the estuaries are deep with many meanders through muddy flat banks. Silt penetrates into the lower reaches of the estuaries and is deposited in the area where fresh and saline water meet, forming shallow banks and bars in the zone.

I.2.5. - CLIMATE AND RAINFALL

Surinam has a tropic climate with two rainy seasons per year, of which the shorter one is rather irregular and sometimes hardly occurs at all. Seasonal variations of temperature, humidity and wind conditions at Paramaribo are very small. Day temperature variations are minor, with an average of approximately 27°C (82°F); and the relative humidity is fairly constant at approximately 80% North-east trade winds are gentle the average wind-force is approximately 1.2° Beaufort. There have been no tornadoes or hurricanes. The differences between the seasons mainly appear in the information about cloudiness and precipitation. Evaporation is highest during the dry seasons when it exceeds the rainfall. In general, temperatures in the interior are slightly higher than along the coast.

Rainfall data over 30 years are available from a number of stations mainly in the coastal plain. Further inland a number of rain gauges was set up in 1960 and 1961. (See drawing included as Appendix I-5 showing the information available and location of 17 stations in Surinam.) A detailed discussion of precipitation is provided in a later section.

The Suriname and Commewijne Estuaries are found in the coastal area. The former is connected to the Saramacca Estuary via the Saramacca canal, forming a transportation link between Paramaribo and Nieuw Nickerie. The Canal provides water for irrigation purposes for the agricultural areas along the Saramacca basin. It is expected that some 40,000 hectares of land in this area, extending to the industrial area to the south, will eventually be developed agriculturally principally for the production of rice and bananas.

Upstream on the Suriname River at Paranam, Onverdacht and Smalkalden are the sites of the country's major industry, an aluminum complex which dispatches large volumes of bauxite and processed products up-and-down-river. Its presence as well as its prominence in the industrial field contributes greatly to the social and economical life of the area.

1.2.6. - DESCRIPTION OF SUPPLY GROUP AREAS

1.2.6.1. - Supply Group I - Paramaribo Metropolitan Area.

The city of Paramaribo, the capital city and seat of government is located above the juncture of the Suriname and Commewijne Rivers and approximately 10 miles from the ocean.

The area contiguous to the urban area of Paramaribo, whose present and future socio-economic status are dependent upon and closely connected with that urban area, is comprised of the 15 communities listed previously in the paragraph entitled: "Preparation of the Long-Term Development Programme".

In addition, and completing the metropolitan area, as defined by the Preparatory Assistance Mission, is the Suriname River Industrial Area, situated about 20 miles south of the city of Paramaribo. In this area are located the communities of Paranam, Onverdacht and Smalkalden along the Suriname River.

1.2.6.2. - Supply Group II - Coastal Provincial Communities. The second group includes smaller urbanized areas, located in the western region of Surinam and includes the communities of Wageningen, Groot and Klein Henar, Paradise and Corantijn Polder. These together with Totness form a rural complex, having agricultural products and their export as a common base. The city of New Nickerie with its harbor and port facilities for smaller ocean vessels is the natural outlet for the products of its area, and as such is the focal point for its present and future economic activity. Further to the east along the Saramacca River are the agricultural communities of Groningen, Tamanredjo, Tijgerkreek, Calcutta, Kampong Baroe and Hildesheim.

To the south of the Paramaribo metropolitan area approximately 60 miles, are located the communities of Brokopondo, Klaaskreek, Lombo and Brownsweg. The present and future main economic interest of this group is in agriculture, with through mining and foresting.

To the east of Paramaribo along the coastal region, in which there is both industrial and agricultural activity, are located the communities of Alliance, Killenstein - L'esperance, Moengo and Albina. The first three communities are situated along the Commewijne River, the natural outlet for the bauxite of Moengo and the agricultural products of Alliance and L'Esperance. Albina on the Marowijne River, represents the eastern gateway to Surinam from French Guiana.

According to the P.A.M., the agricultural and industrial activity in Group II areas will create new demands for public water supplies and sewerage facilities in various communities in keeping with population expansion as these activities develop.

The large deposits of bauxite found in the western reaches of the country south of Nickerie, have plans generated to develop this entire region.

The Government is investigating the possibility of a UNDP(SF) project covering several aspects of development in this area. Large quantities of water for irrigation and hydroelectric power will be required. It is expected that some 80,000 hectares will be involved. While this may have great economic benefit to the entire country, the greatest impact will be in the Nickerie area where it is quite important to explore the water resources in and to prepare for the provision of safe potable water for domestic puposes.

I.2.6.3. - Supply Group III - Small Remote Communities.

The smaller communities situated along or near rivers, are quite remote from the larger centres of population. These villages are, for the most part, inhabited by bush negroes and Amerindians, and because of their social and cultural traditions are clustered in very small groups of relatively static social and cultural development.

I.2.7. - HISTORY AND POLITICAL DEVELOPMENT

Although Amsterdam merchants had been trading with the "wild coast" of Guiana as early as 1613 (the name Parmurbo of Paramaribo was already known at that time), it was not before 1630 that 60 English tobacco planters came to what is now Surinam under Captain Marshall. The actual founding of the colony was attributed to Francis Willoughby, fifth Baron Willoughby, of Parham, governor of Barbados, who dispatched an expedition under Anthony Rowse to find a suitable place for settlement. Rowse was the first governor (1651 - 1654).

Baron Willoughby visited the settlement from March to May 1652 and from November 1664 to May 1665. By Letters Patent dated June 2nd, 1662, Charles II had granted "Willoughbyland" to Francis Lord Willoughby and Lawrence Hide, second son of the High Chancellor Edward, Earl of Clarendon, and their heirs and successors. It became an agricultural colony with 500 small sugar plantations, populated by 1,000 white inhabitants and 2,000 African slaves.

Jews from Holland and Italy joined the colonists; and, in addition, those who originally migrated from Brazil after the final expulsion of the Dutch in 1661, as well as those who were driven by the French out of Cayenne in 1664. On August 17 th, 1665, these colonists obtained from Lord Willoughby, now called the patron of Surinam, a special grant, the first of its kind made by an English Government to the Jews.

On February 27th, 1667, Admiral Crynssen conquered the colony for the states of Zeeland; and Willoughbyfort became the present Fort Zeelandia. Although the English reconquered the colony on October 18th, 1667, a second expedition under Crynssen regained it again for the States of Zeeland. By the peace of Breda - July 31st, 1667 - it had been agreed that the colony should be restored to the Netherlands, while New Amsterdam (New York) should be given to England. In 1682 the States of Zeeland sold the colony to the Dutch West India Company, and the States General gave their sanction by granting a charter to the Company. In the following year this company sold two-thirds of the shares to the town of Amsterdam and one-third to Cornelius van Aerssen, Lord of Sommelsdyck, whose heirs in 1770 sold their share to the town of Amsterdam. The colony was conquered again by the British in 1799 and remained under British rule until 1802, when it was restored to the Netherlands by the peace of Amiens. It again became a British colony in 1804, and not until the peace of Paris in 1851 was it finally restored to the Netherlands.

Slave trading came to an end in the 19th century and slavery was abolished in 1863. To comply with the demand for plantation labor, laborers from China were brought in under a labor contract. When this experiment failed the Netherlands Government entered into an agreement with the British Government which would enable people from India to come to the colony as contract laborers. Altogether approximately 34,000 laborers from India came during the period between 1873 and 1918, of which some 12,000 returned home after their contract period expired. The rest stayed in the country and settled as farmers.

With the labor immigration not running as smoothly as was expected. the Netherlands Government in 1894 started a new experiment, this time utilizing laborers from the island of Java (former Netherlands East Indies, now Indonesia). Similar to the Chinese and Hindustani, they first came as contract laborers, but after 1930 as free laborers. A total of 33,000 emigrated to the colony of which about 8,000 returned to their native country.

The Javanese (now called Indonesians) formed the last large influx of "foreign" element into a population adapted to absorbing people of varying racial origins. This absorbing process resulted in the formation of a new group of people called "creoles", the descendants of intermarriages between members of different groups. They represent all shades and colors, from black to white.

1.2.8. - CONSTITUTIONAL DEVELOPMENT

In 1942 Queen Wilhelmina of the Netherlands in a radio broadcast from London made a pledge to the people of the overseas territories * that the time had come - and that as soon as the war was over - the Netherlands would grant more independence and a greater share in the administration.

Neither Dutch Guiana nor the Netherlands Antilles were occupied during the war. Because the mother country was occupied, Dutch Guiana and the Netherlands Antilles were actually carrying out their own administration.

* Since 1922 the Netherlands Constitution referred to the colonies as overseas territories.

After the war Dutch Guiana and the Netherlands Antilles sought to make the royal pledge effective, and in 1946 sent delegates to the Hague to discuss the necessary changes.

The constitution of the Netherlands had to be changed, but prior to this the Netherlands Government proposed to the States-General (both houses of parliament) a change in the "Staatsregelingen" (Constitutions of both countries) so as to give them as much self government as was possible under the existing constitution.

As a result in 1948 important changes were made which became effective at once. The overseas territories could now pass their own budgets and so provide for the necessary funds that were needed to improve administration, the economic condition improved rapidly after the war. and more money became available to accomplish the necessary improvements.

The final drafting of the over-all charter for the Kingdom into a Statute law, giving complete self government in internal affairs, was completed. It was the wish of the country to maintain the existing relationship with the Crown of the Netherlands on a basis of equality.

The three parliaments ratified the Statute without opposition and the Queen of the Netherlands proclaimed the new Statute for the Kingdom in a joint meeting of both houses of the Netherlnads Parliament on December 17th, 1954.

The new Kingdom was characterized by the principle that each of the countries administer its internal affairs autonomously and that each is committed on a basis of equality to the administration of their common interest and to mutual assistance. They have the right to determine their own constitutions, to revise and amend them, subject to the condition that they do not impair the interests and the general principles (human rights and fundamental freedom) common to the kingdom as a whole.

A number of matters which are of equal concern to all parts of the Kingdom and therefore require to be administered in a uniform manner by organs of the Kingdom are described in the Statute as "Kingdom Affairs". The most important are defence and foreign relations. Surinam and the Netherlands Antilles have far reaching powers which in some instances amount to a vote, in these matters.

1.2.9. - ECONOMICS

1.2.9.1. - Natural Resources

Minerals are of maximum importance among the main natural resources, and bauxite is the most important. Besides the reserves that are being developed by two companies, a new reserve of some 400 million tons has been located recently.
Production of gold is continuing on a small basis with the introduction of some mechanical gold mining. In addition, deposits of over five billion tons of lateritic iron ore

have been discovered. There are also occurrences and indications of beryl, ambligonite, cassiterite, chromite, copper, diamond, hematite, itabirite, kyanite, manganese, mica, platinum, nickel, etc. Indications also point up an abundance of glass sand and kaolinite.

The great water power potential in the rivers represents another important natural resource. A hydro-electric power plant with a capacity of over 150,000 kilowatts has been in operations since October 1965. Other hydro-electric power projects with total capacity of 2,000 megawatts are presently being studied by government and are described in more detail later in this report.

Virgin forest areas contain several hundred timber species, and the very fertile coastal area produces bananas, rice, sugar cane, citrus, coffe, cocoa, papaya, passion fruit, etc.

An oil and gas exploration program is being conducted off-and-on shore in Surinam. Oil has been encountered in small quantities on-shore at depths varying from 200 to 600 feet.

1.2.9.2. - Industries

The principal industry is the mining of bauxite and processing of the ore. However, the majority of the country's working population are employed in agriculture or are on the government payroll; the remainder is scattered through the principal mining and manufacturing industries and commercial enterprises which are centered in Paramaribo and Nickerie.

Following is a list of most of the industries:

a/ Three bauxite and two calcined-bauxite plants, alumina reduction plant and aluminum smelter, mechanical gold-mining, plywood and particle-board plants, saw mills, clay-brick and cement-brick factories and a cement factory.

b/ Manufacturing plants for pre-fabricated houses, paint, aluminum and glass jalousie windows, venetian blinds, wooden and steel furniture, carpets, men's clothing and shirts, shoes, detergents, plastic products, corrugated cardboard boxes, paper bags, oxygen, matches, cigars, cigarettes, electronics, lamps, etc.

c/ Boat building and repair facilities.

d/ Shrimp-freezing plant, ice-manufacturing plants, cold storage units. Meat-preserving factory, milk-pasteurizing plant.

e/ Wine and spirits distilleries, beer brewery, soft-drink bottling plants

f/ Margarine and edible oil manufacturing plants.

The key economic indicators and characteristics are shown in the tables attached as Appendix 1 - 6.

Surinam is the only South American country which ranks as an associate member of the European Commun Community, French Guiana enjoys its association with the ECC through the French departmental structure.

1.2.10 - POPULATION FORECASTS

Some disparity exists among the various forecasts of population growth for Surinam, and these seem to vary with the agency preparing the forecast. Since the numbers of users of individual water supply and sewerage systems tends to be small, i.e., a design total of approximately 50,000 persons for a 15-year design period represents the largest single design total, minor variations in the actual growth rate will not present significant problems in design.

Although the usual values of growth rates are 3.89% or 3.44%, a relatively conservative figure of 4% was adopted for water system design purposes and this was based on the following data:

Source	Estimated % Increase	
General Bureau of Statistics (for total national growth)		3.5
Ministry of Agriculture (for total national growth)	1963-1974	3.0
	1974-1984	3.4
	1984-2000	4.3.
UNDP P.A.M. Report	National	3.8 to 4.0
	Paramaribo up to 7.0	

These percentage increase values are used to provide projections demographically and assume no change in net migration, utilizing the national growth of population estimated on the basis of age, fertility and mortality rates. Graphical projections are shown on the drawing attached as Appendix I - 7.

While the aggregate number of inhabitants in the country is small, (the 1964 official total presented by the General Bureau of Statistics being 324,211, and the total for 1967 estimated at 363,000 by the Planning Bureau in the Macro-Economic Review), exact current figures are almost impossible to obtain. The principal reasons offered for this are: (a) the Amer-indian and Bushnegro population is not "registered" and (b) exact numbers of people migrating within and out of the country are not known.

I.2.11 - POPULATION DISTRIBUTION AND GROWTH

The densely populated urban area of Paramaribo, whose 1951 "boundaries" included approximately 1,700 hectares was expanded in 1965 to an area of about 5,000 hectares, and may be further enlarged by 1975 to 14,500 hectares. The present 1970 population is estimated by the Plan Bureau at approximately 200,000. This represents somewhat less than 50 per cent of the total population of the country. The projected 1975 and 1985 populations for the city are estimated at 270,000 and 410,000 respectively.

The 1969 population of the 15 communities outside Paramaribo but contiguous to that urban area was estimated (by the P.A.M.) at 52,450 indicating past annual growth rates of 3.4 to 3.6 per cent. This would bring the 1969 population for the Group I Paramaribo Metropolitan Area to 252,450, which represented approximately 65 per cent of the total population of Surinam.

Based on an annual growth rate of 3.5 per cent in the area outside of the urban area of Paramaribo, together with the projected population for that area, the projected populations in 1975 and 1985 for the Group I Paramaribo Metropolitan Area, are estimated at 343,300 and 507,800 respectively.

The present population of the Group II areas include that of the districts of Nickerie and Coronie, the agricultural communities along the Saramacca River and in the Brokopondo district, and the group of industrial and agricultural communitieseast of Paramaribo and was estimated at 59,300 in 1964. Population records of recent years for these separate areas indicate annual growth rates of 3.8 to 3.9 per cent.

Therefore, using an average annual growth rate of 3.8 per cent, the 1975 and 1985 projected populations for the Group II areas are estimated at 68,200 and 93,900 respectively.

In the numerous small settlements comprising the Group III areas, the present population is estimated at 20,700 which cannot be considered as reliable because of the great difficulty in obtaining records. For this reason, no attempt has been made to forecast populations in this sector.

It has been estimated by planning authorities and the Bureau of Statistics, that some 45,000 to 48,000 inhabitants reside in areas virtually inaccessible by land transportation. This population occurs in the scattered small villages which are remote from any channels of communication and can only be reached by boat or on foot from the airstrips in the interior.

PART II. HYDROGEOLOGICAL INVESTIGATIONS

II.1 INTRODUCTION

Hydrogeological investigations were underway in April 1970 following the arrival of the Hydrogeologist and Drilling Superintendent. Some test drilling was done before this time, beginning towards the end of 1969.

There exists in Surinam a wealth of data on groundwater and related subjects. These data have been used to the full extent in order to organize a comprehensive exploration programme.

Investigations have been concentrated in Group I areas, with activities extending southward into the Savannah belt in order to understand more fully the regional hydrogeological regime. Activities will be extended into other areas particularly the Group II areas in western Surinam during the last year of the Project.

It has been possible to recognize a number of important aquifer zones. These are generally distinct units, so much so, that the major technical findings are discussed in this report on an aquifer zone basis.

The practical aspects of the findings as they apply to the development of groundwater supplies are discussed in the final section.

II.2 PREVIOUS INVESTIGATIONS

Exploration for groundwater began in Surinam in 1903 when the first deep well was drilled at Sivaplein in Paramaribo to a depth of 164.5 m. The well produced eight to ten litres per minute of water with a chloride content of 168 ppm.

Test drilling was carried out along the railway from 1928 to 1930 following which it was concluded by Van Weijerman, who supervised the exploration, that a supply of water for Paramaribo would best be obtained at Republiek. Wells were drilled and in 1933 water was piped to Paramaribo. Records of water levels and withdrawals have been kept since that time by the Surinam Water Company.

An evaluation of all drilling data was made in 1950 by d'Audretsch. This led to an exploratory drilling programme carried out by the Geological and Mining Service in which 43 wells were drilled and tested over a period of 14 years. Interim reports on this programme were published by d'Audretsch (1953) and van Loon (1958).

More recently drilling for water has been done by the Surinam Water Company, the Ministry of Building and Traffic, and the Ministry of Rural Government and Decentralization in addition to the Geological and Mining Service. The data from 1958 have not been published but most of them are in the files of the respective organizations.

II.3 METHODS OF INVESTIGATION

II.3.1 Inventory of Existing Data

There exists a wealth of data related to groundwater in Surinam. Various publications in which data is listed are outlined in Section II.2, and in the bibliography. Probably the most valuable information is contained in the records of the test wells drilled by the Geological and Mining Service (GMD). A list of these test wells is contained in Table II-1. Included in this table are the aquifer zones tested and the average permeability coefficients and specific capacities determined from the limited pumping data contained in the reports.

Records of three short pumping tests have been made available to the Project. These include tests at Onverdacht and Republiek run by the Surinam Water Company (SWM) and a test run by Suralco on a Coesewijne aquifer that has been excavated to mine the underlying bauxite. A report of the consulting firm Leggette and Brashears on the Paranam wells has been promised by Suralco.

Table II - 1 SUMMARY OF EXPLORATORY DRILLING FOR GROUNDWATER

Geological and Mining Servive 1950 - 1964

Well No.	Date	Location	Elev. m N S P	Depth m	Test Depth m	Ground water zone	Static water level m CL	T m2/day	Av.k. m/day	Q/S l/s/m	Quality Cl ppm	Quality TDS ppm	Quality pH
1	Dec.50	Zorg En Hoop		263	158.0-164	C IV					136	339	6.5
2	Feb.51	Zorg en Hoop		84	41.1-45.6	C I					217		
3	May 51	Zorg enHoop		167.5	157.6-162.5	C IV	+0.65?	394	82	3.8	180	446	6.5
4		Domburg		90.7	26.2-27.9	C I	0				3,300	7,987	8.1
					38.4-43.5	C I ?	0	11	2	0.1	7,400	16,800	6.3
					49.2-52.8	CI or CII	0	58	16	0.5	5,854		6.5
5		Livorno	3.143	167.2	25.7-32.1	CI	-1.2	228	45	2.2	1,309	2,477	6.2
					51.2-58	C II	-1.6	551	110	5.3	781	2,034	3.0
					61 - 66	C II	-1.6	580	116	5.7	1,140	2,792	3.5
					82 - 86.5	C II	-1.6	171	34	1.6	1,684	4,130	6.5
					161.3-166.3	C IV	-0.2	322	64	3.1	111	460	6.5
6		Nieuw Amsterdam		375	179.5-186	C IV	+ 2.37	34	7	0.3	890	2,100	7.7
					262 - 269	0 ?	+ 3.90	155	31	1.5	2,500	4,445	7.0
7	Sept.52	Meerzorg		188.5	141-148	CIII or	+ 0.5	155	31	1.5	177		
					161-166	C IV	+ 0.7	26	5	0.2	323		
					170.5-179.5	C IV or	+ 0.75	41	8	0.4	520		
					180.5-188.5	O	+ 0.75	169	34	1.6	590		
8	Jan.53	Nieuw Amsterdam		171.2	41.5-47	C I	+ 0.35	63	13	0.6	1,080		
					84-92	C II ?	+ 0.45	415	83	4.0	1,374		
					127.4-132	C III	+ 0.50	58	12	0.5	907		
					133.5-138.5	C III	+ 0.50	48	10	0.5	1400		

Table II - 1 Continued

Well No	Date	Location	Elev. m N S P	Depth m	Test Depth m	Ground water zone	Static Water level m CL	T m2/day	Av.k. m/day	Q/S l/s/m	Quality Cl ppm	Quality TDS ppm	Quality pH
9	1953	Nieuw Nickerie	2.36		42-47	C I ?	+ 1.65	398	80	3.8	213		
10	1953	Nieuw Nickerie			40.9-48.5	C I ?		322	64	3.1	203		
11	1953	Nieuw Nickerie			42.8-50.5	C I ?					202		
12	June53	Nieuw Nickerie	1.07	47.5	42 - 45.5	C I ?	+ 1.5	580	116	5.6	235		
13	Sept53	Nieuw Nickerie	0.59	112	46 - 49.6	C I ?	+ 1.6	514	128	4.9	420		6.0
					66.5-71.1		+ 1.5	402	80	3.9	421		6.0
					82.4-86.1		+ 1.95	145	29	1.4	450		6.0
					102.0-106.5	C III?	+ 1.9	178	34	1.7	570		6.5
14	Oct.53	Nieuw Nickerie	1.69	49	43.5-47,7		+ 0.75	269	54	2.6	155	586	5.0
15		Nw.Nickerie			38.2 - 44						232		
16	Apr.55	Jagtlust		205.6	24.5-30	Coropina	-1.97	169	34	1.6	5,200		6.5
					85.5-91	CII	-1.11	174	35	1.6	2,100	6,100	6.5
					161.1-164.8	C IV	+ 0.45	97	24	0.9	614	1,300	7.4
					201.8-205.6	O	+ 0.97	110	28	1.0	1,700	3,200	7.2
17	June 55	Taman Redjo	(+ 1.75 MP)	194.8	30.9-35.5	C I or C II	-1.20	223	45	2.1	1,000	5,300	6.2

Table II - 1 Continued

Well No.	Date	Location	Elev. m N S P	Depth m	Test Depth m	Ground water zone	Static water level m Cl	T m2/day	Av.k. m/day	Q/S l/s/m	Quality Cl ppm	TDS ppm	pH
17	June 55	Tamanrodjo	(+1.75 MP)	194.8	58.4-63	C II or C III	-1.20	143	29	1.4	1,000	3,400	5.9
					159.6-164.2	C IV	-0.20	194	39	1.8	1,700	2,300	6.9
18	Aug.55	Zorg en Hoop N	2.458	176	166.2-170.8	C IV	+ 0.90	185	37	1.8	270	611	6.3
19	Sep.55	Uitvlugt	2.811	163	156.4-161.8	C IV	+ 0.40	192	38	1.8	240		
20	Sep.56	Leiding 8	0.865	303.5	45.2-49.5	C I	+ 0.40	151	30	1.4	348	1,179	6.7
					61.9-66.5	C III	+ 0.58	177	35	1.7	102		6.4
					67.7-72.3	C III	+ 0.65	228	46	2.2	92	637	7.0
					76.8-81.4	C III	+ 0.67	196	39	1.9	86	518	6.7
					91.4-96.0	C III	+ 0.55	343	69	3.3	82	511	7.0
					146.8-151.4	C IV	+ 1.95	38	8	0.3	249	548	6.0
					162.5-165.8	C IV	+ 2.00	302	60	2.9	312	669	6.0
21	May 57	Uitkijk	1.138	255.5	30.2-34.8	C I	+ 0.52	22	4	0.2	309	1,174	6.1
					65 - 66.1	C III	+ 0.53	261	261	2.5	143	596	6.3
					89 - 92.7	C III	+ 0.5	6	1	0.06	83	413	5.8
					97.7-101.5	C III	+ 0.59	107	27	1.0	63	400	6.2
					105.5-110.1	C III	+ 0.47	290	45	2.8	65	366	5.8
					140.4-145	C IV	+ 1.38	397	79	3.8	153	482	6.0
22	Aug.57	Koewarasan	2.674	189.3	40.2-44.5	C I	- 0.9	463	90	4.4	445	1,842	6.4
					56.5-60.0	C I	- 0.92	19	4	0.2	308	1,265	6.0
					65.5-70.0	C III	- 0.92	206	41	2.0	154	749	6.0
					76.2-80.3	C III	- 0.94	615	153	5.9	135	675	6.7
					96.0-99.1	C III	- 2.00	28	9	0.2	45	435	6.8
					114.0-117.9	C III	- 1.07	218	54	2.1	50	475	6.0
					138.3-142.9	C IV	+ 0.30	179	36	1.7	158	468	5.8
					150.8-155.4	C IV	+ 0.30	1870	374	17.8	215	504	6.3

Table II - 1 Continued

Well No.	Date	Location	Elev. m NSP	Depth m	Test Depth m	Ground water zone	Static water level m CL	T m2/day	Av. k m/day	Q/S l/s/m	Quality Cl ppm	Quality TDS ppm	Quality pH
23		Boxel		122.5	45.2-52.8	C I C II	- 0.48 - 0.78	688 498	138 100	6.6 4.8	2,770 2,780	5,410 5,820	6.3 6.1
24	March 58	Lands-boerderij	2.27	112	106.3-111.4	C III	- 0.5	207	41	2.0	59	370	6.3
25	May 58	Zorg en Hoop	2.75	163.2	158.7-163.3	C IV	+ 0.5	660	132	6.3	182	408	6.3
26	July 58	Zorg en Hoop	1.74	163.2	156.4-161	C IV	+ 0.46	421	84	4.0	195	382	6.5
27	Sept 58	Paramaribo	2.48	117.2	111.1-115.7	C III	- 0.86	320	64	3.1	148	522	6.2
28	Aug.59	Alliance	0.838?	337.5	42.0-45.9 62.0-66.6 78.2-82.8 94.4-99 101,4-106		+ 0.93 + 1.44 + 1.27	150 105 142 44 155	50 21 28 9 31	1.4 1.0 1.4 0.4 1.5	1,736 323 263 212 196	5,200 1,300 1,110 1,020 940	6.6 6.8
29	Sep.59	Alliance	1.335?	224									
30	Oct.59	Alliance	0.875?	214	104.2-108			120	30	1.1	198	939	6.8
31	Apr.60	Meerzorg	2.298	146.3	141.7-146.3	C IV?		167	33	1.6	190	450	6.0
32	July.60	Zorg en Hoop	2.043	161	156.4-161	C IV	-0.75	543	109	5.2	150	353	6.2
33		Zorg en Hoop			154.2-160.4	C IV					157	353	6.2
34		Zorg en Hoop			154.8-158.7	C IV		537	134	5.1			
36	Oct.61	Totness	2.27	168	162.4-167		-0.40	308	62	2.9	77	311	6.8

TABLE II - 1 Continued

Well No.	Date	Location	Elev. m N S P	Depth m	Test Depth m	Ground water zone	Static water level m CL	T m2/day	Av.k. m/day	Q/S l/s/m	Quality Cl ppm	Quality TDS ppm	Quality pH
37	Feb.63	Santo Boma	3.30	139.9	131.4-136	C IV	- 1.15	198	40	1.9	69	292	6.0
C3	June 53	Groot Chatillon		42.2	12.3-18 24.8-27 27 - 32 33.5 -36 36.5 - 42		FLOWING				369-1,838 224-1,066 1,050 5,236 5,753		6.8-7.2
C4		Groot Chatillon		12	11-12		FLOWING				159-626		
C5		Groot Chatillon		27.5	7.6 - 8.3 25.1-27.5		FLOWING				400-524 4,566-5,104		7.0
C6		Groot Chatillon		47.1	10.7-11.4 12.6-13.6 20.6-21.8 22.3-33.8		FLOWING				735 1,020 4,188 1,900	3,656 3,744 3,149	7.6 7.6 7.3
D 1 and 2	Sep.64	Kampong Baroe	4.00	129	44-50 60.5-72 123.5-129	C II C II C III	-1.9	120	24	1.1	2,445 2,450 91	5,012 5,200 442	6.0 5.9 6.1

The Surinam Water Company has provided hydrographs of water levels in the Republiek wells and nearby Coropina Creek for the years 1933 to 1954 and data on water levels in observation wells and Coropina Creek for the years 1966 to 1969; the data from 1954 to 1966 is still to be obtained from them.

Meteorological records are available for all years since 1931. River flow records are available at the Hydraulic Research Division. A good summary is contained in the "Surinam Transport Study, a Report on Hydraulic Investigations," by the Netherlands Engineering Consultants in 1958. Unfortunately there is very little information available on the flow of streams that originate in the Savannah belt.

II.3.2 Test-Drilling and Well Construction

Four drilling rigs are being used by the Project. They are the property of the Geological and Mining Service and the Ministry of Rural Government and Decentralization.

In the first instance a truck mounted Failing Combination rotary rig, Model 1250 purchased in 1966, together with a small quantity of spare parts, was provided by the Ministry of Rural Government and Decentralization. (This equipment was originally operated by the Water Supplies Department of the Ministry of Public Works). A limited amount of drilling equipment, a small stock of steel casing and plastic pipe of small diameter were also available.

A trailer mounted Failing rotary rig, model 2500 with a GMC towing truck, purchased in 1967, together with a reasonable quantity of spare parts, was made available to the Project by the Geological and Mining Service. Also, good stocks of steel casing, a variety of drilling equipment and accessories and a trailer mounted auxillary pumping unit were provided.

Rig Model	Year Purchased	Max. Open Hole (estimated) (using 2-7/8" F.E. Drill pipe)		Max. Casing (estimated)		Max. Diameter Casing Handling
		Depth	Diam.	Depth	Diam.	
Failing 1250	1966	225 m	6 ins.	130 m	6-5/8 ins.	8-5/8 ins.
Failing 2500	1967	1.000 m	6 ins.	400 m	6-5/8 ins.	16 ins.
Failing 1500	1949	250 m	6 ins.	180 m	6-5/8 ins.	$12\frac{1}{4}$ ins.
Solite	1964	60 m	$2\frac{1}{2}$ ins. (using E.W. Rods)	50 m	BX	4 ins.

Table II-2 Present-day capacities of the drilling rigs.

TABLE II-3

Organization Chart of the Drilling Section

(on page following)

KEY :

⊕ Assisted project prior to arrival of U.N. Drilling Supt. and during his homeleave

\+ Fulfilling two duties

G.M.D. - Geological and Mining Service

Min. D.& D. - Ministry of Rural Government and Decentralization

Project - Personnel recruited through Min. D.& D. project duty only

C.K. STAPLETON (U.N. Drilling Supt.)

⊠ A. STAPHORST (G.M.D. Drilling Supt.)

STORES

(a) G.M.D. for spare parts
(b) G.M.D. (Doorsteek) for casing & Failing equipment
(c) Min.D. and D. (Doorsteek) for U.N.equipment, water supply fittings and Failing 1250 parts.

MECHANICS

A. Netteb(Field Duty)G.M.D.
R. Faerber(Doorsteek Stores)(Min.D.&.D.)

DRIVERS

(1)J.Watchman*(GMD)
(2)R.Misier(Min.D.&.D.)
(3)K. Djiwan(Min.D.&.D.)
(4)J.Tewarie(Min.D.&.D.)
(5)J.R. Farzand - Ali (Min.D.&.D.)

TRANSPORT

(1)7 ton G.M.C.Truck,Oil-field body with fifth wheel (G.M.D.)
(2)7 ton Cap.I.H.flat body truck (U.N.3)
(3)Landrover,12Seater (Min.D.&.D.)
(4)Isuzu,6Seater Pick-Up (U.N. 5)
(5)Isuzu,6Seater Pick-Up (U.N. 6)
(6)M.F.Agricultural Tractor (G.M.D.)
(7)M.F.Agricultural Tractor (U.N. 7)
(8)Landrover,12 Seater (U.N. 8)

SITE PREPARATION TEAM

+ J. Watchman - in charge (G.M.D.)
3 Labourers (Project)

E.Pocornie - Sample picker(GMD)

W. BOUMAN (GMD.Chief Driller)

FAILING 2500 (GMD)

F.Lanks -Driller (GMD)
P.Viereck-Asst.Driller(GMD)
M.Pansa -Derrickman(GMD)
S.Pinas -Rigman (GMD)
N.Klas -Rigman (Min.D&D)
Winzak -Labourer(Project)
Two Watchmen - (Project)

FAILING 1250(MIN.D&D)

M.Petricie-Driller(GMD)
H.Rother -Rigman(Min.D&D)
J.Fer -Rigman(Min.D&D)
Darim -Labourer(Project)
1 Watchman(Project)

FAILING 1500 (GMD)

S.Doornkamp-Driller(GMD)
L.Wijnerman-Rigman(GMD)
A.Graude -Rigman(GMD)
K.Nestor -Rigman(Min. D&D)
2 Watchmen(Project)

SOLITE (GMD)

E.Wilson -Driller(GMD)
A.Muringen-Rigman(Min.D&D)
Avajona -Labourer(Projec
Cafe-Smith-Labourer(Projec

From the middle of 1970, preparations were put in hand to bring back into service a trailer mounted Failing rotary rig, Model 1500 purchased in 1949, the property of the Geological and Mining Service. Apart from thoroughly checking over the rig, repairs were made to the engine generator and electrical system, the hydraulic cylinder of the drill head, the mast and the rear end of the trailer chassis. Whilst the unit powering the rig, a BUDA diesel engine, was in a fair condition, it is unfortunate that it is a model, which is now obsolete.

At the end of 1970, the Geological and Mining Service provided a Solite rotary prospecting rig complete with accessories, for special service in connexion with the exploration programme.

An estimate of the present-day capacities of the drills is contained in Table II-2.

The organization of personnel in the drilling section is illustrated in Table II-3. The Organization Chart shows the optimum utilization of personnel; the strength of manpower has never been constantly as shown. Not all the personnel mentioned joined the Project at the commencement of drilling operations.

By arrangement with the Geological and Mining Service, one of their Drilling Superintendents has been loaned to the Project on particular occasions, to perform relief duties, as shown in the chart. This step has proved to be of immense value to the Project, in that the man chosen, possessed an extremely good working knowledge of the mechanics of drilling and workshop practice.

The Chief Driller of the Geological and Mining Service attached to the Project is a good, practical man with considerable experience in drilling. The Drillers and Assistant Drillers will be all the better for more guidance in drilling pra tices, coupled with training in testing techniques associated with groundwater exploration.

It was originally envisaged that single shift working would take place during the initial stages of drilling operations, utilizing two rotary rigs. Then, as soon as practicable, to increase the working shifts on each rig to two (16 hours daily) and ultimately to three (round-the-clock working). Unfortunately it has never been possible to increase the working hours beyond eight on each rig. In unusual and special circumstances only, a limited amount of overtime can be worked.

The knowledge acquired by a few members of the drilling crews, of how to construct a borehole, was much appreciated, when demonstrated at the commencement of project activity. This achievement is due in part to the assimilation of previous training, but in the main, perhaps attributable to "trial and error" methods extending over a considerable period of time.

With certain fixed objectives in mind, training has been limited to date, in order that efficiency could be achieved as soon as possible, in such basic fundamentals as:

- viscosity and weight of mud in so far as wall building properties, low gas pressure control, and settling of cuttings out of the circulation are concerned,
- reducing viscosity of mud and avoiding caving conditions,
- cement and clay sealing strings of casing,
- spot cementing and dump bailer cementing in open hole,
- measured back-filling of boreholes,
- inserting and recovering Johnson screens,
- developing of wells; and
- recording water level data during test pumping.

Table II-4. Well data, screens and casing.

Well No.	Location	Drilling Rig	Depth Drilled (m)	Screens for Testing Depth (m)	Screens for Testing O.D. (ins.)	Slot	Casing Position for Test Depth (m)	Casing Position for Test Diameter (ins.) O.D.
1/69	Stolkslust	1250	48.00	43.25-48.00	4¾	40	40.22	8-5/8
			68.50	62.18-66.93	4¾	40	40.22	8-5/8
			74.00	68.45-73.20	4¾	40	40.22	8-5/8
			82.00	77.25-82.00	4¾	40	40.22	8-5/8
			104.20	85.25-90.00	4¾	40	40.22	8-5/8
			110.30	86.65-91.40	4¾	40	77.20	6-5/8
2/69	Houttuin	2500	49.00	40.25-45.00	4¾		30.25	11-¾
			93.15	75.25-80.00		30	49.00	8-5/8
			135.00	126.25-131	5-5/8	30		
1/70	Tout-Lui-Faut	2500	168.15	143.97-148.72	5-5/8	40	78.00	8-5/8
2/70	Groningen	1250	91.50	86.25-91.00	4¾	40	40.90	8-5/8
			140.60	134.83-139.58	4¾	40	128.96	6-5/8
			140.60	132.83-137.58	4¾	40	128.96	6-5/8
3/70	Taman Redjo	2500	Infilled to 29.00	24.25-28.86	4¾	30	21.00	8-5/8
			191.30					

TABLE II - 4 (CONT'D)

Well No.	Location	Rig. No.	Depth Drilled (m)	Screens for Testing		Slot	Casing Position for Test	
				Depth (m)	O.D. (ins.)		Depth (m)	Diameter (ins.) O.D.
4/70	Leiding 9A	1250	Infilled to 90.00 104.00	72.85-87.11	6½	40	72.13	8-5/8
5/70	Leiding 9A	1500	Infilled to 99.00	91.55-96.30	4¾	40	92.17	6-5/8
			Infilled to 80.00 219.00	70.88-75.63	4¾	40	74.05	6-5/8
6/70	Meerzorg	2500	236.20	225.78-230.53	4¾	30	191.66	6-5/8
7/70	Leiding 9A	1500	207.80	No Tests			-0.10-14.68 -0.10-26.68 (21.00)	8-5/8
8/70	Magenta	1250	Infilled to 132.80 193.50	125.38-130.13	4¾	40	-0.80-20.20 -0.60-123.90	8-5/8 6-5/8
9/70	Morico (E.Com.).	2500	Infilled to 118.77 153.20	103.60-112.95	5-5/8	40	-0.80-21.70 -0.67-104.47	8-5/8 6-5/8

TABLE II - 4 (CONT'D)

Well No.	Location	Rig No.	Depth Drilled (m)	Screens for Testing		Slot	Casing Position for Test	
				Depth (m)	O.D. (ins.)		Depth (m)	Diameter (ins.) O.D.
10/70	Leiding 9A	1500	190.00	178.93-188.28	$4\frac{3}{4}$	40	-0.80-19.47 -0.60-168.42	$11\frac{3}{4}$ 6-5/8
			190.00	166.07-175.42	$4\frac{3}{4}$	40	-0.60-168.42	6-5/8
1/71			16.20	Solite Rig				
2/71			14.90	Solite Rig				
3/71	Rijsdijk	1250						
4/71	Commetewane	2500						

N.B. All depths quoted are "Below Collar Level"

Perhaps the only tool introduced by the Project as "new" is a modified version of a surge block. Manufactured under supervision in a local workshop, it has interchangeable parts to facilitate operation in screen diameters of 4" to 8-5/8".

Parts of a sand pump were replaced to make it serviceable. It was found necessary to demonstrate its correct use.

Various tools have been introduced in connexion with casing and borehole cementing.

The probable use of casing of a non-metallic nature has been actively discussed and appraised.

Several new form-type reports and log streets have been introduced to cover the collecting of only that data, which is considered essential.

A list of the wells drilled is in Table II-4, which also contains details of casing and screens.

II.3.3 Well Construction Costs

Records of drilling and construction costs are being kept. Based on records of Well 4/70, the cost to construct an 8-inch diameter well, 90 m deep with steel casing and 14 m of stainless steel screen would be about Sf.10,500 (US$ 5,612). This envisages known conditions and construction taking place in 28 days, but there is no allowance for depreciation of the drills and equipment. Costs for a test well with only one aquifer tested would be similar except that some of the cost of the casing could be recovered. In terms of drilling the cost to drill and ream a production well including mobilization and site preparation and logging would be Sf. 27/m (US$ 14.44) and for a test well would be Sf. 12.60/m (US$ 6.66).

II.3.4 Well Logging

A Neltronic well logger owned by the Geological and Mining Service is at the disposal of the Project. It is capable of logging wells to depths of about 900 m.

The basic logger gives a single point resistivity and a self-potential log. Excellent results have been obtained though there have been problems with the self-potential logging at times. Examples of logs reduced in scale are contained in Appendices II-1 to 4 inclusive. It is an excellent tool for correlating aquifers and for estimating water quality.

The logger has a secondary control panel for operating multisonde and fluid resistivity tools. The multisonde has never worked. The electrode and secondary control panel have been returned to the maker for repairs.

A gamma ray unit is to be added to the logger. This will permit the logging of cased holes. It will be possible to identify the clay and sand layers but not the quality of the water.

II.3.5 Pollen Analysis

A number of clay samples have been submitted to Mr. A.L.E. Amstelveen, of the Geological and Mining Service for pollen analyses. This facilitates aquifer correlation in the coastal area. The correlation is based on the pollen zones established by Van der Hammen and Wijmstra for the Guiana basin.

II.3.6 Mechanical Analyses

Mechanical analyses were run on some of the sand samples from test drilling. The analyses are done by the Geological and Mining Service under the supervision of Mr. L. Krook. The samples are disturbed and analyses therefore are not truly representative of the sand. It has been found that a No.40 slot screen is suitable for most aquifers.

II.3.7 Permeameter Tests

A number of permeabilities have been determined using a Johnson permeameter. Results have been variable. The permeater can be a useful tool when samples are taken accurately. At TW 3/70, Tamanredjo, a transmissivity of 240 m^2/day was apparent for sands between 24 m and 29 m BCL as determined with the permeameter, whereas the transmissivity estimated from pumping test data was 210 m^2/day. At Well 4/70, Leiding 9A, the transmissivity of the aquifer from 72.8 m to 87.1 m BCL was 2270 m^2/day according to the permeameter tests (permeability generally 140 - 190 m/day) and was 2330 m^2/day as estimated from the pumping test (permeability 170 m/day).

II.3.8 Test Pumping

Most testing has been done using horizontal centrifugal pumps, which are ideal for short tests on the 4 inch and 6 inch diameter test wells. This is made possible by the high water levels in the wells. The pumps are capable of pumping up to 5 l/s. At Groningen and Leiding 9A this has been sufficient to cause interference in nearby wells.

One major interference test was run using an 8 inch turbine pump, belt driven from a tractor. The test was run on Well 4/70 at a rate of 29.5 l/s, the capacity of the pump. Interference was measured at a distance of 2120 m. The results are contained in Appendix II-5.; A summary of the pumping test results is given in Table II-5.

II.3.9 Water Quality

An approximate idea of the water quality is obtained during pumping tests by means of field test kits for chlorides, pH, iron, and conductivity.

Well No.	Collar elevation m NSP	Ground-water Zone	Screen m	Static Water Level m BCL	Q/S 1/s/m	T m2/day	Average k m/day
1/69, Stolkslust	1.763	C III	86.6-91.4	0.76	<1.8		(36)
2/69, Houttuin	2.436	C IV	126.4-131	3.03			
1/70, Tout Lui Faut	2.424	C IV	144 - 148.7	3.12	(0.3)		(10)
2/70, Groningen	3.211	C II C III	86.2- 91 132.8 - 137.6	1.79 1.46	2.0 0.54	71	(45) 15
3/70, Tamanredjo	2.731	Coropina	24.2-28.9	1.80	0.6	210	45
4/70, Leiding 9A	2.374	C III	72.8 - 87.1	1.54	6.6	2330	170
5/70, Leiding 9A	2.093	C III C III	70.8 - 75.6 91.5 - 96.3	2.07 2.35	0.2 (0.7)	20 685	5 150
6/70, Meerzorg		Onverdacht	225.8-230.5	2.05	0.02		
8/70, Magenta	3.124	C IV	125.4-130.1	3.8	1.3	220	46
9/70, Morico		C III	103.6-112.9	0.50	1.0	284	30
10/70, Leiding 9A		C IV	166. - 175.4	1.82	≈3		

Table II - 5 Test Well and Aquifer data

Table II - 6 Analyses of water samples from Project test wells

All analyses except pH are reported in parts per million

Well No.	Zone and Depth (m)	Dry Residue	Cl	SO4	Fe	Mn	Total Hard	HCO3 Hard	p-Alk	m-Alk	No3	pH
1/69, Stolkslust	C I											
	43-48	1800	634	192	7.4		890	196			Weak	6.3
	C III											
	62.9 - 65.7	880	184	198	19		410	142			Weak	6.5
	68.5 - 72	770	171	200	13		410	160			Pos	6.3
	78.2 - 81		176	Pos	Weak		360				Neg.	6.0
	86.6 - 91.4		171	Pos	Weak		360				Neg.	6.1
2/69, Houttuin	C I? 41 - 45	1,274	68	44			756					3.7
1/70, Tout Lui Faut	C IV 144.1-148.7		(137)									
2/70, Groningen	C II 86.2 - 91		(2300)									
	C III 132.8-139.6	461	88	108	5.9	0.11	98	98			Neg	8.3
3/70, Tamanredjo	Coropina ? 24.2 - 28.9	3,380	851	138		Neg						8.0
4/70, Leiding 9A	C III 72.8-87.1	617	113	186	7.5	0.2	317	116	12	140	Tr	7.0
				Dissolved Oxygen 2.5 ppm, CO_2 - 75 ppm								
5/70, Leiding 9A	C III 70.9-75.6 91.5-96.3	664	139 (140)	184			356					8.5

Table II - 6 (Continued).

Well No.	Zone and Depth (m).	Dry res.	Cl	SO_4	Fe	Mn	Total Hard	HCO_3 Hard	p-Alk.	m-Alk.	NO_3	pH
6/70, Meerzorg	Onverdacht 225.8-230.5	994	400	32			89					7.0
8/70, Magenta	C IV 125.4-131.1	273	103	21	8.3	1.1	76	59	12	73.2	Neg	6.5
9/70, Morico	C III 103.6-112.9	725	205	119	9.6	0.8	328	169			Neg	6.9

Note. a) Values in parentheses were determined with field kits.
b) Where NO_3, checked NO_2 and NH_4 were negative.

All samples for chemical and bacteriological examination are submitted to the Central Laboratory. Unfortunately analyses of all the ions requested have not been done. Arrangements have been made recently by the Central Laboratory to determine calcium, magnesium, sodium, and potassium utilizing a flame photometer owned by the Ministry of Agriculture.

Up to the present, water quality studies have been based on the content of chlorides and the total dissolved solids. When more complete analyses are available, it is hoped to study the water chemistry in more detail particularly through the use of trilinear graphs.

Analyses of samples submitted to the Central Laboratory are given in Table II-6.

II.3.10 Groundwater Temperature

A study of groundwater temperature from the Geology and Mining Service exploration data indicates that, in the coastal areas, groundwater temperatures increase with increasing depth below the ground surface. This is illustrated in Appendix II-6, where the points on each curve represent groundwater temperatures measured from aquifers at the indicated depths for a single well. The temperature increase is roughly one degree centigrade for 30 to 40 m, which approximates the geothermal gradient of the earth's crust, estimated at about one degree centigrade for each 30 m of depth.

It is interesting that water temperatures above a depth of about 140 m in the area west of Paramaribo are lower than those to the east. This may indicate better recharge conditions to the west in aquifer zones CII and CIII and poor recharge or stagnant conditions in the aquifers of zone CIV and below.

II.3.11 Observation Wells

A number of small diameter observation wells are being drilled in the Savannah belt near Zanderij. The observations will be correlated with precipitation and with the observations in wells at Republiek to the south.

II.4 GEOLOGY

II.4.1 General

Most of Surinam is composed of ancient crystalline rocks of Precambian age. It is part of the Guiena shield. On the northern or coastal flank of the shield a sedimentary artesian basin extends from the Orinoco delta in the west to the Amazon delta in the east. It contains Upper Cretaceous, Tertiary and Quaternary sediments above the Precambrian basement, which dip gently and thicken northward towards the coast. The sediments are thickest about 2,000 m near the Corantijn rivermouth, where the basin extends inland approximately 150 km. Thicknesses on the shelf north of the coastline are not known. Sedimentation was characterised by repeated transgressions and regressions of the ocean. Sands of local origin were deposited in a fluvio-deltaic envrionment, whereas contemporaneous and interbedded clays and sandy clays largely of Amazon origin were deposited in a lagoono-marine.

Near Paramaribo, the basin extends from the coast inland to the Savannah area and terminates at the basement, a distance of approximately 70 km. The basement is at a depth of about 260 m at Paramaribo. With the exception of local bauxite inliers, the oldest sediments that appear at the surface are the Upper Coesewijne sands in the Savannah belt. The older sediments wedge out towards the south against the rising basement.

The geological succession is contained in Table II-7 and the simplified surface geology is illustrated in Appendices II-7, 8 and 9 inclusive.

Age	Pollen Zone	Ground-water Zone	Lithostratigraphical Unit	
Holocene			Demerara	Pegasse, dark swampy clay, streaks of sand.
Pleistocene	G-2		Coropina	Lelydorp. Sandy clays, fine sorted sands.
				Para. Heavy laminated clays with intercalated fine & coarse sand.
Pliocene	G-1	C I C II	Upper Coese-wijne	Upper "white" sands. Very coarse, unsorted, kaolinitic sands to stiff kaolinitic(sandy) clay, lignite.
Miocene	F	C III	Lower Coese-wijne	Intermediate clays. Stiff kaolinitic clay,green clay,orgamic material & interbedded coarse sand.
Oligocene	E	C IV		Lower sands. (A-sand of Guyana). Coarse unsorted sands & kaolinitic clay, lignite.
				(Bauxite interval)
Eocene	D C		Upper Onver-dacht	Upper bauxite,remnants of iron cap, kaolin, kaolinite clay, sands.
Palaeocene	B		Lower Onver-dacht	Lower kaolinitic clays, occasionally humic, coarse & medium sands.
Upper Cretaceous	A			Lower consolidated sands & clays
Precambrian				Basement

Table II - 7, Stratigraphic succession, after Van der Hammen, Wijmstra, Montagne and Krook, with groundwater zones in the Coesewijne series.

II.4.2 Demerara Series

The Demerara series of Holocene age consists mainly of marine and fluviotile clays, swamp-clays, and sand bars mainly within the area of the "Young Coastal Plain." They were deposited at levels varying from about present sea level to + 5 m N.S.P. and extend inland for considerable distances in the present river valleys.

II.3.3 Coropina Series

The sediments of the Coropina series are of Pleistocene age, occurring in pollen zone G-2. Both the lower and upper contacts are unconformable. The series contains two parts, an upper Lelydorp series and a lower Para series separated by a hiatus. The Lelydorp series consists of fine, sorted, in places bleached sands and red and yellow mottled sandy clays and silts. The fine sands were deposited for the most part as off shore bars. The Para series consists mainly of heavy, finely laminated, stiff clays and humic clays with thin films of extremely fine sand and with lenses of coarse, unsorted sand.

The series crops out in the strongly dissected "Old Coastal Plain", the northern edge of which is marked by a small but distinct rise of a few metres. It continues northward beneath the Demerara series and near the coast it is found to depths up to 30 m in the vicinity of Paramaribo and 50 m in western Surinam.

II.4.4 Coesewijne Series

The Coesewijne series takes its name from the "Coesewijne Savannah", a name introduced by Cohen and Van der Eyk in a classification of the Savannahs. It is Mio-Pliocene in age representing the sediments of pollen zones E, F and G-1. Both the upper and lower contacts are unconformable. An Upper and Lower series have been recognized, separated by a strong unconformity.

The upper Coesewijne series of Pliocene age falls within pollen zone G-1. It crops out to form the Savannah belt about 20 km to 50 km wide along the southern edge of the coastal basin. It consists of coarse, angular, generally kaolinitic sand and interbedded clay and sandy clay, with varying amounts of lignite. In the coastal area the thickness is generally between 20 m and 70 m. It is thickest in buried valleys that were eroded in the Lower Coesewijne series. These valleys follow approximately the positions of the existing rivers.

The Lower Coesewijne series of Miocene age, within pollen zones E and F, does not crop out and probably extends southward only to the Bauxite belt. The lowest part consists of coarse, angular, generally kaolinitic sand with interbedded clay and sandy clay and with varying amounts of lignite. Above this the upper part begins with an extensive stiff clay layer up to about 40 m thick, which is followed by stiff clays, sandy clays and organic clays with interbedded coarse sands. The thickness of the Lower Coesewijne series in the coastal area varies up to about 140 m but probably is thicker at and beyond the coastline.

Correlating the Coesewijne series with sediments of the same age in Guyana, the Upper Coesewijne compares with the Mackenzie "white sand" formation, the upper part of the Lower Coesewijne with the Intermediate clays or Montgomery formation, and the lower part with the A-sand.

II.4.5 Onverdacht Series

The Onverdacht series of Palaeocene and Eocene age is in pollen zones B, C and D. The upper part of the series is important for its bauxite. It consists of bauxite, kaolin, sands, and clays. The bauxite formed during the hiatus that followed the deposition of the sediments, which has come to be known as the "Bauxite Interval."

Erosion was deep. It left a series of hills or mesas capped with hard resistant bauxite, which occur in a belt, the "Bauxite belt," following the curvature of the southern margin of the basin. The hills occur above basement highs or where the basement surface steepens as it slopes towards the coast. The bauxite locally crops out but for the most part it is buried beneath Upper Coesewijne and in places,Coropina sediments. The Bauxite belt is north of the Savannah belt in the Onverdacht and Moengo areas but it is within the Savannah belt in Guyana.

The Lower Onverdacht series of Paleocene age, in pollen zone B consists of alternating sands and clays.

The entire series is thickest in the central part of the basin. In western Surinam the thickness is about 400 m with the base at approximately 600 m BGL.

II.4.6 Cretaceous Sediments

A thick series of consolidated sands and clays with lignite zones of Maestrichtian age are the oldest sediments in the coastal basin. In the centre of the basin near the mouth of the Corantijn River their thickness is about 800 m.

II.4.7 Precambrian

The basement complex if igneous and metamorphic rocks, which forms the Guiana shield, continues beneath the basin sediments. The slope of the surface is gentle in the south but it steepens beginning on the north side of the Bauxite belt.

II.5. AQUIFERS

II.5.1. General

Aquifer zones or groups of aquifers conform with the main formations within the coastal artesian basin. For the most part each zone is a separate unit but interconnections exist in some locations.

The main aquifers are contained in the Coesewijne series in which it has been possible to identify four zones. The boundaries are stritigraphic but, because of lack of fossil evidence throughout much of the area, correlation is based on superposition, water quality and head differences. Each of the zones may contain several aquifers identifiable locally, but they likely are interconnected regionally.

The distribution and relationship of the zones is illustrated in Table II-7 and in the maps and sections in Appendices II-7,8,10 and 11 inclusive.

II.5.2. Demerara and Coropina Zones

For the most part the Demerara and Coropina sediments consist of sandy clays and heavy laminated clays. Thin discontinuous coarsegrained sand formations that occur at the base, at least in the Bauxite belt, cannot be differentiated from Zone C I and therefore they are best included in that zone. The Lelydorp sands, that occur in places at the top of the Coropina series, are fine-grained and locally are a source of fresh water tapped by dug wells for individual domestic supplies.

The only water supply system that obtains water apparently from this zone is at Wageningen. The supply comes from two wells constructed in a sand formation from 23 m to 27 m BGL. Short pumping tests were run by the Project on one of these wells and the other was used as an observation well. From the test data a permeability coefficient of 75 m/day to 80 m/day was estimated. The water had a chloride content of 224 ppm. Sandy layers between 35 m and 40 m BGL in the polder area to the north may be a contamination of this aquifer. In this area the chlorides are between 365 ppm and 1128 ppm but the distribution is patchy.

11.5.3. Coesewijne Zone C I

Zone C I has been recognized only in the coastal area, where it represents the uppermost aquifer in the Upper Coesewijne series. It has been considered separately from Zone C II largely because of the difference in water quality. This is most apparent in section C - D of Appendix II-10, where the chlorides in the Kwatta-Leidingen area (Wells 21 and 22) are between 300 ppm and 450 ppm as compared with more than 2000 ppm in the Saramacca and Suriname sections of Zone C II to the west and east respectively. Farther to the north the zone appears to be more extensive but it cannot be distinguished readily from Zone C II (section A-B of Appendix II-10).
The two zones probably are connected in places. At present it is not possible to trace Zone C I southwards through the Bauxite belt to the Savannah belt. In these areas it may not be possible to identify it as a separate zone from Zone C II.

In the Kwatta-Leidingen area the chlorides are a little too high for the water to be attractive as a source for public supplies when better water is present in Zone C III below. To the east near the Suriname River and at least as far as Tamanredjo the chlorides increase to over 1000 ppm but beyond Tamanredjo they decrease. At TW 9/70 near the Commewijne river an electric log indicates that water probably in this zone contains chlorides less than 200 ppm.

At Nieuw Nickerie in western Surinam water from aquifers in the depth interval 40 m to 50 m, which likely belong to this zone, contain chlorides between 200 ppm and 420 ppm.

II.5.4. <u>Coesewijne Zone C II</u>

II.5.4.1 <u>Distribution and Thickness</u>

The sands of Zone C II, together with those of Zone C I crop out to from the Savannah belt along the southern margin of the coastal artesian basin. The Zone extends northward in burried valleys through the bauxite belt into the coastal area. It is not known whether it extends beyond the coastline.
The distribution in the area of the Saramacca and Suriname rivers is shown in Appendix II - 7.

The buried valleys, which contain the zone in the bauxite belt and the coastal area, appear to be the valleys of the ancient Saramacca, Suriname and Commewijne rivers. The buried valleys of the Saramacca and Commewijno rivers seem to be wide as they pass through the Bauxite belt but the burried valley of the Suriname River and the contained Zone C II aquifer can only be three kilometers wide at the most, where it passes through the Bauxite belt near Paranam.

In the Savannah belt the thickness if from 0 m to about 20 m. It thickens northward and in the Bauxite belt it probably exeeds 40 m in places. At Paranam the Suralco wells obtain water from the upper 15 m of aquifer below 23 m and to the west TW 3/71 intersects 14 m of sand below 28 m and interbedded sands and clays that probably belong to this zone to a depth of 67 m BCL. In the coastal area the thickness is up to 65 m in the depth interval 35 m to 100 m BGL; thus, as it occurs in burried valleys, it can be on the same level as the stratigraphically lower Zone C III in the intervening burried spurs.

II.5.4.2. Hydraulic Characteristics

The hydraulic characteristics of this aquifer can only be deduced from old data from Republiek, some figures obtained about the Suralco wells at Paranam, and scattered wells in the coastal area, where the water is brackish and therefore unattractive for exploitation.

From records of a pumping test run on a well at Republiek for 2½ hours at 6 l/s a permeability coefficient of 55 m /day and a storage cooefficient of 8.0×10^{-4} are apparent. The specific capacity of the well was 0.6 l/s/m but large entrance losses were apparent, and when corrected for a specific capacity of about 2 l/s/m was obtained which compares with the permeability. Other pumping data obtained for wells in this field indicate specific capacities of 3 to 4 l/s/m, which suggests permeabilities of 70 m/day to 90 m/day.

At Paranam, Suralco operate 8 wells constructed in this zone. The individual wells are operated at 50 l/s to 60 l/s. The specific capacities are between 4 l/s and

17 l/s suggesting that the permeability of the sands is between 300 m/day and 350 m/day. The sands fill a narrow part of the ancient Suriname valley as it passes through the Bauxite belt, and it is reasonable to expect coarse sands with high permeability.

In the coastal area the permeability calculated from the GMD data range from 34 m/day to 116 m/day. The wells had specific capacities of 1.6 l/s/m to 5.7 l/s/m.

II.5.4.3 Piezometric Surface and Groundwater Flow

The zone is under piezometric conditions everywhere except locally in the Savannah belt.

In the coastal area the piezometric surface is virtually flat at an elevation of approximately 1.5 m NSP. To the south in the Zanderij area water level elevations of 3 m and 5.5 m NSP have been measured at effluent creeks during the dry season when the levels are low. The levels would be higher between the creeks and farther south. At Republiek about 3 km north of the Savannah belt seasonal water level fluctuations have been recorded by the Surinam Water Company since 1933. Water level elevations between October 1929 and March 1930, before the influence of pumping, varied from a low of 0.9 m NSP to 2,2 m NSP. These levels are low because of the proximity of the effluent Coropina Creek, where the corresponding water levels were 0.5 m and 1.8 m NSP.

The difference in the elevation between the coastal area and the Savannah belt is very small. It is only about 1.5 m if an elevation of 3 m NSP is assumed along the northern fringe of the Savannah belt. This is over a distance of 30 km to 35 km.

To obtain some idea of the amount of flow, the Darcy equation has been applied with the following assumptions:

a) the 14 m thick sand layer intersected in TW 3/71 at Rijsdijkweg continues to the east and west and has a transmissivity of 2800 m^2/day.

b) The elevation of the piezometric surface is 3 m NSP along the northern fringe of the Savannah belt and 1.5 m NSP at the northern fringe of the Bauxite belt some 20 km to the north giving a gradient of 7.5 cm/km.

Then: $Q = TIL = 2800 \times \frac{0.075}{1000} \times 1000 = 210\ m^3/day/km.$

In spite of a high transmissivity the flow volume is low because of the small hydraulic gradient.

II.5.4.4 Recharge

At Republiek groundwater levels fluctuate seasonally in relation to the precipitation. Records go back as far as 1933. Not all of the data have been assembled for study but from the information now available the following points are pertinent:

1) A hydrograph of the average water level elevation in the pumped wells shows seasonal variations ranging from 1.6 m to 4.2 m for an average of 3.1 m over the 19 year period 1934 to 1952 inclusive.

2) A hydrograph of the effluent Coropina Creek for the same period, shows fluctuations ranging from 1.6 m to 2.5 m for an average of 2.1 m.

3) The fluctuation of the water level in Observation Well No. 7, located on the northern flank of the well field, was 3.4 m in 1964. The average fluctuation in this well for the three year period 1967 to 1969 inclusive was only 0.5 m.

4) The average fluctuation in 11 observation wells for the three year period 1967 to 1969 inclusive was 0.9 m.

To obtain some idea of the amount of rechange to be expected in the Savannah belt a water level rise of 3 m is considered as a reasonable figure. The aquifer at Republiek is under piezometric conditions and the seasonal water level increase of 3 m must represent an impression caused by recharge in the Savannah belt, which begins about 3 km to the south. In fact the increase should be larger at a distance of 3 km. (Applying the estimated storage coefficient of 8.0 x 10-4 for Republiek the 3 m represents a water equivalent of only 2.4 mm). Assuming that phreatic conditions prevail in the Savannah belt and that the sands have an effective porosity of 15% the 3 m fluctuation would represent a water equivalent of 450 mm or about 20 % of the average precipitation of 2200 mm per year. In terms of volume the rechange would amount to about 450,000 m^3 per year per square kilometer of exposed aquifer. It is obvious from the high water levels that the aquifers are full and that large quantities of groundwater are discharged locally to effluent streams and as evapotranspiration. Certainly the estimated volume of water flowing to the north (see Section II.7.4.3.) is small in comparison.

II.5.4.5. Water Quality

The most noticeable feature of the water quality is the change from fresh water south of the Bauxite belt to brackish water in the coastal area. There are insufficient points to follow the change in detail but it probably takes place within a short distance along or near the northern flank of the bauxite belt. The chlorides are less than 10 ppm at Republiek and as low as 21 ppm at Paranam but in the coastal area they exceed 2000 ppm.

The existance of brackish water in the coastal area, would normally seem unlikely when, unlike the lower zones, this zone crops out and receives recharge in the Savannah belt. The most likely reason is that sea water entered the aquifer during the last marine transgression. In Appendix II-7, the boundary of the Coropina Formation marks the limit of the young coastal plain and the advance of the ocean during Holocene times. It can be seen that ocean water must have extended up the Saramacca and Suriname river valleys into the Savannah belt, where it must have mixed locally with the fresh groundwater. The resultant brackish water would flow northward, particularly after the sea regressed, and apparently is still in the process of being flushed out, the process being extremely slow because of the very small hydraulic gradient. Of interest is the difference in the chlorides between Paranam and Groot Chatillon. The high chlorides at the latter location probably indicate stagnant water in an embayment of the aquifer.

At TW 9/70 near the Commewijne River in the coastal area the chlorides are less than 200 ppm. It may be that ocean water did not enter the aquifer in the Savannah belt south of this area or that the volume was small in relation to fresh water in the aquifer. It is also possible that the flow of fresh water in this area is higher than in the rest.

In and south of the Bauxite belt, where the water is fresh and suitable for use, the iron content is up to 1.0 ppm. At Paranan the pH is between 5.2 and 5.8

Nothing is known about the quality of water in western Surinam. At Nieuw Nickerie water from aquifers in the depth interval that may represent the zone contains 421 ppm and 450 ppm of chlorides.

II.5.4.6. Potential as a Source of Water Supply

The zone is most important as a potential source of water supply in the bauxite belt and the area to the south and in eastern Commewijne where the water is fresh. It is an important groundwater zone because it receives recharge and will be the potential source for the Paramaribo area in the future when the quality of water pumped at the Zorg en Hoop and Leysweg well fields ultimately deteriorates.

II.5.5. Coesewijne Zone C III

II.5.5.1. Distribution and Thickness

The zone comprises the upper part of the Lower Coesewijne series equivalent to the upper part of the Intermediate clays or Montgomery Formation in Guyana. It consists of several sand aquifers interbedded with clay. The sand formations appear to be interconnected in places. It is separated from the lower Zone C IV by a stiff clay layer that acts as an aquiclude regionally. The upper part of the zone is taken as the erosion surface that separates the Upper and Lower Coesewijne series. The position of this surface is not widely proved but it is hoped to locate it more accurately by means of pollen. The upper boundary as shown in the sections of Appendix II-10 is based on marked differences in water quality. This is particularly clear in the division between it and Zone C II in the western part of section C-D.

The zone is continuous from east to west but individual sand aquifers are not necessarily continuous. In this direction the thickness of the zone varies from about 20 m to a little more than 60 m in the depth interval of 60 m to 130 m BGL. The thinnest parts are beneath the thick Zone C II sands.

It is not known how far the zone extends to the south but it is suspected that it does not continue south of the Bauxite belt. It probably continues northward beyond the coastline.

Nothing is known about the zone in western Surinam. Because it is considered equivalent to the upper part of the Montgomery Formation in Guyana it should be present in western Surinam. Sand formations were intersected by Well 36 at Totness from 59 m to 153 m BGL, but they were not tested and it is not known whether they represent Zone C II or C III or both. At Nickerie two aquifers were intersected between 62.2 m and 112 m BGL, which might belong to Zone C III.

Much of the zone thickness is clay. The sand aquifers generally are up to 15 m thick. The thickest known aquifer appears to be 33 m of sand intersected by Well 4/70 from 69 to 102 m BGL, but this probably is a complex of more than one sand formation. To the south at Santo-Boma (Well 37) the zone consists almost enterily of clay.

II.5.5.2. Hydraulic Characteristics

Permeabilities calculated from GMD data and from limited pumping tests range mainly from 10 m/day to 70 m/day with corresponding specific capacities up to 3.3 l/s/m. Most of the values probably are low because they were calculated using the Thiem equation. A high permeability of 153 m/day was calculated for a 4 m section of aquifer at Koewarasan and a section only one meter thick had a value of 261 m/day.

The most comprehensive pumping test was run on Well 4/70 at Leiding 9A. The well was pumped for 72 hours at 29.5 l/s and measurements were made in TW 1/69 at Stolkslust, a distance of 2120 m. The average cooefficient of permeability was 170 m/day and the coefficient of storage was 2.1×10^{-4}. Details of this test are contained in Appendix II-5.

II.5.5.3. Piezometric Surface and Groundwater Flow

The aquifers are everywhere under piezometric conditions with water levels in the coastal area generally 2 m to 3 m BGL, a little more than one meter lower than the level of the underlying Zone C IV.

The piezometric surface is virtually flat in the area between the Saramacca and Suriname rivers, where the zone is best explored. Small differences from place to place probably are due to differences in barometric pressure or tidal loading at the time of measurement. The lowest level of 1.40 m NSP, measured at TW 1/69, the most northern well, is consistent with a northerly flow, but levels at Well 4/70 (1.75 m NSP) and Well 24, (1.83 m

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NSP) are higher than those at Well 21 (Av. 1.67 m NSP) and Well 22 (1.73 m NSP) to the southwest.

II.5.5.4. Recharge

There is no possibility of direct local recharge to the aquifers. They are all under piezometric conditions, confined between clay aquicludes. Any recharge must enter as a flow from the south but as yet it is not known whether the aquifers have contact with upper zones to the south where they crop out and receive recharge.

The test drilling presently being carried out along Rijsdijkweg in the bauxite belt is designed among other reasons to determine whether a connection does exist. If there is a connection the flow of water into the coastal area must be very small because of the low gradient that is evident (see Section II.5.5.3.).

II.5.5.5. Water Quality

In the coastal area the salinity varies in an east-west direction. At Kwatta-Leidingen the zone contains the freshest groundwater. Here the chlorides are between 49 ppm and 200 ppm. They increase towards the north suggesting a flow in this direction. At Well 4/70 the chlorides are 113 ppm whereas at TW 1/69, 2.1 km to the north, they are between 175 ppm and 185 ppm. The corresponding dissolved solids are 615 ppm and 770 ppm. In section C-D of Appendix II-10 it can be seen that chlorides vary from one aquifer to another. The lowest value is 45 ppm for a thin aquifer intersected by Well 22. The chlorides increase away from this pint towards adjacent zones where the chlorides are higher.

East of the Suriname River the chlorides are high. Values are not known at Meerzorg but they are obviously high at Tamanredjo as indicated by the electric log of TW 3/70. Further to the east the chlorides increase and at TW 9/70, water believed to be from this zone has a chloride content of 205 ppm and dissolved solids of 725 ppm.

In the west of the country Well 13 at Nieuw Nickerie intersected three aquifers between 66 m and 106 m BGL, which may be in Zone C III. The chlorides were between 420 ppm and 570 ppm.

The iron is high with values usually up to 15 ppm and the pH is low, generally between 5.8 and 7.

II.5.5.6. Potential as a Source of Water Supply

Where the water quality is suitable the aquifers of Zone C III are a pontential source of water supply. They are important particularly in the Kwatta-Leidingen area and in eastern Commewijne.

However, where large withdrawals are anticipated, it should be emphasized that the zone may not receive much, if any, recharge and that there is a possibility of an induced flow from the adjacent Zone C II, which contains brackish water. Even if there was recharge from the south the recharge area is remote compared with the brackish water of Zone C II and the water with higher chlorides to the north, and therefore contamination should be expected before the benefits of any increased flow induced from the south.

II.5.6. Coesewijne Zone C IV

II.5.6.1. Distribution and Thickness

Zone C IV is equivalent to the lowest part of the Lower Coesewijne series. A complex of sand formations form the most extensive aquifer zone in the coastal area. It is confined beneath an extensive layer of stiff clay, which probably is equivalent to the lower part of the Intermediate clay or Montgomery Formation in Guyana. The base of the zone should be equivalent to the erosion surface (bauxite interval) between the Onverdacht series and the Coesewijne series but the location of this boundary as marked on the sections of Appendix II-10 is assumed.

From investigations in the area of the Saramacca and Suriname rivers it is evident that it wedges out either against the rising basement or the Onverdacht series along the northern flank of the bauxite belt(Appendices II-8 and II-11) Thus its existence is not known in the Savannah belt and it was not intersected by TW 9/70 approximately three kilometers west of the Commewijne River and the east-west highway.To the west the zone apparently continues through Suriname and into Guyana, where its equivalent is the A-sand Formation. It continues northward beyond the coastline probably for several tens of kilometers.

The zone dips gently toward the north. It generally thickens in this direction also but this is complicated in the area south of Paramaribo where it appears to fill a northwest trending burried valley. This is indicated in Appendix II-8 by the isopachs and the contours marking the top of the zone. The known thickness increases from 0 m in the south to about 40 m at Groningen and possibly 50 m at Weg naar Zee.

II.5.6.2. Hydraulic Characteristics

The aquifers are composed mainly of coarse-grained angular quartz sand, which is more or less kaolinitic. In places rounded pea size quartz gravel is included.

There have been no extensive aquifer testsrun within this zone. Coefficients of transmissivity and permeability have been determined from short pumping tests and mainly from limited pumping data from the GMD drilling programme.

It is difficult to compare all the values calculated because of the different screen diameters used. Almost invariable 4.57 m (15 ft) long, 40 slot Johnson screens were used. Lower values were obtained with 4¾ inch diameter screens than with 7 3/8 inch and 8 5/8 inch diameter screens indicating larger entrance losses and perhaps insufficient development for tests with the smaller screens. This is particularly obvious at Paramaribo (Zorg en Hoop). General ranges of permeabilities and specific capacities for tests with different diameter screens are listed in Table II.8.

Screen Dia. inches	Coeff. of Permeability m/day	Specific Capacity l/s/m
4 3/4	24-84	2-4
7 3/8 Paramaribo	109-134	4-6.3
8 5/8 (Well 22, Koewarasan)	374	17.8

Table II-8. Screen diameters in relation to estimated permeability and specific capacity for wells in Zone C IV.

Comparing all the values it is evident that the lowest permeabilities are in the vicinity of Meerzorg and that they increase to the east and particularly to the west. Using the values obtained from tests with the larger diameter screens, the coefficient of permeability for the area west of Meerzorg ranges from 100 m/day to 374 m/day.

II.5.6.3. Piezometric Surface and Groundwater Flow

The zone is everywhere under piezometric conditions and the piezometric surface is higher than in all the upper zones.

The piezometric surface before the influence of withdrawals at Zorg en Hoop has been reconstructed approximately, using data from the GMD drilling programme and some levels determined by the Project. The reconstruction is shown in Appendix II-12.

Small differences in water level elevations may be caused by barometric pressure variations at the times of measurement, however a noticeable slope to the south is evident suggesting an inland flow of water. It amounts to about 7 cm/km near Paramaribo. It is suggested that the groundwater in this zone is ancient and that the natural inland slope of the piezometric surface represented a remnant of ocean loading caused by a rise in sea level after the last glacial period (Würm or Wisconsin) ending about 10,000 years ago, when the sea was about 90 m lower than at present. The gradient probably was greater as the ocean first readvanced.

In the Paramaribo area the piezometric surface now reflects the effect of withdrawals at Zorg en Hoop. The amount of interference is shown in Appendix II-13. It extends approximately 40 km to the west. It is believed, that the aquifer ends about 11 or 12 km to the south therefore the drawdown is greater in this direction.

Well 36 drilled at Totness is probably constructed in this zone (162 m to 164 m). The piezometric level at this location was + 1.87 m MSL when the well was constructed in 1961.

II.5.6.4. Recharge

Any recharge must be so small that it is negligible at least in eastern Surinam. The thick layer of stiff clay under which the zone is confined would not permit the passage of water and the high head in the aquifer excludes the possibility of downward leakage. The aquifer is believed to end north of the bauxite belt probably against the basement or Onverdacht sediments. In the latter case there could be a flow into the zone northward through the Onverdacht sands, but the original inland slope of the peizometric surface is evidence against this. It may be that under present pumping conditions a small flow of water is induced from the Onverdacht sands south of Paramaribo.

II.5.6.5. Water Quality

The chloride ion increases northward towards the coast and at some locations an increase with depth is evident. The northward increase from approximately 100 ppm to more than 300 ppm in the northern part of Paramaribo is illustrated by means of isochlors in Appendix II-8. The equivalent values for total dissolved solids are 300 ppm and 600 ppm. The fresh water to the south suggests that recharge from this direction probably took place some time in the past.

East of the Surinam River the chlorides increase to a measured high of 1,700 ppm at Tamanredjo. The equivalent total dissolved solids are 2,300 ppm. This may represent a pocket of stagnant water north of a buried spur of Onverdacht sediments to the east of the buried valley where the zone is thickest. It is not known whether the chlorides continue at this high level east of Tamanredjo.

At Well 4-70 in the Kwatta-Leidingen areas gas was abundant in the water imparting a fool odour to it. This condition also exists at Koewarasan.

In western Surinam the well at Totness is the only one believed to be constructed in this zone at 162 m to 164 m. Here the chlorides are 77 ppm and the total dissolved solids are 311 ppm. There is no information on the quality of water from the Shell Oil Company drilling. Fresh water at depths between 244 m and 296 m indicated by electric logs of their test wells at Wageningen probably is below this zone.

The iron content of the water is high, varying up to 10 ppm. The pH is low, between 5.8 and 7.7. The lowest values are in the lower Saramacca river area and the only two values higher than 7.0 are at Jagtlust and Nieuw Amsterdam.

II.5.6.6. Potential as a Source of Water Supply

Where the quality is suitable the aquifer can be considered as a source of water supply with the reservation that it may not receive recharge at least in the eastern part of the country.

The most favourable part of the aquifer for public water supplies is in the area south of the 250 ppm isochlor; however, assuming that there is negligible recharge, large scale pumping will induce a flow of water from the north and ultimately there will be an intrusion of salt water from the ocean.

The zone is being used already as a source of water supply for Paramaribo. This and the problems of salt water contamination are discussed in more detail in Section II.6.1.3., Paramaribo.

II.5.7. Onverdacht Zone

The Onverdacht series has been divided stratigraphically into Upper and Lower formations, but there is not much information about groundwater in the series as a whole, and therefore it is not possible to subdivide it into aquifer zones.

Aquifers in the Onverdacht series are important locally in the bauxite belt as a source of water supply. The only wells known to be constructed in it are at Onverdacht, where a water supply system is operated by the Billiton Company. The water is pumped from five wells. A pumping test was run on one of the wells in 1962. Water was pumped at almost 4 l/s/m and water levels were observed in three observation wells. An analysis of the data indicates a transmissivity of about 180 m^2/day. Sections show at least 8 m of aquifer and it is believed that approximately 5 m of this was screened; thus the permeability is probably in the order of 36 m/day. The water from these wells has a chloride content of 16 ppm and the pH is 5.2. It is likely that the fresh water enters the Onverdacht sands from the Upper Coesewijne Zone C I or C II to the south. A sample of water taken from the bauxite that is the uppermost member of the zone had a chloride content of 4065 ppm and a pH of 7.4 and a sample taken from sand immediately below the bauxite and underlying kaolin in the mine area had a chloride content of 3672 ppm and a pH of 5.5.

Throughout most of the coastal area aquifers in the Onverdacht series are not attractive as a source of water supply becasue of the depth and because, where it is present, water is usually available in the overlying Coesewijne aquifers. Well 7 at Meerzorg intersected an aquifer that is probably within the Onverdacht series. It was screened and tested from 180.5 m to 188.5 m BCL. From the limited pumping data a permeability coefficient of 34 m/day was estimated (compare the test at Onverdacht). The chloride content of the water was 590 ppm. Nearby in TW 6/70 a coarse sand with clay from 225 to 230 m BCL yielded negligible water with a chloride content of 400 ppm.

The Shell Oil Company reported the probability of fresh water in sands between 244 m and 296 m BGL at Wageningen in western Surinam. The estimated chloride contents were 120 ppm to 200 ppm but it was indicated that the sand probably are compact and clayey with a... low permeability.

II.5.8. Cretaceous Zone

The Cretaceous sediments have not been explored for groundwater. They are the lowest sediments in the basin. In the Paramaribo area they may be present as the lowest few meters above the bedrock but in western Surinam the top is 400 m to 600 m BGL.

It is unlikely that they receive recharge and the water probably is brackish. Both yield characteristics and water quality likely are inferior to those in the higher aquifer zones.

II.6. SOURCES OF GROUNDWATER FOR WATER SUPPLY PROJECTS

II.6.1. Group I Areas

II.6.1.1. Kwatta-Leidingen

In the Kwatta-Leidingen area the only aquifer containing groundwater with a quality suitable for a potable water supply system is in Zone C III. Water in the Zone C IV aquifers is fresh to the south of the area but there appears to be little or no recharge to this zone, which is already being used as a source of water supply for Paramaribo.

A flow of water in Zone C III from the south into the Kwatta-Leidingen area might take place. If this were so the flow in the important 60 m to 100 m depth interval (Well 4/70) would pass the Uitkijk-Koewarasan area in a flow path only about 10 km wide with a total aquifer thickness of about 20 m. The piezometric surface in this area is virtually flat suggesting very little or no flow; however, to obtain some order of magnitude, it might be assumed that a gradient exists about the same as in Zone C II, which must be the aquifer through which a flow of recharge to Zone C III would pass. An approximate flow volume may be calculated using the Darcy equation:

$$Q = k\ I\ L\ b = 1{,}360\ m^3/day.$$

where:
- Q = Flow volume.
- k = Coefficient of permeability. The value 170 m/day is the highest calculated for this zone.
- I = Hydraulic gradient 4 cm/km estimated for Zone C II
- L = Flow path, 10 km
- b = Total aquifer thickness, 20 m.

It should be noted that maximum figures have been used. The flow volume of 1,360 m^3/day is small and because it is possible that a flow does not take place at all it seems prudent to exclude recharge and consider groundwater withdrawals as a mining operation drawing only on storage.

Well 4/70, constructed in Zone C III is capable of yielding water at the rate of 30 l/s and there is no reason to doubt that higher capacity wells can be constructed at the same site. The pumping of wells at this site would result in a flow of water moving towards them from all directions. The question is how much water can be pumped before the aquifer is spoiled by an invasion of brackish water from Zone C II approximately 11 km to the west and 8 km to the east and south-east (see Appendix II-7) and by an approach of water with higher chlorides in the same zone to the north. An estimate of interference after 10 years pumping Well 4/70 at 29.5 l/s continuously indicates that it would extend to a distance of approximately 15 km from the well. The cumulative pumpage of the proposed water supply system up to 1987, based on estimated water needs, is equivalent to the amount of water pumped at the rate of 29.5 l/s continuously for about 7 years and the extent of interference is estimated at about 14 km. This is shown in Appendix II-7. It can be seen on the map that the estimated interference extends well into Zone C II particularly to the east, and beyond the coastline. This means that, with hydraulic connection between the two zones, brackish water would enter Zone C III. To ascertain the possibility of brackish water reaching the well aquifer volumes equivalent to the cumulative estimates of pumpage were calculated assuming effective porosities of 10% and 20%. The results are shown in Appendix II-15 as estimated distances from which water is pumped for aquifer thicknesses of 10 m, 20 m, and 30 m. It can be seen that, under the poorest conditions likely, with a porosity of 10% and an average aquifer thickness of 10 m, the distance from which water would be pumped is less than 1.5 km. Further calculations indicate that for an aquifer with a porosity of 10% and an average thickness of 10 m occupying a circular area with a radius of 8 km (the distance to Zone C II in the east), the contained water would amount to 201 million m^3. The estimated 6.4 million m^3 of water to be pumped up to 1987 is only 3% of this amount. It is likely that it would be well into the next century before brackish water reached the well unless additional, large and presently unforseen, withdrawals take place; however, it should be noted that pumping this aquifer appears to be purely a removal of water from storage and that the zone ultimately will be contaminated by brackish water. In this sense, pumping from storage means storage in the Zone C III aquifer itself without recharge. The flow of water from Zone C II and from the north would be a form of recharge, undesirable in quality but nevertheless preventing drastic water level declines.

II.6.1.2. Commewijne

It has been estimated that in 1987 the water requirements for a proposed supply system in the northwest part of the District of Commewijne will be 7,440 m^3/day. This is equivalent to 86 l/s for a 24 hour/day pumping operation or 206 l/s for a 10 hour/day operation.

Previous test drilling by the Geological and Mining Service indicates that the groundwater in the area is brackish (Table II-1, Wells 6,8, 16 and 17). An exception is at Meerzorg (Wells 7 and 31), where a well yielding water with 177 ppm of chlorides is the source for a small water supply system. The aquifer is thin and appears to be of limited extent. Below it the main aquifer of Zone C IV contains water with 323 ppm of chlorides. This is the same aquifer from which the Zorg en Hoop wells withdraw water approximately 5 km to the west across the Suriname River. Below this the chlorides amount to 590 ppm in what probably are Onverdacht sands.

From a study of all existing data it was concluded that the distribution of aquifer Zones C II and C IV to the west relate to the locations of the Saramacca and Suriname rivers and that a buried valley containing fresh water in Coesewijne aquifers might exist between the Paranam and Moengo bauxite areas in the vicinity of the Commewijne River. At Morico Creek about 3 km west of the Commewijne River, TW 9/80 intersected sands with interbedded clay from 32 m to 120 m BCL. The aquifer between 103.6 m and 112.9 m BCL yielded water with a chloride content of 205 ppm and an electric log of the well (Appendix II-4) suggests that the sands above contain two aquifers, one from 32 m to 51 m BCL with chlorides probably about 100 ppm, and the other from 74 m to 90 m with chlorides probably about 250 ppm.

Following the discovery of fresh groundwater in eastern Commewijne TW 4/71 was drilled at Commetewane to determine its western extent and what length of supply main would be required to convey the water to the area where it is required. The results of this test are not yet known.

Several wells will be necessary to supply the 7,440 m^3/ day required in 1987.

II.6.1.3. Paramaribo.

The water supply for Paramaribo comes from two areas, Republiek approximately 35 km to the south, and Zorg en Hoop within the city. A third well field is being prepared at Leysweg about two kilometers west of the city.

The original water supply came from a well drilled at Sivaplein in 1903. The well was drilled to a depth of 164.5 m and produced 8 l/m to 10 l/m of water with a chloride content of 168 ppm.

The first major well field was developed at Republiek following the recommendations of Van Weijerman after extensive investigations in 1929 and 1939. The Surinam Water Company (SWM) was formed, the well field and treatment facilities were constructed, the supply main was layed and in 1933 water was pumped to Paramaribo. The water has chlorides generally less than 10 ppm but it is treated because of high iron and low pH.

The well field at Republiek is constructed in aquifer zone C II and possibly C I (II.5.3 and II.5.4) only 3 km north of the Savannah belt or recharge area. The field contains 30 wells, of which 21 are pumped by a vacuum system and 9 are pumped using turbine pumps. Wells in the vacuum system are each capable of yielding about

3 l/s and each of the other wells is capable of pumping 8 l/s to 11 l/s. At the present time water is pumped to Paramaribo at the rate of 350 m^3/hour, which is the capacity of the 14 inch diameter main under the prevailing conditions. A booster station af Lelydorp is planned, which is expected to increase the flow through the line to 500 m^3/hour. This amounts to a supply of 4.38 million m^3/year, which is equivalent to the estimated annual recharge of almost 10 km^2 of exposed aquifer in the Savannah belt (II.5.4.4.). The lowest annual pumping levels have declined steadily from an elevation of approximately - 2 m N.S.P. in 1933 to approximately - 10 m N.S.P. in 1970. The decline was steapest in the first seven years (a low level of -5 m N.S.P. was reached in 1940) but since 1940 the decline was been at an verage rate of about 1.6 m in 10 years.

The first water was pumped from the new well field at Zorg en Hoop in 1958. The wells are constructed in aquifer Zone C IV (see II.5.6.). There are now 14 wells operating in the field. Four new wells have been constructed recently at Leysweg about 4 km west of the Zorg en Hoop field. A large well field with about 17 wells is planned at this location. All of these are to be constructed in Zone C IV. The Zorg en Hoop wells originally yield water with chlorides between 150 ppm and 200 ppm. The chlorides,now at about 180 ppm,have not changed appreciably, except in some wells where the cause is throught to be contamination from the brackish water of the higher Zone C II through corroded casing. At Leysweg the chlorides are 250 ppm.

Interference caused by operating the Zorg en Hoop wells up to 1970 is represented in Appendix II-13. It can be seen that interference extended about 40 km to the west and probably to the north, well beyond the coastline. To the south the drawdown is greater, which is consistent with a boundary to Zone C IV in that direction (II.5.6.1.).

The 250 ppm isochlor (Appendix II-8), which may be considered a water quality standard boundary, passes through Leysweg and close to the north of Zorg en Hoop. The operation of the wells causes water to flow towards them from all directions and the water pumped must be a mixture of relatively low chloride water from the south and high chloride water from the north. To obtain some idea of the quality of water to be expected in the future, the distance from which water flows to be discharged at the wells was calculated for model aquifers with effective porosities of 10%, 20% and 30% and thickness of 10 m, 20 m, and 30 m for the cumulative discharge in 1990. The results of the calculations are contained in Appendix II-16 and in Table II-7. The listed chlorides were estimated approximately from a NNE-SSW line through Zorg en Hoop on Appendix II-8. For 1970 the low chlorides of 200 ppm are closest to the chlorides of the pumped water. Of the three possibilities regarding the combination of aquifer thicknes and effective porosity, an aquifer with a thickness of 20 m and an effective porosity of 20% probably represents the prevailing conditions most closely. For the same aquifer conditions the chlorides in 1990 would be 280 ppm. A similar chloride value is obtained with flow coming the same distance from east and west. It must be emphasized that the estimates given in Table II-7 are for model aquifers. In Zone C IV a boundary to the south is apparent and therefore more flow from the north can be expected. The zone also thickens to the west and becomes thinner to the east.

The estimates of flow distances and chloride contents are based on the assumption that the present rate of increasing withdrawals at Zorg en Hoop will continue, though most of the additional water will come from the new Leysweg well-field. It is assumed also that, after the construction of the Lelydorp booster station, the amount of water from Republiek will remain constant at 500 m^3/hour. In this case, the ratio of water from the two areas - Republiek and Zorg en Hoop - Leysweg would be about 1:7 in 1990, and the dilution of the Zorg en Hoop water by the Republiek water would reduce the chlorides only from about 280 ppm to about 250 ppm.

The estimates do not take into account the need for water in the Pad van Wanica area where the most likely source

	1970									1990								
Total Volume pumped	41 million m3									371 million m3								
	Effective Porosity																	
	10%			20%			30%			10%			20%			30%		
Equivalent Aquifer volume (million m3)	410			205			137			3700			1852			1237		
	Aquifer Thickness (m)																	
	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30
Flow distance to well kilometers	3.6	2.6	2.1	2.6	1.8	1.5	2.1	1.5	1.2	10.7	7.7	6.3	7.7	5.4	4.4	6.3	4.4	3.6
Max.chlorides (n) ppm	350	310	290	310	280	260	290	260	250	800	680	600	680	540	450	600	450	400
Min.chlorides (s) ppm	110	130	140	130	140	140	140	140	150	100	90	90	90	100	110	90	118	120
Av. chlorides ppm	230	220	212	220	210	200	212	200	200	450	385	345	385	320	280	345	280	260

Table II -7, Total pumpage, equivalent aquifer volumes, flow distances to wells and estimated chlorides at Zorg en Hoop - Leysweg for the years 1970 and 1990 of water for a supply system is Zone C IV, the same as at Zorg en Hoop.

It is clear that, in the near future, a decision must be made on the quality of water to be accepted in relation to cost. Ultimately plans must be made to increase the supply from the south. Test drilling is now underway at Rijsdijkweg between Paramaribo and Republiek with this in mind.

II.6.1.4. Pad van Wanica, Domburg and Smalkalden

The water requirement for the proposed Pad van Wanica supply system are expected to be about the same as for the proposed Kwatta-Leidingen system, that is 2,106 m^3/day in 1987.

Aquifers containing water with a quality suitable for a public water supply are in Zones C III and C IV.

Aquifer Zone C III becomes thinner to the east and although the aquifers apparently contain fresh water as indicated by the electric log of TW 8/70 (Appendix II-3), they are likely in contact with Zone C II to the east. This zone contains brackish water with chlorides higher than 2000 ppm and may be within 2 km to 3 km of the upper aquifers and 4 km to 5 km of the lower aquifers intersected by TW 8/70. Based on interferences calculated for Well 4/70 in the Kwatta-Leidingen area it appears that withdrawals from Zone C III aquifers at the site of TW 8/70 would interfere with the Zone C II aquifer but brackish water may not appear at the well until after 1987. Further testing is planned in this area.

The Zone C IV aquifer is the most extensive in the area and the chlorides in the water are only about 100 ppm. There is no doubt that withdrawals fronm this aquifer would interfere w.th the Zorg en Hoop well field. The interference of the latter already extends into this area. Interference caused by withdrawals at Pad van Wanica up to 1987 would extend beyond Paramaribo possibly causing an added draw-down of up to 1 m at Zorg en Hoop, however the distance from which water is pumped to the wells would only be about 1 km. There is no reason why the two systems should not draw water from the same source for a limited time, but the effect of withdrawals at Pad van Wanica would speed up the rate if increasing chlorides at Zorg en Hoop. If this aquifer is to be used plans would best be integrated with Paramaribo. The source would be from the south eventually and the supply main would pass through the Pad van Wanica area.

At Domburg and Smalkalden the water requirements are estimated at 1080 m^3/day for a population of 13,500 in 1987. There are no aquifers containing fresh water locally. It is possible that the Zone C IV aquifer extends to the southeast within 5 km of Domburg. Test drilling is planned to determine this. Close to the southwest of Smalkalden the Suralco wells withdraw large quantities of water apparently. from Zone C II.

II.6.2. GROUP II AREAS

II.6.2.1. Groningen

A well was constructed at the site of the existing treatment plant and storage tank. The existing well had fallen off in production probably because of sand in the screen. The new well was drilled into the same aquifer in Zone C III and had similar yield characteristics. The old well was used for observations during a pumping test. The well is a low producer with a rated yield of about 3 l/s with a horizontal centrifugal pump. Data are listed in Tables II-5 and II-6.

Sections of an old test well drilled to a depth of 180 m at this location shows the presence of aquifer -- Zone C IV. It was learned that the head was above ground, but no information on the quality of the water could be found. It is likely that the chlorides would be about 150 ppm to 200 ppm.

II.6.2.2. Wageningen

Tests were run on the water supply wells at the village of Wageningen (See also II.5.2.). The investigation was before schedule at the request of Mr. de Boer of the Stichting Machinale Landbouw, (SML). The two supply wells tap a shallow aquifer (probably in the Coropina Zone) between 23 m and 27 m. A report dated 31 August 1970, was submitted to SML, in which the estimated capacity of the wells was indicated together with possible effects of withdrawals. It was pointed out that at least one of the pumps must be in need of service or replacement as it was not pumping at the specified rate.

Electric logs run by Shell Oil Company on three deep tests in this area apparently indicate the presence of fresh water between 244 m and 296 m in BGL. Mr. Northoorn, the Company's geologist, indicated that the chlorides probably are betwen 120 ppm and 200 ppm but that the permeability of the formation may be low.

II.6.2.3. Commetewane Creek - Alliance

A water supply system exists already at Alliance. Fresh water is found below 78 m at this location in what probably is aquifer Zone C III. Test drilling to the south (TW's 9/70 and 4/71) is being undertaken to determine the best source of groundwater for a supply system in western Commewijne. Results so far indicate the presence of fresh water to the southest at least (II.6.1.2).

II.6.2.4. Other Areas

There have been no investigations in other Group II areas other than a cursory look at the existing data.. It is planned to move the Failing 2500 drill into western Surinam for the last year of the Project. Exploration will be strictly in a vertical direction though after completing a few tests it may be possible to correlate the aquifers in western Surinam more closely. The Failing 1250 drill will operate in eastern Surinam during the latter months of the Project if required.

II.6.3. GROUP III AREAS

Group III areas include small communities. Dug wells or sand point systems would be ideal for communities along the rivers where there is sufficient pervious alluvium.

Drilling is not generally planned except perhaps at Haarlem and Maria's Lust on the Saramacca River as an extension to exploration for the Group I areas.

PART III - WATER SUPPLY

(Section I - General Considerations)

III.1.1. INTRODUCTION AND BACKGROUND

For several years during the 1950's, the US Agency for International Development through the Surinam-American Technical Cooperation Service (SABTS) conducted a demonstration project for developing rural water supplies through the installation of low-yield, sanitary wells, equipped with hand-operated pumps. This project created considerable interest in water supply development and led to the SABTS program of supplying technical assistance, consultation services and training measures. The general objective was to encourage the Government of Surinam in assuming the responsibility for water supply development and administration with technical assistance being provided by USAID and SABTS.

In 1962 the Director of Public Works indicated his interest in establishing a water supply section within his Ministry which would be responsible for promoting or developing water supply improvements throughout the country and requested SABTS assistance in drafting a plan which could be submitted by the Minister of Public Works to the Cabinet of Ministers for consideration and approval. Subsequently, "a plan" was submitted to the Director of Public Works that provided for establishing within the Ministry a water supply section which eventually might be converted into an autonomous water supply authority. The "plan" called for the Water Supply Section to receive the benefits of (1) a high level advisory committee, (2) a health educator whose services would be made available by the Director General of Public Health, (3) experienced personnel and water supply equipment from SABTS and (4) professional advisory services and assistance in personnel training from USAID.

However, the SAETS assistance as well as the USAID assistance were phased-out during the mid-1960's, and the Government elected to pursue the UNDP(SF) project route for technical assistance in meeting the problems of water supplies as well as sewerage systems in Surinam. Initial efforts to obtain this assistance were commenced in 1964, with the cooperation of the PAHO/WHO Zone office. These efforts eventually led to the fielding of the Preparatory Assistance Mission Team, as previously discussed in the "History of the Project".

The main findings and recommendations of the Preparatory Assistance Mission were as follows:

"I. The Paramaribo metropolitan area and the potential industrial zone to the south of it, with a population of some 252,000 of whom about 120,000 people do not have a safe piped water supply. This area is growing more rapidly than any other part of the country in respect of domestic and industrial water demand; the danger of epidemics due to inadequate potable water supply and waste water disposal facilities is also greater here than in any other part of the country.

II. The provincial centres of population, mainly coastal, in the districts of Nickerie, Coronie, Saramacca, Marowijne and Commewijne, together with centres near the northern extremity of Brokopondo district. These have a population of about 60,000 of whom the great majority lack piped water supplies.

III. Some smaller communities, mostly near rivers, that are remote from the larger centres of population. These have a total population of about 13,000.

In the phasing of the project, Group I will be accorded the highest priority and Group II will follow.

Currently, within Groups I and II, the most economical source of potable water supply is groundwater. Present evidence indicates that such water of acceptable quality should be available in sufficient quantity to meet the future needs. Some problems of salt water intrusion are, however, already being experienced in certain wells (in the Zorg en Hoop well-field in Paramaribo), and other wells may turn saline as the rate of extraction is increased to meet the rapidly growing demands for water. The rates of replenishment of the aquifers have yet to be investigated in detail.

The withdrawal of additional potable groundwater should not adversely affect irrigation, hydropower and navigation development based on surface water, but future impounding of surface water in the basin for hydropower or irrigation storage might, if not co-ordinated, drastically affect the rate and salinity of recharge to groundwater storage. Unified water management is therefore required.

If, eventually, the groundwater supply becomes inadequate, it can be supplemented by surface supplies; but the costs of treatment and transmission of surface supplies would be much higher than those now being incurred for groundwater supplies.

It is inadvisable to commit further investment to groundwater withdrawal until the characteristics of the aquifers in the Lower Suriname River Basin have been investigated. This investigation is a prerequisite to the planning of new water supply installations in Group I area. The findings should be helpful in defining the extent of the subsequent investigations required for the provincial coastal areas.

The progress on the Government's water supply and sewerage development programme is dependent on the progress of these hydrogeological investigations, and only the minimum of specialist expertise is needed to enable investigations to start. Therefore, it is recommended that the preparatory work should start not later than 1 July 1969. Additionally, it is hoped that the outcome of the IACB meeting in October 1969 will result in immediate authorization to incur expenditure of Special [illegible] monies for the remaining equipment required by the Project, so that the Project can be accelerated to a fully operational basis as soon as possible. The Government of Surinam has allocated US$ 92,000 from the 1969 budget and has also made all arrangements for the use of equipment and office space."

These findings are endorsed in general principle with minor exceptions by the UNDP(SF) project team, with regard to the scope of activities as well as the geographical areas included. As in the case in studies of this nature, additional investigations become necessary and these must be implemented in addition to the original tasks in order to provide as comprehensive a picture as possible.

III.1.2. OBJECTIVES

The objectives, therefore, of the immediately following sections of this report are to develop engineering proposals leading to the eventual provision of consistently available quantities of potable water to meet all reasonable domestic requirements as well as the concurrent commercial and industrial needs, while providing a degree of fire protection. Other sections will delineate the hydrogeological investigation program as well as the attendant geological studies and findings.

In order to develop the above proposals it was necessary to determine suitable design allowances (on a per capita or area basis) to meet the present and future needs of the Supply Group areas. Following the establishment of design criteria, total water quantities and quality requirements were determined to the degree possible and, whenever possible, definite suitable services selected.

Existing water supply and distribution facilities were studied in depth with a view of determining the capabilities for meeting design criteria and also with respect to eventual standardization of methods.

Finally, the engineering proposals were developed and are presented according to a schedule of priorities which is designed primarily to provide relief in areas of most immediate need, and also to permit prudent phasing of construction.

III.1.3. PRESENT CONDITIONS AND EXISTING WATER SUPPLY FACILITIES

Within the organizational framework of Surinam's Central Government, the Ministry of Public Works originally had the responsibility for .developing sources of potable water and for distributing it for use by the people of Surinam. To accomplish this task, the Ministry depended on approriations of funds from the national budget, except for those established systems which were operated under contract where in revenue realized from the sale of water was sufficient to offset the cost of making piped water service available to the consumers.

In spite of the magnitude and importance of its responsibilities in this field, the Ministry did not thoroughly develop within its own organization the technical facilities and trained personnel required to plan, install, operate and manage water supply systems. In early years projects undertaken directly by Public Works personnel with respect to water supply and distribution were essentially limited to :

1. Constructing rain water catchments and collection reservoirs.

2. Installation in rural areas of hand-dug wells of the type developed by SABTS, and

3. Transporting water from available sources to people living in areas where stored quantities of fresh (rain) water were not sufficient to supply the demands of consumers during extended periods of dry weather. This transporting of water during dry seasons, by truck, barge or other available means became a routine function of Government and is still provided for in the budget of the Ministry of Rural Government and Decentralization (the budget provides Sf. 75,000 for this purpose).

It is acknowledged that this method of water distribution is costly; and the methods of handling involved expose the water to contamination, and thus to the likelihood of disease transmission. At best, it constitutes an emergency measure undertaken for the express purpose of alleviating chronic problems.

Traditionally the Ministry of Public Works is the Government's Department for designing and building a wide range of public facilities such as buildings, roads, canals, sluicegates and lock installations, airports, hydro-electric plants, etc., but water supply systems and water treatment facilities were not included routinely among the projects justifying direct attention, except those small rain-water systems which in most cases are integral parts of building projects where the roof surfaces are utilized as catchment areas.

As the population of Paramaribo increased through the years, the need for a suitable community water supply system became more urgent. Non-Government interests responded to the growing water demands by creating a water company, which was legally incorporated under the laws of the country. Legislative action in 1929 placed the corporate holdings in the hands of several stock holders which included banks, a trading company and the government of the Netherlands. While records indicate that the enterprise was originally initiated many years prior to that date, it is generally recognized that the operations of the Water Company on a substantial scale got underway in 1930 on the basis of the 1929 legislation. In 1948, the Government acquired all shares of corporate stock and became sole owner of the Surinam Water Company. The corporation is controlled by six commissioners, one of whom is elected each year. Management is entrusted to a Director who is named by and responsible to the Board.

Following its inclusion as a new Ministry in the government established in November, 1969, the Ministry of Rural Government and Decentralization succeeding the Ministry of Public Works in this responsibility is now the government's representative and hence the sole stock holder of the corporation ; this provides the Minister with an implied "veto" authority over actions taken by the Board. However, there is no indication that such authority has ever been exercised. In reality the relations between Government, represented by the Minister, and business interests represented by the members of the Board, are well balanced and this permits the Company, although totally owned by the Government, to function strictly as an autonomous business enterprise.

The Surinam Water Company is soundly established, functions in a businesslike manner and provides water service at acceptable prices to people living within the areas for which it has contracted to accept this responsibility. The Company plans, designs, constructs, operates and manages urban water supply facilities. Authority for the Company's operations in any area is strictly dependent upon a clearly drawn contract agreement negotiated with the Government of Surinam. This device provides a unique and extremely valuable arm for government through which water supply development projects and management of systems can be accomplished. Projects for which the Company has assumed responsibility has been limited to areas with concentrations of population which the Company considers as justifying the installation of community water supply systems (involving pressure systems, treatment works, if indicated, storage facilities and a piped distribution network). Thus, the Company does not undertake the development of water supplies in strictly rural areas.

Since it came into existence, the Surinam Water Company has had total responsibility for all water supply operations in Paramaribo (supply, distribution and management). It has also undertaken water supply projects in other centers pursuant to contracts with Public Works. For instance, it has designed water systems including water treatment plants for New Nickerie, Albina, Moengo, Coronie and Alliance which were constructed by the Company.

In 1962 a plan was proposed by the Ministry of Public Works, SABTS and USAID in which district water supplies would receive greater attention.

The plan provided for the Ministry of Public Works, through a proposed Water Supply Section, to be responsible for:

1. Development, operation and maintenance of water supplies in rural areas. This would involve continuation of the program of water exploration and sanitary well construction previously carried out by SABTS as a demonstration project, and

2. Promotion of improvements in piped water systems and the development of other "urban" systems to serve centers of population in the districts, on the basis of contracts between the Ministry and the Surinam Water Company. Similar contracts would authorize the Water Company to operate and maintain such water systems on a soundly established financial structure, whereby, revenue for water sold would

be used exclusively for operating and improving water works installations. The plan foresaw that the Ministry of Public Works would be required to arrange for grants of funds to be used in financing water supply installations made by the Water Company on the basis of contracts with the Ministry. These grants might be available from the "10-Year Plan", the regular Government budget or from other possible sources, including loans.

In other words, the plan proposed that the Water Supply Section would be the authority within the Government responsible for negotiating contracts with the Surinam Water Company for undertaking development, operation, and management of community (urban) piped water supply systems and that the rural water development (sanitary well) program would be carried out under the direct administration of the Water Supply Section. Also in some cases, the Water Supply Section through the Surinam Water Company could arrange to supply water to consumers on the basis of special agreements with others. As an exception, the two principal bauxite mining companies operate water supply systems which serve their communities at Moengo, Paranam and Onverdacht. The Water Supply Section reviewed the proposals and served as the coordinating agency, however, for the arrangements which were made by the Surinam Water Company to contract the purchase of water from the plant at Moengo for sale to consumers living in nearby Wonoredjo.

Following formation of the Water Supply Section (now a part of the Ministry of Rural Government and Decentralization) the Water Company has progressively turned over the smaller systems to the Section for maintenance and operation. At present, the Water Company retains the Paramaribo, New Nickerie and Albina urban systems.

III.1.4. NEED FOR IMPROVEMENTS

Table III-1 lists the existing non-private water-supply systemsin Surinam together with the population served by the supplies. Invariably each system is either being expanded or is under consideration for augmentation.

In most cases, water is supplied on a continuous 24-hour per day basis, but in some of the systems intermittent supply is necessary. The ever-present danger of contamination inherent in intermittent supplies is well-known, and the World Health Organization maintains as a basic precept in design, the requirement for a continuous supply of potable water.

The present inadequacies in water supplies are considered an important factor in contributing to low standards of health particularly in those areas where there tends to be a prevalence of gastro-intestinal disease. The use of questionable surface sources of water which may be polluted with pathogenic organisms should be reduced through the provision of saf , adequate and readily available community supplies.

Economic benefits also will derive through increased productivity following the varying of standards of health by means of improved water supplies.

TABLE III-1 - EXISTING WATER SUPPLY SYSTEMS IN SURINAM

Supply Population Served	Source	Treatment	Storage	Distribution
Paramaribo (S.W.C.) 200,000	25 shallow wells & 9 deep wells at Republiek 11 deep wells at Zorg en Hoop 4 deep wells at Leysweg (proposed)	A,R,S	4000 m^3:Republiek 4000 m^3:Zorg-en-Hoop 300 m^3: (elevated) 4000 m^3:Blauwgrond	Approx. 330 km mostly asbestos cement. 2 in. to 12 in. Also 40 km 14-in. transmission from Republiek
Kuwarasan (D&D) 2,000	2 deep wells	A,R	60 m^3:groundlevel 10 m^3: elevated	Approx. 6 km 2 in. to 3 in. PVC
Meerzorg (D&D) 6,000	2 deep wells	A, R,M.	16 m^3:groundlevel 9 secondancy of 8 m^3 each with handpump	Approx. 9 km of 2 in.PVC
Wonoredjo (D&D) 2,000	Bulk purchase from Suralco	Total surface water treatment	300 m^3:groundlevel 12 m^3: elevated	Approx. 14 km km of 2 in. PVC
Albina (S.W.C.) 2,000	2 shallow wells	A,R	100 m^3: groundlevel 10 m^3:elevated	Approx.4 km of 4 in. and 2 in. PVC
Nw.Nickerie (S.W.C) 8,000	2 deep wells	A,R,S	300 m^3:groundlevel 40 m^3:elevated	Approx. 16 km of 6 in. a.c. pipe and 2 in. PVC pipe
Coronie (D&D) 3,000	1 deep well	A,R	70 m^3: groundlevel 8 m^3: elevated	Approx. 20 km of 4 in. a.c. and PVC and 2 in. PVC
Groningen Sidodadie (D&D) 3,000	2 deep wells	A,R	100 m^3: groundlevel 10 m^3: elevated	Approx. 12 km of 4 in. and 2 in. PVC
Brownsweg (D&D) 3,000	Surface creek	C	Four tanks of 180 m^3 combined capacity	5 km of 2 in. galvanised iron pipes
Klaaskreek (D&D) 4,000	1 deep well	C	Reservoir on a hill, capacity 30 m^3	2,5 km of 2 in. PVC.

Supply Population Served	Source	Treatment	Storage	Distribution
Brokopondo (D&D) 1,000	1 deep well	A, R	Two 3 m^3 pressure tanks and clear well of 70 m^3 capacity	2 km of 2 in. PVC
Kampong Baroe (D&D) 2,000	1 deep well	A, R	20 m^3 groundlevel 10 m^3 elevated	Approx. 11 km of 4 in., 3 in. and 2 in. PVC

Key : A = Aeration
R= Rapid Sand Filtration
S = Shell filtration
M = Manganese filtration
C = Chlorination

S.W.C. = Surinam Water Company

D&D = Ministry of Rural Government & Decentralization

PART III - WATER SUPPLY

(Section 2 - Bases for Design)

III.2.1. GENERAL

Population studies conducted in the project area emphasize the predominantly residential character of the population zones. Because of this, the domestic water demands serve as the primary basis for estimating individual water supply requirements. Since there is no substantial requirement for government and commercial establishments and industries, the allowance for these is calculated as a percentage of domestic allowances.

III.2.2. DOMESTIC REQUIREMENTS

It is noted that the Paramaribo metropolitan water supply system continues to be operated and maintained by the Surinam Water Company and is regarded as a separate entity. As such it is not included in this report, except to provide data which will contribute to the whole picture of water supply in Surinam.

Average per capita requirements of water for small urban or rural communities are usually derived from studies of records of existing supplies and also the population served. The increase in per capita consumption is then projected in order to determine future design allowances.

In Surinam the usage quantities vary widely for the small systems which have been established for several years. For example, the average per capita usage for the Klaaskreek system is 10 l/c/d, while the average for Nieuw Nickerie is 204 l/c/d. Conditions other than normal usage tend to cause these extreme values to develop.

In view of the above and also because water consumption data in Surinam tend to be limited in scope and availability, the average per capita usage was estimated on the basis of judgement, conditioning the judgement in accordance with experience gained in other developing countries.

Consumers were divided into three categories as follows:

Category I : Occupants of dwellings supplied a single Fordilla valve, but without metered service. (These valves are self-closing and will deliver only a certain given quantity of water for each opening of the valve).

Category II: Occupants of dwellings supplied by a single tap in the dwelling and with metered service.

Category III: Occupants of dwellings which contain a variety of plumbing fixtures and have metered service.

It is noted that no special consideration is given to public stand pipe usage. While this type of service exists to a degree in the country, the government is seeking to discontinue this approach, providing instead the Fordilla valve service as the minimum acceptable. The Executing Agency concurs in this procedure, deeming it desirable to provide individual services wherever possible.

III.2.2.1. Category I - Consumers

This group of consumers is common to all small urban and rural supply systems in Surinam. A study of the ratio of consumer types in these systems showed that approximately 35% of the house services fit in this category.

Estimates for domestic per capita usages for the several years covered by this project are as follows:

Commissioning year - 1972	30 l/c/d
15-year design year - 1987	40 l/c/d
Ultimate Plan Year - 2001	50 l/c/d

III.2.2.2. Category II - Consumers

Similar to the Category I group, these consumers constitute approximately 35% of the total number of house services in the existing water supply systems.

Estimates for domestic per capita usage are given as follows:

Commissioning Year - 1972	50 l/c/d
15-Year Design Year - 1987	70 l/c/d
Ultimate Plan Year - 2001	90 l/c/d

III.2.2.3. Category III - Consumers

This group of consumers occupy dwellings which constitute approximately 30% of the total number of house services in the water supply systems.

Estimates for domestic per capita consumption are as follows:

Commissioning year - 1972	70 l/c/d
15-Year Design Year - 1987	90 l/c/d
Ultimate Plan Year - 2001	110 l/c/d

III.2.3. CONSUMPTION ANALYSIS

Obviously, not all the systems to be built in Surinam will be commissioned during 1972. This datum was established for the initial feasibility studies; and, by utilizing the above cyles as a standard, comparisons among all system designs can be made.

In addition to the estimates of the per capita usages for the above categories, further consideration was given with respect to the probable changes within the categories which would obtain subsequent to the experience gained by users. In other words, it was anticipated that the progression from Fordilla valve service to single-tap service to "plumbed-house" service would take place. It was also assumed that, in the average water supply system, the number of connections would increase. With regard to the types of service, it was assumed that during the first 15-year period the number of "plumbed" houses would increase from 35% to 40% - a trend which is similar to that in Paramaribo. Thus, the remaining 60% would be fairly evenly divided among the two types of singletap service. This situation would then be assumed to hold relatively constant until the Ultimate plan year.

Further it was estimated that the percentage of dwellings connected during the first year of operation of the water supply systems would be approximately 25%. This percentage would then be assumed to increase over the first 15-year period until 90% of the dwellings would be connected. Again, the percentage of houses connected was assumed to remain constant until the year 2001.

Per capita consumption including all uses and losses projected through the design cycles were developed as follows:

Year	Domestic per Capita Consumption	Industrial, Commercial & Institutional		Unaccounted for water 25% of total 1/c/d	Average per capita consumption 1/c/d
		% of Domestic	1/c/d		
1972	49	10	5	13	67
1987	67	20	13	20	100
2001	86	25	22	27	135

As shown above, the value for industrial, commercial, and institutional uses were estimated on the basis of probable growth in these sectors rather than actual anticipated growth. Since no official development has been accepted by government as yet the"industrial estate" concept cannot be applied, nor is there enforcement of strict zoning ordinances. Thus the above values represent estimates only.

TABLE III-2 - AVERAGE DAILY DOMESTIC WATER DEMANDS BY POPULATION

	Estimated Population 1987	Estimated Population 2001	Estimated Daily water consumption 1987 (m^3)	Estimated Daily water consumption 2001 (m^3)
Group I				
A. SWC present and potential areas of supply	[illegible].500	770.000		
Kwatta Leiding	2[illegible].800	[illegible]	2.580	5.580
Koewarasan	6.000	10.300	600	1.400
Uitkijk & Jarikaba	10.500	17.800	1.050	2.400
Houttuin	7.100	12.400	710	1.670
Domburg	12.500	21.500	1.250	2.900
Meerzorg	12.500	21.500	1.250	2.900
Jagtlust	2.950	5.100	295	590
Nw. Amsterdam & Voorburg	3.800	6.550	380	870
Mariënburg	6.000	10.400	600	1.400
Alkmaar	9.750	16.800	975	2.300
Spieringshoek	1.410	2.450	141	350
Tamanredjo	2.950	5.100	295	870
B. Suriname River Industrial Area				
Paranam	3.800	6.550	380	690
Billiton	1.520	2.650	152	360
Smalkalden	2.160	3.750	216	375
Group II				
A. Saramacca Distr.				
Groningen & Tambaredjo	10.800	18.800	1.080	2.550
Calcutta & Tijgerkreek	7.050	12.200	705	1.645
Hildesheim	2.160	3.750	216	515
Kampong Baroe	4.330	7.500	433	1.015
B. Coronie Distr.				
Totness	4.860	8.400	486	1.135
C. Nickerie Distr.				
SWC Area of Supply				
Wageningen	5.200	9.000	520	1.220
Groot & Klein Henar	6.300	10.900	630	1.470
Paradise	15.190	26.300	1.519	3.550
Corantijn Polder	15.190	26.300	1.519	3.550
D. Brokopondo Distr.				
Brokopondo	1.620	2.800	162	377
Klaaskreek & Lombo	7.000	12.200	700	1.645
Brownsweg	3.800	6.550	380	882
E. Commewijne Distr.				
Marowijne Distr.				
SWC Area of Supply	755	1.350		
Alliance, Killenstein, l'Esperance	1.730	3.000	173	405
Moengo	10.800	18.800	1.080	2.550
Albina	4.860	8.400	486	1.135

It is noted in connection with the above table that the population estimates are subject to change in the actual design phase for some of the above communities. This is because the communities tend to overlap in some cases or, in other cases, the inter-lying populated areas are included in given water supply systems.

III.2.4. DESIGN CRITERIA

III.2.4.1. Population growth

As previously mentioned, the average growth in population is assumed at approximately 4% per year since actual trends or concentrations cannot be accurately prophesied. All projects are based on this population increase with an interim design population reached after 15 years. Local industrial expansion is included as a percentage in this interim design figure.

III.2.4.2. Rate of water usage

Average daily use = 100 l/person, including drinking, cooking, laundering, toilet flushing and bathing. Peak daily use = 250 l/person. Number of persons per house is estimated at 6 persons.

III.2.4.3. Water usage for specific purposes : (peak flows)

Movie theaters

Average capacity 1,000 persons, with 3 performances on Saturdays, each lasting 2 hours. All other days

daily : 3.0 m^3
hourly: 0.5 m^3

Restaurants

Average capacity 35 tables, 4 persons on 1 table. Used the most on Saturdays from 12.00 noon till Sunday morning 1.00 O'clock. Also included are kitchen and cleaning use of the water.

daily : 6.5 m^3
hourly: 0.65 m^3

Local shops

Average 100 persons passing through every hour at peaktime. Also included are cleaning use of water. Peaktime lasts 4 hours/day.

daily : 1.0 m^3
hourly: 0.2 m^3

Schools

Flow based on : 12 grade schools and 4 preschool classes. Also included are gardening and cleaning of use of the water.

daily : 6.0 m^3
hourly: 0.8 m^3

Service stations

Also included are car washing facilities. Station will be open for 16 hours/day.

daily : 21.0 m^3
hourly: 1.3 m^3

Swimming pool

Volume 900 m^3. Cleaning of pool every 4 weeks. Included are evaporation and water losses. Gradual change of water volume is 10 days.

daily : 900 m^3 (every 4 weeks in 24 hours time)
hourly: 37.5 m^3 (every 4 weeks in 24 hours time)
daily : 90 m^3 (average during 4 weeks)
hourly: 3.75 m^3 (average during 4 weeks)

Government office

In use for local administration tasks. 40 Employees working 8 hours a day. Also includes water used for cleaning and gardening. No waiting room for visitors.

daily : 2 m^3
hourly: 3 m^3

Recreation building

Capacity 200 persons on Saturdays, and building is used for a 6 hour time period. Also includes water used for kitchen facilities, cleaning and gardening.

daily : 10.0 m^3
hourly: 1.6 m^3

Medical building (Polikliniek)
Capacity 50 visitors per day and 5 persons professional staff. Building open for 8 hours a day. Also includes water for cleaning.

daily : 1.5 m^3
hourly: 0.2 m^3

Churches
Will be calculated on a surface area basis. Average flow per hectare = 500 l/day.

Shops for Maintenance Equipment
Flows based on a shop which serves a 1,000 persons area, consisting of people with an agricultural type of income. Included are wash racks and water use for after work cleaning. Shop will be open for 8 hours/day.

daily : 7 m^3
hourly: 0.9 m^3

III.2.4.4. Distribution System

All systems are designed utilizing the Hazen-Williams formula :

$$Q = 0.0103\ C\ H^{0.54}\ D^{2.63}$$

Q = rate of flows, cfs.

C = friction coefficient

H = head loss per 1.000 ft. of pipe

D = diameter of pipe, ft.

For cast iron pipe, C = 120

For plastic pipe, C = 130

For A.C. pipe, C = 130

Depending on the availability of pipe, plastic or asbestos cement pipe is used with sizes up to 6" in plastic pipe, from 6" and up asbestos-cement pipe.

III.2.4.5. Pressures in Distribution systems

All systems are evaluated with the Hardy-Cross method in order to establish pressures at the junction points. Since most homes and buildings in rural areas do not exceed two storeys in height, a minimum residual pressure of 20 psi is maintained in the designs.

III.2.4.6. Fire Protection

In most rural areas, no fire protection is being considered, mainly because the dwellings are widely spaced and hydrants for fire protection cannot be economically justified. Most of the dwellings are located along irrigation canals with water readily available at all times in case of a fire. But if fire protection is justified in built-up areas, minimum pressures will be maintained at 20 psi at the fire hydrants. Assumptions are made that these areas can be served by fire pumping engines and that a local fire station centrally located serves the community.

		fire flow
For built up rural areas with a population of	1,000 P	= 250 gpm
" " " " " " " "	1,000 P	= 500 "
" " " " " " " "	2,500 P/ 4,000 P	= 1000 "

III.2.4.7. Rate of flow in the distribution system

A. No fire protection

The systems will be designed for peak flows, arrived at by adding the present population and depending on the area, the estimated future population. To this total are added all the miscellaneous flows, such as Industrial, Commercial and Institutional.

B. With ~~no~~ fire protection

The systems are designed for service demand and fire flow (at one point on the system). This fire flow point delivering the full fire flow is established at the most distant point from the source of supply. Pressure at this point = 20 psi minimum (residual pressure).

III.2.4.8. Storage

A. With no fire protection

A ground storage tank containing 50% of the total average daily flows is designed at the supply point. In addition to this reservoir, elevated storage with a volume necessary to provide working pressures in the distribution system, is also included in the individual designs.

B. With fire protection

Total storage capacity depends upon the fire flow rate but is sufficient to fight a fire for $1\frac{1}{2}$ hours + 50% of the total average daily flow. An elevated tank is included with a capacity of $\frac{1}{2}$ hour fire flow plus the capacity needed to maintain suitable working pressures in the system.

III.2.4.9. Pumping stations

Stations are small and designed for the average daily flow. Pumps are considered as operating on 9- or 10 hour shifts, since automation of the pumping station is kept to a minimum. The design includes space for a small office, storage space, transformer house and living space for the caretaker (only if the size of the station warrants his full time presence). Electric power is used as the main supply of power. Standby power for the larger stations is considered in the form of diesel engines.

III.2.4.10. Pipeline Corrosion and Incrustation

Since the pipe to be used will be plastic, asbestos cement or cast-iron, corrosion or incrustation will not constitute a problem.

During the early stages of the project samples of plastic pipe were taken from a 6-year old water supply system in order to examine these for deposition, incrustation, or deformation, while there appeared to be a very small amount of iron deposited, no serious problems could be attributed to any of the above sources of difficulty.

III.2.5. Design Periods

(a) Land Requirements.

The present situation in Surinam covering land ownership is such that, except in densely populated areas, most of the land is under central government control. Therefore, the procurement of land for major elements in the water supply systems should pose no problem even if these needs are projected over a 40-year period. It is assumed, however, that the procurement will proceed within a reasonable length of time, thus precluding the occurence of later problems.

(b) Major Production Elements.

The design period for buildings is estimated at 40 years, as are the concrete structures, such as filters, storage, etc. The mechanical equipment design period is 15 years. Elevated storage design period is estimated at 25 years.

(c) Distribution Elements.

Since the pipe sizes are relatively small the design period is estimated at 40 years. Also, the difference in construction costs between short-term and long-term design periods tends to be moderate because of the small sizes involved.

Shorter design periods than the above can be justified on economic grounds for equipment or lines, for example, in those areas in which replacements or extensions do not cause severe dislocation of service or public inconvenience. Actual calculations on the basis of present worth can be performed, but the interest rates for capital development are not officially available at the time of writing this report.

PART III - WATER SUPPLY

(Section 3 - Water Quality Requirements)

III.3.1. GENERAL

This section deals with the development of the future water demands of the project area principally as affected by the water quality requirements for drinking water supplies. Water demands, as used herein, refer to diversion requirements and not to consumptive use, or in other words, the established water demands represent the amounts of water which have to be derived from either groundwater or surface sources.

The water quality standards presented represent the minimum requirements for bacteriological, chemical, and physical characteristics of water for domestic use. These standards will be helpful in assessing the suitability of the various sources of water supply.

III.3.2. QUANTITY REQUIREMENTS

The total water requirement of the project areas is that quantity which must be available to meet the estimated future domestic and industrial water demands. Detailed discussions of the determination of the basic domestic and industrial requirements were presented in Section III-2.

III.3.3. QUALITY REQUIREMENTS

Standards relating to the quality of public water supply systems are set forth in the World Health Organization. International Drinking Water Standards, 1963 edition. These standards prescribe minimum requirements for the bacteriological and chemical characteristics of dr nking water supplies. The WHO International Drinking Water Standards are considered to be within the reach of all countries throughout the world at the present time. The WHO European standards for drinking water (1970) were also reviewed for possible application to the Surinam water supplies, but it was decided to consider these as a "next step" in development.

It should be noted here that the quality requirements discussed herein are those which, unless stated otherwise, must be maintained within the distribution system or in other words reflect water qualities at the point of use. These standards therefore serve as a very useful tool in assessing the relative suitability of various sources of supply.

Water quality standards are considered in the three following categories : physical standards, bacteriological standards, and chemical standards.

III.3.4. PHYSICAL CHARACTERISTICS

In the WHO International Drinking Water standards it is stipulated that turbidity of the water reaching the consumer shall not exceed 25 units, that the color shall not exceed 50 units, and that objectionable taste or odor should not be present. These requirements, because they have no direct bearing on public health, may not need to be rigidly enforced. Turbidity and color limits and freedom from taste and odor should be based on reasonable judgement and discretion, giving due consideration to all the local factors involved. Acceptance of drinking water with a relatively high color level is common to several areas in Surinam.

III.3.5. BACTERIOLOGICAL CHARACTERISTICS

Methods used to evaluate the bacterial quality of public water supply usually involve techniques which are designed to demonstrate the probable presence or absence of pathogenic or disease producing organisms. Of primary significance are those organisms which are known to be waterborne and possibly may be transmitted through the medium of public water supplies.

Actual laboratory procedures are not designed to identify specific pathogens because the isolation and identification of such organisms involves tedious and time consuming techniques which are impractical for routine purposes.

Instead, procedures presently used involve the relatively simple examination for the presence of organisms of the coliform or intestinal group which are found invariably in the presence of waterborne pathogens. Identification of coliform organisms on a group basis, while relatively simple, is not entirely satisfactory. This is because positive results are produced not only by non-pathogenic forms but by certain other forms which originate in soil and therefore have no association with the intestinal tracts of man or of warm blooded animals. Standards of bacterial quality, as established by the WHO International Drinking Water Standards, require that the arithmetic mean coliform density should not exceed one organism in 100 ml of water. (This is essentially equivalent to the Public Health Service Drinking Water Standards of the U.S. Government).

The limit of bacterial loading carried by a water prior to its treatment for public use is also defined in the WHO standards. The WHO Standards categorize raw waters into four groups, all based on degree of bacterial contamination, as follows:

Classification	MPN/100 ml coliform bacteria
I. Bacterial quality applicable to disinfection treatment only	0-50
II. Bacterial quality requiring conventional methods of treatment (coagulation, filtration, disinfection)	50-5000
III. Heavy pollution requiring extensive types of treatment	5000-50,000
IV. Very heavy pollution, unacceptable unless special treatments designed for such water are used ; source to be used only when unavoidable	greater than 50,000

In addition to the above data certain recommendations have been developed by the U.S. Public Health Service and are given in a "Manual of Recommended Water Sanitation Practice" prepared by that agency. In considering the subject of treatment requirements, the manual classes waters in four groups, all based on a degree of treatment required, as follows :

(a) Group I : Waters requiring no treatment. This group is limited to underground waters not subject to any possibility of contamination and meeting, in all respects, the requirements of the U.S. Public Health Service drinking water standards as shown by satisfactory, regular, and frequent sanitary inspections and laboratory tests.

(b) Group II : Waters requiring simple chlorination or its equivalent. This group includes both underground and surface waters subject to a low degree of contamination and meeting the requirements of the U.S. Public Health Service drinking water standards in all respects except coliform bacterial content, which should average not more than 50 organisms per 100 ml in any month.

(c) Group III : Waters requiring complete rapid sand filtration treatment or its equivalent together with continuous post-chlorination. This group includes all waters requiring filtration treatment for turbidity and color removal : waters of high or variable chlorine demand; and water polluted by sewage to such an extent as to be inadmissible to Group I and II, but containing a number of coliform bacteria averaging not more than 5,000 organisms per 100 ml in any one month and exceeding this number in not more than 20 percent of the samples examined in any one month.

(d) Group IV : Waters requiring auxiliary treatment in addition to complete filtration treatment and post-chlorination. This group includes waters meeting the requirements of Group III with respect to the limiting monthly average coliform numbers, but showing numbers of coliform bacteria exceeding 5,000 organisms per 100 ml in more than 20 percent of the samples examined during any one month and not exceeding 20,000 organisms per 100 ml in more than five percent of the samples examined during any one month.
It should be noted here that the term "Auxiliary treatment" as used in the above discussion is presedimentation or prechlorination, or their equivalents, either separately or combined, as may be necessary. Long-time ponding or

storage, for periods of 30 days or more, represents a permanent and reliable safeguard in many cases, and would provide something more than an effective substitute for one or both of the other methods indicated.

III.3.6. CHEMICAL CHARACTERISTICS

Domestic Use : The limits for chemical elements or compounds in water are divided into mandatory requirements for certain substances and recommended criteria for others. The mandatory or or maximum allowable limits are shown in the first part of Table III-3. The non-mandatory but recommended limits for less critical substances are also shown in Table III-3.

Industrial Use : The chemical characteristics presented in Table III-3 represent quality requirements for the use of water by human beings for drinking and other domestic purposes. Domestic water use is conceded generally to be the primary and the most essential use of water. Specific characteristics and quality requirements for industrial use water are not included in this report since the industrial usage has not been clearly established except in the Paramaribo area.

TABLE III-3

WORLD HEALTH ORGANIZATION STANDARDS FOR CHEMICALS CONSTITUENTS IN DRINKING WATER

Substance	Mandatory limits	Maximum Allowable Concentration (ppm)
Lead		0.05
Arsenic		0.05
Selenium		0.01
Chromium (Cr hexavalent)		0.05
Cyanide		0.2
Cadmium		0.01
Barium		1.0

Non-mandatory Limits

Substance	Max. acceptable concentration	Max. allowable concentration
Total solids	500 m /1	1500 mg/1
Colour	5 units ')	50 units ')
Turbidity	5 units '')	25 units '')
Taste	unobjectionable	--
Odour	unobjectionable	--
Iron (Fe)	0.3 mg/1	1.0 mg/1
Manganese (Mn)	0.1 mg/1	0.5 mg/1
Copper (Cu)	1.0 mg/1	1.5 mg/1
Zinc (Zn)	5.0 mg/1	15 mg/1
Calcium (Ca)	75 mg/1	200 mg/1
Magnesium (Mg)	50 mg/1	150 mg/1
Sulfate (SO_4)	200 mg/1	400 mg/1
Chloride (Ci)	200 mg/1	600 mg/1
pH range	7.0-8.5	Less than 6.5 or greater than 9.2
Magnesium + sodium sulfate	500 mg/1	1000 mg/1
Phenolic substances (as phenol)	0.001 mg/1	0.002 mg/1
Carbon chloroform extract (CCE:organic pollutants)	0.2 mg/1	0.5 mg/1 ''')
Alkyl benzyl sulfonates (ABS:surfactants)	0.5 mg/1	1.0 mg/1

') Platinum-cobalt scale
'') Turbidity units
''') Concentrations greater than 0.2 mg/1 indicate the necessity for further analyses to determine the causative agent.

Industries are generally willing to accept for most processes water that meets drinking water standards. Where water of higher quality is needed, for example, for certain electronic equipment manufacture, food and beverage preparation, or for high-pressure boilers, industry must recognize that additional water treatment is the responsibility of the water user.

The WHO standards classify the chemical components of water resources into four groups : (1) those compounds affecting potability ; (2) those having definite effects upon health; (3) those components thay are definitely toxic and whose presence in greater than the limiting amounts would be sufficient grounds for rejecting the water as a source of public supply ; and (4) chemical indicators of pollution. The recommended standards for each of these groups are as follows :

(1) Compounds affecting the potability of water

Substance	Maximum allowable limit
Total dissolved solids	1500 mg/l
Iron	50 mg/l
Manganese (assuming that the ammonia content is less than 0.5 mg/l)...........	5 mg/l
Copper (a)	1.5 mg/l
Zinc (a)	1.5 mg/l
Magnesium plus sodium sulfate	1000 mg/l
Alkyl benzyl sulfonates (ABS): surfactants (b)	0.5 mg/l

(2) Components hazardous to health

Substance	Maximum allowable limit
Nitrate as NO_3.............................	45 mg/l
Fluoride	1.5 mg/l

(3) Toxic Substances

Substance	Maximum allowable limit
Phenolic substances	0.002 mg/l
Arsenic	0.5 mg/l
Cadmium	0.01 mg/l
Chromium	0.05 mg/l
Cyanide	0.2 mg/l
Lead	0.05 mg/l
Selenium	0.01 mg/l
Radionuclides (gross beta activity)	1000 μμg/l

(4) Chemical Indicators of Pollution

Indicator	Maximum limit of pollution
Chemical oxygen demand (COD)	10 mg/l
Biochemical oxygen demand (BOD)	6 mg/l
Total nitrogen exclusive of NO_3	1 mg/l
Ammonia (NH_3)	0.5 mg/l
Carbon chloroform extract (CCE) organic pollutants (c) ..	0.5 mg/l
Grease	1 mg/l

Notes :

(a) These are values for raw water quality and for that reason are lower than the allowable limits for drinking water where the presence of these metallic substances would probably be the result of the aggressive action of the water on service pipe metals.

(b) This value has been established on the basis of the maximum sensitivity of the presently accepted analytical procedures.

(c) Any amount greater than 0.2 indicates the necessity for further analytical determinations of the causative material.

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PART III - WATER SUPPLY

(Section 4 - Sources of Supply)

III.4.1. GENERAL

Concurrent with the determination of the magnitude of existing and anticipated demands for potable water, investigations were undertaken to locate suitable sources. A general discussion of the occurence of water follows:

Surinam receives an abundance of rainfall, most of which falls during the periods April to July and December to February. A large part of this precipitation is carried northward to the sea by the several rivers and their tributaries; the rest, except for losses by evaporation and transpiration, seeps into the earth and may serve to recharge ground water supplies. Unfortunately, surface supplies from streams, from a quality standpoint, are not always suitable for domestic consumption, unless needed conditioning is accomplished through suitable water treatment.

In most areas some rainwater is available from catchments, and this is a popular source of water during the wet seasons. However, catchment areas and collection tanks have only limited capacities and supplies are generally depleted well before the rains of the next wet season commence. Thus, during the hot, dry seasons when water is most urgently needed, rain water supplies become exhausted and acute problems develop and this requires emergency action by government officials, which involves the previously discussed transporting of water over great distances for distribution to the people. These situations show that rainwater catchment in the vast majority of cases cannot be depended on to supply reliable water service throughout the year.

Ground water supplies also present problems; this is true largely from a standpoint of chemical quality. Water from aquifers in the coastal plain, where the larger concentrations of population are found, frequently contains large amounts of chlorides. Further inland, water of lower chloride content may be found in many places but generally it has other objectionable properties due to the presence of iron salts and gases such as hydrogen sulfide and methane. This problem is usually more pronounced in water from the deeper strata. Simple treatment methods can be employed (essentially aeration, pH adjustment, rapid sand filtration and shell filtration)to effect removal of iron and objectionable gases, but a treatment plant with suitable equipment is required. The treatment process also tends to stabilize the water by reducing its tendency to be corrosive.

In 1956, SABTS initiated a project for demonstrating practical methods of installing low-yield, shallow, sanitary wells for supplying water for farms and small groups of families. On the basis of 230 wells installed, it was concluded that it is possible in many places in Surinam to develop sanitary wells, the water from which does not contain excessive amounts of iron. Also it had been observed that fresh water is generally found in the upper layers of the aquifers, indicating that low-yield wells might be developed in the same sections to supply water needs of small groups without having to resort to the installation of elaborate treatment facilities. The SABTS demonstration developed valuable information about the groundwater supplies, but considerably more exploratory work was needed in all of the Districts in order to gain a more comprehensive view of the possibilities for solving the basic problems.

III.4.2. RAINWATER

In its natural state, rainwater is almost completely void of chemicals and if collected on clean catchment surfaces may be relatively free of contamination. However, it is difficult from a practical standpoint to maintain good sanitary conditions in catchments and collecting tanks; also handling methods employed are apt to cause contamination of the water.

Holding of rainwater for long periods of time (without replenishing) especially during abnormally long dry seasons, requires extensive storage capacities making provision of adequate facilities impractical for most communities.

In Surinam, rainwater collection does not constitute a dependable method of water supply because rainy seasons do not always provide the total precipitation required. Precipitation information gathered over 30 years show that the west-central coastal area is rather dry, with more precipitation towards the east and the extreme west and in the higher interior. Comparison of the 30-year information with the 1961-1966 data shows that the latter are about 20% (400 - 500 m) lower than the figures from the preceding 30 years. It is not known if this dry period extended farther into the interior, but it seems reasonable to assume that the mean values for the 1961-1966 period are below normal (see Appendix III.1).

It would appear then, that 1965 was a very dry year throughout the whole country, particularly in the higher central areas. Considerably more rain fell in 1966, especially in the interior and also along the coast, but with a relatively dry belt across the country from Apoera to Brokopondo. In general, however, the 1966 figures are below the 30 years average.

In a precipitation study covering several Surinam and foreign areas conducted in connection with river and coastal transportation project, it was determined that the most extreme rainfall patterns occur at Georgetown and Cayenne, which have two and one distinct rainy seasons respectively. In Surinam the seasonal variations showed a transition between these two with a recurring rainy season during May and June, but with a variable intensity of the short rainy period in December and January. It was characteristic of the south-west part of the country that one long dry season lasting about eight months occurredannually. A similar, agriculturally disastrous, situation seems to occur in the coastal plain when, in approximate 10 year cycles, rains fail to materialize in the short dry season.

There is a paucity of evaporation data in Surinam. In the study referred to above, 6-year averages show variations

Between 3.6 and 5.5 mm per day, which is much less than the variations in precipitation. During the whole period of six years the monthly average varied between 3.0 and 6.4 mm per day.

Evapotranspiration from natural vegetation depends on the meteorological conditions and the nature of the vegetation. Little is known about Surinam conditions but in the above transportation study comparison with similar areas led to a rough estimate of 1,000 mm/a. The consumption of crops varies between 600 and 1,000 mm/a. The report estimates that in Venezuela the evaporation is between 1,250 and 1,450 mm/a in arid areas and between 600 and 1,000 mm/a in the valleys of the Andean range. The consumptive use of crops in California (U.S.A.) is shown in Table III-4.

TABLE III-4

Consumptive Use of Crops in California (U.S.A.)

Crop	Evaporation (soil) and Transpiration plant inch/p.month	Pts/sf/d'')	Growing Season months	Average Annual Transvap ') pts/sf/d
Alfalfa	5	0.83	6 or 7	0.35
Truck garden	4	0.66	5	0.275
Cotton	4	0.66	7	0.38
Citrus orchard	3	0.50	7	0.3
Citrus orchard	5	0.83	6	0.415

') Soil evaporation for 7 to 5 months outside of growing season not included.

'') Pints per square foot per day = pts/sf/d.

III.4.3. SURFACE WATER

Water from surface supplies (rivers, swamps, lakes, etc.) including those in the more remote, undeveloped sections of the country can be used for domestic consumption, but requires suitable treatment. High quality water (satisfactory both chemically and bacteriologically) can be produced in treatment plants at a relatively nominal cost, provided the system is of such magnitude as to justify the cost of installation.

The occurence of surface water in Surinam is principally in the many rivers which traverse the country. A considerable amount of hydrological and meteorological investigation has been done and is continuing. The Hydraulic Research Division of the Ministry of Public Works conducts a continuing program in the study of the quality and availability of river water in Surinam. Hydrological data reports covering the lower Corantijn river, the Nickerie river and the Lower Marowijne river have been published; and another report which concerns the lower Suriname river is ready for release.

Several investigations have attempted correlation of the river discharges and have also compared precipitation data with discharges in order to estimate flows in the main Surinam rivers.

One estimate of the mean flow at the river mouth is shown as follows :

River	Discharge m^3 per sec.	km^3 per annum	Run-off mm per annum
Corantijn	2,000	63	950
Nickerie	200	6,3	650
Coppename	470	15	810
Saramacca	240	7.5	735
Suriname	440	14	800
Commewijne	120	3,8	565
Marowijne	2,000	6	950

Variations in the discharges of Surinam rivers are caused by several factors. The hydrographs of the Corantijn and Coppename Rivers show strong variations in relation to the periods of heavy precipitation. The regimen of the lower Suriname River is completely governed by the operation of the hydro-electric power station in the dam near Afobakka, which started operating in October 1965 after a period of complete closure since the beginning of 1964.

The sediment discharges of the rivers are relatively small. This, together with strong tides, causes the estuaries to reflect considerable wear.

The tide along the Surinam coast is diurnal, and the mean tidal range is approximately two meters at the river mouths. Penetration of the tidal wave is deep, and during periods of low flow the tidal influence can in some cases be detected over 200 km inland from the river mouth.

A continual inter-action takes place between the more dense ocean water moving upstream along the estuary bottom, reinforced by the tidal currents, and the river discharge which tends to push the "salt-wedge" back into the ocean. River discharge, therefore, tends to control the movement of the salt-wedge. In the case of the Suriname river, for example, the so-called "acceptable" level of ~~chlorinity~~ chlorides of 100 mg/l extends to Torarica (km 105) during periods of minimal discharge.

Several proposals are being considered by Government which may have a decided effect on river discharges and their control. Principally, there are hydroelectric projects which would be associated with the bauxite exploitation and aluminum production.

The initial hydro-electric station, with a capacity of 120,000 KW was constructed at Afobakka, approximately 150 kilometers upstream from Paramaribo on the Suriname river. Completed in early 1964, the dam impounds a water storage covering an area of about 1600 square kilometers. Controlled discharge at Brokopondo provides a mean yearly flow of approximately 250 m^3/sec. A preliminary study and plans have been developed for another dam on the Suriname river. Located at Jodon Savanna, the "Torarica" dam hydro-electric plant would deliver 18 MW.

Plans have also been drawn to dam the Kabalebo river at Avanavero Falls and Kabalebo Falls, linking the Corantijn river at Frederik Willem IV Falls with the upper Kabalebo river.

Through the diversion of the Corantijn river, hydroelectric power of up to 870 MW could be developed in an average year. Additional diversion of the Corantijn into the Nanni river reservoir was also studied in order to provide irrigation water for the Wageningen rice polders at all times of need.

Another plan, for a dam at Stondansie on the Nickerie river, considered the need for better regulation of the lower Nickerie river for irrigation purposes.

The possibilities of developing hydroelectric power on the Lawa, Tapanahony and Marowijne rivers have been initially investigated with several potential dam-sites being considered. The Lawa and Marowijne rivers, of course, are also of interest to the French government.

A typical map, prepared by the Hydraulic Research Division of the Ministry of Public Works, showing the pertinent discharge measurement stations for the lower Suriname river, is included as Appendix III-2.

A topographical map with longitudial profile for the lower Suriname River is provided as Appendix III-3.

The list of hydrometric observation stations for Surinam is attached as Appendix III-4.

Investigation covering the quality of river waters particularly in the estuaries, was initiated in 1960 by the Bureau for Rural Development and responsibility for this operation was assumed by the Hydraulics Research Division in 1964. So-called "salt-trips" are part of this investigation, and 88 sampling tours were conducted from 1960 to 1970 in order to determine the surface chlori~~nities~~des at given points on the river.

Early consideration was given in the project to the possibility of utilizing surface water as a potential source for water supplies. This led to the development of the biological filtration test program for those areas in which there was a possibility of using surface water.

However, in a number of other cases it was decided that the surface water source was such as to present difficulties.

The most obvious source of large quantities of surface water is, of course, the Van Blommensteinmeer, the large man-made lake which supplies water to the hydroelectric facility at Afobakka dam. While it appears a not-too-difficult task to design a transmission line from this lake to serve the populated areas to the north (including Paramaribo) there are several impelling reasons why this had not been accomplished in the past. First, and most important, the Brokopondo Agreement between the government of Surinam and the aluminum company stipulates that all the water impounded behind the dam is under the control of the company and is not available for exploitation. Next, even should the water become available for community supplies, the present needs are being met closer to the populated coastal area, thereby precluding the need for a large present investment in treatment and transmission facilities. Finally, the level in the lake has not developed to the height considered sufficient for maximum power production, and any extraction for uses other than hydroelectric power generation would not be possible.

Also considered were the following: Suriname river, Para Creek, Surnau Creek, Saramacca River, and Orleana Creek. All were studied in the context of providing raw water for the lower Surinam basin area projects. Although each showed promise, the frequency of contamination occurrences through high chloride levels in each of these surface water sources caused them to be rejected. A six-month's chemical sampling program was conducted, however. In the case of the Suriname river and the Saramacca river it is possible to install intakes, but the distances from the coastal area become lengthy. For the Commewijne service area project, the Surinam river with an intake near Groot-Chatillon was studied and is reported in greater detail in a later section.

III.4.4. GROUNDWATER

General and specific aspects of groundwater as supply are considered in detail in Part II of this report. It is noted that, in connection with groundwater, the possibility of using windmills was considered. However, this method was not pursued since the winds are generally weak in Surinam (Beaufort 1.2°) and usually are less than the 8 km per hour required 60% of the time which is considered minimum for practical operation of the windmill pumping system.

III.4.5. WATER QUALITY

Although the number of samples submitted for testing to the Central Laboratory of the Public Health Department has been substantial, the number of reports received and the results as reported have been somewhat short of what had been anticipated. However, Tables III-5, through III-8 shows typical physical chemical and bacteriological quality of raw surface water for various sources. Table III-9 shows similar characteristics of filtered water.

TABLE III-3

FILTERED SURFACE WATER

SOURCE: PROF. DR. IR. W.J. V. BLOMMENSTEIN LAKE

CHEMICAL ANALYSIS

SUBSTANCE OR PROPERTY	DRY SEASON 1970			RAINNY SEASON 1970	DRY SEASON 1970
AMMONIA NH_3	neg	neg	neg		neg
IRON Fe	2.1	1.4	1.1		0.9
MANGANES Mn	neg	neg	neg		neg
RESIDUE	90	45	95		160
CHLORIDE Cl	6	8	13		19
NITRITE NO_2	pos	neg	neg		neg
NITRATE NO_3	pos	neg	neg		neg
SULFATE SO_4	neg	neg	T.		T.
pH	6.0	7.3	7.1		6.5
COLOUR	CL.	CL.	CL.		CL.
BIC. HARDNESS	0.8°	0.4°	0.6°		0.6°
TOT. HARDNESS	0.8°	0.8°	0.6°		0.6°
$KMnO_4$	30	27	45		25
H_2S.	neg				

Bacteriological Examination

PLATE COUNTS	> 30				
MOST PROBABLE NUMBER	0				
EICHMANN	neg				

1) * Note: All samples were light yellow.
No color scale was used.
CL.= Clear, CD.= Cloudy, TU= Turbid

TABLE III-4

SURFACE WATER

SOURCE: PARARIVER AT HIGH WAY

CHEMICAL ANALYSIS

SUBSTANCE OR PROPERTY	DRY SEASON 1970			RAINNY SEASON 1970					DRY SEASON 1970			
NH_3 AMMONIA	neg.	neg.	neg	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	
IRON Fe	3.8	2.4	3.5	2.4	3.7	1.2	2.0	1.7	2.7	2.	1.4	
MANGANESE Mn	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	
RESIDUE	400	374	231	104	121	127	676	51	57	23	330	
CHLORIDE CL.	117	104	40	21	16	42	49	35	27	11	151	
NITRITE NO_2	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	
NITRATE NO_3	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	
SULFATE SO_4	32	41	16	T.	T.	T.	T.	T.	T.	T.	29	
pH	6.1	5.7	5.9	5.8	7.0	6.3	7.0	5.9	6.1	6.0	6.7	
COLOR	CL.	CL.		TU.	CL.	CL.	TU.	CL.	CL.	CL.	CL.	
BIC. HARDNESS D.H.	0.5°	0.5°	0.7°	0.7°	0.9°	1.0	0.7°	0.6°	0.5°	0.6°	0.6°	
TOT. HARDNESS D.H.	3.6°	3.6°	1.6°	1.0°	1.0°	1.4°	1.1°	0.6°	1.1°	0.7°	3.7°	
$KMnO_4$ DEMAND	25	50	94	67	83	85	65	46		50	34	
H_2S.	neg.						neg.					
BACTERIOLOGICAL EXAMINATION												
PLATE COUNTS	>300	>300	>300	900	190	900						
MOST PROBABLE/SINGLE NUMBER		0	0	40.000	1000	100						
EICHMANN/TEST	pos.	0	0	pos.	pos.	pos.						

1) * Note: All samples were light yellow.
[illegible] was used.
CL.= Clear, CD.= Cloudy, TU.= Turbid.

TABLE III - 5

SURFACE WATER

SOURCE - SARAMACCA DOORSTEEK

CHEMICAL ANALYSIS

SUBSTANCE OR PROPERTY	DRY SEASON 1970			RAINNY SEASON 1970				DRY SEASON 1970	
NH_3 AMMONIA	neg.	neg.	neg.	pos.	neg.	neg.	neg.	neg.	neg.
IRON Fe.	5.9	0.5	3.2	1.3	5.9	4.0	4.4	1.8	4.2
MANGANESE Mn.	neg,	neg.	neg.	neg.	neg.	neg.	neg.	neg.	0.08
RESIDUE	510	732	340	362	549	609	167	142	223
CHLORIDE CL.	92	55	30	55	31	T.	22	35	65
NITRITE NO_2	neg.	neg.	neg.	Str.pos	neg.	neg.	neg.	neg.	neg.
NITRATE NO_3	neg.	neg.	neg.	Str.pos.	neg.	neg.	neg.	neg.	neg.
SULFATE SO_4	29	92	5	19	neg.	T.	T.	T.	23
pH.	7.1	7.4	7.6	6.8	7.5	6.7	6.8	6.8	8.1
COLOUR	CL.	TU.	TU.	TU.	---	TU.	---	---	---
BIC. HARDNESS D.H.	2.3°	3.1°	2.9°	6.8°	2.9°	3.1°	0.3°	2.5°	3.6°
TOT. HARDNESS D.H.	5.3°	6.1°	3.0°	6.8°	3.7°	4.0°	0.9°	2.8°	3.9°
$KMn\ O_4$ DEMAND	39	55	55	59	59	59	47	39	40
H_2S.	neg.				neg.	neg.	neg.		

BACTERIOLOGICAL EXAMINATION

NIL

1) * Note: All samples were light yellow
No color scale was used.
CL.= Clear, CD.= Cloudy, TU.= Turbid.

TABLE III - 6

SURFACE WATER

SOURCE: PARA DOORSTEEK
CHEMICAL ANALYSIS

SUBSTANCE OR PROPERTY	DRY SEASON 1970			RANNY SEASON 1970					DRY SEASON 1970			
AMMONIA NH_3	neg.	pos.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.
IRON Fe.	1.2	1.6	1.1	2.4	2.3	1.3	1.1	1.4	1.3	1.0	0.45	2.1
MANGANESE Mn.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.
RESIDUE	60	120	152	215	82		85			55	67	71
CHLORIDE CL.	4	2	13	7	7	14	19	16	20	21	18	18
NITRITE NO_2	pos.	neg.	neg.	neg.	pos.	neg.	neg.	neg.	neg.	neg.	neg.	neg.
NITRATE NO_3	pos.	pos.	neg.	neg.	pos.	neg.	neg.	neg.	neg.	neg.	neg.	neg.
SULFATE SO_4	neg.	neg.	10	TU.	TU.	neg.	TU.	TU.	TU.	TU.	neg.	neg.
pH.	3.6	6.4	5.0	4.5	7.3	4.3	6.2	5.9	5.6	6.2	6.4	6.4
COLOR	CL.	CL.	TU.	TU.	CL.	CL.	TU.	CL.	CL	CL.	CL.	CL.
BIC. HARDNESS D.H.	0.5°	1.0°	0.7°	0.4°	1.0°	0.5°	0.1°	0.3°	0.3°	1.0°	0.3°	
TOT. HARDNESS D.H.	3.6°	1.0°	0.7°	0.6°	1.1°	0.5°	0.4°	0.6°	0.3°	1.0°	0.3°	
KMn O4 DEMAND	25	31	60	85	80	92	78	37	78	42	79	
H2S.	neg.						neg.	neg.				

BACTERIOLOGICAL EXAMINATION

PLATE COUNTS	71	4	> 300	> 330	30	210						
MOST PROBABLE SINGLE NUMBER		0	0	5.000	8.000	100						
EICHMANN/TEST	pos.	0	0	pos.	pos.	pos.						

1) * Note: All samples were light yellow.
No color scale was used.
CL.= Clear, CD.= Cloudy, TU.= Turbid.

TABLE III - 7

SURFACE WATER

SOURCE: TOUT LUI FAUT KANAAL

CHEMICAL ANALYSIS

SUBSTANCE OR PROPERTY	DRY SEASON 1970			RAINNY SEASON 1970					DRY SEASON 1970				
AMMONIA NH_3	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.			
IRON Fe.	2.0	1.8	5.3	3.2	7.1	4.0	3.3	3.0	1.5	1.6			
MANGANESE Mn.	neg.	neg.	0.4	neg.	neg.	neg.	neg.	neg.	neg.	neg.			
RESIDUE	140	188	139	281	417	301	361	69	309	96			
CHLORIDE CL.	21	22	15	13	16	22	43	14	11	27			
NITRITE NO_2	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.			
NITRATE NO_3	pos.	pos.	neg.	neg.	neg.	neg.	neg.	[illegible]	neg.	neg.			
SULFATE SO_4	neg.	neg.	6	TU.	TU.	TU.	TU.	TU.	TU.	7			
pH.	7.4	7.4	6.8	5.9	3.3	6.3	8.0	6.3	6.3	7.4			
COLOUR	CL.	CL.	TU.	TU.	TU.	TU.	TU.						
BIC. HARDNESS D.H.	2.5°	3.1°	1.1°	0.9°	0.9°	0.8°	3.0°	0.9°	0.9°	1.5°			
TOT. HARDNESS D.H.	2.6°	3.1°	1.1°	0.9°	1.0°	0.3°	4.0°	0.9°	0.9°	1.6°			
KMn 04 DEMAND	24	26	60	72	83	75	59	28	31	30			
H2 S.	neg.						neg.						
BACTERIOLOGICAL EXAMINATOR													
PLATE COUNTS	>300	200	300	600	730								
MOST PROBABLE SINGLE NUMBER	0	0	0	10000	35000								
EICHMANN/TEST	pos.	0	0	pos.	pos.								

1) * Note: All samples were light yellow.
No color scale was used.
CL.= Clear, CD.= Cloudy, TU.= Turbid.

PART III - WATER SUPPLY

(Section 5 : Water Treatment)

III.5.1. NEED FOR TREATMENT

Standards for water quality for public water supplies were discussed in section III-3, Water Requirements, and the quality of available water was discussed in Section III-4, Sources of Supply. This chapter concerns the need for treatment of existing raw water in order to provide an end product which is hygienically safe, aesthetically attractive and palatable.

The selection and development of raw water sources for small water supplies, levels of necessary treatment are of prime importance.

In the consideration of levels of treatment to be provided is defined in the World Health Organization Monograph series no. 42, "Water Supply for Rural Areas and Small Communities", as follows:

"Source and Treatment"

First-priority consideration

Water which requires no treatment to meet bacteriological, physical, and chemical requirements ¹) and which can be delivered to the consumer by a gravity system should be given first consideration. This would usually be limited to springs and protected drainage areas. Such as a system requires no treatment and no pumping, and, therefore, is ideal from the point of view of maintenance, which is thus reduced to an absolute minimum.

Second-priority consideration

Water which requires no treatment to meet bacteriological, physical, and chemical requirements but which must be pumped to consumers would be the second choice. Well supplies fall within this category.

¹) These requirements depend on water quality standards applied by each country, and will vary from one place to another.

Pumping can be an economical and simple solution, but it can also be an expensive and complicated one, according to local circumstances. It depends on the availability of qualified operators and on the local cost of fuel. Such factors vary widely from country to country and even from one rural area to another of a given country; they vary also with the types and efficiency of operation and maintenance programmes developed for providing aid to municipalities from centrally located headquarters.

<u>Third-priority consideration</u> [*)]

Water which requires simple treatment before it can meet bacteriological, physical, or chemical requirements but which can be delivered to the consumer through a gravity system should be given third-priority consideration. Simple treatment is considered to be limited to : (1) storage which would provide plain sedimentation and some reduction in bacteria, (2) chlorination without the use of a mechanically operated chlorinator, (3) slow sand filtration; or a combination of these.

For rural areas this is normally an inferior solution. It is usually more expensive than the above solutions and involves operational procedures which are most difficult to maintain in small rural communities. In such places, when the chlorine stock runs out, chlorination is abandoned in almost every instance; and, when the slow sand filters become clogged, a by-pass is often considered an easy arrangement. Such is the history of treatment measures in most rural areas where routine technical assistance is not provided by a responsible agency.

<u>Fourth-priority Consideration</u>

Water which requires simple treatment, as mentioned above, and which must be delivered to the consumers by pumping would obviously be the most expensive choice to make."

*) Depending on local circumstances, this could be a second priority.

Because of the limitations imposed by topography, salinity, population concentrations and the like, the water supplies in the more populated areas of Surinam generally fall into the fourth priority consideration as defined above. Since this is the most expensive choice to make, it behooves the designer to exercise imagination and ingenuity in effecting as many economies as possible in the design of treatment and distribution facilities in order to keep the water supplies within the financial reach of as many communities as possible.

III.5.2. TREATMENT OF GROUNDWATER

The groundwater sources supplying existing systems in Surinam as well as the potential planned systems is of such physical and chemical quality as to require only a relatively simple method of treatment. Bacteriological pollution of groundwater has also not constitued a major problem as yet.

Principally, the need for treatment, therefore, is limited to aeration, rapid sand filtration and shell filtration.

In order to meet the relatively high standard for potable water in Surinam the groundwater treatment is related to iron, carbon dioxide, sulphates, manganese, and methane, which are found in sufficient quantities to merit special treatment. Iron is removed by revising the originally acidic condition of the water. Because carbon dioxide is mainly responsible for causing the acidic condition, the aeration is actually applied to adjust this condition.

At the same time as the water is being de-gassified, other objectionable gases such as H_2S and methane are removed, and pH correction is effected.

Aeration as a method of iron oxidation and degassification is considered useful when applied to typical Surinam groundwater because of the following:

1) Simplicity

The mechanics of aeration is simple, although the process itself is multivarious. It does not involve chemicals which have to be imported, nor is special feeding equipment required.

2) Composition

Because Surinam groundwater has a relatively constant composition and does not contain inhibiting compounds, iron removal by other means would be difficult and require chemicals. The dissolved iron present in the raw water is unstable. Water which is clear when drawn will turn cloudy and precipitate when the sample is exposed to air for a period of time.

3) Standardization

This method is already familiar to treatment plant personnel and has been succesfully applied in this country for years. This would justify continuing this type of application for practical purposes.

4) Maintenance

The well-designed aeration system will operate relatively trouble-free for long periods without the need of highly-trained, skilled maintenance workers.

5) Corrosion Control

While providing atmospheric oxygen for the oxidation of iron and liberating the gases, the aeration process serves to present corrosion.

Shell filtration is used (in addition to aeration) in Surinam as a final step in the groundwater treatment process for several reasons. Shell is readily available in the country in large amounts and needs only washing to prepare it for use. As a treatment medium it promotes stabilization and effects final reduction of the CO_2 as well as contributing to pH correction.

Therefore, when treatment by aeration and filtration alone tends to be inadequate, a shell filter is included as an additional means of producing high quality drinking water.

Shell filtration has the following specific advantages :

- adjusts the pH up to a maximum of 7.8
- limits the CO_2 contents to approximately 2.0 mg/liter

III.5.3. TREATMENT OF SURFACE WATER

III.5.3.1. River Supplies

Treatment of surface water in Surinam can be traced to 1926 in which the Surinaamsche Bauxite Maatschappij began treating Cottica river water at Moengo through chlorination and filtration. Excessive chlorination in the final product led to the discontinuance of the treatment plant operation.

A new plant was constructed in 1937 but this, too, was discontinued after adequate groundwater supplies were developed. However, with the average daily demand reaching approximately 100,000 gallons/day by 1954, the need existed again for treatment of river water.

Subsequently a treatment plant was built which incorporated the following steps:

1. Screening at intake
2. Addition of chemical flocculent
3. Mixing
4. Flocculation
5. Sedimentation
6. Rapid sand filtration
7. pH adjustment
8. Chlorination

This plant is still in operation.

In 1958 the water treatment plant for the leprosarium at Groot Chatillon was placed in operation, by the Public Health Division of S.A.B.T.S. Serious problems in water transport to the leprosarium by barge had been encountered during dry seasons and these problems were alleviated by construction of the new plant. The Ministry of Health still operates this small 30 to 40 m^3/day plant utilizing alum, pre-chlorination and rapid sand filtration for treatment of Surinam river water. Pressure is developed through use of a hydrophor.

In both of the above treatment plants the relatively high color and organics level in the raw water does not seem to pose a problem.

On only one occasion was the chloride level in the Suriname river of a sufficiently high level and for a sufficiently long period to be troublesome in the operation of the Groot Chatillon plant.

With the above observations in mind, it was decided to investigate the possibility of subjecting surface water to slow sand ~~or~~ (biological) filtration. The decision was based on the need to develop a system of water treatment which would satisfy the following conditions:

1. Economy of construction and operation.
2. Requiring little skilled labor for design, construction, operation and maintenance.
3. Strong, simple construction.
4. Acceptability of final product.

The advantages and disadvantages of slow-sand filters are listed in "Operation and Control of Water Treatment Process" by Charles R. ~~Rex~~ Cox, W.H.O. Monograph Series No. 49, as follows:

"<u>Slow Sand Filters</u>

The advantages of slow sand filters may be summarized as follows:

1. There is no need for coagulation facilities.
2. Equipment is simple and need not be imported.

3. Suitable sand is readily secured.
4. Supervision is simple.
5. The effluent is less corrosive and more uniform in quality than chemically treated waters.
6. They give effective bacterial removal.

The disadvantages as compared to rapid sand filters are as follows:

1. A large area is required, with correspondingly large structure and volume of sand and higher structural costs.
2. They have less flexibility in operation.
3. They are not economical with raw waters having turbidities over about 30 units for prolonged periods, unless preliminary plain sedimentation will secure such turbidities in the settled water.
4. They are less effective in removing colour.
5. They give poor results with water of high algal content, unless pretreatment is practised."

In view of the above disadvantages it was decided to construct small, portable test filters which could be installed in several locations in Surinam in which the surface water exhibited different characteristics. Appendix III-5 shows the main features of the test filters. The vertical height of the test filter was determined in such a manner as to approximate the height of an actual slow sand filter. Short-circuiting was countered by painting the inner surfaces of the test filter with Inertol, and dusting the wet paint with sand in order to roughen the surface.

Tests were conducted at the following locations:

Brownsweg (Van Blommenstein Meer)
Saramacca Canal (Uitkijk)
Saramacca Canal (Saramacca Doorsteek)
Groot Chatillon (Surinam River)
Blaka Watra (Surinam River)

In all cases in which test runs were initiated the length of run was continued over at least a 10-day period in order to allow building-up of the "Schmutzdecke" or biological layer.

A number of variables were introduced into the test program including selecting filter sand from several different locations. This allowed variation of grain sizes and uniformity co-efficients. A graph showing typical sieve analyses is included as Appendix IV-6. Also included was a test incorporating the use of charcoal as part of the filter media. For one series of tests, a mixed-media in which fractured sea shells were present was utilized. For another series, activated charcoal was used in the filter media.

Because time and available manpower were not available for an exhaustive and definitive test program, the program could not be extended over a long period of time, nor could an exact evaluation of all variables be made.

However, the following positive basic results were obtained by varying the media:

1. Definite reduction in color level.
2. Effective filtration of turbid waters.
3. Satisfactory pH adjustment.
4. Reduction in iron level
5. Reduction of bacteriological counts.

Although it was not deemed necessary in the process, except as a precautionary measure if the filters are to be used in public water supplies, the subsequent chlorination of some of the samples of filtered water in which minimal color was still evident resulted in "bleaching" of the color after a 15-minute retention period.

Reviewing the disadvantages of slow sand filters which were listed earlier, the large areas of land required are readily available in Surinam, flexibility of operation would not be required since the raw water varies little in quality over long periods of time, the turbidity and color of the raw water does not seem to pose a problem, and the raw water does not possess a high algal content.

In view of the encouraging results as demonstrated above, a slow-sand filtration plant is being installed as part of the Brownsweg water supply. This will be discussed in further detail later in this report.

The incorporation of slow-sand filtration into major water supply systems in Surinam will depend upon the continuing availability of groundwater. Since it appears that supplying groundwater to communities such as Kwatta-Leidingen and Pad van Wanica West probably constitutes a "mining" operation, the need for utilizing surface water sources will probably occur in the distant future, but certainly not within the "Ultimate Phase" projections.

III.5.3.2. Swamp Supplies

The possibility of developing reservoirs of surface water in swampy areas was also given primary consideration particularly in areas such as Commewijne where suitable groundwater seemed to be virtually non-existent, but this possibility was rejected for several reasons.

There has been some experience gained in impounding this water in connection with the Mariënburg supply, and it was found that aquatic weed growth and algal growth presented serious problems.

In order to store sufficient quantities of water to provide a continuous supply over the dry seasons, it would be necessary to construct large reservoirs. For example, to serve 10,000 persons at an average daily demand of 100 l/c/d for a 3-month dry season would require a reservoir containing 90,000 m^3 disregarding evaporation. At a depth of 2 meters, a net area of 45,000 sq. meters would be required. Construction of an impervious reservoir of this size would be costly and the capital cost would also necessarily reflect pumping costs, since gravity flow would be impossible.

Additional treatment beyond the oxidation realized in storage would also be needed because the swamp water tends to contain considerable organic matter and other pollutants.

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PART III - WATER SUPPLY

(Section 6 - Interim Supplies)

III.6.1. STATUS OF EXISTING WATER SUPPLIES

During late 1969 when the UNDP (SF) project was initiated in Surinam the following status existed with regard to community water supply systems in the country :

Existing Operational Systems

1. Paramaribo, Albina, and Nieuw Nickerie (SWC)
2. Koewarasan
3. Meerzorg
4. Groningen
5. Brokopondo
6. Klaaskreek
7. Brownsweg
8. Alliance
9. Totness
10. Kampong Baroe

Systems Under Expansion

1. Paramaribo S.W.C.
2. Wonoredjo
3. Groningen

Systems Under Planning

1. Brokopondo (power augmentation)
2. Coronie (elevated storage)
3. Koewarasan (expansion)
4. Meerzorg (expansion)
5. Klaaskreek (expansion)

It was anticipated that, in addition to the above, the Supply Group I Systems would commence to be constructed as the final designs and financing would become available.

In connection with the original Project Activity Plan it was estimated that the final designs for all Supply Group I Systems would be prepared and that this would constitute a practical feasible target for fulfillment as a major part of the Interim Supplies. It is becoming apparent that this was an optimistic forecast, however. With the problems connected with fielding international staff in several categories sufficiently early in the project life and with similar problems induced by limitation of availability of counterpart staff and with the further complication of equipment shortages due to inordinate time requirement for deliveries, it appears that the actual design-population which can be considered within the above restraints in the UNDP (SF) project in the final design phase of the Supply Group I systems will probably be between 50,000 and 75,000 instead of the greater than 100,000 originally anticipated.

This situation could change, subject to immediate solution of staffing problems ; but these solutions appear remote at this writing.

A further specific limitation is based on the need of a total picture of the groundwater availability in the Commewijne area. At the present time groundwater investigations, although promising, are still in progress.

III.6.2. PRESENT STATUS OF SUPPLY GROUP I SYSTEMS

The original listing of communities in the Request and Plan of Operation delineated population groups according to existing built-up areas. Based on field experience, a regrouping has been effected according to the following :

Supply System	Interim 1987 Design Population
Kwatta-Leidingen	25,000
Pad van Wanica West	25,000
Commewijne	50,000
Domburg-Smalkalden	13,500

The design populations shown above indicate that, for Supply Group I areas, the systems will be relatively small;

but, more important, the systems can be designed on the basis of populations in multiples of 25,000 persons (excepting Domburg-Smalkalden, which will be a special case). This, in turn, provides the opportunity to design the community water supply systems on the basis of basic standard design elements. In major urban water supplies, of course, this approach is not possible since each element of a large system presents unique and individual problems. This standardized approach also emphasizes the serious responsibility facing the designer, who cannot sacrifice good engineering judgement for the sake of standardization. Because the Interim Program will consist essentially of a number of similar systems, it follows that many design features will be repeated several times. In the selection of these design features, therefore, the designer must carefully select and compare in order to develop, a design which accomplishes the planned objective at the least cost.

In the Supply Group I systems, the standardization is basically connected with the treatment plant elements, because the individual distribution systems tend to differ from each other.

Referring to the Supply Group I areas, the original Grouping in Appendix I of the Plan of Operation listed (in addition to Kwatta-Leidingen) Marienburg, Tamanredjo, Nieuw Amsterdam and Voorburg, Spieringshoek, Jagtlust, Alkmaar and Meerzorg. These latter have all been incorporated into the Commewijne Supply Group. Houttuin is not being considered, since the area is very scarcely populated and shows little reason for further accelerated expansion. Uitkijk and Jarikaba are considered with the Kwatta-Leidingen Project. Koewarasan is an existing supply undergoing augmentation at present which will provide for the next 15 years of growth. Paranam and Onverdacht are "company towns" of the aluminum industries in Surinam; and, although the project staff has worked closely with the water utility and geology staff in the companies, it was made known that the water supply needs of these communities will be met by the aluminum companies themselves.

In the case of Pad van Wanica West, this represents a new population group which was somehow not included in the original Request or Plan of Operation and is a relatively large geographical area of medium population concentration. The communities of Domburg and Smalkalden are considered as a single project, since this project will be developed for potential UNICEF assistance.

III.6.3. PROPOSED SYSTEMS

III.6.3.1. Kwatta-Leidingen System

III.6.3.1.1. General

Selections of the overall area to be included in the Kwatta-Leidingen area was based on a general survey of the area which included a review of present development together with existing population concentration and also potential possibilities. Further, it was decided to limit the eastern extent of the system in accordance with probable expansion of the facilities of the Surinam Water Company. This was discussed with and agreed to by the Surinam Water Company.

Early consideration was given to the possibility of staging construction of various aspects of the project. The staging would also include the sizing of the various elements of the plant. Since the plant is more or less unique in the water supply picture in the country, the availability of comparisons with other plants does not exist. For that reason, the approach taken in sizing the elements of the water supply project was based on judgement rather than on precedent. Staging will be limited to the pumping and filtration installations.

The distribution system has been designed to handle a peak flow of 2.5 times the average daily flow required for the 1987 design year. While it would have been possible to reduce the sizes of some of the distribution lines in the project area, it is not known at this time what the exact progression of development will be in the project area, particularly with the possibility of including Jarikaba and Uitkijk. The existing development is concentrated along presently established roads, and it does not appear that additional roads will be constructed as major thoroughfares during the period between the commissioning year and the 15-year design year. No provision is included in present designs for this kind of expansion to the distribution system, but individual subdivisions could be served within the existing capacity of the system.

The location of the water supply project and the layout of the distribution system are shown on the drawing included as Appendix III-7.

Pumping requirements are such that the average daily demand required during the 1987 design year can be achieved during a 16 hour pumping day. It is assumed that the hours of pumping will be reduced to fit the actual needs during the intervening years. In addition, pump sizes are decreased in order to meet low initial demands with subsequent replacement of the smaller pumps at a later date.

The plant as presently conceived has a built-in unit flexibility which will allow for substantial increases in population served. However, should it be necessary to provide service for the Ultimate Year (year 2001) population of 50,000 persons, which is more than double the interim design period population, this can be achieved through the use of booster pumping, added clearwater and elevated storage and an increase in the filtration capacity through additional unit construction. The site is such that additional units can be constructed with few problems.

The sizes selected for the units are based on the conclusion that for small treatment elements the cost per cubic meter would be extremely high for minimal amounts of water treated. Further, the Kwatta-Leidingen project has been selected as a prototype for use in other similar water supply systems in the country. Potentially, a similar installation could be incorporated in service areas such as Pad van Wanica West and Commewijne. This, of course, is subject to further study based on availability of groundwater, determination of priorities, etc. Standardization of treatment methods and operations provides flexibility and promotes efficiency since operating personnel can be easily transferred from one plant to another and interchangeability of equipment allows reduced inventories of spares.

The selection of the location of the treatment plant in the approximate center of the service area was based on the principle of averaging the distances between the plant and the extremities of the distribution system. Expansion within the service areas would therefore be simplified.

At the time of preparing this study, it has not clearly been established what the ultimate potential of the groundwater supply is in the plant area. Indications are such that the needs could be met for even major expansions but this has not been specifically determined.

Should the need arise for conversion of the plant to surface water treatment, as a result of limitation in groundwater supply, it would be possible to do so. This change could be effected by converting the clear water storage to slow sand (biological) filtration units and utilizing the sand filter and aeration unit for storage. Additional storage can easily be constructed at the plant site.

III.6.3.1.2. Design Bases

The following assumptions were made :

Treatment based on chemical analysis of samples of raw ground water taken at the plant site, would include aeration, rapid sand filtration, and pH adjustment.

Criteria for water supply treatment are the World Health Organization "International Standards for Drinking Water", second edition, 1963.

Initial population (1970) : 12,000 persons.

15-year design population (1987) : 25,000 persons (includes approx. 2500 persons for possible Jarikaba extension).

Initial Average Flow (at 100 l/c/d) = 1,200,000 l/d = 220 gpm

15-year design
Initial Average Flow (at 100 l/c/d) = 2,500,000 l/d = 460 gpm.

Peak flow factor : = 2.5 x Average flow.

Initial Peak Flow: 2.5 x 1.2 million = 3 million l/day = 1150 gpm.

Analysis of the distribution system for pipe size determination was made on the basis of the Hardy Cross method of successive approximations. In no case was a line smaller than 3 in. diameter used.

Calculations of friction losses to the most distant points in the system resulted in an approximate maximum friction loss of 100 ft. or 43.5 psi.

Minimum pressure at the most distant point was initially assumed at 20 psi. Thus, the required pressure at the point of supply was approximated at 63.5 psi or 146 ft. On the basis of a 16/ft tank height and a 125 ft tower, a supply pressure of approximately 141 ft or 61.4 psi is available. This will allow for minimum pressure of between 10 and 20 psi depending upon drawdown in the elevated storage tank.

For clear water ground level storage a capacity of 50% of the total average daily flow for the design year was used. In the case of the elevated storage a value of 5,5% (which is consistent with present practice in the country) was used. Thus:

ground level storage = 50% x 2,500 m^3 = 1250 m^3
elevated storage = 5,5% x 2,500 m^3 = 138 m^3

For the elevated storage a 40,000 gallon tank is recommended.

Rapid sand filter designs was based on the following :

loading rate = 2 gpm/sq.ft.
backwash rate= 15 gpm/sq.ft.

For an assumed 18 hour pumping day with an average demand of 460 gpm (for a 24 hour day) a filter area of 30 m^2 was recommended.

For the aeration unit, a pressure of 7.0 psi at the nozzles was assumed. Using 24 nozzles the flow was 24 gpm/nozzle with a head loss of 1.20 ft through each nozzle or a pressure differential of 4.65 psi between the first and last nozzles.

Turbine pumps were used for pumping from clear water storage to the elevated storage. For the initial phase, two 200 gpm constant speed pumps were proposed, with two 575 gpm pumps to be used during the second phase. Horse power requirements were 15 Hp and 35 Hp respectively, including standby.

For the well pump installation the initial recommendation is for a $7\frac{1}{2}$ Hp turbine pump, and for the 15-year design a 30 Hp turbine pump is used.

Water meters are to be installed as part of this project, and it is estimated that an initial need of 500 $\frac{1}{2}$ in - $\frac{3}{4}$ in. meters will exist. Actual meter installations are estimated to be somewhat less than this.

The schedule of pipe sizes and quantities for the distribution system is as follows :

3,300 m.	10-in asbestos cement-pipe
6,000 m.	8-in asbestos cement-pipe
7,300 m.	6-in P.V.C. pipe

12,300 m.	4-in P.V.C. pipe
44,500 m.	3-in P.V.C. pipe
72 m.	8-in C.I.P.
154 m.	6-in C.I.P.
90 m.	4-in C.I.P.

The reliability of the groundwater source which is to be used for the Kwatta-Leidingen system was established as a part of the groundwater investigation program in the UNDP (SF) project. In connection with the groundwater investigation for Kwatta-Leidingen the observations are made in Part II of this report.

The degree of treatment required to produce an adequate potable drinking water is anticipated to be similar to that required for other groundwater supply systems in the area. The basic treatment includes: aeration, for iron removal; sand filtration; and pH adjustment and carbon dioxide reduction through the use of shell filters. Should it be possible to avoid the use of shell filters by utilizing mixed media or other innovations, the excess area would be used for clear water storage. In addition to this use of a method of filtration with which the water supply system staff in Surinam is readily familiar, it was decided that the retention of the uncomplicated method was justified since the equipment and structure used are not complicated or overly-sophisticated.

As an alternate, the possibility of using a surface water supply, the Saramacca River with an intake at Uitkijk, was considered and investigated. The chemical analysis of river water samples indicated that the characteristics of the raw water were such that a slow sand or biological filter could be used, particularly since the turbidity of the raw water was less than the limiting value of 10 mg/l (measured as SiO_2). A program of testing utilizing two small test filters was intiated and, although operational difficulties were encountered in the test program, the results were encouraging. However, the use of the surface water was decided against in view of the remote possibility of excessively high chloride content in the raw water during protracted dry seasons. This is discussed in greater detail in the "Preliminary Studies and Plans" paragraph of this report.

III.6.3.1.3. Construction Standards

Generally the standards of quality of construction for the project will be similar to those already in effect in the country, since extremely divergent applications would not be justified. In the case of concrete construction, for example, it is understood that the actual strengths achieved in concrete produced in Surinam tend to be somewhat less than those of other countries. This is reflected in the structural designs of the filter plant units.

The unavailability of European standards for piping, fittings and pumps for design purposes has created the necessity for establishing the U.S. standards for these elements of the project. A complete set of prototype specifications has been prepared for this project. However, it is clearly stipulated that the equipment and materials specified according to the U.S. standards could be substituted with acceptable European material. The designs are such that any minor differences in dimensions can be compensated for with few problems.

III.6.3.1.4. Preliminary Studies and Plan

During the initial development stages at the Kwatta-Leidingen project two alternatives were considered in connection with the raw water supply.

The possibility of bulk supply from the proposed Surinam Water Company installations at Landsboerderij was investigated. This alternative possessed the attractive aspect of eliminating the need for construction of a treatment plant facility. However, it was determined that the total productive capacity of the Landsboerderij station would be approximately 750 gpm or 0.047 m^3/sec. The average daily demand for the Kwatta-Leidingen project is based on a figure of 570 gpm or 0.036 m^3/sec. Since the provision of this amount of water is prohibitive for the Landsboerderij station and, since the station would not be expanded in the forseeable future, this alternative was not pursued.

The second alternative investigated was based on use of the Saramacca River and a slow sand (biological) filter treatment plant. A test filter was installed at the sluice gate on the Saramacca canal at the Saramacca river and a testing program was initiated. Although a number of operational difficulties were encountered, it became evident that the raw surface water could be satisfactorily treated. At the same time, hydrological and hydraulic data was being collected for the river. The data showed that, when the flow in the river reduced to less than 4.0 m^3/sec., the chloride concentration rose to approximately 400 mg/l. This had occurred twice during the period 1962 - 1968 and continued for a two-month period. Because of the possibility of a recurrence of this condition, it was decided to eliminate the river as a raw water supply source. Were groundwater unavailable the use of the river would be mandatory, but this would necessitate construction of sufficient storage volume to tide over the period of excessive salinity - an expensive prospect.

With regard to the distribution systems, two alternatives were investigated ; and these concerned the Jarikaba and also the Uitkijk areas. These were studied from the point of view of providing ground water as well as using the Saramacca River as a source. If the surface water were to be used, it would be necessary to install a total of three elevated storage tanks : oneeach at Uitkijk, Jarikaba and at the center of the L...ingen area. Treatment would be accomplished through a biological filtration plant at the Saramcca river at Uitkijk. If groundwater were utilized as the raw water source, the supply to Jarikaba would not present a problem with regard to demand or pressure. However, if Uitkijk were to be included with the Kwatta-Leidingen project, it would be necessary to provide booster pumping from some intermediate point between Uitkijk and the Kwatta-Leidingen treatment plant.

III.6.3.1.5. Construction, Labor, Materials and Equipment

The availability of skilled and unskilled labor in the country is such that the construction of the project could proceed without too much difficulty. A number of projects of considerable size and complexity have been completed in Surinam in which local labor took an active part. In connection with the bauxite industry particularly, local labor was used extensively in the construction of plant facilities, roads and bridges, dams and water installations. Also, the operation of heavy duty construction equipment was initiated and developed to a great degree. The Surinam Water Company had built several systems in which local labor had a large part. The "trainability" of local labor is entirely possible and has been demonstrated many times.

Generally speaking, the technical and supervisory personnel available in the country are already committed to existing organizations. Private and government sector organizations compete for the services on this level of employees; and, therefore the number of technical, supervisory and professional personnel is limited. However, the staff that is available seems to be competent and capable of handling the responsibilities of this kind of project.

Cement, aggregates, water for concrete, and lumber are readily obtainable in the country and are in stock. Items such as reinforcing steel, structural steel, hardware, pumps, motors, electrical wiring and switchgear, glass, paint and piping must be imported and sufficient lead time must be allowed for this importation.

Logistical items such as housing, food, fuel and lubricants, repair facilities and the like are not likely to pose any serious problems. Similarly, the construction site is such that construction pre-fabrication and storage facility space is not limited, thereby allowing maximum utilization of the construction forces.

Heavy duty construction equipment and specialized construction equipment is available from several contractors in the metropolitan areas. The maintenance and repair facilities for these are also present.

Subcontracting of some of the branches of the work such as electrical and mechanical could be possible since there are contractors of this type actively engaged in these fields at present. However, the individual subcontracts might prove to be somewhat expensive since the amount of this specialized work involved on the project is not very great.

III.6.3.1.5. Special Construction Problems Foreseen

Construction may be affected by the rainy seasons which normally occur twice during the year. The seasons and rainfall can be shown as follows :

Month	J	F	M	A	M	J	J	A	S	O	N	D	Year total
Season	Rainy		Short dry			Long Rainy			Long dry			Rainy	
Rainfall	193	150	162	232	321	303	226	167	86	87	109	174	2208 mm

Some delays due to seasonal rains might be anticipated; although the rains may be heavy but are of short duration, and the normal practice in construction during the rainy season seems to be to work in spite of the rain. Flooding at the project site will probably not occur, since the drainage system existing in the area is quite suitable. Temperatures tend to remain fairly constant with humidity contributing to personal discomfort more than will excessive temperature. However, it is expected that no serious construction delays would stem from existing precipitation, temperatures, or weather conditions and that the overall effect on the construction schedule, equipment use and labor forces will be minimal.

Generally the surface soil in the project area is sandy with some clay or shell mixture. Soil tests have been conducted and the necessary recommendations concerning structural requirements have been made. Results of the soils analyses and subsurface investigations for determination of quality foundations and method of foundation construction are attached as Appendix III-8.

The project site is free of large trees or vegetation and can be cleared without too much effort.

The problem of groundwater elevation may assume serious proportions but will not be of a critical nature. It is planned to excavate to an elevation of - 1.25 m.N.S.P. from the existing ground surface at the deepest point. The elevation of the ground water table reaches a maximum height of + 0.83 m. N.S.P. Thus, site de-watering will be required.

Rerouting of street traffic during construction of the distribution system will, in all probability, not be necessary. While there may be brief delays in traffic movement, these will be of short duration and will not require any special scheduling of these construction elements which will be contiguous to major roads. Two major roads will require special attention as far as buried cables, power poles, etc. are concerned.

Lead-time for scheduling deliveries of equipment and materials which are to be imported should be estimated as three to four months. This time element can, of course, be reduced depending upon where the orders will be placed and what commitments can be obtained from the suppliers.

There should be no difficulty in obtaining temporary service power from the electrical supply organization for use during construction. The electric company (OGEM) has been advised that this need should be anticipated and has accepted the responsibility for providing for the added load.

Because the property on which the treatment plant is to be located has already been identified as belonging to the central government, there should be no delays due to condemnation proceedings or similar actions necessary to secure title to the property. The well site is also located in the same plot and is, therefore, not subject to dispute.

A possible source of difficulty may be the existing bridge spanning the canal which fronts on the construction site. While the load-bearing capacity of this structure has been adequate for large trucks and also for the drilling rigs used in the exploration program, it could possibly be of insufficient strength to support excessive loading. A careful examination and inspection is recommended prior to construction start-up.

III.6.3.2. COMMEWIJNE SYSTEM

The proposed Commewijne project has not been developed beyond the "Preliminary Studies and Plan" phase, although a considerable amount of effort has been expended in this regard.

The general considerations for this project (design criteria, population growth, etc.) are the same as for the Kwatta-Leidingen project and, therefore, are not repeated here.

Basically different, however, is the type of service area and also the problem of availability of groundwater as a supply source.

The Commewijne service area (See Appendix III-9) is made up of a number of small scattered communities connected by long reaches of sparsely populated roads. The historical absence of potable ground water in sufficient quantities to provide water for any community(except Meerzorg, which represents an extremely limited supply) has tended to limit the expansion and growth of these communities. Following is a list of the communities and the estimated populations to be served in each :

Community	1970	1987
Mariënburg	4400	8800
Zoelen	5870	9800
Leliendal	580	1160
Katwijk	1915	3830
Wederzorg	310	620
Spieringshoek	250	500
Alkmaar	2320	4600
Tamanredjo	2580	5160
Meerzorg	7340	15,000
Peperpot	240	500
Lust en Rust	300	600
Belwaarde	240	480
Nieuw Amsterdam	2340	4700
Voorburg	875	1750
Total	29,560	57,500

Only Meerzorg has a piped supply, including a small treatment plant with pressure filtration and pressure storage serving a system of small storage structures from which the users must handpump water. The systems operates 12 hours per day.

As will be noted from a review of the system drawing (Appendix III-9) Commewijne supply system reflects the need for a large transmission main, and booster stations (at Meerzorg and Marienburg), in addition to the usual treatment plant and individual distribution systems.

The transmission system will represent the greatest cost element in this system and will depend upon the availability of ground water. The potential for supply is discussed in Part II of this report. At this stage of the study, it is assumed that sufficient groundwater will be available approximately 5 to 6 kilometers east of the proposed treatment plant. If this is not the case, a further move to the east must be made (probably 13 kilometers), incurring substantial costs for additional 20-inch transmission main.

Early in the project life it was decided to investigate the Suriname river as a potential source of supply for the Commewijne service area. It was proposed to install an intake in the vicinity of Groot Chatillon, at approximately 20 kilometers south of Tamanredjo. Raw water would be pumped to a treatment plant site at Tamanredjo through an overland transmission main. While this alternate might still be justified, assuming insufficient groundwater availability, the high costs (probably greater than Sf. 2 million) due to extremely difficult construction problems would seem to preclude its recommendation. Some of the construction problems include : a number of river and creek crossings, approximately 10 kilometers of swampy terrain which would necessitate building an all-weather access road and pile-driving for pipe supports, and probable booster pumping requirements. A large slow-sand filtration plant would also need to be constructed.

Another alternative which might merit further consideration is a river crossing from Leonsberg to Mariënburg in which bulk supplies of treated water (purchased from the Surinam Water Company) could be transported to the Commewijne area. Siting the crossing at this point in the river has the advantages of the river bottom at this location being below the lowest point planned for Surinam river basin dredging in the river transportation study and also the distance across the river is shorter here than any other location on the lower Surinam river. Project staff have been able to obtain only the cost of the crossing pipe from a United States manufacturer. The cost of installation has not been determined as yet, although three construction companies are to be queried for estimates when time permits. In addition, it is still not known whether the Surinam Water Company could, in fact, provide sufficient quantities of treated water to meet the Commewijne area demand which is estimated at an average flow of 1365 gpm and a peak flow of 2800 gpm at the Orleana Creek treatment plant.

Other alternates include several suggestions by government agencies. One is for a combination water barge and ferry to haul passengers, freight and water to Nieuw Amsterdam from Paramaribo. This would replace the present dry season barging of water from the outlet of the 4-inch SWC main at Leonsberg to holding tanks at Nieuw Amsterdam. Another is a proposed fresh water canal from a considerable distance south of the area in which irrigation and community water supplies could be provided. Project staff have not investigated either of these alternates.

Principal elements of the system include :

At Mariënburg : ground storage of 195,000 gallons
elevated storage of 21,500 gallons, height of 150 ft.
average flow of 270 gpm
Booster pump station

At Meerzorg : ground storage of 230,000 gallons
elevated storage of 25,000 gallons, height of 150 ft.
average flow of 320 gpm
booster pump station

At Orleans Creek: rapid sand filtration treatment plant
ground storage of 1,000,000 gallons
average flow of 1365 gpm
peak flow of 2800 gpm
elevated storage of approximately 200,000 gallons
pumping station

Principal Distribution System

20-inch	asbestos-cement	pipe	5,600	meters
18-inch	"	"	3,000	"
16-inch	"	"	12,600	"
14-inch	"	"	3,500	"
12-inch	"	"	11,500	"
10-inch	"	"	10,500	"
8-inch	"	"	4,000	"
6-inch	plastic	"	9,000	"

III.6.3.3. Pad van Wanica West System

The Pad van Wanica West system will be approximately the same in size and general characteristics as the Kwatta-Leidingen system. The design population of approximately 25,000 is also similar to that of the K-L system.

The system is bounded by the following :

- Pad van Wanica
- Nieuw Zorgweg
- Magentakanaal
- Libanonweg

At this stage of the study, only very preliminary estimates have been made for the system. The principal reason for this is that the priority attached to the Kwatta-Leidingen and to the Commewijne system are higher than that given to Pad van Wanica West. Further, project staff has not been available for full-time assignment to the tasks connected with the designs. Lastly, the availability of sufficient quantities of groundwater is still in doubt.

Part of the area included in the above system is already served by a standpipe supply which is operated by the SWC from its transmission line from Republiek to Paramaribo. This occurs along Pad van Wanica, the main north-south highway to Zanderij, but extends only several hundred meters west of the highway.

III.6.3.4. Other Systems under Study

The system for Brownsweg has already been given considerable attention even though it is in the Supply Group II areas. Critical problems in maintaining the existing (intermittent) water supply systems has placed the obligation on project personnel to operate out of planned sequence in order to assist in problem-solving. The existing plant includes : a small river intake and pumping station with chlorination facility, a 4-inch diameter galvanized-iron 7-kilometer long water main to storage tanks at Brownsweg, and a standpipe supply together with individual services to government and military installations.

It has been planned as part of this project to assist in the design and construction of a new treatment system which will serve a total of 3,000 persons. Based on moving the intake from the Macami Creek to the Van Blommenstein meer (thereby shortening the transmission main from 7-kilometers to less than 2 kilometers and reducing the critical maintenance problems involved) the system would thus be guaranteed a sufficient continuous supply. During protracted dry seasons with the existing system, the source fails and water must be transported by tr k and by rail to Brownsweg. Discussions with the aluminum company which controls the water in the lake have produced positive results in that the company has no objection to the extraction of water for this purpose, subject to a limit of 300 cubic meters per day.

Topographic surveying of the new treatment plant site adjoining the military reservation and site preparations have been completed and two 60 cubic meter tanks are being renovated for use as slow-sand filters. Foundations designs have been completed.

Present plans call for filtration and chlorination prior to gravity flow to existing storage. As mentioned previously in this report, the raw water can be treated through biological filtration and will produce an aesthetically more attractive product that has been available to the users in the past.

It is expected that this system will be constructed and in operation prior to the end of this UNDP(SF) project and will afford an excellent opportunity to gain experience in biological filtration under full-scale operating conditions.

Investigations have also been initiated into the following areas of existing supplies : Wageningen, Nieuw Nickerie areas, Koewarasan, Wonoredjo and Coronie.

Visits have been made to Supply Group III areas for preliminary planning and include : Stoelman Island, Kwakagron, and Palocmoe.

In connection with potential UNICEF financing of water supply systems, the following systems have been given consideration:

1. <u>Groot & Klein Henar</u>

Design population : 6,000 (1987)

Average Daily Demand : 480 cu.m.

Source : Ground water - 1 well, 100 m. depth (existing)

Treatment : Aeration, Sand and Shell Filtration (iron removal pH control)

Ground Storage (concrete) 200 cu. m. Elevated Storage (steel) 16 cu.m. el 72 ft.

Distribution System : 8 km. 4" pvc
7 km. 3" pvc

2. <u>Domburg & Smalkalden</u>

Design population : 13,500 (1987)

Average Daily Demand 1,080 cu.m.

Source : Groundwater - 2 wells (6") 100 m. depth (one existing)

Treatment : Aeration, Sand and Shell Filtration

Ground Storage (concrete) 300 cu.m. Elevated Storage (steel) 24 cu.m. el 72 ft.

Distribution System : 12 km 4" pvc
13 km 3" pvc

3. <u>Calcutta & Tijgerkreek</u>

Design population : 6,500 (1987)

Average Daily Demand : 520 cu.m.

Source : Groundwater - 2 wells (6") 180 m. depth (one existing)

Treatment : Aeration, Sand filtration

Storage tank (concrete) 200 cu.m. Elevated storage (steel) 16 cu.m. el 72 ft.

Distribution System : 15 km. 4" pvc
10 km. 3" pvc

4. Corantijn Polder

Design population : 14,000 (1987)

Average Daily Demand : 1,120 cu.m.

Source : Groundwater - 2 wells (6") 100 m. depth (one existing)

Treatment : Aeration, Sand filtration

Ground storage (concrete) 300 cu.m. Elevated storage (steel) 24 cu.m.

Distribution System : 8 km. 4" pvc
8 km. 3" pvc

5. Paradise

Design population 14,000 (1987)

Average Daily Demand : 1,120 cu.m.

Source : Groundwater - 2 wells (6") 100 m. depth (one existing)

Treatment : Aeration, Sand filtration

Ground Storage (concrete) 300 cu.m. Elevated Storage (steel) 24 cu.m.

Distribution System : 10 km. 4" pvc
5 km. 3" pvc

6. Kwakoegron

Design Population : 1,000 (1987)

Source : Surface water

Average Daily Demand : 80 cu.m.

Ground storage - 30 cu.m.

Treatment : Biological Sand filtration, chlorination

Distribution System : 4 km. 3" pvc

7. Van Drimmelend Polder

Design population : 6,000 (1987)

Average Daily Demand 480 cu.m.

Source : Groundwater - 1 well (6") 100 m. depth

Treatment : Aeration, Sand and Shell Filtration

Ground Storage (concrete) 200 cu.m. Elevated Storage (steel) 16 cu.m.

Distribution System : 8 km 4" pvc
7 km 3" pvc

The phasing of these projects, is largely based on the level of financing available and priorities assigned a d is as follows:

Water Supply Facilities	Estimated Year of Implementation				
	1973	1974	1975	1976	1977
1. Groot and Klein Henar	x				
2. Domburg & Smalkalden		x			
3. Calcutta & Tijgerkreek			x		
4. Corantijn Polder				x	
5. Paradise				x	
6. Kwakoegron	x				
7. Van Drimmeland					x

PART IV - SEWERAGE

(SECTION I - General Considerations)

IV.1.1 INTRODUCTION

In Part III of this report, the results of detailed investigations are presented in problems involving the provision of adequate potable water supplies. However, in order to maintain adequate standards of public health emphasis not only should be placed upon providing readily available suitable water supplies but also upon the removal of waste waters, largely in the form of domestic sewage and industrial wastes, from populated areas and ultimate disposal by sanitary means. While not included in this project, the removal of storm waters from populated areas is also an important requirement, especially under conditions prevailing throughout the Surinam coastal areas where drainage by natural means is difficult because of the flat terrain.

In pursuance of the over-riding objective of improving environmental sanitary conditions throughout the project area, preliminary investigations have been initiated into the existing situation with regard to sewerage. Basic data and design criteria for sewerage are being developed in the frame of reference of the population estimates and water supply proposals previously presented.

IV.1.2 EXISTING FACILITIES

Within the project area, with the exception of Paramaribo, there is no sanitary sewerage system in operation. The Paramaribo system, in itself, does not constitute a sanitary sewage collection and treatment facility in that the waste water collected is the effluent from septic tanks rather than raw sewage. A combined system, carrying this effluent as well as storm drainage, transports the wastewater to outfall pumping stations for disposal in the Surinam river. (See Annex IV-1). This system has grown with the growth of the city; and, because of this, reflects some hydraulie inadequacies.

As Paramaribo continues to expand, the existing combined sewers are sometimes limited in capacity and surcharging results. Further, some of the lines have a definite need for structural rehabilitation.

The use of open canals also creates a problem in that most are hydraulically inefficient and subject to rapid weed growth, and because of this (together with trash dumping in the canals) serious sanitation problems are created.

In connection with the Paramaribo system, the Ministry of Public Works retained a European consulting engineering firm to investigate the sewage and drainage problems in the city and to provide solutions. This effort is still being sponsored through assistance of the European Economic Community. As a result of this study, the consulting engineers observed the following:

(a) the central Paramaribo system was functioning adequately,

(b) the northern urban area contiguous to the city was in a state of flux and this seemed to preclude accurate appraisal of the problem, thereby affecting solutions,

(c) collection and treatment in the southern area should be such as to allow only treated effluent to be discharged into the Saramacca Canal,

(d) the western area development was such that further economic review was necessary prior to reaching any design conclusions or to making proposals,

(e) whenever possible, separate systems should be installed instead of combined sewers.

Also in connection with the above study the consulting engineers established the following "urgency" list which refers to the drawing attached as Appendix IV-1, and is translated as follows:

1. <u>Drambrandersgracht</u>

   Here a good working sewerage system could be realized with a small amount of work. A big investment is already made but seems to be very unproductive. Regular flooding problems are presently existing which can be eliminated by the construction of a lift-station.

2. Limesgracht

The mainline and the discharge in this drainage area have to be improved because it is in a very deplorable state.

3. Sommelsdijkse Kreek

Discharge to the Surinam River has to be improved on a short time basis. The Creek has to be constructed in accordance with the ultimate discharge criteria. Certain upstream portions have to be improved as soon as possible.

4. Overeemkanaal, Zonnebloemkanaal and Cottica (Flora) Canal

The improvement of these canals is urgent. The improvement of the water quality of these canals by treatment is necessary for hygienic reasons.

5. Calcutta Kanaal

A bad discharge resulting in poor hygienic conditions is presently exisitng. A well-designed sewer system has to be designed for this area.

6. Knuffelsgracht

Enclosing of the Picorni and Viotte Creeks is very much desired.

7. Steenbakkersgracht

Enclosing is desired.

8. In the remaining areas the urgency is less acute caused by the less population density

Above mentioned list of projects is given in the order of urgency degree. We would like to mention the following differences between the grades of urgency -

Point 1. certainly is the most urgent, points 2 through 5 are all very urgent, the remaining points are less urgent.

Future studies will indicate in accordance with which principles the improvement program has to be realized. At the same time a cost price calculation for all the construction projects will be estimated. "

In addition to the above study, the consulting engineers proposed a sanitary sewage treatment plant on the Flora Canal for which a preliminary design was provided to Government. This advanced secondary treatment plant was designed for an initial population of 10,000 persons with expansion to 30,000 suggested by the consultants Industrial waste treatment was not included in the plant capability. The design of the collection system is not available in Surinam, as far as could be determined at this writing.

Government is considering its own alternate design for the Flora Project at present. This design would utilize oxidation ditches with sludge disposal.

The P.A.M. report recommended that the urban areas contiguous to Paramaribo which were to be included in the detailed designs included in the UNDP (SF) project would be "only those sewerage systems that will be directly connected to the projected Paramaribo city system (now under investigation by the Government consulting engineers)." It appears that this assumption was optimistic since there are no plans or designs (in preliminary or final stages) for the Paramaribo municipal system nor will any be forthcoming during the life of the UNDP(SF) project. The unfortunate result of this situation is that the suburban systems will have to be designed independent of any potential connections to a larger urban system.

The only community system in Surinam which collects and treats domestic waste through a piped collection system and a secondary treatment (activated sludge) plant is the small "Via Bella" system which is operated in a small residential subdivision in Paramaribo by Suralco. This system handles the wastewater of approximately 50 houses.

At the Santo Boma prison, septic tank effluent is collected and ponded in a series of lagoons which provide approximately 90 days retention (See Appendix IV-2). After post-chlorination the effluent is disposed of in open drainage ditches. A total population of approximately 500 inmates and personnel is served by this system, which is unique in Surinam.

IV.1.3 PRESENT METHODS OF DOMESTIC WASTE DISPOSAL

As stated previously the sanitary sewage treatment in most of the populated areas is effected through the use of septic tanks and effluent collection. In those areas where no piped system exists, the septic tank effluent is discharged into seepage areas or into drainage ditches. During dry seasons, with no storm flows, the total discharge of some of these ditches is partially treated or untreated sewage.

Ditch systems are generally installed at flat grades and at only a slightly lower elevation than the surrounding terrain. Installation of culverts is not controlled as far as invert elevations are concerned. This, together with debris accumulation and encroachment, creates conditions in which sewage collects and stagnates, frequently becoming septic.

Conversely, during the rainy seasons, the resultant overflows which result from the lack of hydraulic capacity spread heavily-polluted water. This is further aggravated by tide-locking of the channels at certain periods.

Obviously the above conditions create severe health hazards and point up the need for immediate consideration of improvements to the sewer and storm drain systems in order to remove sewage and storm waters from the populated areas.

There is less urgency with regard to sewage treatment. The condition of the lower Surinam river is such that the disposal of untreated sewage into it in the immediate future should not create hazards to public health.

In the more rural areas and in some built-up areas, pit latrines are used almost exclusively, except when no facilities at all are provided. Occasionally a septic tank is installed particularly when a larger residence is constructed. In these cases, the installations also generally include seepage areas or drain fields.

Little regard is given to the sanitary requirements of the latrines. World Health Organization in the Monograph Series, No 39, "Excreta Disposal for Rural Areas and Small Communities" by Wagner and Lanoix, recommends construction of pit latrines in rural areas, but, only if they satisfy the following seven requirements:

1) The surface soil should not be contaminated.
2) There should be no contamination of ground water that may enter springs or wells.
3) There should be no contamination of surface water.
4) Excreta should not be accessible to flies or animals.
5) There should be no handling of fresh excreta; or, when this is indispensable, it should be kept to a strict minimum.
6) There should be freedom from odours or unsightly conditions.
7) The method used should be simple and inexpensive in construction and operation.

Cleaning of latrines is a necessity if the size is insufficient to develop decomposition of excreta. The Ministry of Health is understandably concerned over this practice, particularly as it requires workers to break up solid fecal material by hand followed by water-mixing and pumping.

In addition to the unsanitary and socially degrading practices connected with pumping latrines in the country, the depth of the pit and the high elevation of the groundwater table combine to cause contamination of the groundwater. Further, there is little control over the locations of the latrines, especially on small lots and the inevitable result is contamination of shallow wells.

IV.1.4 PRESENT METHODS OF INDUSTRIAL WASTE DISPOSAL

Methods of disposal of wastes generated by industries in the lower Surinam river basin were considered by a shortterm consultant. It had been planned to attach his investigation and conclusions to this report but this report has not been released for publication by PAHO/WHO at this writing.

IV.1.5 COMBINED AND SEPARATE SYSTEMS

In a country such as Surinam in which the existing major sewerage system is a combined system and in which much of the "system" consists of open ditches, advocating a separate system for sanitary sewage may not be simple.

As already stated, the Paramaribo system has been constructed on the combined principle. Although this is a fairly old system and may contain some design defects, these are not sufficient reasons to abandon or extensively modify the system. The system appears to have been well-constructed and functions effectively except in periods of heavy, protracted rainfall.

However, it cannot be justified to design combined sewers for new installations. In Surinam, the high rainfall intensities produce an unbalanced ratio of storm water quantities to sanitary sewage quantities. This large ratio induces the requirement for collection lines which have to operate under a wide range of flow conditions. In order to develop self-cleaning velocities under dry-weather flow, the conduits must be installed at steep grades; and this, in turn, results in the need for pumping large quantities of storm water. If pumping economy is to be effected through designing for maximum flow conditions with gravity flows predominant, sewer maintenance problems multiply during long dry seasons.

Buried pipelines for handling huge quantities of storm water are expensive to construct. However, sanitary sewage must be conveyed in this type of system in order to maintain reasonable levels of public health. This, too, would emphasize the need for separate systems.

Treatment of sanitary sewage in municipal plants will become necessary at some future date. Designs of such plants are based not only upon the "strength" of sewage but also upon the hydraulic loading. Plant design and construction in Surinam based upon handling moderate sewage flows during dry seasons and massive flows during rainy seasons is prohibitive in terms of cost and questionable in terms of sound engineering judgement.

IV.2.1 INTRODUCTION

The provision of piped water supplies immediately introduces the requirement for the sanitary removal of the waste water and sewage. In municipalities where a collection and treatment system for sewage are available, connection to the sewer is a minor problem. Where central treatment is not provided or anticipated, special consideration must be given to the proposed method of collection, removal, treatment and disposal of sewage.

IV.2.2 SEPTIC TANK DESIGN

The common method for sewage treatment and disposal, generally in rural areas including those of "developed" countries, consists of an adequate septic tank for the settling and treatment of the sewage together with a subsurface leaching system for the disposal of the overflow. In Paramaribo, as previously stated, the effluent is collected in the combined system and disposed of in the Surinam river.

In the coastal area, specifically in that part of the project area for which the Supply Group I systems are planned, the relatively high water table elevation (40 cm to 80 cm below surface level,generally) generates problems in the design of leaching fields or drainage areas. The design of leaching fields usually is based on the ability of the soil from a depth of 1 meter up to 3 meters (and in some cases up to 6 or 8 meters when permeable strata are deep) to absorb water.

A number of factors, in addition to the groundwater table location, also affect the "treatment" of septic tank effluent. The soil structure, earthworm presence and root penetration have a definite effect on the aerobic oxidizing bacteria and animal organisms, liquids or gases. A waterlogged soil tends to destroy these effective organisms which in turn serve to preserve the organic matter in the effluent. The use of well-drained, artificial leaching fields may be used in lieu of a conventional leaching system, but this generally results in disposal of the effluent into ditches, canals or other watersources.

IV.2.3 GENERAL SEWERAGE DESIGN

IV.2.3.1 Introduction:

The design of collection, treatment, and disposal facilities for waste water is primarily controlled by the estimated BOD and hydraulic loadings to be handled as well as the method of collection and treatment which is justified. In developing cost estimates, it is necessary to determine on a unit basis not only the flow or volume of waste but its strength and composition. With respect to flow in collection systems, peak flow rates must be known in order to determine the required hydraulic capacities of sewers, pumping stations, treatment plants, and effluent disposal facilities. Similarly, strength and composition must be known in order to determine the degree and type of treatment required to produce an effluent of acceptable quality. Thus, a study of waste volumes and characteristics is a necessary preliminary to the development of design criteria. In this project (UNDP/SF), international and counterpart manpower limitations have been such as to severely limit this study.

IV.2.3.2 Waste Water Quantities:

There are three important components of waste water volume: the first consists of sanitary sewage, the second industrial waste, and the third consists both of subsurface water which enters a sewer system through joints and other openings and of storm water which enters through manhole openings and illicit drain connections. The third component is generally termed infiltration.

Because the major portion of infiltration occurs during periods of heavy rainfall, it is necessary to consider sewage volume in terms of both dry weather and wet weather flow. Dry weather flow consists of waste water occurring during periods of zero or minimal rainfall. Similarly, wet weather flow consists of waste water plus infiltration and storm water inflow. Dry weather flow usually determines the normal loading to be imposed on major units of a treatment plant, whereas wet weather flow indicates the hydraulic capacity required for sewers, pumping stations, and force mains.

IV.2.3.3 Domestic Sewage:

Unit, or per capita, sewage flows are conventionally determined from a study of recorded flow data andpopulation served. Then with the basic data of present flow at hand, future changes are projected and suitable future design allowances are determined.

In Surinam as previously stated, only one fairly extensive sewerage system is presently in operation: the Paramaribo system, which is designed on the combined basis. Because the average per capita water supply (hence per capita sewage flow) is restricted by limitations in the present water supply system, metering of water flows within the Paramaribo system does not provide a reliable guide to the per capita waste water flows of the population served. In view of the above factors, and the necessity for establishing unit sewage flows for use in the design of separate sewerage systems, per capita sewage flows have been determined by estimation. For design purposes therefore, the quantity of sewage obtained from residential areas is estimated to be 70 per cent of the established per capita water allowances (as noted in Part III). This percentage generally corresponds to conventional practice for metropolitan areas of this size.

IV.2.3.4 Industrial Waste:

Because of the varied nature (type and size) of the existing or anticipated future industries within Surinam, industrial waste flows are difficult to predict with any degree of accuracy. Hence only general estimates of the industrial contribution are possible. Certain types of industrial wastes will require pre-treatment prior to being discharged into the public sewers, in order to provide proper protection to the sewerage system. The extent of such pre-treatment will be indicated in the suggested ordinance presented in the comprehensive report which will be prepared at the end of the project.

It is expected that 50 percent of the industrial water consumption can be estimated as being discharged to the sewerage system. This value has been found in general to be a reasonable allowance for industrial areas where suitable regulatory controls are applied.

In areas served by combined sewers, it is estimated that 80 percent of the industrial water consumption is discharged to the public sewers.

IV.2.3.5 Infiltration:

In areas served by combined sewers, no consideration has been given to infiltration because the quantities involved are generally insignificant in relation to total hydraulic capacities of the sewers.

For areas with separate sewers, an infiltration allowance of metric equivalent to 2,000 gallons per inch diameter of sewer per mile per day will be assumed, corresponding to general practice elsewhere where groundwater is prevalent and sewers reasonably well constructed. The purpose of this procedure will be to obtain a reasonable estimate of infiltration on a per acre basis which can properly be used for estimating total infiltration in the future.

IV.2.3.6 Design Flows:

The design of sewers is based on maximum rather than average flow, and the ratio of maximum to average flow varies according to location within the sewerage system, that is, on the extent of the tributary area from which sewage is being collected. For design purposes estimates will be made of this peaking factor (rate of maximum to average flow), but is tentatively assumed as a factor of 2.0.

IV.2.3.7 <u>Basis of Design for Sewerage Systems in Rural Areas</u>:

IV.2.3.7.1 <u>Population growth</u>

The average growth in population can be assumed at approximately 4% per year. Additional assumptions were covered in the sections on water system design.

IV.2.3.7.2 Rate of sewage flows

Number of people in a home is assumed to be six. As stated earlier, flows can only be predicted since no existing sanitary sewer systems are presently in service.

Average daily flow - 70 L/person

Peak daily flow - 140 L/person

This includes effluent from sinks, toilets, bathrooms, etc.

IV.2.3.7.3 Peak Sewage Flows From Specific Buildings:

Movie houses

Average capacity 1,000 persons, with 3 performances on Saturdays, each lasting 2 hours. All other days 2 performances/day.

A. For septic tanks and drain field design:

daily : 2.4 m^3

hourly : 0.4 m3

B. For overall treatment and gravity system design:

daily : 3.0 m3

hourly : 0.5 m3

Restaurants

Average capacity 35 tables, 4 persons at one table. Used the most on Saturdays from 12.00 noon till Sunday morning 1.00 o'clock. Also included is kitchen cleaning effluent.

A. For septic tank and drainfield design:

daily : 0.6 m^3

hourly : 0.1 m3

B. For overall treatment and gravity system design:

daily : 4.8 m3

hourly : 0.5 m3

Local shops

Average 100 persons passing through every hour at peak time.

Peak time lasts 4 hours/day.

A. For septic tank and drainfield design:

daily : 0.5 m^3

hourly : 0.1 m^3

B. For overall treatment and gravity system design:

daily : 0.6 m^3

hourly : 0.2 m^3

Schools

Flow based on 12 grade school and 4 pre-school classes:

A. For septic tank and drainfield design:

daily : 3.0 m^3

hourly : 0.4 m^3

B. For overall treatment and gravity system design:

daily : 0.4 m^3

hourly : 0.5 m^3

Service stations

Station will be open for 16 hours/day. Included are car washing outflows (only for overall gravity system designs)

A. For septic tank and drain field design:

daily : 0.8 m^3

hourly : 0.1 m^3

B. For overall treatment and gravity system design:

daily : 20.0 m^3

hourly : 1.2 m^3

Government offices

In use for local administration tasks. 40 employees working 8 hours a day. No waiting room for visitors.

A. For septic tanks and drainfield design:

daily : 0.7 m^3

hourly : 0.1 m^3

B. For overall treatment and gravity system design:

daily : 1.0 m^3

hourly : 1.15 m^3

Recreation buildings

Capacity 200 persons on Saturdays and building is used for a 6-hour time period. Also includes effluent from kitchen facilities, except for septic tank design:

A. For septic tank and drainfield design:

daily : 8.0 m^3

hourly : 1.0 m^3

B. For overall treatment and gravity system design:

daily : 9.2 m^3

hourly : 1.5 m^3

Medical buildings

(Polikliniek) Capacity 50 visitors per day and 5 persons professional staff. Buildings open for 8 hours a day.

A. For septic tank and drainfield design:

daily : 0.5 m^3

hourly : 0.1 m^3

B. For overall treatment and gravity system design:

daily : 0.6 m^3

hourly : 0.15 m^3

Medical building and small hospital

Hospital with a capacity of 20 beds and kitchen facilities.

Included are 7 employees, 2 employees each on a 3 shift program.

A. For septic tank and drainfield design:

daily : 1.9 m^3

hourly : 0.2 m^3

B. For overall treatment and gravity system design:

daily : 2.4 m^3

hourly : 1.0 m^3

Shop for maintenance equipment

Flows based on a shop which serves an agricultural community of approximately 1,000 persons. Includes wash rack effluent only for overall treatment and gravity system design. Shop will be open for 8 hours/day.

A. For septic tank and drainfield design:

daily : 0.5 m^3

hourly : 0.1 m^3

B. For overall treatment and gravity system design:

daily : 5.1 m^3

hourly : 0.6 m^3

Note: All above-mentioned sewage flows are only for specific purposes and should only apply to the rural areas located outside the metropolitan area of Paramaribo.

IV.2.3.7.4 Collection system: Minimum size of pipe used 6".

IV.2.3.8 Sewage Characteristics:

Sewage characteristics are significant in that they determine both the type of treatment and the degree of treatment which must be provided to meet established discharge criteria, and also may affect the design of sewers and other sewerage facilities.

In a comprehensive study of this type, data obtained from representative samples collected at various existing facilities are analyzed to determine present waste water characteristics. After the present character of the waste water will be established, this information will be used as a basis for estimating future design loadings. Some B.O.D. sampling has been initiated by Government, but this reflects only the receiving water in the Surinam River. Sampling and analyses for evaluating per capita BOD, suspended solids, and grease loadings hopefully will be performed later in the project life by project staff.

IV.2.3.9 Preliminary Design Loadings:

For purposes of this report loading factors were estimated on the basis of BOD and suspended solids concentrations used in actual designs in other countries. It is recognized that these estimated loadings must be reviewed in the light of the future studies discussed in the previous paragraph and on the basis of operational data; and, if necessary, adjusted to suit local conditions.

The waste water of the project area will be derived from predominantly domestic sewage and smaller industrial discharges. Since industries of various types could be located throughout the project area, it is hardly possible to estimate the exact magnitude and nature of the industrial loadings. However, it is assumed that industrial loadings will be regulated to comply with the provisions contained in suitable future industrial waste ordinances. The design factors adopted for various stages of development are presented below:

TABLE IV - 1

DESIGN FACTORS FOR WASTE CHARACTERISTICS

Factor	1987 Value
BOD, 5 day 20°C, lbs/cap/day	0.17
Suspended Solids, lbs/cap/day	0.20

The above design concentrations of BOD and suspended solids estimated design for the year 1987 were probably higher than existing values to allow for the expected increases in living standard and increased industrial loads on the municipal systems. It is assumed that the concentration of BOD and suspended solids in industrial wastes is equal to that of domestic sewage.

IV.2.4 DESIGN OF COLLECTION SYSTEMS

The design criteria used in the general design of sewerage projects are presented in the following sections.

IV.2.4.1 Sewers

Roughness Coefficients: The Manning formula has been used for the solution of problems involving open-channel flow in sewers. The following values of "n" (roughness coefficient) have been adopted for use with this formula, corresponding to field observations of existing sewers and anticipated future conditions:

IV.2.4.1.2 Design "n" values

0.014 for all proposed sewers over 18-inch diameter
- flow at 1/2 depth

0.015 for all proposed sewers of 18-inch and smaller diameter
- flow at 1/2 depth

The Manning formula: $V = \frac{1486}{17} \times R^{2/3} \times S^{1/2}$

Roughness coefficients of above-mentioned values are being used for both of vitrified clay pipe and concrete pipe for gravity systems.

IV.2 4.1 3 Analysis "n" values:

0 015 for existing sewers in average condition

0.017 for existing sewers in poor condition

IV.2.4.1.4 Design Depth of Flow: Sewers of 15-inch diameter and less are designed at 1/2 depth of flow. Sewers of 18-inch diameter and larger are designed at 3/4 depth of flow. This allows flexibility in providing for additional flows because of future increases in population.

IV.2.4.1.5 Minimum Slopes and Velocities: For smaller sewers, the following minimum invert slopes have been adopted:

Diameter of Sewer (inches)	Minimum Invert Slope
6	0.005
8	0.0032
10	0.0024
12	0.0018
15	0.0012
18	0.0008
21	0.0006
24	0.0005

Minimum slopes are such as to provide a velocity of 1.7 fps (feet per second) with the sewer flowing at design depths, except that higher minimum velocities are adopted where necessary to inhibit the formation of hydrogen sulfide. Where sulfide problems are significant, good practice would suggest average velocities not less than 3 fps and preferably as high as 4 fps.

For sewers 15-inches and larger in diameter, peak velocities should not exceed 14 fps in order to avoid excessive turbulence and subsequent pipe damage.

IV.2.4.1.6 Manhole Location

Placing of the manholes are based on maintenance procedures:

for sewers 8" to 21" in diameter the maximum distance between manholes is 400 ft (122 m)

for sewers 24" to 30" in diameter the maximum distance between manholes is 700 ft. (214 m)

for sewers over 30" in diameter the maximum distance between manholes is 900 ft (275 m)

on large sewers (15" and larger) manholes are placed at the beginning or end of all curves.

IV.2.4.1.7 Elevation Difference in Mahhole Inverts

A. The vertical drop across manholes (minimum drop of invert) for small sewers (15" and smaller) with straight-through flow, is adopted as 0.10 foot (3 cm). For a side inlet, the minimum drop of invert is 0. 20 foot (6 cm). For straight-through flow across manholes with different sizes of pipes with matched water surfaces see following table:

Diameter of outlet	Drop in Feet (Diameter of inlet in inches)							
	6"		8"		10"		12"	
	feet	meters	feet	meters	feet	meters	feet	meters
8"	0.008	(.02)						
10"	0.17	(.05)	.08	(.02)				
12"	0.25	(.08)	.17	(.05)	0.08	(0.02)	0.02	(0.005)
15"	0.38	(.11)	.29	(.09)	0.21	(0.06)	0.13	(0.04)

The maximum drop for straight-through flow is 0.60 ft. (0.18 m) and for side inlet 1.0 ft. (0.30 m).

B. Invert drop across manholes for large sewers (18" and larger) with straight-through flow (inlet size = outlet size), minimum drop of invert is adopted as 0.05 foot (1.5 cm).

For inlet size less than outlet size (expanding transition) and a decreasing velocity, the drop of invert is calculated by a loss of energy $= \frac{0.24\ (V_1 - V_2)^2}{2g}$

For inlet size greater than outlet size (contracting transition) and an increase in velocity, the drop of invert is calculated by the loss of energy $= \frac{0.12\ (V_1 - V_2)^2}{2g}$

For manhole structures with side inlets (confluence structures) the drop of inverts are calculated using the principle of the conservation of momentum (pressure + momentum).

IV.2.4.2 Lift Stations

Capacity of wet wells and pump stations are designed to handle the average sewage flow. Piping is designed for peak flows, pumps and motors can be replaced and re-used to handle future increased flows. Wet wells are designed to handle a flow of five minutes time between successive starts of a pump (where possible). Enough flexibility is available to accomodate future increased flows which decrease the lapse time to 2 1/2, set as a minimum between the starts of a pump. Wet wells are prefabricated with a poured-in-place concrete slab. Slab thickness is considerable since the maximum gravity sewer depth would be kept at approximately 5.5 m below the existing ground. Ground water level as stated earlier, is on the average approximately 0.50 to 1.00 meters below the existing ground level, causing uplift, which has to be carefully examined in station design.

Pump stations are located aboveground The top slab of the wet well is an integral part of the pump station floor. Stations are of the package type with interchangeable pumps and motors to satisfy future increases in sewage flows. Each pump station has a standby capacity equal to the required pump and power capacity to handle the flow. Pumps are of the self-priming type driven by electric or diesel engines depending on the availability of the cheapest source of power.

Each station operates fully automatically on the sewage level in the wet well.

Alarms are provided for high water, malfunction of pumps and power failures. Stations are connected with each other in certain specific areas by an alarm telemetoring system which will be centrally located.

Pump station discharge force mains underground are either reinforced concrete pipe with rubber joints or asbestos-cement pipe. Above ground materials for bridge crossings are made of cast-iron pipe. Velocities are kept to a maximum of 10 ft/sec. and a minimum of 2.5 ft/sec.

Hydraulic calculations are based on the Hazen-Williams formula with a friction coefficient of C = 120.

IV.2.4.3 Sewage Lagoons

Sizing of the raw sewage stabilization ponds is arrived at by using a BOD_5 of 0.17 lb/capita/day, which develops an approximate detention time requirement of 120 days. The treatment is accomplished primarily under aerobic conditions, therefore the maximum depth of the ponds is kept at 2.00 meters, with a freeboard of approximately 0.50 meter

The ponds are designed with a maximum length of three times the width and the bottoms should not vary more than 10 cm from a plane surface by keeping a maximum depth of 2.00 m, assurance is made of relatively full sunlight penetration. Since high groundwater problems exist, the limiting cut in the existing ground is kept at a maximum of 1.00 meter. Surrounding dikes are built on compacted fill to a maximum height of 1.50 meters above the existing ground and covered with grass on the outside slopes to minimize erosion problems.

Side slopes inside the lagoons are approximately 10:1 (10 horizontal and 1 vertical), thus increasing the water surface area available for the natural disinfection process.

Outside slopes of the dikes are approximately 2:1 (2 horizontal and 1 vertical). Each lagoon has a tower-like effluent structure flow over the pond surface area. Overflow weirs maintain a constant sewage level in the ponds and are connected to an underground system which drains to its final discharge point. To this system are also connected the emergency lagoon outflow structures which are operated with hand-wheel controlled sliding gates.

The final lagoon effluent is to be chlorine-treated before being discharged in a drainage ditch or watercourses.

IV.2.4.4 Septic Tanks and Drainfields

In areas of light population where the distance between the homes is considerable, septic tank treatment is the only alternative from an economic point of view.

For design purposes, a number of 6 persons for each house is used, which is an average and accurate figure for these rural areas. Project staff have conducted several house counts in order to verify this figure. Only toilet effluent is considered.

SEWERAGE

1 home (6 persons)	- septic tank dimensions: 1.00 m. inside diameter with a depth of 1.00 m., drainfield 3.70 m. x 2.00 m., depth 1.00 m. 4 perforated rows of 4" pipe 6" pipe for the distribution structure 6" effluent pipe - 4" diameter collection system.
2 and 3 homes (12-18 persons)	- septic tank: 1.00 m. inside diameter with a depth of 2.00 meters, drainfield max. 6.00 m. x 2.00 m., depth 1.00 m. 4 rows of perforated 4" pipe 6" pipe for the distribution structure 6" effluent pipe - 4" collection system

(A graph of septic tank volumetric requirements is attached as Appendix IV-3)

IV.2.5 DESIGN PERIODS

The following design period criteria are provided to allow for an orderly expansion in capacities of sewerage systems.

(a) Land Requirements: Similar to the situation for water supplies, most land is under central government control. Therefore it should be no problem to acquire ample acreage in the first instance to meet anticipated ultimate requirements (i.e., for a design period of 40 years or more). Inadequate initial acreage can severely inhibit expansion at a later date. Wherever possible, acquire a margin of land around sewage treatment plants to remain permanently undeveloped as a "buffer zone" to prevent nearby development of residential property.

(b) Outfall Structures such as Ocean Outfalls: A design period of 40 years or more

(c) Major Structures for Structures such as Pumping Stations: The design period should be 40 years or more. The mechanical and electrical equipment within pumping stations should be designed for periods of 15 years or less with provisions for later modifications or additions.

(d) Major Sewage Treatment Plants Elements: Design period should be 15 years or less, with provisions for parallel expansions.

(e) Collection Systems: The design period for trunk sewers and secondary sewers should be 40 years or more.

(SECTION 3 - Waste Treatment and Disposal)

IV.3 1 INTRODUCTION

Sewage treatment results from community or government interest in improving sanitation and public health. The extent to which waste treatment is needed or implemented is, of course, closely related to the level of development (particularly economic) in the area.

In Surinam, in the immediate future, except in the Paramaribo central area, each type of community will suggest different approaches to sewage handling and treatment. It would appear that much of the treatment will be limited to individual or "cluster" septic tank disposal in the rural populated areas, small collection systems with lagooning in those areas where the population concentration justifies this type of treatment, and possibly a few secondary treatment facilities in the built-up areas. As previously discussed, the most practical method of treatment of wastes from some of the Paramaribo peripheral areas would be in central plants, but this seems highly unlikely with no designs forthcoming.

One of the basic requirements in the planning of any sewerage system is that of providing a safe, effective, and innocuous disposal method for the wastes collected. It is the primary purpose of this section of the report to anticipate and to assess the various factors governing the disposal of the waste effluents of the project area; to establish, in general terms and in the context of present knowledge, reasonable effluent quality criteria for the various waste discharges; and finally, to determine what degree of treatment will be necessary to meet these criteria.

The design of treatment facilities must be such as to meet the criteria mentioned previously. For this reason, the method of treatment selected must not only maintain the desired quality of the receiving water, but will also depend upon the character of the waste to be treated and the land area available for treatment. In some countries, discharge requirements are developed when requests are made by prospective dischargers into receiving waters or, when an investigation of an existing waste discharge following treatment shows the existing requirements to be inadequate.

The discharge requirements which determine the level of treatment generally limit the amount of B.O.D., grease, suspended matter and coliform organisms that may be contained in the waste discharge as well as a minimum amount of dissolved oxygen to be found in the discharge. In addition, depending upon the degree of development in the country, the requirements may include maximum amounts for A.B.S., phenols, arsenic, color, pH or any other material or waste characteristic that may have a harmful effect on the receiving water quality.

After the criteria or requirements have been determined, the decision on the waste treatment necessary to meet these criteria must be made. If the area is sewered, existing waste flows will be measured, sampled, and analyzed for B.O.D., pH, A.B.S., grease, suspended matter and any other quantity that might influence the selection of the treatment process. If the area is not sewered, other steps are necessary; and the ingenuity and judgement of the designer becomes extremely important.

IV.3.2 FACTORS INFLUENCING WASTE DISCHARGE CRITERIA

In developing appropriate discharge criteria the following basic factors will be taken into account:

(1) Beneficial uses made of the receiving waters are the controlling factors in determining water-quality levels that are to be maintained.

(2) For every beneficial use, there are certain water-quality requirements which must be met to assure that the water will be suitable for that beneficial use.

(3) Receiving waters, which may be canals, rivers or ocean, have varying degrees of waste assimilative capacity, and the addition of waste materials may change the chemical, physical, and biological characteristics of the water without necessarily creating significant adverse effects on the beneficial water uses.

(4) The formulation of waste discharge requirements should be so designed as to (a) secure that degree of care in the planning and operation of works for the treatment and disposal of sewage and industrial wastes as will adequately protect the public health and other beneficial uses of waters, and (b) at the same time permit the legitimate planned usage of those waters for receiving suitably prepared wastes so that an orderly growth and expansion of cities and industries may be possible.

Presently the lower Surinam River and, to a lesser extent, the lower Commewijne River, serve as the receiving bodies for the water-borne wastes of the lower Surinam river basin, and it is anticipated that in the future both the Surinam and the Commewijne Rivers will continue to serve as the primary means for dispersion and assimilation of the wastes.

Although the Surinam River is not a source of water for public use, it is the major navigation facility of the basin area; hence it is vital to the growth and overall economy of this area. Also, since some use is made of tributary local canal water for potable water needs by the public, it is essential that waste discharge criteria be so formulated that protection of this vital resource for all planned uses particularly navigation, and waste disposal is guaranteed.

It should be noted that the discharge requirements to be developed must be based on a number of broad assumptions. It must be recognized that in the future there will be changes in not only the magnitude and variety of new substances which will be discharged but also in the qualitative and quantitative character of the receiving bodies. Because of these factors, the status of waste disposal within the lower Surinam River area is in a state of flux, and must be reviewed, from time to time, in the light of changed conditions and increased knowledge of the many problems involved.

As stated earlier in this report, some investigations are being conducted by the Hydraulics Research Division, of the Ministry of Public Works, particularly in connection with B.O.D., solids, chemical characteristics and dissolved oxygen in the Surinam River and in some of the canals in the lower Surinam River basin. A location map of sampling points and receiving water characteristics are attached as Appendix IV-4 and Appendix IV-5 respectively.

No international project staff has been available as yet to assist in this effort or to co-ordinate this activity within the scope of the project.

IV.3.3 WASTE DISPOSAL CONSIDERATIONS FOR METROPOLITAN PARAMARIBO

Although consideration of sewerage for the central Paramaribo area is not included in the project activity plan, this brief reference is included for background purposes.

The receiving waters into which the waste water effluents of Paramaribo are discharged include the Surinam River or the canal systems flowing to final discharge in the river.

The primary factors which must be considered in the disposal of wastes by dilution in surface waters are as follows:

(1) The quality level which must be maintained to protect the various beneficial uses of the receiving waters, such as possible drinking water supplies, industrial water supply, and agricultural uses.

(2) The volume and strength of the wastes to be discharged.

(3) The capacity of the receiving waters to handle the wastes, which in turn is based on the quality of the receiving water available for diluting and absorbing the waste effluents.

At present or during the Interim Design period, disposal of Paramaribo wastes will have little effect on the dilution capability of the Surinam River.

IV.3.3.1 Quantity of Wastes

A breakdown of the quantities of waste water effluents to be discharged in the Surinam River (including its tributaries) is presented in Table IV-2, based on the assumption that the entire population of Paramaribo is to be sewered (both at Interim and for Ultimate conditions). The table includes rough estimates of the population tributary to the various disposal points as well as a very general breakdown of domestic and industrial wastes for the Interim and Ultimate conditions.

TABLE IV-2

ESTIMATED QUANTITIES OF WASTE TO BE DISCHARGED INTO THE SURINAME RIVER

(Suriname River)

	Tributary Population	Domestic Flow m3/day	Industrial Flow m3/day	Total Flow m3/day
Interim:	400,000	2,000	1,000	3,000
Ultimate:	700,000	4,000	2,000	6,000

Notes: (a) Interim flows are based on the 1987 estimated population figures and water use.

(b) Ultimate flows are based on 2001 conditions.

IV.3.3.2 Waste Characteristics

The waste waters of the Paramaribo area will be derived from two basic sources, domestic sewage and industrial wastes.

IV.3.3.2.1 Domestic Sewage:

In addition to the discussion of the characteristics of domestic sewage presented in the section of this report entitled "Bases for Design" are the following remarks.

Besides adding organic waste materials, domestic use of water will add dissolved mineral salts. It is estimated that domestic water use will increase the total dissolved solids (TDS) content by about 250 to 300 mg/l. This represents an insignificant contribution to the Suriname River solids content. Table IV-3 presents a general list obtained from W.H.O. sources of the additions to various major chemical constituents found in water through domestic use. Domestic wastes, of course, may also contain biological pathogens including bacteria and viruses.

TABLE IV-3

CONSTITUENT ADDITIONS AFTER DOMESTIC WATER USE

Constituent	Added Amounts (mg/1)
Total dissolved solids	250 to 300
Boron	0.1 to 0.4
Sodium	40 to 70
Potassium	7 to 15
Magnesium (as $CaCO_3$)	15 to 40
Calcium (as $CaCO_3$)	15 to 40
Total Nitrogen	20 to 40
Sulfate	15 to 30
Phosphate	20 to 40
Chloride	20 to 50
Alkalinity (as $CaCO_3$)	100 to 150

IV.3.3.2.2 Industrial Wastes:

Industrial waste matters of varying kinds are contained in the spent process waters of manufacturing establishments and are produced in washing, flushing, extracting, and impregnating operations. Like domestic sewage, industrial wastes contain suspended, colloidal, and dissolved solids of mineral and organic origin. Pathogenic organisms are rarely found in industrial waste waters.

The strength of industrial waste waters varies widely from industry to industry and with changing manufacturing procedures within the same industry. Hence, it is not feasible to attempt to assign definite values to the characteristics of industrial wastes to be produced in Paramaribo, until a comprehensive review of all major industrial wastes is performed.

Effective control of the discharges of industrial wastes into the sewerage system is best accomplished by regulations through which existing and proposed discharges may be reviewed in order to evaluate their effects, and by which reasonable pre-treatment can be required if needed. Such industrial waste regulations should be based on the philosophy that the sewerage systems should afford maximum service for industry, and hence should receive and handle such wastes or treated wastes to the extent possible without impairment of the sewerage system's capacities for receiving and handling domestic wastes. On this basis a sample of typical regulations submitted by the W.H.O. shortterm consultant for industrial wastes will be supplied to Government when his report is released for distribution.

IV.3.4 WASTEWATER RECLAMATION

At the writing of the report, no consideration had been given to studying wastewater reclamation. In some countries in which chronic shortages of water for community supplies or for agricultural purposes are experienced, the practice of wastewater reclamation is pursued in order to meet these demands. However, this frequently inplies the need for additional investment in treatment elements, an approach which would be difficult to implement in Surinam where the needs for agriculture are not on the same scale as the discharge which would be available from treatment plants. Depending upon public contact with the irrigated area, or with the produce grown in the irrigated area, more or less rigorous disinfection criteria would need to be applied.

Some standards proposed by the California Department of Health (USA) are:

	Max. MPN
For irrigation of parks, playgrounds, etc.	5/100ml
For irrigation of golf courses	23/100 ml
For vegetable and raw foods	0/100 ml
For certain other crops	Partial disinfection

Further, if it is desired to re-use effluent for drinking water, public health standards and aesthetics would practically demand tertiary treatment. The tertiary treatment chosen would have to be justified by an economic analysis. In other words, the reclaimed or tertiary treated effluent would have to cost less than the cost of hauling fresh water or treating raw water. This, in turn, would require a comparative investigation of the costs of desalination of water of extremely high chloride content.

It is not planned at this time to proceed with the above investigations because of the unavailability of project staff for this pursuit.

PART IV - SEWERAGE

SECTION 4 - KWATTA - LEIDINGEN SEWERAGE SYSTEM

IV.4.1 General

At this point in the UNDP(SF) project, only the Kwatta-Leidingen sewerage system has been given extensive consideration. This is because of the shortage of staff (particularly the absence of an international staff waste water engineer) in the project.

A drawing of the proposed piped sewerage system for the Kwatta-Leidingen Area is included as Appendix IV-6.

The Kwatta-Leidingen system has been investigated on the basis of two alternate methods of collection and disposal: (1) a piped system of collection with treatment and disposal through lagooning and (2) a cluster-type septic tank system with small drainage areas.

Any sewerage collection system in the Kwatta-Leidingen area as well as in most of the coastal region of Surinam will be expensive to build and maintain, regardless of the method used. Two factors create this condition: (1) the extremely high ground water table and (b) the method of road construction in which native material is scraped from both sides of the road centerline to build the fill for the road-bed, but also creating wide irrigation and drainage channels along each side of the right-of-way. House services must cross these channels, either on supports or by use of siphons, or parallel lines must be constructed. Another effect of this method of road/dike construction is to develop a height of crown in the road which is considerably above the first floor elevation of houses adjoining the roadway, thereby impelling the need for deep excavation in the roadway for sewer lines.

IV.4.2. LOCATION, BOUNDARIES AND DESCRIPTION OF AREA

The Kwatta-Leidingen sewerage project is located in the same area described in Part III to be served by the Kwatta-Leidingen water supply system.

Characteristic of the rural areas contiguous to Paramaribo, the typical density of housing is shown on the drawing attached as Appendix IV - 7.

The boundaries of the sewerage zone encompass a somewhat larger service area than was included in the water supply project, and this was based on the assumption that piped water would be available in the south-easterly section through another system of supply.

IV.4.3. POPULATION SERVED

The design population for the sewer service area was based on the similar design population for the water supply system and this, in turn, was projected from an actual present day house count. For estimating and design purposes the total population was projected to 1987 and is estimated at 25,000.

IV.4.4. DESIGN ANALYSES

IV.4.4.1. Piped Collection System

As stated earlier, the average flow was estimated at 80 liters per capita per day and this includes domestic, commercial and industrial contributions. A peaking factor of 2.0 is utilized for the collection system design.

This would develop an average daily flow of 2 million and a peak flow of 4 million lpd. Infiltration, based on an approximate value of 2000 gallons per day per diameter per mile of pipe and averaged over the total collection system represents approximately 10% of the peak flow. Design criteria for sewerage design were discussed in an earlier section.

Collection system design was based on establishing initial depths of invert at 1.0 meter and installing pumping stations when a 6.5 meter depth was reached.

Following are the pipe sizes and lengths included in the collection system. Pipe used would be vitrified clay or asbestos-cement.

6 - in diameter	21.200 m
8 - in "	39.100
10 - in "	6.200
12 - in "	3.000
15 - in "	2.500

Because of the flat terrain, a total of 19 pumping stations will be required. It is proposed to use package-type lift stations complete with two self-priming, horizontal centrifugal pumps; valves;internal piping; motor control center; and liquid level control system. The pumps will be required to handle solids up to 4-inches in diameter.

The pumping stations will be above ground with wet wells installed as shown on the drawing, Appendix IV-6.

Also shown on the above drawing are the location and details of the sewage lagoon system for the sewerage projects. Immediate needs would compel the initial construction of two lagoons of approximately 100 x 300 m size, in order to provide 90-day retention of the sewage. At an intermediate phase, during 1978, a third lagoon could be needed and a fourth would be built by 1987. Discharge, after chlorination, would be into canals.

IV.4.4.2 Cluster Septic Tank System

The design of the septic tank system was based on serving either one, two, three, four or five houses in a cluster. The limits are reached when the limit of gravity flow is reached, and the situation in the Kwatta-Leidingen area is such that the maximum number of houses which can conceivably be served is five, because of the flat terrain.

Again, a flow of 80 l/c/d was used. Detention time in the septic tank was assumed to be 12 hours. Because of the high water table and the waterlogged condition of the existing soil, it is proposed to include an open sand filter with each septic tank. Design of the filters is based on a loading rate of 100,000 gallons per acre day. After filtration the effluent will be discharged into canals.

PART V - PROGRAM COSTS AND IMPLEMENTATION

V.1 - General

As mentioned in the Plan of Operation, the government had allocated an amount of US $ 8,000,000 for the construction of water supplies and sewerage systems in the country during the period from 1971 to 1981. During 1972, as preparation of the Comprehensive Plans for water supplies and sewerage is in final progress a master construction plan will be prepared in accordance with an estimate of the relative urgency of need for the proposed systems, taking into account the earlier preliminary planning which has been executed in the UNDP(SF) project consistent with government's definition of immediate priorities.

In accordance with government's decision to budget the above capital expenditure during the years 1971 to 1981 and, keeping in view government's allocation of US $ 4.5 million of this amount toward the construction of water supplies and US $ 3.5 million toward the building of sewerage systems, and assuming that this type of expenditure would at least continue and probably increase over a period of time, the following phases of development are tentatively proposed:

Phase	Period	Construction Program	
		Water Supplies	Sewerage
Initial	1971-1981	sf.8.4 million	6.5 million
Medial	1981-1991	10.0 million	8.0 million
Terminal	1991-2001	12.0 million	10.0 million

V.2 - Initial Phase:

This phase contains works for which detailed construction plans have already been prepared or are to be prepared as a part of the UNDP(SF) project or will be in advanced planning stage as a result of the project.

V.3 - Medial Phase:

Systems within this phase are scheduled to be fully operational by the year 1991. In order to realize this level of project maturity, some of the medial projects will need at least preliminary engineering studies during the UNDP(SF) project.

V.4.- Terminal Phase:

This phase includes works scheduled to reach maturity by 2001.

Phase Definitions:

As stated earlier, the above phase definitions can only be termed as "proposed" at this level of investigations. A number of intangibles may have a decided effect upon this phasing. Most important is the availability of financial assistance which, at present, stems generally from Dutch and European Economic Community sources. A change in the governmental structure in Surinam could change the sources of external financing, thereby causing unpremediated increases or decreases. The effect of the Paramaribo water supply and sewerage systems on the phasing would also be substantial were it decided by government to create an autonomous agency for water supplies and sewerage in which the Paramaribo systems would dwarf other systems in size and complexity.

The capability with which the existing organizations could handle the proposed design and construction programs would need to be examined carefully. It would appear that the present separation of design and construction facilities (in these agencies) tends to duplicate efforts and this type of fragmentation would not promote concerted efforts in construction planning and augmentation.

It would also follow that systems constructed during the Initial Phase would become integrated into the Medial Phase, and these, in turn, would become part of the Terminal Phase. Similarly, Initial Phase elements may have become obsolete by the Terminal Phase. The term "Terminal Phase" should not be construed as representing finality, of course. The sequence of Initial, Medial and Terminal Phases refer respectively to those immediately necessary, those that can be predicted with reasonable confidence and those that can be considered in the frame of reference of future community development.

At this writing, only some of the Initial Phase projects can be projected with any degree of certainty and these projections must also be qualified by the need for further co-ordinated study. Initial Phase projects are listed in the following sections in terms of construction cost and sequence of implementation.

V.5--PROPOSED CONSTRUCTION: INITIAL PHASE PROJECTS

Undoubtedly this will be the most difficult phase of the entire construction program, in that it requires a design and construction effort on an unprecedented scale in Surinam, and by its very nature it implies the several necessary changes in established administrative, technical, and construction practices and techniques if the targets are to be met. Emphasis and priorities have been established in accordance with definition of greatest need, according to government, and also in accordance with consistent engineering judgement which will enable maximum benefits to be obtained from the following estimated capital expenditures.

V.5.1 WATER SUPPLY SYSTEMS:

System	Estimated Construction cost	Implementation years
Kwatta-Leidingen	sf. 1,200,000	1971-73
Pad van Wanica West	1,300,000	1973-75
Groot and Klein Henar	120,000	1973
Kwakoegron	45,000	1973
Domburg and Smalkalden	193,000	1974
Calcutta and Tijgerkreek	177,000	1975
Corantyne Polder	155,000	1976
Paradise	153,000	1977
Van Drimmelen	125,000	1977
Commewijne**	3,800,000	1978-1981
Total	sf. 7,268,000	

** depends upon sources, could approach sf.5,000,000.

Detailed estimated costs are available in the UNDP(SF) project for several of these systems but are not included here because of space limitation.

It will be noted that the "middle years" in the above implementation are somewhat less active than the earlier or later period. This approach is suggested in view of the possible formation of an autonomous water and sewage agency in Surinam. If this occurs, it will probably generate augmentation projects in the present Surinam Water Company service zones which will also require study and implementation.

V.5.2. SEWERAGE SYSTEMS

At this stage of the UNDP(SF) project, only the Kwatta-Leidingen sewerage project has been studies to any degree. It is estimated that the construction cost of the system will approximate sf. 1,500,000 for the cluster septic tank alternate and will probably be at least twice that amount for the piped system.

V.6 - DESIGN SCHEDULE:

While several of the designs and construction documents required for the above systems will be completed during the life of the UNDP(SF) project, for proper co-ordination of a construction program of this magnitude, some improvements should be made in the current engineering procedures in Surinam. These will be discussed further in Part VI.

As a result of shortage of project staff in both national and international categories, all necessary data were not available at the time of preparation of this report for projection of design scheduling through the Medial and Terminal Phases. Consequently schedule development and adjustment will be needed during the remainder of the project in accordance with the technical needs as well as the budgetary requirements of the Surinam government. It might also be government's purpose to later expand the schedules to produce an order or priorities in considerably creater detail that can be shown at this time.

PART VI - MID-PROJECT EVALUATION AND RECOMMENDATIONS

(Section 1 - Technical Recommendations)

VI.1.1. GENERAL

At this stage of development in the UNDP (SF) project the technical recommendations which can be made must, of necessity, be of a broad, general nature because the investigations of some aspects of the project have just begun, and some have not commenced as yet. Definite, conclusive recommendations will form part of the comprehensive plan reports which will be published at the conclusion of the project.

VI.1.2. GROUNDWATER AVAILABILITY AND WITHDRAWAL RECOMMENDATIONS

The most important aquifers are contained in the Coesewijne series of Mio-Pliocene age in which four aquifer zones can be recognized. The upper two aquifer zones Cl and C II are the only ones that crop out and receive recharge. This is in the savannah belt along the southern flank of the basin. The aquifers are full of water and it appears that much of the recharge is locally discharged to effluent streams and evapotranspires. The water in Zones C I and C II is fresh south of the bauxite belt but brackish in the coastal area except in eastern Commewijne where it is fresh in the coastal area. Aquifer Zone C III is an important aquifer zone locally in the coastal area. Aquifer Zone C III is an important aquifer zone locally in the coastal area, but it is not present everywhere. It probably receives some recharge as a flow from Zone C II in the north but this must be small because of the low gradient. Aquifer Zone C IV exists only north of the bauxite belts and apparently does not receive charge. Water is fresh to the south but chlorides inc rase to the north.

The main centres of population area in the coastal area where the aquifers that receive recharge contain brackish water with the exception of aquifers in Zone C III which may receive recharge locally and indirectly. This latter Zone and

and Zone C IV contain the only aquifers of importance in the coastal area; however withdrawals from them should be considered as drawing on storage reserves only, eventually resulting in an invasion of the fresh water zones by brackish water. Withdrawals of fresh water may continue for a long time but ultimately it will be necessary to obtain groundwater from Zones C I and C II south of the bauxite belt.

Paramaribo pumped water in the amount of 3.4 million m^3 from Republiek and 5.9 million m^3 from Zorg-en-Hoop in 1970. In 1990 the ratio may be 1:7 respectively with most additional supplies from the new Leysweg well field. Because the withdrawals in the coastal area may come only from storage, it is expected that water high in chlorides will advance inland and that by 1990 the chlorides in the pumped water will have increased to 280 ppm which would be diluted to about 250 ppm by the water from Republiek. This does not account for possible withdrawals from zone C IV for the proposed Pad van Wanica water supply system. It seems that long range plans for Paramaribo and Pad van Wanica should be integrated with a common source of supply in mind south of the bauxite belt.

The best source of water supply for the Kwatta-Leidingen system is from aquifer Zone C III. One supply well has been conctructed already. It is estimated that interference will extend to a distance of about 14 km. by 1987 and that brackish water will enter the zone from Zone C II in the west and east; however, it is expected that the brackish water will not reach the supply wells until well into the next century, unless additional, large and presently unforeseen withdrawals take place.

Groundwater in the populated area of northwest Commewijne is brackish. Fresh water has been discovered about 30 km east of the area to be supplied and exploration is currently underway to determine how far the fresh water extends to the west.

VI.1.2.2. Hydrogeological Recommendations

Legislation should be introduced to control the taking of water more effectively. At the present time it is required only to obtain permission to drill a well. This should be continued but expanded to specify the amount of water taking. The issuing of permits should be based on the maximum beneficial use of the water in a given aquifer and on long range planning. Due regard should be given to small communities in fringe areas where source of supply might be depleted or contaminated by withdrawals elsewhere in the aquifer. Ideally all permits should be appraised by a hydrogeologist.

The City of Paramaribo and the District of Surinam should integrate long range plans for water supplies. These plans should allow for a common source area to the south, probably in the vicinity of Rijsdijkweg.

VI.1.3. WATER SUPPLY

Generally the technical recommendations for water supply are in reference to methods and priorities.

Present methods of supplying and distributing community water are commendable as far as reliability, quantity and potability are concerned. Surinam community water supplies are safe, but limited in extent.

The use of Fordilla valves and metered services with the concurrent dimunition of public standpipe service reflects a progressive attitude in the part of government, and this should be encouraged.

The present approach to implementation of water supply systems through two governmental agencies (in which there is considerable duplication of effort in exploration, engineering and management) plus numerous other governmental, private and even military agencies must yield, however, to a unification of approach as well as control. The management aspects of this situation are discussed later.

Duplication of engineering efforts such as investigations, drilling, design and construction lead not only to increased costs but to actual interference of programs if allowed to progress to that point.

As far as the construction program envisaged as a result of this UNDP (SF) project is concerned, unless positive measures are taken to consolidate engineering procedures, completion of proposed projects will undoubtedly fall behind in some areas with the result that new projects will be idle or underemployed because one or more elements of the whole effort is lacking.

The constant need for adequate training and for worthwhile research can be met efficiently only when an organization has the size and facility to support such programs. While some of this has been done in the existing water supply agencies as well as through the UNDP (SF) project fellowships, "on-the-job" training, and test programs, the need remains for accelerated programs to be developed in those areas through concerted efforts following amalgamation of the water supply agencies.

A combined effort will also be needed as far as implementation of physical systems is concerned. The practice of providing water supplies in only the more densely populated areas, while the smaller rural areas are not similarly provided, stifles development and encourages greater influx of population into already crowded areas.

Also, as discussed in the hydrogeological sections of this report, a continuing un-coordinated approach to ground water exploitation may lead to serious consequences.

VI.1.4. SEWERAGE

While only preliminary designs have been investigated at this stage of project life, it appears that the construction of piped sewages collection systems and central facilities will be limited to a minimum number of areas outside the present areas of population concentration. Most development is of the "ribbon" type, and this makes for long mains with few connections, an exceedingly expensive procedure. However, Nieuw Nickerie for example, in the Group II areas should provide an opportunity to incorporate a grid system of sewers, and this will be given close consideration.

It would appear then, that most of the domestic sewage would be handled through septic tank installations. This will require detailed investigations, including studies covering evapotranspiration or transvap systems.

In addition, if possible, a program establishing appropriate methods of latrine design and construction will be developed.

For the peripheral area surrounding Paramaribo, the inclusion of this area into a metropolitan sewer service would be the most practical solution to sewage disposal problems. This, however, cannot be considered feasible because the extent of the studies by the consulting engineers firm which was engaged for solution of Paramaribo's problems is still not known. The UNDP (SF) project cannot add the Paramaribo system investigation to the present project work load since staff is not available for this effort.

It would be conceivable to consider this aspect of Paramaribo sewerage as an extension to the UNDP (SF) project should Government decide that further study is necessary.

VI.1.4. MANAGEMENT AND ORGANIZATION

Studies which have been made thus far indicate that the development of an autonomous agency, in the form of a corporate entity named : Surinam Water and Sewerage Corporation or similar designation, would best serve the purpose of development and operation of water and sewerage systems on a national basis in order to bring about a permanent, long-range solution to water and sewerage problems for the communities of Surinam.

Autonomy is necessary in order to develop self-sufficiency and flexibility in financing, constructing, and administering water and severage projects.

It can be considered inevitable that the city of Paramaribo would incorporate under a municipal form of government in the future. Traditionally, city governments operate their own water supply and sewage utilities. If this occurs prior to the formation of an autonomous water and sewage agency the probability of including the Paramaribo systems in a national organization would be remote under those circumstances.

The immediate task of the government of Surinam then, is to develop and expand water facilities and to develop sewerage work on a national and self-supporting basis. The long range aim would be to include water resources development and control.

It is hoped that the Executing Agency will be able to discharge its responsibility for the preparation of recommendations covering identificationor strenghthening of the legislation, management, operation and financial practices in order for the government to achieve the goal of forming an autonomous agency which will operate as a business enterprise combining managerial skills and engineering expertise.

(Section 2 - Project Administration Recommendations)

VI.2.1. GENERAL

While overall progress in the project has generally been satisfactory it appears that, because of staff shortages in both international and national staff categories, the overall objectives of the project will not be met to the degree originally delineated in the Project Activity Plan.

Requests for the above staff have been submitted and discussed frequently with the Executing Agency and with the government, respectively. While no definite results have materialized at this writing, it is hoped that the situation will improve prior to the end of the project.

As far as international staff assignment to the project is concerned, at the beginning of March, 1971, a total of 66 "expert" man-months was to have been provided in the project. In actual, fact, a total of 48 man-months was provided (the total of 66 man-months is based on the conformed Plan of Operations and not on the proposed revised Plan of Operations). Thus there is a total shortage of 18 man-months of international staff at the mid-point in the project life.

VI.2.2. HYDROGEOLOGICAL INVESTIGATIONS

Except for a very brief period in the beginning of the project, this element of the project has not had the geological counterpart staff originally proposed in the Request, P.A.M. report and Plan of Operation. With but one technical supervisor and the part-time services of one engineer, the training of professional counterpart staff will not take place. In addition, the two fellowships allocated to the Participating Agency for professional training purposes will not be filled because of the lack of qualified candidates. This, of course, limits the development of a continuing groundwater exploration program subsequent to the end of the UNDP (SF) project.

Provision of counterpartpart staff in this category by government would, therefore, serve a valuable purpose.

It would appear that, within the allotted project timing, the groundwater exploration program will adequately cover the hydrogeological aspects in the project, providing a fairly comprehensive picture of the groundwater conditions which obtain in the project area.

VI.2.3. WATER SUPPLY

A review of the Project Activity Plan shows that, in some respects the targets have not been met. For example, investigation of the sources and requirements to supply Group II systems have only received very preliminary attention, but should, in fact, be nearing the preliminary design stage. The feasibility studies for all supply Group I systems were to be complete by this date, but only one feasibility study was complete - with the other two only in process.

Because the two sanitary engineers in the project had to concentrate on sewerage as well as water supply investigation for Group II and III communities, construction and investment, and the management studies, the above aspects are behind schedule. This is discussed further in the following paragraphs.

Government counterpart staff has been provided in depth in this category, but replacement staff must be assigned during forthcoming fellowships.

No international staff candidate for the hydrology consultantship has been nominated at this writing. The STC for biological filtration suggested by the field staff has not accepted the consultantship for administrative reasons.

VI.2.4. SEWERAGE SYSTEMS

It had been anticipated that a waste water engineer would be assigned to the project by this writing, but this has not transpired.

As the Project Activity [illegible] unless the waste water engineer is provided, the incumbent staff will be required to continue dividing its efforts. (Preliminary designs for group I systems were scheduled for completion as of 1 May, 1971). No candidate has been nominated at this writing.

VI.2.5. <u>CONSTRUCTION AND INVESTMENT PROGRAMS</u>

As mentioned earlier the feasibility studies have not been completed according to schedule. While this has penalized government in its seeking financial assistance, the feasibility studies assist government in its own fiscal deliberations and should, therefore, be available according to schedule.

It will be possible to finalize the feasibility studies if all the additional international staff shown in the Plan of Operation is provided even at this late date.

VI.2.6. <u>MANAGEMENT AND ORGANIZATION STUDIES</u>

The category of the management and organization studies is considerably behind schedule. It had been planned by the Project Manager to initiate the studies as early as February, 1970 on a continuing basis involving at least 6 man-months of STC effort, with further assignments totalling an additional 6 to 10 months. However, only 3 weeks of consultantship has been provided, placing a burden on incumbent field staff.

Should government require assistance to develop the legislative and administrative means to achieve autonomy in the water supply and sewage utilities the project staff would be hard put to provide such assistance. Management proposals were prepared in brief reports by the STC and the project manager but these are not sufficient in the depth and scope required to fit the complexities of a complete shift to autonomy. The legislative recommendations, also, are only preliminary, while according to the Project

Activity Plan these should have been finalized by March, 1971.

No candidates for the 12 man-months of consultantship have been nominated at this writing.

VI.2.7. TRAINING

One three-months fellowship in groundwater techniques has been implemented by the Executing Agency. Applications for two further fellowships of 9-months each in water and waste water technical training have been submitted to the Executing Agency fellowships unit.

Implementation of the fellowships through the Participating Agency will depend upon the availability of suitable candidates.

PURE WATER SUPPLY IN GUYANA

by

BHOJ ROOPNARINE & SALEEM ISRAEL
GUYANA WATER AUTHORITY

Paper presented at the Seventh Annual Conference
of Caribbean Water Engineers
Georgetown, Guyana
July 26 - 28, 1976

G U Y A N A

1.1 Geographic Location

The Cooperative Republic of Guyana is situated on the Northern Coast of South America, bounded on the north and southeast by the Atlantic Ocean, on the East by Surinam, on the South by Brazil, and on the West by Brazil and Venezuela within the coordinates 1° and 9° North Latitude and 57° and 61° West longitude (Figure 1). Its area is 83,000 square miles.

1.2 Political Sub-divisions

Guyana is divided into the three counties of, Berbice, Demerara and Essequibo the boundaries of which generally coincide those of the drainage basins of the main rivers by the same names. Berbice, the easternmost country, includes the drainage areas of the Berbice and Canje Rivers and the western tributary of Corentyne River.

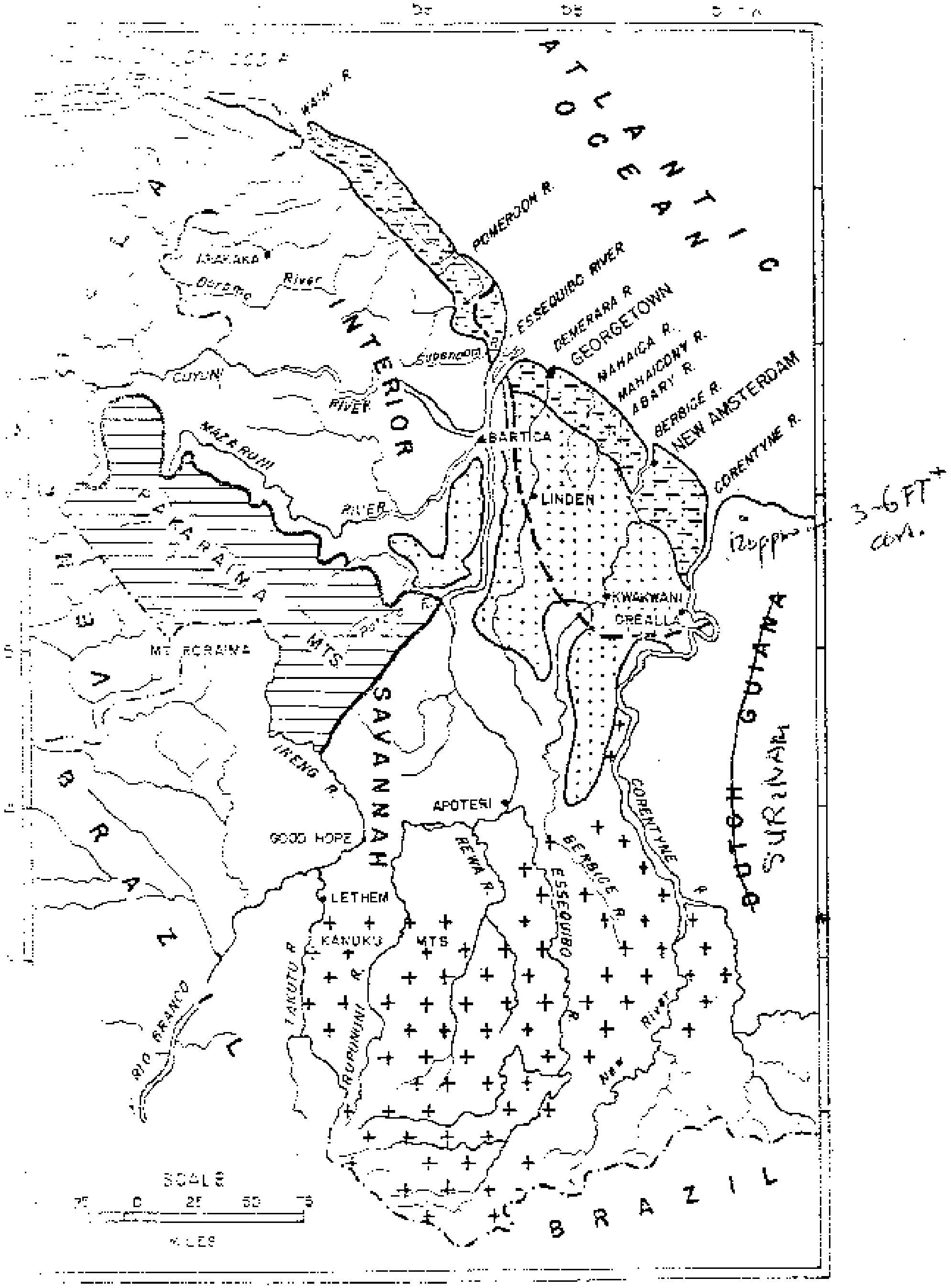
The county of Demerara includes the drainage areas of Mahaica, Mahaicony and Abary rivers in addition to that of the Demerara. It contains Georgetown, the capital, situated at the mouth of the Demerara River.

Essequibo, the largest of the three counties, includes the drainage areas of the Essequibo and the other coastal rivers to its west, the Pomeroon, Waini and Barima.

1.3 Physical Features

The country can be divided into four regions (Figure 1)

a) The Coastal Plain: Comprising mainly of two units, that is, the Coastal Plain proper and the White Sand Series.
The Coastal Plain proper varies in width from 5 to 50 miles and stretches along the entire Atlantic foreshore. The deposits of Demerara Clay are Pleistocene to subrecent sediments.



LEGEND

Young Sediments } COASTAL PLAINS SEDIMENT

White Sand Formation

PLATEAU COUNTRY

MOUNTAINOUS AREA OF BASEMENT COMPLEX

APPROXIMATE BOUNDARY OF COASTAL ARTESIAN BASIN

MAP OF

MAJOR PHYSIOGRAPHICAL GROUPS

GUYANA

of the Intermediate Clays.

1.3.4. Alternating Sands and Clays

Underlying the 'A' Sands is a Series of alternating sands and clays, but since most of the boreholes do not penetrate this unit, data concerning its nature are scarce. However, recent boreholes tend to suggest that this layer varies in thickness from about 200 to 400 feet in the Georgetown area to about 500 to 900 feet in the east-southeast of the Berbice River.

1.3.5. 'B' Sands: Information from deep oil well boreholes and water wells near Georgetown indicate the existence of a lower aquifer the 'B' Sands within the alternating sands and clays, The depth, so far as is known, seems to be approximately 1300 feet near Georgetown, 1700 feet in Mahaicony, and 2600 feet at Rose Hall Canje (just East of the Berbice River). The thickness of the aquifer averages a minimum of 100 feet. The 'B' Sands is non-existent west of the Demerara River.

1.3.6. Basement Complex: Underlying the 'B' Sands is a basement complex which outcrops in an arculate fashion, that is, close to the Atlantic Shore in the North-West, Bartica on the Essequibo Coast, Mackenzie on the Demerara River, Kwakwani on the Berbice River and just south of Orealla on the Corentyne River (Figure 1). From offshore oil drillings and seismic survey, there are indications that the basement complex is basin shaped, the greatest thickness of sediments being approximately 6000 feet near the mouth of the Berbice River. A geologic cross section of the Coastal Basin is shown in Figure 2.

1.4 Hydrology of the Coastal Aquifers

The Coastal artesian Basin occupies a total surface area of 7500 square miles, and the sediments achieve a maximum thickness of 6000 feet onshore increasing to about 16,000 feet at a distance of 90 miles offshore. The sediments are known to contain three main aquifers. The shallowest of these, the Upper Sands, is not much used because of the high iron content (more than 5 mg/l) and salinity (up to 1200 mg/l).

Between 1862 and 1867 the first steam powered pumping station and distribution system was completed. No treatment of the water was done at this stage.

This system of canals was later found to be ineffective during periods of low rainfall since the canals dried up. In 1877, William Russell started empoldering works on several creeks southeast of Georgetown including the Lamaha Creek. The object was to provide a storage reservoir to supply the needs of irrigation, navigation and the water needs of the City of Georgetown . This reservoir has since been widened and deepened to form the East Demerara Water Conservancy, which now supplies the Georgetown Water Works with surface water to meet the demands of Georgetown.

Due to a serious drought in 1911 - 1912 which cause a water shortage in Georgetown, an alternative source had to be ascertained.

In 1913, a well was dug which led to the discovery of the "A" Sands Aquifer at a depth of about 561 feet below ground surface. By 1918, 28 wells were sunk but because of the corrosive nature of the water the screens in the wells started to block. This caused a suspension of drilling during the period 1919 - 1925. After 1925 several wells were dug using various materials but it was not until 1930 that an asbestos cement pipe with cemented ceramic slotted buttons was developed and used successfully. At around this time also, a new water division was formed - Pure Water Supply Division. The main responsibility of this division was to drill wells in the rural areas. This division later developed into one of the main water agency in Guyana responsible for development, operation and maintainance of over 134 wells along the coast of Guyana.

While the water supply situation in rural areas improved, the Georgetown system continued to develop with the establishment of a water treatment facility (1948 - 1950). The final stage of this facility was completed during 1955/1956 with a total capacity of 10 million gallons per day.

Another water treatment plant in the bauxite township of Mackenzie (Linden) was put into service in 1953 by the then Demerara Bauxite Company (Demba).

g) To advise the Minister assigned responsibility for the Authority on matters relating to the collection, production, transmission, treatment storage, supply and distribution of water, and to the treatment and disposal of sewage;

h) To perform such other functions, not inconsistent with this Act, as may be assigned to them, from time to time, by the Minister assigned responsibility for the Authority;

i) To carry on such other activities as may appear to the Authority, advantageous or conducive for or in connection with the performance of their functions under this Act.

With the enactment of the Guyana Water Authority Act 1972, GUYWA took control of responsibility of water services and sewage services or either which were provided by the Pure Water Supply Division of the Ministry of Work & Hydraulics. The Pure Water Supply Division started out with responsibility of drilling wells in rural areas in 1930. This division served all water supply systems in villages classified as Local Authorities and unorganised areas which fall outside the responsibility of the other agencies. Development of water systems in the interior districts was also handled by this Division.

The S.I.L.W.F. is one of three funds established by British Law (Sugar Industry Special Fund Ordinance, Chapter 248). The purpose of this fund is to provide money to meet the cost of improvement of the Welfare of Sugar Workers. Part of this fund covers the establishment of pure water supply system in Extra Nuclear Housing Areas also established under the S.I.L.W.F. The fund does not operate a regular maintainance organisation since the maintainance works in the Extra Nuclear Housing Areas are delegated to, and carried out by, the respective sugar estate management.

The Georgetown Sewage and Water Commissioners and the City Council of New Amsterdam are responsible for the development, operation and maintainance of the water supply system in their respective townships.

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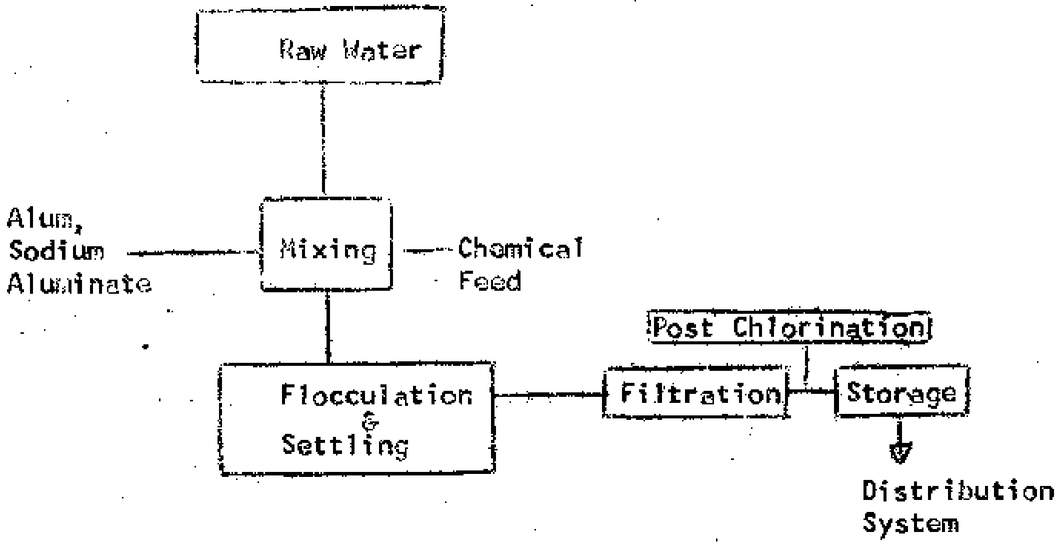
welfare fund

At the surface water plants at Georgetown, Linden and Wismar, the raw water is treated as follows:-



induce water from river or stream via 'P' or 'B' sand

In the Interior, the source of water is mainly streams, creeks and rivers, except in the Rupununi Savannahs where shallow wells to depths of 40 to 80 feet are dug to supply the small scattered communities. The main Hinterland areas served with surface water are Mabaruma/Hosororo/Barabina, Matthew's Ridge and Papaya in the North West and Tumatumari in the Mazaruni/Pataro Region. The water from these Hinterland streams are generally free of sediments, except during very heavy rainfall and the only treatment afforded is chlorination. At Lethem in the Rupununi, water from 4 wells (average depth 55 ft.) supply some 57,000 G.P.D., and supplementary water is obtained from a River.

In all of these interior areas, the water is pumped from the source chlorinated, and stored in an overhead tank which supplies water to the consumers under gravity.

Priority Area I B — Includes the Linden/Wismar/Christenburg areas upper Demerara River.

Priority Area II — Includes the coastal strip of villages from Non Pariel at the easterly limits to Ithaca on the east bank of the Berbice River taking in villages along the Mahaica, Mahaicony and Abary Rivers.

Priority Area III — Comprises the West Bank of the Demerara River, the West Demerara area and the east bank of the Essequibo River.

Priority Area lV — Comprises the area east of priority area I to Crabwood Creek and includes Black Bush Polder.

Priority Area V — Comprises the islands of Leguan and Wakenaam and the villages on west bank of Essequibo River and villages on the Atlantic Coast of the Essequibo District.

4.2 Project Background Feasibility Study Area "A"

The Consultant James M. Montgomery Consulting Engineers Inc., entered into an agreement with the Government of Guyana for investigation of water supply conditions and study of the feasibility of the project, as outlined earlier in May 11, 1968.

On June 14, 1968 the feasibility report, completed and transmitted to the Government of Guyana revealed that a comprehensive water supply improvement project was economically based on the Consultant recommendations, the Government of Guyana obtained financing of the U.S. Dollar component of the cost of the project in the sum of U.S.$2,600,000. In addition, the Government of Guyana allocated a local fund equivalent to US$1,220,000 (G$2,440,000) On August 28, 1968 the Government of Guyana entered into an agreement with James M. Montgomery, Consulting Engineers for consulting engineering services, including design of new facilities, supervision of rehabilitation of existing distribution systems, and supervision of construction of new facilities.

During the first seventeen months of the project an extensive rehabilitation programme of existing pipelines was undertaken.

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This first priority project was not void of delay problems. The cost and duration of the project substantially exceeded projections, which resulted from a combination of interrelated causes principally.

(i) Changes in the scope of work;

(ii) Worldwide inflation;

(iii) Administrative delays in review of contract documents, execution of contracts and opening of letters of credit and

(iv) Failure of contractors employed to complete their work on time for various unrelated reasons.

The Facilities provided under this project were designed to meet water demands through 1975. At the present, the demand exceeds the supply and efforts are now in train to expand on the core facilities provided under the contract. The problem of some of the distribution main existing prior to the start of the project are still plagued by excess leakage. Efforts to upgrade these are being intensified but availability of finance restricts the extent of this rehabilitation. With the installation of water meters in this project area starting in the next three to four months, it is hoped that consumer wastage will be cut thereby reducing the present 100 gallons per capital per day consumption to about 80 gallons per caiptal per day.

Figures 4, 5 and 6 show the area covered by Project Priority A and location of new facility.

Figure 7 and 8 show the treatment provided for "A" Sand and "B" Sand Facilities.

4.3 Project Background Feasibility Priority Area 1A and 2

Due to delays in completing Priority Area A, the feasibility for Priority area 1A fell behind schedule. In order to provide for lapse in schedule, priority areas 1A and 2 have been combined into one feasibility area.

Advantages to be gained include:

1. Reduced drawdown - and therfore pumping costs will drop - because water would be taken in reduced quantities from each aquifer;
2. Reduced treatment costs - filtration not required;
3. Enhanced flexibility of operations if utilizations of acquifer is later dicated by local hydrogeologic and water quality conditions

Alternative II is similar to those plants constructed in Priority Area A with the exception that (a) Standby wells with pump and diesel drive will be provided and (b) elevated storage located within production facility.

The capital and operating cost for Alternative 2 will be higher than Alternative I. Alternative 3 was submitted since the quality of water from the "A" Aquifer does no harm to health once adequate pressures is maintained in the system.

The project area has also been divided to provide nine distinct systems with a three-stage development costing approxima tely US$24.2 million for stage 1 and 2 and the 3rd stage US$ 10 million to be developed during 1980 - 1990.

4.4 <u>Project Background Priority Area 1 - B</u>

The Feasibility for this area covers the communities of Linden - Wismar, Christainburg on the Upper Demerara River. It was intiated by the Local Authority in collaboration with the Demerara Bauxite Co. (DEMBA) now the Guyana Bauxite Co. (GUYBAU).

The Feasibility was completed in March, 1969 and the scope was to examine and report on the technical and economic feasibility and the viability of a new, integrated pure water system to replace the existing systems at Linden and Wismar.

The main recommendations that a completely new water system be designed and constructed and that the present distribution system be rehabilitated and new lines laid in new development areawithout cost to consumers. It was found that the existing systems are

4.6 U.N.D.P. Study

Apart from its commitment under the Water Supply Improvement Project, the Government of Guyana in June 1971 requested the assistance from United Nation Development Programme for a mission to study the needs for improvement of sanitation and water supply. A mission was set up in July, 1971 and completed its assignment in August, 1971. On the recommendations submitted, the Government of Guyana further requested assistance to carry out

(i) A Sector study in the field of water supply and sewerage on a material scale;

(ii) to conduct technical -economic feasibility studies for the sewerage and storm drainage systems of Georgetown, New Amsterdam and Linden and for extensions and improvements in the water supply of Greater Georgetown, including a leak detection study and leakage survey;

(iii) To provide technical assistance in management, administration, operation and finance to the Guyana Water Authority;

(iv) To conduct a programme of training of local specialist staff through the provision of fellowships for advanced training of professional personnel in specialized fields, as well as in-service and on the job training to various professional and sub-professional categories.

All activities listed above have been completed by the U.N.D.P. Team and the Project Finding and Recommendations submitted to the Government of Guyana.

The feasibility study for Improvement to the Georgetown Water Supply System was carried out by a sub-contractor to U.N.D.P. and works started in July, 1973. The Study, which was to be completed within 18 months, was completed in December, 1975 due mainly to initial delays and changes necessary during the Project.

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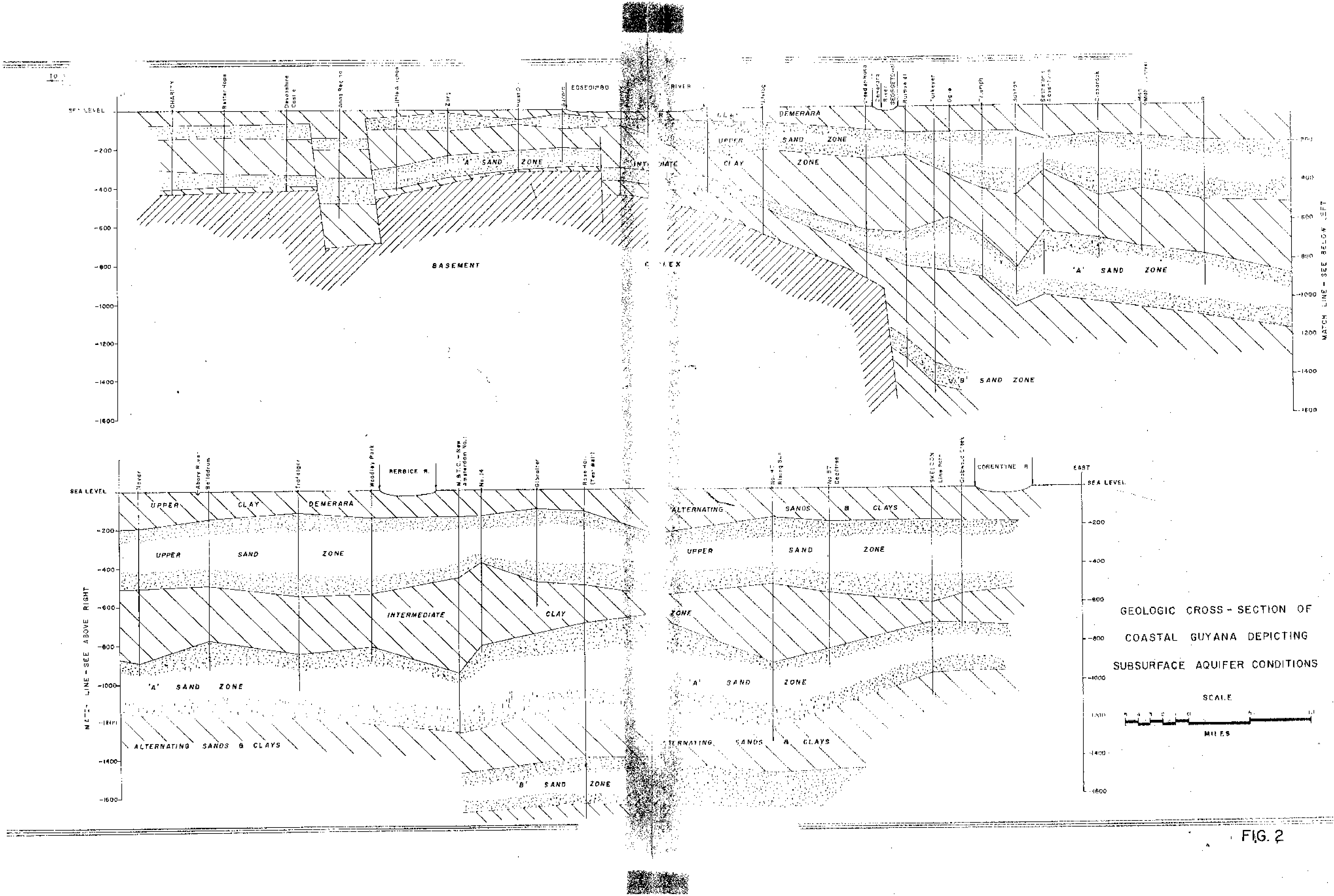
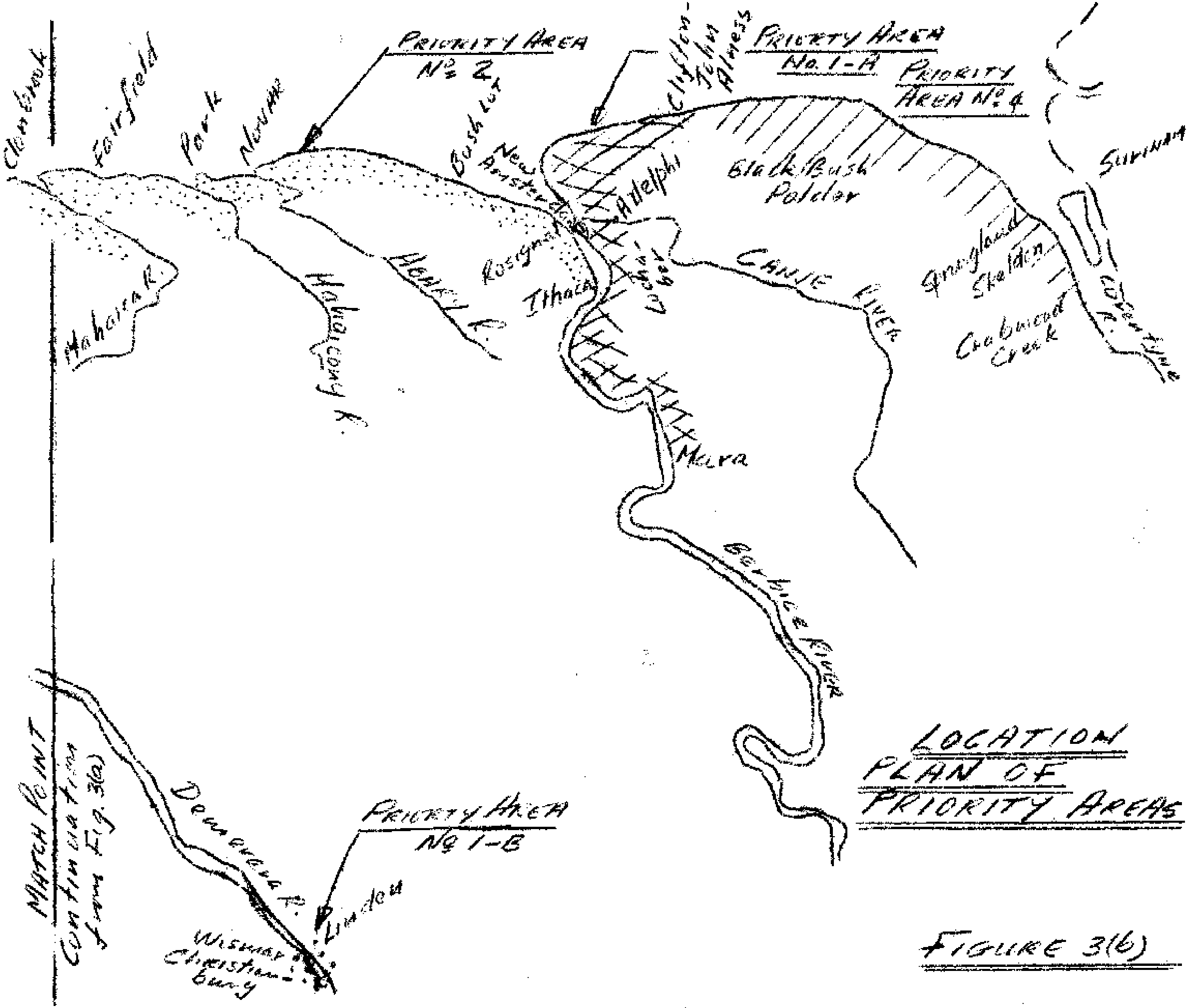
During the next few weeks, a course will be mounted for Pipe Fitters and will be financed by U.N.I.C.E.F.

Plans are now being made to mount a second Course in Public Health Engineering at the University of Guyana during 1977 - 1978 to provide the Authority with additional engineers. It is hoped that Caribbean participation will be possible. GUYWA also intends sending its Engineers for post-graduate training in Sanitary Engineering, Water Resources Management, Groundwater Development and related areas.



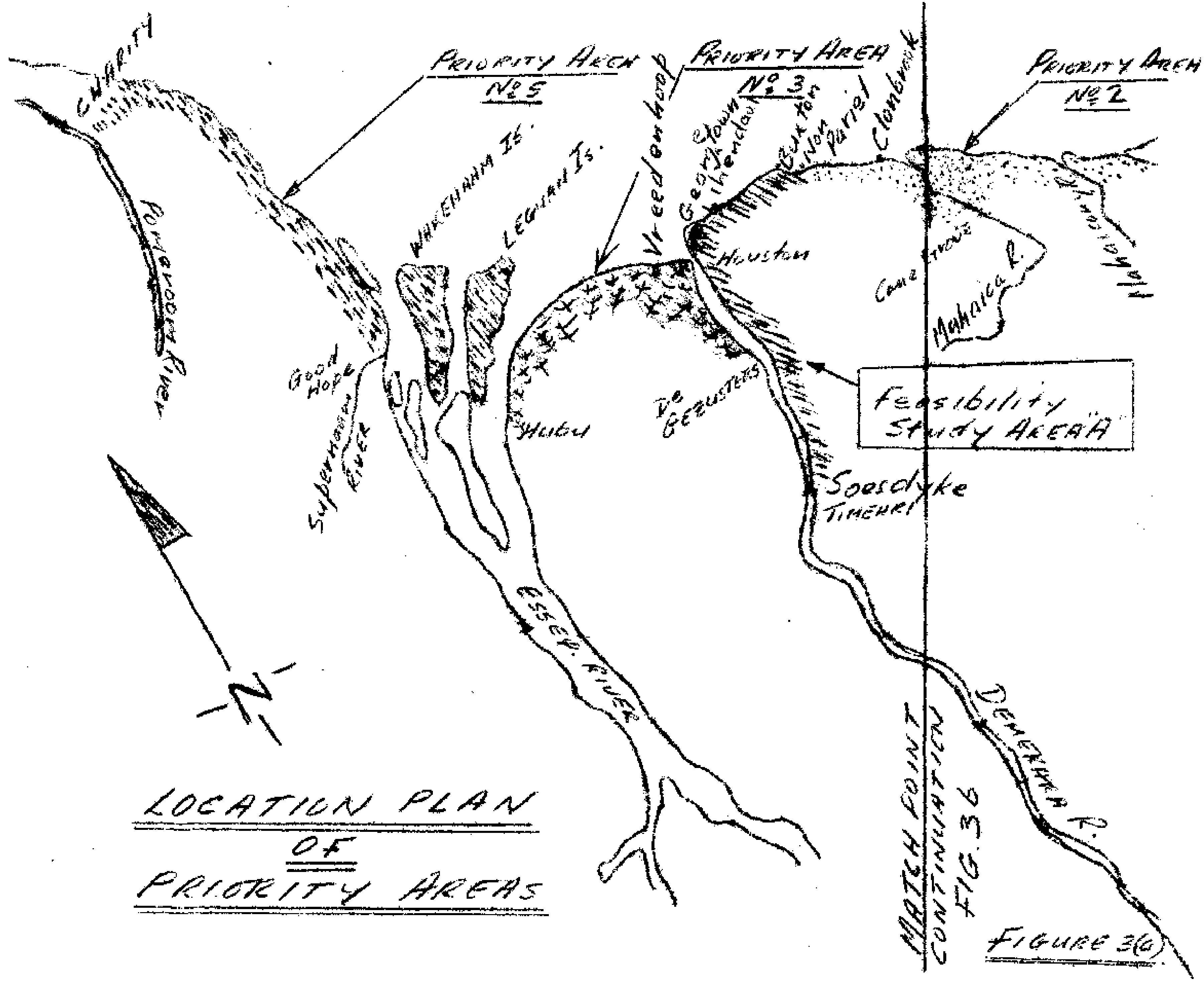
GEOLOGIC CROSS-SECTION OF COASTAL GUYANA DEPICTING SUBSURFACE AQUIFER CONDITIONS

FIG. 2



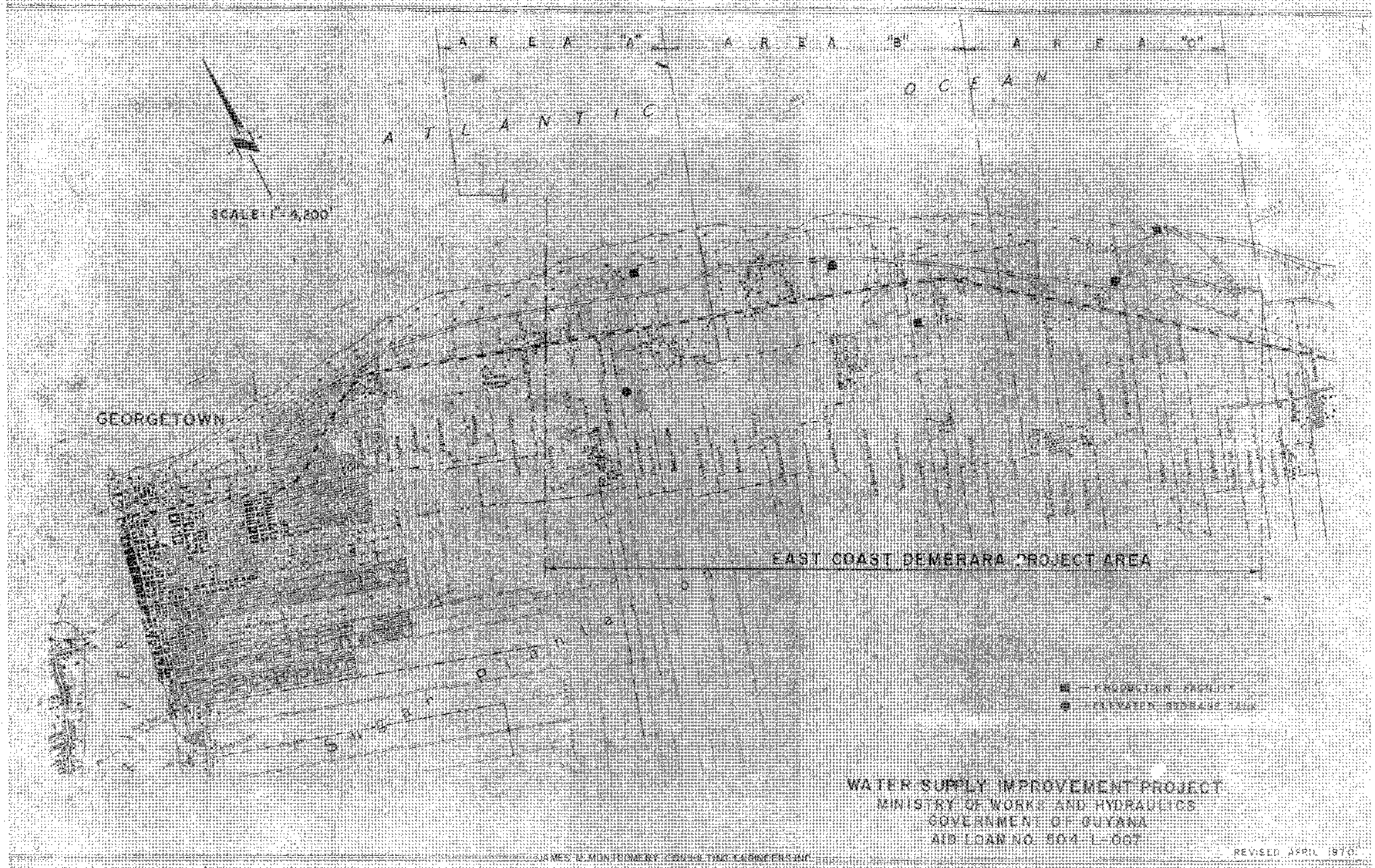
LOCATION PLAN OF PRIORITY AREAS

FIGURE 3(b)



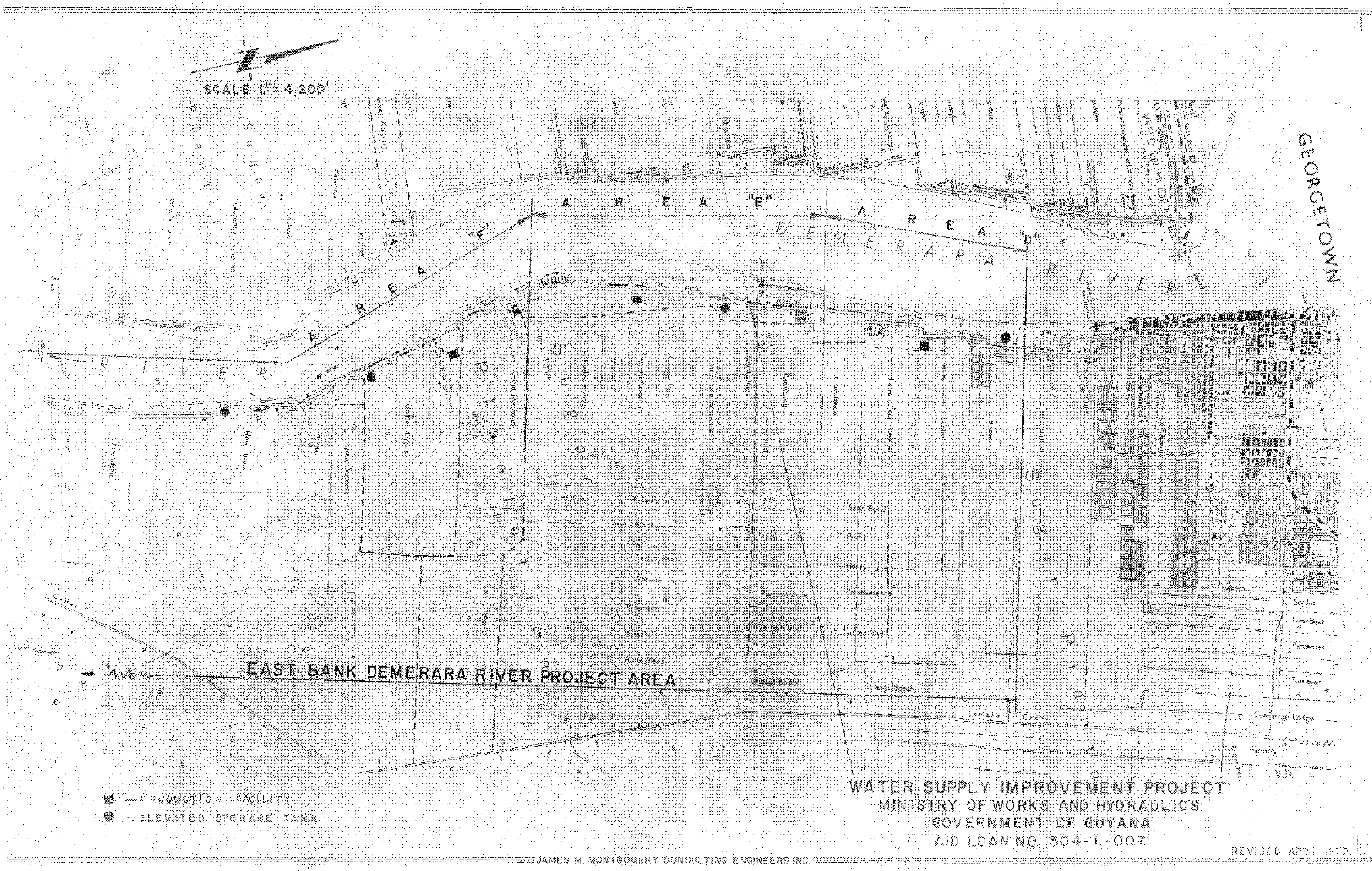
LOCATION PLAN OF PRIORITY AREAS

FIGURE 3(G)



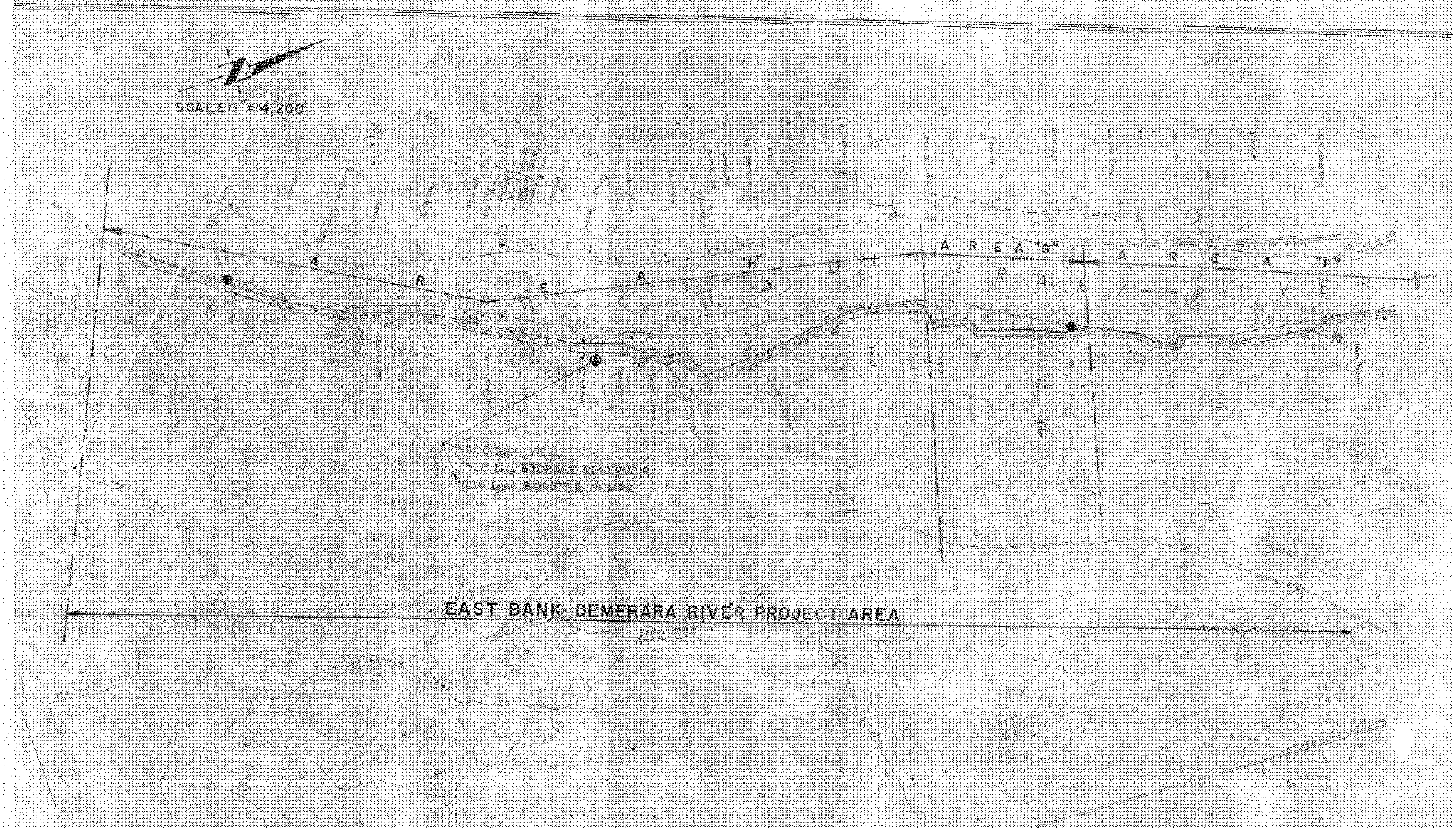
AREA "A"
AREA "B"
AREA "C"
ATLANTIC OCEAN
SCALE: 1" = 4,200'
GEORGETOWN
EAST COAST DEMERARA PROJECT AREA
PRODUCTION FACILITY
ELEVATED STORAGE TANK
WATER SUPPLY IMPROVEMENT PROJECT
MINISTRY OF WORKS AND HYDRAULICS
GOVERNMENT OF GUYANA
AID LOAN NO. 504-L-007
JAMES M. MONTGOMERY CONSULTING ENGINEERS INC.
REVISED APRIL 1970

FIG 4



WATER SUPPLY IMPROVEMENT PROJECT
MINISTRY OF WORKS AND HYDRAULICS
GOVERNMENT OF GUYANA
AID LOAN NO. 504-L-007

FIG. 5



— PRODUCTION FACILITY

— ELEVATED STORAGE TANK

WATER SUPPLY IMPROVEMENT PROJECT
MINISTRY OF WORKS AND HYDRAULICS
GOVERNMENT OF GUYANA
AID LOAN NO. 504-L-007

JAMES M. MONTGOMERY, CONSULTING ENGINEERS, INC.

REVISED APRIL 1970

FIG. 6

SCHEMATIC PROFILE – PRODUCTION FACILITIES
"A" SAND FACILITIES

PRODUCTION FACILITIES SITE		ELEV. TANK SITE
① Eccles	AREA "D"	AGRICOLA
② COVENT GARDENS	AREA "E"	HERSTELLING
③ GOLDEN GROVE	AREA "F"	GOLDEN GROVE/ NEW HOPE
④ FRIEDSHIP, EAST COAST, DEMERARA	AREA C	ANNANDALE

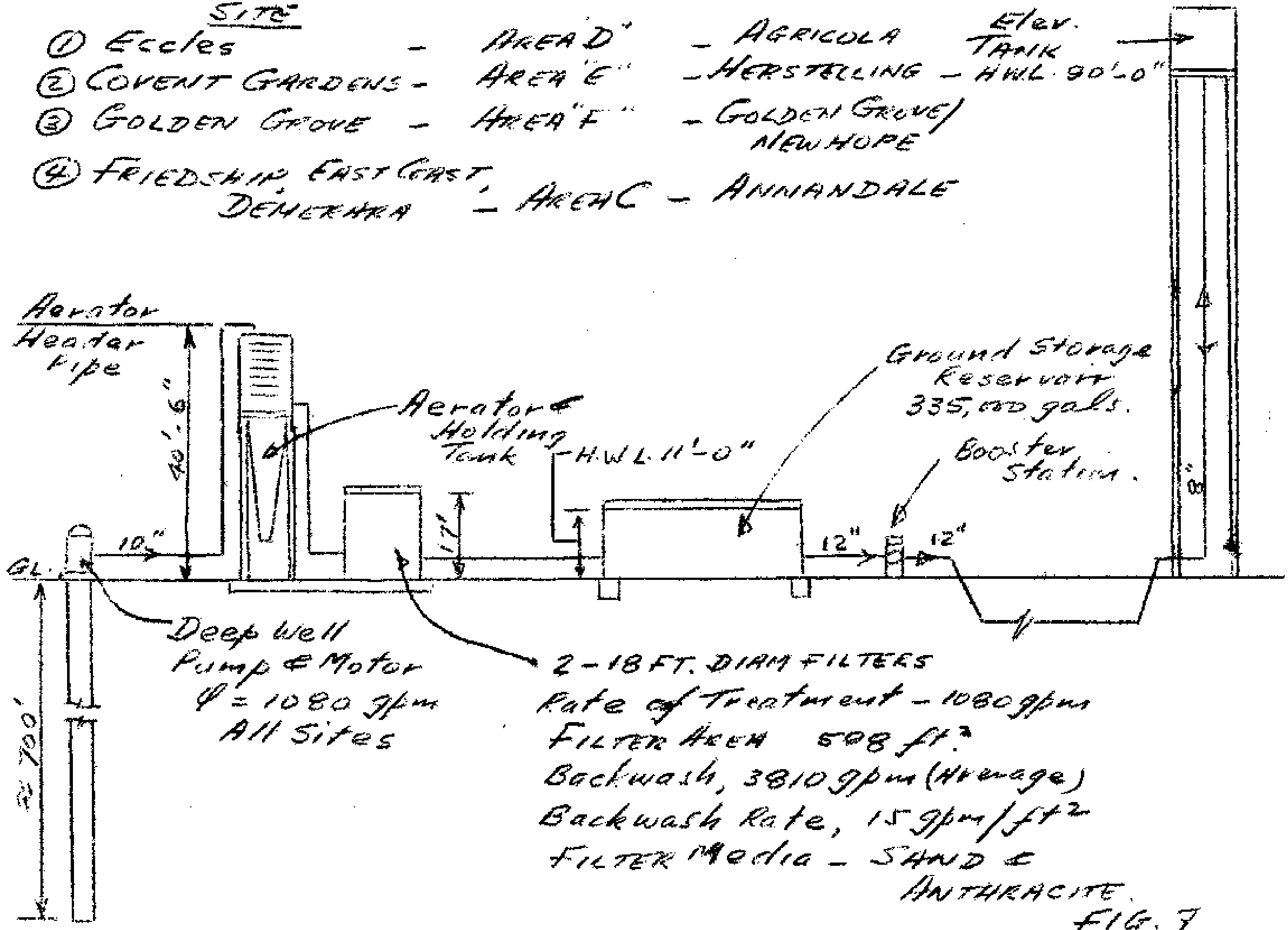


FIG. 7

Schematic Profile – Production Facilities

"B" Sand Facilities

Production Facilities Site

1. Better Hope
2. Mon Repos

Elev. Tank Site

- Area A – Sparendaam
- Area B – La Bonne Intention

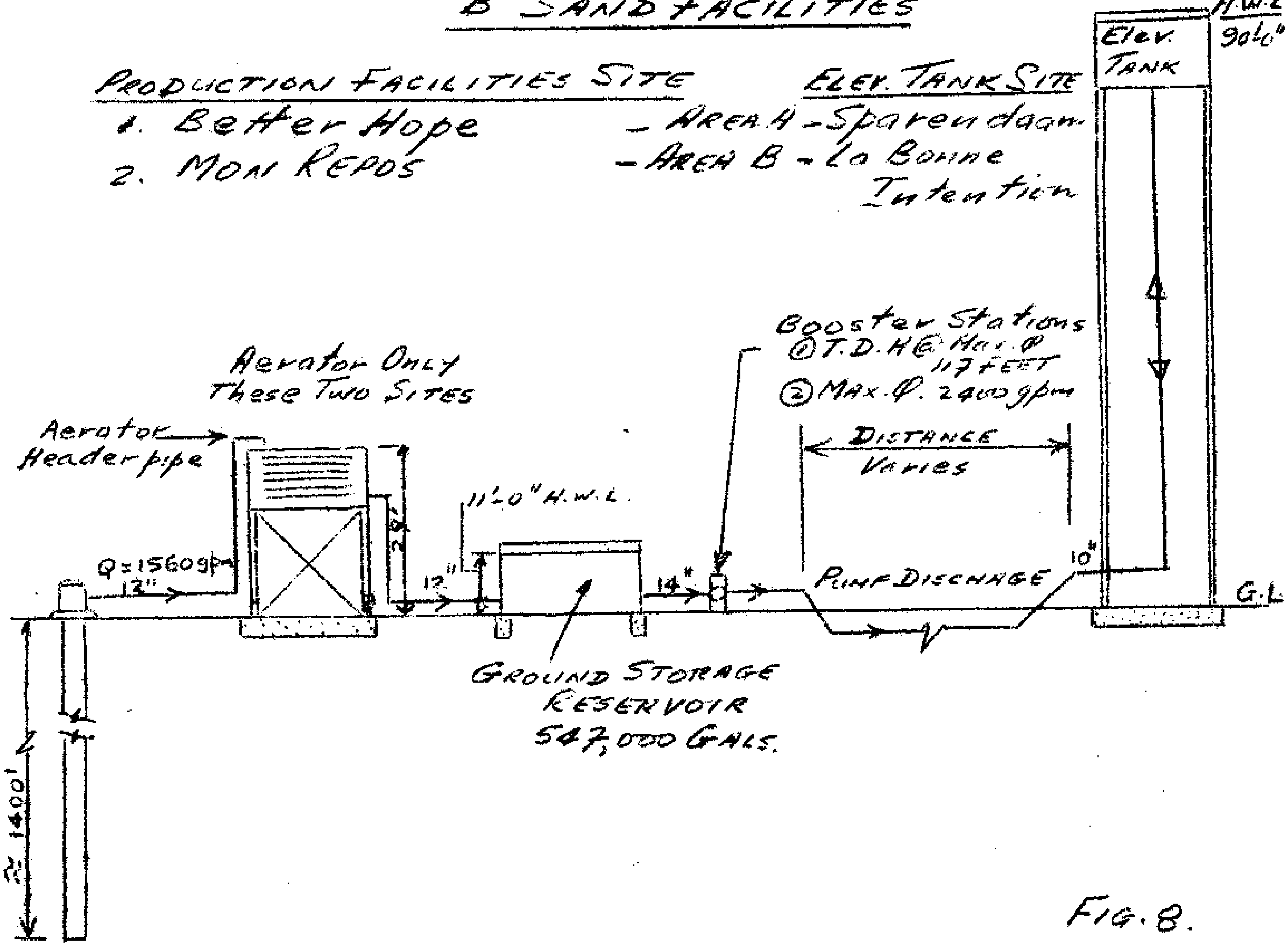


Fig. 8.