THE REPUBLIC OF HAUTE-VOLTA
SURVEY REPORT
ON
ROAD AND CITY PLANNING
RELATED TO
THE TAMBAO MANGANESE MINE PROJECT

NOVEMBER 1976

JAPAN INTERNATIONAL COOPERATION AGENCY

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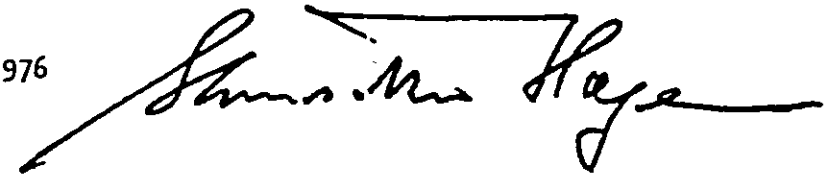
P R E F A C E

The Government of Japan sent a mission to the Republic of Haute-Volta in March 1976 to conduct a survey for the study of necessary facilities related to the development of Tambao Manganese Mine. The six-member mission, headed by Prof. Hiroo Takagiwa, made a trip to Haute-Volta for 25 days from March 6 to 30, during which time the survey was conducted according to schedule with the cooperation of l'Office Général des Projets de Tambao (the General Office for the Tambao Project) and other interested organizations of the Haute-Voltaic Government. After returning to Japan the mission studied in detail the data collected in Haute-Volta and formulated township and road plans also on the basis of the results of the survey.

This report describes the results of technical and economic studies made with respect to the construction of various facilities in the township of Tambao where a manganese mine is to be developed, and to the improvement of the trunk road between Dori and Tambao. It is sincerely hoped that this report will be of help to the Tambao mine development project.

The Japan International Cooperation Agency wishes to acknowledge, on behalf of the members of the mission, the generous cooperation and assistance extended to the mission by the Government of Haute-Volta and the Japanese Embassy in Côte d'Ivoire.

November 1976



Shinsaku Hogen
President
Japan International Cooperation Agency

C O N T E N T S

CHAPTER 1

INTRODUCTION

1-1 Background of Present Surveys

For the development of the manganese mine located in the Tambao district of the Republic of Haute-Volta, the Government of the Republic, and four corporations of Japan, West Germany, the United States of America and France have jointly invested in and established a local company, Société Minière de Tambao (abbreviated as SOMITAM), which is carrying out exploration work for preparing a detailed development plan.

The district of Tambao, located in a remote northern corner of the country, is one of the undeveloped regions. In developing the mine, construction and improvement of various related facilities are necessary, and surveys for this purpose should be made in parallel with the exploration work.

Tambao Manganese Mine Development Co., Ltd. (or TAMCO), the company for financing SOMITAM from Japan, requested the Japan International Cooperation Agency for surveys of a construction and improvement plan for related facilities.

The Government of Japan and the Japan International Cooperation Agency studied the proposition and dispatched this survey team, obtaining the approval of the Government of the Republic of Haute-Volta.

1-2 Object of Surveys

Out of the related facilities to be needed for the mine development, construction of an about 350km long railroad between Ouagadougou and Tambao, which has been the greatest problem in realizing the project, water supply by drawing water from the Beri River and piping it to the mine, and setting up shipping facilities at Abidjan port, will be arranged by the Government of Haute-Volta.

The object of the surveys was to make technological and economic studies of the road and township facilities, among the other related facilities, and to study the development effects on surrounding areas. The contents of our surveys were as follows:

(a) Concerning township facilities
  i) Selection of a site for residential district
  ii) Basic planning of facilities
  iii) Calculation of construction costs
  iv) Investigation of development effects

(b) Concerning the road between Dori and Tambao
  i) Survey of the present conditions of existing road
  ii) Selection of route
  iii) Technical investigation of road improvement
  iv) Calculation of construction costs
  v) Investigation of development effects

I-3 Organization of Survey Team

The survey team was organized as follows:

Name	Duty	Affiliation
Hiroo Takagiwa (Leader)	Overall arrangement and development effects	International Development Center of Japan
Yasuo Koga	Regional development	Nittetsu Mining Consultants Co., Ltd.
Toyoo Horikawa	Road and township facilities	Nittetsu Mining Consultants Co., Ltd.
Masao Nakata	Road and township facilities	Mitsui Consultants Co., Ltd.
Kazuta Kawamura	Geology and price survey	Nittetsu Mining Consultants Co., Ltd.
Hironao Hagiwara	Business coordination	Mining & Industrial Planning and Survey Department, Japan International Cooperation Agency

I-4 Itinerary of Survey Team

The survey team departed from Japan on March 6, 1976, stayed in Haute-Volta and Cote d'Ivoire for a period of 21 days from March 8 to 28 and returned home on March 30, making the surveys according to the following schedule.

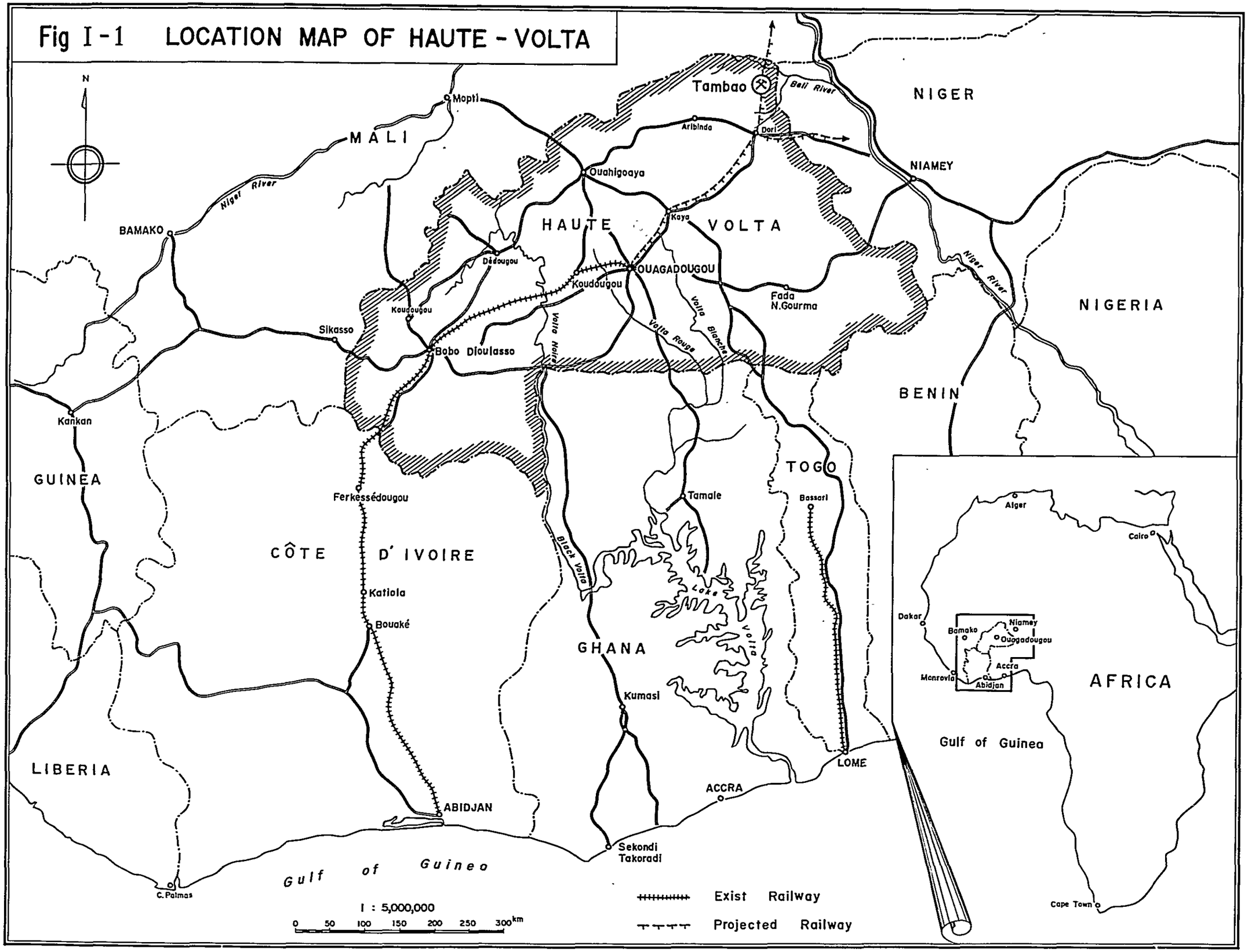
Itinerary of Survey Team

Date	Itinerary & Surveyed Matters	Place of Stay
March 6 (Sat.)	Left Tokyo (LH-659), arrived at Paris.	Paris
7 (Sun.)	Left Paris (UT-867).	Plane
8 (Mon.)	Arrived at Abidjan. Visited Japanese Embassy for courtesy call and discussion.	Abidjan
9 (Tues.)	Collected information at Abidjan Branch of Komatsu Mfg. Co. and SETAO, a contractor.	Abidjan
10 (Wed.)	Left Abidjan (RK-30), arrived at Ouagadougou. Obtained local information from Ouagadougou resident of Nittetsu Mining Co. Visited General Office of Tambao Project and decided items and time schedule of survey.	Ouagadougou
11 (Thurs.)	Paid courtesy calls on government agencies (Ministère du Plan; Ministère de la Justice; Ministère de Commerce, de Développement Industriel et des Mines; and Ministère des Finances). Had a conference with General Office of Tambao Project.	Ouagadougou
12 (Fri.)	Left Ouagadougou for Dori, then for Markoye. Visited Office of Sahel Dept. at Dori, accompanied by Director, General Office of Tambao Project.	Markoye
13 (Sat.)	Made field survey of Tambao mine area. Inspected Beri River, accompanied by Director, General Office of Tambao Project.	Markoye

March 14 (Sun.)	Inspected a dam site at Tin Akof and a limestone deposit at Tin Hrassan. Had discussion with Tambao residents of Nittetsu Mining Co. about development plan. Director, General Office of Tambao Project, returned to Ouagadougou.	Markoye
15 (Mon.)	Investigated data at Sahel Dept. Office. Surveyed road (Tambao - Markoye - Koiréziéna). Made survey around Tambao Mine.	Markoye
16 (Tues.)	Inspected schools, hospitals and other facilities at Gorom Gorom and Dori. Surveyed road (Koiréziéna - Dori). Inspected Dori airfield. Conferred with Tambao resident of Nittetsu Mining Co. about details of development plan.	Markoye
17 (Wed.)	Inspected Markoye airfield and Tambao airstrip.	Markoye
18 (Thurs.)	Left Markoye for Dori, then for Ouagadougou. Paid courtesy call on Sahel Dept. Office.	Ouagadougou
19 (Fri.)	Collected data from government agencies. Visited New Town of Cissin, Ouagadougou. Obtained information from the following contractors: U.D.E.L. U.T.P.A. Biraham Nacoolma O. Kanazoe	Ouagadougou
20 (Sat.)	Inspected a factory of Voltex Textile Co. at Koudougou.	Ouagadougou
21 (Sun.)	Arranged results of surveys.	Ouagadougou
22 (Mon.)	Made a report to General Office of Tambao Project. Collected data at PNUD and RAN.	Ouagadougou

March 23 (Tues.)	Collected data at Ministry of Planning. Visited U.S.A.I.O. Left Ouagadougou(RK-37) for Abidjan.	Abidjan
24 (Wed.)	Obtained information at Abidjan Port Authority. Inspected proposed site of a new port.	Abidjan
25 (Thurs.)	Visited Fougerolle, a construction company, to obtain information. Obtained information at Import, Export, Maritime-Aérién on customs procedures for imports and their railway transportation to Haute-Volta.	Abidjan
26 (Fri.)	Made a progress report of surveys to Japanese Embassy.	Abidjan
27 (Sat.)	Rearranged collected data.	Abidjan
28 (Sun.)	Left Abidjan (UT-802), arrived at Paris.	Paris
29 (Mon.)	Purchased air photos of Tambao area. Left Paris (AF-274) for Tokyo.	Plane
30 (Tue.)	Arrived at Tokyo.	

Fig I-1 LOCATION MAP OF HAUTE-VOLTA



CHAPTER II

BASIC GUIDELINES FOR SURVEYS

II-1 Basic Guidelines for Surveys

The object of the present surveys was the facilities related to Tambao Manganese Mine, these facilities being incidental on the development of the mine. In making the surveys and planning for the facilities, we referred to TAMCO's feasibility study report which was then the only available systematic compilation of a development plan for the mine. We conducted our field surveys and worked out a rational layout for the facilities on the basis of the personnel plan and the plan for related facilities as described in TAMCO's report. We also drew suggestions from the Tambao development plans described to us by the General Office of the Tambao Project, the Government of Haute-Volta.

In planning for these facilities and studying their effect on the regional community, we referred to the 2nd Five-Year Plan for Economic and Social Development (Plan Quinquennal de Développement Economique et Social, 1972-1976) of the Government of Haute-Volta; this material was used for the specific purpose of grasping the general conditions of the country with particular reference to the development of infrastructure.

This second five-year plan, following the first launched back in 1967, is the basic national development program of Haute-Volta. Among the various targets set out in this national development program, the following are related directly or indirectly to the present survey:

- o Decision and implementation of water resources policy
- o Improvement of livestock sector
- o Building up an effective system for securing food supply through agricultural development and commercialization of agricultural and stock-farming products

- o Irrigation, cultivation and land improvement in lowlands
- o Systematic studies for development of mines
- o Promotion of industries producing substitutes for imports
- o Improvement of infrastructure for transport and communication
- o Improvement of welfare of people
- o Making effective use of human resources
- o Establishment of University of Haute-Volta

As the principal long-term projects to attain the objects of the second five-year plan, the Government of Haute-Volta has listed the following projects:

- o Training leaders in agriculture
- o Improvement of stock-farming
- o Solution of urban and rural problems
- o Development of the Liptako Gourma region*, in particular, mine development -- including development of a railroad connecting Ouagadougou, Kaya, Dori and the frontier, and of Tambao Mine
- o Extermination of onchocerciasis and development of Volta valleys
- o Development of technical arts in farming villages and cities
- o Training of present and future workers

Each of the above projects requires a long time for achievement. We considered infrastructure as the facilities related with development of Tambao Mine, in such a manner that they may contribute to the above projects as far as possible.

* The Liptako-Gourma area refers to an area of approximately 470,000km^2 straddling the three countries Haute-Volta, Mali and Niger. In December 1970, the heads of state of the three countries signed a treaty for development of the area and in June 1971 an agency for that purpose was set up.

Liptako-Gourma is an underdeveloped landlocked area marked by severe natural conditions, but is believed to have wide-ranging reserves of mineral resources, which are the primary object of a comprehensive development project now being studied. The project envisages the following:

(1) Construction of a railway linking Ouagadougou, Tambao and Ansongo.
(2) Exploration for mineral resources.
(3) Utilization of the Niger River.
(4) Improvement of the road network covering the three countries.
(5) Improvement of the communication network covering the three countries.
(6) Development of agricultural, livestock and fishing industries.

II-2 Principles of Infrastructure

If infrastructure is considered the underpinnings necessary for supporting economic development, it should not be restricted to physical matters, but should involve social aspects such as the following:

- Education (literacy rate, technological education, etc.)
- It has tremendous significance in social development whether there is incorporated a social system which accepts, fosters, and accumulates technological advance.
- The value concept (The value concept in industrial societies differs from that in nonindustrial societies. The value concept prevalent in nonindustrial societies denies industrialization, and thereby hinders economic development.)
- Corporate behavior (The behavior of enterprises fitting economic development should be of a venturesome spirit, entrepreneurship or an enterprising spirit.)
- Level of science and technology (Enhancement of the level of science and technology is indispensable to social development.)

This social infrastructure and physical structure, or infrastructure in the narrow sense, support each other and form an organic social system; accumulation of infrastructure incorporating these two aspects, or infrastructure in the broad sense, is of great significance for economic development. However, if a certain sector of infrastructure excels the others markedly, this sector cannot be put to effective use.

It may be thought that a sector falling back most in development restrains the effectiveness of infrastructure as a whole. What we can concern ourselves with directly is only the physical infrastructure, or infrastructure in the narrow sense.

II-3 Estimation of Development Effects of Infrastructure

The particulars of the infrastructure to be dealt with in the present survey -- namely, construction of facilities for a Tambao township and improvement of the road linking Tambao to Dori -- must be determined after weighing its possible effects on neighboring areas but, in the final analysis, will be restricted by SOMITAM's economic capacity to bear the cost on the premise that SOMITAM will be responsible for its own lasting and sound management, which can provide a foothold for Haute-Volta's economic development.

The effects of social development to be produced by building these facilities in the Sahel area in northeastern Haute-Volta cannot be easily quantified owing partly to a lack of basic statistics. If, however, the social and economic development process is properly appreciated, a correct conclusion may be drawn by qualitative means.

Note:

In the course of discussion between the Agency for Development of Tambao and the survey team, Mr. Ph. Ouedrago, Director of the Agency, made the following requests to us:

(a) In planning a power plant, water-supply facilities and the

like, allowance should be made for future expansion. (The Agency plans to set up a cement factory in the Tambao area and envisages formation of an industrial zone with mining and cement manufacture.)

(b) In planning for housing, employees may be assigned houses of different qualities, depending on their social classes, but they should not be segregated area-wise for that reason.

(c) Welfare facilities and the like should be made available to inhabitants of surrounding areas on an equal basis.

(d) The repair shop for the mine should be designed for possible future expansion.

(e) Alien employees for mine operation should be limited to 10 to 15 in the initial stage, and all positions at the mine should be filled by Haute Voltaic nationals in eight years after the start of production.

(f) Advice concerning a rapid population increase in the mine areas. (Each employee will likely have a family of about ten members. Also it is anticipated that non-employee families will flow into the area, attracted by fine urban facilities such as running water, electricity, infirmary and school.)

(g) The plan for mine facilities -- in particular, the airfield, product stocking yard, and waste dumping site -- should be properly balanced with the plan for the residential district.

In response to the above requests, we explained that the object of surveys by this team was confined to the Dori-Tambao road and the facilities of the Tambao Mine township, and the Director understood our explanation. Accordingly, among the above requests, the purport of items (b), (c), (f) and (g) has been incorporated into the town plan.

CHAPTER III

INDUSTRIES AND INFRASTRUCTURE OF HAUTE-VOLTA

The Republic of Haute-Volta is located in West Africa and is surrounded by Mali to the north-west, Côte d'Ivoire, Ghana, Togo and Benin to the south, and Niger to the east. Latitudinally, it is situated between 9°30' and 15° north lat.; longitudinally, Dori and Tambao are at approximately 0°, most of the country extending to the west therefrom.

The capital is Ouagadougou, which is connected to Abidjan of Côte d'Ivoire 1,145km away by RAN railway. The capital is also linked by a paved road to Lomé of Togo 1,150km away and to Accra of Ghana 1,010km away.

The total area of this country is 274,200 square kilometers. The population is estimated at 5,772,000 as of 1974, and the average population density at 21 per square kilometer.

Natural conditions of this country are severe, marked as they are by high temperatures, little precipitation, and a long dry season. As a result water resources are extremely scarce, making economic development difficult. The only streams that have a flow throughout the year are the Black Volta River and the Komoe River, others drying up during the long spells of drought. The rugged terrain through which the two rivers flow makes them unsuitable as a site for a large dam for irrigation. Moreover, the basins of the Volta Rivers are sparsely populated because of the endemic disease onchocerciasis, which presents another major obstacle to the utilization of what little water resources available in this country.

III-1 Industries of Haute-Volta

III-1-1 Industries in general

Agriculture and stock-farming are the leading industries of Haute-Volta, and 95% of the total working population engages in

primary industries including forestry. Primary industries accounted for 51% of gross domestic product (GDP) in 1970; their productivity is very low and a considerable portion of their products is consumed by the producers themselves, not appearing on the market.

Industrialization rate is low, and secondary industries account for only 17% of the GDP. Moreover, 10% of the GDP comes from traditional cottage industries. Modern industries have a productivity far higher than that of primary industries, but make up only 7% of GDP.

The tertiary industries (service sector) account for 32%, but modern services which gain weight along with economic expansion, account for 12% only; the remaining 20% is traditional services, the greater part being traditional commerce.

Table III-1 Gross Domestic Product Classified by Industry (1970)

Sector	Amount	Share
	million FCFA	
Primary industries	41,200	51.4%
Secondary industries	13,740	17.1
Tertiary industries	25,200	31.5
Total	80,140	100.0

Source: Five-year Plan, 1972, Haute-Volta Government

The average annual growth rate of GDP during the period from 1964 to 1970 was 4%, but there is a large disparity between sectors of industry.

Modern light industries (secondary) show particularly high growth rates: 40% for textile industry, 22% for foodstuff industry, 12.5% for metalworking industry. This is followed by 8.3% for modern transport and communication business (tertiary). The rates for other sectors are not more than 4%: 3.3% for traditional industry, 3% for agriculture, and 1.4% for stock-farming. And the

construction industry, energy industry, and the banking and insurance business (modern business sectors), which depend on economic growth of a country as a whole, have extremely low growth rates, 1.8%, 2.2% and 2.5% respectively.

III-1-2 Agriculture

Agriculture is the mainstay industry of Haute-Volta, accounting for 29% of the gross domestic product (GDP). Most of the crops, however, are internally consumed. The Government is trying to encourage the farmers to produce more crops for sale. Most farmers tend to play it safe by producing the traditional crops for their own consumption.

The crops include millet, sorghum, maize, rice, fonio, peanuts, karite, sesame, cotton and potatoes (yam, taro and sweet potato). Staple grains for domestic consumption account for a large portion of the country's farm production.

Peanuts are an important crop both for domestic consumption and export. So farmers are being encouraged to produce more peanuts. Cotton production has increased markedly in recent years, and so has its share in the total exports. Cotton is a highly profitable crop.

Trends in agricultural production (main crops) from 1971 to 1973 are indicated in Table III-2. Output declined as a result of the drought that hit the country from 1972 to 1973.

Table III-2 Agricultural Production (in thousands of tons)

Crop \ Year	1971	1972	1973
Millet	297.7	265.6	252.5
Sorghum	474.4	512.3	481.4
Maize	66.4	58.7	58.3
Peanuts	66.2	60.4	62.8
Rice	36.9	33.6	Not available
Cotton	28.1	32.6	"
Sesame	4.0	5.7	"

Sources: (1) Bulletin Annuaire d'Information Statistique et Economique de la République Voltaique, 1975
(2) Relation Plan d'Aménagement Economique Plan de Transport

Agriculture in Haute-Volta involves the following problems:

(a) Rainfall is extremely limited and unstable.

(b) A dry spell follows the seeding season at the beginning of the rainy season. The length of this dry spell affects harvests. In addition, whirlwinds and torrential rains plague the farmers during the harvesting season. Squalls and gusty winds hit the farms at the beginning and end of the rainy season. The winds often have a velocity of about 30m/sec.

(c) There is no organic relationship between stock raising and field farming. For example, farmers don't use the manure for composting.

(d) The burning method used in the cultivation of cropland does not prove effective enough because of washout due to torrential rains and of severe erosion by strong winds.

(e) Tilled area is limited because of inefficient farm implements.

(f) Cropland used for producing commercial crops represents only one-fourth of the entire farmland.

III-1-3 Forestry

Timber production accounts for an estimated 7.4% of the GDP. The total forested area is 3,844,000 ha. or 14% of the total land area. Less than one-third of the forests is protected.

III-1-4 Stockfarming

This industry makes up 10% of the GDP, but it depends on the traditional methods which are subject entirely to the elements. In the Sahel region, nomads raise domestic animals grazing them on extensive pastureland. In areas where farmers have permanent residence, livestock is raised in a more concentrated manner.

The share of livestock industry in the GDP has diminished since 1968 because of shortages in fiscal funds and droughts. Numbers of domesticated animals and livestock production in 1971 are given in Table III-3. Livestock exports represented as much as 44% of the country's total exports in 1971.

Table III-3 Scale of Livestock Industry (1971)

Kind	Number of head
Cattle	2,492,000
Sheep	1,560,000
Goats	2,490,000
Swine	153,000
Horses	67,000
Donkeys	200,500
Camels	5,200
Poultry	10,050,000

Source: Five-year Plan, 1972, Haute-Volta Government

Table III-4 Livestock Production

Product	Value (FCFA)
Meat	6,590,200,000
Other (milk, eggs, etc.)	1,901,500,000
Total	8,491,700,000

Source: Five-year Plan, 1972, Haute-Volta Government

III-1-5 Traditional cottage industry

Cottage industry carries heavy weight in the industrial sector. In 1968, for example, 30,595 persons were gainfully occupied in the cottage industry as against 3,616 persons in modern industries. However, productivity in this traditional sector is much lower than in the modern industrial sector.

Cottage industry is widespread in both urban and rural areas. In the latter, most people are engaged concurrently in farming. Cottage industry in Haute-Volta includes the following: food industry (flour, grain mills, bread, confectionary, etc.); textile industry (spinning, weaving, dyeing and sewing); smithery; pottery; and furniture making. Traditional techniques are used in all these fields.

The Haute-Volta Government gives priority to the modernization of cottage industry in order to promote industrialization. Efforts are being exerted, e.g., to raise the level of technology, modernize management methods, increase employment, and produce more up-to-date products.

Smithery and pottery manufacture, two typical examples of cottage industry in the Sahel region, will be outlined below:

(a) Smithery

Main products are farm implements such as hoes, plows, picks and sickles. Other items include knives, augers, nails, frying pans and lamp stands. Scrap iron, iron ore and laterite are the raw materials. Charcoal (cinders) are used as the fuel.

The techniques have been handed down from generation to generation under the hereditary system. Work is done at the family level. Most families, however, are engaged also in field farming.

The poor quality of charcoal is one problem involved in smithery. So forging is not sufficient. Another problem is the lack of quenching techniques. So methods for making charcoal of better quality and quenching techniques should be introduced to improve the quality of products. This will make it possible to produce better farm implements and raise agricultural productivity.

(b) Pottery manufacture

Main products include water and food jars, lamp stands, incense burners and ornaments. They are all unglazed. Two to four different kinds of clay are mixed to make raw material clay. Pieces of broken jars are often crushed and powderized for use as part of the raw material.

Pottery is manufactured across the country although the technology level varies widely. The overall level of technology, however, is low. Instruction is being given to improve the techniques.

III-1-6 Modern industries

Modern industries in Haute-Volta produced 8,870 million FCFA worth of goods in 1970. They employed a total of 2,600 persons in the same year. The total annual income of the workers reached 630 million FCFA. Annual income per worker was about 240,000 FCFA (equivalent to about ¥320,000).

Productivity in this sector is naturally much higher than in other industries. The number of factories increased from 38 in 1965 to 63 in 1972, including such diverse industries as food, auto bodies, textiles, construction material, lumbering, printing, chemical products and metalworking. Food, textile and metalworking industries combined account for 95% of total output. Thirty factories are located in Ouagadougou, 24 in Bobo Dioulasso and 9 in other areas.

III-1-7 Commerce

Commercial activities in Haute-Volta divide into two main sectors: traditional commerce and modern commerce. Modern commerce is conducted by 18 major trading companies such as Sovolci, Peyrissac and Sar. However, they account for a small proportion of total commercial activity in the country.

Other commercial activities are in the traditional sector where merchants, brokers and other businessmen play a dominant role. No rules have been established yet for commercial transactions. The lack of a credit system and the poor condition of regional roads, combined with the absence of common trading rules, have retarded the development of domestic commerce.

Numbers of workers and amounts of value added in the two sectors of commerce, both in 1968, are given in Table III-5. The traditional sector employs about 27 times as many people as the modern sector, yet the value added in the former sector is only five times as much. Thus there is a great gap in the profit-making capacity of the two sectors.

Table III-5 Workforce and Income in Commerce Sector (1968)

	Traditional sector	Modern sector	Total
Number of employees	40,172	1,474	41,646
Value added (millions of FCFA)	10,084	2,050	12,134

Five-Year Plan, 1972, Haute-Volta Government

III-1-8 General problems facing industry in Haute-Volta

The tendency of people in farming villages to feel a psychological inhibition against the entry of modern industries into their areas poses a fundamental problem which could decide the success or failure of industrial development in the country. There is a similar tendency even among residents in urban areas. This makes it urgently necessary to train instructors and enlighten the people in order to spread the use of modern techniques.

Essentially, the way of living deeply entrenched in traditional customs must be changed. Farming, for instance, depends excessively on traditional techniques. Many things can be done to raise farm productivity, such as improving cultivation methods and farm implements, and making better use of domesticated animals. Customs that retard progress toward a higher living standard and superstitious views on natural phenomena should be discarded.

The drought that hit the country from 1970 to 1971 threatened to starve to death as many as 115,000 head of livestock. As it turned out, 50,000 head were spared death because cotton seeds were used as feed. This is said to have greatly influenced -- for the better -- the farmers' fatalistic attitude toward natural disasters.

This episode points up the need to bring home to the farmers that they should try to make improvements and that they can do so only if they have the will to improve their lot.

Farmers should be told, for example, that they can raise rice and vegetables by irrigating arid areas. In the context of agricultural development described above, there is much significance to be attached to this approach. Education in farming areas should not be confined to technical training. It should be promoted in a way that would change the mentality of young people.

III-2 Infrastructure of Haute-Volta

Here we examine the present situation of infrastructure in Haute-Volta, to find a foothold for planning facilities pertinent to the development of Tambao Mine.

III-2-1 Medical treatment

In 1971 Ouagadougou and Bobo Dioulasso, which are the most advanced areas in Haute-Volta, had a total of 30 physicians and 376 nurses for their combined population of 237,000, which means one physician for 7,900 and one nurse for 630. The situation is worse in rural areas, with one physician for 188,000 and one nurse for 6,200. There is serious backwardness in medical treatment, and sanitary conditions are extremely poor.

III-2-2 Education

Education has the greatest significance for the future of a nation. In this nation, backwardness of education defies imagination. In a society composed of a handful of highly educated leaders, a minority of people educated to an extent, and the majority of people without any education, or illiterate people, education is a problem of greatest importance. However, it remains in an unsatisfactory stage despite the urgency for improvement, because of the difficulty peculiar to education which involves much time and money.

The percentage of school attendance in elementary education is only about 10% on the average. School children in 1972-73 numbered 108,000, out of which only 22% of boys and 15% of girls finished their elementary education. And the ratio of those who go further into secondary and higher education is extremely low.

In addition to regular schools, there are rural community education centers, established for the purpose of educating people who have not received school education. In 1971, 750 centers were giving instruction in the fundamentals of modern agriculture and practical skill.

In higher education, there is remarkable imbalance between branches. What presents a problem is the fact that the humanities attract the great majority of students, while students enrolled in science, medicine, and agricultural courses, particularly agricultural, are very few. In Haute-Volta where natural conditions are hard, educational development in the fields of science, engineering, agriculture and medicine is desired in order to attain economic development.

Table III-6 Statistics of Education

(as of 1971)

Type of education	Number of schools	Number of classrooms	Number of students	Remarks
Elementary education	605	2,254	105,706 (108,000)	Number of school age children: 1,058,000 Percentage of school attendance: 10% (boys: 12%, girls: 4.5%)
Secondary education	38	295	9,006	
Higher education	1		270	In addition, there are 750 students studying abroad.
Rural community education	(centers) 750		30,005	
Technical & homemaking education	11	69	1,734	

Source: Five-year Plan, 1972, Haute-Volta Government, with the exception of parenthesized figures, which are based on Atlas de la Haute-Volta, 1975

What should be done first in education would be to reduce the illiterate to none, and next to disseminate technological education. Some measures should be taken urgently. At least a deep interest in education should be engendered in people. One of the big problems about education is to provide those who have received education with appropriate places for work. About this problem a vicious cycle is obvious. In short, lagging economic growth causes persistent under-employment. That is, those who have the will and ability to work are not given the opportunity to work, so that economic development does not make progress, which means again that the economy can not provide educated people with a place to work.

III-2-3 Transport, communication and roads

(1) Railroad

The most economical means of transport to connect this landlocked country with the outer world is the railroad.

The only railroad in Haute-Volta extends from the capital, Ouagadougou, to Abidjan of Côte d'Ivoire. The length is 1,145km, of which the portion within Haute-Volta is 517km, connecting the major cities of Koudougou, Bobo Dioulasso and Banfora. This railroad will be extended before long from Ouagadougou to Tambao, via Kaya and Dori, over a distance of 353km. When completed, this extension will be of great importance for not only Haute-Volta but also Mali and Niger.

Table III-7 Trends in Passengers and Goods Transported by Railway

Year / Passengers and goods	1970	1971	1972	1973
Passengers (in thousands)	711.7	797.5	880.0	968.0
Passengers/km (in millions)	380.9	436.9	510.0	591.6
Goods (in thousands of tons)	342.6	376.7	409.7	448.3
Goods t/km (in millions of tons)	303.4	331.6	339.0	345.7

Source: Economic Situation of Haute-Volta, 1975 by the Bank for Development of Africa.

As Table III-7 indicates, the volume of passengers as well as goods transported is growing. The problem is the imbalance of flow of goods, far more coming from Côte d'Ivoire to Haute-Volta than in the reverse direction, but this will be solved through the development of Tambao.

(2) Aviation

International airports are located in Ouagadougou and Bobo Dioulasso, which are linked to Europe and Western Africa by scheduled flights of Air Afrique and UTA. Domestic routes are served not only

by Air Afrique and UTA but also by Air Volta, a state-owned airline established in 1967. Domestic flights link Ouagadougou, Bobo Dioulasso and Banfora.

Passengers and cargoes carried by these airlines in the period from 1970 to 1973 are tabulated in Table III-8. The average annual rate of increase in the volume of air transport service in the same period exceeded 10%.

Table III-8 Trends in Air Transport Service (1970 - 1973)

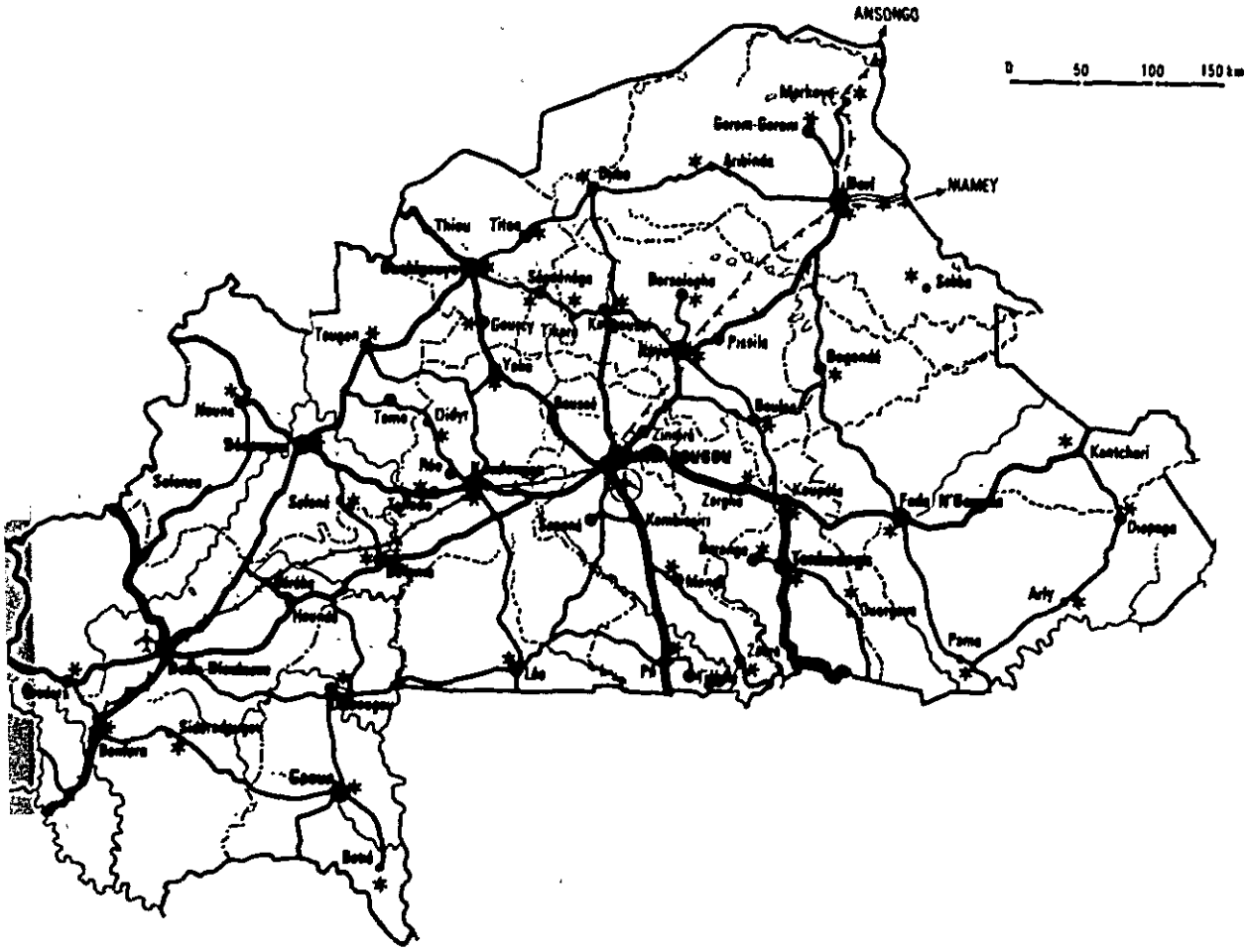
Item		1970	1971	1972	1973
Passengers	Ouagadougou (of which transit passengers)	46,691 (23,803)	51,390 (26,033)	59,278 (27,091)	68,169 (28,174)
	Bobo Dioulasso	10,471	10,360	11,274	12,288
	Total	57,162	61,750	70,552	80,457
Cargoes (tons)	Ouagadougou	947	1,178	1,336	1,509
	Bobo Dioulasso	210	135	107	98
	Total	1,157	1,313	1,443	1,607

In addition to the two international airports, many local airports of class D are scattered across the country (Table III-9).

Table III-9 Types of Airports

Class	Specifications	Locations
Class A	4-engine jets	Ouagadougou
Class B	Twin-engine jets	Bobo Dioulasso
Class D	Light planes	47 points

Fig. III-1 TRANSPORTATION SYSTEMS



Main roads
- Usable in all seasons
- Not usable in rainy season

Local roads
- Usable in all seasons
- Not usable in rainy season

Railroads
- Existing
- Planned

Airports
- Class A
- Class B
- Class D

Administration
- Department boundaries
- Seat of department government
- Seat of subprefecture government
- Other cities, towns and villages

(3) Communications

The communications system has been operated since 1969 under the jurisdiction of l'Office des Postes et Télécommunications (The Office of Posts and Telecommunications).

Twenty-seven post offices are located across the country, of which 22 provide all kinds of postal service. The remaining five provide only money collection and mail delivery services. In addition, there are 35 postal agencies. In all, postal services are provided by 62 postal offices and agencies. However, the population served by these organizations is only about 10% of the national total.

Automatic telephone exchanges are located in Ouagadougou (1,000 circuits) and Bobo Dioulasso (800 circuits). Inter-city connections are available in these two cities and also in Banfora, Koudougou and Fada N'Gourma. Direct phone calls can be made via an international wireless telephone network linked to such foreign cities as Paris, Abidjan and Niamey.

(4) Automobile ownership

Automobile ownership was 15,000 units in 1972 and 17,400 in 1974 (see Table III-10). Major exporting countries are France, Germany and Côte d'Ivoire, in this order.

Table III-10 Automobile Ownership

Type / Year	Passenger cars	Trucks	Subtotal	Tractors, trailers	Grand Total
1972	Unknown	Unknown	15,000	594	18,012
1974	12,600	4,800	17,400	Unknown	Unknown

Automobile imports in the period from 1968 to 1972 are indicated in Table III-11. The number dropped markedly in 1972 because of the aggravated economic situation. However, the basic trend in automobile imports is expected to remain firm.

Table III-11 Passenger Car and Truck Imports

Type \ year	1968	1969	1970	1971	1972
Passenger cars	473	742	719	783	666
Trucks	458	573	566	474	447

Source: République de Haute-Volta, Balance Commerciale et Commerce Exterieur 1972

(5) Roads

Roads in Haute-Volta have a total length of 16,410km, of which 8,910km comprises national roads, department roads and regional roads available for motor traffic. The rest -- 7,500km -- consist of narrower regional roads (e.g. chemin rural). The following is a breakdown:

National roads	4,460km (incl. 620km paved roads)
Department roads	1,995km
Regional roads	2,455km
Total	8,910km
Other regional roads	7,500km
Grand total	16,410km

Of these roads only 5,400km of trunk roads are usable all the year round. Most of the other roads are not usable during the rainy season from July to September.

According to a survey by the Bank of Africa, transport volume on the trunk roads has been increasing at a rate of about 7% annually. However, delivery via local roads is seriously hampered by the poor road conditions and by the closing of these roads during the rainy season. Therefore, merchants do not want to visit remote places. Furthermore, the sharp rise in oil prices has driven up freights, thus raising the cost of long-distance transportation to remote areas.

Farmers are now deprived of opportunities to sell their produce, so that they raise only enough crops to meet their own needs. The poor road conditions have dampened their will to expand output. This has retarded progress in agricultural development. It is very important therefore to improve the regional roads.

It could be argued that there is not much sense in improving the local road network because the volume of motor traffic is extremely limited. The fact remains, however, that merchants do not travel to remote places because the road conditions there are bad. The resulting absence of commercial incentives in the provincial areas keeps production at a minimum level required for self-sufficiency. This fact should be considered seriously.

III-3 Sahel and Infrastructure

III-3-1 Outline of Sahel area

The Sahel area, or the Department of Sahel is located in the northeastern part of Haute-Volta. Natural conditions in the region are particularly severe. It borders Mali and Niger and consists of three subprefectures -- Dori, Oudalan and Djibo. The department government is in Dori, and a subprefectural office in each of the following districts: Dori, Gorom Gorom (Oudalan) and Djibo. Tambao Mine is located 20km north of Markoye in the northeastern part of Oudalan subprefecture. There are three major towns in the vicinity of the mine. They are Markoye (population: about 3,000), Gorom Gorom (3,000) and Dori (6,000). The population of Sahel Department was 262,000 in 1970, or only about 5% of the total population for that year (estimated at 5,308,000). This is the lowest population density (7 persons/km^2) of any department in Haute-Volta. At the subprefectural level, the lowest density in Sahel is that in Oudalan, 5 persons/km^2.

Table III-12 Demographic Statistics of Sahel (1970)

District	Population	Labor force population	Density (per km^2)	Area (km^2)
Djibo	96,000	47,000	7	13,350
Dori	120,000	59,000	9	13,470
Oudalan	46,000	23,000	5	10,050
Total	262,000	129,000	7	36,870

Source: Five-year Plan, 1972, Haute-Volta Government

Tribal distribution in the department is diverse. In Oudalan alone three different tribes live. They are Bella, Tuareg and Fulani. The first two tribes speak Tamachek, and the last, Peulh.

Another demographic feature of Sahel Department is the high percentage of nomads, who make up 53% of the department's population. The remaining 47% live in 455 towns and villages across the department.

(1) Natural Environment in Sahel

Precipitation in Sahel is marginal. Temperature is high, and so also is the level of evapotranspiration. Precipitation, number of rainy days and the evapotranspiration level are indicated in the following table:

Table III-13 Precipitation, Rainy Days and Evapotranspiration Level (1961-70 average) in Sahel

Item	Dori	Djibo	Gorom Gorom	Markoye
Precipitation (mm)	590	574	494	389
Rainy days	54	36	33	35
Evapotranspiration level (mm)	1,740	Unknown	Unknown	Unknown

Source: Five-year Plan, 1972, Haute-Volta Government

As indicated in the above table, annual precipitation in Dori, a major area in Sahel, is 590mm. Rainfall decreases toward the north.

In Markoye, which lies nearest Tambao, precipitation is at the lowest level (389mm). The number of rainy days is about 35 in Markoye. Atmospheric temperature in Sahel drops to 6-7°C at night during January. But in May, daytime temperature in the shade goes up to 45°C.

The level of evapotranspiration, measured on an annual basis, goes much higher than the level of rainfall. This is a notable feature of climatic conditions in Sahel Department. Water balance is of course on the minus side.

(2) Industry

The severe natural environment in Sahel would make it difficult for residents there to develop any major industry other than their traditional occupation -- stock farming. A large-scale irrigation project also would be inconceivable for them in light of the great aridness of the area in which they live. For these reasons, little investment has been made to build up infrastructure. With the exception of livestock industry, self-sufficient farming and traditional handicraft industry are about the only means of living.

The livestock industry there is on a very large scale because the region covers a vast land area. The biggest problem, however, is that it depends excessively on traditional methods. The scale of stock farming is indicated in the following table:

Table III-14 Stockfarming in Sahel

(head of livestock)

Subprefecture	Cattle	Sheep	Goats	Horses	Donkeys	Camels
Dori	60,000	80,000	90,000	8,000	5,000	200
Djibo	60,000	40,000	50,000	9,000	4,000	--
Oudalan	20,000	200,000	225,000	9,000	10,000	3,000
Total	140,000	320,000	365,000	26,000	19,000	3,200
% share of national total	5%	17%	13%	17%	28%	62%

Source: Sahel Department Government

As noted above, camels have the largest percentage share of the national total. Cattle have the smallest share.

Agriculture in Sahel is outlined in Tables III-15 and 16. Nomads, like farmers with fixed residence, also engage in field farming. But vagrant farmers raise only millet, their staple grain. The average area under cultivation is 2.20 ha. per family. Farmers who have fixed abodes cultivate an average of 2.40 ha. per family. They raise not only millet but other crops as well. One major problem with agriculture in this region is that only a small portion of output is available for sale. As indicated in Table III-16, only 5% of the millet produced is made available as cash crop. In the case of sesame and peanuts, major cash crops in Sahel, the ratio of merchandization is only 20%.

Table III-15 Land Under Cultivation in Sahel

(hectares)

Crop / Farmland	Millet	Peanuts	Sesame	Total
Per family				
Nomads	2.20	--	--	2.20
Residents	2.40	0.15	0.10	2.65
Total farmland				
Nomads	45,100	--	--	45,100
Residents	44,400	2,775	1,850	49,025
Total	89,500	2,775	1,850	94,125

Remarks: Nomads comprise 20,500 families and residents, 18,500.

Source: Five-year Plan (appendix), 1972, Haute-Volta Government

Table III-16 Farmland, Output and Cash Crops in Sahel

Farmland, output, etc. / Crop	Farmland (1,000ha.)	Yield (tons/ha.)	Output (1,000t)	Cash crop ratio (%)
Millet	89.500	0.45	40.3	5
Beans	(1)	--	4.0	--
Sesame	1,850	0.20	0.4	20
Peanuts	2.775	0.30	0.8	20
Total	94.125			

Source: Five-year Plan (appendix), 1972, Haute-Volta Government

III-3-2 Infrastructure

Infrastructure in Sahel is insufficient to promote economic development in the department. Economic progress is hampered by a combination of limiting factors such as bad roads, ill-equipped medical facilities, extremely low level of school enrollment, and inadequate water supply. Details are given below:

(1) Clinics

Medical facilities in Haute-Volta are generally in unsatisfactory condition. This is especially true in Sahel. Availability of general clinics and maternities is as follows (population divided by number of clinics or maternities):

	Clinics	Maternities
Sahel	1/22,500 persons	1/18,000 persons
National average	1/18,000 persons	1/40,000 persons

At clinics in Gorom Gorom and Markoye very little medical equipment is available. Stocks of medicine are also inadequate. Certified physicians are stationed only in Dori and Gorom Gorom. There is only one nurse (male) in Markoye but no qualified doctor. Considering the inclement natural environment in Sahel, clinics are what the department needs urgently.

(2) Elementary Schools

There is one school each in Markoye, Gorom Gorom, and Dori. One class has 30-35 pupils. All schools are coeducational and maintain a six-year schooling system. But the age at which schooling begins varies widely. The rate of enrollment is also extremely low. The average enrollment rate in Haute-Volta is only 10%. In Dori subprefecture the rate is 3% and in Oudalan 2.7%.

(3) Transport, Communications and Roads

In general, road conditions in Sahel Department are exceedingly bad. During the rainy season extensive damage is caused. Even in the dry season, repair work is far from adequate.

The chief means of transportation is animals (camels, donkeys, horses). Few roads provide easy access to passenger cars. Vehicles like jeeps must be used in most cases. Road conditions are so bad that a car used there must be overhauled after returning home. Communications systems are also underdeveloped to a serious extent.

The natural environment in Sahel is severe, and people there are essentially nomadic. This makes it extremely difficult to promote agricultural development. If irrigation even with manual labor is impossible due to the lack of will to continue production in the same area, then it is desirable that stock farming be promoted. This can be done by using the existing U.S. Ranch* and also railways to be constructed and by improving roads. In addition, facilities in Tambao township can be made available to migratory farmers. All this will produce enough results, tangible and intangible, to develop the livestock industry. A resulting increase in cash income will enable the farmers to purchase better food. In the end this will contribute to agricultural development.

However, as described before, infrastructure in Sahel is noticeably inadequate, and natural conditions are very severe. Considerable investment is required for an economic "take-off."

* A modern ranch constructed with U.S. financial assistance. It is located about 2km west of Markoye.

In view of the vast land area covered by Sahel, the "concentrated development" approach may be worth trying. An infrastructure buildup in Tambao would make it possible to incorporate the sustainable mechanism of economic development into Sahel's society although this would certainly take time.

CHAPTER IV

PLAN FOR TAMBAO TOWN FACILITIES

IV-1 Basic Principles of Township of Tambao Mine

The development of Tambao Mine needs a new residential district for people working for the mine, for the mine railroad and other public and private services.

As for the location of this residential district, it is thought appropriate to establish it anew near the mine, considering the distance between the mine and existing villages, e.g. Markoye, and the size and nature of the proposed residential district, etc.

This new residential district, or the township of Tambao Mine, will be a town for employees of the mine and related industries, and will differ in nature from the villages in its vicinity. More specifically, this town will be set up on the basis of accumulated modern industrial know-how, and the behavior pattern of the residents will resemble that of an industrial society.

Regarding water supply, this town will depend on artificial feedwater from Tin Akof, whereas the existing villages around the mine have grown up in places where water is available. This town is assumed to have a population of about 2,000 including family members, at the time of start of mine production, which is about the same size as Markoye and Gorom Gorom, comparatively large villages in the vicinity.

When the above conditions are considered, the following two ways can be visualized for establishment of the township of Tambao Mine:

Plan A: In the light of severe natural and social conditions, it is planned just as a mine town equipped with minimum facilities necessary for mine operation; in other words a town which will have finished its function at the time of mine closure.

Plan B: It is planned and designed not as a mere mine town but in the direction of strengthening and expanding the above

stated functions deliberately. This township will have the following characteristics:

(a) A town where modern industrial know-how is accumulated in the technical areas of forging, operation and repair of machines, etc.

(b) A town with the same behavior pattern as an industrial society in the aspects of education, medical treatment, housing, living standard, etc.

(c) A town having a function as an information center by virtue of communication facilities.

(d) A center of commodity distribution and personal interchange by virtue of the railroad and road.

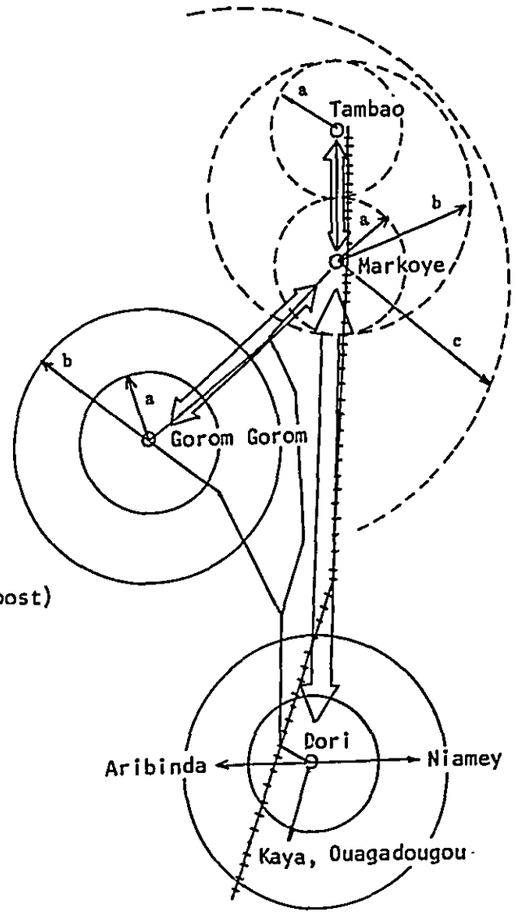
Accordingly, in the light of the new functions and physical position of Tambao Town, it may in future have the nature as a central community of Sahel Department vying with Dori, and furthermore as a center of the Liptako Gourma area stretching over the three countries of Haute-Volta, Mali and Niger. Therefore, the town may offer the possibility of appearance of various modern industries and expansion of employment, in addition to the mine.

Figs. IV-1 and IV-2 show the likely functions of the township of Tambao Mine at the start of mine operation and at a more distant future, respectively. As mine operation is commenced (Fig. IV-1), the Tambao township will perform normal services to the mine and also social services to the neighboring areas. Markoye then will perform social services and services related to farming and stock raising to the Markoye district; it will also function as the center of the subprefecture of Oudalan, taking over from Gorom Gorom. Fig. IV-2 is a projection into the future when the Tambao township will have accumulated some social overhead capital. Specifically, in addition to providing social services and services connected with farming and stock raising, the township will function as the hub of activities in the subprefecture of Oudalan and serve as

the center of international exchange with Mali and Niger. Meanwhile, Markoye will perform social services to the Markoye district and, at the same time, will take charge of its traditional function relevant to farming and stock raising.

If one thinks of economic expansion embracing the surrounding areas, Plan B would obviously be a better choice than Plan A.

FIG. IV-1 FUNCTIONS OF TAMBAO MINE TOWNSHIP
(AT START OF MINE OPERATION)



Functions of Gorom Gorom

1. As center of Gorom Gorom district, it will provide:
   1) Administrative service (as Oudalan subprefecture office outpost)
   • 2) Farming and stock raising service (as marketplace)
   • 3) Airstrip (class D)
2. As center of Gorom Gorom town, it will also provide:
   Social and educational facilities and services, such as:
   • Elementary school
   • Infirmary

Functions of Tambao

1. As center of Tambao town, it will provide:
   1) Housing area
   2) Social and educational facilities and services, such as:
      Elementary school
      Infirmary
   3) Marketplace (for daily necessities)

Functions of Markoye

1. As center of Oudalan subprefecture, Markoye will provide:
   1) Administrative service (as subprefecture office)
   2) Permanent marketplace
   3) Airstrip (class D)
   4) Social and educational facilities and services, such as:
      Hospital
      School
2. As center of Markoye district, it will also provide:
   1) Administrative service (as Oudalan subprefecture office outpost)
   • 2) Farming and stock raising service (as marketplace)
3. As center of Markoye town, it will also provide:
   Social and educational facilities and services, such as:
   • Elementary school
   • Infirmary

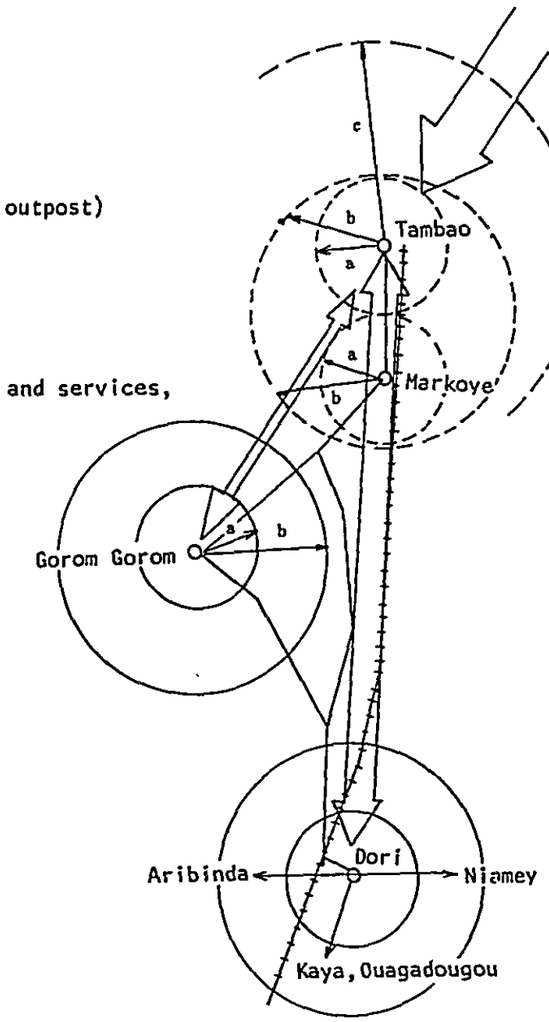
a: (10 to 15km) Range of social facilities and services
b: (20 to 30km) Range of farming and stock raising services
c: Oudalan subprefecture
⟺ Expected volume of transport
● Existing facilities

FIG. IV-2 FUNCTIONS OF TAMBAO MINE TOWNSHIP (FUTURE)

Functions of Gorom Gorom

1. As center of Gorom Gorom district, it will provide:
   1) Administrative service
      (as Oudalan subprefecture office outpost)
   • 2) Farming and stock raising service
      (as marketplace)
   • 3) Airstrip (class D)
2. As center of Gorom Gorom town, it will also provide:

   Social and educational facilities and services, such as:
   - Elementary school
   - Infirmary



Functions of Tambao

1. As international city
2. As center of Oudalan subprefecture, it will provide:
   1) Administrative service
      (as subprefecture office)
   2) Permanent marketplace
   3) Airstrip (class C)
   4) Social and educational facilities and services, such as:
      Hospital
      School
3. As center of Tambao town, it will also provide:
   1) Administrative service
      (as Oudalan subprefecture office outpost)
   2) Housing area (mine)
   3) Social and educational facilities and services, such as:
      Elementary school
      Infirmary

Functions of Markoye

1. As center of Markoye district, it will provide:
   1) Administrative service
      (as Oudalan subprefecture office outpost)
   • 2) Farming and stock raising service
      (as marketplace)
   3) Airstrip (class D)
2. As center of Markoye town, it will also provide:
   Social and educational facilities and services, such as:
   - Elementary school
   - Infirmary

a: (10 to 15km) Range of social and educational facilities and services
b: (20 to 30km) Range of farming and stock raising services
c: Oudalan subprefecture
⟺ Expected volume of transport
• Existing facilities

IV-2 Selection of Site for Residential District

The site of the residential district was determined on the basis of studies of natural and planning conditions.

IV-2-1 Selection from natural conditions

(a) Topography

Although there is no particular problem because the surrounding topography is flat, low land and places where streams are formed in the rainy season should be avoided, and an area at an altitude of approximately 270 to 280m above the sea level was selected.

(b) Geology

From the necessity of maintenance of roads for the residential district and so forth, the laterite section was selected.

(c) Vegetation

Although there is no vegetation worthy of special mention, consideration was given, for future vegetation, so that a lower part with possibility of spring water may be contained in the periphery of the residential district.

(d) Meteorological conditions

Meteorological conditions such as temperature, precipitation, etc. are severe and unavoidable. Another important problem is wind directions. The prevailing wind directions are east-northeast and west-southwest. The residential district was so located as to avoid harmful effects of dust from the mine, anticipated after the start of mine production.

Accordingly, the following three areas can be considered in the selection of an area suitable for the residential district around Tambao Mine from natural conditions (see Fig. IV-3):

Area A: This area is located 2 to 4km to the northwest of Tambao deposit, being contiguous to the road between Markoye and Tin Akof. It is within the mine concession.

Area B: This is located 3 to 5km to the east of Tambao deposit, and is within the mine concession.

Area C: This is located 4 to 8km to the south of Tambao deposit, and most of it is outside the mine concession.

IV-2-2 Selection from planning conditions

We checked up on the above suitable areas of A, B and C selected from natural conditions, by planning conditions as follows, for deciding the residential district.

(a) Distance from the mine

Most of the employees will walk to work except a handful who will drive or use bicycles. Therefore, the suitable distance between the mine and the residential district is 2 to 3km, which means Area A or B.

(b) Distance from a planned railroad station

The railroad will be routed from Markoye to Tambao, and in future further on to Mali beyond the border. The suitable distance from the spot planned for Tambao Station is 2 to 3km, which means Area B or C.

(c) Relation with existing roads

An area from which an existing road is readily accessible is preferred, meaning Area A or C.

(d) Relation with laying of raceway

From the standpoint of laying a raceway from Tin Akof, an area requiring a shortest possible distance, or closest to Tin Akof, is preferred, meaning Area A.

(e) Relation with mining concession

From the standpoint of environmental preservation, a residential district within the mining concession is desired for management of the township, meaning Area A or B.

(f) Possibility of underground resources

Although Area B is unexplored, there is a possibility of gold ore veins thereabout. Accordingly planning a residential

district there should be avoided at this time, which means that Areas A and C remain.

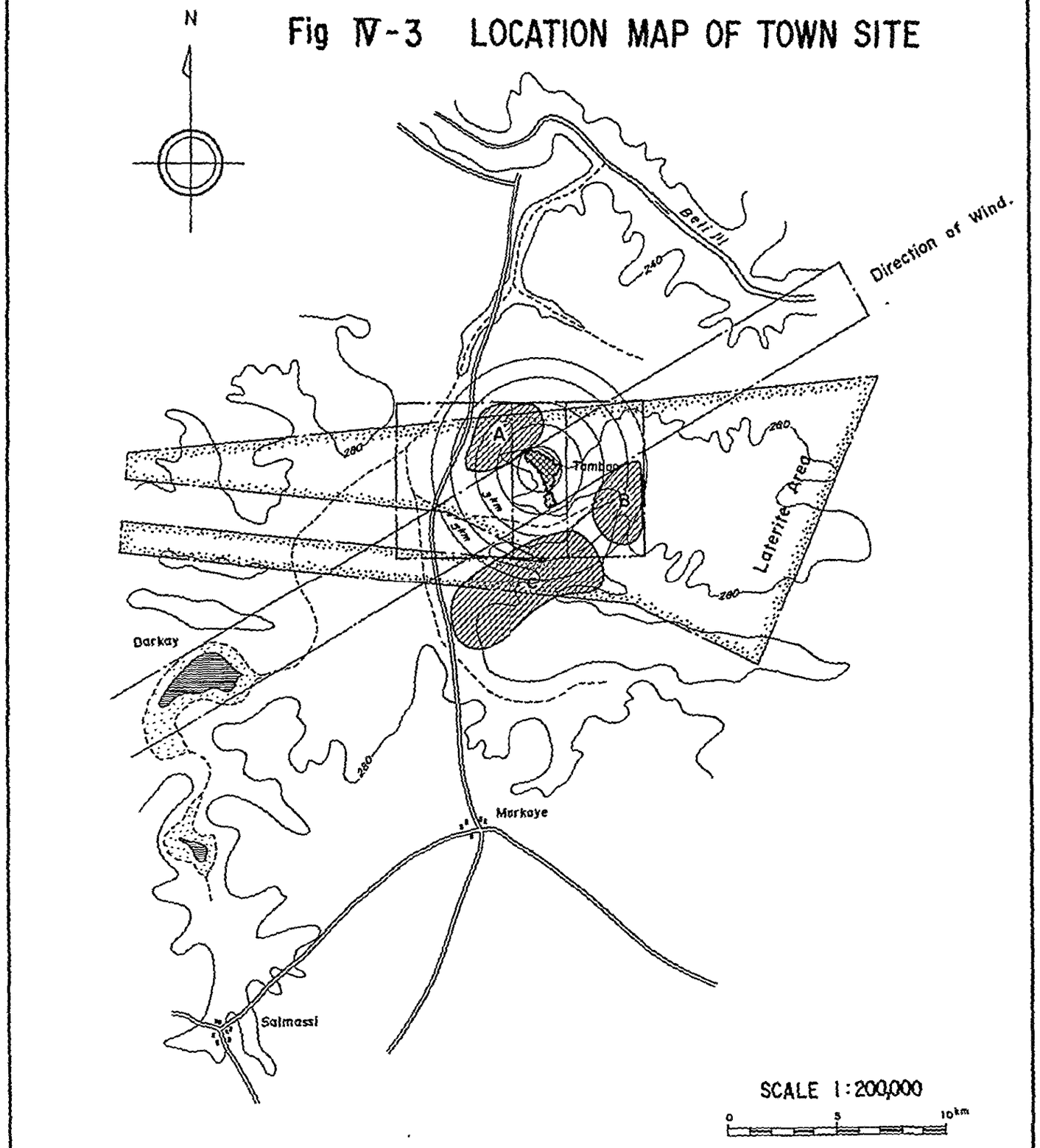
Judging from the above-mentioned points, as set forth in Table IV-1, Area A is most suitable for the present purpose.

Table IV-1 Comparisons of Conditions for Selecting Residential District

Conditions for selection \ Area symbol	A	B	C	Remarks
1. Distance from mine	○	○	△	Criterion: 2 to 3km
2. Distance from planned railroad station	△	○	○	Criterion: 2 to 3km
3. Relation with existing road	○	X	○	
4. Relation with laying of raceway	○	X	X	Length of raceway from Tin Akof dam
5. Relation with mining concession	○	○	X	Setting up within mining concession is preferable
6. Possibility of underground resources	○	*X	○	Possibility of other underground resources
Conclusion	○	X	△	

Legend: ○ Suitable
△ Between ○ and X
X Unsuitable at present
* Possible gold veins

Fig Ⅳ-3 LOCATION MAP OF TOWN SITE



IV-3 Basic Guidelines for Establishing Township

IV-3-1 Town frame

The population of the township of Tambao as at the start of mine operation has been calculated as follows, on the basis of the manning plan of mine in the Feasibility Study Report by TAMCO 1975.

(a) Mine personnel

Locals (married)	124
Locals (single)	41
Aliens (single)	19
Total	184

(b) People working for related industries (married locals)

50% of the above number: $184 \times 0.50 = 92$

(c) Total of working people

Locals (married)	216
Locals (single)	41
Aliens (single)	19
Total	276

In addition, assuming that each married local has 8 family members, the total population would be:

$$216 \times 8 + 41 + 19 = 1,788$$

So the planned population of Tambao Town has been assumed to be about 2,000.

IV-3-2 Guideline of plan (see Fig. IV-4)

Assuming that the residential district should have sufficient room for future expansion, we considered the following matters:

(a) The residential district will definitely be separated from the industrial zone, and a buffer zone will be set between them. The industrial zone will include the whole of mine facilities.

(b) Since the use of the residential district should be controlled for the sake of preservation of residential environment, the

district is to be located within the boundary of mine concession, which will facilitate solution of this problem.

(c) The residential district will not have segregation by class.

(d) In this district the road network will be designed so as to bypass any through-traffic.

(e) Sufficient open spaces will be provided in this district to make it possible to build a market, religious buildings, etc.

(f) Such facilities as a filtration plant, a water tower and so forth required for this buffer will be appropriately laid out in the neutral zone, to prevent the zone from sprawling without order.

IV-3-3 Plan for residential district (see Figs. IV-4 and IV-5)

(1) Housing district

The housing district, where there will not be discrimination by class, will have an average house density of 15 to 20 houses per gross hectare in consideration of preserving a good residential environment. Parks, green areas and squares will be provided as open spaces in the housing district. These spaces, together with the roads within, will make up 40% of the housing district as standard.

(2) Commercial district

A permanent market cannot be considered for the town population of about 2,000, so that provisionally the spaces of parks will be utilized for a market. As for the future commercial district, it will be secured in advance in an area for planned extension of the township.

(3) Road pattern in residential district

Although we need not be particularly conscious of a road pattern, in the light of the town size of 2,000 population, it is devised that automobiles will not come direct into the housing district from an approach road to the town. The

approach roads to the houses in the housing district will be designed in the form of cul-de-sac.

(4) Landscape

The surroundings of the residential district slope very gently toward the Beri River, but do not provide any landscape. Therefore a landscape will be created by arranging parks, squares, buildings, etc. There is practically no vegetation usable in the surroundings of this district, and it is at present difficult to grow plants in the buffer zone and even in the open spaces.

However, the layout is made in the expectation that growing plants will be made possible through development of water resources in future.

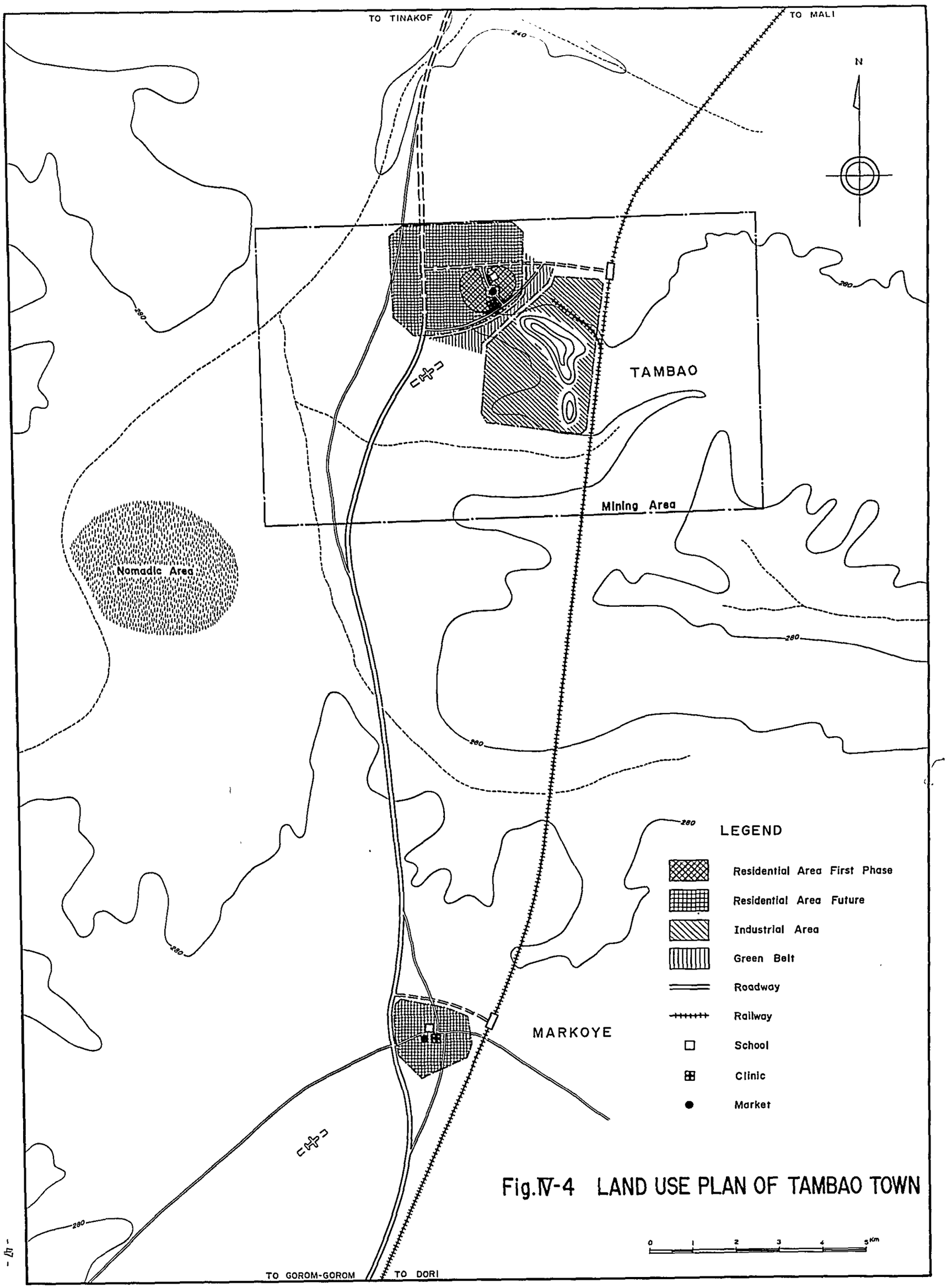


Fig.Ⅳ-4 LAND USE PLAN OF TAMBAO TOWN

IV-4 Housing Plan

IV-4-1 Kinds and numbers of residential buildings

The kinds, sizes and numbers of residential buildings were determined as shown in Table IV-2, on the basis of the number of Tambao Mine employees, their job classes, and their family sizes, as obtained from TAMCO's Feasibility Study Report of 1975.

In determining the number of residential buildings, it was assumed that senior staff members and junior staff members will all be accompanied by their families. As for the workers, it is assumed that two-thirds of them will be accompanied by their families and the rest will be either single or living away from their families. Those with families will be assigned to individual houses, the others to a dormitory. It is assumed that alien staff members will be accommodated in the guest house.

Table IV-2 Kinds and Numbers of Residential Buildings

Classification	Type	Floor space (m^2)	Number	Remarks
Mining personnel	Type-1	120	1	Resident manager
	Type-2	100	8	Senior staff
	Type-3A	90	11	Junior staff A
	Type-3B	70	22	Junior staff B
	Type-4A	70	42	Worker A
	Type-4B	60	42	Worker B
	Dormitory	420	1	Worker (for 60)
	Subtotal		127	9,330m^2
Medical personnel	Type-2	100	1	Physician
	Type-3A	90	1	Nurse A
	Type-3B	70	1	Nurse B
	Subtotal		3	(260m^2)
Educational personnel	Type-3A	90	1	School principal
	Type-3B	70	3	Teachers
	Subtotal		4	(160m^2)
Total			134	(9,890m^2)

IV-4-2 Structure of residential buildings

Because of the unusual severity of climate here, escape from heat is an important factor. Accordingly the following points are considered in planning buildings:

(a) Thick walls, ranging from 20 to 25cm, will be used in order to insulate against heat.

(b) Openings will be provided above room windows to facilitate ventilation.

(c) Eaves will be built in an effective way to shut out sunlight.

(d) The buildings will be of concrete structure for high-class employees (Types 1, 2, and 3A) and of adobe for ordinary employees (Types 3B, 4A and 4B).

IV-5 Plan for Other Facilities in Residential Area

The mine township is isolated in a remote place in Sahel, so that it is particularly important to pay attention to the education and welfare of the residents. In addition to dwelling houses, an elementary school, an infirmary, a canteen for daily necessities, a general-purpose hall, a guest house and a swimming pool will be provided in the residential area, and these facilities will be made available also to residents of neighboring areas.

(1) Elementary school: 2 buildings ($240m^2$ x 2)

In consideration of the population (2,000) of the mine township, school enrollment is estimated at 120 children, who are to be divided into four classes. Further, the site for the school will be large enough to allow expansion of the school buildings along with possible increases in population and school enrollment.

- o Population of mine township: 2,000
- o Number of school age children: 2,000 x 15% = 300
- o Enrollment estimated: 300 x 40% = 120

Note: National average rate of school attendence is 10%.

The total floor space of the school buildings is estimated at about $480m^2$, assuming a classroom space of $3.0m^2$ per pupil, viz.

four class rooms, each with a floor space of about 100m^2; and considering other facilities needed including a room for teachers.

(2) Infirmary: one building (240m^2)

In addition to an internal medicine department, the infirmary will have equipment and facilities for surgery in case of injuries, in consideration of the special nature of mining operations. Further, since no other adequate medical care facilities are found in Sahel, it is necessary to consider opening the infirmary to people living in neighboring areas. A physician-surgeon and two male nurses will be posted at the infirmary on a resident basis. The infirmary will have a waiting room, a lavatory and a kitchen, in addition to an office (20m^2), consultation rooms (40m^2), and an eight-bed ward (50m^2). The total floor space of the infirmary will be about 240m^2.

(3) Canteen: one building (120m^2)

Sundry goods, foodstuffs, table luxuries and other daily necessities will be sold at the canteen, which will be equipped with large-capacity cold storage facilities for storing foodstuffs and other goods.

(4) Multipurpose hall: one building (240m^2)

The multipurpose hall will be equipped with facilities for showing motion pictures, for indoor sports, and other entertainment so that it may be utilized as a rest house by residents of the town. It will also be used for various kinds of meetings.

(5) Guest house: one building (220m^2)

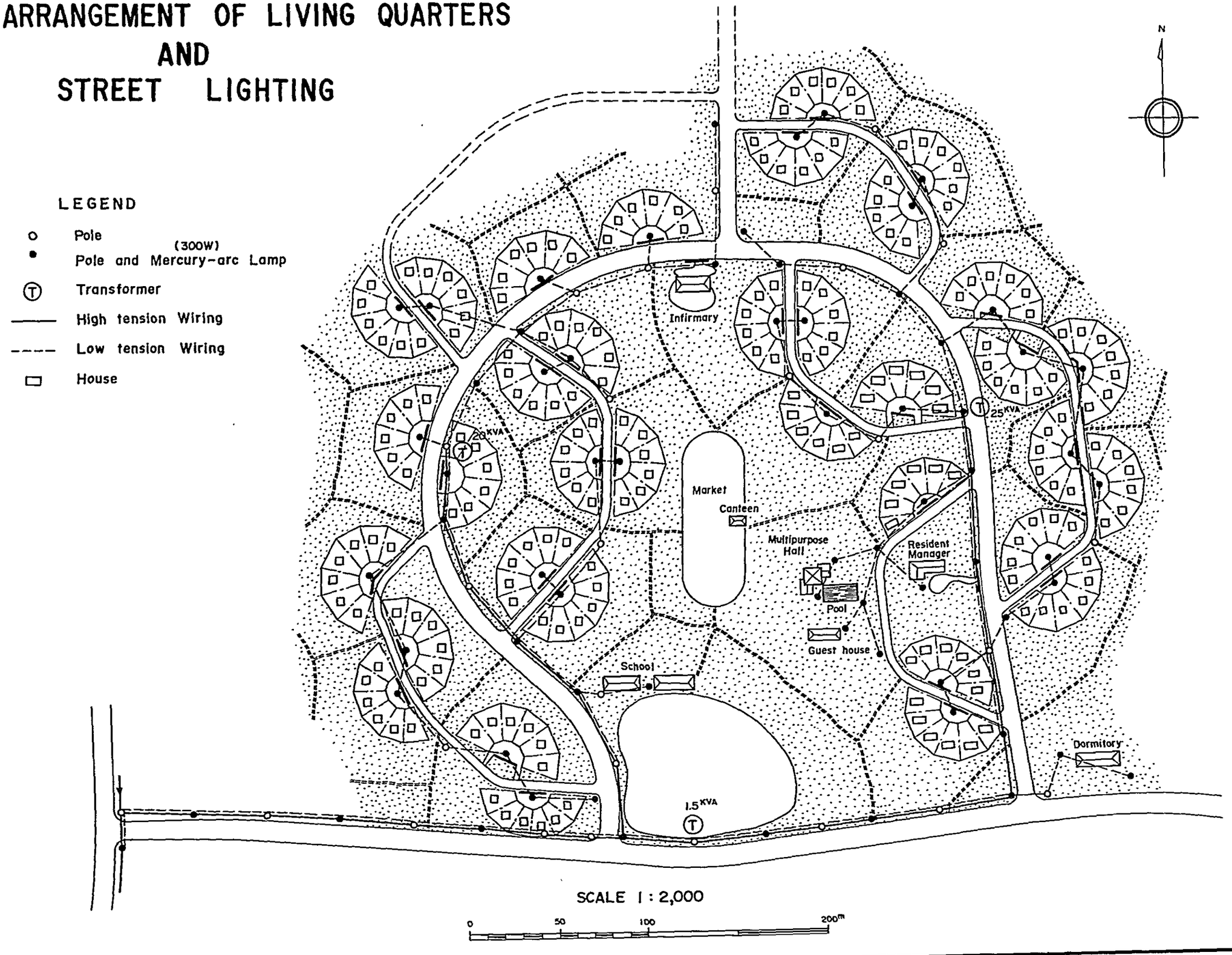
The guest house will be used as a lodging facility to accommodate visitors to the town, persons dispatched to Tambao Mine, staff members including aliens who will be sent to the mine site to work there alone, leaving their families at home.

(6) Swimming pool: 25m x 10m with a set of facilities

The swimming pool will be an important recreation facility for the residents of the town, particularly because the area is poor in water supply.

Fig Ⅳ-5

ARRANGEMENT OF LIVING QUARTERS AND STREET LIGHTING



IV-6 Service Water Plan

IV-6-1 General

Securing water supply for the Tambao area is an important matter in the light of the special environment of the community. A permanent water source should be secured for the mine development and other development projects to be undertaken in parallel or subsequently. Regarding the water source, the Government of Haute-Volta is proceeding with a project to build a storage dam at Tin Akof on the Beri River, which will be used as the water source.

The Tin Akof dam is described below:

(a) The maximum water level is 3.5m and the maximum capacity is about 10,000,000m^3. The water volume conveyed to the Tambao area is regulated at 1,200m^3 a day. At the end of the rainy season (around October 1st) when inflow into the dam ceases, the water level must be at least 2.8m. This was calculated by measuring evaporation volume at the dam site.

(b) For the dam spillway, a 200m long overflow weir will be set up assuming a flood discharge of 100m^3/sec. The intake structure will be a concrete conduit 500mm in diameter, ending at the lowest part of the dam. It will be so designed as to permit maintenance, inspection and control of intake level.

(c) At the pumping station, two pumps capable of conveying 1,200 tons of water a day over a distance of 31.5km from Tin Akof to Tambao and power generating equipment for the pumps are to be installed. Immediately downstream of the pumping station, there will be installed an air chamber of 1.3m^3 capacity to dampen high-pressure water-hammering.

(d) The water pipeline, made of steel pipes 200mm in diameter, will extend over a distance of 31.5km. The flow volume will be 139ℓ/sec, and flow speed 0.44m/sec. In the middle of the pipeline, equipment for removing water in piping, arrangements

for crossing streams, and equipment for preventing erosion will be provided.

(e) A reservoir with a capacity of 1,200m^3 will be installed at the end of the pipeline, at Tambao.

The facilities of Tin Akof dam ((a) to (e) above) are planned separately, and the present water supply plan for development of Tambao Mine concerns itself with facilities after the outlet of the water reservoir (1,200m^3 capacity).

IV-6-2 Water supply plan for Tambao area

(1) Volume of supply water

Assuming that 2,000 people will live in the residential district of Tambao Mine, the necessary daily consumption, or maximum daily water supply, is estimated as follows:

Water for personal consumption: 0.15m^3 x 2,000	300m^3/day
Water for mine operation:	100m^3/day
Total	400m^3/day

Therefore, a capacity of 400m^3/day is required for the water treatment facilities in order to secure the maximum daily water supply.

(2) Quality of raw water

The Beri River has a stream flow in the rainy season, but in the dry season the flow ceases entirely, the river turning into water pools, around which herds of grazing animals gather. The pools are gradually polluted. In the survey trip we took a small amount of water sample from a pool at Tin Akof, brought it back to Japan, and had it tested for the purpose of studying service water facilities. The water sample was collected about the end of the dry season, when the water level was low owing to evaporation. The water was badly polluted by the grazing animals; it was turbid with suspended matter, presented a milky brown color, and smelled of mud. The raw water is of extremely bad quality.

The results of tests of the raw water as a source of potable

water is set forth in Appendix II. Comparisons of the water with the standard potable water quality of Japan are shown in Table IV-3 below:

Table IV-3 Comparisons of Water Analyses

Item	Measured value	Standard value	Comparison
Consumption of potassium permanganate	116.2	10	12 times
Evaporation residue	1,404	500	3 times
Turbidity	1,530	2	--
Coliform count	Detected	*	--
Other bacilli count	110×10^2	10^2	110 times

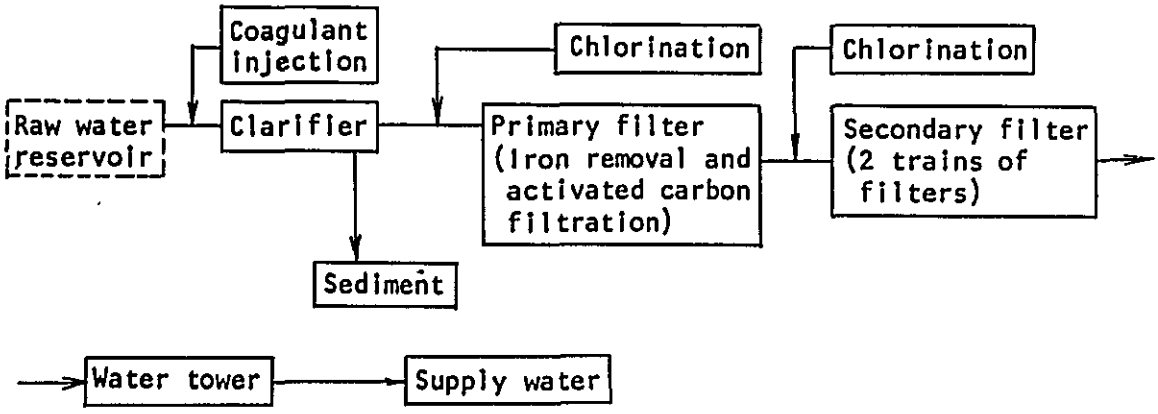
* Should not be detected

Although the above analyses may not be accurate because of the limited sample quantity, it is inferred that the raw water is of considerably bad quality. Hence careful study is needed concerning water treatment facilities.

(3) Treatment process (see Fig. IV-6)

Assuming that the reservoir of raw water is to secure, at least, the maximum daily supply water, it will have to have a capacity of $400m^3$ at first, and $1,200m^3$ eventually (This is in the realm of the dam building plan.). Owing to the large amounts of sediments anticipated from the quantity of suspended matter contained in the raw water, two settling ponds, each having a capacity of $400m^3$, will have to be provided and alternately used and cleaned, in order to remove the sediments. Also, in future, it is desirable to add a settling pond of $400m^3$ capacity, for a total of three $400m^3$ ponds for alternate use. If the raw water reservoir is provided for storing a day's volume of maximum daily supply water, a settling pond included in the ordinary supply water treatment process can double as a raw water storage. For the treatment process after the settling pond, the following treatment system is required for securing good-quality water, in consideration of the properties of the raw water.

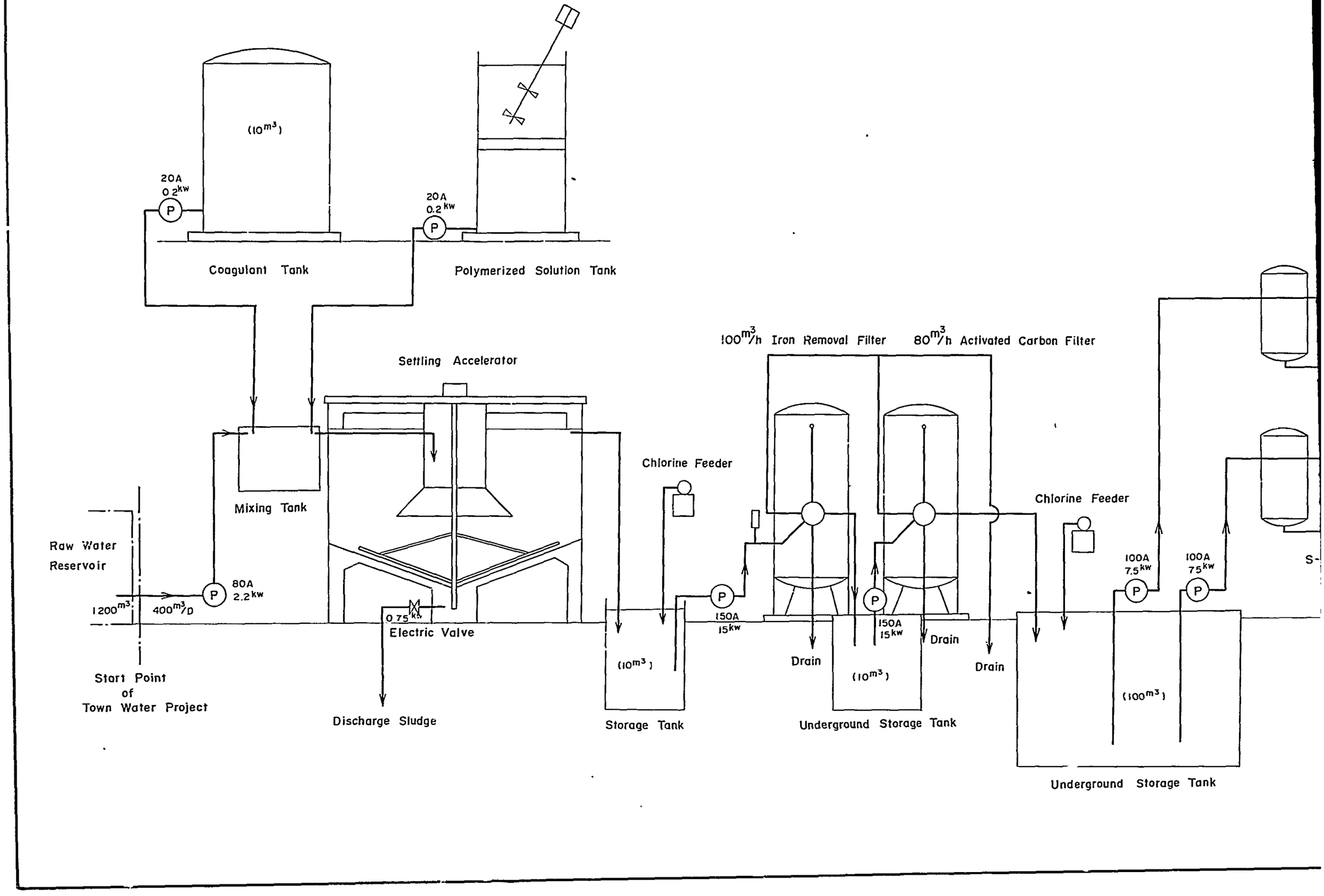
Flow of Raw Water Treatment



The treatment capacity per unit time, considering peak hours, should be designed for about $20m^3$ per hour, which is derived from:

$$400m^3/day \div 24 = 16.7m^3 \fallingdotseq 20m^3/hr$$

The details of the proposed treatment system is shown in Fig. IV-6.


(10m3)
20A
0.2kw
P
20A
0.2kw
P
Coagulant Tank
Polymerized Solution Tank
Settling Accelerator
100m3/h Iron Removal Filter
80m3/h Activated Carbon Filter
Mixing Tank
Chlorine Feeder
Chlorine Feeder
Raw Water
Reservoir
1200m3
400m3/D
80A
2.2kw
0.75kw
Electric Valve
150A
15kw
150A
15kw
100A
7.5kw
100A
7.5kw
Drain
Drain
Drain
Start Point
of
Town Water Project
Discharge Sludge
(10m3)
Storage Tank
(10m3)
Underground Storage Tank
(100m3)
Underground Storage Tank

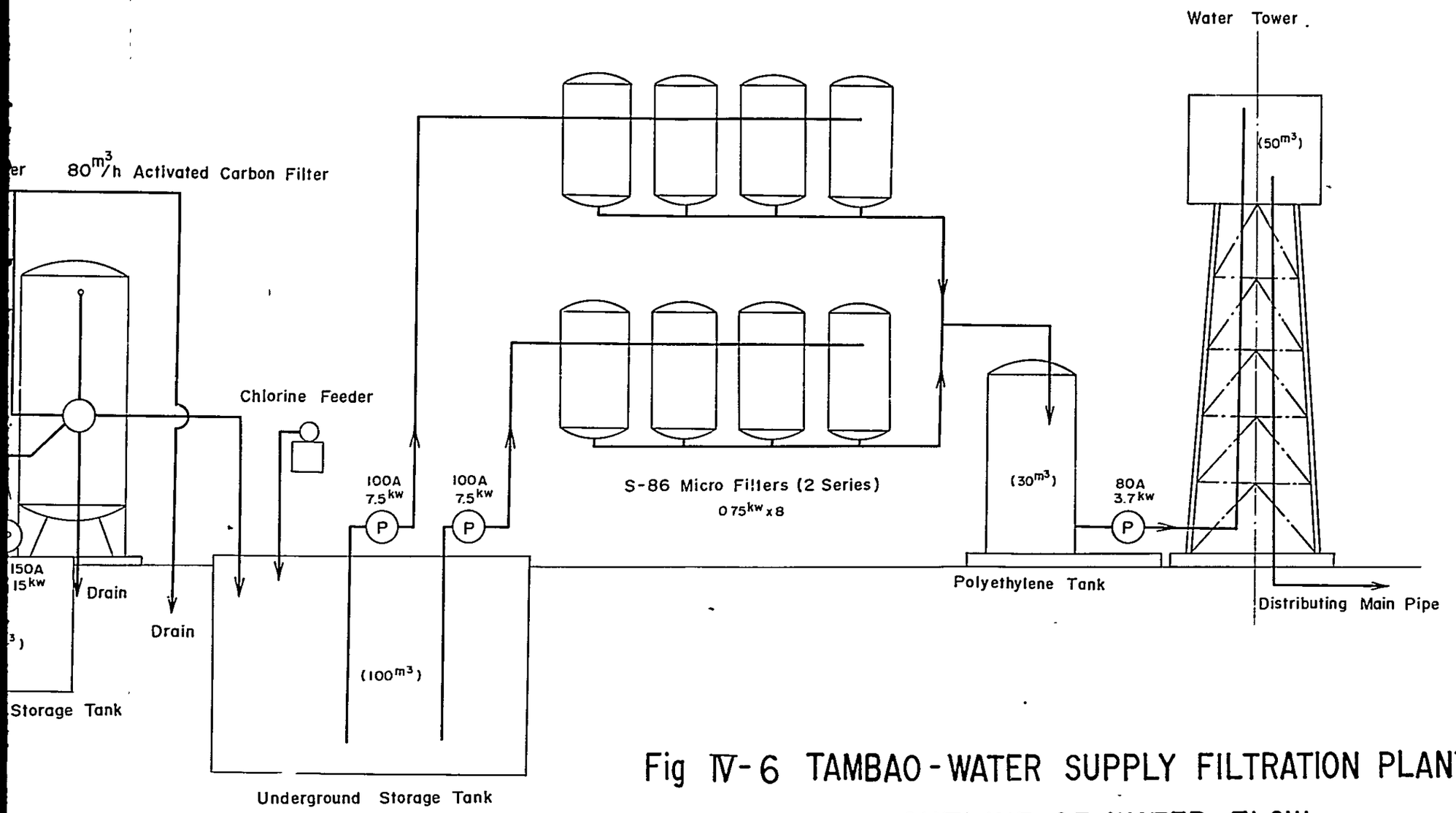


Fig Ⅳ-6 TAMBAO-WATER SUPPLY FILTRATION PLANT
OUTLINE OF WATER FLOW

IV-7 Plan for Airstrip

An airstrip will be constructed for use in emergency, for instance, in case a person is seriously injured or suddenly falls ill in the mine township and requires urgent medical treatment. It will also serve the urgent needs of people living in neighboring areas. The airstrip can serve these purposes sufficiently if it can be used by a small airplane seating up to 10.

At present there is an airstrip about 2 kilometers to the west of Tambao. This is a class D airstrip thought to have been built when a UN team conducted a mine survey in the area. It is 30 meters wide and 600 meters long, with an allowance of about 100 meters at both ends. It is surrounded by expanses of open flat fields. The airstrip has a surface of compacted laterite, excellent in flatness and hardness. With some repairs it can serve the purpose even today as it stands.

Table IV-4 Specifications of Various Kinds of Aircraft

Aircraft	Overall width (A) (m)	Overall height (C) (m)	Main landing gear spacing (m)	Fully equipped weight (t)	Airstrip length needed for		No. of passengers
					Landing (m)	Take-off (m)	
YS-11	32.0	9.07	8.60	23.5	705	905	60
Friendship F-27	29.0	8.40	7.20	17.86	1,113	1,052	40
Douglas DC-3	28.96	5.15	5.64	11.88	792	838	30
De Havilland DHC-6	19.8	--	--	5.70	600	450	20
Beechcraft G-185	15.14	2.94	3.93	4.5	520	630	8
Aerocommander 680-F	15.09	4.42	3.95	3.63	560	685	6
Cessna 310-B	11.25	3.02	3.66	2.26	533	448	4

IV-8 Plan for Electrical Equipment

Electric power for the residential area is for the water service and sewerage systems, for lighting of the roads, and for use in houses and public facilities. The total load is estimated at 100kW. Electric power will be supplied from the power plant at the mine site.

Included in the electrical equipment are outdoor wiring, electric poles, pole transformers, and outdoor lighting equipment.

IV-9 Other Facilities

In addition to the above-mentioned facilities, sewerage systems, as well as garbage disposal facilities, are to be provided at the mine township. In consideration of its estimated population (about 2,000) at the time of its construction, it was decided under the present plan that each home is to incinerate its own garbage and dispose of sewage by ground filtration. As for fuel, each home is to use kerosene or propane gas depending on the appliances owned.

IV-10 How to Run Tambao Mine Township

The town is an artificial "oasis" created in a desert. As such it has a great value for people living around the town. However, although the town has various facilities and functions as an efficient municipality it must secure potable water by an artificial method because of the harsh natural environment.

The volume of water that can be supplied in the area cannot be increased unless more sources are tapped. It is quite likely that residents in the neighborhood of the town will move into it in droves as more facilities are built there. If this is allowed to happen without restraint, the living environment in the town will deteriorate.

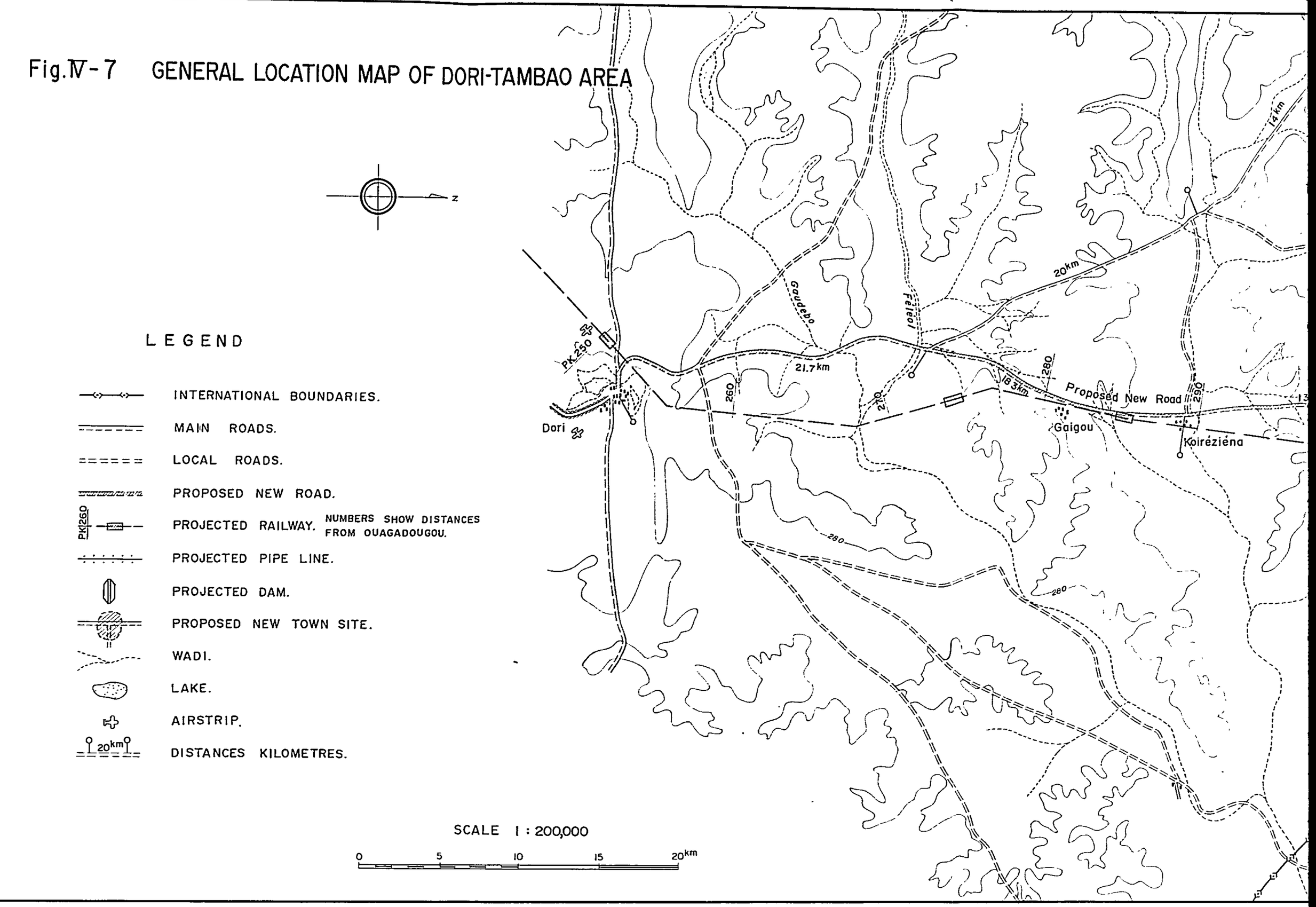
It is necessary therefore to maintain the town in good condition by, for example, establishing municipal ordinances if it is to be developed as a model town in Haute-Volta. Authorities concerned would do well to pay as much attention to the town's development in the post-construction period as they did in the planning stage.

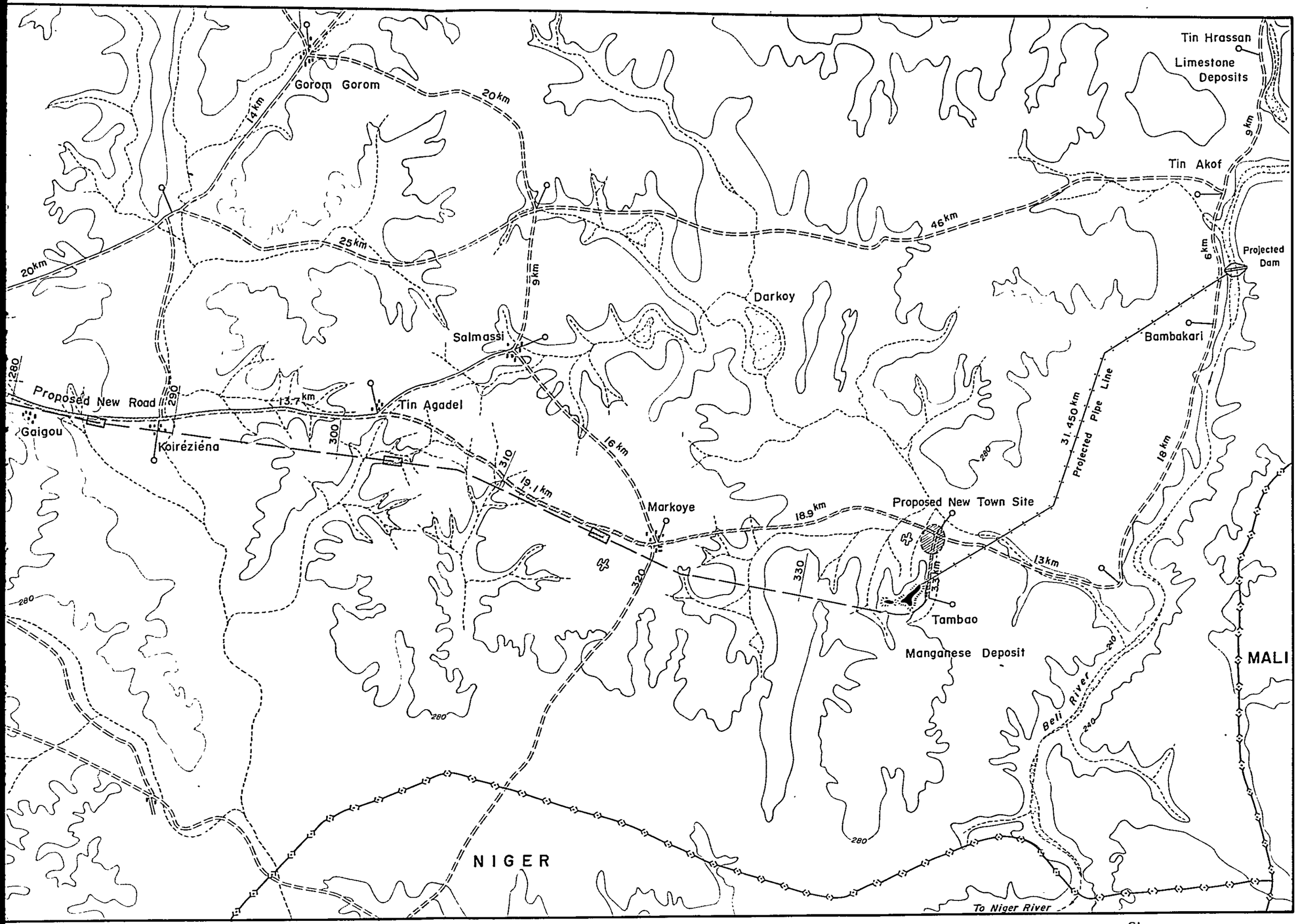
A municipal ordinance may be established to regulate the use of land in the area designated for development under the present project. By attaching conditions to land use the land in the area can be utilized in an orderly manner.

Coordination between all interested agencies is necessary, of course, to make such regulations work. It is also necessary to familiarize neighboring residents with such statutory requirements. This will certainly take time. To make certain that the regulations will be observed, the town is proposed to be established within the mining concession so that the responsibility of running it may be assumed by the mining authority.

Note: For the relative positions of the proposed town construction site, Dori-Tambao road, railway line, Tin Akof dam site, and water pipeline, refer to Fig. IV-7.

Fig.Ⅳ-7 GENERAL LOCATION MAP OF DORI-TAMBAO AREA




Gorom Gorom
14km
20km
20km
25km
9km
46km
Tin Hrassan
Limestone
Deposits
9km
Tin Akof
6km
Projected
Dam
Darkoy
Salmassi
Bambakari
1280
Proposed New Road
290
13.7 km
Tin Agadel
Gaigou
Koiréziéna
300
310
16km
19.1 km
Markoye
18.9km
Proposed New Town Site
31.450 km
Projected Pipe Line
18km
280
330
13km
33km
Tambao
Manganese Deposit
320
280
240
Beli River
240
MALI
NIGER
To Niger River

CHAPTER V

ROAD PLAN

V-1 Background and Outline of the Plan

The road to be repaired is the existing road with a length of about 95km from Dori to Tambao, as shown in Fig. V-1.

This existing road, designated as Route Départementale RD-11, is in poor condition over a larger part of its total length so that, as it is, it cannot permit the passage of heavily loaded vehicles. More problems are posed in the rainy season because of an almost complete lack of bridges and drainage structures including underground drain pipes (there are some such structures between Dori and the junction at Féléol because the road between them, covering a distance of about 21.7km, is in better repair), and there is a certain period of time in a year when traffic along the road is completely suspended. In order to develop Tambao Mine, it is necessary to repair the road to make it usable on a constant basis for the purpose of transporting construction materials and development personnel, and carrying daily necessities including foodstuff, and for other purposes.

The situation will be the same after the start of operation of Tambao Mine as during its construction. It would be extremely inadvisable to depend solely on railway transportation, which is subject to restrictions on transport time and transport volume.

The road will be used not only for purposes of the mine but, after its construction, for the benefit of people in the neighboring areas as well. Therefore, attention should be paid to maximum contribution of the road to regional development.

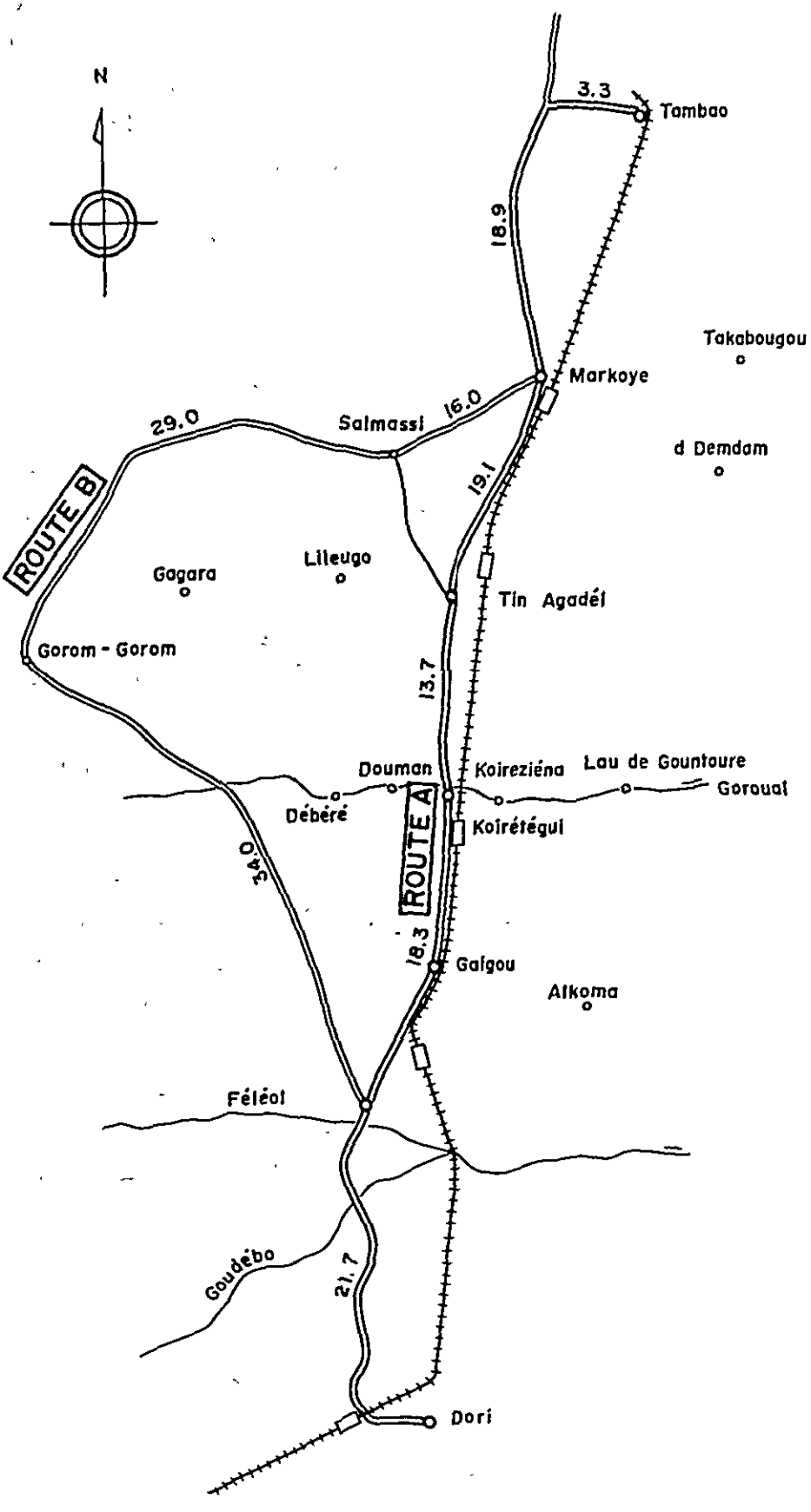
The road repair and construction plan is outlined below.

Total length: About 95km, including a new road extending 73.3km and a section of 21.7km to be repaired.

Width: Overall width -- 7.0m; effective width -- 5.0m

Base course:	Standard banking -- 0.5m; of which the wearing course -- 0.15m of lateritic soil compacted by rolling	
	Cross-grade of road -- 3%; normal slope of shoulder -- 1:1.5	
Cross-road structures:	Causeways	2
	Culverts	9
	Corrugated drain pipes	in 85 places

Fig. V-1 GENERAL MAP OF DORI-TAMBAO ROUTE



V-2 Present Status of Existing Roads

There are at present two routes of roads in use from Dori to Tambao as shown in Fig. V-1. These routes are:

(a) Route (A)

Dori → Féléol → Koiréziéna → Markoye → Tambao

Total length -- about 95km

(b) Route (B)

Dori → Féléol → Gorom Gorom → Markoye → Tambao

Total length -- about 123km

Of these routes, the sections between Dori and Féléol (21.7km) and between Markoye and Tambao (22.2km) are common. Of these sections, that from Dori to Féléol (21.7km) has a width of about 4.0 to 7.0m and is relatively in good repair, so that it can be used without difficulty, by making some repairs and enlarging its width.

The section from Dori to Markoye of Route (A), though designated as RD-11, is in extremely bad condition north of Féléol. It is a beaten track, such as is seen in a desert, rather than a road. It is about 3.5m in width and becomes completely impassable in the rainy season. There are some communities such as Gaigou, Koiréziéna and Tin Agadel on this part of the route.

Route (B) branches off at Féléol, passes through Gorom Gorom and merges with Route (A) at Markoye. This route is about 28km longer than Route (A). The 34km section between Féléol and Gorom Gorom is somewhat repaired but the other parts are in as bad a condition as the unrepaired sections of Route (A).

Next, let us consider this plan in relation to the plan now under study to extend the railway route from Ouagadougou to Tambao. The planned railway route is scheduled to be constructed roughly along Route (A), and stations are planned to be built at Féléol, Koiréziéna, Tin Agadel and Markoye on the railway.

V-3 Selection of Road to be Repaired and Constructed

Route (A) now in use was selected as the road to be repaired and constructed, as it was considered advantageous over Route (B). The main reasons are as follows:

(a) Route (A) is shorter by about 28km than Route (B), and offers greater efficiency in transportation.

(b) The section between Dori and Markoye of Route (A) is designated as RD-11, and will serve as the trunk road of the Department of Sahel in future, too. It can also provide an international route leading to Mali and Niger.

(c) If we consider the relations of Route (A) to the neighboring communities, it will be seen that Route (A) will be more efficiently utilized than Route (B).

Reference data:

	Route (A)	Route (B)
Number of neighboring communities	12	9
Estimated present population	8,000	6,000

(d) If we consider the relations of Route (A) to the planned railway route, there are greater chances of development for the areas along Route (A), as railway stations are to be built along this route.

From all these factors, it will be clear that Route (A) has advantages over Route (B) in respect of transport efficiency, efficiency of utilization and contribution to regional communities. This route may have to be changed a little and connecting roads to the stations may have to be constructed depending on its relations to the railway route. But this will not pose any difficult problems.

V-4 Technical Examination of the Selected Route

V-4-1 Geological features

The area which Route (A) traverses over a total length of 95km between Dori and Tambao is generally level, and is considered to be a sub-plain on levels between 250 and 300m above the sea level.

The area is marked by gentle undulations and the network of water drainage over the area does not present any remarkable characteristics. The slope of the river beds is gentle, and the rivers widen in the rainy season and swamps are formed in many parts of the area.

V-4-2 Geology of Dori-Tambao area and its neighborhood

The geological eras and structures of the area between Dori and Tambao and its neighboring areas are outlined in Table V-1.

Table V-1 Geological Periods and Features of Dori-Tambao and Neighboring Areas

Geological period		Geological Structure and Lithology
Quaternary		Consists of aeolian deposits forming sand dunes and alluvium in wadis and depressions. Sand dunes, 20m high and 2 to 6km wide, run E-W over a distance of 100km and make up 30% of the area. The alluvium is 1 to several meters thick, consisting of muddy sand, sand and occasionally gravel.
(Tertiary)		Only lateritization and peneplanation are found. Lateritization is particularly notable in the Birrimian crystalline schist area to the west. On the plain, Precambrian sediments form 30 to 50m high tables covered with iron-rich porous laterite several meters thick.
Infracambrian (Precambrian Upper)		A Ydouban group distributed along the Beli river to the north of Tambao. It irregularly covers the Precambrian middle and lower groups, and consists of flysh schists, sandstones, quartz schists, jaspers, conglomerates, breccias, limestone, and dolomite. Structurally, the Ydouban group is a repetition of anticlines and synclines running in the NW-SE direction. With a width of 10 to 20km and an inclination of 30 to 60°, it forms a basin between the two Precambrian series of Haute-Volta and Adrar.
Precambrian	Middle	In this area, the Precambrian middle series consists of a Birrimian system. The geological structure is folded on a N-S or NNE-SSW axis. The Birrimian system is divided into the upper part and lower part. The lower part is made up of slate, quartzite, phyllite, graywacke, tuff and lava, and also of schists and gneisses formed from them by metamorphism. The upper part is composed of Tarkwaienne molasse type deposits made up primarily of green rock. Calc-alkali rock (granodiorite) intrudes into these deposits.
	Lower	The Precambrian lower series consists of calc-alkali granite, gneisses, migmatite, and also of groups of volcanic sedimentary rocks of Sikiday and Gouba. They are dated 2,400 to 2,700 million years. The Tambao manganese deposits are found in the Gouba group.

V-4-3 Soil conditions

The soil that occurs along the route can be classified into the following three kinds:

(a) Lateritic soil
(b) Sandy soil
(c) Clayey soil

The lateritic soil is very hard and compact so that a road can be built on it without any need for further preparation. The sandy soil is found in the sand dune areas, and where it is loose, no vehicle can run on it. The clayey soil is expected to be completely inundated during the rainy season, preventing any vehicles from traveling on it.

V-4-4 Soil tests

During the field survey, the survey team classified the soil with the naked eye, and took representative samples of the three kinds of soil according to the classification. After returning home, the survey team conducted physical and compaction tests (by the informal method) on the samples. The results of the tests are summed up in Table V-2. (For details, refer to the tables of soil test results in Appendix I.)

Table V-2 Outline of Soil Test Results

Item	Sample		
	No. 1	No. 2	No. 3
Sampling site (km from Dori)	66.8	61.8	36.8
Soil conditions	Lateritic soil	Clayey soil	Sandy soil
Japan unified soil classification	SF	CL	S-F
Japan unified soil name	Silty sand	Clay	Fine sand mixed with clay
Maximum grain size (mm)	9.52	4.76	2.0
Uniformity coefficient (Uc)	176.0	--	4.12
Liquid limit (WL%)	Nonplastic	37.0	Nonplastic
Maximum dry density(γd_{max})	2.086	1.689	1.785
Optimum moisture (W_{opt})%	8.4	16.0	11.4

Notes:

SF: This is sandy soil, and viewed from its grain size distribution curve, it corresponds to silty sand (SM). This soil is classified as "good" for foundation, "high" in shearing strength, "easy to fairly easy" in the execution of construction work, and as "appropriate" as banking material.

CL: This is sandy clay or silty soil, and is classified as "good to poor" for foundation, "medium" in shearing strength, "easy to fairly easy" in the execution of construction work, and as "appropriate" as banking material.

S-F: This means sand whose fine soil content comes under the classification of S-M of silt. It is "good to poor" for foundation, "high" in shearing strength, "easy to fairly easy" in the execution of construction work, and "appropriate" as banking material.

V-4-5 Road standards

According to the specifications given by the General Office for the Tambao Project at the time of the second research work on the road repair and construction work, the main points of the geometrical and technical standards of the road are as follows:

Width	7.0m
Cross-grade of road surface	3%
Radius of plane curve	500m
Longitudinal slope	6%

The thickness of tread surface layer of vehicle road is to be determined by a pair of rubber wheels with a shaft load of 13t and by its frequency of traffic.
The structures are to be designed to withstand a longitudinal row of 30t vehicles (French standards).
The gradient of the slope is to be determined according to natural topography.

Consequently, these standards are also applied to the plan for repairs and construction of the road between Dori and Tambao.

Suppose the lane width is 2.50m, and if a two-lane road is to be constructed with a shoulder width of 1.0m on both sides, the overall road width will be 2.5m x 2 + 1m x 2 = 7.0m. Therefore, the above-mentioned road width of 7.0m is considered appropriate.

Regarding the radius of plane curve (500m) and the longitudinal slope of 6%, it may be said that there are no restricting conditions on them, since the configuration of the area is marked by levelness and limited undulations, characteristic of a savannah.

Further, if selected laterite, which occurs amply in the area, is banked and compacted by rolling to form the wearing course of the vehicle road, the road will have a sufficient load-bearing strength in view of its CBR value.

V-4-6 Subgrade and base course

(1) The subgrade soil in the area along the existing road, Route (A), between Dori and Tambao, can be classified roughly as in Table V-3. For details, refer to Table V-1 and Fig. V-2.

Table V-3 Soil Distribution Along Route (A)

Soil classification	Length	Proportion in total length
Laterite and laterite mixed with sand	35.8km	38%
Sand and sand mixed with clay	40.4km	43%
Clay and clay mixed with laterite	18.8km	19%
Total	95.0km	100%

(2) As will be clear from the percentages in Table V-3 lateritic and sandy soil account for about 80% of the total length. These offer sufficient strength as the subgrade, so that there are no problems at all in this respect. However, judging from the results of the field survey and aerial photographs

of the area, numerous small streams collecting rainwater cross the road. The natural ground surface of these parts is clayey, so that the strength of the road may be lowered by water infiltration.

Consequently, it is necessary to adopt a construction method to prevent the natural ground surface from weakening by improving drainage through provision of drain pipes, culverts and so on in this part of the route.

(3) Lateritic soil is easily amenable to compaction and is therefore a material soil suitable for subgrades and base courses. However, it suffers from some defects: When it is dry, it is easily pulverized and blown away as dust, and it is also easily eroded by the action of water. However, considering the fact that at present, all the main national roads in Haute-Volta, excepting those paved with asphalt, are red belts of laterite, the occurrence of high quality material for base courses over 30-40% of the total length of the route is undoubtedly a favorable condition for the execution of the road construction plan in terms of cost of work as well as technique.

(4) Distribution of soil along Route (A) based on judgment by the naked eye.

Fig. V-2 shows a macroscopic classification of the quality of soil distributed along the entire length of Route (A). Further, distribution rates of different kinds of soil are set out in Table V-4 on a section-by-section basis.

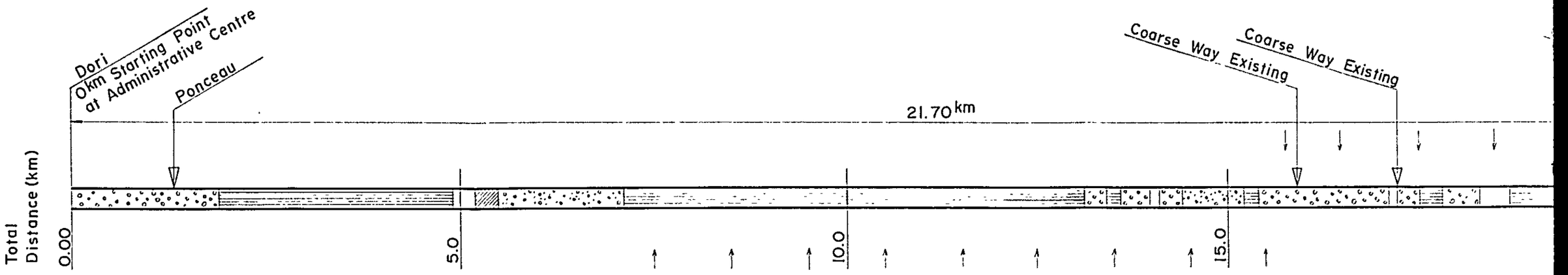
Table V-4 Soil Distribution Along Route (A)

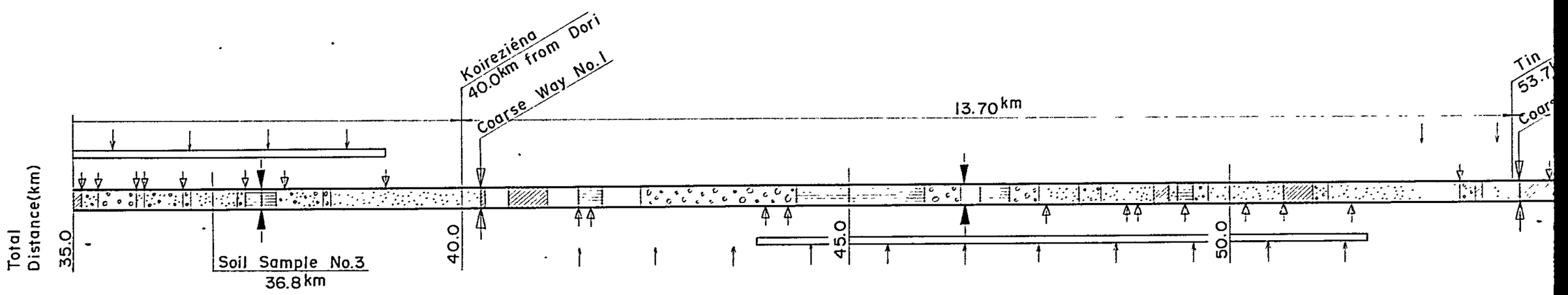
Classification of soil / Sections	Lateritic soil			Sandy soil			Clayey soil			Total
	Laterite	Laterite mixed with sand	Total	Sand	Sand mixed with clay	Total	Clay	Laterite mixed with clay	Total	
Dori → Féléol										
Length (km)	5.4	2.4	7.8	--	12.0	12.0	1.6	0.3	1.9	21.7
Percentage			36.0			55.0			9.0	100
Féléol → Koiréziéna										
Length (km)	3.75	2.7	6.45	4.8	1.0	5.8	2.85	3.2	6.05	18.3
Percentage			35.0			32.0			33.0	100
Koiréziéna → Markoye										
Length (km)	14.25	2.3	16.55	5.45	3.25	8.7	2.95	4.60	7.55	32.8
Percentage			50.0			27.0			23.0	100
Markoye → Tambao										
Length (km)	4.8	0.2	5.0	10.65	3.25	13.9	1.7	1.6	3.3	22.2
Percentage			22.0			63.0			15.0	100
Total										
Length (km)	28.2	7.6	35.8	20.9	19.5	40.4	9.1	9.7	18.8	95.0
Percentage			38.0			43.0			19.0	100

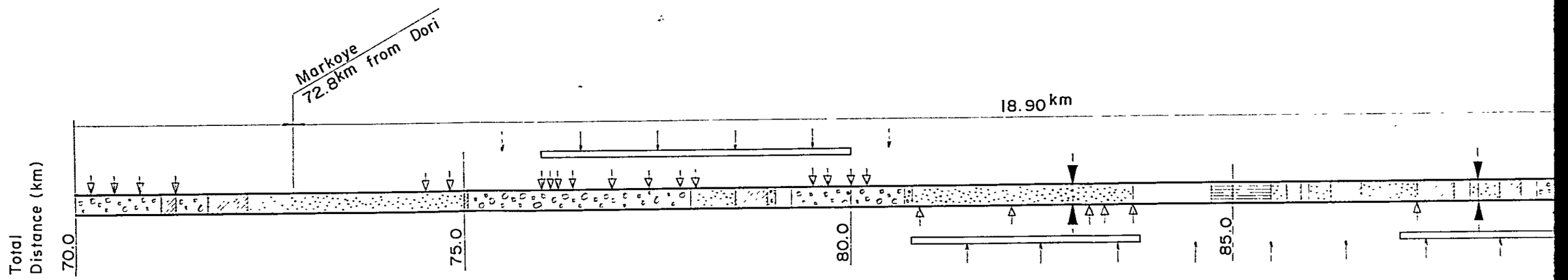
(5) In the section from Dori to Féléol, crude base courses have been built and maintenance work has been performed. However, the section north of Féléol has a natural ground surface, is level and limited in undulations, with gentle slopes. Therefore, it is expected that water will stagnate over a wide area during the rainy season (According to the BCEOM Report, this area is marked by torrential rains with thunders, with precipitation amounting to 53 - 61mm/h), so that it is necessary to form a base course of 0.5m or more by banking on the natural ground surface.

(6) Available as banking materials are clayey, sandy and lateritic soils that are found in the area along the route. These soils should be banked in layers according to their optimum moisture contents and also to the characteristics peculiar to them, and then should be compacted by rolling. In this way a base course with enough bearing power to permit traffic of heavy vehicles can be provided without difficulty.

(7) It is necessary to take proper measures in construction for the clayey part of the subgrade so that the bearing power of the natural ground may not decrease. In order to obtain data on the thickness of the clayey layer and flow conditions of rainwater, which are considered to decrease of bearing power, it is necessary to study these conditions in detail by conducting boring, pit-excavation and other work on the spot. While the effect of reduced bearing power cannot be ignored, it is very difficult to predict it for certain. As a countermeasure against the decrease of bearing power, it is recommended that the surface clay be removed to a depth of about 20cm and be replaced with a sand mat, before banking the base course. The material to replace the clay is readily available because sandy soil is widely distributed in the area.


Dori
Okm Starting Point
at Administrative Centre
Ponceau
Coarse Way Existing
Coarse Way Existing
21.70km
Total
Distance (km)
0.00
5.0
10.0
15.0


Koireziéna
40.0km from Dori
Coarse Way No.1
13.70km
Tin
53.7
Coars
Total
Distance(km)
35.0
40.0
45.0
50.0
Soil Sample No.3
36.8km


Markoye
72.8km from Dori
18.90km
Total
Distance (km)
70.0
75.0
80.0
85.0

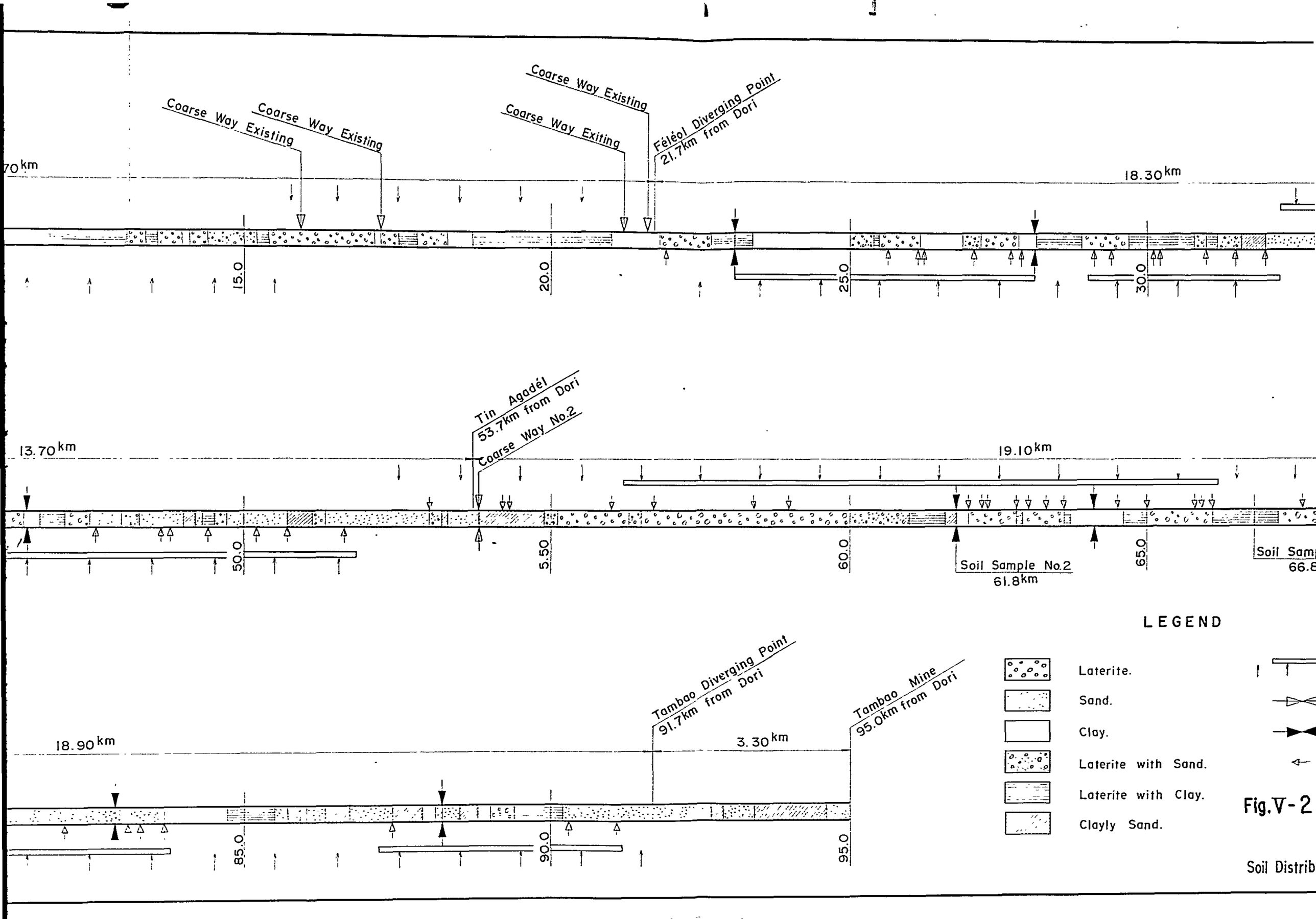
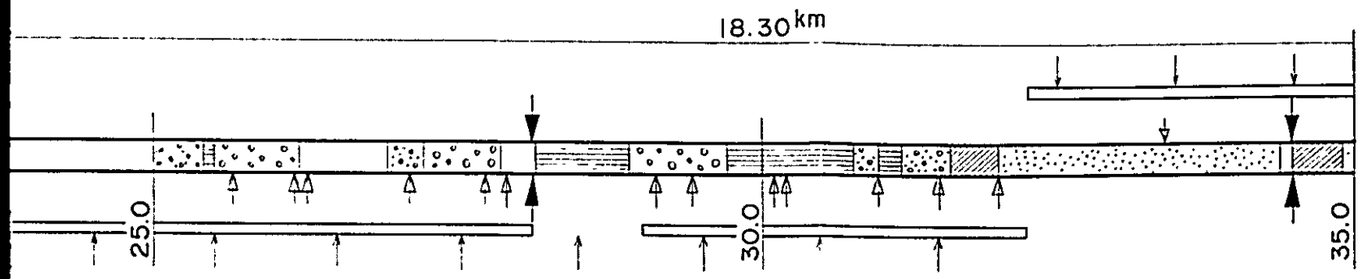
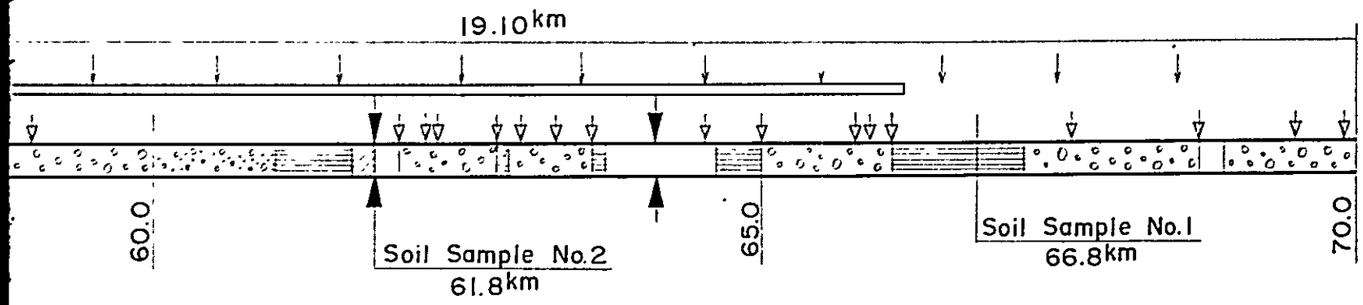


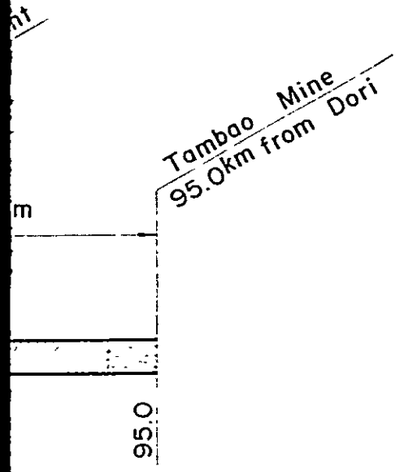
Fig.V-2

Soil Distrib





LEGEND



Laterite.
Sand.
Clay.
Laterite with Sand.
Laterite with Clay.
Clayly Sand.

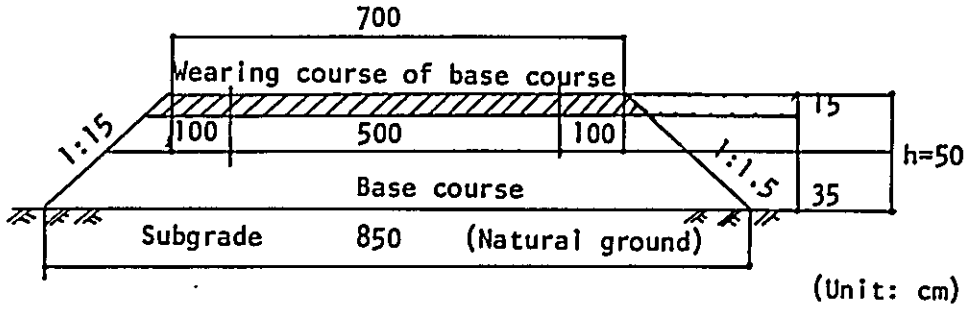
Non Lining Ditch. (Discharge Direction.)
Coarse Way.
Concrete Culvert.
Corrugate Pipe.

Fig.V-2 PLAN MAP OF NEW PROJECTED ROAD FROM DORI TO TAMBAO

Soil Distribution and Arrangement of Discharge Structures

(8) The standard cross section of the base course is as shown in Fig. V-3. The overall width is to be 7.0m, and the effective width 5.0m, while the overall height of the banking is to be 0.5m, of which the wearing course (0.15m) is to be of lateritic soil. The normal slope of the road shoulder is to be 1:1.5, and the cross-grade of the road surface 3%.

Fig. V-3 Standard Cross Section of Base Course



Where cross-road drain pipes and culverts are laid, the overburden on the pipes is required to be 40 to 50cm thick. Therefore, h = 1.0 to 1.5m.

Further, the cross section of the banking as against the standard cross section of the base course should be as follows, considering errors due to the slope and unevenness of natural ground surface and giving a 10% shrinkage allowance for the banking:

For h = 0.5m

Wearing course $\frac{7.0 + 7.45}{2} \times 0.15 \times 1.1 = 1.19m^2$

Base course $\frac{7.45 + 8.5}{2} \times 0.35 \times 1.1 \fallingdotseq 3.07m^2$

For h = 1.0m

Wearing course $\frac{7.0 + 7.45}{2} \times 0.15 \times 1.1 = 1.19m^2$

Base course $\frac{7.45 + 10.0}{2} \times 0.85 \times 1.1 \fallingdotseq 8.16m^2$

For h = 1.5m

Wearing course $\frac{7.0 + 7.45}{2} \times 0.15 \times 1.1 = 1.19m^2$

Base course $\frac{7.45 + 11.5}{2} \times 1.35 \times 1.1 \fallingdotseq 14.07m^2$

(9) Where natural ground is of sand or sandy soil, use of sand or sandy soil mechanically mixed with lateritic or clayey soil as material for base course banking is desirable. This is important in preventing loss of soil particles or scouring of the base course due to water infiltration from the wearing course.

(10) The wearing course is to be 15cm thick. It is desirable that lateritic material with the following characteristics be selected from locally available lateritic materials and used for the wearing course:

50% grain size	2mm
CBR value at 95% of optimum moisture content	30
Plasticity index	15

If lateritic material with a moisture content close to the above-mentioned optimum moisture content is evenly laid and compacted sufficiently by rolling, it is possible to obtain a road surface that can sufficiently withstand heavy-vehicle traffic.

(11) There are however problems in the lateritic wearing course to be considered -- scouring in the rainy season and partial loss due to pulverization during the dry season, resulting in the uneveness of the road surface. As it is expected that such a bad road condition may cause traffic accidents, it would be necessary to pay sufficient attention to road maintenance. Thus, it is necessary to establish a system of road maintenance and control by which the road surface may be repaired regularly with the aid of graders, tire rollers and so forth.

(12) The road width is narrower in some places in the already repaired section of the route from Dori to the junction at Féléol, while the bridge at about 0.9km from the starting point at Dori is in need of repairs. Therefore, costs for enlarging the road width and repairing are required to be included in the estimated construction cost.

V-4-7 Drainage facilities

(1) Rainfall and its characteristics

Rainfall in this area is concentrated on five months of the year (May through September) and the highest monthly precipitation is recorded in August. The distribution of annual rainfall in the area is as follows: 700-900mm in the Ouagadougou-Kaya district, 500-600mm in the Dori district, and 400mm in the Tambao district. Thus, rainfall characteristically decreases regularly from the south to the north. The Dori-Tambao district is marked by the so-called Sahel climate characterized by a clear distinction between the rainy and the dry seasons. The rainy season accounts for a larger part of the annual precipitation, and there is hardly any rainfall in the dry season. Further, floods in the area are due to tornados; in a small catchment basin with an area of 200-300km^2 a flood due to a tornado is rarely augmented by a following tornado. In other words, no flood is caused by a new tornado before a flood due to the preceding one recedes. Rainfall in Ouagadougou and to the north is as shown in Table V-5 in terms of daily rainfall for 1, 10 and 100 years return periods.

Table V-5 Daily Probability Rainfall at Ouagadougou, Kaya and Dori

Place	Frequency of measurements per year	1 year return period	10 years return period	100 years return period
Ouagadougou	10	64mm	117mm	189mm
Kaya	35	55	89	134
Dori	25	50	83.2	123

Source: BCEOM Report

Isohyets for daily rainfall (10 years return period) and annual precipitation at Ouagadougou and to the north are illustrated in Fig. V-4.

(2) Classification of drainage facilities (See Fig. 8, 9, 10.)
The following drainage facilities are to be provided in consideration of the neighboring terrain, water discharge and flow conditions.

(a) Causeways
No. 1 Length 100m
No. 2 Length 47m

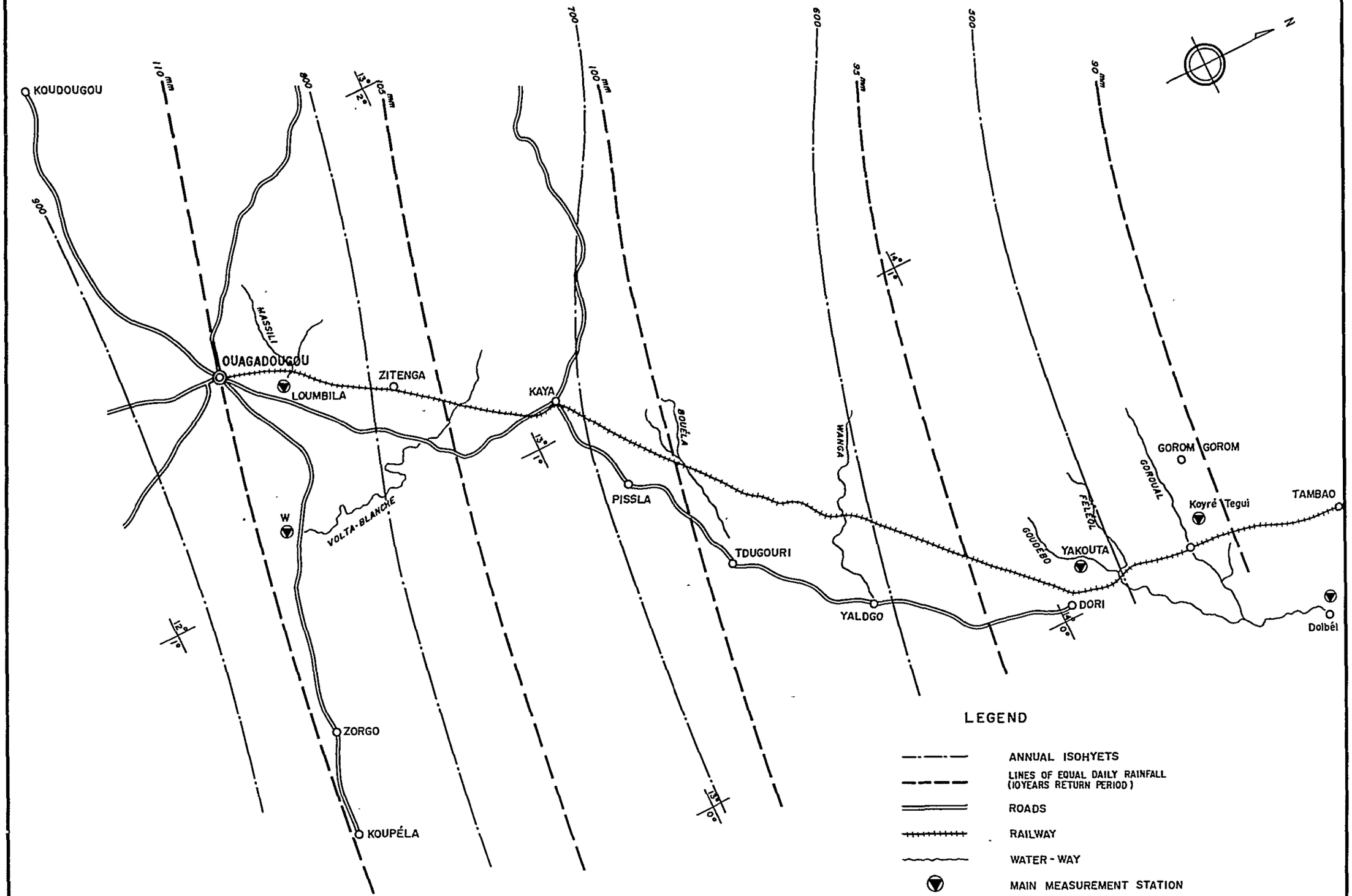
(b) Culverts
i) (Single) 1 x 100cm x 200cm in five places
ii) (Double) 2 x 100cm x 200cm in four places

(c) Drain pipes
i) Corrugated drain pipes 1ϕ 65cm x 100cm in 64 places
ii) Corrugated drain pipes 2ϕ 65cm x 100cm in 14 places
iii) Corrugated drain pipes 1ϕ 100cm x 150cm in 7 places

(d) Non-lining ditches
Three kinds, Total length 44,000m

(3) Location of drainage facilities (See Fig. V-2.)
(a) Causeway No. 1

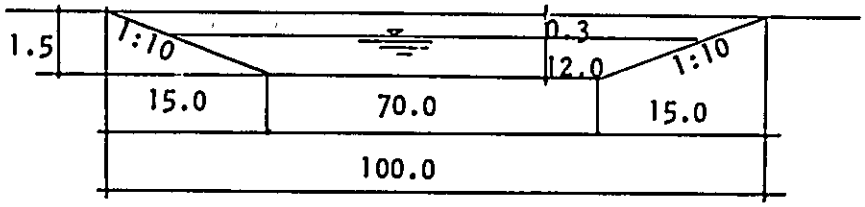
Fig V-4 CLIMATIC MAP OF HAUTE VOLTA



Causeway No. 1 is to be provided where the route crosses the river Gorouol, at 40.25km from the starting point of Dori, or at the northern end of Koiréziéna. Its specifications are:

Estimated flood discharge Q = 145m³/sec
Overflow water head h = 1.2m

Fig. V-5 Cross Section of Causeway No. 1



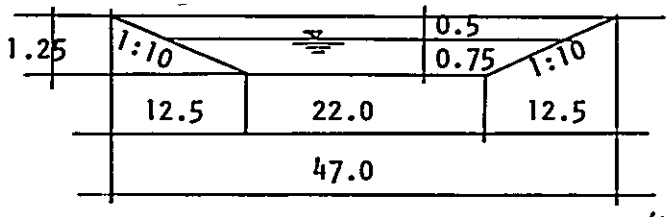
(Unit: m)

(b) Causeway No. 2

Causeway No. 2 is to be provided at 53.8km from the starting point of Dori, or at the northern end of Tin Agadel. Its specifications are:

Estimated flood discharge Q = 22m³/sec
Overflow water head h = 0.75m

Fig. V-6 Cross Section of Causeway No. 2



(Unit: m)

(c) Culverts

Two kinds of culverts, totaling nine, are to be provided. Five of them will be single culverts and the remaining four double culverts.

Table V-6 Location of Culverts

Distance from Dori	Kind	Distance from Dori	Kind
23.1km	Single	61.8km	Double
28.1	Single	64.1	Single
34.5	Single	82.9	Double
37.4	Double	88.2	Double
46.5	Single	--	--

(d) Corrugated drain pipes

Three kinds of corrugated drain pipes are to be laid in the places shown in Table V-7.

Table V-7 Location of Drain Pipes (km)

Distance from Dori		Distance from Dori		Distance from Dori		Distance from Dori		Distance from Dori	
Drain pipe (i)		19	44.2	38	66.1	57	79.7	10	59.0
1	21.9	20	48.65	39	67.6	58	80.0	11	63.0
2	25.65	21	48.8	40	68.2	59	80.9	12	65.9
3	26.2	22	50.2	41	68.7	60	82.6	13	69.9
4	26.3	23	51.6	42	69.5	61	83.1	14	80.2
5	27.1	24	54.2	43	70.2	62	83.3		
6	27.7	25	54.3	44	70.5	63	87.4	Drain pipe (iii)	
7	27.9	26	56.0	45	70.8	64	90.3	1	30.2
8	29.1	27	58.4	46	71.3			2	32.0
9	29.4	28	62.0	47	74.5	Drain pipe (ii)		3	41.5
10	30.1	29	62.2	48	74.8	1	31.0	4	53.0
11	31.5	30	62.3	49	76.0	2	33.4	5	78.0
12	35.3	31	62.8	50	76.1	3	35.1	6	83.7
13	35.8	32	63.3	51	76.2	4	36.4	7	91.1
14	35.9	33	63.6	52	76.4	5	39.0		
15	37.2	34	64.5	53	76.9	6	47.6		
16	37.7	35	65.0	54	77.4	7	49.4		
17	41.65	36	65.8	55	77.8	8	50.7		
18	43.9	37	66.0	56	79.5	9	56.7		

(e) Non-lining ditches

As the base course is to be banked on natural ground, it is necessary to provide drain ditches along the road to connect cross-road drainage facilities (culverts, corrugated drain pipes, etc.).

These ditches are to be provided for the purpose of collecting rainwater distributed over a broad area quickly and without delay toward the cross-road drainage facilities so that it may be safely discharged downstream, they are therefore required to be provided close to the base course. However, at the same time, it is necessary to provide them in parallel with the road, with a certain safe distance maintained between them and the road, so that the base course may not be damaged even if water overflows the ditches in an accident.

Proper drain ditches are required to be selected from the three kinds, whose cross sections are shown in Fig. V-8, in consideration of the size of catchment basin and conditions of natural ground. The length of these ditches is estimated in Table V-8 according to the topographic map (scale = 1/200,000).

Table V-8 Location of Non-Lining Ditches

Section	Length (km) of ditches
Féléol -- Koiréziéna	5.0 + 6.0 + 4.0 = 15.0
Koiréziéna -- Markoye	8.0 + 10.0 = 18.0
Markoye -- Tambao	4.0 + 3.0 + 4.0 = 11.0
Total	44.0

Note: The lengths of ditches are estimated from the topographic map. Therefore, these should be adjusted on the basis of a field survey prior to execution of the construction work.

V-4-8 Hydraulic study

(1) Causeway No. 1

This causeway is to cross the catchment basin of the river Gorouol at the northern end of Koiréziéna.

Area of catchment basin $A = 2,500km^2$

Average slope of river bed $I = 0.5\%$

Flood discharge is as follows according to the BCEOM Report.

T = 100 years $Q_{100} = 210m^3/sec$

T = 30 years $Q_{30} = 178m^3/sec$

T = 10 years $Q_{10} = 145m^3/sec$

Where T: Return period

Q_{100}: Flood discharge for 100 years return period

The flood discharge estimated from the records of water levels at the time of an abnormal flood in the winter of 1974 is $130m^3/sec$ and it would be reasonable to adopt as estimated flood discharge for 10 years return period, that is $Q_{10} = 145m^3/sec$, in consideration of the effect of a flood downstream of the river.

The length of the weir for the causeway can be obtained from overflow discharge for a broad-crest weir.

$$Q = C \cdot B \cdot h^{\frac{3}{2}}$$

Where Q: Overflow discharge for broad-crest weir (m^3/sec)

B: Length of weir (m)

h: Overflow head of water upstream of weir (m)

C: Coefficient of discharge

Further, the coefficient of discharge (C) is obtained in the following way:

If $h = 1.2$, and $W = 1.5$,

$$h/W = \frac{1.2}{1.5} = 0.8 < 1$$

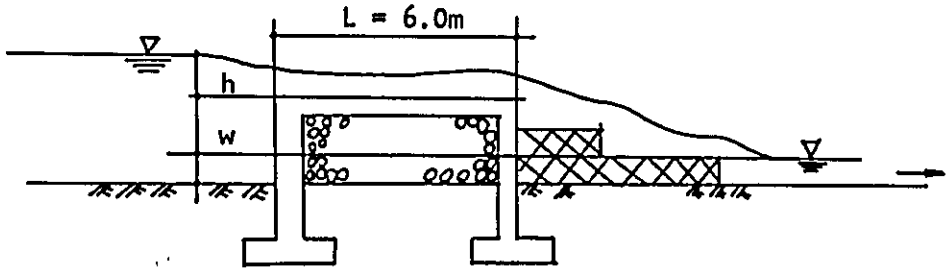
$$h/L = \frac{1.2}{6.0} = 0.2$$

Where W: Water depth up to overflow crest on upstream side of weir (m)

L: Width of weir (m)

(Refer to Fig. V-7)

Fig. V-7 Cross Section of Causeway



Applying Govando Rao Muralidhar's formula, we get

$$0.1 \leqq h/L \leqq 0.4$$

Therefore,

$$C = 1.552 + 0.083\ (h/L)$$
$$= 1.552 + 0.083 \times 0.2 = 1.5686 \fallingdotseq 1.57$$

Therefore, overflow discharge (Q) is

$$Q = 1.57 \cdot B \cdot 1.2^{\frac{3}{2}}$$

Thus, the length of the weir (B) is

$$B = \frac{Q}{1.57 \times 1.2^{\frac{3}{2}}} = \frac{145}{1.57 \times 1.2^{\frac{3}{2}}} = 70.258 \fallingdotseq 70m$$

From the above calculation, the cross section of the causeway will be as shown in Fig. V-5 (for details, see Fig. V-9).

(2) Causeway No. 2

This causeway is to be provided at the northern end of Tin Agadel.

Area of the valley $A = 25km^2$ (estimated from a 1/200,000 scale map)

Slope of river bed $I = 0.5\%$

Flood discharge can be estimated in the following way:
According to the BCEOM Report, the relationship between the total area of catchment basin of the rivers Goudebo, Gorouol and Wanga

and the outflow (flood discharge for 100 years return period) is expressed by the following equation:

$$Q_{100} = 9.43 \cdot A^{0.395}$$

Where Q: Flood discharge for 100 years return period (m^3/sec)

A: Area of catchment basin (km^2)

By using this formula, it is possible to obtain immediately the flood discharge for 100 years return period for the area within the annual isohyets of 500 to 600mm. Therefore, this formula is used to estimate the probability flood discharge for 100 years return period. Assuming that A = 25km^2, we get Q_{100} in the following way:

$$Q_{100} = 9.43 \times 25^{0.395} = 33.3 m^3/sec$$

Next, Q_{10} (flood discharge for 10 years return period) is obtained. By using $Q_{100}/Q_{10} = 1.54$, that is, the rate of probability flood discharge for 100 years return period to flood discharge for 10 years return period at Goroual (according to the BCEOM Report), Q_{10} (flood discharge for 10 years return period) can be obtained as follows:

$$Q_{10} = Q_{100}/1.54 = 21.6 \fallingdotseq 22 m^3/sec$$

The length of the weir (B) can be obtained as follows:

Assuming that Q = 22m^3/sec and h = 0.75m, we can use the same formula applied in obtaining the length of the weir for causeway No. 1, to calculate the length of the weir for causeway No. 2:

$$B = \frac{Q}{1.5 \times h^{\frac{3}{2}}} = \frac{22}{1.5 \times 0.75^{\frac{3}{2}}} = 22.58 \fallingdotseq 22.0m$$

Therefore, the cross section of the causeway is as shown in Fig. V-6 (for details, see Fig. V-9).

(3) Culverts and drain pipes

No hydraulic study is to be made to determine the location of culverts and drain pipes, because the catchment basin is limited in area and the flow conditions are complex. However, in the

execution of the construction work, it is necessary to make sure that the positions and sizes of the culverts and drain pipes are suitable in consideration of outflow in the rainy season.

Used as drain pipes are compound radius arch corrugated pipes. In laying these pipes, it is necessary to pay special attention to backfilling. In other words, in assembling these pipes, struts should be provided inside them to prevent them from being deformed when covered with earth. Good quality sand should be placed on both sides of the pipe and compacted while water is sprayed on the sand.

V-4-9 Work requirements

The volume of work required for new construction work between Féléol and Tambao is summarized in Table V-9 on a section-by-section basis.

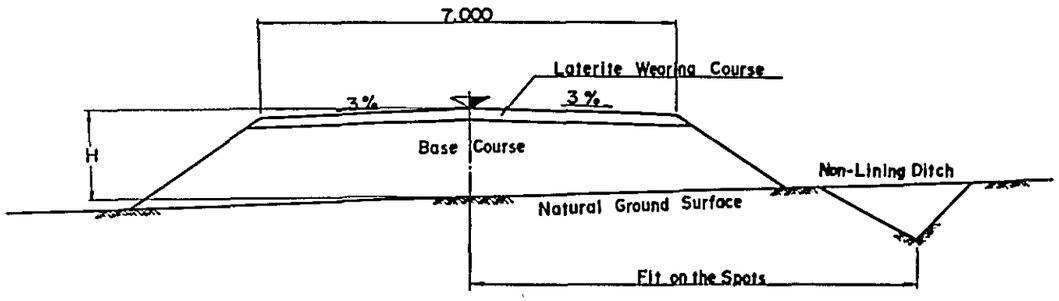
In addition to the construction work listed in the table, repair work for enlarging the road width over a distance of 21.7km between Dori and Féléol is needed.

Table V-9 Section-by-Section Distribution of Work Volume

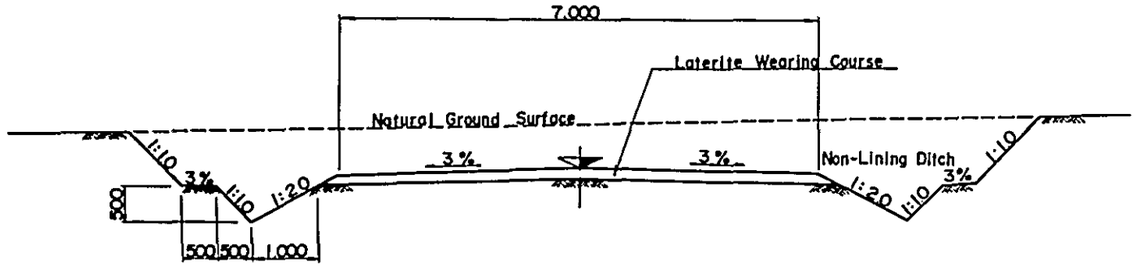
Kind of work	Specifications	Unit	Féléol → Koiréziéna	Koiréziéna → Markoye	Markoye → Tambao	Total
Excavation of ground	Clay and clayey soil 16.9km	m^3	10,900	13,600	6,000	30,500
	Sand and sandy soil 28.4km	"	7,900	11,800	18,800	38,500
Sand mat	Excavated sandy soil used	"	10,900	13,600	6,000	30,500
Banking of base course	h = 0.5m 71.025km	"	54,500	97,000	66,700	218,200
	h = 1.0m 1.759km	"	4,200	6,800	3,500	14,500
	h = 1.5m 0.140km	"	600	600	900	2,100
	h = 2.5m 0.203km	"	--	6,000	--	6,000
Banking of wearing course	h = 0.15m 73.1km	"	15,100	27,000	18,400	60,500
Causeways	Koiréziéna No. 1, Tin Agadel No. 2	No. of places	--	2	--	2
Culverts (i)	1 x 200cm x 100cm	"	3	2	--	5
Culverts (ii)	2 x 200cm x 100cm	"	1	1	2	4
Corrugated drain pipes (i)	1ϕ x 65cm x 100cm	"	16	30	18	64
Corrugated drain pipes (ii)	2ϕ x 65cm x 100cm	"	5	8	1	4
Corrugated drain pipes (iii)	1ϕ x 100cm x 150cm	"	2	2	3	7

Cross Section

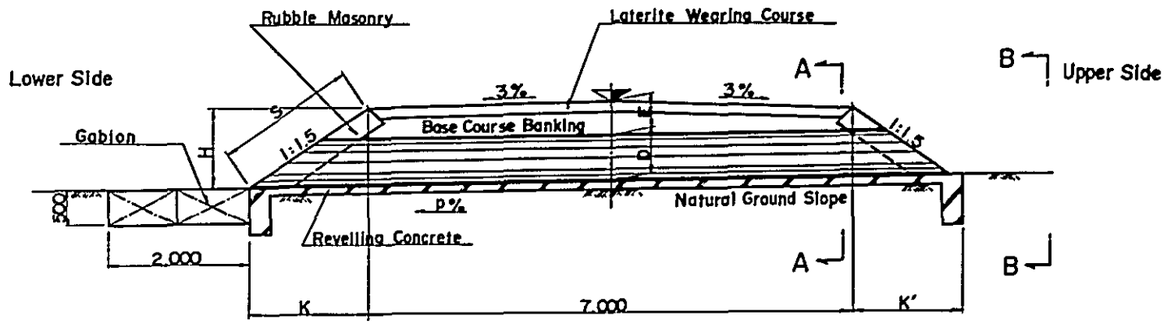
Banking



Cutting

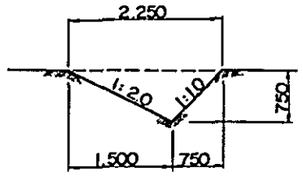


Longitudinal Section of Drain Pipe

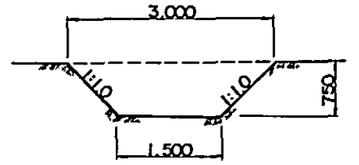


P : River Bed Slope %
D : Depth of Drain Pipe
E : Covering Thickness of Minimum . 500
H : D + E + P% x 7.000
K : 1.5 x H
S : $\sqrt{H^2+K^2}$

Non-Lining Ditch

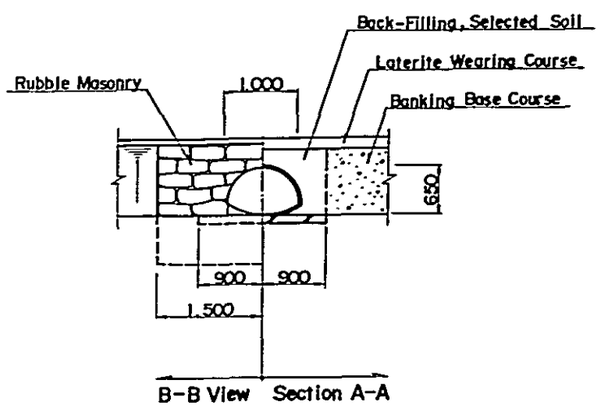


Type 1

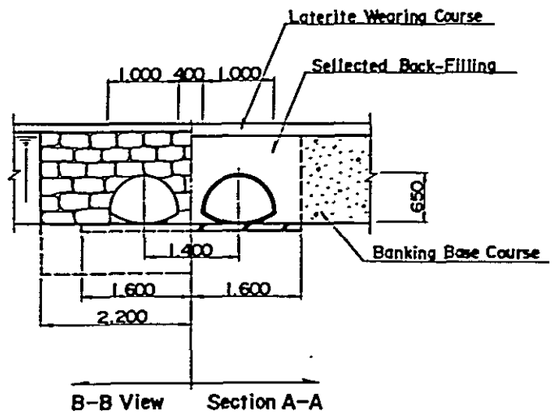


Type 2

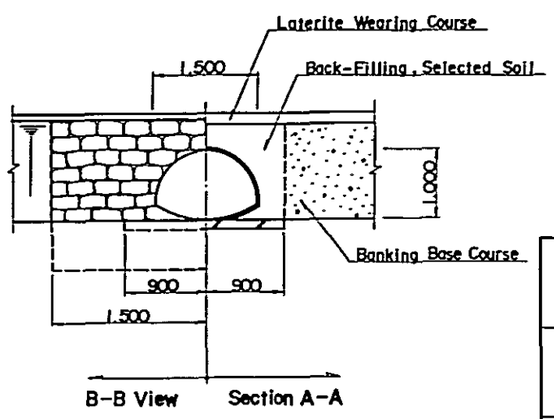
Front View & Cross Section of Drain Pipe (Single)

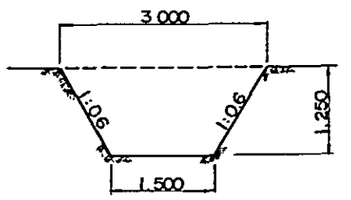


Front View & Cross Section of Drain Pipe (Double)



Front View & Cross Section of Drain Pipe (Single)





Type 3

Unit mm.

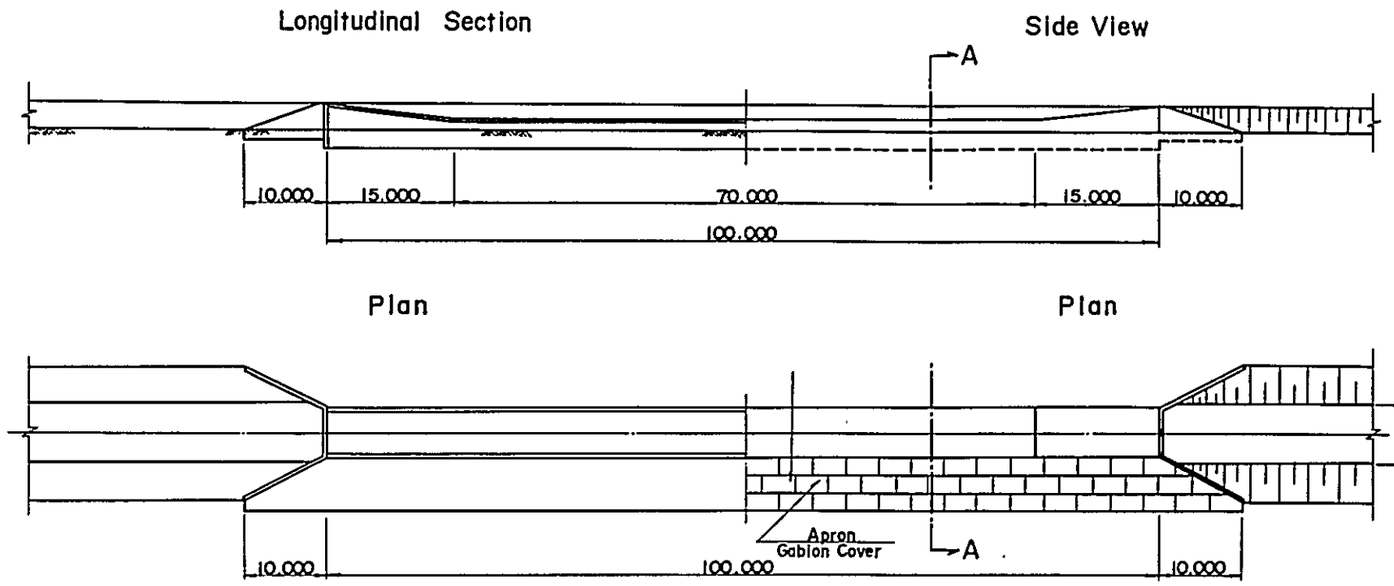
0 1 2m

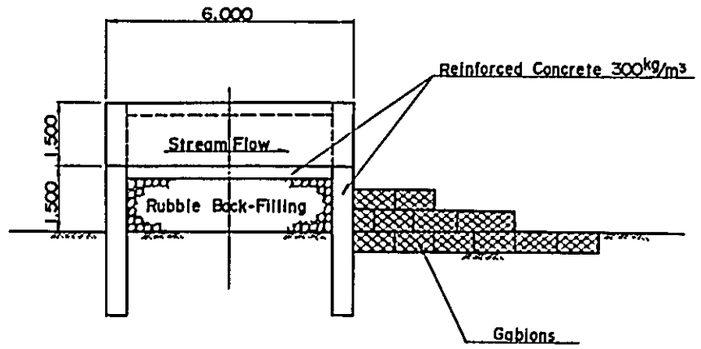
ROAD DORI ~ TAMBAO

Base course, Drain pipe & Ditch

Fig V - 8

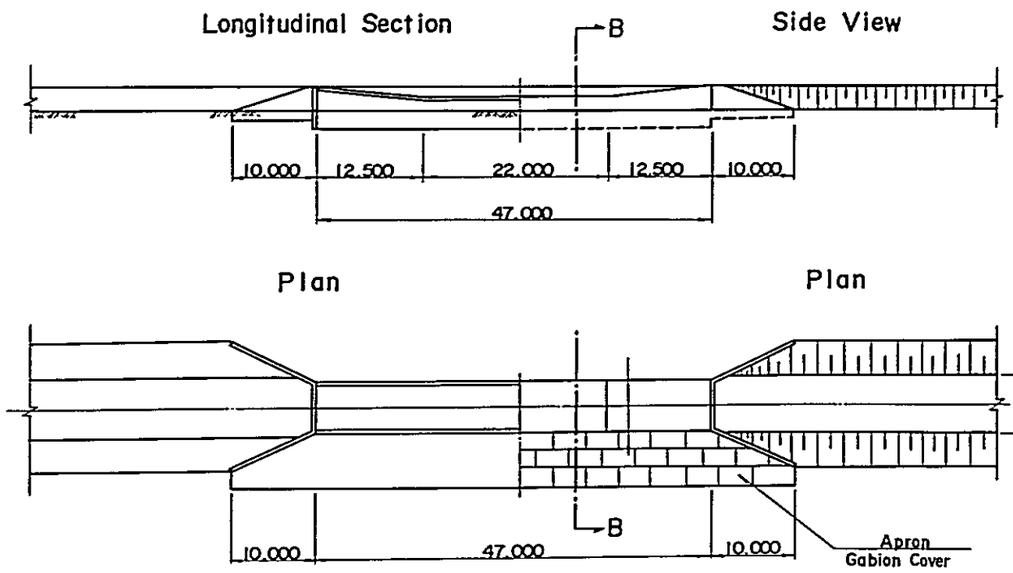
Cause Way No.1

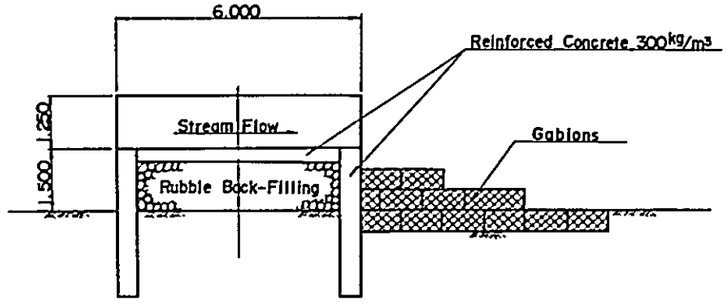




Cross Section A-A View

Cause Way No.2





Cross Section B-B View

Unit mm.

0 10 20m Longitudinal Section

0 5m Cross Section

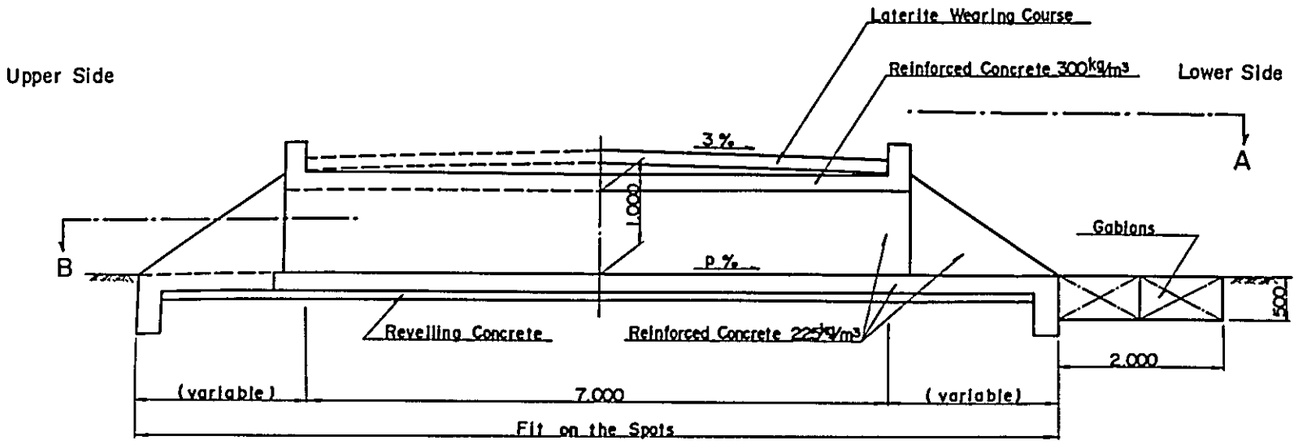
ROAD DORI ~ TAMBAO

Cause way No.1 & No.2

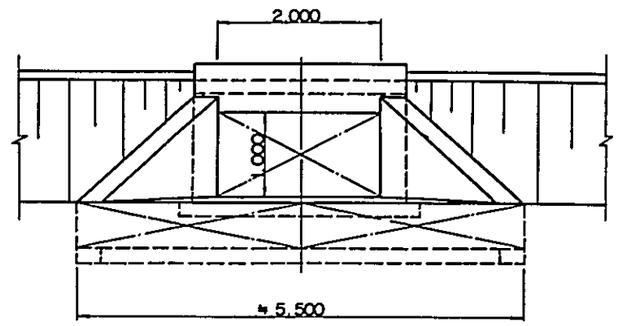
Fig V - 9

Side View

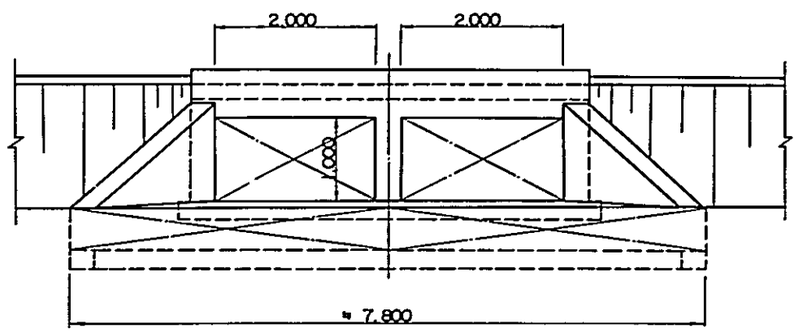
Longitudinal Section



Culvert Single
Front View Lower Side

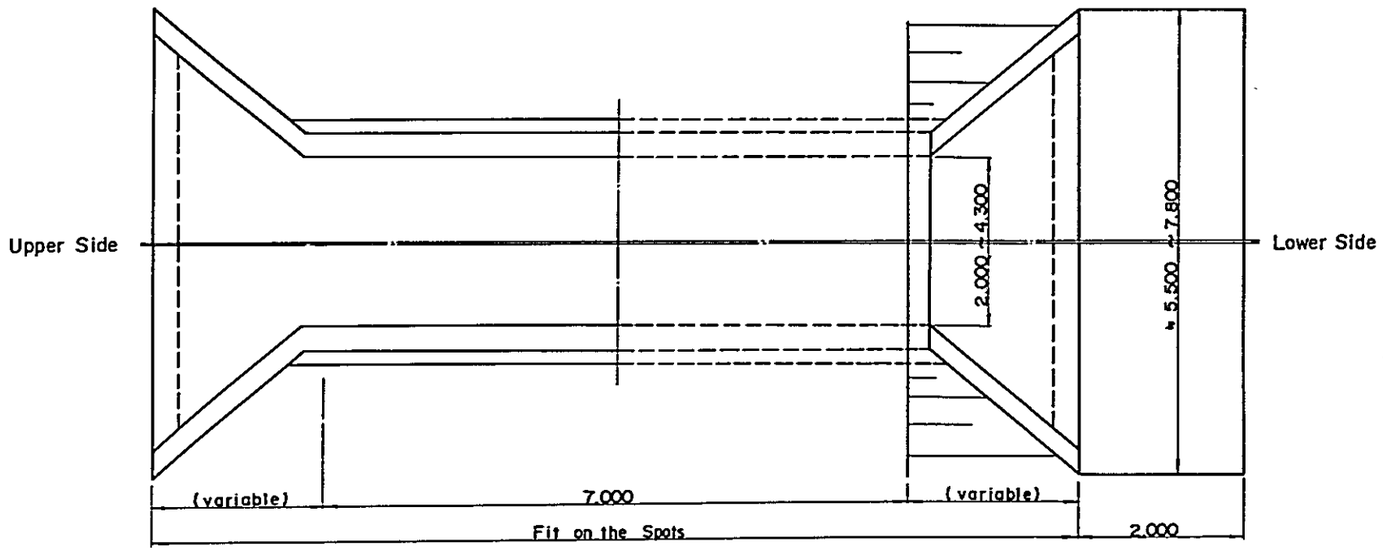


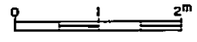
Culvert Double
Front View Lower Side



Plan B-View

Plan A-View





Unit mm.

ROAD DORI ~ TAMBAO
Culvert
Fig V - 10

CHAPTER VI

CONSTRUCTION COST

VI-1 Summary

The cost of road improvement and construction of town facilities for Tambao amounts to 2,442,010,000 yen -- 1,385,600,000 yen for the town facilities and 1,056,410,000 yen for the road. These convert into CFA francs and U.S. dollars as in the table below:

Table VI-1 Summary of Construction Cost of Related Facilities

Item	Cost		
	CFA francs	US$	Yen
	(thousands of francs)		(thousands of yen)
Town facilities construction work	1,039,200	4,618,670	1,385,600
Road improvement work	792,310	3,521,380	1,056.410
Total	1,831,510	8,140,050	2,442,010

Conversion rate: US$1 = 225 CFA Fr. = 300 yen

VI-2 Cost of Town Facilities Construction Work

The cost of town facilities construction work is divided into those for the residential district, service water facilities, airstrip, and electric installations.

Table VI-2 Cost of Town Facilities Construction Work

Item	Cost		
	CFA francs	US$	Yen
	(thousands of francs)		(thousands of yen)
1. Residential district	901,200	4,005,330	1,201,600
2. Service water facilities	126,000	560,000	168,000
3. Airstrip	2,000	8,890	2,670
4. Electric installation	10,000	44,450	13,330
Total	1,039,200	4,618,670	1,385,600

(a) Cost of residential district construction

Table VI-3

Item	Unit	Qty.	Unit cost CFA francs	Amount CFA francs	Remarks
				(thousands of francs)	
1. Infrastructure for residential district					
Road construction	m^2	17,540	80	1,400	
Service water & sewerage piping	m	2,270	3,800	8,600	Inc. excavation, burying
Subtotal				10,000	
2. Housing					
(1) Mine personnel					
Type-1	m^2	120	123,300	14,790	$120m^2$ x 1 (for resident manager)
Type-2	"	800	123,300	98,640	$100m^2$ x 8 (for senior staff)
Type-3A	"	990	123,300	122,070	$90m^2$ x 11 (for junior staff)
Type-3B	"	1,540	86,300	132,900	$70m^2$ x 22 (for junior staff A)
Type-4A	"	2,940	20,700	60,860	$70m^2$ x 42 (for workers A)
Type-4B	"	2,520	20,700	52,160	$60m^2$ x 42 (for workers B)
Dormitory	"	420	19,320	8,110	$420m^2$ x 1 (for workers A, B)
Subtotal	"	9,330		489,530	
(2) For medical personnel					
Type-2	m^2	100	123,300	12,330	$100m^2$ x 1 (for physician)
Type-3A	"	90	123,300	11,100	$90m^2$ x 1 (for nurse A)

Type-3B	m^2	70	86,300	6,040	$70m^2$ x 1 (for nurse B)
Subtotal	"	260		29,470	
(3) For educational personnel					
Type-3A	m^2	90	123,300	11,100	$90m^2$ x 1 (for school principal)
Type-3B	"	210	86,300	18,120	$70m^2$ x 3 (for teachers)
Subtotal	"	300		29,220	
Total for housing		9,890		548,220	
3. Other facilities					
Elementary school	m^2	480	123,300	59,180	
Infirmary	"	240	123,300	29,590	
Medical instruments				22,500	
Multipurpose hall	m^2	240	123,300	29,590	
Guest house	"	220	123,300	27,130	
Canteen	"	120	123,300	14,790	
Swimming pool		1		10,000	
Subtotal				192,780	
4. Cost of investigation & design				75,100	10% of 1 + 2 + 3
5. Contingency				75,100	10% of 1 + 2 + 3
Total				901,200	

(b) Cost of service water facilities work

Table VI-4

Item	Qty.	Amount CFA francs	Remarks
		(thousands of francs)	
Coagulant injection equipment	2	1,500	Aluminum sulfate polymer
Settling accelerator ($100m^3$)	1	15,000	
Chlorinator	2	750	
Water receiving tank ($10m^3$)	2	1,500	
Iron remover and activated carbon filter	1 each	12,000	
Underground tank ($100m^3$)	1	3,750	
Filter	2	19,500	
Polyethylene tank	1	3,000	
Water tower	1	22,500	Tank capacity: $100m^3$
Installation work	-	9,000	
Transport and sundry expenses	-	19,800	
Subtotal		108,300	
Investigation & design	-	8,850	10% of ("Subtotal" *minus* "Transport and sundry expenses")
Contingency		8,850	
Grand Total		126,000	

(c) Cost of airstrip improvement work: 2,000,000 CFA francs

(d) Cost of electric installation work: 10,000,000 CFA francs

VI-3 Cost of Road Improvement Work

This cost is broken down by type of work as in Table VI-5.

Table VI-5 Cost of Road Improvement Work

Item	Unit	Qty.	Unit cost CFA francs	Amount CFA francs (thousands of francs)	Remarks
Excavation of ground	m^3	69,000	600	41,400	
Sand mat	"	30,500	350	10,670	
Banking of base course	"	240,800	900	216,720	
Banking of wearing course	"	60,500	1,600	96,800	
Causeway No. 1		1		36,600	Length: 100m
Causeway No. 2		1		22,300	Length: 47m
Culvert, single		5	1,500,000	7,500	1 x 200 x 100cm
Culvert, double		4	2,900,000	11,600	2 x 200 x 100cm
Corrugated drain pipe		64	800,000	51,200	1ϕ 65 x 100cm
Corrugated drain pipe		14	1,600,000	22,400	2ϕ 65 x 100cm
Corrugated drain pipe		7	1,080,000	7,560	1ϕ 100 x 150cm
Non-lining ditch, Type 1	m	40,000	700	28,000	
Non-lining ditch, Type 2	"	3,000	1,300	3,900	
Non-lining ditch, Type 3	"	1,000	2,200	2,200	
Repair of road between Dori and Féléol	"	21,700	3,920	85,060	
Temporary work				16,400	
Subtotal				660,310	
Investigation & design				66,000	10% of work cost
Contingency				66,000	10% of work cost
Grand Total				792,310	

IN CLOSING

-- For the Development of the Sahel Area --

The various facilities of Tambao mine township and the road linking Dori and Tambao are indispensable to the operation of the mine. At the same time, they are of great significance as the first step in building up the infrastructure that will serve as the foundation for the economic and social development of the Sahel area.

Further, if construction of the town facilities and the Dori-Tambao road is followed by the measures listed below, it will have an even greater effect on the neighboring areas through stirring up farming, stock raising and industrial activities.

Improving Regional Roads in Sahel

It does not suffice to improve only the trunk road between Dori and Tambao if the whole Sahel region is to be developed. Regional roads must also be improved to provide traffic links between small villages and connect them to the trunk road. Only when this is done will it become possible to transport primary products in this region to the market. Improved regional roads will also prompt the farmers to step up production, thus making economic development possible.

Utilizing Repair Shops of Tambao Mine

Improving farming implements is one of the most urgent tasks in Haute-Volta. Techniques acquired at the repair shops can be applied for various purposes. While water shortage probably will be a limiting factor, a small industrial park or a technical training center nearby would go a long way toward spreading the use of advanced technology in Sahel.

Developing Related Industries

When a certain industry arises it becomes possible to establish another industry in the same area, for supplying the raw material required by that industry. This is termed "forward linkage effects." Similarly, an industry for producing something else from the product supplied by the first industry can be set up in the same area ("backward linkage effects"). Progress toward industrialization may be secured through such a process. It is desirable, therefore, that related industries be developed with Tambao Mine township as the starting point.

Linking Tambao to Sahel

Steps must be taken to link the mine township in Tambao to the Sahel region. The former, of course, is the product of industrial development in Tambao and includes repair shops. The latter, however, is a nonindustrial society which has no organic relationship to the industrial society of Tambao. In order to industrialize the Sahel region it is necessary to promote education by seizing every opportunity. It is possible to link Tambao and Sahel by improving the present system of adult education and introducing various industries into the latter region. Sahel's society needs "external pressure" for industrial development.

APPENDIX I

SOIL TESTS FOR DORI-TAMBAO ROAD

1. Purpose of Test

Soil tests were carried out to obtain basic data for determining the suitability of three different soil samples in connection with the improvement of the road between Dori and Tambao. The three samples are as follows:

Sample No.	Soil	Sampling point (distance from Dori)
1	Laterite (silty sand)	66.8km
2	Clayey soil (clay)	61.8km
3	Sandy soil (mixture of fine sand and clay)	36.8km

2. Test Method and Results

(1) Water content was measured on the basis of JIS A 1203.

(2) Specific gravity of soil particles was calculated in accordance with JIS A 1202.

(3) Mechanical analysis of soil was conducted by the method specified under JIS A 1204.

(4) Liquid limit and plastic limit of soil were tested under JIS A 1205 and 1206.

In the case of samples No. 1 and 3 it became impossible to test the liquid limit when the frequency of rammer dropping exceeded 13 times. This was due to the high content of fine sand. The test result showed liquid limit to be smaller than plastic limit. So the final judgment was given as nonplastic.

(5) Compaction Test

The test was made by the informal method described below, because samples were not sufficiently available.

(Informal Method)

A layer of soil was compacted 15 times during one round

of testing. The method used is based on "the compaction test method for stably treated soil prepared through compaction." Maximum dry density and optimum moisture content were measured. Mold diameter was 5cm, mold height 18cm (height of finished sample -- 10cm), rammer weight 2.5kg, and height from which rammer was dropped, 30cm.

The test was carried out by the repetition method using nondry samples. Compaction energy was given as 5.7kg/cm^3, which is almost equal to 5.6kg/cm^3 for a three-layer sample subjected to 25 times of compaction under JIS A 1210.

App. Table I-1. Results of Soil Tests

Sample No.				1	2	3
Sampling point				66.8km	61.8km	36.8km
Kinds of sample				Disturbed	Disturbed	Disturbed
Mechanical analysis	Gravel		%	18	1	0
	Sand		%	60	39	91
	Silt		%	22	21	9
	Clay		%	10	39	0
	Maximum grain size of soil		mm	9.52	4.76	2.0
	60% grain size	D_{60}	mm	0.88	0.075	0.33
	30% grain size	D_{30}	mm	0.115	0.0019	0.19
	10% grain size	D_{10}	mm	0.005	--	0.08
	Uniformity coefficient	U_C		176.0	--	4.12
Classification	Triangular classification chart			Sandy soil	Fine grained soil	Sand with fine soil
	Japan unified soil classification			(SF)	(CL)	(S-F)
	Japan unified soil nomenclature			Silty sand	Clay	Clayey fine sand
	Judgment with naked eye (field method)			Sand	Clay	Fine sand
Consistency test	Liquid limit	w_L	%	N.P	37.0	N.P
	Plastic limit	w_P	%	N.P	14.1	N.P
	Plasticity index	I_P		--	22.9	--
Specific gravity of soil particle		G_S		2.688	2.692	2.665
Natural condition	Natural water content	w	%	0.51	2.42	0.08
Compaction	Maximum dry density	γd_{max}	g/cm^3	2.086	1.689	1.785
	Optimum moisture content	w_{opt}	%	8.40	16.0	11.4

Note: Compaction test was carried out by the informal method.

App. Table 1-2. Results of Water Content Test (JIS A 1203)

$$\text{Water content } w = \frac{W_a - W_b}{W_b - W_c} \times 100 = \frac{W_w}{W_s} \times 100 \quad (\%)$$

Sample No.	Water content			Average
	1	2	3	
No. 1	W_a 60.82 W_b 60.62 W_c 21.96 W_w 0.20 W_s 38.66 w = 0.52%	W_a 62.97 W_b 62.75 W_c 21.65 W_w 0.22 W_s 41.10 w = 0.54%	W_a 56.18 W_b 55.62 W_c 21.74 W_w 0.16 W_s 33.88 w = 0.47%	w=0.51%
No. 2	W_a 56.62 W_b 55.74 W_c 21.87 W_w 0.88 W_s 33.87 w = 2.60%	W_a 64.01 W_b 63.06 W_c 21.61 W_w 0.95 W_s 41.45 w = 2.29%	W_a 56.23 W_b 56.21 W_c 19.86 W_w 0.02 W_s 36.35 w = 0.05%	w=2.42%
No. 3	W_a 54.82 W_b 54.77 W_c 19.55 W_w 0.05 W_s 35.22 w = 0.14%	W_a 57.08 W_b 57.06 W_c 21.93 W_w 0.02 W_s 35.13 w = 0.06%	W_a 56.23 W_b 56.21 W_c 19.86 W_w 0.02 W_s 36.35 w = 0.05%	w=0.08%

App. Table 1-3. Results of Tests on Specific Gravity of Soil Particles (JIS A 1202)

Test date: May 12, 1976

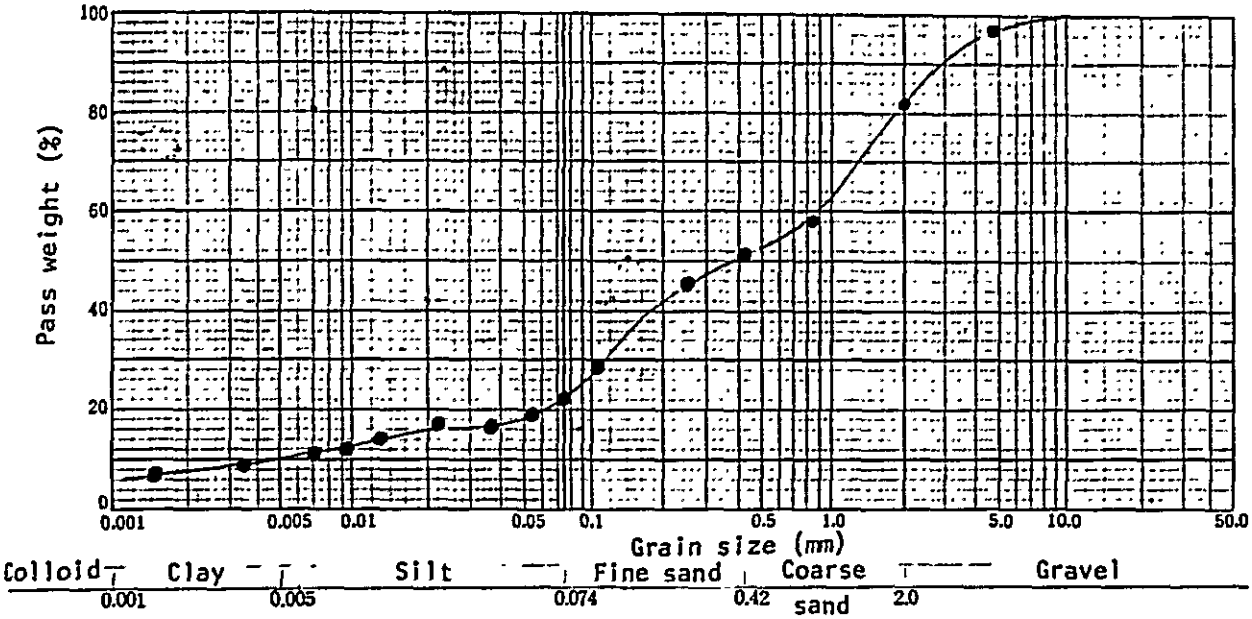
Sample No.	No. 1			No. 2			No. 3		
Test No.	1	2	3	1	2	3	1	2	3
Pycnometer No.	6	8	9	12	13	18	20	23	24
Pycnometer weight, W_f (grams)	53.2511	52.6889	39.3800	55.0612	54.2573	44.2835	47.3116	47.3014	53.5600
Weight of pycnometer + water, $W_{a'}$ (grams)	149.9385	152.2655	139.3203	155.2181	154.4313	148.7837	150.4724	145.4388	153.9385
Water temperature on measuring $W_{a'}$, T' (°C)	23	23	23	23	23	23	23	23	23
Weight of pycnometer + oven-dried soil (grams)	88.3178	90.5370	72.9254	85.5017	80.2595	72.0004	79.3236	77.4592	85.7499
Weight of oven-dried soil, W_o (grams)	35.0667	37.8481	33.5454	30.4405	26.0022	27.7169	32.0120	30.1578	32.1899
Weight of pycnometer + water + oven-dried soil, W_b (grams)	171.9914	176.1343	160.4936	174.4343	170.8512	166.2901	170.5583	164.3700	174.1054
Water temperature on measuring W_b, T (°C)	20	20	20	20	20	20	20	20	20
①Water specific gravity at T°C/water specific gravity at T'°C, $W_{a'} - W_f$ (grams)	1.0007 96.6874	1.0007 99.5766	1.0007 99.9403	1.0007 100.1569	1.0007 100.1740	1.0007 104.5002	1.0007 103.1608	1.0007 98.1374	1.0007 100.3785
② ①x $(W_{a'} - W_f)$ (grams)	96.7520	99.6431	100.0071	100.2238	100.2409	104.5700	103.2297	98.2030	100.4456
Converted weight at T°C, W_a=②+ W_f (grams)	150.0031	152.3320	139.3871	155.2850	154.4982	148.8535	150.5413	145.5044	154.0056
$W_o + W_a - W_b$ (grams)	13.0784	14.0458	12.4389	11.3012	9.6492	10.2803	11.9950	11.2922	12.0900
③ Specific gravity at T°C, $W_o/(W_o + W_a - W_b)$	2.681	2.645	2.697	2.694	2.695	2.696	2.669	2.671	2.663
Coefficient of correction, K	0.9991	0.9991	0.9991	0.9991	0.9991	0.9991	0.9991	0.9991	0.9991
Specific gravity at 15°C, ③x K	2.679	2.692	2.694	2.691	2.692	2.693	2.666	2.668	2.660
Mean value	2.688			2.692			2.665		

App. Fig. I-1. Mechanical Analysis (Grain Size Accumulation Curve)

JIS A 1204 Test date: May 12, 1976

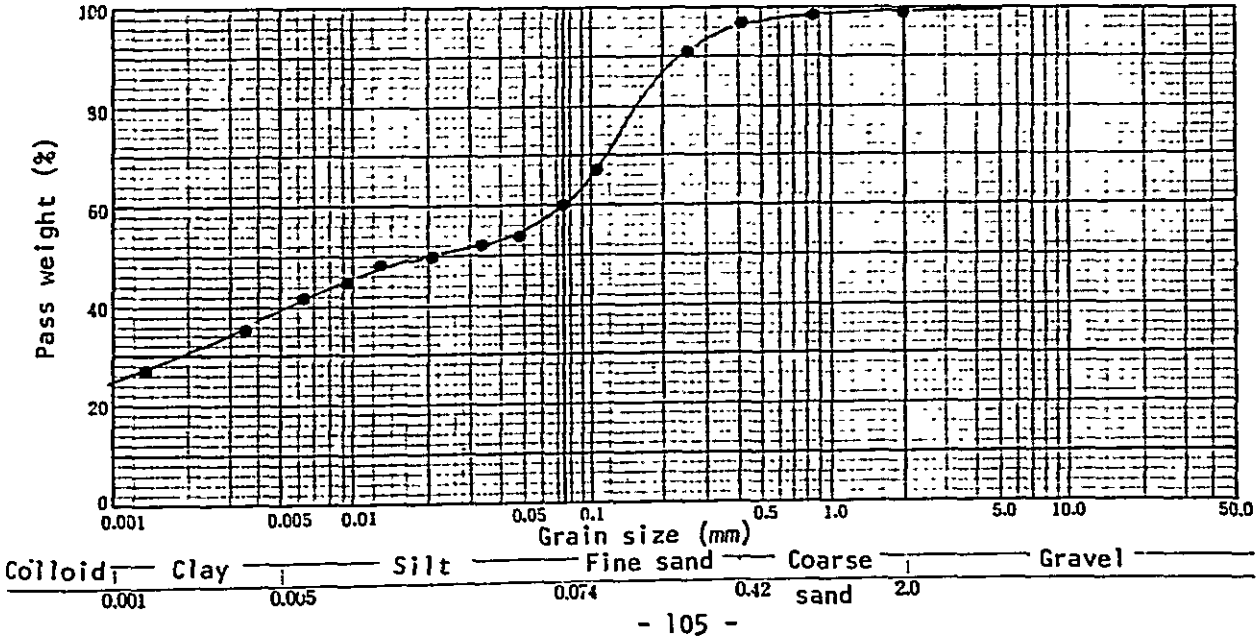
Sample No. 1

Gravel	(%)	18	Max. grain size	(mm)	9.52	2,000μ sieve pass (%)	82
Sand	(%)	60	60% grain size	(mm)	0.88	420μ sieve pass (%)	51
Silt	(%)	22	30% grain size	(mm)	0.115	74μ sieve pass (%)	22
Clay	(%)	10	10% grain size	(mm)	0.005	Triangular classification chart	Sandy soil
			Uniformity coefficient, U_C		176.0		



Sample No. 2

Gravel	(%)	1	Max. grain size	(mm)	4.76	2,000μ sieve pass (%)	99
Sand	(%)	39	60% grain size	(mm)	0.075	420μ sieve pass (%)	97
Silt	(%)	21	30% grain size	(mm)	0.0019	74μ sieve pass (%)	60
Clay	(%)	39	10% grain size	(mm)	--	Triangular classification chart	Fine-grained soil
			Uniformity coefficient, U_C		--		

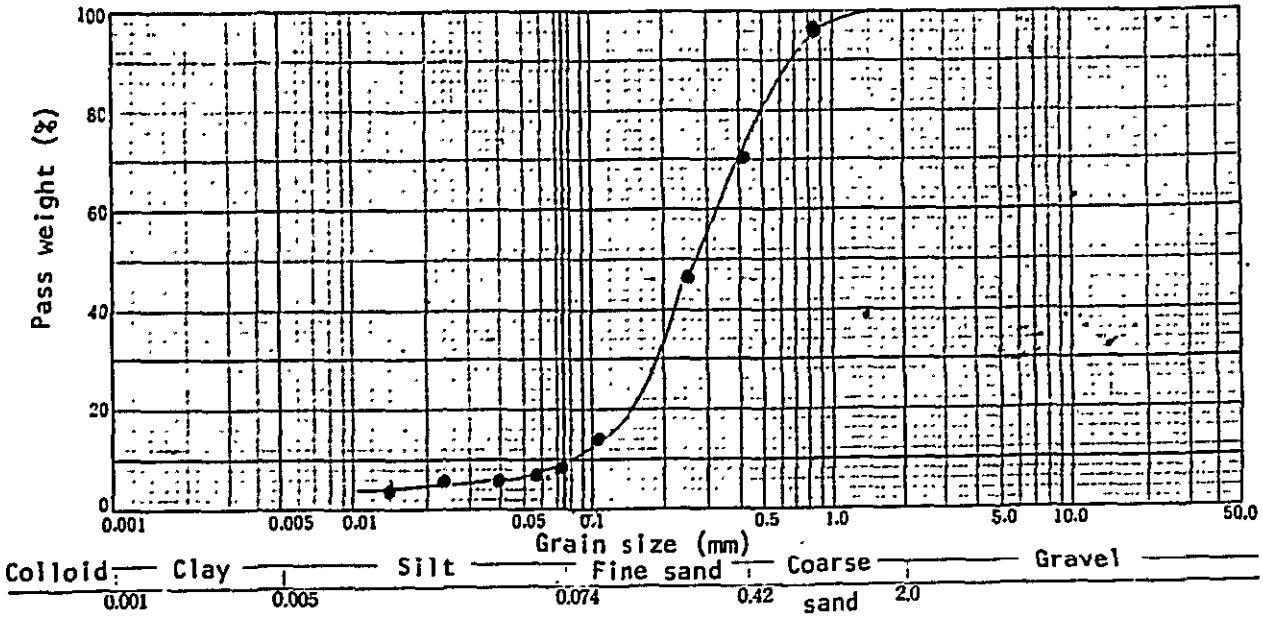


App. Fig. 1-2. Mechanical Analysis (Grain Size Accumulation Curve)

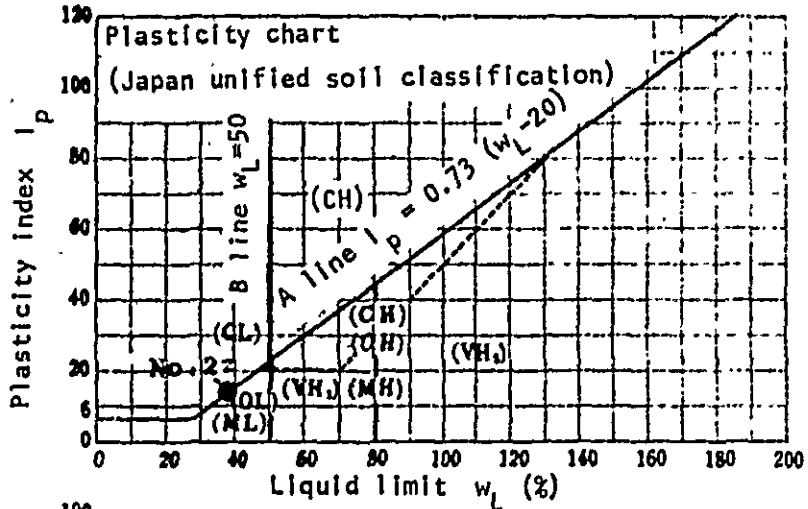
JIS A 1204 Test date: May 12, 1976

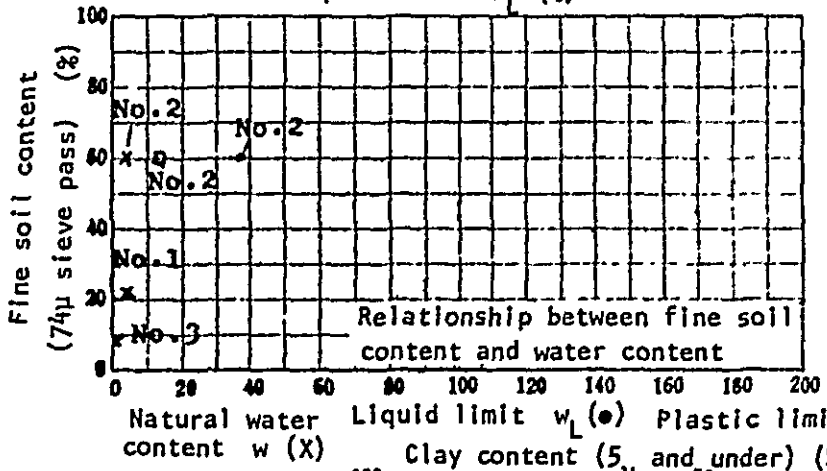
Sample No. 3

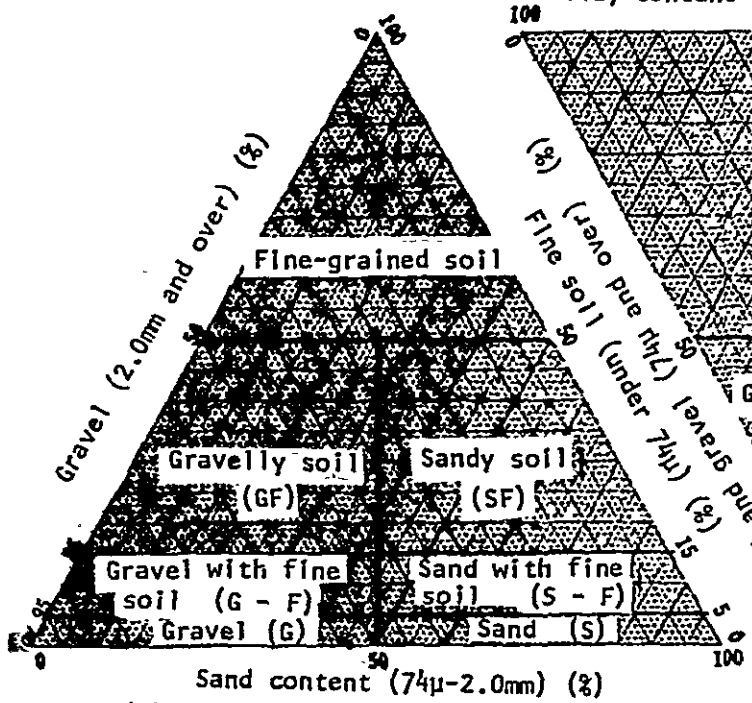
Gravel	(%)	0	Max. grain size	(mm)	2.0	2,000μ sieve pass (%)	100
Sand	(%)	91	60% grain size	(mm)	0.33	420μ sieve pass (%)	72
Silt	(%)	9	30% grain size	(mm)	0.19	74μ sieve pass (%)	9
Clay	(%)	0	10% grain size	(mm)	0.08	Triangular classification chart	Sand with fine soil
			Uniformity coefficient, U_C		4.12		



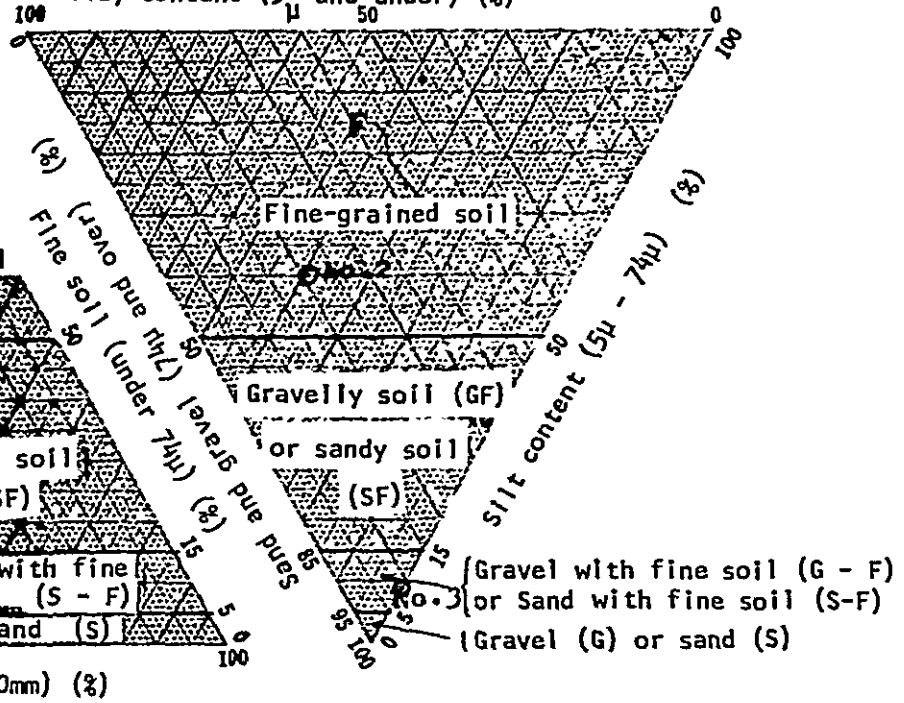
App. Fig. 1-3. Classification of Soils







(a) When grain size was measured only by sieve method



(b) When grain size was measured also by specific gravity hydrometer

App. Fig. 1-4. Results of Liquid Limit and Plastic Limit Tests
JIS A 1205 , 1206

Test date: May 14, 1976

Sample No. 1

Liquid limit test			Plastic limit test		Remarks
No.	Rammer dropping frequency	Water content (%)	No.	Water content (%)	0.42mm pass sample was used.
1	13	13.05	1	12.72	
2	Test made impossible when frequency exceeded 13		2	12.48	
			3		

Liquid limit, w_L (%)	Plastic limit, w_P (%)	Plasticity index, I_P (%)	Natural water content, w (%)
Np	Np	--	--

Sample No. 2

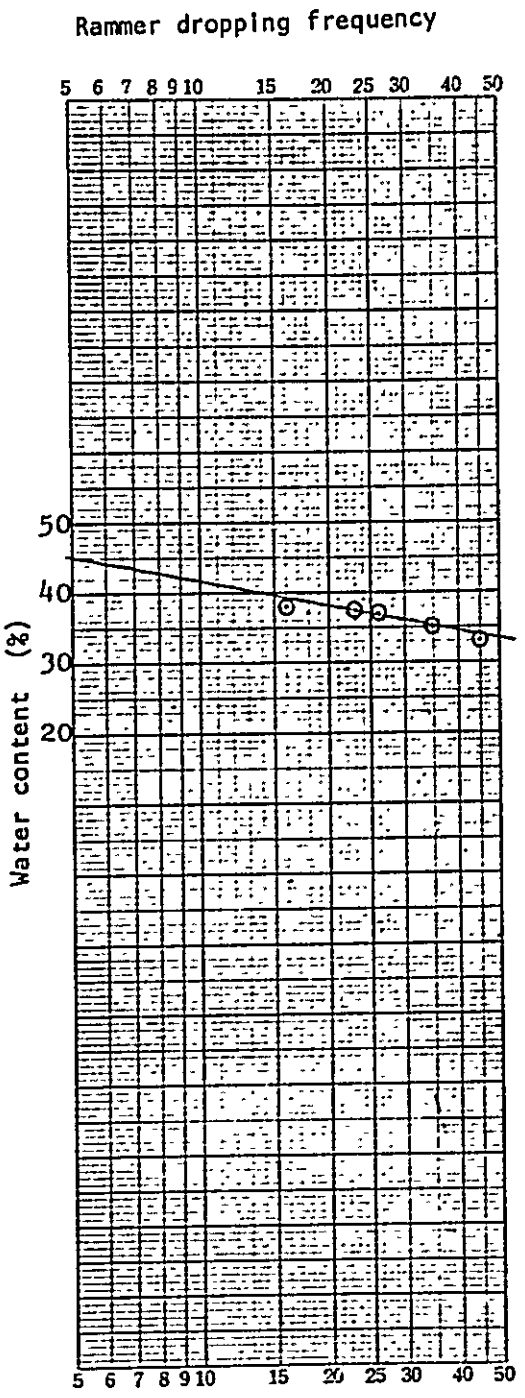
Liquid limit test			Plastic limit test		Remarks
No.	Rammer dropping frequency	Water content (%)	No.	Water content (%)	0.42mm pass sample was used.
1	45	33.58	1	14.16	
2	35	35.23	2	14.14	
3	26	36.66	3	13.97	
4	23	37.29			
5	16	38.14			

Liquid limit, w_L (%)	Plastic limit, w_P (%)	Plasticity index, I_P (%)	Natural water content, w (%)
37.0	14.1	22.9	--

Sample No. 3

Liquid limit test			Plastic limit test		Remarks
No.	Rammer dropping frequency	Water content (%)	No.	Water content (%)	0.42mm pass sample was used.
1	3	20.05	1	Not measurable	
2	Test made impossible when frequency exceeded 3		2		
3			3		
4					
5					

Liquid limit, w_L (%)	Plastic limit, w_P (%)	Plasticity index, I_P (%)	Natural water content, w (%)
Np	Np	--	--



Relative water content $W_R = \frac{w-w_P}{I_P}$

(Relative consistency) $C_R = 1-w_R$

App. Fig. I-5. Compaction Test by Testing Rammer (JIS A 1210)

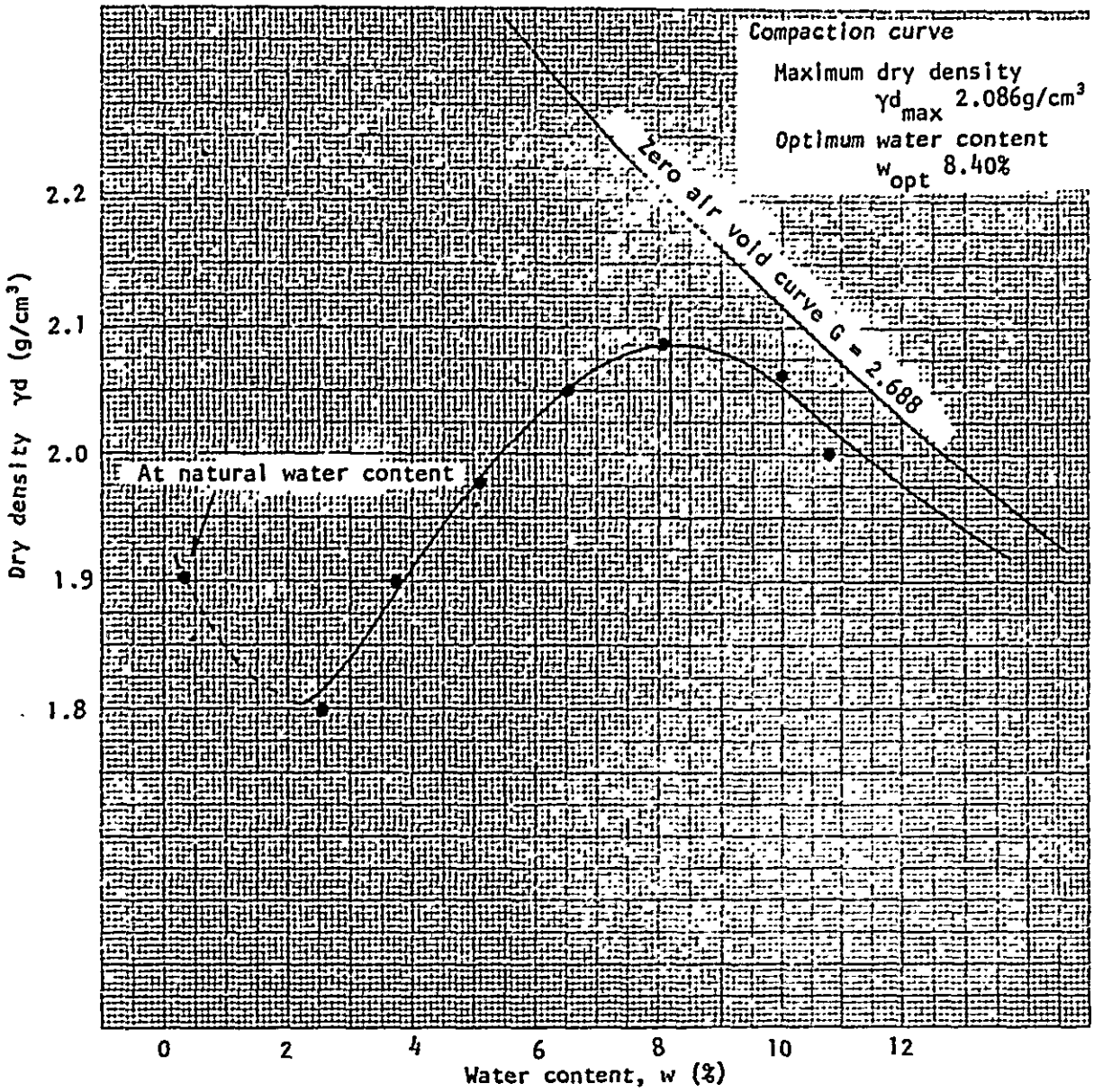
Sample No. 1 Test date: May 18, 1976

Compaction method: "Other"* Sample using method: Used repeatedly

Water content before test**: 0.32% Sample preparation: Nondrying method

Soil grain specific gravity: 2.688

Test No.	1	2	3	4	5	6	7	8
Dry density γd (g/cm³)	1.904	1.797	1.899	1.982	2.049	2.087	2.064	2.000
Mean water content w(%)	0.32	2.58	3.75	5.11	6.58	8.10	10.04	10.74



Remarks: * Rammer weight: 2.5kg Dropping height: 30cm
Rammer dropping frequency per layer: 15 times (1 layer)

** When nondrying method was used.

App. Table I-4. Compaction Test by Testing Rammer (JIS A 1210)

Sample No.: No. 1 Test date: May 18, 1976

Compaction method: Informal method by stable soil treatment* Water content before drying: 0.32%

Sample using method: Used repeatedly Mold weight: 3,415g

Sample preparation: Nondry method

Test No.	1	2	3	4
Weight of moist sample + mold (grams)	3,790	3,777	3,802	3,824
Weight of moist sample (grams)	375	362	387	409
Moist density, γt (g/cm^3)	1.909	1.844	1.971	2.083
Water content analysis	W_a 61.80 W_b 61.66 W_b W_c 18.47 W_w 0.14 W_s 43.19 w = 0.32%	W_a 59.44 W_b 58.43 W_b W_c 18.60 W_w 1.01 W_s 39.83 w = 2.54%	W_a 57.74 W_b 56.26 W_b W_c 16.11 W_w 1.48 W_s 40.15 w = 3.69%	W_a 55.69 W_b 54.00 W_b W_c 21.77 W_w 1.69 W_s 32.23 w = 5.24%
	W_a 57.64 W_b 57.53 W_b W_c 22.87 W_w 0.11 W_s 34.66 w = 0.32%	W_a 54.48 W_b 53.62 W_b W_c 20.61 W_w 0.86 W_s 33.01 w = 2.61%	W_a 70.39 W_b 68.57 W_b W_c 20.88 W_w 1.82 W_s 47.69 w = 3.82%	W_a 54.16 W_b 52.52 W_b W_c 19.66 W_w 1.64 W_s 32.86 w = 4.99%
Mean water content, w (%)	0.32	2.58	3.75	5.11
Dry density, γd (g/cm^3)	1.904	1.797	1.899	1.982
Test No.	5	6	7	8
Weight of moist sample + mold (grams)	3,844	3,866	3,861	3,850
Weight of moist sample (grams)	429	443	446	435
Moist density, γt (g/cm^3)	2.185	2.256	2.271	2.215
Water content analysis	W_a 51.88 W_b 49.77 W_b W_c 17.30 W_w 2.11 W_s 32.47 w = 6.50%	W_a 76.12 W_b 72.02 W_b W_c 21.78 W_w 4.10 W_s 50.24 w = 8.16%	W_a 93.27 W_b 86.76 W_b W_c 21.75 W_w 6.51 W_s 65.01 w = 10.01%	W_a 99.64 W_b 91.97 W_b W_c 20.49 W_w 7.67 W_s 71.48 w = 10.73%
	W_a 75.08 W_b 71.63 W_b W_c 19.93 W_w 3.45 W_s 51.70 w = 6.67%	W_a 60.51 W_b 57.36 W_b W_c 18.22 W_w 3.15 W_s 39.14 w = 8.05%	W_a 71.40 W_b 66.63 W_b W_c 19.26 W_w 4.77 W_s 47.37 w = 10.07%	W_a 92.09 W_b 85.10 W_b W_c 20.07 W_w 6.99 W_s 65.03 w = 10.75%
Mean water content, w (%)	6.58	8.10	10.04	10.74
Dry density, γd (g/cm^3)	2.049	2.087	2.064	2.000

* Details of test Rammer weight 2.5kg Dropping height 30cm

Rammer dropping frequency per layer: 15 times (1 layer)

Mold capacity V = 196.35cm^3

Dry density: $\gamma d = \frac{\gamma t}{w + 100} \times 100 g/cm^3$, Zero air void curve: $\gamma d = \frac{\gamma w}{1/G_s + w/100}$ g/cm^3

App. Fig. I-6. Compaction Test by Testing Rammer (JIS A 1210)

Test date: May 19, 1976

Sample No. 2

Compaction method: "Other"*

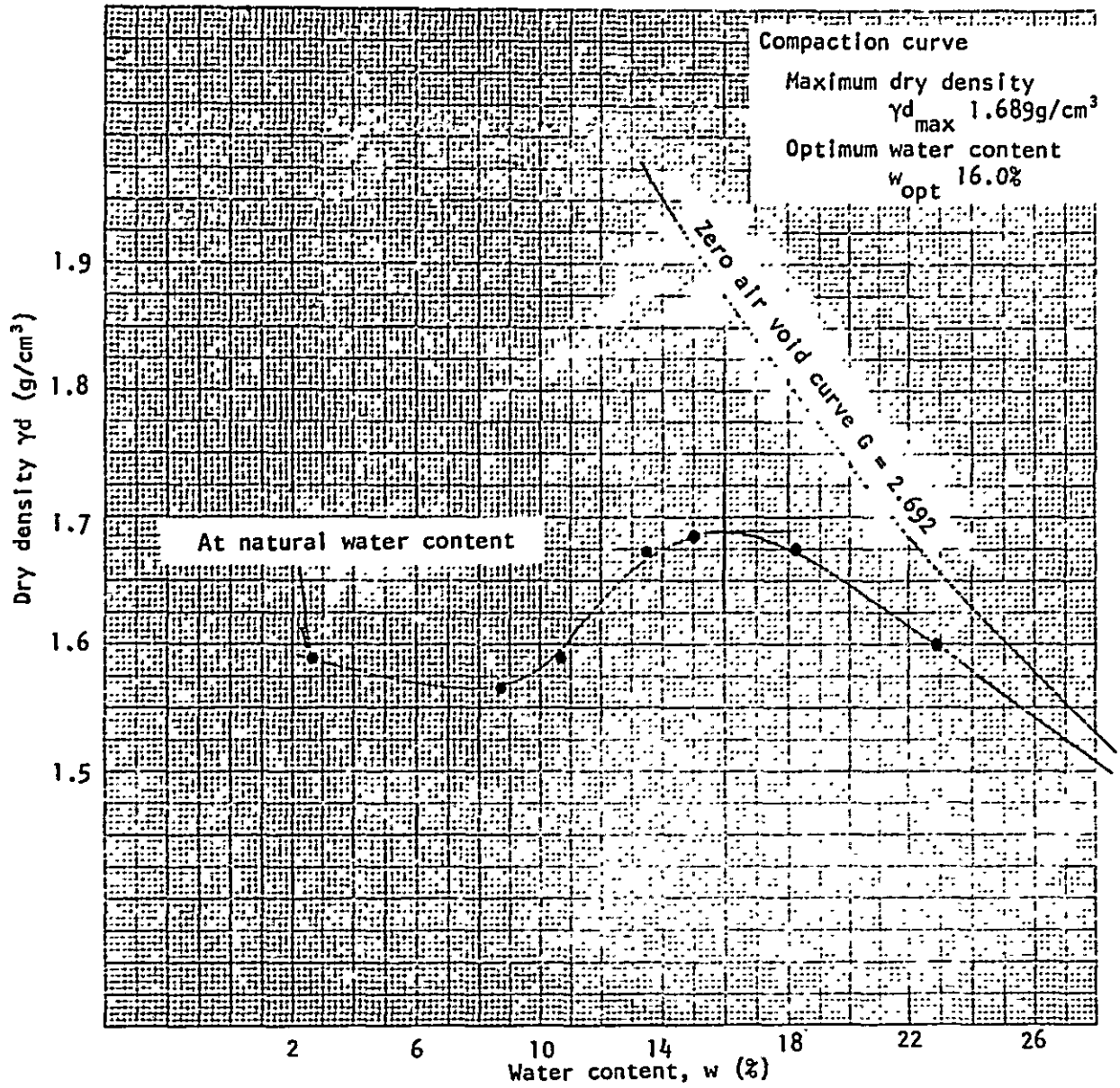
Sample using method: Used repeatedly

Water content before test**: 2.65%

Sample preparation: Nondrying method

Soil grain specific gravity: 2.692

Test No.	1	2	3	4	5	6	7
Dry density γd (g/cm³)	1.587	1.565	1.588	1.674	1.685	1.675	1.600
Mean water content w(%)	2.65	8.69	10.65	13.48	15.01	18.27	22.94



Remarks: * Rammer weight: 2.5kg Dropping height: 30cm
Rammer dropping frequency per layer: 15 times (1 layer)

** When nondrying method was used.

App. Table I-5. Compaction Test by Testing Rammer (JIS A 1210)

Test date: May 19, 1976

Sample No.: No. 2

Compaction method: Informal method by stable soil treatment*

Sample using method: Used repeatedly

Sample preparation: Nondry method

Water content before drying: 2.65%

Mold weight: 3,415g

Test No.	1	2	3	4
Weight of moist sample + mold (grams)	3,735	3,749	3,760	3,788
Weight of moist sample (grams)	320	334	345	373
Moist density, γt (g/cm^3)	1.629	1.701	1.757	1.899
Water content analysis	W_a 47.17 W_b 46.43 W_b W_c 18.11 W_w 0.74 W_s 28.32 w = 2.61%	W_a 54.44 W_b 51.73 W_b W_c 19.86 W_w 2.71 W_s 31.87 w = 8.50%	W_a 54.66 W_b 51.57 W_b W_c 22.16 W_w 3.09 W_s 29.41 w = 10.51%	W_a 56.80 W_b 52.46 W_b W_c 19.93 W_w 4.34 W_s 32.53 w = 13.34%
	W_a 45.27 W_b 44.60 W_b W_c 19.75 W_w 0.67 W_s 24.85 w = 2.70%	W_a 47.00 W_b 44.90 W_b W_c 21.25 W_w 2.10 W_s 23.65 w = 8.88%	W_a 52.97 W_b 49.70 W_b W_c 19.42 W_w 3.27 W_s 30.28 w = 10.80%	W_a 57.00 W_b 52.52 W_b W_c 19.66 W_w 4.48 W_s 32.86 w = 13.63%
Mean water content, w (%)	2.65	8.69	10.65	13.48
Dry density, γt (g/cm^3)	1.587	1.565	1.588	1.674

Test No.	5	6	7
Weight of moist sample + mold (grams)	3,809	3,855	3,867
Weight of moist sample (grams)	394	420	452
Moist density, γt (g/cm^3)	1.939	1.980	1.967
Water content analysis	W_a 61.14 W_b 55.83 W_b W_c 20.64 W_w 5.31 W_s 35.19 w = 15.09%	W_a 67.99 W_b 60.23 W_b W_c 18.22 W_w 7.76 W_s 42.01 w = 18.47%	W_a 80.14 W_b 69.28 W_b W_c 21.78 W_w 10.86 W_s 47.50 w = 22.86%
	W_a 56.25 W_b 52.25 W_b W_c 16.11 W_w 5.40 W_s 36.14 w = 14.94%	W_a 58.78 W_b 52.63 W_b W_c 18.60 W_w 6.15 W_s 34.03 w = 18.07%	W_a 72.14 W_b 62.71 W_b W_c 21.77 W_w 9.43 W_s 40.94 w = 23.03%
Mean water content, w (%)	15.01	18.27	22.94
Dry density, γt (g/cm^3)	1.685	1.675	1.600

* Details of test Rammer weight 2.5kg Dropping height 30cm

Rammer dropping frequency per layer: 15 times (1 layer)

Mold capacity $V = 196.35 cm^3$

Dry density: $\gamma d = \frac{\gamma t}{w + 100} \times 100 g/cm^3$, Zero air void curve: $\gamma d = \frac{\gamma w}{1/G_s + w/100}$ g/cm^3

App. Fig. 1-7. Compaction Test by Testing Rammer (JIS A 1210)

Test date: May 20, 1976

Sample No. 3

Compaction method: "Other"*

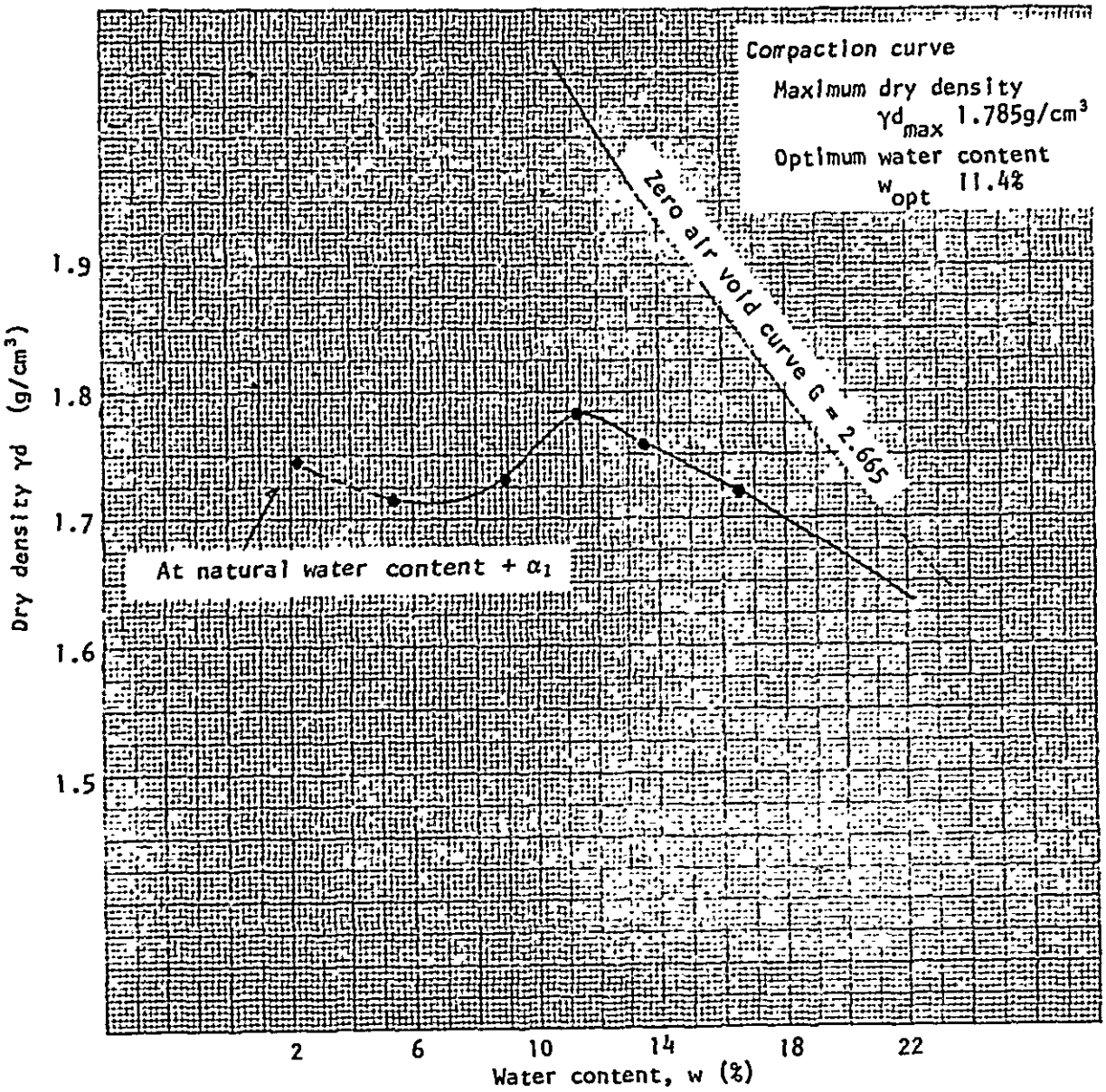
Sample using method: Used repeatedly

Water content before test**: 2.19%

Sample preparation: Nondrying method

Soil grain specific gravity: 2.665

Test No.	1	2	3	4	5	6
Dry density γd (g/cm³)	1.745	1.715	1.729	1.784	1.758	1.718
Mean water content w(%)	2.19	5.43	8.95	11.32	13.53	16.49



Remarks: * Rammer weight: 2.5kg Dropping height: 30cm
Rammer dropping frequency per layer: 15 times (1 layer)

** When nondrying method was used.

App. Table 1-6. Compaction Test by Testing Rammer (JIS A 1210)

Test date: May 20, 1976

Sample No.: No. 3

Compaction method: Informal method by stable soil treatment*

Sample using method: Used repeatedly

Sample preparation: Nondry method

Water content before drying: 0.11%

Mold weight: 3,415g

Test No.	1	2	3	4	5	6
Weight of moist sample + mold (grams)	3,770	3,770	3,785	3,796	3,807	3,808
Weight of moist sample (grams)	355	355	370	390	392	393
Moist density, γt (g/cm^3)	1.808	1.808	1.884	1.986	1.996	2.001
Water content analysis	W_a 45.96 W_b 45.36 W_b W_c 19.26 W_w 0.60 W_s 26.10 w = 2.30%	W_a 66.91 W_b 64.58 W_b W_c 21.57 W_w 2.33 W_s 5.42 w = 5.42%	W_a 58.11 W_b 55.04 W_b W_c 20.73 W_w 3.07 W_s 34.31 w = 8.95%	W_a 66.46 W_b 61.77 W_b W_c 20.68 W_w 4.69 W_s 41.09 w = 11.41%	W_a 47.58 W_b 44.15 W_b W_c 18.29 W_w 3.43 W_s 25.86 w = 13.26%	W_a 66.75 W_b 60.29 W_b W_c 21.53 W_w 6.46 W_s 38.76 w = 16.67%
	W_a 50.17 W_b 49.59 W_b W_c 21.75 W_w 0.58 W_s 27.84 w = 2.08%	W_a 62.51 W_b 60.56 W_b W_c 24.73 W_w 1.75 W_s 25.83 w = 5.44%	W_a 58.17 W_b 54.85 W_b W_c 17.79 W_w 3.32 W_s 37.06 w = 8.96%	W_a 62.32 W_b 58.26 W_b W_c 22.15 W_w 4.06 W_s 36.11 w = 11.24%	W_a 59.26 W_b 54.40 W_b W_c 19.20 W_w 4.86 W_s 35.20 w = 13.81%	W_a 56.57 W_b 52.00 W_b W_c 23.93 W_w 4.57 W_s 28.02 w = 16.31%
Mean water content, w (%)	2.19	5.43	8.95	11.32	13.53	16.49
Dry density, γd (g/cm^3)	1.745	1.715	1.729	1.784	1.758	1.718

* Details of test Rammer weight 2.5kg Dropping height 30cm

Rammer dropping frequency per layer: 15 times (1 layer)

Mold capacity $V = 196.35cm^3$

Dry density: $\gamma d = \frac{\gamma t}{w + 100} \times 100 g/cm^3$, Zero air void curve: $\gamma d = \frac{\gamma w}{1/G_s + w/100}\ g/cm^3$

APPENDIX II

ANALYSES OF BELI RIVER WATER

App. Table II-1. General Potable Water Test

Sample Item	River water	Criteria
Physical appearance	White-brownish, brown suspended matter, brown sediments observed	Almost colorless and clear
Odor	Muddy smell	Not abnormal
pH	7.5	5.8 - 8.6
Ammoniacal nitrogen	Not detected	Not simultaneously detectable
Nitrous nitrogen	Detected	
Nitric nitrogen	0.76ppm	Below 10ppm
Chloride ion	4.7ppm	Below 200ppm
Potassium permanganate consumption	116.2ppm	Below 10ppm
Iron	5.30ppm	Below 0.3ppm
Total hardness	52.0ppm	Below 300ppm
Evaporation residue	1,404.0ppm	Below 500ppm
Residual chlorine	0.0ppm	
Turbidity	1,530.0°	Below 2°
Coliform count	Detected in 50ml	Not detectable
Common bacteria count	110 x 10^2/ml	Less than 100/mℓ
Opinion	Not suitable for potable water	
Remarks	Contamination with organic matter is very likely. Sanitary precautions seem necessary.	

App. Table II-2. Results of Bacterial Tests

Coliform bacilli	Qualitative	Presumed analysis	LB 24hr 48hr	+AG
		Definite analysis	BGLB	+AG
		Complete analysis	EMB	Standard colony
		I M V I C	Indole	(+)
			Methyl red	(+)
			Voges-Proskaver	(-)
			Citrate	(-)
		Properties		TSI: A/AG
		Identification		E. coli
	Quantitative	Most probable number		170
		Deso plate	Original solution	1st test: 3
			10^{-1}	1st test: 0
Standard plate count (common bacteria)		Condition of culture medium: Agar, 31±1°C, 24hr	Original solution	1st test: Numerous; 2nd test: Numerous
			10^{-1}	1st test: 840; 2nd test: 640
			10^{-2}	1st test: 109; 2nd test: 106
			10^{-3}	1st test: 12; 2nd test: 8
			10^{-4}	1st test: 1; 2nd test: 1
			10^{-5}	1st test: 0; 2nd test: 0
Classification		E. coli Pseudomonas aeruginosa Aeromonas sp Bacillus sp		
Remarks		Coliform group count: 170/100mℓ (MPN), 2/mℓ (Deso plate) Common bacteria count: 110 x 10^2/mℓ		

Legend:
- LB Lactose broth
- BGLB Rrilliant green lactose bile
- EMB Eosin methylene blue
- TSI Triple sugar iron
- A Acid
- G Gas