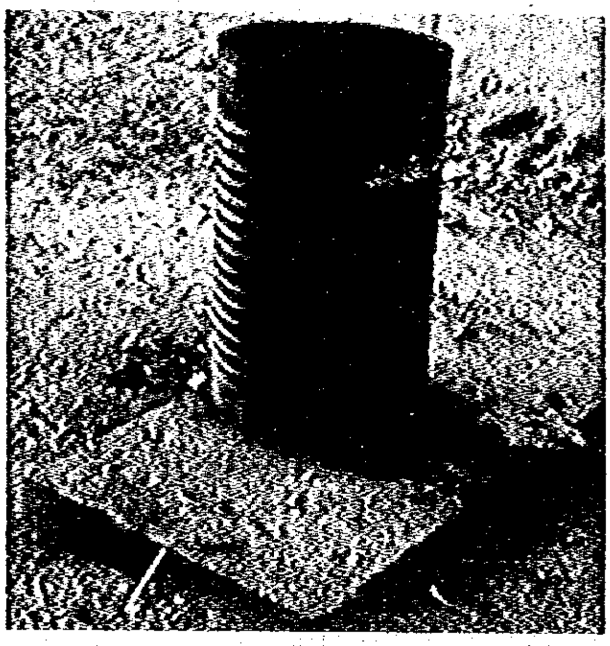
5.3.4 Present State of the Collection System

Solid waste from the surveyed area is collected by 5 dump trucks, as shown in Table 5.3.1. Collection is done from 6 A.M. to 4 P.M. every day, indicating that the maximum effort is made within the range of the present service capacity of the Na Klua Sanitary District.

However, viewed from the residents side, some part of the residential district do not have daily collection because much time and energy is spent for collecting waste from hotels, and an impartial service (twice a day) is provided for downtown areas in Pattaya where tourists gather.

Concerning the collection method, the station system is adopted, preparing drums of 100ℓ and 200ℓ as shown in the pictures, to designated stations in the town and the beaches. This system is recommendable because of its efficiency in collection work.



200ℓ drum

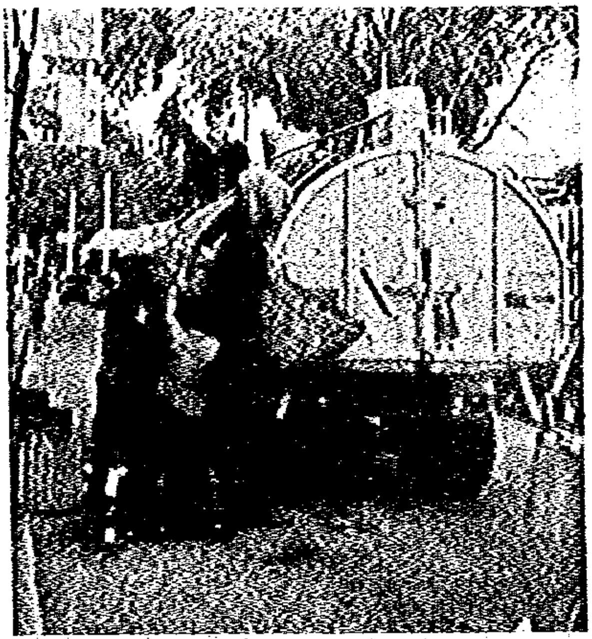
(Pattaya Beach)

100ℓ drum

(Na Klua Village)

All trucks used for collection are modern dump trucks, 3 out of the 5 trucks are large dump trucks of the sanitary closed type.

Solid waste is first poured into bamboo baskets from drums, and then loaded onto the trucks. The high loading point for the solid waste seems to force heavy muscle work on the collectors. Waste from hotels is kept at spots equipped individually by hotels, but most of them are generally unsanitary and variety in shape and size of containers cause inefficiency in the collection work.



Collection Scene at the Street
(Pattaya Downtown)

Solid Waste Storage in a Hotel (Pattaya)

The beach is kept clean by nine workers. Solid waste is thrown into 65 drums of 200ℓ and collected by dump trucks.

5.3.5 Present State of Solid Waste Disposal

Collected waste was dumped into the privately owned site situated at the east side of the Sukhumvit Highway north of Na Klua up to October, 1977. Now it is dumped into the concave public land 7 km to the south of the volumetric center of the site of collection and 2.3 km to the east from the highway.

This landfill site has an area of approximately 2 hectares and an average depth of 2 m. Judging from the present quantity of solid waste, this site has the capacity to dispose of waste for one year and a half from now.

At present, solid waste is dumped evenly all over the surface of the dumping site and burned after being dried by the sun without using soil coverage. As a result, the site causes odour and fly problems to the residents near the site.

Existing Disposal Site
(South Pattaya)

One notable thing found in the course of the survey was the fact that a part of waste is dumped into a coconut field or the request of the owner of a coconut plantation. This could be called a form of primitive re-cycling of solid waste for the effective utilization of waste, re-using it as a fertilizer.

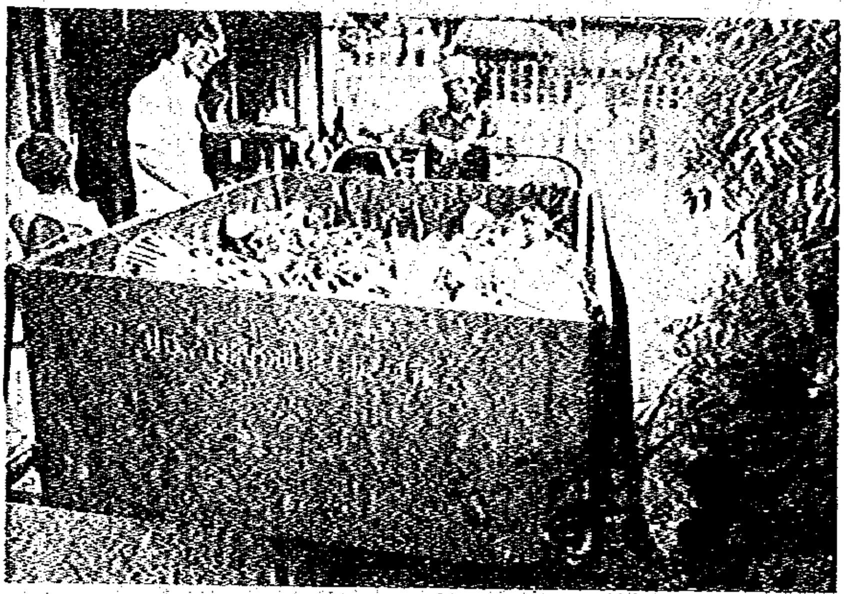
Solid Waste Brought to Coconut Field

This dumping site has already finished its role as a landfill site and does not give off odour and flies are scarce in the site itself, but some of the wells situated below the ground water route from the site is contaminated and undrinkable.

Former Disposal Site (Na Klua)

5.3.6 Present State of Solid Waste Collection in Ko Lan Island

In Ko Lan village, one family collects solid waste 3-4 times a day using a manual collection cart with a capacity of 1 m^3. The amount of waste is estimated to be approximately 2ℓ (600 g) per capita per day assuming the average loading quantity to be 80% of the capacity of the cart, and a population of 1,400.



Collection Cart at Ko Lan Village

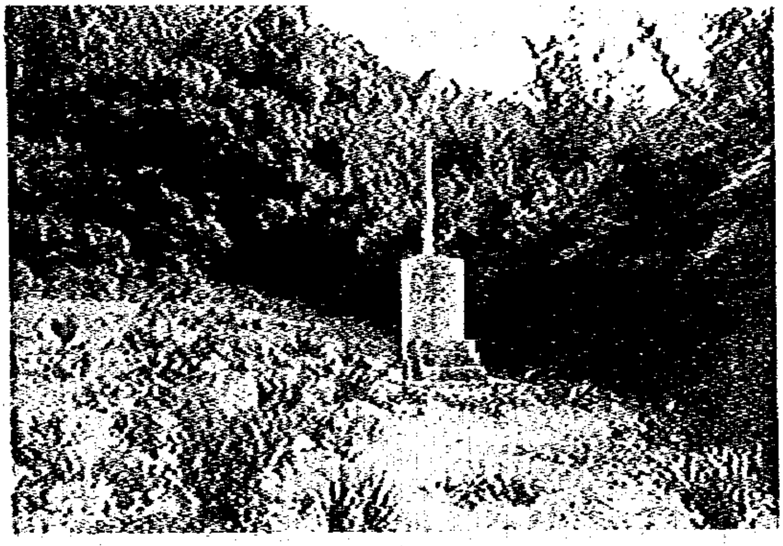
Disposal Site at Ko Lan Village

The disposal method is open dumping along the road a little way from the village and burning after drying as on the mainland.

This method is not recommendable, however, this cannot be helped considering the present condition of local streets not being sufficient in this village.

The solid waste from the beaches, on the other hand, is mostly thrown into holes dug by residents. But some of the solid waste was observed being transported by boat and thrown into the sea. The sea dumping of solid waste should be urgently controlled, especially very near the island.

A notable feature on Ko Lan island is a pilot incinerator plant established in Ta Van beach by Sanitary Center II, Chonburi Province. Though the survey team does not know the effect yet, because the plant has not started operations yet, this will prove to be important for those beaches close to where a suitable landfill site has not been found.



A Pilot Incineration Plant
(Ta Van Beach in Ko Lan Island)
refer to Fig. 5.5.1

5.4 Planning and Design on the Mainland

5.4.1 Project Area

The project area for solid waste disposal is shown in Fig.5.4.1, which includes a part of southern Pattaya Hill, situated in south Pattaya.

5.4.2 Project Duration

The project starts from 1980, when investment is started, and lasts until 1986 like the other projects for the establishment of an infrastructure.

5.4.3 Projected Amount of Solid Waste

(a) Sources of solid waste

In assuming the volume of solid waste, which will form the basis for the system, four main sources of solid waste have been established, namely, 1) residents, 2) hotels, 3) restaurants, 4) beaches and parks. The volume of waste is estimated for each source according to the flow chart shown in Fig. 5.4.2, and used as the planned amount of solid waste.

The figures in Fig. 5.4.2 on population, the number of guest rooms in hotels, the number of restaurant guests, the number of beach and park users, the area of the beaches, the area of the parks are based on those in the Masterplan prepared last year.

(b) Bulk density of solid waste

The bulk density of solid waste, which will be one of the indices for estimating the quality and quantity of solid waste, is determined below, as the expected bulk density for the future taking into consideration the results of the analysis obtained during the field survey.

Residents	0.30 ton per cubic meter
Hotels	0.45 ton per cubic meter
Restaurants	0.50 ton per cubic meter
Garden wastes	0.15 ton per cubic meter

(c) Quantity of solid waste from residents

The quantity of waste from the residents is estimated from the population increase in the project area and the unit amount per capita per day.

1) Population

The population in the project area is obtained from the future estimation of population in the Masterplan as shown in Fig. 5.4.3.

2) Unit discharge per capita

The unit discharge of waste from residents is calculated from the questionnaire survey and the field survey to be 720 g per capita per day as of 1978. Generally, the volume should increase year after year so that following methods might be used for estimating the rate of increase.

Fig. 5.4.1 Projected Area

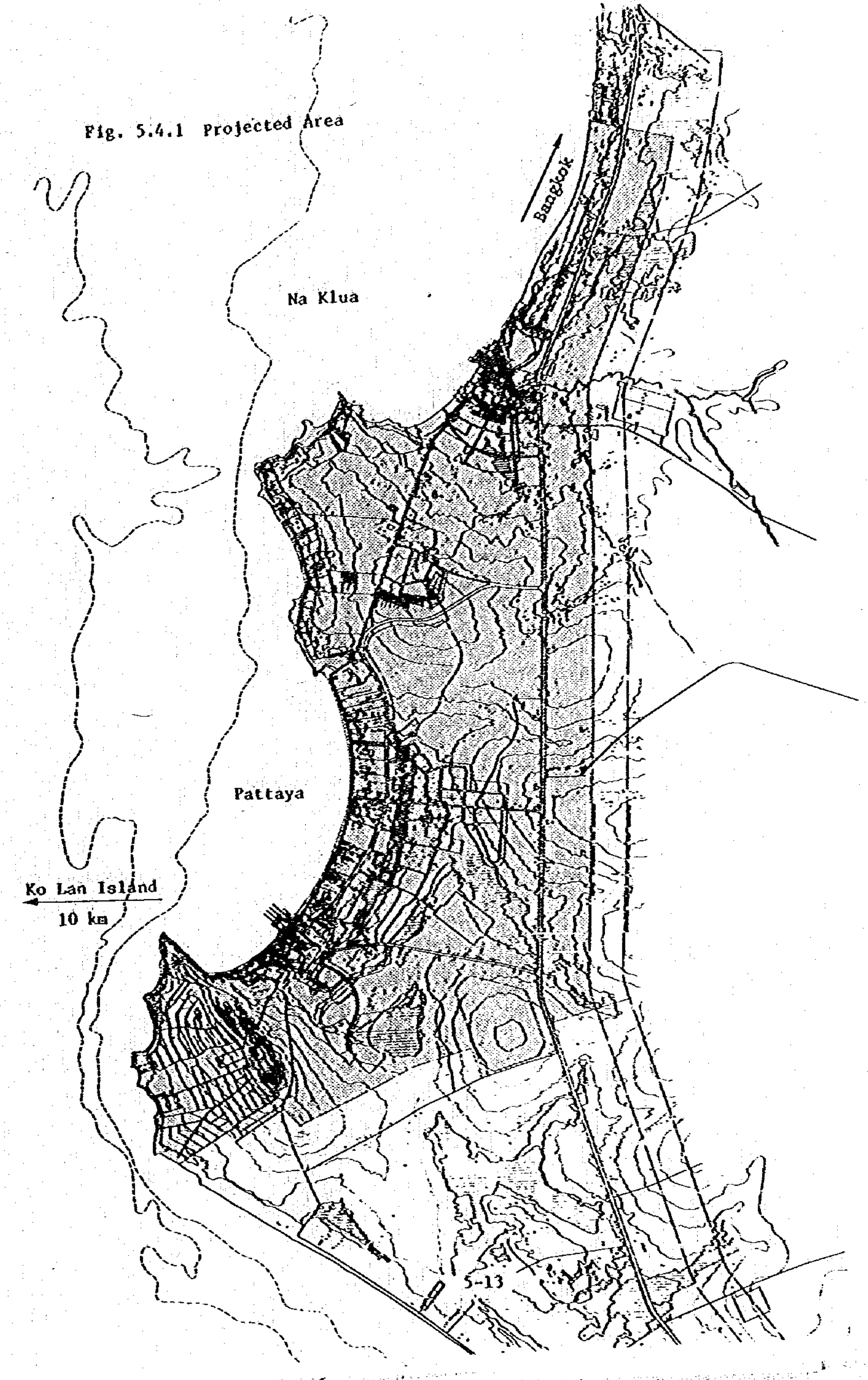


Fig. 5.4.2 Sources of Solid Waste and Flow of Volume Estimation

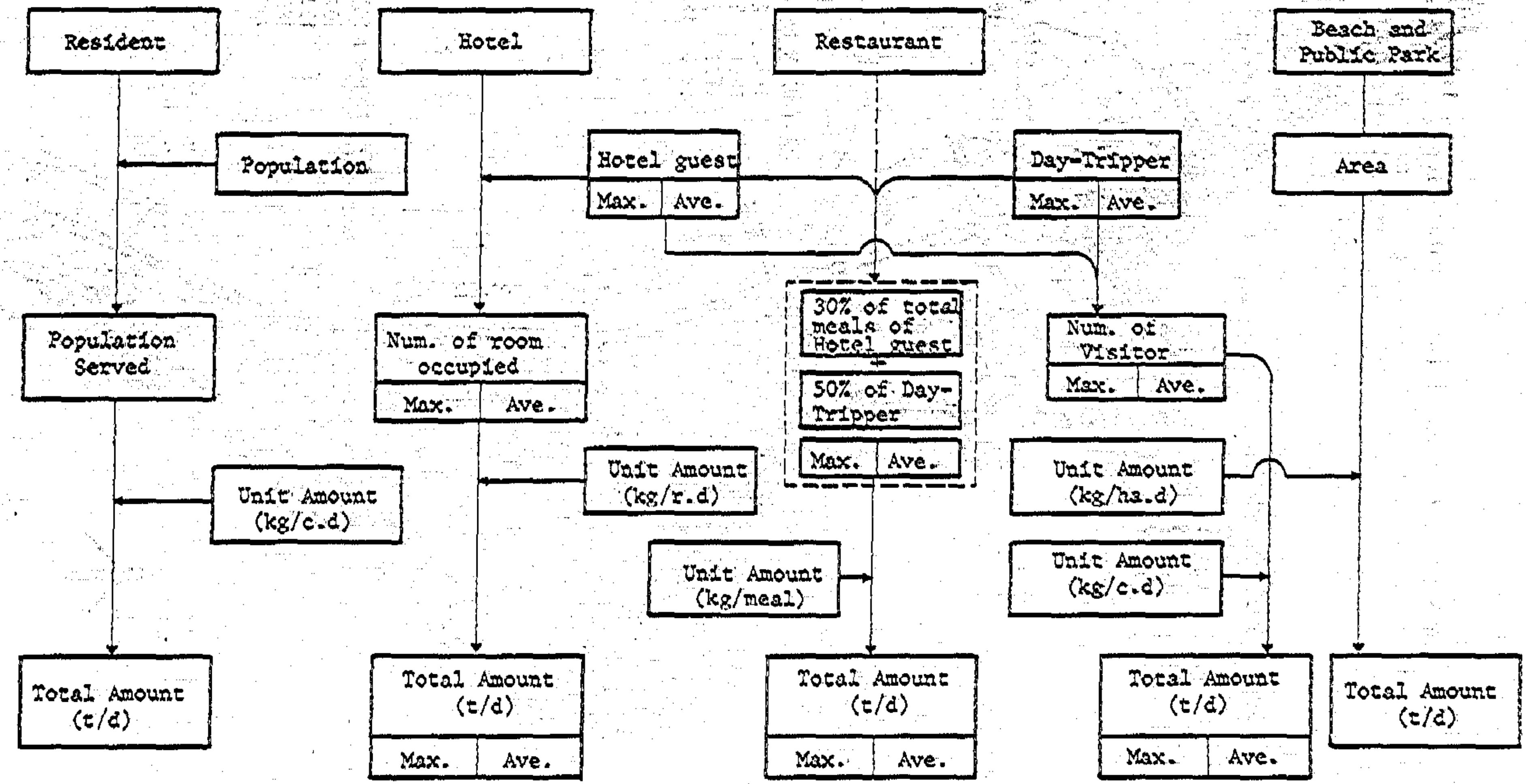
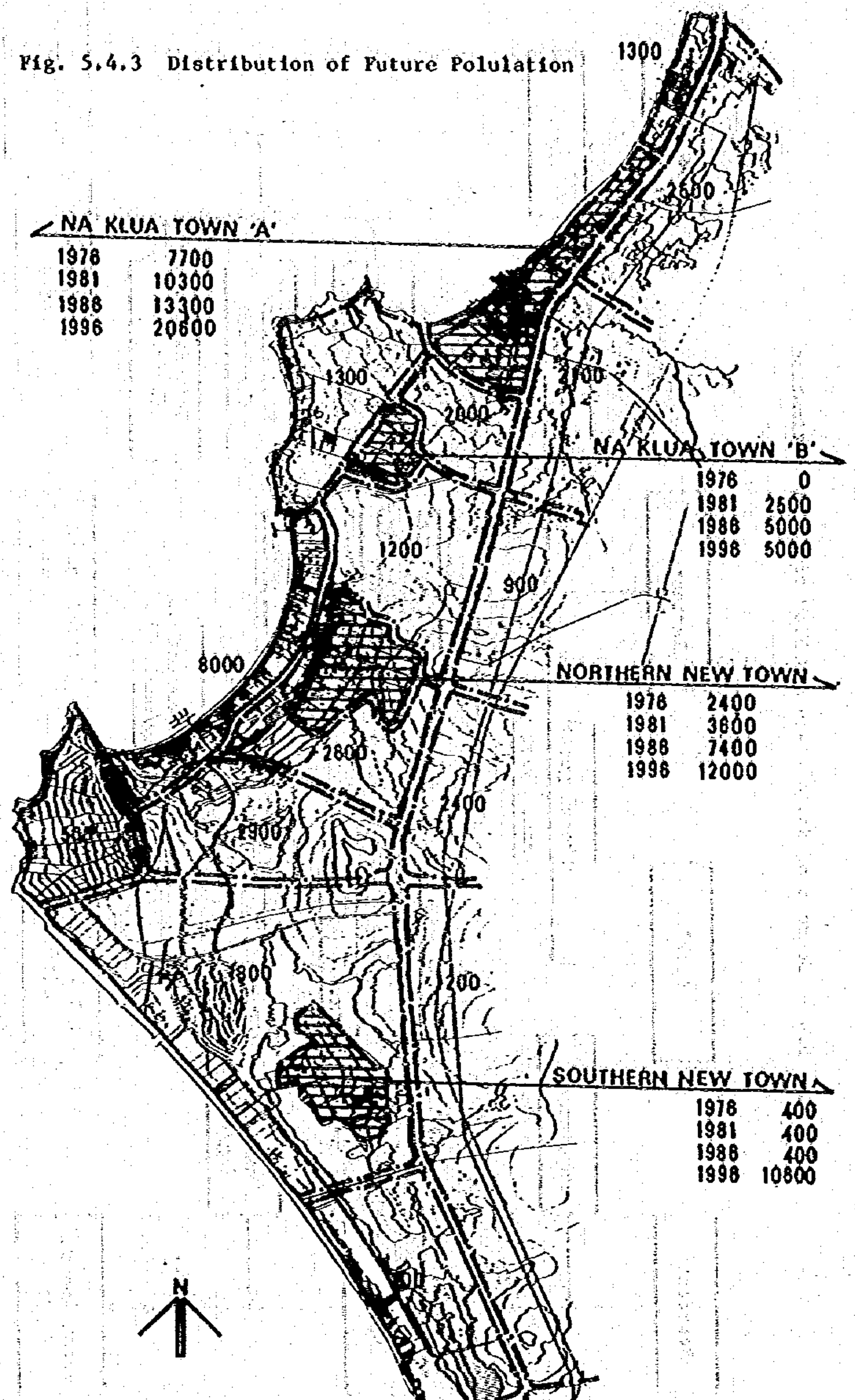


Fig. 5.4.3 Distribution of Future Polulation



- Time sequential analysis method to estimate the future volume of solid waste from the past data.

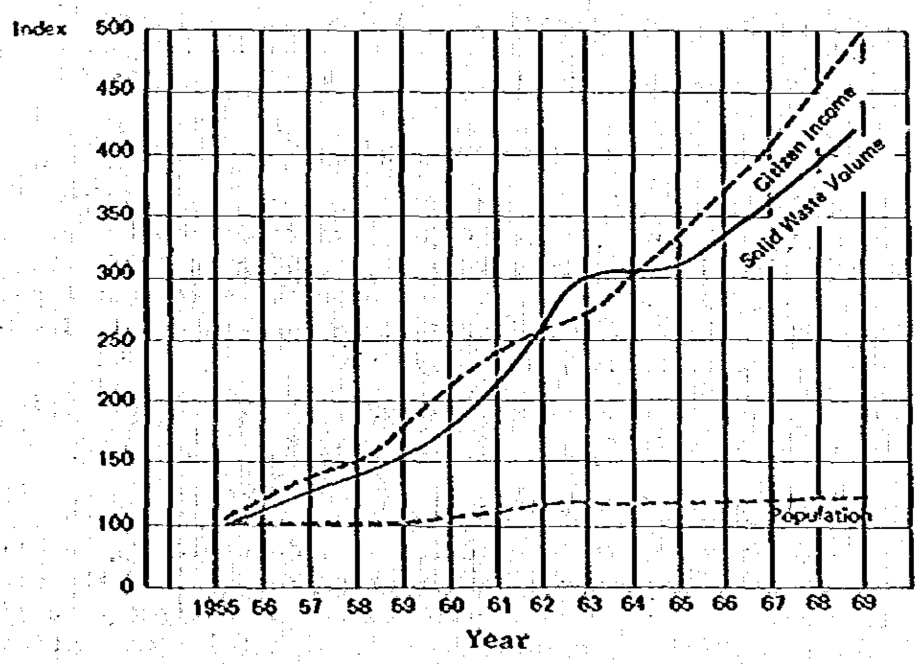
- Method of estimation from the example of other areas having similar conditions.

- Method of estimation from several elements having a close correlation with the increase rate of solid waste (eg. increase rate of national income).

In applying the above methods, sufficient data was not obtainable from the information acquired in the study area and its vicinity for the adoption of the first and second methods. Therefore, the third method was utilized and the amount of unit discharge of solid waste per capita per day was estimated utilizing the growth rate of the national income as an index.

Judging by a Japanese example, the unit discharge of solid waste per capita per day has a close correlation with the annual growth of incomes as shown in Fig. 5.4.4.

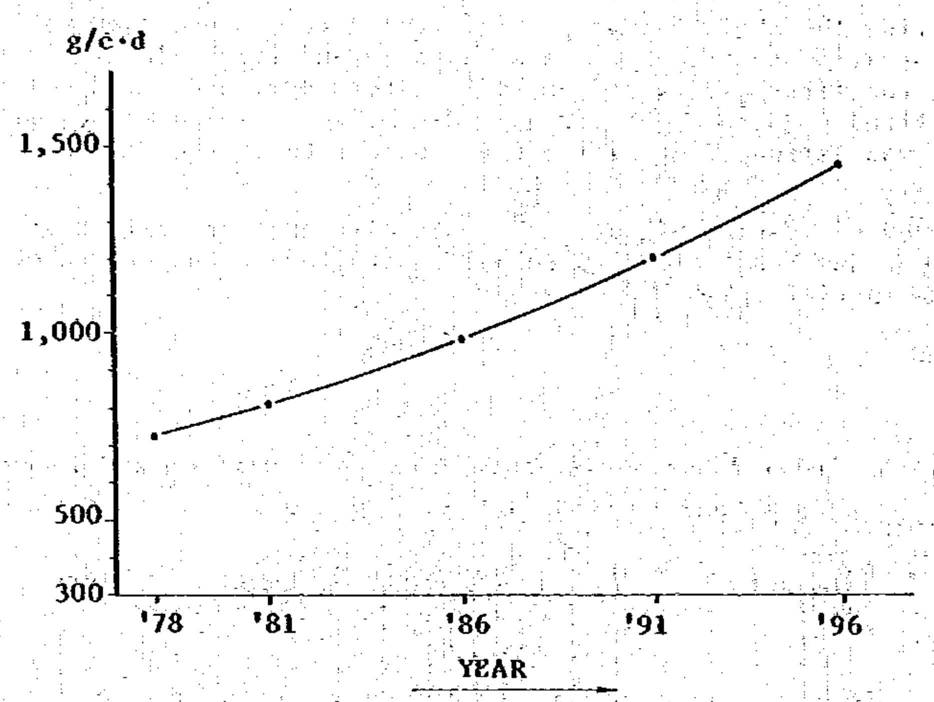
Fig. 5.4.4 Index Among Solid Waste Volume, Population and Income (Example) (Base Year : 1955 Tokyo Area)



Source : "Statistical Year Book for Solid Waste & Night Soil Works", Dept. of Solid Waste & Night Soil Works, Metropolis Tokyo, 19 76

According to data from the Bangkok Bank, the average annual growth rate of the per capita national income is 3.9%. From this figure, it would be assumed that the unit amount of waste per capita per day in 1978 (720g) would increase at the rate of 4% a year. The result is shown in Fig. 5.4.5.

Fig. 5.4.5 Assumed Solid Waste from Residents (g per capia per day)



Based on Fig. 5.4.5, the unit amount of solid waste per capita per day of residents is designed to be 800 g in 1981, 1,000 g in 1986. The annual increase is set to be 40 g per year to determine the unit amount per capita per day. After 1986, also, it would be able to foresee a unit discharge with an increase of approximately 40 g a year.

On the basis of the aforementioned estimations, the volume of solid waste from residents would be obtained as shown in Table 5.4.1.

(d) Volume of solid waste from hotels

The volume of waste from hotels is calculated by determining the maximum number of rooms occupied (the number of existing rooms), and the annual average of occupied rooms for each year based on the estimated tourist demand for hotel rooms and the existing number of hotel rooms mentioned in the masterplan. The maximum and average quantity of waste per day are obtained through multiplying the maximum and average number of occupied rooms by the quantity of solid waste per room.

For the quantity of solid waste per occupied room per day, 7 kg per room per day was adopted from the results of the field survey.

On the basis of the above mentioned calculations, the volume of waste from hotels was estimated to be as shown in Table 5.4.2.

Table 5.4.1 Solid Waste from Residents

Year	Study Area (km^2)	Population (persons)	Unit Amount (kg/c·d)	Daily Amount (t/d)	Daily Amount (m^3/d)	Annual Amount (t/Y)	Annual Amount (m^3/Y)
1980	23.9	42,140	0.76	32.0	107	11,680	39,060
1981	"	43,400	0.80	34.7	116	12,670	42,340
1982	"	45,260	0.84	38.0	127	13,870	46,360
1983	"	47,120	0.88	41.5	138	15,150	50,370
1984	"	48,950	0.92	45.1	150	16,460	54,750
1985	"	50,840	0.96	48.8	163	17,810	59,500
1986	"	52,700	1.00	52.7	176	19,240	64,240

Bulk density : 0.30 t/m^3

Table 5.4.2 Solid Waste from Hotel

Year	① Num. of room needed (rooms)	② Num. of existing room (rooms)	Num. of room occupied: Daily max. 100% of ②	Num. of room occupied: Daily ave. 80% of ①	Unit Amount per room occupied (kg/r·d)	③ Amount of solid waste: Daily max. t/d	Daily max. m^3/d	Daily ave. t/d	Daily ave. m^3/d	Annual amount t/y	Annual amount m^3/y
1976	---	3,270	---	---	---	---	---	---	---	---	---
80	1,730	3,270	3,270	1,380	7.0	22.9	50.9	9.7	21.6	3,540	7,880
81	2,090	3,270	3,270	1,670	7.0	22.9	50.9	11.7	26.0	4,270	9,490
82	2,450	3,270	3,270	1,960	7.0	22.9	50.9	13.7	30.4	5,000	11,100
83	2,770	3,270	3,270	2,220	7.0	22.9	50.9	15.5	34.4	5,660	12,560
84	3,110	3,270	3,270	2,490	7.0	22.9	50.0	17.4	38.7	6,350	14,130
85	3,470	3,470	3,470	2,780	7.0	24.3	54.0	19.5	43.3	7,120	15,800
86	3,800	3,800	3,800	3,040	7.0	26.6	59.1	21.3	47.3	7,770	17,260

Bulk density : 0.45 t/m^3

(e) Volume of solid waste from restaurants

The volume of waste from restaurants is calculated from the number of guests and volume of waste per meal per guest. According to the estimation in the Masterplan, 30% of all meals hotel guests take in a day will be in restaurants, and 50% of day trippers are supposed to take meals in restaurants. The volume of waste discharged after these tourists take meals in restaurants are supposed to be 0.5 kg per meal juding from figures in such reference materials as study reports,[5-1] data prepared by a kitchen equipment manufacturer and so on.

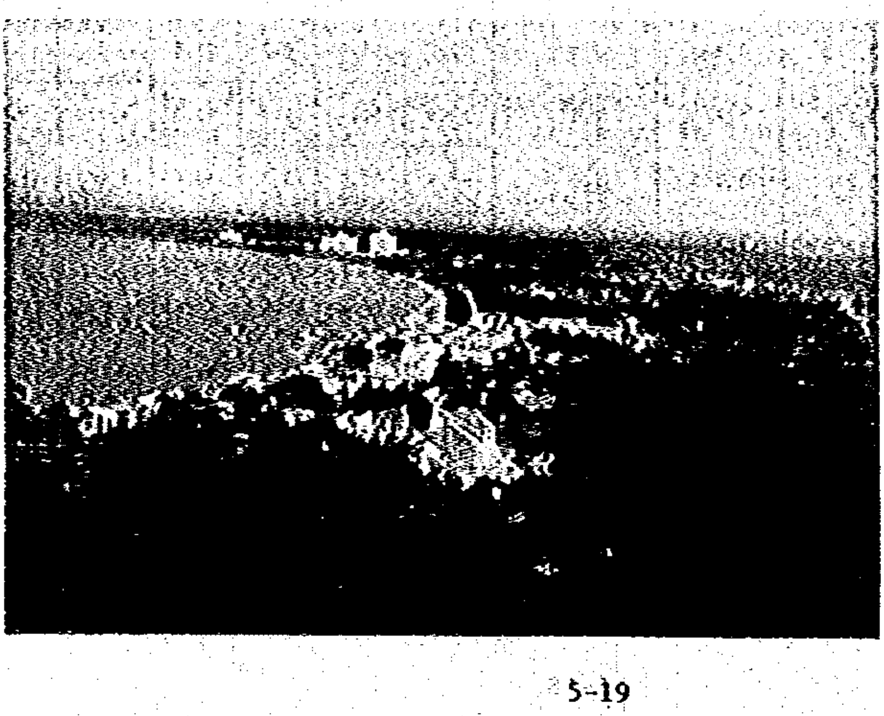
Table 5.4.3 shows the solid waste from restaurants calculated by the above-mentioned process.

(f) Volume of solid waste from beaches and parks

The wastes from beaches and parks are mainly the solid waste of visitors and yard waste like fallen leaves and moved lawns. The number of visitors and the areas of beaches and parks are based on the figures in the Masterplan. The water areas of parks are eliminated from the park area in forecasting the waste volume. The unit volume of waste per visitor is assumed to be 0.2 kg per capita per day based on data gathered in the study area, and the data of waste per visitor in Japan.[5-2] Concerning yard waste, like leaves fallen from trees, there is little data, which makes estimation difficult. Judging from the volume of yard waste in a large hotel in Pattaya and the waste from parks in other countries, 0.25 ton per hectare per day might be used as a basis for calculation. The results are shown in Table 5.4.4.

(g) Total volume of solid waste from the project area

In planning the solid waste disposal system in the project area, the total volume of waste was estimated from the sources of solid wastes which are classified into 4 main items, i.e. residents, hotels, restaurants, and beaches & parks. The total quantity is shown in Table 5.4.5, and 5.4.6 in volume and weight respectively. In this project, the total quantity of waste would be collected and disposed.



General View of Pattaya Phase-1 Area.

Table 5.4.3 Solid Waste from Restaurant

Year	① Hotel guests *1		② Day trippers *2		③ Sub - total		Unit	④ Amount of solid waste					
	Daily max. (persons/d)	Daily ave. (persons/d)	Daily max. (persons/d)	Daily ave. (persons/d)	Daily max. (persons/d)	Daily ave. (persond/d)	Amount (kg/c·d)	Daily max. t/d	Daily max. m^3/d	Daily ave. t/d	Daily ave. m^3/d	Annual amount t/Y	Annual amount m^3/Y
1980	6,350	2,110	2,550	610	8,890	2,720	0.5	4.4	8.8	1.4	2.8	510	1,020
81	6,340	2,570	2,750	650	9,090	3,220	0.5	4.5	9.0	1.6	3.2	580	1,170
82	6,340	3,020	2,950	690	9,290	3,710	0.5	4.6	9.2	1.9	3.8	690	1,390
83	6,340	3,410	3,150	730	9,490	4,140	0.5	4.7	9.4	2.1	4.2	770	1,530
84	6,340	3,840	3,350	770	9,690	4,610	0.5	4.8	9.6	2.3	4.6	840	1,680
85	6,700	4,290	3,550	810	10,250	5,100	0.5	5.1	10.2	2.6	5.2	950	1,900
86	7,290	4,660	3,750	850	11,040	5,510	0.5	5.5	11.0	2.8	5.6	1,020	3,070

Bulk density : 0.50 t/m^3

Table 5.4.4 Solid Waste from Beach and Park

Year	① Solid Waste from Visitors									② Solid Waste from Trees & Others						③ Total Amount					
	No. of Visitors		Unit	Amount of solid waste						Beach & Park area	Unit Amount	Amount of solid waste									
	Daily max.	Daily ave.	Amount	Daily max.		Daily ave.		Annual amount				Daily amount		Annual amount		Daily max.		Daily ave.		Annual amount	
Year	(persons/d)	(persons/d)	(kg/c·d)	(t/d)	(m^3/d)	(t/d)	(m^3/d)	(t/y)	(m^3/y)	(ha)	(t/ha·d)	(t/d)	(m^3/d)	(t/y)	(m^3/y)	(t/d)	(m^3/d)	(t/d)	(m^3/d)	(t/y)	(m^3/y)
1980	7,350	2,150	0.2	1.5	5.0	0.4	1.3	150	470	6.4	0.25	1.6	10.7	580	3,910	3.1	15.7	2.0	11.0	730	4,380
81	7,610	2,500	0.2	1.5	5.0	0.5	1.7	180	620	6.4	0.25	1.6	10.7	580	3,910	3.1	15.7	2.1	12.4	760	4,530
82	7,890	2,885	0.2	1.6	5.3	0.6	2.0	220	730	10.4	0.25	2.6	17.3	950	6,310	4.2	22.6	3.2	19.3	1,170	7,040
83	8,180	3,220	0.2	1.6	5.3	0.6	2.0	220	730	14.4	0.25	3.6	24.0	1,310	8,760	5.2	29.3	4.2	26.0	1,530	9,490
84	8,450	3,540	0.2	1.7	5.7	0.7	2.3	260	840	18.4	0.25	4.6	30.7	1,680	11,210	6.3	36.4	5.3	33.0	1,940	12,050
85	9,000	3,920	0.2	1.8	6.0	0.8	2.7	290	950	22.4	0.25	5.6	37.3	2,040	13,610	7.4	43.3	6.4	40.0	2,330	14,600
86	9,490	4,240	0.2	1.9	6.3	0.8	2.7	290	990	26.4	0.25	6.6	44.0	2,410	16,060	8.5	50.3	7.4	45.7	2,700	17,050

Bulk density : Solid Waste from Visitors --- 0.3 t/m^3
" from Trees & Others --- 0.35 t/m^3

Table 5.4.5 Total Volume of Solid Waste in Project Area

Year	Resident Daily Amount (m^3/d)	Resident Annual Amount (m^3/y)	Hotel Daily Max. (m^3/d)	Hotel Daily Ave. (m^3/d)	Hotel Annual Amount (m^3/y)	Restaurant Daily Max. (m^3/d)	Restaurant Daily Ave. (m^3/d)	Restaurant Annual Amount (m^3/y)	Beach & Park Daily Max. (m^3/d)	Beach & Park Daily Ave. (m^3/d)	Beach & Park Annual Amount (m^3/y)	Total Daily Max. (m^3/d)	Total Daily Ave. (m^3/d)	Total Annual Amount (m^3/y)
1980	107	39,060	50.9	21.6	7,880	8.8	2.8	1,020	15.7	12.0	4,380	182.4	143.4	52,340
1981	116	42,340	50.9	26.0	9,490	9.0	3.2	1,170	15.7	12.4	4,530	191.6	157.6	57,530
1982	127	46,360	50.9	30.4	11,100	9.2	3.8	1,390	22.6	19.3	7,050	209.7	180.5	65.890
1983	138	50,370	50.9	34.4	12,560	9.4	4.2	1,530	29.3	26.0	9,490	227.6	202.6	73,950
1984	150	54,750	50.9	38.7	14.130	9.6	4.6	1,680	36.4	33.0	12,050	246.9	226.3	82,610
1985	163	59,500	54.0	43.3	15,800	10.2	5.2	1,900	43.3	40.0	14,600	270.5	251.5	91,800
1986	176	64,240	59.1	47.3	17,260	11.0	5.6	2,040	50.3	46.7	17,050	296.4	275.6	100,590
Total	-	356,620 (68%)	-		88,220 (17%)	-		10,730 (2%)	-		69,140 (13%)	-		524,710 (100%)

Table 5.4.6 Total Weight of Solid Waste in Project Area

Year	Resident Daily Amount (t/d)	Resident Annual Amount (t/y)	Hotel Daily Max. (t/d)	Hotel Daily Ave. (t/d)	Hotel Annual Amount (t/y)	Restaurant Daily Max. (t/d)	Restaurant Daily Ave. (t/d)	Restaurant Annual Amount (t/y)	Beach & Park Daily Max. (t/d)	Beach & Park Daily Ave. (t/d)	Beach & Park Annual Amount (t/y)	Total Daily Max. (t/d)	Total Daily Ave. (t/d)	Total Annual Amount (t/y)
1980	32.0	11,680	22.9	9.7	3,540	4.4	1.4	510	3.1	2.0	730	62.4	45.1	16,460
1981	34.7	12,670	22.9	11.7	4,270	4.5	1.6	590	3.1	2.1	760	65.2	50.1	18,280
1982	38.0	13,870	22.9	13.7	5,000	4.6	1.9	690	4.2	3.2	1,170	69.7	56.8	20,730
1983	41.5	15,150	22.9	15.5	5,660	4.7	2.1	770	5.2	4.2	1,530	74.3	63.3	23,110
1984	45.1	16,460	22.9	17.4	6,350	4.8	2.3	840	6.3	5.3	1,950	79.1	70.1	25,590
1985	48.8	17,810	24.3	19.5	7,120	5.1	2.6	950	7.4	6.4	2,330	85.6	77.3	28,210
1986	52.7	19,240	26.6	21.3	7,770	5.5	2.8	1,020	8.5	7.4	2,700	93.3	84.2	30,730
Total	-	106,880 (65%)	-		39,710 (24%)	-		5,360 (3%)	-		11,160 (7%)	-		163,110 (100%)

(h) Consideration to Other Area than Projected Area

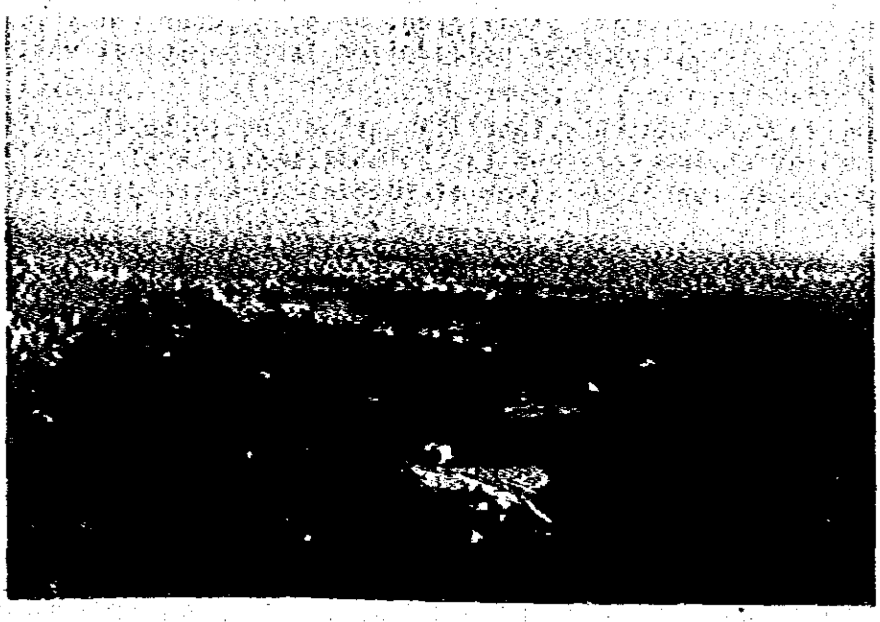
Considering the fact of the establishment of Pattaya township, the management of the solid waste in the area other than projected such as northern portion of Na Klua and southern portion of Pattaya area may have to be included.

Estimation of the quantity of solid waste in such areas is roughly estimated as in Table 5.4.7, however, planning and cost estimation of the collection and disposal system are not included in this feasibility study.

Table 5.4.7

Year	Population outside of projected area (persons)	Unit Amount (kg/c·d)	Daily Amount		Annual Amount	
			(t/d)	(m^3/d)	(t/Y)	(m^3/Y)
1980	5,000	0.76	3.8	12.7	1,390	4,640
1981	5,000	0.80	4.0	13.3	1,460	4,850
1982	5,000	0.84	4.2	14.0	1,530	5,110
1983	5,000	0.88	4.4	14.7	1,610	5,370
1984	5,000	0.92	4.6	15.3	1,680	5,580
1985	5,000	0.96	4.8	16.0	1,750	5,840
1986	5,000	1.00	5.0	16.7	1,830	6,100

* Assuming a bulk density of solid waste of 0.3 t/m^3.



General View of Pattaya behind Back Road.

5.4.4 Plan for Disposal System

(a) Examination of Disposal Method

1) Intorduction

In considering a disposal method for Municipal waste, the following methods would be generally listed. Most of the cities in the world where public solid waste disposal is provided adopt one or a combination of the following methods according to the situation of the respective cities in disposing of waste generated every day.

(1) Standard Sanitary Landfill

(2) Shredding and sanitary landfill

(3) Pre-salvage, shredding and disposal by in-place composting at sanitary landfill

(4) Pre-salvage, shredding and high-rate composting

(5) Incineration

(6) Pre-salvage, shredding and burning in a utility electric generation plant

(7) Baling and disposal on land or at sea

(8) Pyrolysis

(9) Dumping at sea

(10) Open dumping on land

In considering waste disposal systems, it is important to choose a method which is in harmony with the local situation considering their manners and customs, the environment, economic standards, technical levels in general, and so on. It is also necessary to select one which minimizes the breeding of flies and rats, bad odour problems, air pollution and contamination of ground water and surface water by the solid waste itself or by leachate from the waste.

From these standpoints, direct dumping of raw waste on the land or in the sea should not be adopted. The study area, however, does not suit a complexed method involving heat utilization from municipal waste incineration or pyrolysis.

In this study, the standard sanitary landfill method should be chosen for comparison as the first choice, (2) and (3) as modifications of the first, and (4) and (5) as representatives of mechanical waste disposal methods.

2) Comparison of disposal methods

(1) Standard sanitary landfill

The standard sanitary landfill method of waste disposal has been widely utilized in most of the cities in the U.S.A. and in small cities in Europe and other areas. The merit of this method lies in its low cost, and its wide application to all kinds of Municipal waste. It has much flexibility as regards the daily fluctuation of waste quantities. By covering the waste with soil every day, it is possible to prevent flies, rats, and unpleasant odours from the disposing site.

As for demerits, a large land area is required, lack of adequate land in the centers of cities pushes the cost up, large quantities of covering material is needed, and there is the danger of contamination of the ground and surface water by leachate, and it takes a long time before the filled land stabilizes. It must be mentioned, also, that work efficiency is lowered in the rainy season.

(2) Shredding and sanitary landfill

This method was developed to make up for some of the defects of the standard sanitary landfill method. Solid waste would be first shredded and disposed in the landfill area.

Shredding reduces the quantity of waste and homogenizes its quality, thus contributing to the economizing of the land area, and also raising the efficiency of the landfill work. Organic substances in the shredded waste would be more easily decomposed, expediting the geological stabilization of the site and reducing the degree of contamination by leachate.

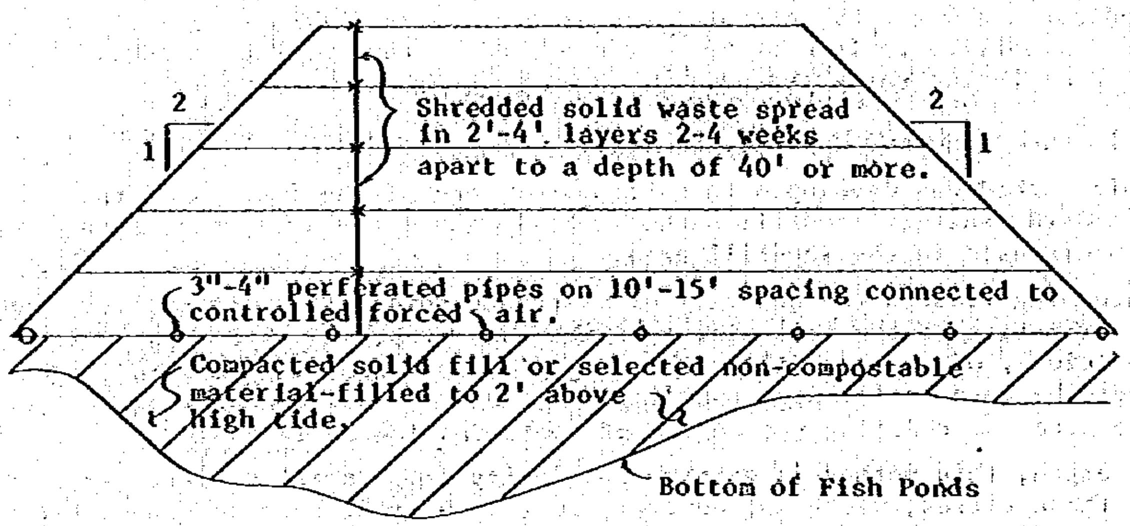
In Japan, this method is gaining popularity among small cities. In some of these cities, waste is, however, left uncovered, because the surface of the filled waste is kept naturally in an aerobic condition, and the heat of fermentation from organic substances in the waste prevents the breeding of flies and rats. Odours also are kept to a negligible degree.

However, a shredder would push up the cost and complicate operations and maintenance.

3) Pre-salvage, shredding and disposal by in-place composing at the sanitary landfill. (in-place composting)

While the first and the second methods are for disposing of the Municipal waste in the land once and for all, this method aims at recycling the organic substances in the solid waste as compost.

Valuable materials like metals, empty bottles, and other non-compostable materials are first separated manually and organic waste is then shredded and piled on the land where perforated pipes are laid on the bottom as shown in Fig. 5.4.6, and composted with forced air controlled by blowers. After one to three months, a stable compost is obtained. As a feature of this method, solid waste turned into compost would be dug out and applied to farming, the site being made ready for new shredded waste and composted again. In this manner, landfill site allows for cyclical use after a certain duration. As a result, the area required for landfill site is economized to a large extent, and the quantity of leachate is reduced considerably, and solid waste is recycled as compost which has a monetary value; therefore, it would be a feasible method for cities in agricultural areas where the demand exists for compost. Compared to the second method, however, the cost of construction would be 50% to 100% more, and complicated landfill work raises the operation and maintenance costs, too.



Source : "Masterplan for Solid Waste Collection & Disposal for Manila & Suburbs." 1974, Pacific Consultants International

Fig. 5.4.6 Cross Section of In-place Forced Air Composting in a Landfill

(4) Pre-salvage, shredding and high-rate composting (High-rate composting)

This method is similar to (3) as regards combining waste disposal with the recycling of the organic resources in solid waste.

This is a mechanical composting system with a quicker (2-7 days) process of composting. It was developed in European countries and in the USA, and many examples are found in Japan, too.

This method economizes land, and minimizes air pollution and ground-water contamination by leachate, but construction costs are high and the disposal of non-compostable materials requires extra costs.

Before adopting this method, demand for compost should exist in the vicinity of the facility, and the compost produced every day should be salable to make it worthwhile.

(5) Incineration

Incineration of solid waste has the best quality of the five disposal methods examined in this study for stabilizing solid waste and reducing its weight sanitarily and quickly. However, the construction costs are high and operation and maintenance are difficult, especially in the case of large incinerations. Some kind of local waste might impede adoption of this method. In making a decision on this type of disposal method, thorough examination of the quality of the solid waste on a yearly basis will be required.

(6) Cost of construction and operation

A comparison of the construction costs and running costs of the five disposal methods to dispose waste created during 1980 to 1986 in the Pattaya area is shown in Table 5.4.8. As for incineration, a system manufactured by a company, which has produced the largest number of incinerators in Japan is used as a basis for estimation. In the case of (4), a composting system, produced by a Japanese manufacturer who has a technical tie-up with an American firm provides the basis for the cost estimation.

Table 5.4.8 Rough Estimation of Construction Costs & Running Costs

Method	*1 Construction Cost ($x10^3$ Baht)	Unit Const. Cost (Baht/Ton)	*2 Running Cost Baht/Ton	Remarks
Standard sanitary landfill	6,600	40	25	Non-residue
Shredding then sanitary landfill	12,500	80	70	Non-residue
In-place compositing	21,300	130	75 *3	Including costs for residue disposal
High-rate compositing 2 units of 50 t/d	94,100	580	120 *3	Including costs for residue disposal
Incineration 2 units of 50 t/d	112,100	690	175	Including costs for residue disposal

*1 Including land cost.

*2 Excluding depreciation of instruments.

*3 Excluding revenue from selling valuable matters.

As shown in this table, the standard sanitary landfill system is much cheaper both for construction and operations, while either of the mechanical treatment systems, (4), (5) show high construction and running costs.

Fig. 5.4.7 Sample of Incinerator (Capacity : 100 ~ 150 tons per day)

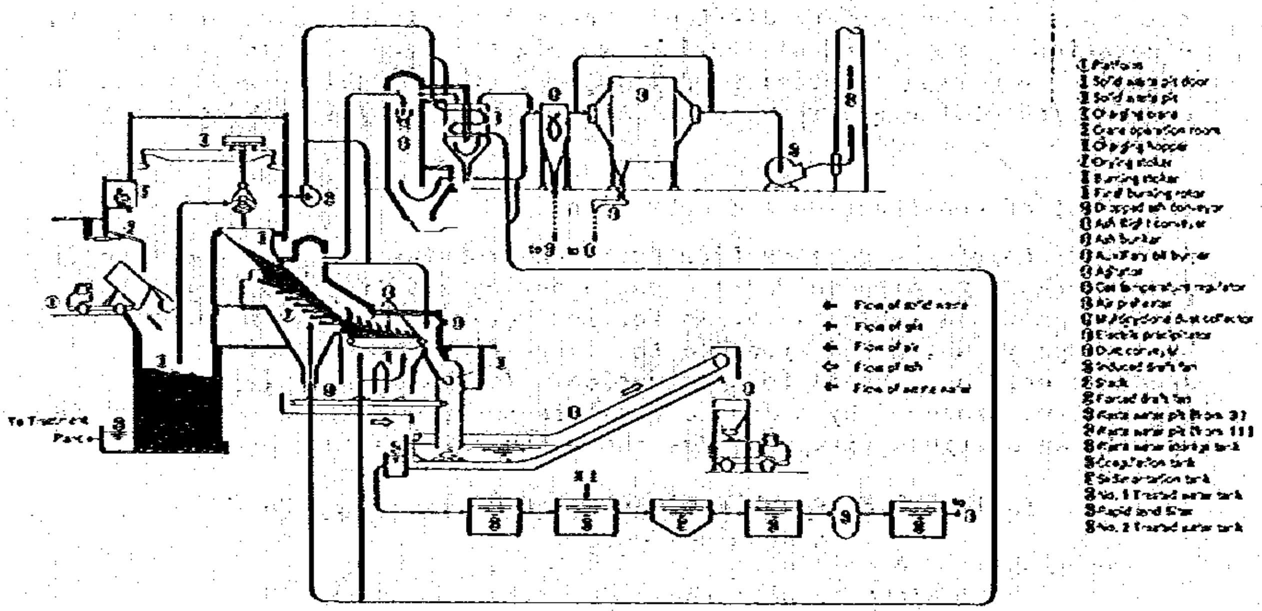
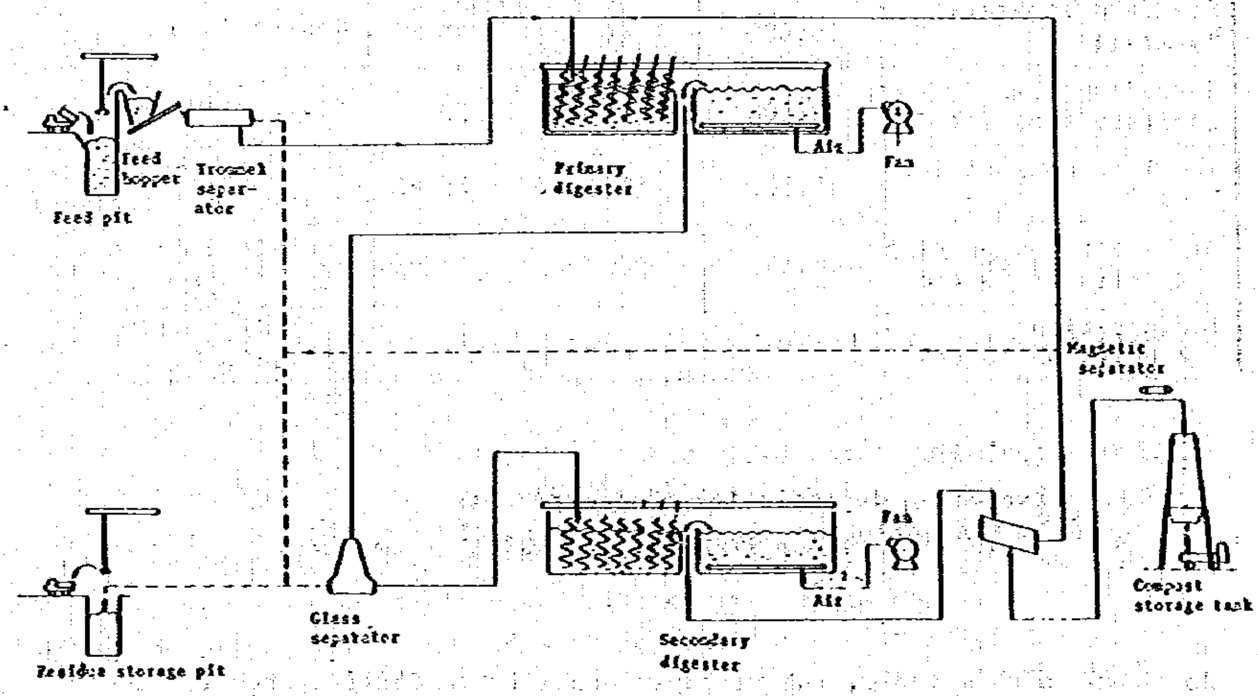


Fig. 5.4.8 Sample of Mechanical Composting System



3) Selection of the optimum waste disposal method

In this paragraph, five waste disposal methods for the study area are described, and the costs of construction and operation are compared. In choosing the most suitable method for the study area, the following seven evaluation items are chosen and examined.

	Evaluation Items	Weighted Point
A.	Cost of construction and operation	(Max.10 point)
B.	Maintainability and workability	(Max. 5 point)
C.	Evaluation from sanitary point of view	(-do-)
D.	Adaptability to the area	(-do-)
E.	Land cost	(Max. 3 point)
F.	Adaptability to the quality of refuse	(-do-)
G.	Evaluation for recycling	(Max. 2 point)

Table 5.4.9 Evaluation of the Disposal Method for the Study Area

Method	Items							Total
	A	B	C	D	E	F	G	
Standard sanitary landfill	10	5	3	5	1	3	1	28
Shredding then sanitary landfill	7	4		4	1	3	1	23
In-place compositing	5	3	4	3	2	3		22
High-rate compositing 2 units of 50 t/d	2	2	4	2	2	3		17
Incineration 2 units of 50 t/d	1	1	5	2	3	2	1	15

From the result of these evaluations, the standard sanitary landfill method would be recommendable as the most suitable method for Pattaya. In this project, therefore, the standard sanitary landfill method would be assumed to be adopted, and implementation of the project should be worked out fully considering the merits and demerits of this method.

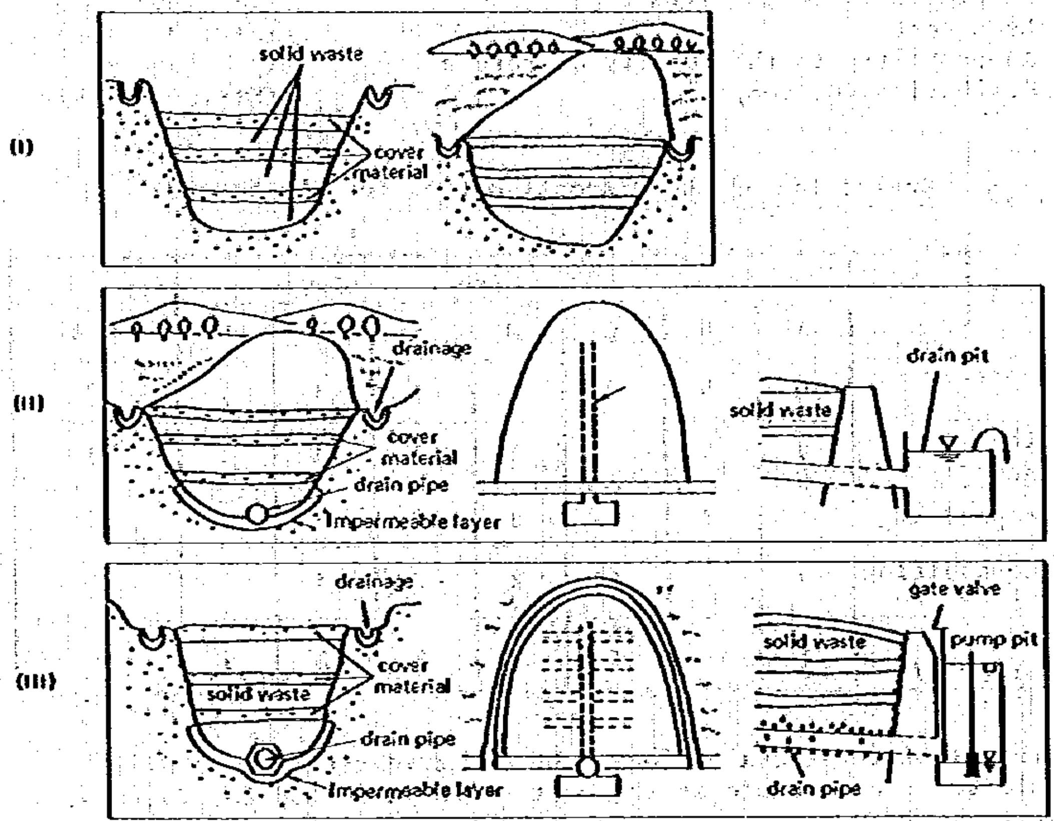
(b) Selection of the Landfill Site

1) Structure of the landfill site

Typical structures of a sanitary landfill site are shown in Fig. 5.4.9.

The structure of the landfill site for the project area should be selected based on a thorough going survey of the geological conditions of the study area, the level and flow direction of the ground water, and its influence on the nearby wells.

Fig. 5.4.9 Structure Types of Sanitary Landfill



Source: Dr. M. HANAJIMA
"Data in Japan & U.S.A. Waste Management Conference"

The first structure would be the simplest and cheapest for areas where the ground water level is lower than the bottom of the landfill site, and at the same time, the bottom soil has low permeability, therefore, there is little danger of contaminating nearby wells and surface water.

The second and the third must be adopted when it is assumed that leachate contaminates ground water and surface water, and a leachate treatment facility has to be provided.

If the quality of leachate is quite bad, higher construction and operation costs are required. What is worse, the quality and quantity of leachate fluctuates greatly under the influence of rain, which might make the maintenance of a leachate treatment facility difficult. Inadequate maintenance and control might cause greater contamination of the nearby surface water.

In this project, therefore, it would be better to study places where the first structure type could be adopted as much as possible. Therefore field survey had been practiced in due consideration of this matter.

2) Study of landfill site alternatives

The following conditions were evaluated in selecting the landfill site.

- From the point of view of efficiency of the collection and transportation of waste, the transportation distance should be short from the center of the collection zone and the site should be located within an area projecting a small traffic volume.
- To prevent contamination of public water ways and underground water, the site should have a small quantity of surface and ground water, and be far from irrigation channels and water supply systems.
- The site should be as far away as possible from residential areas and from public facilities like schools.
- The site should have little danger of overflow of leachate and solid waste outside the site as a result of natural disasters like landslides and floods.

Judging from the above-mentioned items, five sites in Fig. 5.4.10 have to be evaluated, and preliminary examination was made of the geological and hydrological conditions of the respective sites.

For this examination, part of the data is from the "Feasibility Report on the Water Supply for Pattaya Bang-Lanumg" compiled by the Water Resources Planning Subcommittee of the National Economic and Social Development Board, Thailand, 1976.

(1) Topographic and botanical condition

Five points (A, B, C, D, E) were proposed and examined for landfill sites after the field survey. Point A is on the slope of a mountain, and a brook and a village are located 1 km down the southern slope. Points B, C and D are on terraces, and point E is almost in the center of an alluvial eroded valley and close to a river. In points A, B, C and D, the underground water level is low with thick dry soil. Point E is alluvial low land and wet. As for botanical conditions in Points A, B, C, D, coppices and tapioca fields are observed, and point E is partially used for fields and agricultural land, such as paddys.

(2) Geological conditions

As shown in Fig. 5.4.11, the geological condition of the study area is composed of beach sand, alluvial deposits (sand and clay), terrace deposits (sand and clay), and granite (the surface is normally weathered). The results of electric probing (Fig. 5.4.12) show a surface deposit with a thickness of 10 m approximately. Below that layer is weathered granite and fresh granite layers.

Fig. 5.4.10 Sites Studied for Landfill

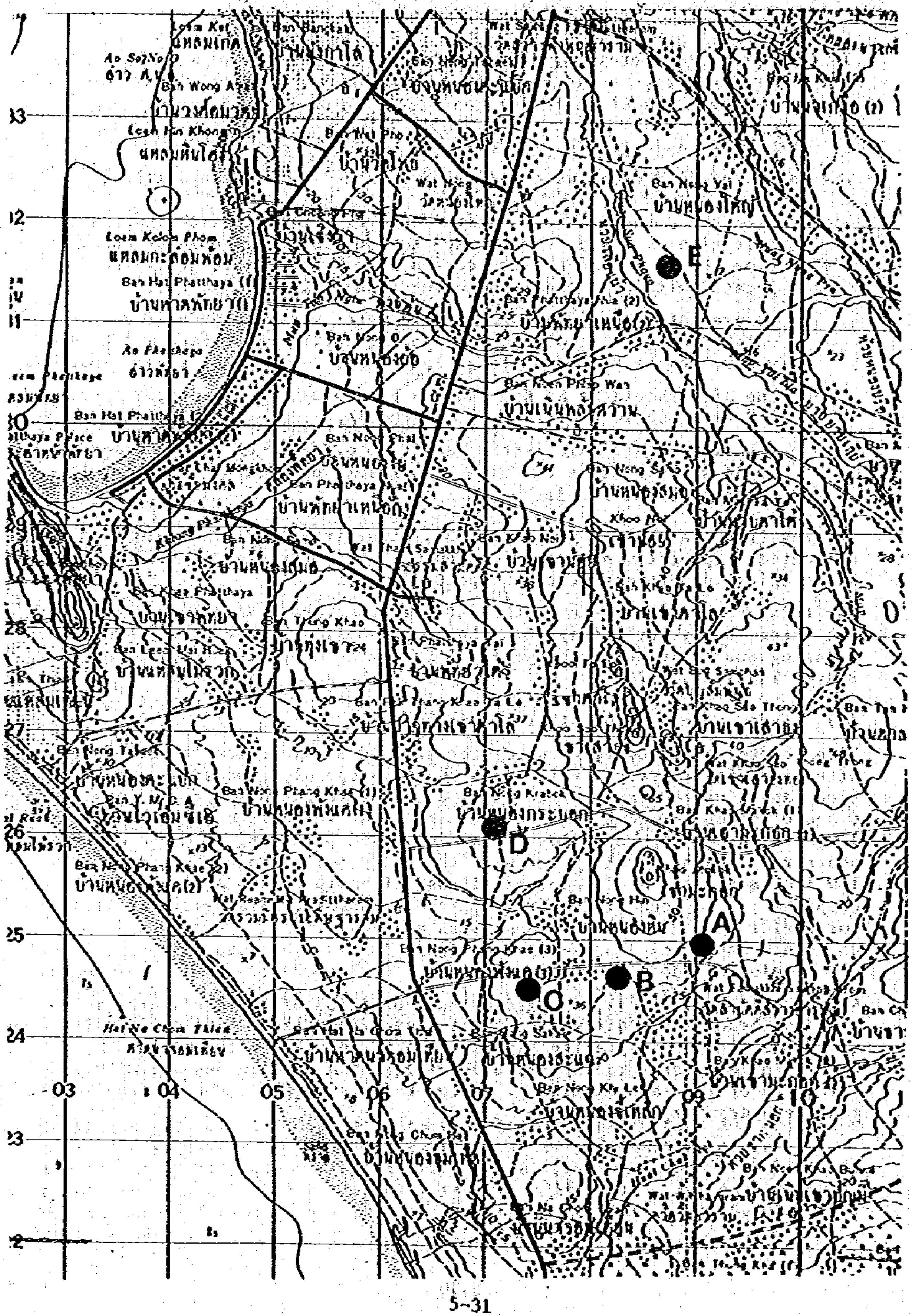
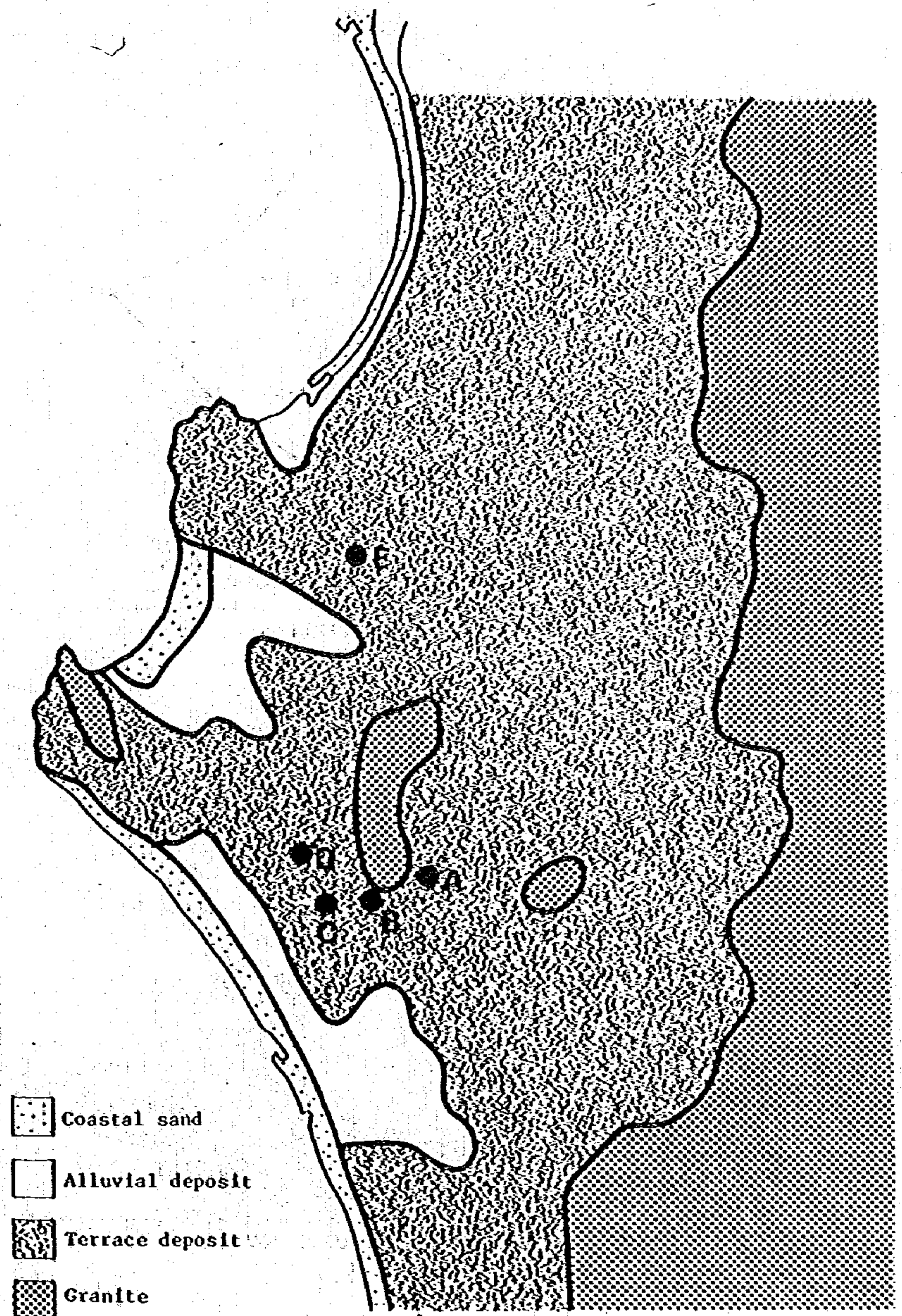
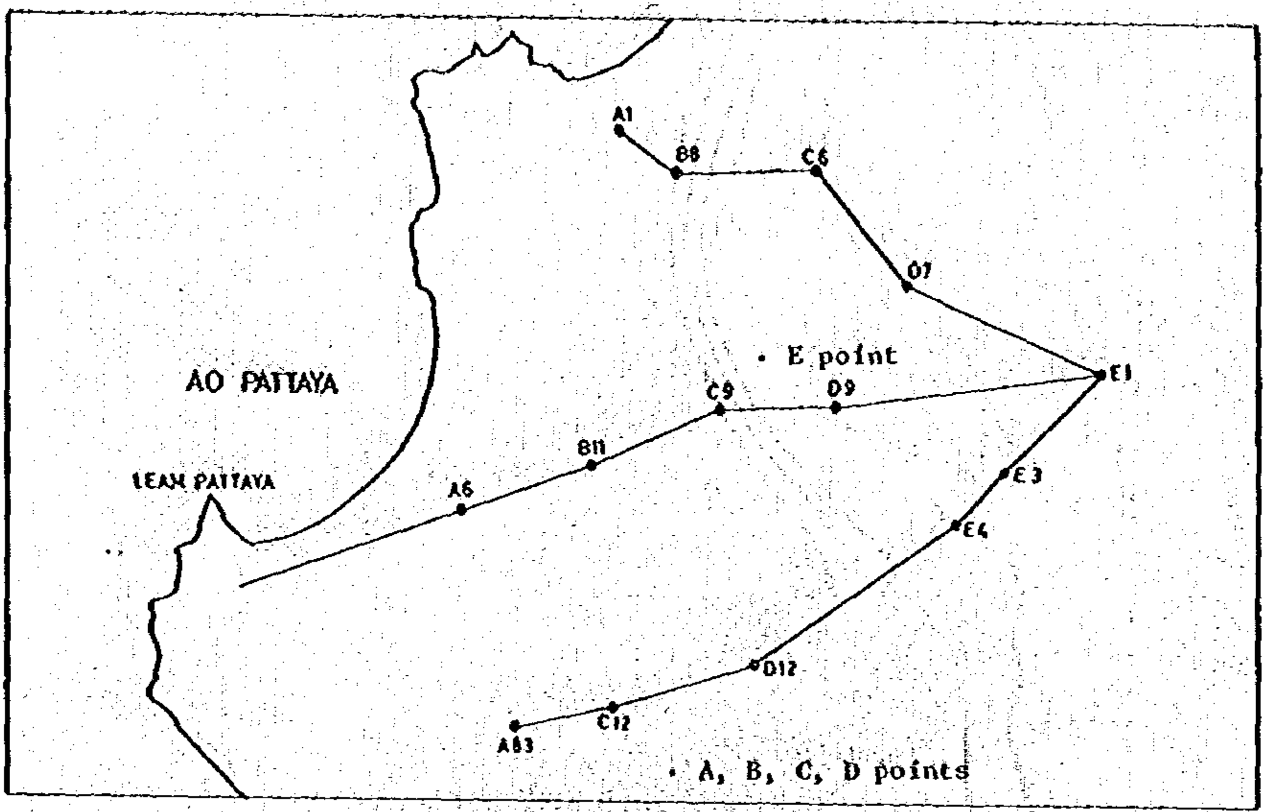


Fig. 5.4.11 The Geological Condition of The Study Area

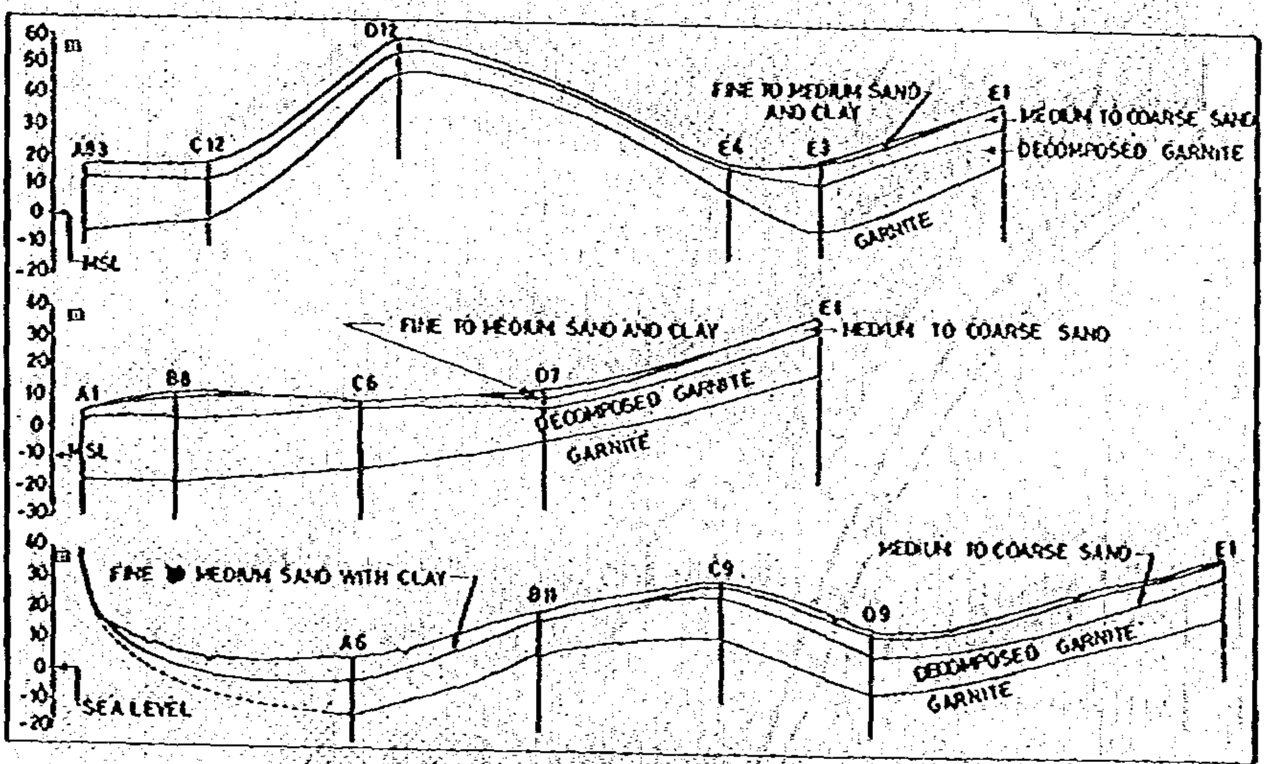


Source : Water Resources Planning Subcommittee NESDB Thailand
"Feasibility Report on Water Supply for Pattaya Bang-lamung"

Fig. 5.4.12 Hydrogeologic Map of Pattaya and Adjacent Area



GENERALIZED GEOLOGIC SECTION



GENERALIZED GEOLOGIC SECTION ALONG NW-SE
BASED ON RESISTIVITY SURVEY

Source : Water Resources Planning Subcommittee NESDB Thailand "Feasibility Report on Water Supply for Pattaya Bang-lamung"

(3) Hydrogeological conditions

Ground water : Ground water at points A, B, C and D is depressured. It is in a shallow aquifer base which has low storage properties. Ground water of the respective points, except point C, is concentrated in ground water valleys and flows as shown in Fig. 5.4.13. The ground hydrological conditions tend to fluctuate by season. Point E, on the other hand, is situated almost in the center of a ground water valley which flows into the Na Klua area, and this flow of ground water is expected to be steady.

Ground water level : The ground-water level at points A, B, C and D is deep, as shown in Fig. 5.4.14; however, the level at point E is very shallow. Their surface slopes are expected to be 1.0 percent for points A, B, C and D and 0.5 percent for point E.

Permeability of the earth : According to the field test, the permeability of the earth at points A, B and C are low (10^{-4} to 10^{-5} cm per second), however, it is 10^{-2} cm per second at points C and E.

General Topograpy in Pattaya

Fig. 5.4.13 Zoning Map of Underground Water Movement

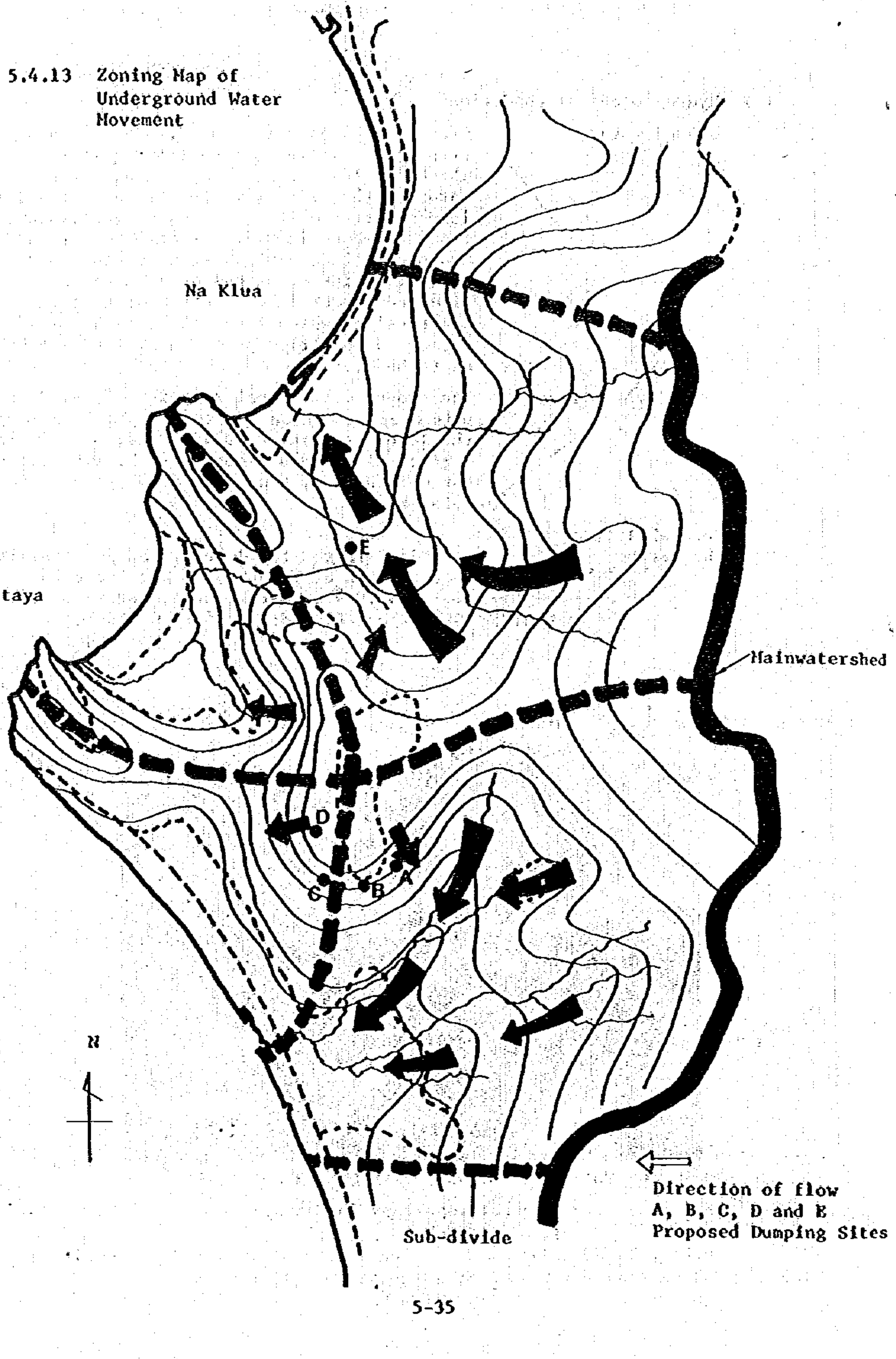
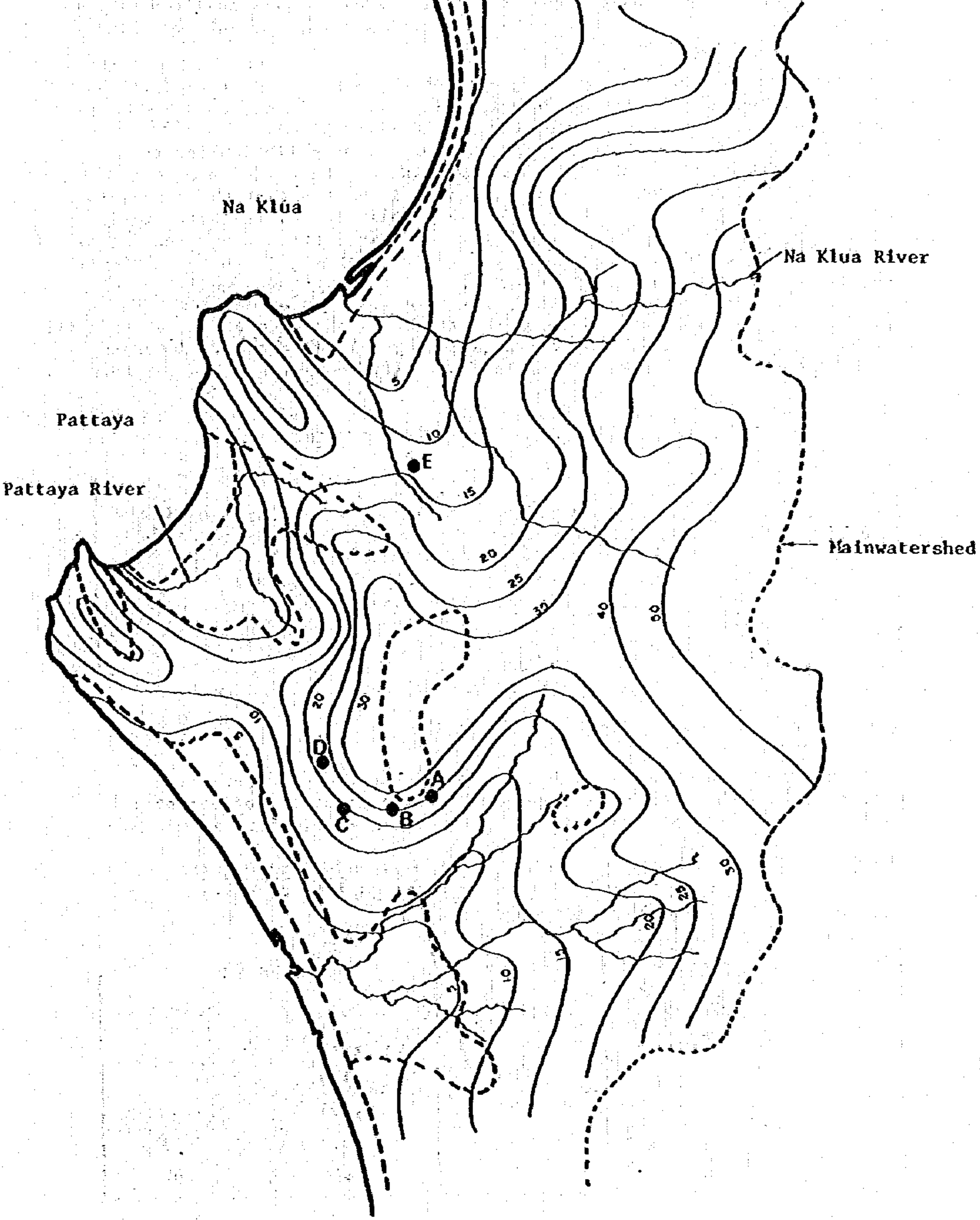


Fig. 5.4.14 Contour Line of Ground Water



(4) Permeability coefficient and effective porosity of each point

The geological data and permeability coefficient of each point were obtained from boring and permeability tests examined by a Thai consultant. Because point A was not available in the boring data, the data of point B was used for reference.

When the unsaturated zone of the ground water is composed of sandy soil, it will not cause problems for the landfill sites. On the other hand, when the saturated zone of the ground water is composed of a sandy layer, it will increase the possibility of pollution for the reclaimed sites. Accordingly, it is advantageous that facies of the aquifier be composed of clayey soil, and it is better that the permeability coefficient be as small as possible. Pollution by leachates would result by their moving down through the voids in a stratum and the actual flow velocity would be affected by the effective porosity in the aquifer. The effective porosity was determined by the Eckis method, obtaining an effective grain size D_{10} from the grain size analysis of samples obtained by the boring. Table 5.4.10 shows the strata as the foundations of landfill sites, their permeability coefficients and actual velocities. According to the table, point C has the smallest velocity and point D has the largest.

Table 5.4.10 Velocity of Ground Water

Location	Facies of aquifer	Permeability cm/sec	Inclination	Specific yield	Velocity cm/day
A, B site	Sandy clay	5.52×10^{-4}	1/100	0.05	9.54
C site	Clayey sand	1.3×10^{-4}	1/100	0.03	3.74
D site	Sand and Clayey sand	5.0×10^{-2}	1/100	0.10	4.32
E site	Clayey sand	1.0×10^{-2}	1/200	0.25	17.28

(5) The effect on the existing wells in the adjacent area

Pollution would be expanded with the flow of the ground water. The number of days which might be required to bring about the effect of pollution on the wells of most adjacent private houses was forecasted.

Table 5.4.11 Forecast of the Number of Days and Years Required to Effect the Pollution on Water Quality of Wells Adjacent to the Landfill Site

Location	Velocity of ground water (m/day)	Distance to adjacent well (m)	During Time	
			Day	Year
A	0.095	400	4,210	11.5
B	0.095	200	2,105	5.7
C	0.037	200	5,405	14.8
D	4.32	200	46.3	0.13
E	0.173	500	2,890	7.92

The results reveal that point C will be the first choice and A the second choice, if a safe landfill site is to be selected from the standpoint of pollution of the existing wells of residents. Concerning point B, which is the existing dumping site, it is geologically suitable for the landfill site, but it should be disposed as a tentative landfill site until the proposed system is put in operation. Concerning point E, there is a large possibility of affecting the surface water in the neighbouring area before having an effect on the wells of private houses.

(6) Water quality of wells located downstream of the former and existing sites

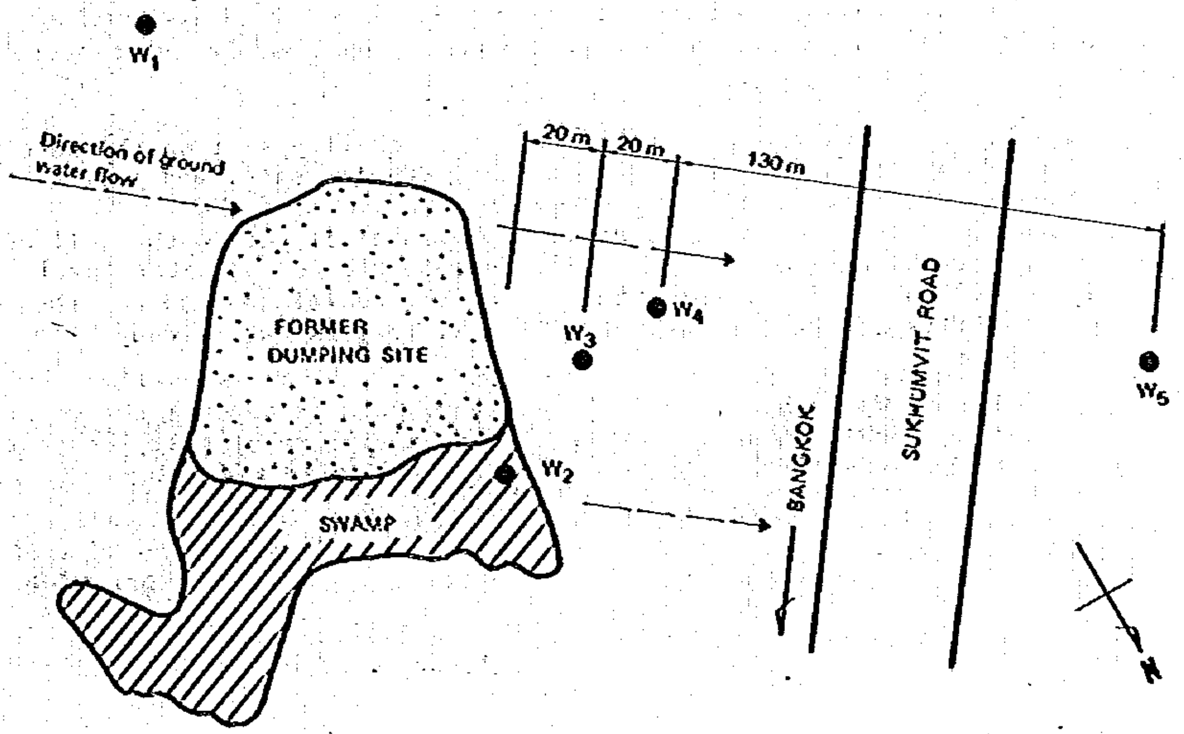
5 proposed sites were selected to determine the optimum land fill site for this project, and the respective cases for installing a land fill site at the individual points were discussed through investigation of geological, soil and hydrological conditions, etc. On the other hand, the water quality analysis of wells located downstream of the ground water flow from the former dumping site and the existing dumping site was conducted by a Consultant at the request of the study team during the field investigation.

This paragraph refers to these results as the reference data for the selection of the landfill site.

a. Former dumping site

The former dumping site is a swamp located north of Na Klua, which was being filled with solid waste until last October, since 7 years ago. The wells subjected to the investigation in this site were located at 3 points on the downstream side of the site, and at a point on the upstream side of the site, along the flow direction of the underground water. The locations of these points and the results of water quality analysis are as shown in Fig. 5.4.15.

Fig. 5.4.15 Water Quality of Wells near Former Dumping Site



Item	Unit	W_1	W_2	W_3	W_4	W_5
pH	-	6.8	6.8	8.1	7.0	6.75
Color (as Pt Unit)	mg/ℓ	20	700	1,000	50	40
BOD_5	mg/ℓ	0.8	25.0	15.0	11.5	3.0
COD	mg/ℓ	8.0	248.0	404.0	28.0	36.0
NH_3-N	mg N/ℓ	0	3.4	100.2	0	0
NO_3-N	mg N/ℓ	-	1.0	39.5	8.3	3.3
Kjeldahl-N	mg N/ℓ	1.4	14.7	122.4	3.9	1.7
Chlorides	mg/ℓ	190.0	530.0	1,170.0	115.0	270.0

In this area, the ground water level is above the bottom of the landfill, and the permeability of the ground is found to be $K = 3.6 \times 10^{-2}$ cm/sec as a result of the permeability test at the site, and the inclination of the ground water is estimated to be approximately 1/200. Accordingly, it is forecasted that leachate will have an effect on the adjacent wells at a comparatively early stage, and even the sampling point which is farthest from the reclaimed dumping site on the east side of the Sukumvit Highway will be affected within one year. The well of W_3 closest to the dumping site is evidently affected by leachate from it, and the well of W_4 farthest from the reclaimed site indicates its effect in COD value.

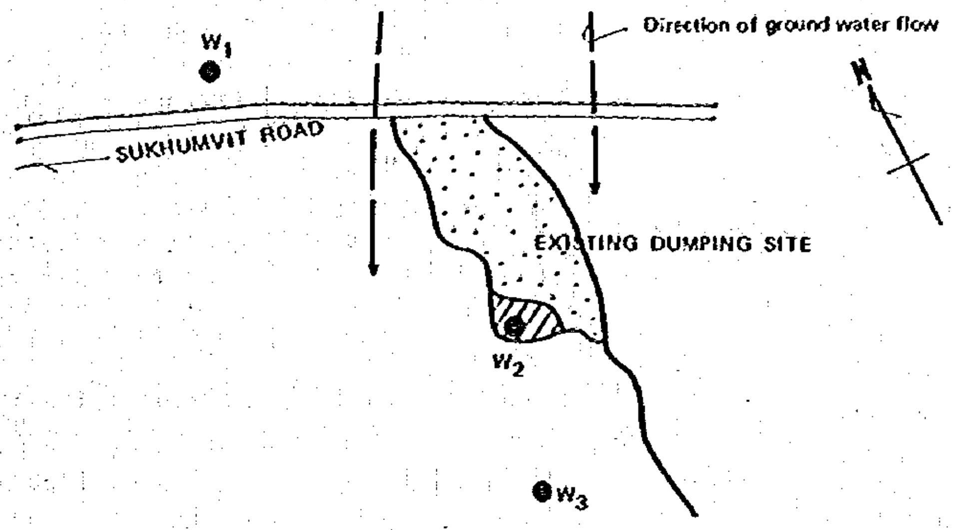
As can be clearly seen from the data, however, the pollution indices such as color, BOD_5, NH_3-N and the like are evidently reduced when the distance of the sampling point is far from the dumping site. It is assumed that the pollution indices were reduced by the diffusion due to stream and the purification function of microorganisms living in the soil, which decompose easily decomposable substances.

b. Existing dumping site

Fig. 5.4.16 shows the results of the water quality test on the water of wells in the environs of the existing dumping site, and on the standing water composed of waste water downstream of the reclaimed site. However, no effect appears as of yet in the well of W_3 downstream of the reclaimed site because the ground water level at this point is lower than the base of the reclaimed land and the permeability of the soil at this point is low, as has already been mentioned.

The color of W_3 is high, 40 mg/ℓ; however, this is because the water has become turbid in white resulting from a mixture of silty content without any effect from the leachate from the solid waste dumping site.

Fig. 5.4.16 Water Quality of Wells near Existing Dumping Site



Item	Unit	W_1	W_2	W_3
pH	-	6.45	8.8	5.9
Color (as Pt unit)	mg/ℓ	10	250	40
BOD_5	mg/ℓ	0.5	62.0	0.8
COD	mg/ℓ	8.0	256.0	8.0
NH_3-N	mg N/ℓ	0	2.2	0
NO_3-N	mg N/ℓ	0.1	0	0.1
Kjeldahl-N	mg N/ℓ	0.3	18.2	0.6
Chlorides	mg/ℓ	105.0	145.0	40.0
Fe	mg/ℓ	0.05	-	0.45
Mn	mg/ℓ	trace	-	0.3

(7) Determination of the most pertinent site for landfill

The proposed five sites A to E have been subjected to geological and hydrogeological investigations and the water of the wells in the former and existing sites has been analysed. In view of the results of such investigations and analysis, it is desirable that the site for the landfill be one where the base of the landfill is higher than the groundwater table and where the permeability of the ground is low.

The geographical, geological and hydrogeological conditions of the proposed sites are shown in Table 5.4.12.

Table 5.4.12 Table of Geographical and Geological Conditons

Location		A	B	C	D	E
Topography	Topography	Terrace	Terrace	Terrace	Terrace	Alluvial plain
	Humidity of surface	Dry	Dry	Dry	Dry	Wet
	Botany	Grassy	Tapioca grassy	Tapioca grassy	Tapioca grassy	Paddy field
Geology		Sandy clay	Sandy clay	Clayey sand	Clayey sand	Clayey sand
Hydrogeology	Distance between the base of landfill and water table *1	3m	3m	3m	1m	-4.2m
	Permeability	5.5×10^{-4} cm/sec	5.5×10^{-4} cm/sec	1.3×10^{-4} cm/sec	5.0×10^{-2} cm/sec	1.0×10^{-2} cm/sec
	Slope of water table	1/100	1/100	1/100	1/100	1/200
	Velocity of ground water flow	0.095m/d	0.095m/d	0.037m/d	4.32m/d	0.173m/d
Influence on Environment	Influence on existing wells	400m	200m	200m	200m	500m
	Influence on agriculture	None	None	None	None	Affectable
Soil Mechanics	Stability of slope	Stable	Stable	Stable	Stable	Unstable

Note: *1 The bottom level of the landfill is supposed to be 5m below the ground level.

The following Table 5.4.13 shows the items to be duly considered in selecting the site for landfill other than the geological and hydrogeological conditions stated above.

Table 5.4.13 Comparative Table for Landfill

	Location	A	B	C	D	E
1	Distance from the center of collection	×	×	△	△	○
2	Access road from main road	×	△	△	△	△
3	Wind direction	○	○	○	△	△
4	Land cost	○	○	○	○	△
5	Surrounding condition	○	△	△	△	×
6	Geographical & geological condition	○	○	○	×	×
	Preferablity	for phase-2		for phase-1		

Remark : ○..... good △..... not so bad ×..... bad

From the results of the alternatives referred above, either of the sites A, B or C should be selected for the landfill site after evaluation of the system. Site C is considered to be the most preferable, because the influence on the wells in the neighbourhood of the site would be delayed and might appear only after a very long time indeed, and that there is a smaller number of dwelling houses downstream of the ground water flow.

A further important reason for selecting site C as the most suitable site is that the region including site C is enclosed within the Pataya Tourist Development Project and therefore is expected to be supplied with a water supply system in the near future. Consequently, even if a trifling influence on downstream wells were caused by the buried waste materials at a later time, it is expected that city water will be supplied for drinking water by that time.

Site B which is currently used by the Sanirary office will end its role by 1980 when the proposed system will start operations.

Site A is recommended for the site in phase-2, if its planning and implementation are studied considering to the following points:

- to improve current situation of access way approaching to the site to the extent of needs, and
- to check the hydrogeological influence to ground water flow and its quality caused by leachate.

(c) Landfill Method

1) Explanation of various landfill methods

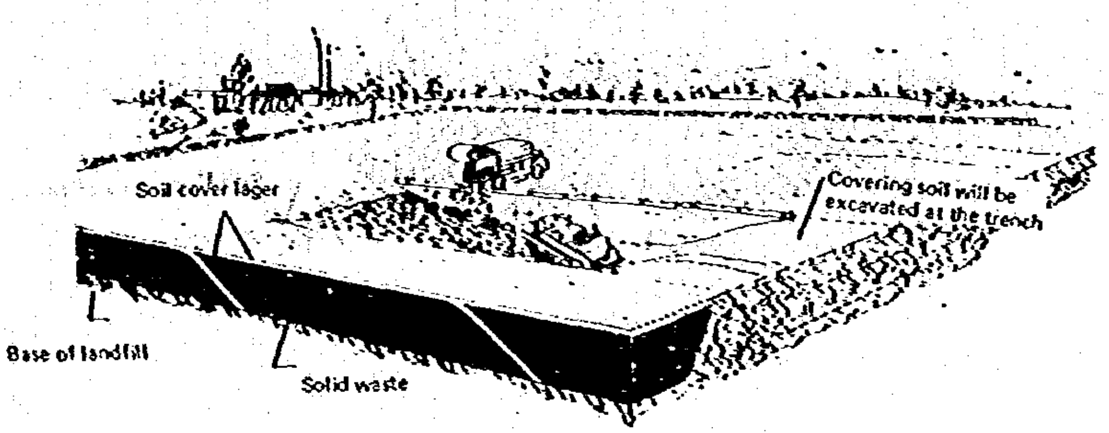
(1) Trench method

The Trench Method is a method of digging the ground in the manner shown in Fig. 5.4.17 to form a trench in which the waste materials are buried.

This system may be sorted into two distinct methods. In the first method, the soil and sand obtained by digging the ground behind the trench is used as the covering soil. While in the second method, another trench is formed adjacent to the trench for dumping the waste materials to obtain soil and sand usable as covering materials.

The Trench Method is normally employed on plains or gentle slopes with a surface soil thickness of more than 2 meters and where the ground water table is positioned at a low level.

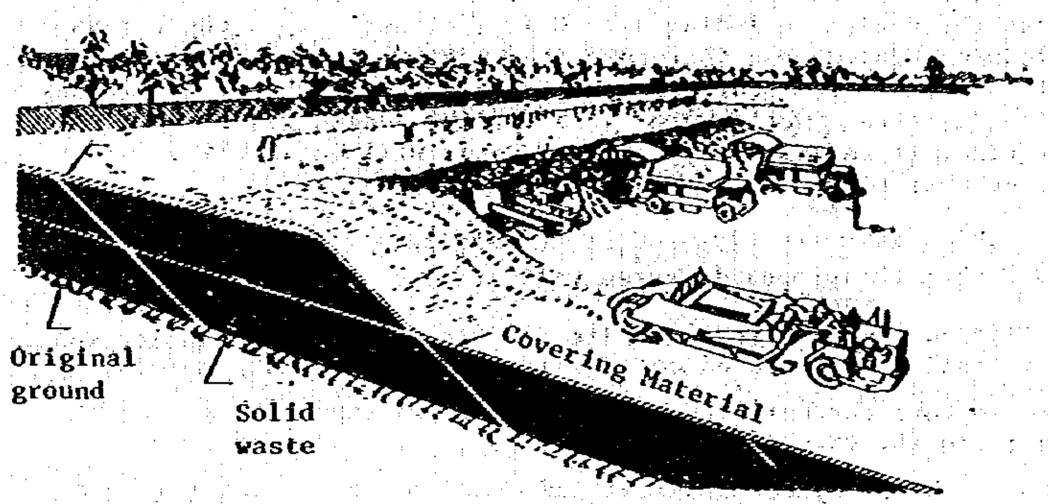
Fig. 5.4.17 Trench Method (5-3)



(2) Area Method

The method for this system involves roll-filling the solid waste with a bulldozer, or the like, and then covering the same with covering soil, followed by compaction. This method is most conveniently employed on flat ground and is frequently applied for large-scale landfill projects.

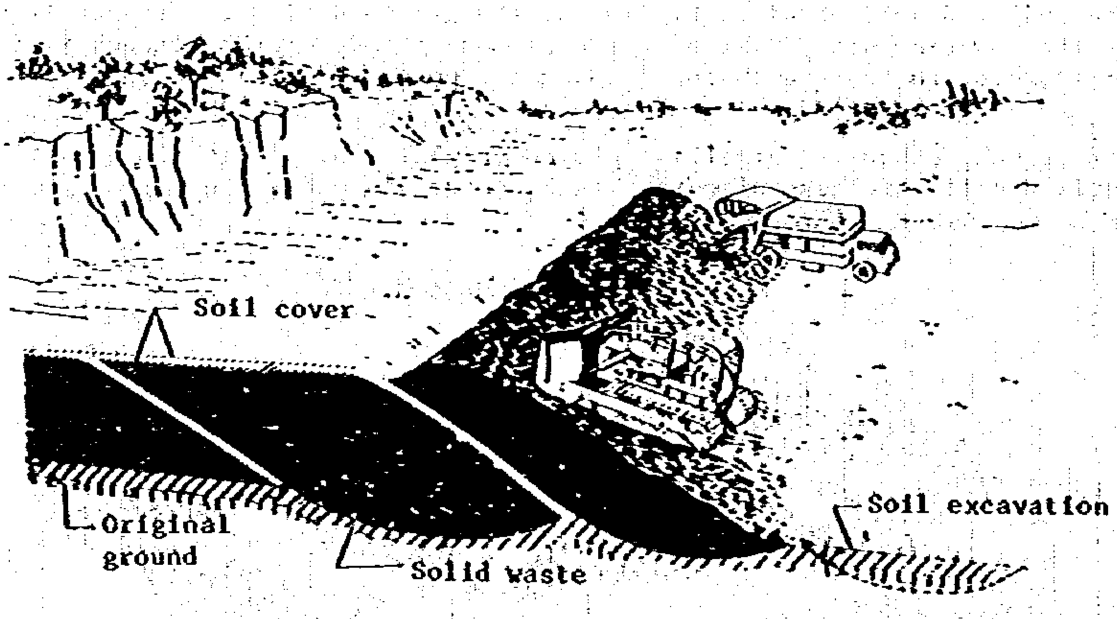
Fig. 5.4.18 Area Method[5-3]



(3) Ramp Method

This system is a combination of the Trench Method and the Area Method, wherein the waste materials are spread over the slope on which the covering soil is laid. This system is also conveniently employed on large scale landfill projects.

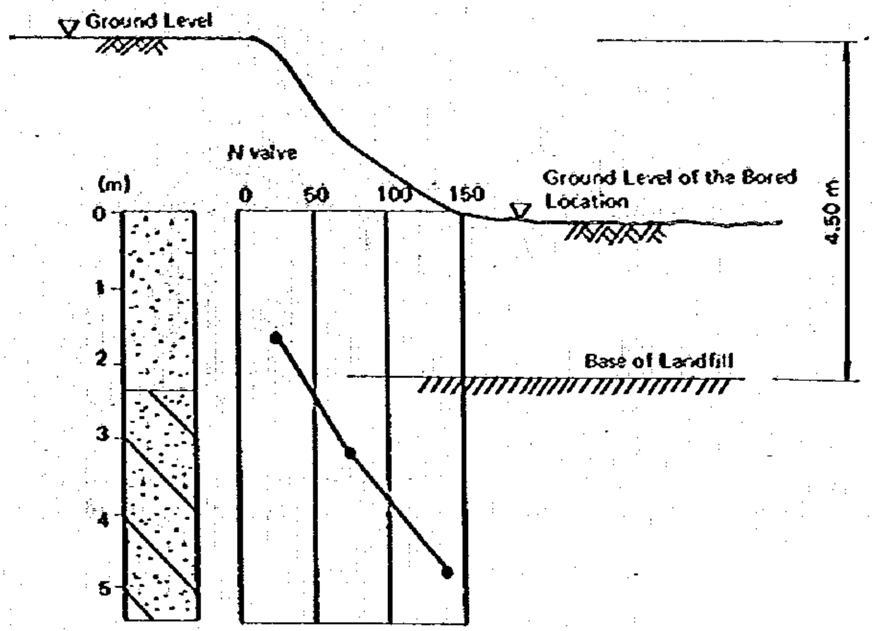
Fig. 5.4.19 Ramp Method[5-3]



2) Determination of the landfill method

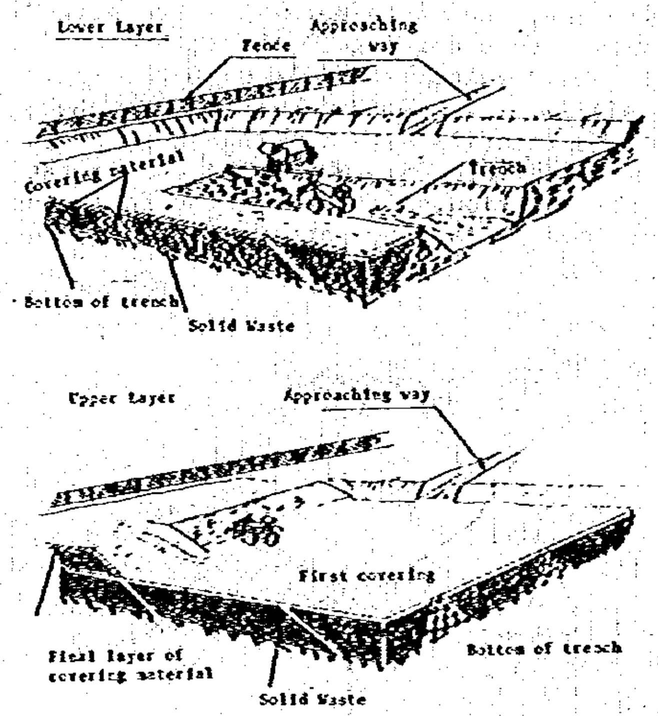
In the current project, the waste materials are buried under flat ground on a terrace-shaped site according to the method of digging the ground and covering the buried waste materials with the residual soil. In order to reduce the landfill area and the amount of leachate, the depth of the ground dug up in the landfill site is planned to be as deep as possible, and has been determined to be 4.5 meters in consideration of the boring test results at the location, as shown in the following Fig. 5.4.20. Based on the this determined depth, the method of landfilling has been discussed as above.

Fig. 5.4.20 Determination of the Depth of Landfill



While having determined the depth of the landfill to be 4.5 meters, it is recommended that the preferable landfill system applicable to this landfill site be a sanitary landfill system wherein the Trench system and the Area system are used in combination. It can be said that the full-scale trench system is disadvantageous in those lost portions, each being generally triangular in cross section are formed at both sides of the trench. Besides, it is difficult to dig out a 4.5 m depth trench in a single step from the standpoint of actual operations. In order to overcome the aforementioned disadvantages, it is recommended to adopt the system, as shown in Fig. 5.4.21, wherein the lower waste material layer is formed in accordance with the Trench system, whereas the upper waste material layer is formed in accordance with the Area system.

Fig. 5.4.21 Imaginary Figure for Landfill



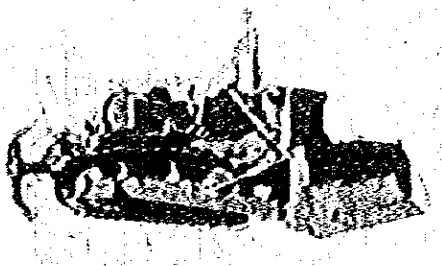
3) Machines for the landfill site

The machines listed in the following Table are generally used on landfill sites, and have respective merits and demerits when used for specified purposes.

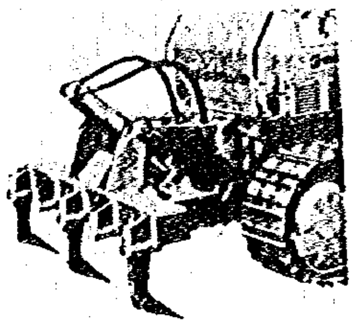
Table 5.4.14 Comparison of Machines for Different Purposes

Use / Machine	Waste		Covering		Soil & Sand		
	Levelling	Compaction	Digging	Levelling	Compaction	Loading	Transport
Crawlerdozer (Bulldozer)	◎	○	◎	◎	○	×	△
Crawler Loader	○	○	◎	○	○	○	△
Wheeldozer	◎	○	△	○	○	×	△
Wheel Loader	○	○	△	○	○	◎	○
Landfill Compaction	◎	◎	×	○	◎	×	△
Scraper	×	×	○	◎	×	×	◎
Dragline	×	×	◎	△	×	△	△

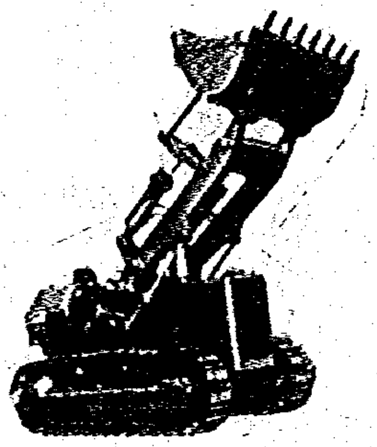
Remarks: ◎ Excellent ○ Good △ Acceptable × Not Acceptable



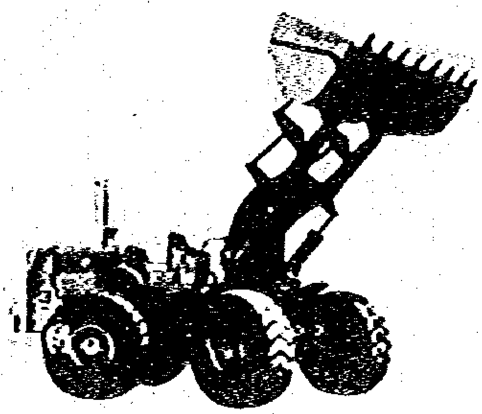
Crawlerdozer (Bulldozer)



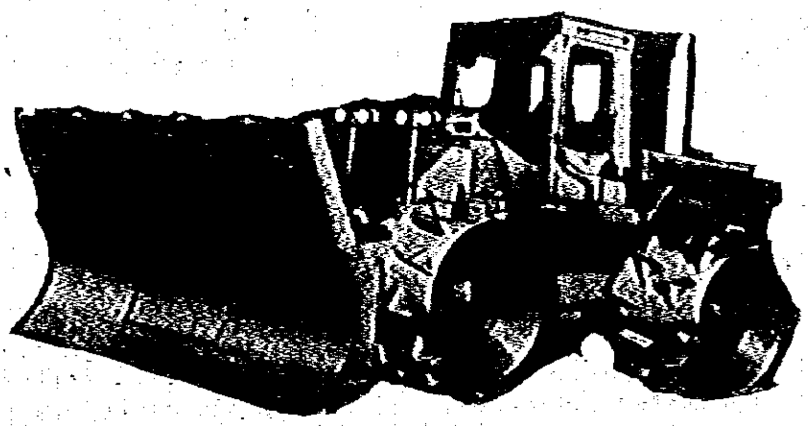
With Ripper



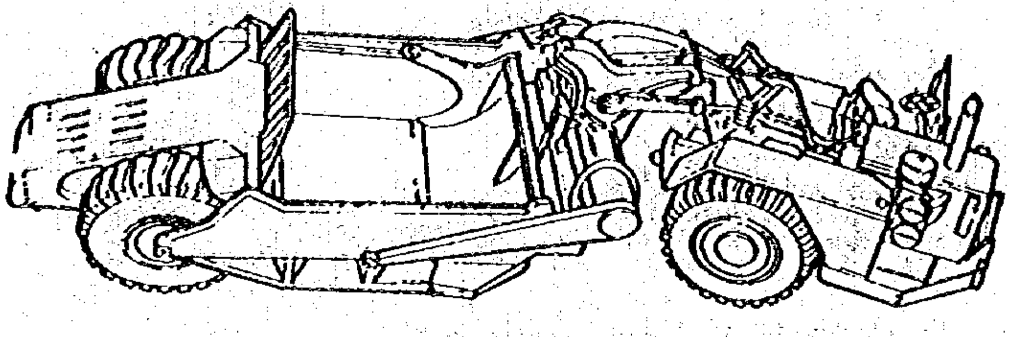
Crawler Loader



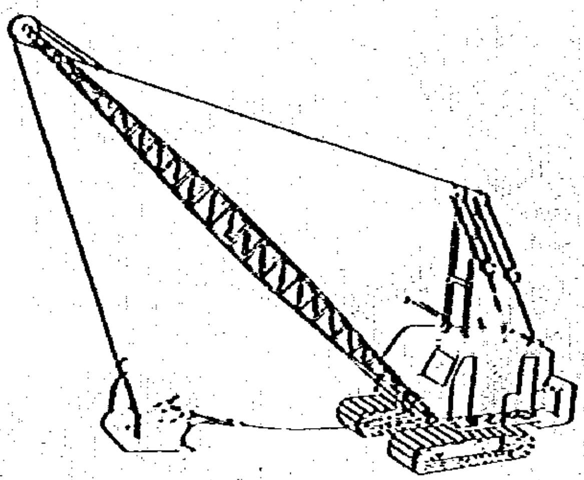
Wheel Loader



Land-fill Compactor



Scraper



Dragline

Three of the machines listed in Table 5.4.14 would be used in the proposed dumping site as follows.

- Landfill compactor:
  The most appropriate and convenient machine for levelling and compacting.
- Crawlerdozer with a ripper:
  For digging, levelling and compacting the covering soil.
- Wheel loader:
  For moving the dug soil and for transporting the excess soil.

(d) Planning of the Landfill Disposal Site

1) Scheduled Solid Waste Quantity for Landfill

The quantities of solid waste to be buried in the landfill site for each coming year have already been estimated in paragraph 5.4.3 (g). It is empirically known from the municipal solid waste fill-in test conducted in Japan that the total volume of waste materials decreases by 45 to 50% when they are transported to a landfill site and roll-compacted by a landfill compactor. With this in mind the real volume of waste materials compacted according to the present project was estimated supposing that a 40% decrease in volume would be expected while making some allowances. The estimated volumes for each coming year are shown in Table 5.4.15

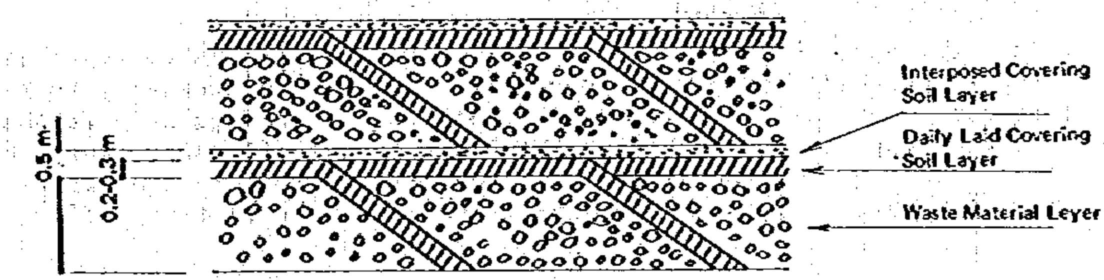
Table 5.4.15 Volume of Waste Materials to be Buried

Year	Volume of the Waste Brought to the Site		Real Filled-in Volume (m^3/Year) $V=V_Y$ (1-0.4)	Total Sum (m^3)
	Average Vol. per Day V_D (m^3/Day)	Total Vol. per Year V_Y (m^3/Year)		
1980	143.4	52,340	31,400	31,400
1981	157.6	57,530	34,520	65,920
1982	180.5	65,950	39,570	105,490
1983	202.6	73,950	44,370	149,860
1984	226.3	82,610	49,570	199,430
1985	251.5	91,800	55,080	254,510
1986	275.6	100,590	60,350	314,860

2) Scheduled Covering Soil Quantity

As shown in Fig. 5.4.21, the solid waste would be filled in two layers and a 50 cm thick covering soil layer interposed between the said two waste material layers. The thickness of the covering soil layer which shall be laid over the daily buried waste material every day in order to effectively make a sanitary landfill is proposed to be 20 to 30 cm for standard operations. Thus, the covering soil layers would be laid over the landfill site in the manner shown in Fig. 5.4.22. Consolidation of the covering procedure is determined with reference to the "Guide Lines for Waste Material Disposal Sites" prescribed by the Japanese Ministry of Health and Walfare.

Fig. 5.4.22 Typical Section of Fill - (1)



On the other hand, the total height of the filled-in layers is designed to be as shown in Fig. 5.4.23. Settlement of the filled-in layers should occur by about 20% due to consolidation and decomposition of the organic compounds contained in the solid waste after the completion of fill-in operations. The ground level of the landfill site after stabilization would become finally the same level the existing ground level.

In view of the above considerations, the required quantities of covering soil for each coming year have been estimated as shown in Table 5.4.16 together with total quantities of the waste materials to be buried and the covering soil.

Fig. 5.4.23 Typical Section of Fill - (2)

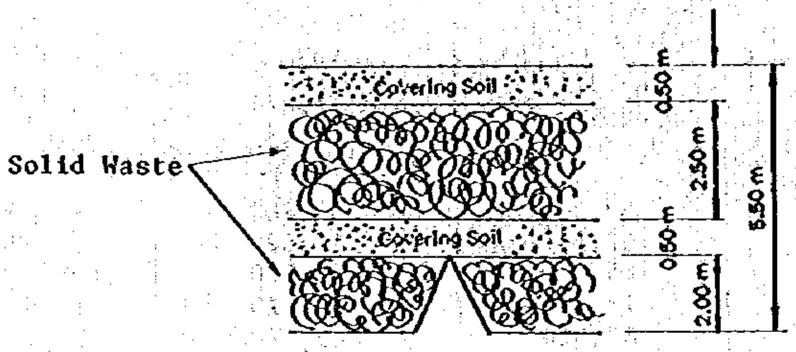


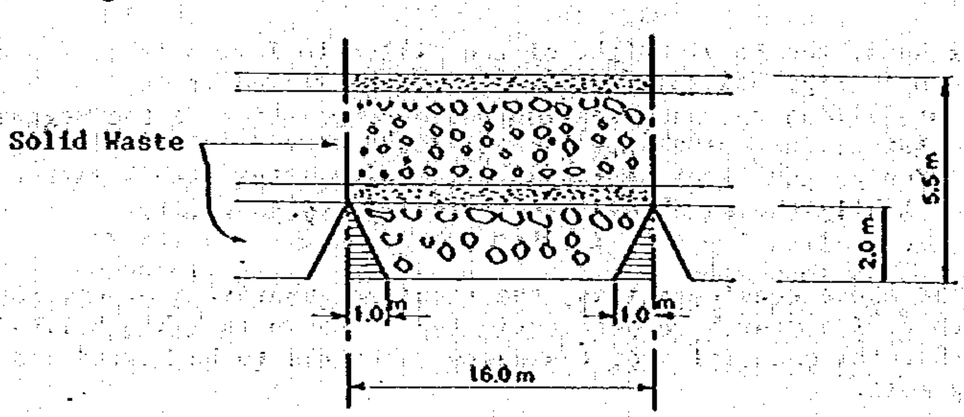
Table 5.4.16 Estimated Annual Volume of Covering Soil

Year	Real Filled-in Volume of the Waste Material (m^3/Year)	Volume of the Covering Soil (m^3/Year)	Total (m^3/Year)	Total Sum (m^3)
1980	31,400	15,370	46,770	46,770
1981	34,520	16,590	51,110	97,880
1982	39,570	18,850	58,420	156,300
1983	44,370	20,420	64,790	221,090
1984	49,570	22,340	71,910	293,000
1985	55,080	24,190	79,270	372,270
1986	60,350	25,940	86,290	458,560

3) Scheduled Landfill Area

In this paragraph, the required area for dumping is estimated together with the actual efficiency of land utilization. It is necessary to take into account such useless earth as the soil in the triangular portions between the respective trenches in the lower layers of waste. They should be added to the quantities of both the real filled-in volume of waste and the covering soils. Then the landfill site area must be estimated.

Fig. 5.4.24 Diagrammatical View of the Filled-in Layers



Let it be supposed that the average width of each trench is 16 m and that the tangential gradient of the slopes of the trench is 1 : 0.5, the ratio of the soil quantities occupying the triangular cross-sectional portions in terms of the total volume of filled-in waste and the covering soil will be obtained as follows:

Cross-sectional area of the waste & covering soil portion:

$a_1 = 5.5 \times 16 - 1/2 \times 1 \times 2 \times 2 = 86\ m^2$

Cross-sectional area of the triangular portion:

$a_2 = 1/2 \times 1 \times 2 \times 2 = 2\ m^2$

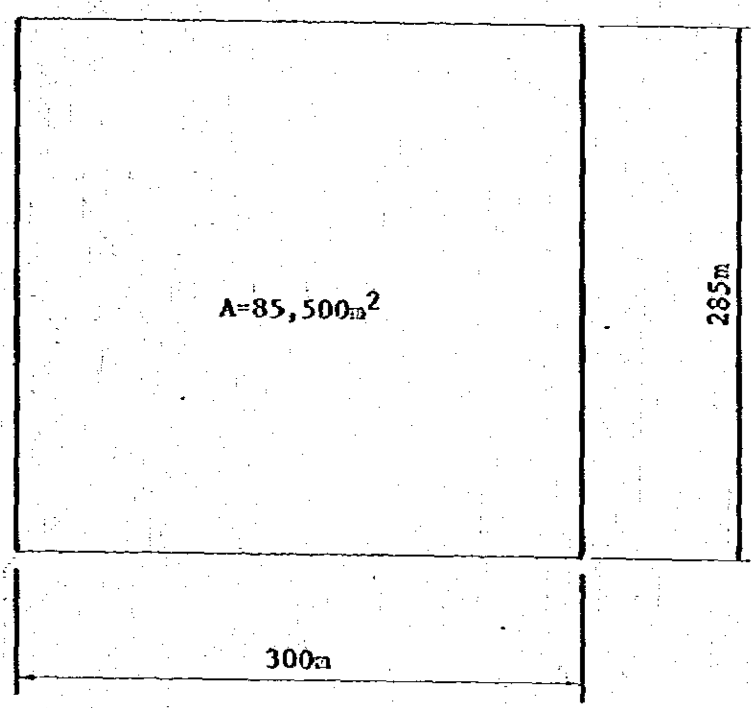
Ratio : $r = a_2/a_1 = 0.023$

Hence, the required area (A) of the landfill site would be:

$A = 458,560\ (1 + 0.023)/5.5 = 85,300\ m^2$

In view of the above, the plan of the landfill site would be designed to be 300 m x 285 m (=85,500 m^2).

Fig. 5.4.25 Diagram of the Shape of the Landfill Site

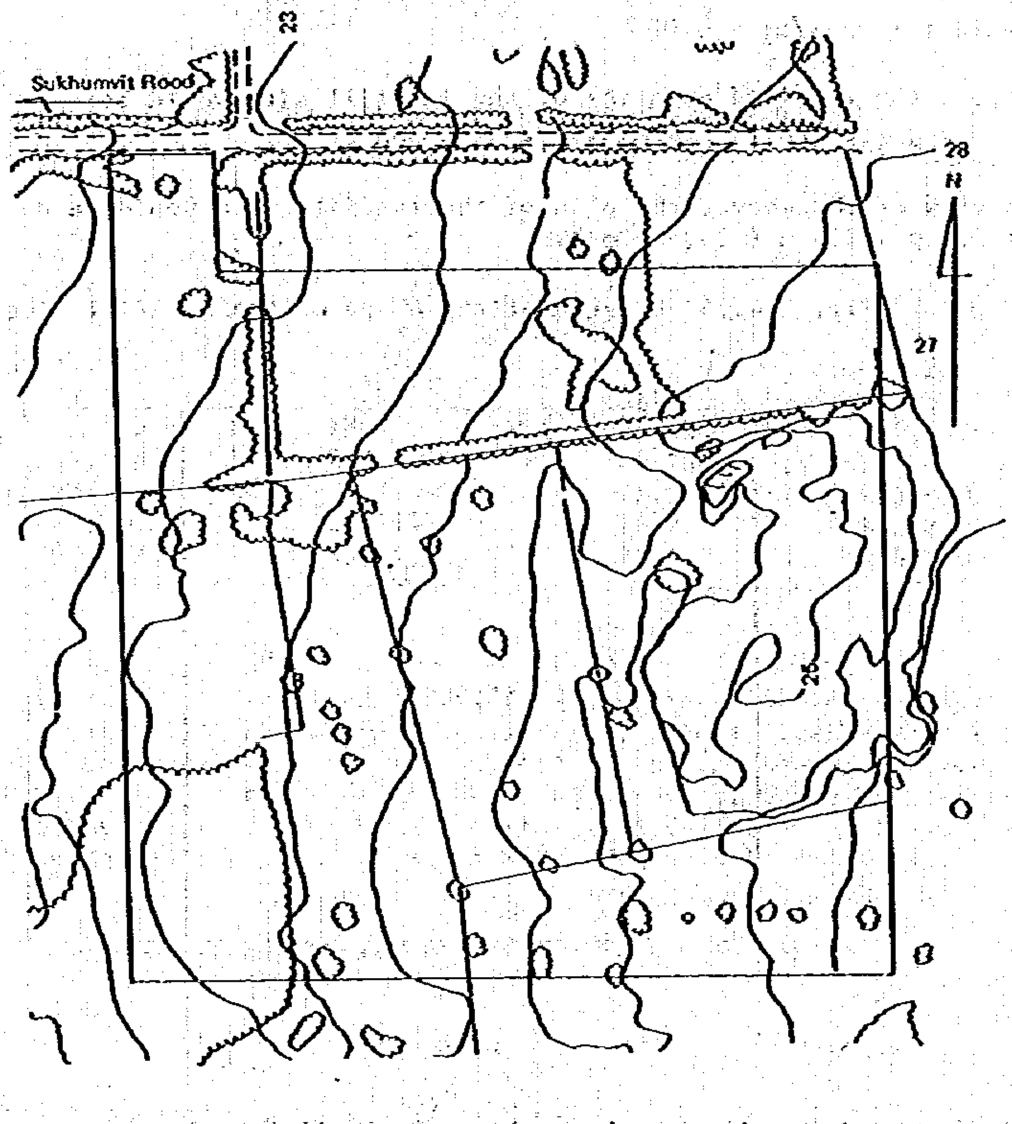


4) Estimation of the Quantity of Soil to be Excavated

(1) Landfill Procedure

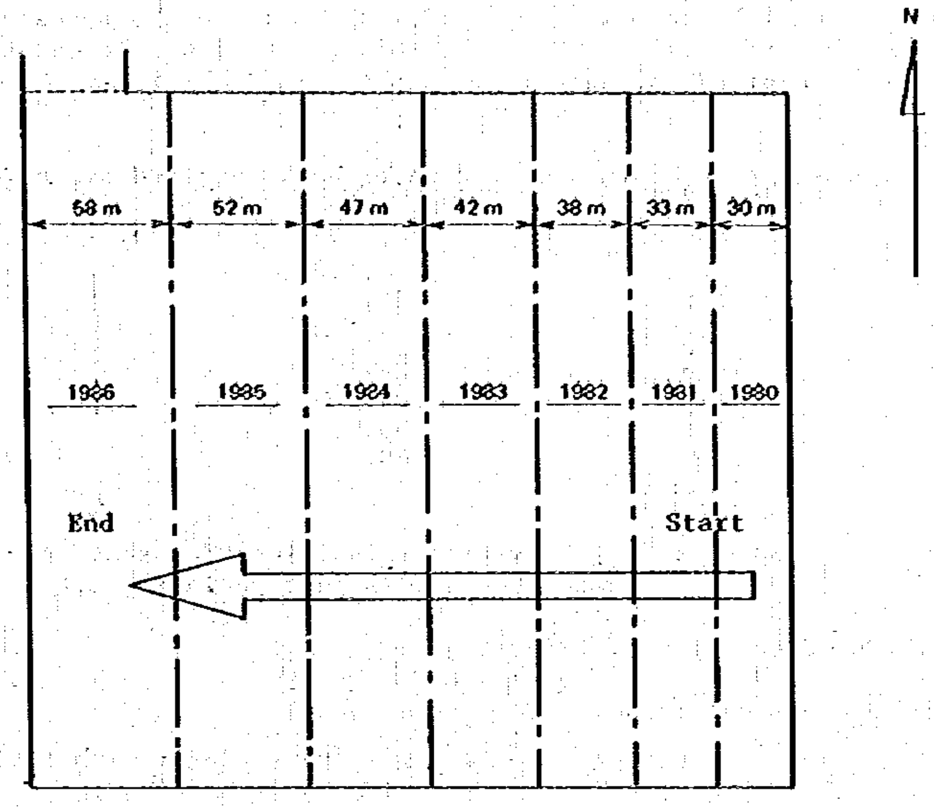
The landfill site would be constructed on the proposed site as illustrated by the following sketch plan, and the solid waste should be buried or filled-first at the east side of the site, gradually extending toward the west side every year.

Fig. 5.4.26 Sketch Plan of the Landfill Site



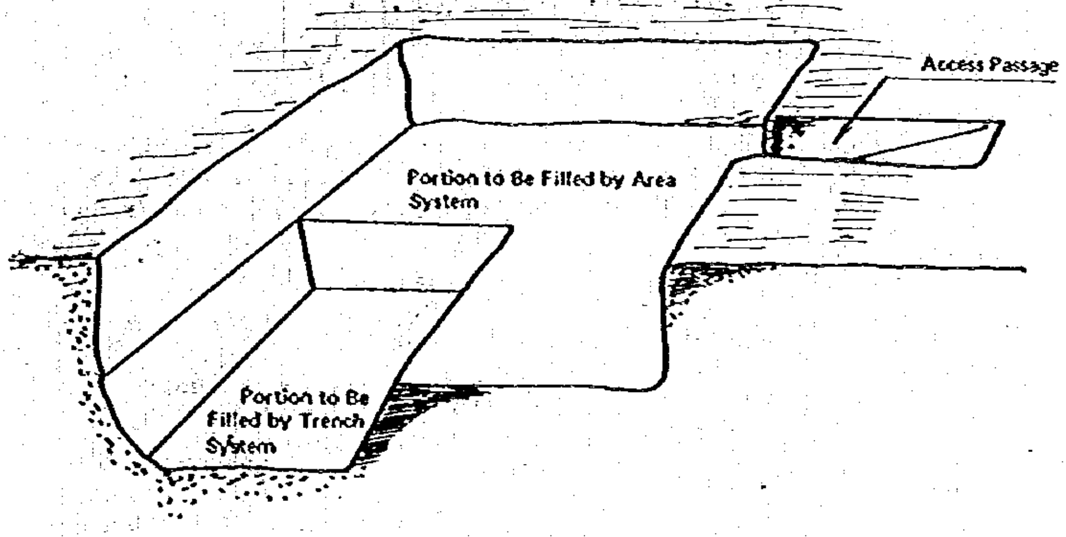
In the meantime, the required area to be filled-in each year corresponding to the volume of solid waste to be buried has been estimated as shown in Fig. 5.4.27. The proposed annual progress has been planned with a view to delay the influence on the ground water downstream caused by leachate as much as possible. And it is also intended to keep the rainwater flow which would flow into the filled-in solid waste layer during rainy days to a minimum.

Fig. 5.4.27 Expected Annual Progress



The landfill procedure will be carried out in the following manner. First, the upper portion of 2.5 m in depth from the existing ground, which is the portion to be filles-in by the Area Method, has to be excavated at the required area according to the annual projected volume. The lower portion, which is to be filled-in by the Trench Method, has to be excavated according to the monthly projected volume, as a general rule, in consideration of the landfill process procedure. Fig. 5.4.28 below is a rough sketch of the proposed progress of the landfill process.

Fig. 5.4.28 Rough Sketch of the Proposed Progress of the Landfill



(2) Quantity of the earth work

In accordance with the principal policies mentioned above, excavation plans for the site will be made. In this connection, the quantity of excavations required for each year is shown in Table 5.4.17 based on the volume of solid waste.

Table 5.4.17 Volume of the Earth Work Required Every Year

Year	Quantity of Excavation (m^3)
1980	25,800
1981	26,400
1982	39,000
1983	50,900
1984	56,200
1985	63,000
1986	68,000
Total	329,900

Note: : The excavation volume includes that required for forming the access passage in the site.

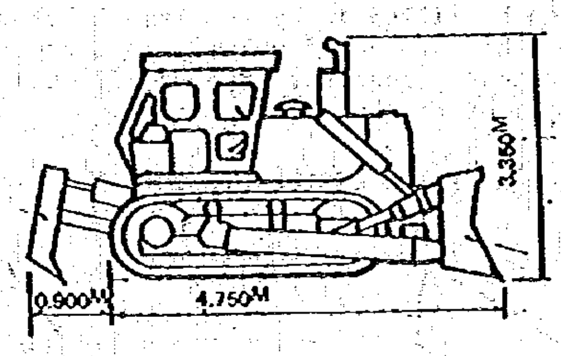
(3) Scheduled quantity of excavation

1) Operational capacity for earth work

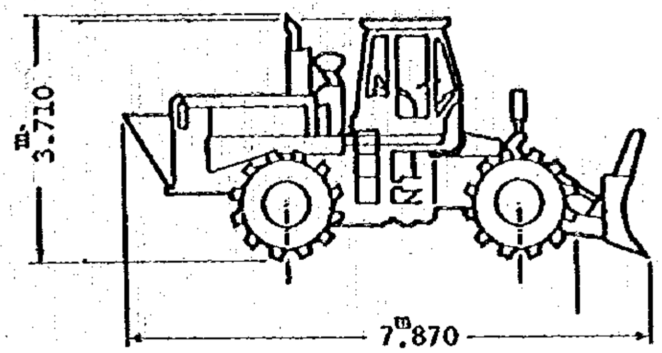
As mentioned in paragraph (c), 3), a crawlerdozer with a ripper, a landfill compactor and a wheel loader would be used in the landfill site.

a. Configuration of the machines

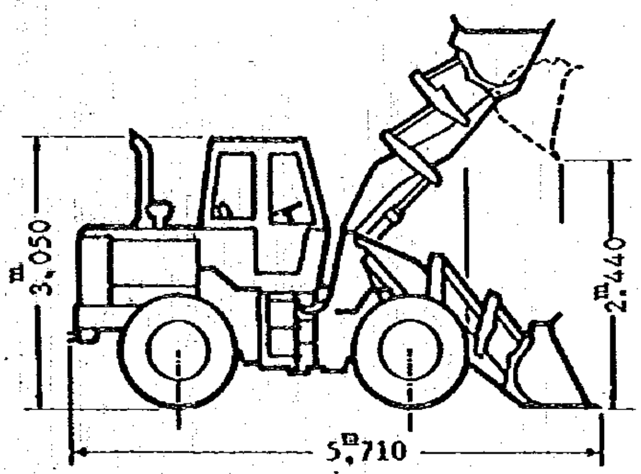
Figures Showing the Configurations of the Machines



Crawlerdozer



Wheel Loader



Landfill Compactor

b. Operational capacities per day of the machines

The operational capacities of the machines are estimated by referring to the "Guide Lines for Road Construction" issued by the Japan Road Association for crawlerdozers and wheel loaders, and by referring to the specifications presented by machine makers for estimating the capacity of the landfill compactor.

Assuming that the average real working time of each machine is 4 hours a day, the operational capacity per day of each machine is estimated and shown in Table 5.4.18.

Table 5.4.18 Operational Capacity per Day

Machine	Operational Capacity per Hour (m^3)	Working Time per Day (hr.)	Operational Capacity per Day (m^3)
Crawlerdozer	49	4	196
Wheel Loader	59	4	236
Landfill Compactor	182	4	728

Table 5.4.19 Table of the Working Schedule

Year	Operation Item \ Month	1	2	3	4	5	6	7	8	9	10	11	12
1980	Access Road	10											
	Office	20											
	Motor Pool	20											
	Fence & Gate	60											
	Fence & U-Shaped Groove Forming Operation	40											
	Upper Portion Digging-out Operation	14	14	14	9*							45	
	Lower Portion Digging-out Operation	16	16	16	16	23							17
1981	Upper Portion Digging-out Operation										98		
	Lower Portion Digging-out Operation	17	17	17	17	7							19
1982	Upper Portion Digging-out Operation									147			
	Lower Portion Digging-out Operation	19	19	19	19	8							22
1983	Upper Portion Digging-out Operation									159			
	Lower Portion Digging-out Operation	22	22	22	22	9							24
1984	Upper Portion Digging-out Operation									180			
	Lower Portion Digging-out Operation	24	24	24	24	10							27
1985	Upper Portion Digging-out Operation								191				
	Lower Portion Digging-out Operation	27	27	27	27	11							30
1986	Upper Portion Digging-out Operation												
	Lower Portion Digging-out Operation	30	30	30	30	12	12						

Remark * Duration in days

II) Working schedule

Supposing that the construction and preparation of the landfill site would start from January of 1980, Table 5.4.19 is drawn up in view of the operational capacity of the crawlerdozer.

III) Scheduled quantity of excavation

If the landfill procedure is carried out in accordance with the time schedule shown in Table 5.4.19, the actual quantities of excavated earth every year will reach the volume set forth in the following Table 5.4.20.

While excavated soil is to be used as a covering material, the volume of excess soil to be transported out of the site would be as shown in Table 5.4.20.

Table 5.4.20 Volume of the Excavated Soil and the Excess Soil

Year	Volume of Excavation (m^3)	Volume of Excavation Soil After Loosening (m^3)	Volume of the Required Covering Soil in the Loosened Condition (m^3)	Volume of the Excess Soil to be Hauled (m^3)
1980	37,800	47,300	21,800	25,500
1981	37,100	46,400	23,600	22,800
1982	49,100	61,400	26,800	34,600
1983	53,800	67,300	29,000	38,300
1984	60,700	75,900	31,700	44,200
1985	65,800	82,300	34,400	47,900-4,900*2 =43,000
1986	25,500	31,900	36,800	0
	329,800	412,500	204,100	208,400

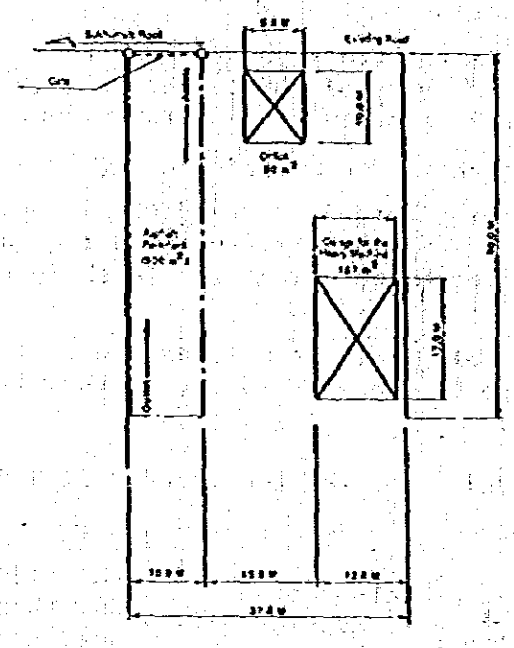
Remarks: *1 The ratio of increase in volume after loosening is estimated to be 25%.

*2 This soil will be stored within the landfill site and reused as the covering soil required in 1986.

5) Other Related Facilities

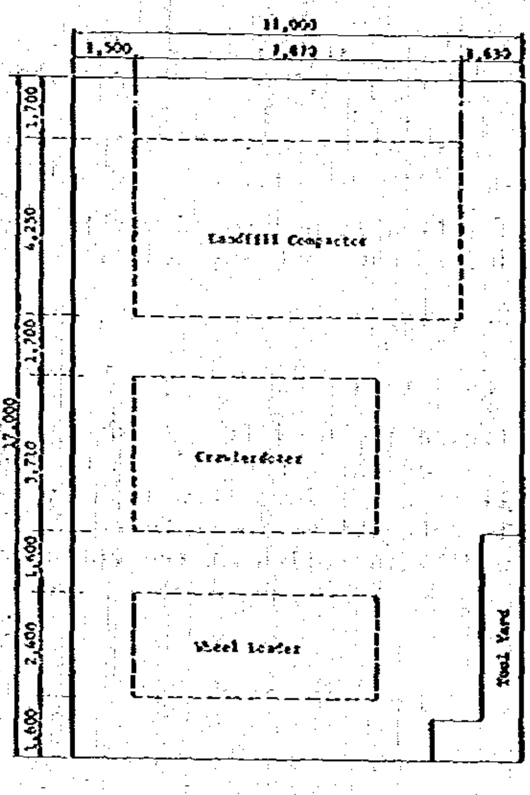
(1) Office, gate & access road

Within the landfill site, a field office would be constructed to manage checking and registration of the number of collection trucks entering the site, and to control the fill-in operations. An asphalt pavement road might be also arranged to enable collection trucks to come in and out conveniently, and a gate would be installed at the entrance.



(2) A garage for the machines

A garage would be provided containing three different kinds of landfill machines, as shown in the following figure.

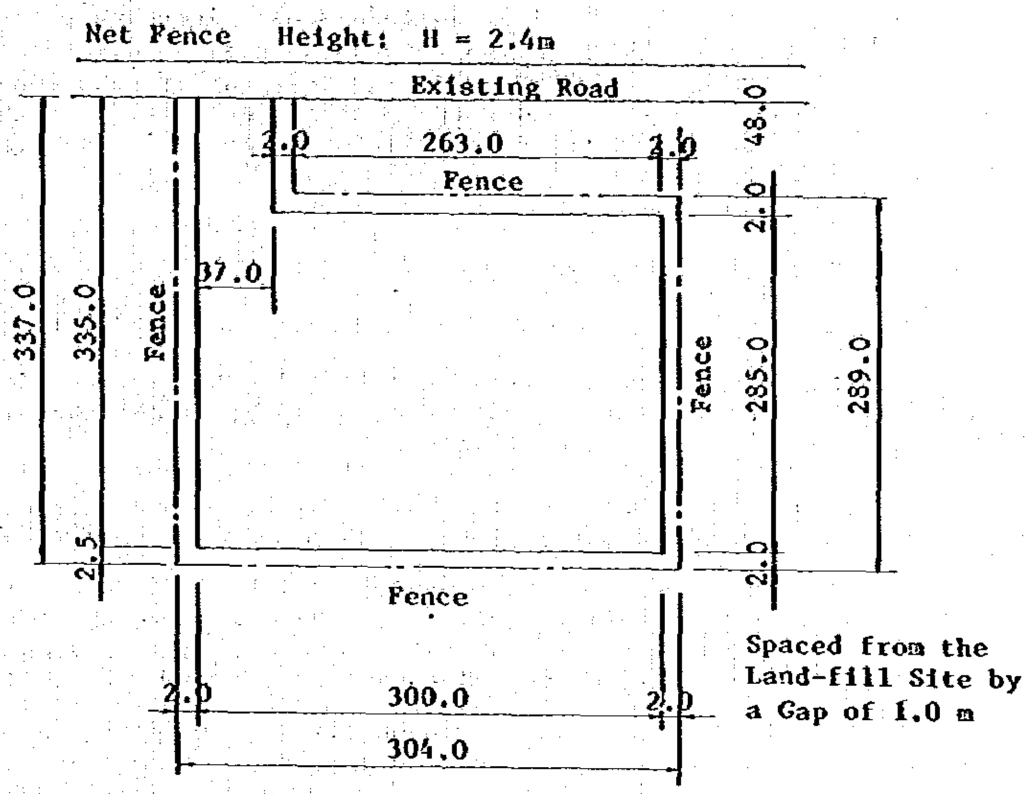


Garage Site Area : 187 m²

(3) Net-fence & side drain ditch

An enclosing net-fence of 2.4 m in height will be provided around the periphery of the landfill site in order to prevent light-weight waste materials from scattering outside the site and to protect the landfill site from being trespassed by outsiders.

A 0.5 m x 0.5 m side drain ditch (Length: 1 = 325 m) will be provided at the upstream side of the landfill site in order to prevent rainwater from flowing into the site.



Extension of the Net Fence:

337.0+304.0+389.0+365.0+48.0 = 1,243 m

(e) Land Use of Filled Land

It is necessary to study carefully the use of filled land during the planning stage of landfill construction. However, comparatively a long period would be required until the landfill area will be settled enough to become stable. A means to predict the degree of stability is to know how the settlement is progressing after the completion of the landfill.

Settlement of landfill area varies a lot according to the nature of solid wastes to be filled and the methods of landfill to be practiced. In case of the municipal solid waste landfill, it is said that the settlement occurs mostly within 1 to 2 years, the final volume of settlement being approximately 30% of the filled depth.(5-4) Also, the results of studies (5-5) in the U.S.A. indicate that in the first year approx.

15% of settlement was recorded second year approx. 6%, and approx. 3% for following 2-4 years. Finally the settlement reached approximately one third of the total depth of landfill.

Since the landfill operations in this plan will be carried out by the landfill compactor so as to be compacted effectively, the settlement of the landfill area is considered less than the amount said above.

Since the stability of the landfill area makes such slow progress and is continued for a long term as mentioned above, the plans on using filled land must be made with these points taking into consideration.

Accordingly, in the land use plans in this scheme it seems preferable to use the filled land for public purposes such as natural park, athletic fields, heli-port, etc. where large areas are required, rather than constructing heavy structures, when we consider the problems of settlement and the leakage of methane gas produced in the decomposition process of the organic matters in solid waste.

5.4.5 Plan for Collecting System

(a) Introduction

Upon full consideration of the current collecting system, the collecting method for solid waste in the study area should be established in accordance with the following basic policies.

- A schedule is planned for the Daily Maximum Amount discharged within the whole project area.
- In planning the collecting system, special emphasis should be placed in alleviating existing problems while respecting the current system; thereby, a review should be made of the system to ensure efficient collection of solid waste generated from various places daily.
- Sufficient consideration should be given to reduction of the heavy manual labour by collection workers to ensure easier and safe working conditions.
- Current methods should be applied as much as possible as regards collecting, time-schedule and frequency, etc.

Based on the above ideas, the solid waste collecting system in the project area is planned as follows:

(b) Comparative Review of the System of Collection and Transportation

In general, the collection of solid waste might mean both collection and transportation. Various collecting systems have been devised, planned and performed in various cities around the world. The adoption of the best suitable system should be decided upon full understanding of the various conditions in each region.

The railway system and the barge system might be out of consideration because the study area is relatively narrow, being 15 km long north-to-south and 3 km wide east-to-west. Also, the proposed landfill site is so close to the center of the solid waste generating area. The average distance between the site and generating area is estimated to be about 7 km.

The pipe-line system is expected to be applied to high density areas, such as high-rise areas; however, this system would not provide the study area with any advantages. If this system were to be used for Pattaya beach, which is 1.5 km^2 with a high population density and most of the major hotels already built, the scale of the system would be as follows.

Table 5.4.21 Pipe-line System

Item	Scale and Size
System	Transporting by pipe-line
Area to be covered	about 1.5 sq. km.
Kind of area	Tourism industry
Length of pipe-line	approx. 10 km
Number of gathering stations	1
Construction cost, up to 1986	150 million Baht
Maintenance cost, up to 1986	15 million Baht a year

As far as tourist demand forecasts and land use in the Masterplan, is concerned, this system would not be practically justifiable.

Collection and transportation by trucks would be the best system for solid waste in the study area.

(c) Collection and Transportation with Trucks

The vehicles or means for collection would be as follows:

① Loading and unloading by manpower with cargo-trucks

② Loading with manpower and transporting with dump-cars

③ Man-power loading with mechanical collecting cars having consolidating and dumping equipment

④ Automatic loading and unloading with mechanical collecting cars having consolidating and dumping equipment

Historically, development has been made from ① to ④.
While a review will be made of these vehicles later, generally, the following transportation-systems can be considered:

ⓐ Using the same vehicles from collection to discharge

ⓑ Each exclusive car to be used for collection and transportation respectively, while performing loading and unloading at the transfer-station

The above method ⓐ would be suitable for the study area, judging from the distance up to the landfill site and the generating quantity of solid waste. Moreover, as listed in Table 5.4.22, higher efficiency can be obtained with bigger vehicles, whereas the larger vehicles are inferior in movability.

Table 5.4.22 Loading Capacity of Vehicles

Chassis	Dump track	Mechanical collecting cars
2 ton class	2- 4 m^3	4 m^3
4 ton class	4- 8 m^3	6- 8 m^3
6 ton class	6-15 m^3	10-16 m^3

Medium-sized vehicles in the 4-ton class would be recommended because of their rather favorable transport efficiency and their higher mobility, making them the most suitable vehicles in size for the study area considering the quantity of solid waste generated and the condition of the roads.

(d) Type of Vehicle and Loading System

In the current collecting system, it has been decided to use the station-system of distributing drums to appropriate places in the town. This system can be effective, thus, it should be adopted even for the study area. However, other containers with bigger capacities should be employed for places where a great deal of solid waste is generated at one site, like a hotel.
On the other hand, concerning the collecting type of vehicle and loading system of solid waste, the current dump trucks with covers can be operated easily with less disorder, thus maintenance can be performed favorably. However, more workers are necessary for each vehicle, and hard labor is needed for their operation. Also, the loading time is longer than that of mechanical collecting cars, and collecting efficiency is low.

Therefore, for collecting vehicles in the future, mechanically equipped cars are recommended for collecting solid waste with less hard labor for loading, and easier and safer operations.

Fig. 5.4.29 shows the review of alternatives for the system and type of mechanical collecting cars considered in the case of adoption of station-collecting system using containers. Each system has its merits and demerits, while in this project, Method I, being similar to the current system, will be mainly adopted. To shorten collection time and to reduce the number of collection workers, the auto-loading system should be adopted using containers with a capacity of 1.5m^3 for hotels.

From the above evaluation, the type of vehicle to be used for this collecting system should generally be mechanical collecting cars with push and loading equipment.

Also, as regards existing dump trucks, those capable of lasting fully or partially through the project period should be considered effective collecting cars.

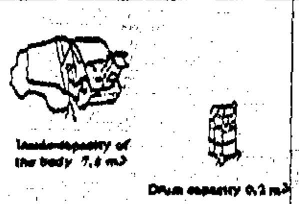
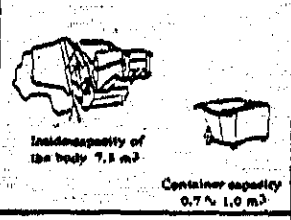
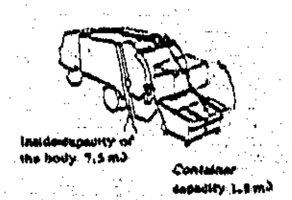
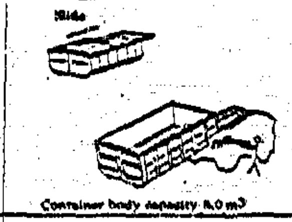
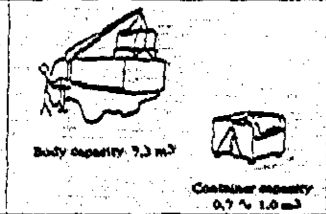
The existence of new two dump trucks would give the system flexibility, because many mechanical collecting cars could be used for a variety of collecting functions. In this case, the loading system might be conventional transference from drums to bamboobaskets first, followed by loading onto dump-trucks.

(e) Establishment of Collecting Pattern

The number of vehicles needed for collection each year can be estimated by establishing the collecting pattern of various vehicles after deciding the collection system.

A study of the collection pattern was made in accordance with the discharge frequency of solid waste and the road-situation in each region, and the work time and generation of solid waste in each subdivided area for the establishment of collection patterns.

Fig. 5.4.29 Container System for Collecting Solid Waste (Medium 4 Tons Grade)

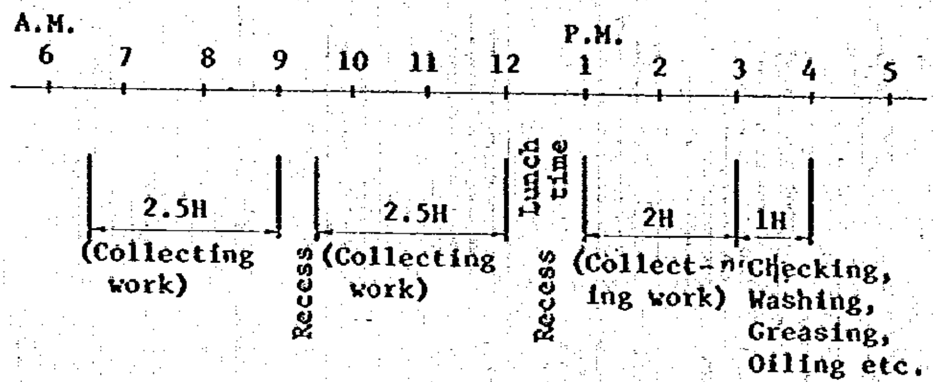
Name of System	System 1 Drum Reversing System	System 2 Small Container Reversing System	System 3 Big Container Reversing System	System 4 Containerloader	System 5 Cleaning Dump Car (track) with Crane
Rough Sketch	 Inside capacity of the body 7.4 m³ Drum capacity 0.2 m³	 Inside capacity of the body 7.5 m³ Container capacity 0.7 ~ 1.0 m³	 Inside capacity of the body 7.5 m³ Container capacity 1.5 m³	 Slide Container body capacity 8.0 m³	 Body capacity 7.3 m³ Container capacity 0.7 ~ 1.0 m³
Using Locality	General home solid waste. Restaurant, Pleasure ground, Zoo. General solid waste in factory. Industrial waste materials	General home solid waste. Department store, Supermarket, Station, Terminal, Park, Pleasure ground, Zoo, General solid waste in factory	Park, Pleasure ground, Zoo. Department store, Supermarket, Station, Terminal building, General solid waste in factory, Industrial waste materials, Public corporation's houses	Department store, Supermarket, Station, Terminal, Park, Pleasure ground, Zoo. General solid waste in factory, Industrial waste materials	General home solid waste. Department store, Supermarket, Outdoor works for public corporation's houses, Park, Pleasure ground, Zoo
Safety Stability	•It is stable because of no hanging.	•Like drum-reversing device, it is stable because of no hanging.	•Even big container is safe because of the support with hinge for throwing port like small container. •With the big size, it is not easily moved, thus no movement can be made for fun by children in their gathering site.	•Loading or unloading of container-body is safe because of direct raising from the earth instead of overhead lifting with crane.	•Outrigger is mounted for preventing the overturn at the time of lifting.
Hygienic Character	•A cover is necessary for drum to prevent the splash of garbage or or odor. •Drum is of water tight system, and there is no worry for leakage of sewage.	•The container itself has a cover for preventing the splash of garbage. •Low part of the container is of water-tight structure, thus there is no worry of leakage of sewage or bad odor.	•There is a cover for preventing the splash of garbage. •It is hygienic.	•Some containers have a cover which can be sliding, thus garbage-throwing can be done easily, thus it is hygienic.	•A sheet is necessary for preventing the splash of garbage during the operation of damp track.
Loading Efficiency	•The collecting car is able to collect massive garbage at one time with the powerful compressive and pushing strength. •Raw garbage 2,500 ~ 3,000 kg (average) can be collected.	•The loading amount is the same as that of System 1.	•Raw garbage 2,500 ~ 3,000 kg (average) can be collected. •Container-collecting system for big sized garbage (refuse) can be applicable.	•For the elevation of loading efficiency, it is necessary to mount a stationary compressive device with the cover on the body.	•Without compressive device (compressor), raw garbage 1,350 kg (average) can be loaded.
Operativity	•The reversing operation, is made being connected with the loading cycle of the collecting car, thus automatic loading can be made by hanging (mounting) the chain to the cart. •One man operation is possible.	•Similar to System 1, the reversing operation is connected with the loading cycle of the collecting car, thus automatic loading can be made by by hanging (mounting) the chain to the the cart. •One man-operation is possible.	•Operation is easy because of hydraulic reversing action of the container.	•A big body can be loaded or unloaded by one person.	•With bigger crane reach, operative range is wide. •Lifting can be made even if there is a height-difference over one meter between the level of road and site of the container.
Movability	•With the use of exclusive cart, drum can be easily moved.	•With the wheels in the container itself, it is easily moved with its small size, thus the space is not limited for parking the collecting car which can be operative even in a little space. •Indoor-operation is possible because of lower height for reversing operation.	•With the bigger size of the container, it should be made docking to a vehicle, and a space for receding is necessary. •At the time of discharge-running, similar movability to that of system 1, 2 can be obtained.	•One-touch operation is possible with the damping mechanism.	•In addition the case for lifting the container, big sized garbage or refuse can be collected in application of wire.
Economic Features	•It is economic because of the use of cheap drums instead of containers.	•With the mounting of cheaper reversing device, the combining use is possible with container-collection, thus it is economical as compared with the expensive exclusive car.	•Because of a big container, it is economical with less number of containers.	•Several or ten odd container-bodies can be used for one carrier, thus the efficiency of carrier is high. •At the place which is always discharged with garbage, one spare container body is necessary for one carrier.	•Even if the container is not of the same type, its lifting system is capable of collection, thus no selection is made for the use.

The basic year was set at 1981 for the establishment of collection patterns.

1) Collecting frequency and working hours

Collecting operations would be conducted every day in order to prevent confusion of changing from the conventional system; also because of the quicker putrefaction of solid waste due to the local climate with its higher atmospheric temperatures.

The working time would be 8 hours a day and the daily work should be done in accordance with the following time-chart



In the above 8 hours of operations, it is estimated that 6-7 hours would be spent on collection, transportation and dumping.

2) Collecting system in each block

The outline of the collecting system in the study area is as mentioned above. Here, a detailed explanation is made of the collecting system for each block subdivided in Fig. 5.4.30.

(1) Collection of the solid waste in residential area

The station-system would be employed, using 200 lit.-drums for residented areas (1) - (16) in Fig. 5.4.30. Collecting areas with mechanical collecting cars should be arranged with 200-lit. drums. Whereas effective use of collecting areas using dump-trucks and distributing 100-lit. drums should be done.

The station-system would be difficult to adopt in the residential area (17) because of the small population in relation to the collection area. Thus, in this block, collection would be made for each house, and each home would have hygienic and easily operative 30 lit.-buckets made of polyvinyl. Supposing that the population of the area is 500 on average and each home consists of 5 persons, a total of 100 buckets would be needed.

(2) Solid waste collection in hotels

The current method is performed at low efficiency, thus mechanization should be introduced as soon as possible. Most hotels have enough space to keep solid waste, thus it should not be difficult to provide $1.5m^3$ containers.