ASIAN WATER TECHNOLOGY CONFERENCE '85

5 - 7 November 1985

"CONFERENCE PAPERS"

PAPERS PRESENTED AT THE

ASIAN WATER TECHNOLOGY CONFERENCE

TUESDAY, 5TH NOVEMBER TO THURSDAY, 7TH NOVEMBER 1985

HELD AT THE

PUTRA WORLD TRADE CENTRE,

KUALA LUMPUR, MALAYSIA

ORGANISED BY:
INTERNATIONAL CONFERENCES AND EXHIBITIONS LTD.
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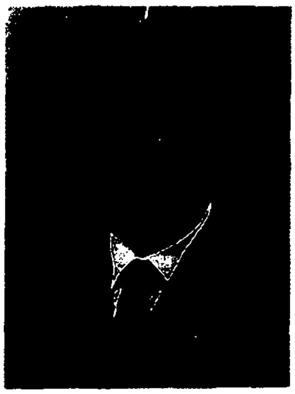
MESSAGE GIVEN BY THE HONOURABLE MINISTER OF WORKS MALAYSIA, DATO' S. SAMY VELLU, TO THE ASIAN WATER TECHNOLOGY CONFERENCE TO BE HELD ON 5TH - 7TH NOVEMBER, 1985 AT PUTRA WORLD TRADE CENTRE.



Water is basic to our needs. It always had been and always will be, but we can no longer take it for granted. It is fast becoming a precious commodity to be guarded and carefully preserved in quantity and quality. We must all look after it and one way of doing this is the dissemination of the latest in water technology at conferences and exhibitions.

I heartily congratulate the organizers for bringing together such a large number of manufacturers from no less than 16 countries around the world to exhibit such a large range of products of the latest technology. I am sure we will all benefit from this Exhibition and Conference.

The goal of the International Drinking Water Decade (1981-1990) is to provide safe water supply and sanitation for all by 1990. Although we are now half way through the Decade, I understand that many Asian countries are still very far from achieving this goal of 100% coverage by 1990. I hope that extra efforts will be made in the second half of the Decade to accelerate water supply and sanitation development in Asia.

As for Malaysia, since the Fourth 5 year National Development Plan (1981-1985), the Government has stepped up the pace of water supply development and allocated M$2053 million for water supply as compared to M$690 million in the Third Plan (1976-1980). Despite the economic recession, it is likely that more funds will be set aside for development in this sector.

I am pleased as Minister responsible for water supply that the first International Conference to be held in the newly completed Putra World Trade Centre focuses on water supply.

On behalf of the Ministry of Works, Malaysia, I wish the Exhibition and Conference every success and extend a warm welcome to exhibitors, visitors and conference delegates.

PERUTUSAN DARIPADA Y.B. MENTERI KERJA RAYA, MALAYSIA, DATO' S. SAMY VELLU SEMPENA PROGRAM CENDERAMATA UNTUK PERSIDANGAN TEKNOLOGI AIR ASIA DAN PAMIRAN YANG AKAN DIADAKAN PADA 5 HINGGA 7 NOVEMBER 1985 DI PUSAT DAGANGAN DUNIA PUTRA

Air adalah asas keperluan kita. Ianya adalah kenyataan dan akan tetap menjadi kenyataan, tetapi kita sudah tidak boleh mengambil ringan sahaja mengenainya. Ianya kini sedang pesat menjadi satu komoditi yang berharga dan perlu dilindungi serta dijaga dengan rapi dari segi jumlah dan mutunya. Kita mestilah menjaganya dan salah satu cara ialah dengan menyiarkan perkembangan terakhir mengenai teknologi air dalam persidangan ataupun pamiran.

Dengan sepenuh hati saya mengucapkan tahniah kepada pihak penganjur yang telah berjaya mengumpulkan sebilangan besar pengeluar-pengeluar tidak kurang dari 16 negara-negara di seluruh dunia untuk mempamirkan berbagai-bagai keluaran teknologi terbaru. Saya percaya kita semua akan mendapat menafaat dari pamiran dan persidangan ini.

Matalamat "International Drinking Water Decade (1981-1990)" ialah untuk membekalkan air yang selamat serta kesihatan untuk semua menjelang tahun 1990. Walaupun kita baru saja separuh jalan menempuh abad ini, saya percaya banyak negara-negara Asia yang masih jauh lagi untuk mencapai matalamat 100% menjelang tahun 1990. Saya berharap usaha-usaha tambahan akan dijalankan di separuh penggal kedua abad ini untuk mempercepatkan lagi perkembangan bekalan air dan kesihatan di Asia.

Bagi Malaysia, sejak tahun keempat dalam 5 tahun Rancangan Pembangunan Negara (1981-1985), Kerajaan telah mempercepatkan langkah perkembangan bekalan air dan memperuntukkan $2053 juta bagi bekalan air berbanding dengan $690 juta dalam Rancangan Malaysia Ketiga (1976-1980). Walaupun dalam keadaan kesempitan ekonomi, adalah dijangka banyak lagi peruntukkan akan diketepikan untuk perkembangan dalam sektor ini.

Sebagai Menteri yang bertanggungjawab bagi bekalan air, saya berpuas hati kerana Persidangan Antarabangsa yang pertama akan diadakan di Pusat Dagangan Dunia Putra yang baru disiapkan ini, yang menumpukan kepada soal bekalan air.

Bagi pihak Kementerian Kerja Raya Malaysia, saya mengucapkan kejayaan kepada pamiran dan persidangan ini serta mengalu-alukan kedatangan peserta-peserta pamiran, pengunjung-pengunjung dan perwakilan-perwakilan persidangan ini.

ASIAN WATER TECHNOLOGY CONFERENCE '85
PUTRA WORLD TRADE CENTRE - KUALA LUMPUR, MALAYSIA.

DAY ONE - 5TH NOVEMBER, 1985.

0900 hrs	Formal Inauguration/Welcome Address - Dato' S. Samy Vellu, Minister for Works, Malaysia.
0930 hrs	Coffee
0945 hrs	SESSION CHAIRMAN: Datuk Talha Haji Mohd. Hashim
	PAPER 1 - WATER SUPPLY IN MALAYSIA. Ir. Chan Boon Teik, Director of Water Supplies, Public Works Dept., Kuala Lumpur, Malaysia.
	PAPER 2 - OPERATION AND MAINTENANCE Laurie Wild, Independent Consultant, U. Kingdom.
1100 hrs	Coffee
1115 hrs	PAPER 3 - WATER DISTRIBUTION OPERATIONS J. Gordon Devine, Water Research Centre, U. Kingdom.
	PAPER 4 - INFORMATION SUPPORT FOR TRANSFER OF WATER TECHNOLOGY IN ASIA S.G. Bhat, National Environmental Engineering Research Institute, India.
1300 hrs	Lunch
1400 hrs	SESSION CHAIRMAN: Ir. Chan Boon Teik
	PAPER 5 - MAINTENANCE FOR HIGH TECHNOLOGY AND LOW COST SYSTEMS John Pickford, Water and Waste Engineering for Developing Countries, Loughborough University, U. Kingdom.
	PAPER 6 - ASPECTS OF A MEDIUM-SCALE IRRIGATION PACKAGE PROJECT IN THAILAND J.R. Hennessy, J.H. Andrew; Sir Alexander Gibb & Partners, U. Kingdom.
1515 hrs	Tea
1530 hrs	PAPER 7 - DEEP TUBEWELL IRRIGATION IN NORTHERN BANGLADESH - A CASE STUDY Dr. Saleemul Huq, Associated Engineers & Drillers, Bangladesh.
	PAPER 8 - A RURAL IRRIGATION PROGRAMME IN INDONESIA Invited Speaker.
1700 hrs	Close of Session

Cont/d....

DAY TWO - 6TH NOVEMBER, 1985.

0930 hrs SESSION CHAIRMAN:
Mr. Cheong Chup Lim

PAPER 9 - THE INTERNATIONAL DRINKING WATER SUPPLY AND SANITATION DECADE
Mr. Yoon Yul Kim, United Nations Development Programme in Malaysia.

PAPER 10 - URBAN DRAINAGE AND SEWERAGE IN KUALA TERENGGANU, MALAYSIA.
Mr. A. Rashid Araffin, Bina Runding Sdn. Bhd., Malaysia & Bob Owens, John Taylor & Sons, U. Kingdom.

1100 hrs Coffee

1115 hrs PAPER 11 - DESIGN, CONSTRUCTION AND OPERATION OF WASTE STABILISATION PONDS AND THE RE-USE POTENTIAL OF THEIR EFFLUENTS
W.J. Maidment & P.A.R. Scott, Scott Wilson Kirkpatrick & Partners, U. Kingdom.

PAPER 12 - SEWAGE SLUDGE IN ASIAN METROPOLITAN AREAS - A WASTE OR RESOURCE?
A.J. Starmer, Balfour International, U. Kingdom and C.J. Osborne, Alamrunding Sdn. Bhd., Malaysia.

1300 hrs Lunch

1400 hrs SESSION CHAIRMAN:
Mr. John Pickford

PAPER 13 - THE APPLICATION OF MEMBRANE SEPARATIONS TECHNOLOGY FOR WATER EFFLUENT TREATMENT
Peter S. Cartwright, C International, U.S.A.

PAPER 14 - RODENT CONTROL IN SEWERS
Roger Harris & Norman Crane, Howard Humphreys & Partners, U. Kingdom.

1515 hrs Tea

1530 hrs PAPER 15 - THE APPLICATION OF THE OXYGEN ACTIVATED SLUDGE PROCESS FOR THE TREATMENT OF BREWERY WASTE WATERS
Abdul Manaf Ishak, Project Engineer, Bumi Watson, Msia.
K.H. Allum, Process Group Manager, Watson Hawksley, U. Kingdom.

PAPER 16 - REVIEW OF A SUCCESSFUL WATER SUPPLY PROGRAMME IN THE PHILIPPINES
Somnath Som P.E. Sheladia Associates Inc., Philippines.

1700 hrs Close of Session

DAY THREE - 7TH NOVEMBER, 1985.

A.M. Programme of visits to selected water and sewage installations in Kuala Lumpur environs.

PAPER 1

WATER SUPPLY IN MALAYSIA

BY

Ir. Chan Boon Teik
Director of Water Supplies
Public Works Department
Peninsular Malaysia

SYNOPSIS

Water supplies in Malaysia operated by the Government through the State Public Works Departments and Water Boards are satisfactory in terms of quantity and quality. The Malaysian Government has given priority to water supply development since five years ago. Water supply is likely to continue to enjoy priority in the Fifth Malaysia Plan (1986-1990). Water demand has grown almost ten-fold since 1959 although the population has not even doubled. Generally water supply development is keeping pace with demands estimated at 3250, 188 & 218 MLD for Peninsular Malaysia, Sabah and Sarawak respectively.

Development is mostly financed by way of Federal loans and loans from international lending agencies. Water tariffs which vary from state to state are generally considered low compared to other infrastructures. Most supplies are subsidised by the state governments. Water supply systems follow closely the British system including treatment processes.

A common feature of Malaysian Treatment plants is the lovo sedimentation tank, first introduced 25 years ago. Malaysia is faced with similar problems on water supply as those encountered by other developing countries and common among these are manpower shortage, inadequate training programmes, high unaccounted for water and problems associated with revenue collection.

1. GENERAL PROFILE OF WATER SUPPLY SECTOR IN MALAYSIA

This general profile covers the following topics:

- Malaysian objective
- Institutional framework
- Water production, distribution and coverage
- Water supply standard
- Water tariff
- Financing system

1.1 Objectives

The objective of the Malaysian Government is to provide safe water to all as soon as possible, taking into consideration physical and monetary constraints. This is in line with the

New Economic Policy which has the objective of upgrading the standard of living and promoting national unity by eradication of poverty and improving the level of health of the people.

Water supply has been given high priority especially in the last five years because of its importance as a basic need in life, as well as an essential infrastructural facility for development. This trend is likely to continue in the next five years. Water supply will continue to be developed to meet the growing demand both for domestic and industrial uses.

1.2 Institutional framework

Constitutionally the state governments are responsible both physically and financially for water supply. This includes the development, operation and maintenance of water supply systems. The states execute this responsibility through the state water supply authorities either in the form of water boards, State Public Works Departments or the State Water Supply Departments. Table 1 below shows the types of organisations responsible for water supply:

Table 1 - Types of Water Supply Authorities in the States

Type	Water Boards	State Water Supply Dept.	State Public Works Dept.	Federal P.W.D. H/Quarters
	Melaka	Negeri Sembilan	Johor	Federal Territory (Labuan)
	P. Pinang	Perak	Kedah	
	Sarawak (Kuching & Sibu only)	Selangor (Including Federal Territory of Kuala Lumpur	Kelantan	
			Pahang	
			Perlis	
			Sabah	
		Terengganu	Sarawak (except Kuching & Sibu)	

The water supplies branch of the Federal PWD, under the control of Director-General of Public Works, Peninsular Malaysia functions as a federal agency for providing technical consultation and assistance for all the state water supply authorities, except the States of Sabah and Sarawak, which function independently insofar as water supply is concerned.

It is also a co-ordinating agency for all water supply projects funded by the Federal Government, both in the form of loans or grants. It is also an implementing agency for water supply schemes of Federal Land Development Authority (FELDA) and for regional development authority projects in the states such as the Regional Development Schemes (South-East Pahang, South East Johor and Central Terengganu). All completed water supply schemes by Federal agencies are handed over free of charge to the states for operation and maintenance. The Water Supplies Branch of Federal PWD is also responsible for the development, operation and maintenance of water supply in the newly created Federal Territory (Labuan).

The Federal Ministry of National and Rural (MNRD) is responsible for approval of all rural water supply projects. Approved projects are implemented by the Water Boards/State Water Supply Departments/State Public Works Departments.

The Ministry of Health is involved in the drinking water quality surveillance in the country and some community water supply projects in the rural area.

The Chemistry Department is responsible for water sample analysis.

1.3. Water Production, Distribution and Coverage

Water supply coverage for Peninsular Malaysia is 75% in 1985. There e xist differences in coverage between regions of urban and rural areas. In 1985, water supply coverage is 93% in urban areas and 65% in rural areas. The overall coverage for Sabah and Sarawak is 54% and 46% respectively. Rural coverage in these two areas is 38% and 33% respectively.

Areas and communities not covered by public piped water supply systems still depend on natural sources such as streams, canals and shallow dug wells.

The yearly demand growth for water in Peninsular Malaysia both for domestic and industrial use, which used to be 6% per annum a few years ago, has now gone up to more than 10% per annum. Between 1959 and 1985, due to rapid development, increase in per capita consumption, increase in coverage and industrial expansion, water demand has increased 9 times although population in this intervening period has not even doubled.

The total water supply demand in Peninsular Malaysia presently is 3250 MLD which is 82% of the total production capacity of 3982 MLD from 260 Treatment plants throughout the peninsular. Table 2 overleaf shows the present treatment works capacity, the water demand and the length of water mains in service in the various States of Peninsular Malaysia.

Table 2 - Treatment Works Capacity, Water Demand and Pipe Length for 1985

State	Treatment Work Capacity (MLD)	Water Demand (MLD)	Length of Pipes in service Km(75mm dia & above)
Johor	634	398	5,600
Negeri Sembilan	223	131	2,830
Selangor	990	(1097)*	6,000
Perak	681	468	6,900
Kedah	237	(287)**	2,700
Perlis	22	12	440
Pahang	296	200	4,000
Terangganu	177	71	1,400
Kelantan	104	104	2,300
Melaka	232	140	1,900
Pulau Pinang	376	342	1,200
PENINSULAR MALAYSIA	3,982	3,250	35,270
Sabah	318	188	NA
Sarawak	339	218	NA

NOTE: * Treatment works capacity in the State of Selangor will be increased to 1535 mld after the completion of the Sungai Semenyih Scheme in 1986, which can meet the demand until 1989/1990.

** The treatment works capacity in Kedah will be increased to 490 mld after completion of several projects in 1986/1987.

1.4 Water Supply Standards

Generally water supply is available 24 hours a day and is fully treated. Water quality meets the World Health Organisation (WHO) International Standards for drinking water. In the majority of cases rural water supply is of the same standard as that of urban supplies. In general, water supplies for domestic and industrial uses are drawn from the same supply system and are of the same quality.

The pressure available in the main varies slightly from system to system. Generally day pressure available in most urban areas ranges from 12m to 18m (40 ft. to 60 ft.) and night pressure ranges from 18m to 24m (60 ft. to 80 ft.).

The average per capita consumption is 250 litres per day (55 gpd) for urban areas and 182 lpd (40 gpd) for rural areas. In Kuala Lumpur, per capita consumption is 280 lpd (62 gpd).

1.5 Water Tariff

All supplies except for fire fighting are metered and water consumed is charged according to the types of uses. Water rates vary from State to State. Domestic supplies are charged on block rates on an increasing scale. The present average rate for domestic supplies is about M$ 0.50 per m^3 (M$2.27 per 1,000 Imperial gallons). While that for commercial/industrial supplies is $0.88 per m^3 (M$4.00 per 1,000 gallons) charged at a flat rate in most states. Most of the States have revised the water rates during the 1983 - 1985 period. Although water rate is not uniform for all States, most States have adopted a uniform structure formula which provides a low rate for life-line consumption and higher rates for higher consumption to reduce wasteful consumption.

On the average, commercial and industrial supplies which account for about 26% of the total demand are charged 75% higher than domestic supplies. About two-thirds of the total revenue are from sale of water for domestic supplies.

1.6 Financing System

Each State Government finances the cost of development of new water supply projects and the cost of operation and maintenance of public water supply systems.

As most water supply schemes require heavy capital investments, the majority of urban water supply schemes is financed by either Federal loans or loans obtained from international lending agencies such as the Asian Development Bank or the World Bank through the Federal Government.

Generally, the cost of operation and maintenance of water supplies and capital loan repayment are met from revenue collected from sale of water. However since a few years ago, due to great increases in operation and maintenance costs and also the fact that water rate revision has not been keeping pace with such increases in cost of production, water supplies have been mostly operated on a deficit and have to be subsidised by the State Governments.

The Federal Government is also increasing its participation in water supply and is paying for water supply development works in Federal Land Development Authority (FELDA) Schemes and rural water supplies (through the Ministry of National and Rural Development). It is also assisting the States financially by way of part interest free loan and part low interest loans for major schemes. In rural water supply development States have been classified as 'deficit' and 'non-deficit' depending on the status of their economy. Deficit states which include the states of Kedah, Perlis and Melaka are provided with 100 per cent Federal financial assistance on all the capital costs of water supply development in the form of grants. The other States including Sabah and Sarawak are classified as non-deficit States and are provided with grants equal to 2/3 of the cost of the rural water supply projects.

2.0 WATER SUPPLY SYSTEM IN MALAYSIA

The typical water supply system in Malaysia will be discussed under the following subjects:-

- Planning and design
- Raw water source and intake
- Water treatment processes
- Storage and distribution system
- Internal plumbing
- Quality control

2.1 Planning and Design

The planning period adopted is normally about 20 years and a water supply scheme may be developed in a single or more stages. Staging of a scheme usually follows the criteria of a 10 year horizon. Domestic demands are mainly projected based on population growth of about 2.5 to 4% per annum. For the purpose of assessing the demand, consumption rate per capita in urban areas is generally estimated to be about 220 to 300 litres per day (50 to 65 gpd) depending on the area while in rural areas, 160 lpd (35 gpd) is allowed for. Industrial demands are based on the actual requirements or estimated based on the nature of industries to be set up.

2.2 Water Source and Intake

97% of water supply sources in Malaysia is from the surface source in the upper reaches of the streams or rivers with or without impounding or regulating reservoirs. Yield from the river source is normally estimated based on rainfall records and flow records if available or otherwise estimated based on empirical formulae with the rational method.

Underground water source has not been widely used due to its limited availability. At present it is only used as a reliable source in the States of Kelantan and Perlis and total abstraction accounts for less than 3% of the total demand of the country.

Impounding reservoirs will be increasingly used as a water source as the more easily developed surface water sources had been developed. There are only 5 major impounded reservoirs constructed for the purpose of water supply but several new dams are under construction. Impounding reservoirs are being used to feed raw water directly to water treatment plants or to regulate river flows for abstraction downstream.

Raw water is either fed by gravity or pumped to the water treatment plants from the intake.

The most commonly used intake structure is the river side intake with an open channel or conduit leading to raw water pumping suction sump. In the case of conveyance using open channels, design horizontal flow velocity of 0.15 m/s (0.5 ft/s) with a slope of 1 in 500 is used. Where an intake is sited in a flood plain or high fluctuating flood level locality, the form of intake channel is likely to be a conduit. The conduit is sized with a self-cleansing velocity of 0.75 m/s to 0.91 m/s (2½ to 3 ft/sec). In both cases, a grit chamber with a retention period of about 1 to 1½ minutes is provided. It is normally sized to have a horizontal flow velocity of 0.2 m/s to 0.3 m/s (0.7 to 1.0 ft/s) for removing sand particles of 0.20 mm.

Verticle spindle pumps and submersible pumps are most widely used due to great fluctuation of flood levels in most rivers. Flow velocity in suction line is normally limited to below 1.5 - 2 m/sec. (5 - 6.5 ft/sec) and in delivery line limited to 2.5 - 3 m/sec. (8.5 - 10 ft/sec). In the delivery line a non-return valve are normally used and a surge suppression tank with air compressor equipment are installed in many cases.

2.3 Water Treatment Processes

2.3.1 General

Generally all water supplied is fully treated. Treatment processes required are determined from chemical analysis of raw water samples. Water treatment processes employed in most of the treatment plants include aeration, flocculation, sedimentation, filtration, disinfection and pH conditioning. In certain plants, pre-chlorination and pH adjustment are carried out as necessitated by the raw water quality.

Fluoridation of water is also widely carried out on treated water to prevent dental caries. The method employed for each of the treatment processes is briefly described in the following paragraphs.

2.3.2 Aeration

The most frequently used method is the cascade type.

Fig. 1. shows the typical arrangement of this type of aerator combined with the mixing flume.

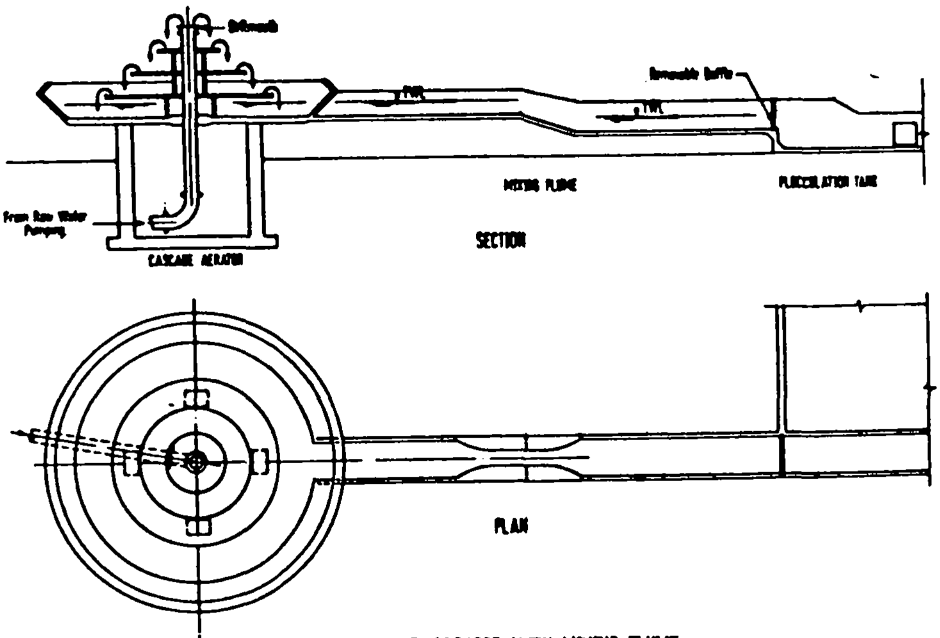


FIG.1 -TYPICAL CASCADE AERATOR WITH MIXING FLUME

2.3.3 Chemical Mixing & Flocculation

Flocculation process is preceded by chemical mixing where the mixing is achieved by one of the following ways:

(a) Mixing flume

(b) Flash mixer

with method (a) being most commonly used. The mixing flume is constructed of reinforced concrete and chemical mixing is achieved by the creation of hydraulic jump. The design of the mixing flume is carried out based on a hydraulic model which was well established with successful application in the country.

Flash mixers are sometimes used to mix chemicals and water in the form of water jet in a tank for about 10 minutes.

The most commonly used coagulant is aluminium sulphate with normal dosage from 15 to 40 ppm.

Flocculation methods employed are the baffle type and mechanical flocculators. The round-the-end baffle type is the most commonly used method. Flocculation is achieved by controlling horizontal flow velocities in 3 compartments or zones through varying the distances between baffles in the 3 compartments. The first compartment is normally designed with flow velocity of 0.25 to 0.31 m/s (0.8 - 1.0 ft/sec), the second compartment 0.15 to 0.21 m/s (0.5 - 0.7 ft/sec) and the third compartment 0.03 to 0.09 m/s (0.1 - 0.3 ft/sec). The tank is sized with a detention time in the order of 25 to 30 minutes. The head loss through the baffle is normally in the order of 0.6m (2 ft) or more.

2.3.4 Sedimentation

The types of sedimentation tanks which are being used are horizontal and vertical flow tanks with the horizontal flow and lovo tanks being the most widely used in this country. The lovo type sedimentation tank is normally designed to have a retention period of 2 to 2½ hours with a surface loading of about 24.5 m^3/m^2/day (500 g/day/ft^2). The inlet velocity into the tank is in the region of 0.03 to 0.09 m/s (0.1 to 0.3 ft/sec), whereas the outlet velocity is in the region of 0.15 to 0.24 m/s (0.5 to 0.8 ft/sec). The horizontal flow velocity allowed for is 1.8 m/min (6ft/min) for the lower half and 2.4 m/min (8ft/min) for the top half of the 'Lovo' tank respectively. The depth of the 'Lovo' sedimentation tank usually varies from 3m to 5m (10 to 16 ft). The floor slopes towards the inlet end at a gradient of 1 in 18 to 1 in 24. Length and breadth ratio of the tank ranges between 2:1 and 4:1. Figure 2 shows the typical arrangement of the lovo type sedimentation tank.

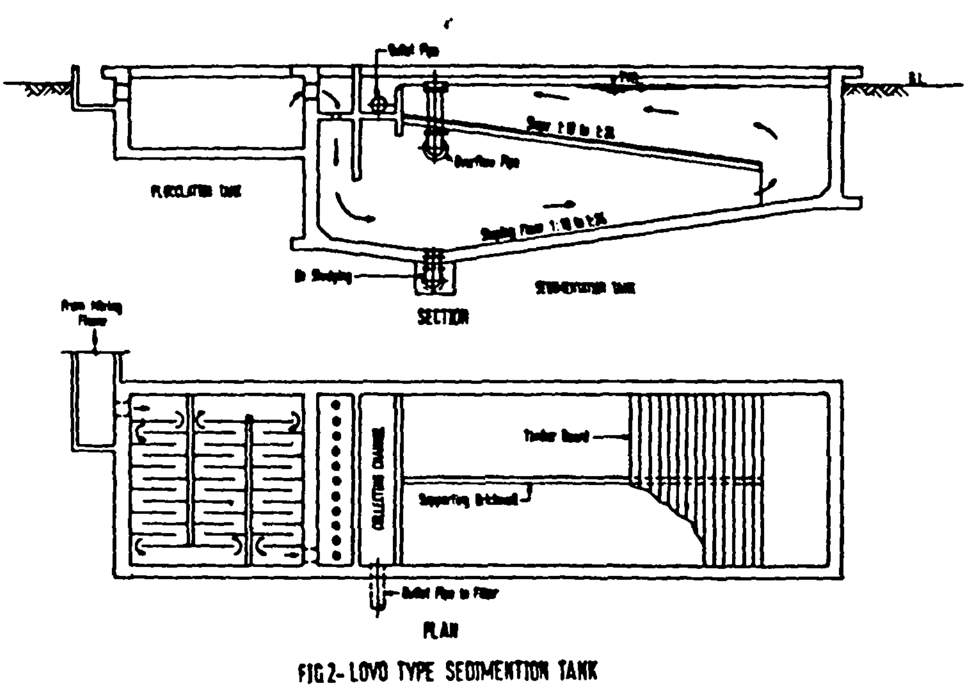


FIG 2- LOVO TYPE SEDIMENTION TANK

2.3.5 Chemical Treatments

The most commonly used chemical treatment is as follows:

Coagulant	:	aluminium sulphate solution with dosage usually ranging from 15 to 40 ppm at a strength of 5%. This is normally fed by a gravity doser or metering pump. In some cases, sodium aluminate of up to 20 ppm is used to produce better coagulation.
Softening	:	Softening is achieved by Soda ash (Na_2CO_3) with dosage varying up to 5ppm. Maximum solution strength is 5%. The solution is fed either by gravity dosing apparatus or metering pumps.
Disinfection	:	Liquid chlorine up to a dosage of 3ppm is commonly used. Prechlorination of over 5 ppm is occasionally applied for polluted raw water. Chlorination is carried out using chlorinating apparatus.
pH conditioning	:	This is normally achieved by dosing hydrated lime of up to 10 ppm. The dosing is usually by means of dry lime doser, or solution feed by gravity feeder or metering pump.
Fluoridation	:	Most water treatment plants have facilities for fluoridation for dosing up to 1 ppm using sodium silico fluoride.

2.3.6. Filtration

Both pressure filters and rapid gravity filters are being used with the latter being most widely used. The designed filtration rate for the rapid gravity filters varies from 5 $m^3/m^2/hr$. (100 $g/ft^2/hr$) to 7 $m^3/m^2/hr$. (160 $g/ft^2/hr$). The shape of each filter is normally rectangular with length to width ratio of between 1.11 and 1.66. Backwash is normally carried out by air agitation followed by backwash using filtered water. The air is applied usually by means of a blower at a rate of 0.3 to 0.38 m^3/m^2 per min. (1 to 1.25 cu.ft. per min. per sq.ft.) at a pressure of approximately 0.35 kgf/cm^2 (5 psi) and for a period of 5 minutes. Wash water flow requirement where air agitation is provided is applied at a rate equivalent to a rise of water surface in the filter box of 0.45 to 0.6 m/min (18" to 24" per min) for a period of 5 to 6 min.

2.3.7 Treated Water Pumping

Normally treated water is pumped either to a balancing reservoir or to service reservoir before distribution. Pumping equipment is usually installed with a 50 to 100% standby. The most commonly used pumpsets are horizontal split casing centrifugal pumps, coupled with slip-ring drip proof motors or diesel engines as prime movers. In areas where public electricity is not available, power is generated from a generator house.

2.4 Storage and Distribution Systems

Generally water is supplied to the public by gravity fed systems. Treated water is normally distributed to service reservoirs before being supplied to consumers. Most reservoirs are sized for ½ to 1 day's storage. Distribution mains are designed for peak flow factor of 2.5 and in high fire-risk areas, designed for fire flow as well. Very few systems have in-line boosting. Where supply has to be boosted, booster pumping from suction tank to high level tank system is used.

Various types of water mains have been used viz: steel, cast iron, spun iron, asbestos cement and lately some ductile iron pipes. Before introduction of asbestos cement pipe into this country in mid-1950's, trunk mains and reticulation mains laid were mostly of cast iron. Today, asbestos cement pipes form the greater part of the system. Asbestos cement pipes of sizes 75mm to 600mm diameter are used extensively for reticulation and even trunk mains. Mains of larger sizes are usually steel pipes. The biggest sized main laid is 2050 mm diameter. Steel pipes are cement lined internally and externally protected with bituminous felt materials.

2.5 Internal Plumbing

The Water Supplies Branch of PWD. Headquarters has prepared a set of uniform Water Supply Rules which is being adopted for use throughout Peninsular Malaysia. The Water Supply Rules is designed to regulate water supply practices with the aim of controlling waste, undue consumption and contamination of the public water supply system. All internal plumbing systems require approval from the water supply authorities before installation and installation work can only be carried out by licensed plumbers registered with the respective state water authorities.

All water consumed is metered and maintenance of the internal plumbing system after the meter point is the responsibility of the consumer. Meters of semi-positive type with an accuracy better than 3% are used.

In multi-storey buildings, water is supplied to a suction tank located at lower levels and pumped to a storage tanks at roof level, before being supplied to the building by gravity.

For internal plumbing, service pipes are of heavy duty galvanised iron pipes and distribution pipes are galvanised iron or unplasticised PVC pipes. Water supply rules require all taps in a house to be fed from a small storage cistern with the exception of the kitchen tap which is fed directly from the public mains.

2.6 Quality Control

Water samples of raw water and treated water are taken on a regular basis for chemical, physical and biological analysis by the Chemistry Department. The number of samples and sampling intervals are generally carried out in accordance with the guidelines provided by the WHO.

In this respect, the Ministry of Health has also prepared the water quality monitoring and surveillance programme. The revised program is being implemented in various stages in selected states, and will be implemented nation wide when sufficient experience has been gained.

3.0 DEVELOPMENT OF WATER SUPPLY IN MALAYSIA

3.1 General

Malaysia carries out its development in Five-Year Plans. At present it is at the end of Fourth Malaysia Plan. The Fifth Malaysia Five-Year Plan (FFYP: 1986 - 1990) is now being finalised. The water supply sector has been given priority in terms of allocations in the Fourth Plan. Table 3 below gives details of expenditure on water supplies:

Table 3 - Expenditure on Water Supply in Malaysia Five-Year Plans

Five Year Development Plan	Period	Total Allocation for Development M$ Million	Allocation* For Water Supplies	
			M$ Million	As % of Total
First Plan	1966-70	4,242	179	4.2%
Second Plan	1971-75	9,800	277	2.8%
Third Plan	1976-80	24,900	397.5	1.6%
Fourth Plan	1980-85	59,700	2,053	3.4%

* Excluding expenditure in Sabah and Sarawak.

3.2 The growth of the Water Supply Sector

Due to rapid development in Malaysia, growth in population, increase in per capita consumption, increase in urban and rural coverage and industrial expansion, the growth of water demand has been rapid. The growth in demand for water both for domestic and industrial use, which used to be 6% per annum a few years ago, has now gone up to about 10% per annum. Between the year 1959 and 1985, the water demand in Peninsular Malaysia has increased more than 9 times from 345 MLD in 1959 to 3250 MLD in 1985 although population in this intervening period has not even doubled.

As a result of implementation of water supply development programme, water supply coverage has been increased rapidly both in rural and urban areas. In 1959, only about 77% of the urban population and 22% of the rural population has been served with proper water supply whereas in 1983, 91.1% of the population in urban areas and 51.2% in rural areas are served with public water supply. Appendix 1 indicates the coverage in each state.

3.3 Urban Water Supply

About 31.8% of the total occupied housing units were located in urban areas in 1980 *(1).

Urban water supply projects are being implemented by the state water authorities. This is carried out with the assistance and coordination of the Water Supplies Branch PWD. Headquarters. The planning, design and supervision of most of the projects are being carried out by local consultants, and in some cases in association with international consultants.

A few major urban water supply projects which have been completed recently are as listed in Table 4.

Table 4 - Major Urban Water Supply Projects completed recently

Name of Projects	Output Capacity MLD	Cost of Project M$ Million
Segamat I	13.6	9.5
Muar I	36.4	25.2
Durian Tunggal II & III	72.8	58.0
Sg. Linggi II & III	31.9	14.5
Sg. Batu	113.8	43.2
Kuala Lumpur III	193.8	78.8

Krian/Larut/Matang	34.1	40.5
Alor Star IV	113.8	41.1
Mengkuang	23.7	66.3
Pasir Putih	7.5	6.8
Tumpat	10.0	11.5
Kuantan	9.1	35.9
Temerloh/Mentakab	18.2	20.0
Kuala Terengganu Baru	31.9	42.0
Tanah Merah/Machang	20.5	17.8

*(1) Population and Housing Census of Malaysia 1980

A few major urban water supply projects currently under implementation are listed in Table 5 below:

Table 5 - Major Urban Water Supply Projects Under Implementation

Name of Projects	Output Capacity MLD	Estimated Cost M$ Million
Johor Bahru Phase I	182	174.30
Johor Barat I (Macap)	27.3	40.0
Johor Barat II (Semberong/ Bekok)	85.0	97.0
Kahang	113.8	130.7
Kota Tinggi	13.6	9.0
Senai/Kulai	9.1	6.4
Sg. Terip I	42.0	66.6
Sg. Semenyih	546.0	408.7
Perak Selatan & Hilir Perak	118.3	91.1
Kuala Kangsar	11.4	10.5
Dinding II & III	63.7	84.0
Ahning I	159.0	94.8
Kedah Tengah/Selantan	95.6	75.1
Pulau Langkawi	43.1	76.9
Sg. Muda IIB	-	10.0
Bukit Dumbar/Bayan Baru	-	3.2

Kota Bharu	45.8	42.0
Terengganu Coastal Areas	163.8	132.8
Greater Kuantan	136.5	94.1
Sg. Selangor	540.0	700
Segamat II	13.6	65.0
Muar II	36.4	75.0

3.4 Klang Valley Water Supply

The Klang Valley where the capital city of Kuala Lumpur is located is currently consuming about 910 MLD of water. The demand is met mainly from the Bukit Nanas Treatment works and the Sungai Langat treatment works. The Bukit Nanas Treatment works (180 MLD) draws its raw water from the upper Klang Gates Dam through twin 1145 mm diameter mild steel mains by gravity flow. The Bukit Nanas treatment plant is ideally located on a hill in the centre of the Kuala Lumpur city. Treated water is then supplied to the Kuala Lumpur city by gravity flow from the treatment plant. The Sungai Langat treatment works (432 MLD) draws its raw water from the Langat River where the flow is regulated by the Ulu Langat Dam.

The growth in demand in the Klang Valley is 12% per annum. In order to meet the projected demand, the Sg. Semenyih Scheme estimated to cost M$408 million, which to-date is the biggest scheme in the country is being carried out. It is under construction and scheduled for completion in 1986. Its capacity is 546 MLD which is sufficient to meet the increase in demand of the Klang Valley up to the year 1989/1990.

To further augment the water supply production of the Klang Valley, a new water supply scheme called the Sg. Selangor Water Supply Scheme with a capacity of 540 MLD and estimated to cost M$700 is being planned for implementation under the Fifth Malaysia Plan. Figure 3 shows the Sungai Semenyih Water Supply Project.

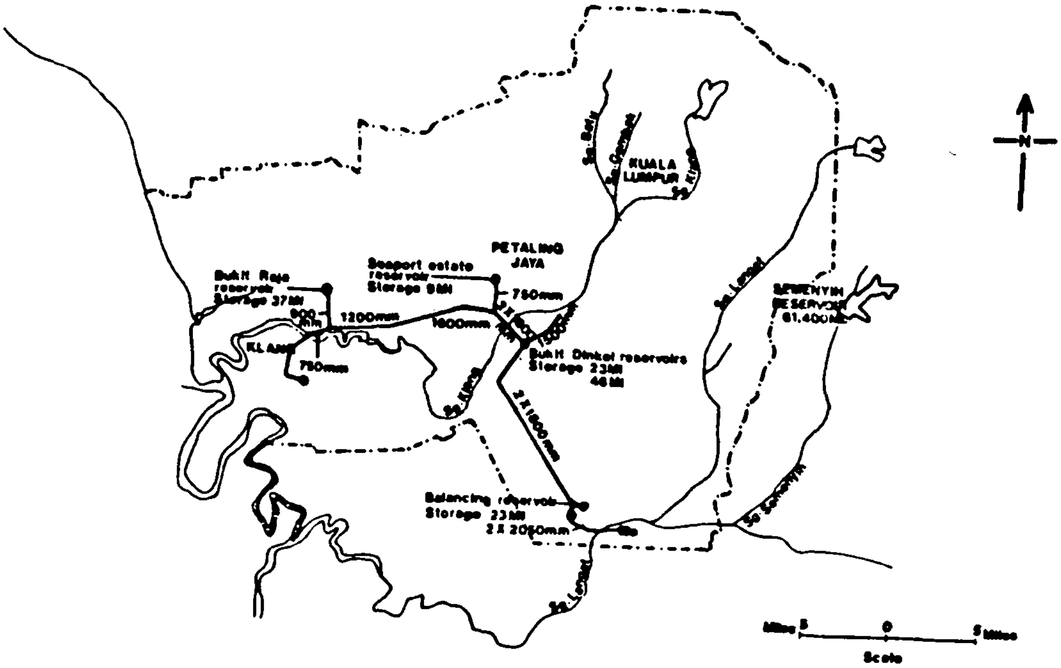


FIG.3 - SUNGAI SEMENYIH SCHEME, KLANG VALLEY WATER SUPPLY

3.5 Rural Water Supply

The Government is increasingly concerned with the improvement of living conditions and health of the population in the rural areas where 68.2% of all occupied housing units were located in 1980*(1). Greater emphasis is now being laid on integrated rural developments of which rural water supply is a significant component.

Public expenditure on rural water supply before 1975 was insignificant. In the Third Malaysia Plan (1976-1980), the Federal Government allocated M$146.7 million as Federal Government's contribution for rural water supplies in Peninsular Malaysia. For the Fourth Malaysia Plan, the contribution is M$290.3 million.

Rural water supply schemes developed by the P.W.D. consist mostly of extension of reticulation mains into the rural areas from the urban water supply system. In certain areas, new water sources are developed and new water supply systems are established to serve rural areas. Extension to rural areas from urban centres has been found to be the best system considering water resource constraints, costs and operational problems.

*(1) Population and Housing Census of Malaysia 1980.

The approval of funds and monitoring of progress for rural water supply projects are by the Ministry of National and Rural Development. The planning and implementation of the programme is carried out by the State Water Authorities, with the assistance and coordination of the Federal Public Works Department.

In addition to the rural water supply programmes done by the water authorities, the Ministry of Health (MoH) has a national rural water supply and environmental sanitation programme. The MoH constructs simple water supply systems in rural areas with community participation where the Public water authorities have no plans to construct water supply systems during the current Malaysia Development plans. The simple water systems consisting of gravity feed piped water systems supply one or more villages, Community well water supplies consisting of shallow wells which are protected and fitted with hand pumps, serve 5 to 15 households.

3.6 The Fifth Malaysia Five-Year Plan (1986-1990) (FFYP)

It is anticipated that the demand will continue to grow at a rate of 10-11% in the coming years. The FFYP has been planned to meet the growing demand. By 1990, the total projected water demand in Peninsular Malaysia will be increased to 5567 MLD and the production capacity is also expected to be increased to 5758 MLD through the implementation of various water supply projects during the next five years. It is projected that by the year 1990, the urban coverage would be increased to 96.6% and in rural areas increased to 81.4%, represent an overall water supply coverage of 87.3% for Peninsular Malaysia.

3.7 Private Sector in Water Supply Development

3.7.1 General

Traditionally, the private sector involvement in water supply is confined to the development of distribution systems within their own development areas and handing over to the water supply authorities for operation and maintenance. The water supply authorities will ensure that the system is built to their requirements before taking over the system.

With the current policy of the Government to privatise some of its activities, there may be more active participation from the private sector in the water supply industry, including provision of financial packages in the coming years.

3.7.2 Consultants

The capability of local consultants to provide services required for the planning, design and supervision of the construction of the projects related to water supply has proven effective over the years, except in certain cases such as water supply resources studies and dam design. Such projects are however, being carried out in association with foreign consulting firms.

3.7.3 Contractors

The construction of most of the water supply projects carried out to-date have been undertaken by local contractors. In some of the projects, where international contractors have been involved, a large extent of the work has been sub-contracted to local contractors who have gained valuable experience in the process and will be able to undertake these jobs independently in the future.

3.7.4 Manufacturers and Suppliers

Most of the civil engineering work materials for water supply are easily available locally. Most of the water treatment plant equipment, pumping equipments and instrumentations are imported. Electrical switchgears are assembled locally with imported components. Most of the commonly used pipeline materials are manufactured locally except for ductile iron pipes. There is no difficulty in the foreseeable future in meeting the demand.

4. WATER SUPPLY PROBLEMS

The rapid water demand growth and accelerated development of water supply systems in Malaysia has brought about several problems.

A few of the important problems are discussed in the subsequent paragraphs:

(a) Manpower

(b) Water resources development

(c) Revenue collection and Financing Water Supply

4.1 Manpower

Rapid development of water supply projects has enlarged the water supply system over the years, both in terms of magnitude and complexities. Adequate and appropriately trained manpower are required to develop operate and maintain the water supply systems so as to provide the desired level of service. Most water authorities have expressed increasing difficulties to provide the desired level of service and generally there are indications of its deterioration. Most water authorities have related the situation to manpower problems.

One of the major problems as reported is lack of training of water works personnel.

Most of the skilled labourers, plant superintendents and middle management personnel are recruited fresh from schools and colleges without any formal or regular training. There is a need to intensify training programmes.

Shortage of manpower has been regarded as one of the major problems and in particular for the purpose of operation and maintenance of the water supply system. This was resulted from rapid expansion of the water supply system without corresponding increase in manpower to operate and maintain them properly and effectively. At the moment, the ratio of approved water works post to the number of metered connection in all states ranges between 1 to 58 and 1 to 176.

4.2 Water Resources Development

The government has undertaken a National Water Resources study to establish a basic framework for the orderly planning and implementation of water resources development programs which is expected to enable national water resources management consistent with overall development objectives. Although the country is rich in water resources, water shortages have occurred because of high surface run-offs, unequal distribution of water resources between demand and supply centres, increasing level of pollution of rivers and conflicts in use of water resources. The study recommended that increasing water demand has to be met by increasing storage capacities and where possible, for multi-purpose use as well as through interbasin and interstate transfer of water where storage development is not feasible. The study also recommended a set of criteria for control of pollution in rivers, the maintenance of minimum river flow, as well as the mechanism to effect coordination of water resources activities, and inter-basin and inter-state transfer of water. These recommendations after careful review and acceptance, form the basis for policies in future water resources management.

In order to develop firm water supply development programmes, further studies are required for timely project identification and development. This is to prevent the emergence of water-stress regions as most of the water supply projects require 4 to 6 years for implementation.

4.3 Revenue Collection and Financing Water Supply

Federal loans are given to state governments to finance water supply development projects. It is anticipated that in future, projects will become more costly because of the development of water sources further and further away from the water demand centres, and the need to build dams. Bigger loans and hence the bigger repayments will be necessary.

The cost for operation and maintenance of water supplies in the country has increased sharply over the years due to higher cost of power supply, fuel, chemicals, materials and wages. For 1985, the total expenditure on operation and maintenance of water supplies in Peninsular Malaysia is estimated to be M$281.2 million which is 73% more than the expenditure of M$162.6 million in 1982.

The main source of revenue for the states is from the sale of water. In the year of 1983, the total expenditure on operation and maintenance of the water supply system amounted to M$186.39 million as compared to total revenue from sale of water amounted to M$206.14 million. Thus there was hardly adequate revenue to service the capital loan repayment and to provide sufficient fund for proper maintenance. Water supply has to be operated as deficit and has to be subsidised by state governments. There is a need to review tariffs and increase water charges.

Due to shortage of qualified and trained accounting staff some problem is encountered by water authorities in revenue collection.

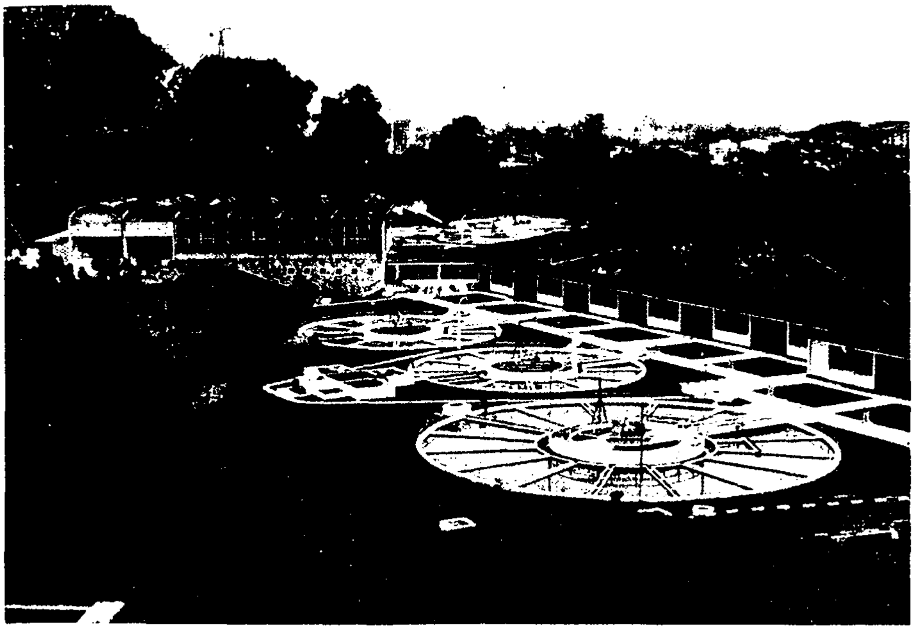
The percentage unaccounted for water (Non-revenue water) in Peninsular Malaysia varies from 18% in one state to as high as 58% in another state. The average is 31.7% which is higher than the acceptable limit of 25%.

Privatising some of the services such as water production or distribution system including revenue collection is being seriously considered by some local authorities

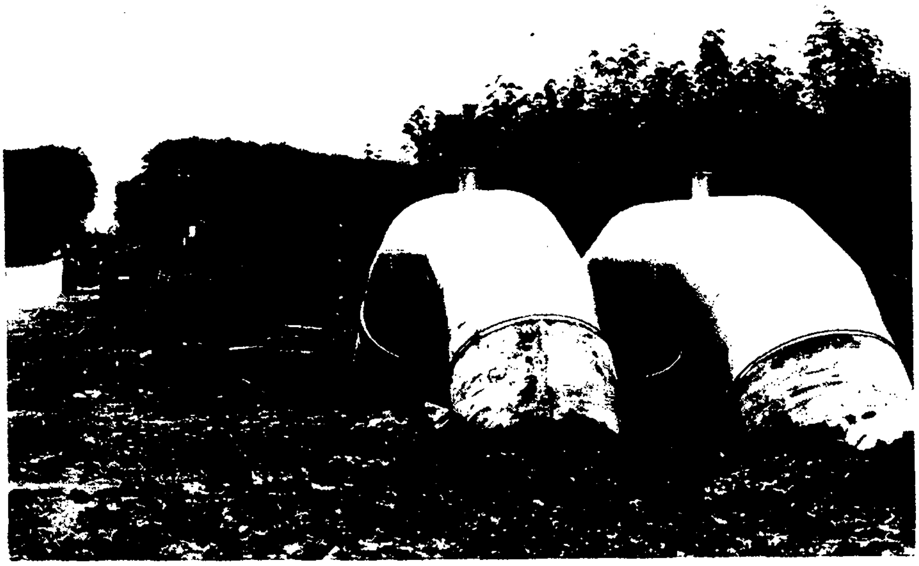
Water Supply Coverage (1983)

Appendix : 1

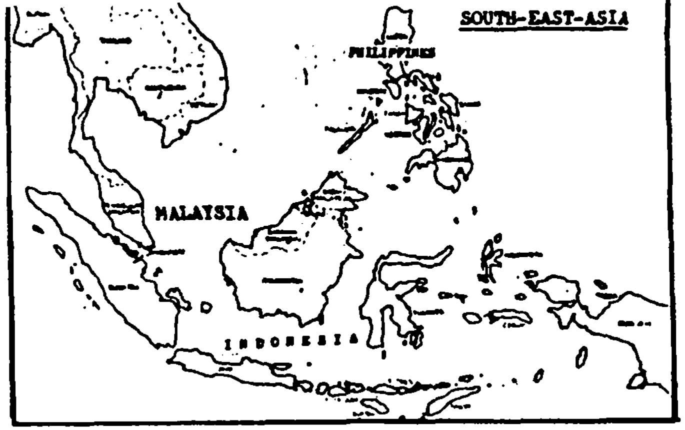
States	Urban		Rural		Total	
	Population	% coverage	Population	% coverage	Population	% coverage
Johor	640,600	90.0	1,115,000	39.0	1,755,600	57.6
Kedah/Perlis	182,500	94.0	1,135,301	58.5	1,317,801	63.4
Kelantan	310,501	61.5	654,298	23.5	964,799	35.7
Melaka	140,099	98.5	342,400	75.0	482,499	81.8
N. Sembilan	210,700	88.1	389,699	70.5	600,399	76.7
Pahang	255,000	93.5	653,600	56.0	908,600	66.5
Perak	611,000	97.0	1,262,200	65.0	1,873,200	75.4
Pulau Pinang	470,499	97.5	533,299	81.5	1,003,798	89.0
Sabah	259,500	99.0	861,000	29.0	1,120,500	45.2
Sarawak	290,600	92.0	1,115,800	29.0	1,406,400	42.0
Selangor/ Federal Territory	1,775,000	92.5	1,018,600	71.5	2,793,600	84.8
Terengganu	287,000	80.0	297,400	32.5	584,400	55.8
Total	5,432,999	91.1	9,378,597	51.2	14,811,596	65.8



180 MLD Bukit Nanas Treatment Plant
located in the heart of Kuala Lumpur City



Twin 1800mm steel mains - ready to deliver
546 MLD from Sungai Semenyih Treatment Plant
to Klang Valley in early 1986



MALAYSIA

1. Perlis
2. Kedah
3. Penang
4. Perak
5. Selangor
6. Federal Territory - Kuala Lumpur
7. Negeri Sembilan
8. Malacca
9. Johore
10. Pahang
11. Terengganu
12. Kelantan

(1–12: PENINSULAR MALAYSIA)

13. Sabah
14. Sarawak
15. Federal Territory - I bu n

MALAYSIA: Background information & statistics

AREA: 330 434 km^3

Peninsular Malaysia: 129,000 Km^2
Sabah : 77,000 Km^2
Sarawak : 124,000 Km^2

POPULATION: 15. 262 million (1984)

Birth rate: 2.45% natural growth (1983)

Population density:
Peninsular Malaysia: 121 Person/km^2
Sabah : 15.6 " " "
Sarawak : 11.9 " " "

Composition:

Malay	:	54%
Chinese	:	35%
Indian	:	10%
Others	:	1%

GNP: R $71,764 million (1984)

GNP per capita: R$4,702 (1984)

MAIN TOWNS: (1980 census)

Peninsular Malaysia

Kuala Lumpur	:	938,000 (Capital City)
George Town	:	251,000
Ipoh	:	301,000
Johor Bahru	:	250,000
Sabah	:	Kota Kinabalu
Sarawak	:	Kuching

EMPLOYMENT

Total labour force (84) 5,762,000

Unemployment:
1983: 6.0%
1984: 6.2%

LANGUAGES

Official: Malay

Others : English
Chinese (including Mandarin)
Tamil
Local dialects

CURRENCY AND EXCHANGE RATE:

Ringgit (R $) = 100 sens
US$ 1 = R $ 2.48 (Sept 85)

MEASUREMENT

Transition period of changing imperial to metric system.

GEOGRAPHY

Malaysia comprises 13 Federated states as follows:

Peninsular Malaysia: (11 states) Johor, Kedah, Kelantan, Selangor, Melaka, N. Sembilan, Pahang, Terengganu, Perak, Perlis, Pulau Pinang

North Borneo Island: Sabah, Sarawak

In both parts of Malaysia, coastal regions are low lying and are backed by high mountain ranges. Much of the country is covered with dense rain forest and extensive swamps. Agriculture is largely confined to lowlands.

The climate is hot and humid throughout the year with temperatures in the range of 23 to 31^{o}C. South west monsoon occurs from May to September, and the North East monsoon from November to February which bring heavier rains to the East coast. Average rainfall is about 2500 mm per annum. East Malaysia (Sabah and Sarawak) are slightly wetter, with average rainfalls up to 4000 mm a year.

GOVERNMENT

Constitutional Monarchy with a King as head of state. Nine of the states are ruled by hereditary Sultans, and these elect the King from among themselves for a five year term.

The Federation of Malaysia is ruled by multiparty coalition government in which the United Malays National Organisation (UMNO) dominates. Other key parties are the Malaysia Chinese Association (MCA) and the Malaysia Indian Congress (MIC).

The Government is by an elected Parliament headed by the Prime Minister, YAB Datuk Seri Dr. Mahathir Mohamad.

ECONOMY AND TRADE

Economic Growth:	1981	:	8.0%
	1982	:	4.5%
	1983	:	4.4%
	1984	:	6.1%

Malaysia's economy is based on exports of petroleum, palm oil, rubber, tin, hardwoods. Light industries particularly electrical and electronics ventures are expanding rapidly. About 40% of the population is directly dependent on agriculture. Main export markets are Japan, ASEAN countries, the EEC and the USA.

Imports mainly comprise machinery, transport equipment, manufacture goods, food and fuel.

PAPER 2

OPERATIONS AND MAINTENANCE

BY

LAURIE WILD
DIRECTOR
LAURIE WILD CONSULTANTS LTD
UNITED KINGDOM

INTRODUCTION

Engineers who travel the world advising on problems in the water industry, repeatedly find plant which is not being operated and maintained correctly. Often, the problems are written off by blaming the poor quality of the local workmen. The trouble-shooter hopefully puts things right, but leaves the site convinced it is only a question of time before it fails again.

Need this situation continue? There can be no case for believing that there are nations with intelligent workforces and others whose manual workers are incapable. It therefore falls upon designers , manufacturers and those responsible for operations and maintenance, together, to provide the correct equipment, management structure and adequate training to ensure a secure, efficient and economic service in each and every country.

DESIGNERS AND MANUFACTURERS

When designing and manufacturing equipment for a new works, there should be an awareness of the need for fully trained operational and maintenance staff from the very beginning. They should be ready to take over the highly advanced equipment, which is even more necessary in underdeveloped countries. Consideration should be given to the skills already acquired by local workers, what further training they need and where and when this should be given.

This paper is therefore written as much for suppliers of plant for developing countries as those who will be required to manage it. Their responsibilities do not end when the plant leaves the works or the resident engineer goes home, but is reflected throughout its life.

For example, a design suitable for an area where specialist assistance is available a few miles away, and where communications are efficient, needs to be even better designed for a remote area where a fitter or electrician might be on his own without help. If he faces a problem where the instructions or manuals do not at least suggest an answer, this is a failure on the part of the manufacturer or supplier, not the tradesman. It follows that comprehensive manuals, fully illustrated, easily under-standable and printed in the local language, are essential. There are many manuals supplied today which are incomprehensible even to the expert!

Video recordings are now used extensively by manufacturers for advertising purposes, but rarely as aids to operations and maintenance. A video which clearly shows a technician carrying out a series of tasks would be invaluable in the remote place where the equipment could be installed. As a bonus, it would at least ensure that the task can be carried out. I have found instances where it has been impossible to replace a small item, as it was installed before the complete part was welded. The same use of videos is also a suggestion for use in older works. An experienced technician could carry out a task which could be followed easily by his less skilled colleagues.

There is the need for more consideration on the spares situation. They should be provided in the form most usable by the maintenance staff involved. Say, for example, wear takes place on only one item is a composite part. It this is difficult to fit it would be, overall, more economic to supply a made-up section which can be replaced without difficulty.

If possible, package units should be provided as these have many advantages over built-up units on site. One of these is that the terrain is altered to suit the package (or series of packages), whereas with site constructed units each plant has unique features due to site considerations, or sometimes the desire (or ignorance) of the local constructor to include his own ideas. Where size precludes package units the instructions to the constructor should be comprehensive and clear to the very last detail to avoid error.

The manufacturer should advise, with his tender, the number of staff required to operate and maintain the equipment, and their competence, including proposals for training. The impression should never be given that operation and maintenance is easy. It never is.

Finally, there should be the realisation that most systems will expand and additional equipment will be required eventually. The use of the computer today is ever growing and although, perhaps, not always installed initially, any system should obviously be so designed to provide for this in the near future.

MANAGEMENT STRUCTURE

It is not usually recognised that creating a completely new water operational unit can be easier than expanding or modifying one which has been operating for a long time. Old practices die hard and the existing staff will often resist changes, particularly if the situation involves retraining or redundancies. However, methods and plant used in the water industry have changed considerably during the past decade and unless a radical new approach in staff structure is made, the management will be continually faced with problems caused by the "we have always done it that way" attitude.

The structure depends on the type and scale of the undertaking and intimate knowledge of the system. Some assistance may be available from the design consultant or manufacturer, but it should be appreciated they seldom have experience of long-term operation and maintenance. Advice should therefore be sought from those who specialise in this. These may be consultants or water authorities who provide such a service.

Some organisations make the mistake of setting up an operating division from the top downwards. Obviously, a manager is required but preconceived ideas should not be used to fill the second and third tier posts without study. The correct way is to start with the plant and system to be operated, consider the staff and services required at that level, and then build upwards.

Any system can be defined as the product to be dealt with, where it comes from, what treatment is required and where it goes to. The necessary plant can be added and a flow chart prepared. Each item, or combination of items, in the flow chart can have the number of operating staff added and the level of skills, and so on. The operating structure can be completed by considering what grouping will be the most efficient and economic.

Decisions need to be made regarding maintenance - whether central or local control is required and the type of maintenance to be provided (planned or just emergency); the workshop facilities, spares and stores, the financial control and administration of the whole, complete the task.

At this stage the higher levels of management will become obvious and, by sharing the responsibilities equally, a suitable structure will evolve. However, the operational staff is our first consideration.

POTABLE WATER

Situations vary widely throughout the world and, in order to give an example of setting up an operational unit, a liberty is taken (appropriate for this conference) of using a typical State in Malaysia, say, Perak. It is assumed that an operational structure already exists; some of the equipment used is time expired and is due to be replaced by new plant. The coverage is also to be increased by the addition of a large number of new installations and systems. The area is large and communication between some of the treatment works and systems is difficult.

The water sources include wells, boreholes and rivers, and while many sites are served by public electricity supplies, there are others requiring diesel generators. The new plant will consist of package units for the smaller stations and prefabricated parts and site construction for the others. Finally, in order to provide security of supplies, as many treatment plants as possible will be interconnected via the distribution system.

With the above information, it is possible to arrive at a basic flow chart.

FLOW CHART

1. Raw Water - Wells, boreholes and surface abstraction of the raw water is either continuous or intermittent. Continuous operation requires minimal staff; virtually none for submersible borehole pumps, and only screen cleaning duties for surface water. However, if the source

works are not part of the treatment works the provision of staff here can be very unproductive. Quite simple remote operational control with only an indication of pump failure or pressure drop through intake screens, is of great value and very economic, as is bankside storage to cover outage periods.

2. Treatment - Filters of various kinds can be most economic in the use of staff. Depending on the quality of the raw water, a cleaning cycle is necessary, but with a well designed system this is a routine, unskilled task.

The use of more complicated chemical treatment plants is not always an advantage, unless the quality of raw water requires such treatment. Automated and remote control can, however, reduce the staff required, but is an added complication when operation and maintenance is being considered. Some installations can be designed for relatively unskilled operation. Simple sight tests can be drawn up to give measurements of many compositions and, for others, kits are available which can ensure accuracy by adding a set amount of chemicals.

3. Disinfectant - London's water supply has been considered to be the safest water for many decades, be it from the rivers (Thames and Lee) which receive effluent from various communities, or wells and boreholes. The principle always applied is that the raw water is possibly contaminated and therefore treated by processes, in series, which will ensure that every drop of water supplied to the public is pure and wholesome.

The disinfectant normally used is chlorine, but more recently ozone has also been included. Certain continental water authorities have now rejected chlorine, due to the possibility of harmful by-products. The majority, however, do not accept this view and the evidence of millions of people being supplied with water disinfected by chlorine would appear to justify their view.

In the main, chlorine dosing is carried out by automatic devices, but it is advisable to have a sight test manually applied, which will ensure the attendant is not only present but is carrying out his task. Chlorine is, however, a dangerous substance and staff should be carefully trained in the use of protective devices and safety procedures.

4. Quality Control - The purity of the water supplied is obtained by the addition of chemicals to neutralise contaminants or assist in the removal of suspended matter and, finally, to disinfect. However, cases have been reported where the management control has failed and the water supplied has been of potentially greater danger than even the use of raw water. This has occurred where the continuous use of small quantities of chemicals has been (by the attendant) replaced by batch dosing, and even toxic levels have been reached. In other cases, over-use of

flocculants (such as alum) has resulted in slime formation on the delivery pipe. An instance of one 700 mm. diameter, 40 km. long pipeline in Guinea resulted in the throughput being reduced from 500 l/s to 200 l/s and the entire length had to be cleaned by swabs before the design flow was restored.

Such difficulties are easily avoided by the use of reagent kits, previously mentioned. All manner of tests are available, which enables semi-skilled operatives and laboratory assistants to determine hardness, chlorine levels, pH, acidity, ammonia, calcium and so on.

5. Distribution - A well designed distribution complex requires only a minimum of operational personnel to trim the system to meet peak loads and unusual demands. This duty can be met by the gangs employed to lay on new supplies and deal with the inevitable fractures which occur on new pipelines. Experience has shown that most fractures happen in the first few months after construction, due to ground settlement, imposed stresses or faulty construction. After this, a long period of trouble free operation can be anticipated until corrosion, wear or major ground disturbances takes place. Care should be taken to have detailed records of where the pipes have been laid. In London, many days and trial holes have been required to locate pipelines laid over a century ago and not accurately recorded.

6. Distribution Procedures - With any new, or extension of the distribution system, it is essential to establish procedures for main laying, laying on new supplies, dealing with complaints, byelaw infringements and so on. A series of guides is available which can ensure that all distribution staff operate in the same way to obtain and record all necessary information. Typical of this is the "Request for a Connection to the System", as illustrated in Figs. 1 and 2. Many of these guides and special forms are available for the distribution section alone. Of great use is the mains record which notes every action (lay-ons, repairs, excavations nearby) covering each section of pipe.

7. Distribution Design - A point of interest in distribution mains, and the need for designers to consider the subsequent operational problems they can cause, was revealed by the above-mentioned 40 km steel pipe in Guinea. The pipe, which was laid over very hilly jungle terrain, was completely welded into one piece. Only three division valves were provided, and even these were welded into the main. Before the cleaning operation could begin, sections of the pipe had to be cut out under very difficult conditions. Suitable access points on any system should always be provided and are easy to include in the original design.

8. Leak Detection - Every water supply organisation should have a leak detection service as wastage, even on relatively new systems, can be considerable. Detection needs to be focused on two principal sectors - the fractured main, from which

large quantities can disappear into the ground, and the multitude of minor leaks which, together add up to a considerable quantity.

Leak detection involves all operational staff carefully recording unexplained changes in output, management being required to explain the changes and a leakage section which should consist of at least a technician, trained inspectors and semi-skilled workmen.

For many years now, systems have been designed as waste water areas, in which sections of the piping configuration can be isolated by valves so that accurate measurements can be made of the demand in the area, usually during the low usage night period. When carried out at, say, three or six monthly intervals, the demand figures can be compared with those taken during a similar time (season, weather) and any changes noted. By isolating further within the waste water area, leakage points can then be identified.

Special leak detection mobile laboratories are now used by the Thames Water Advisory Service, who serve the water industry throughout the world. These vehicles are provided with the latest devices, developed by the British Water Research Council and, when used by the trained operators, can rapidly detect leakage over a wide area.

9. Metering - Water supplies in much of England have previously been considered a social necessity and, for this reason, a nominal charge for each household, based on the general rateable value of the property, has been made. Until two years ago domestic properties have not been metered, and only then when the consumer has requested it.

It is now obvious that the fairest way to charge for water is to meter the quantity supplied to each property. However, the task is great; London alone will require over 2,000,000 domestic meters and, while the cost of these will be expensive, the installation will make the whole cost enormous.

It is therefore advisable, when the initial designs are being made, to include meters, even when building quite nominal size systems. Consideration should also be given as to the methods of reading such meters. Employment of staff to take readings, whether inside the premises or in a pit outside, can be very expensive. An advance is to have the meter connected to a visual reading point for quick observation. For situations where it is suitable, the best way is to have a connection from the meter to either a telephone line or the electricity supply, when digital readings can then be taken remotely.

SEWERAGE

Any improvement in a water supply will result in the need for examination of the effects caused by waste water. Experience has shown that when supplies become available, flushing water toilets, baths, washing machines and industrial waste, follow. Even if the provision of a sewerage system is not programmed, it is advisable to consider the implications and requirements of waste water, otherwise the effect of improving clean water supplies will be negated by the resulting waste water pollution. At the very least, this will avoid the often seen mistake of sewage flowing into a watercourse upstream of the clean water intake, or seepage polluting underground resources.

One authority, responsible for both clean and waste water, (as is now the fact in nine areas of England and Wales) can be of great advantage economically as many of the functions are identical and savings can be made in both manpower and equipment. This can be indicated by a brief consideration of the requirements of a waste water system and the common services that can be used when the complete water cycle is considered.

FLOW CHART

1. Collection - The sewer configuration is largely static, consisting of rudimentary gullies or pipes, flowing by gravity to a collection or treatment works. In some cases , usually dictated by the terrain, pumping-on stations may be required, but the system seldom calls for skilled operatives - only labourers for cleaning duties.

2. Treatment - The type of sewage treatment necessary and desirable varies widely, depending on the composition of the waste water and the purity of the effluent required. In many countries, particularly those with normally high temperatures, large areas of land and small population, simple lagoons are all that is required. Basically, these follow the natural action of waste water entering a pond with aerobic algal/bacterial activity, followed by the anaerobic biological process in the sludge layer. Labour is required only infrequently for cleaning out the sludge.

   All further treatment processes are just ways to intensify the natural action which occurs in the lagoon. Additional oxygen can be provided by the use of mechanical aerators, which thereby increase the throughput. Other processes are the trickling filter, rotating biological filter and, finally, activated sludge plants. Sludge is dealt with in a variety of ways, from spreading on the land as waste to the use of anaerobic digesters which not only makes the sludge safer to use but the resulting methane gas can be used as a source of power, substantially altering the overall cost of the system.

   The use of advanced methods of treatment makes the provision of skilled managers, chemists and operatives essential and, as previously stated for pure water systems, the manufacturers should be asked to state the number of operators required, and for how long per day. Management can then determine how many staff will be needed to cover the whole works.

TRANSPORT (common service)

The types and variety of transport now available can cover all the needs of the water industry. There are specially designed long-base vans and landrovers for carrying pipes; lorries with built-in cranes; tankers of many volumes for emergency water supplies and liquid sludge. Some can be provided with tracks for very rough country roads. There are also refrigerated vans for instrument fitting work, mobile laboratories and workshops for any type of maintenance. Servicing of these vehicles is simplified by the provision of comprehensive, well illustrated manuals - an example many manufacturers of plant and machinery could copy.

For any medium size or large organisation, it is economic to centralise transport and mobile plant, and have drivers and maintenance staff separately managed from the main plant. Equipment and staff can then be seconded to the operating sections. This avoids the purchase of plant which, with a low load factor, is not only uneconomic but can result in the rapid deterioration which occurs with idle machinery.

STORES (common service)

Many mistakes can be made when a new organisation attempts to determine the requirements of their stores section. Guidance from manufacturers for spares usually results in either under-provision (to keep the initial cost low), or over-provision (playing safe). The answer is to seek advice from an operating organisation having a similar system and plant. A major consideration is to have a stores procedure and a complete record of where items are kept, as it is an often noticed fact that local stores assistants jealously guard the items under their control.

LABORATORIES (common service)

The requirements of an organisation for laboratories and staff will naturally depend on its size and type. Most potable water stations can operate safely with visits by sample collectors, who transmit the samples to a central laboratory. Sewage works need hour-by-hour information and therefore each will probably require its own. As previously mentioned, the reagent kits are of great assistance, but most undertakings require chemists, biologists and bacteriologists of some standard, together with laboratory assistants.

MAINTENANCE (common service)

As previously stated, the maintenance structure should be formed from the lowest level upwards. The first task, therefore, is to identify the plant and its service requirements. In order to have the skilled staff to collate and interpret these, an initial decision on the basic form of structure would have to be made. The complexity of the undertaking will largely determine the size of the organisation, but the most economic is to have an area defined and controlled from a central base, with sub-areas carrying out the actual work under directives from the centre. Again, taking Malaysia as an example, it would appear that the country could be divided into three maintenance centres, each state having a number of sub-areas based on one of the larger works. Alternatively, it could be politic for each state to have its own centre, but in this case to avoid overmanning and excess spares, a nationwide co-ordination centre should be considered.

The central base would require a manager and sufficient staff to construct and maintain records of all plant and equipment installed and used, records of maintenance carried out, breakdowns, spares used and all costs involved, and be in a position to provide specialist assistance to the sub-areas.

PLANT RECORDS

Even a small, relatively simple, organisation will have thousands of parts which should be easily identifiable. This means that plant records are essential for an efficient and economic system of maintenance. There are many coding systems available to identify the parts, but when the choice is being made it should be appreciated that it may well be economic at a later date to computerise the set up.

An easy method to introduce and, more important, one which all staff can understand, is to have a series of numbers indicating sub-area, station, section of plant, item, part and interchange. For example:

21	12	6	64
Perak	Kerian	Clarifier	Sludge valve

8	329
Gland	Interchange

The above is self-explanatory, with the exception of interchange. A well-designed system will have many hundreds of parts which can be interchanged between stations and machines. Replacement bearings are an obvious example, and instead of carrying spare bearings for each machine it is possible to hold just a few centrally.

The plant records should cover all aspects, not only of the equipment, but of all the work carried out. For this reason, no task should be undertaken without a work order and, on completion, a repair report and an entry made on the history card. Typical records, as used by operation and maintenance contractors Roxby Engineering International Ltd., are illustrated as Figs. 3, 4 and 5.

PREVENTIVE MAINTENANCE

The objective of any installation is to run at the lowest cost consistent with reliability of service. This is best achieved by preventive maintenance, which leads to fewer interruptions due to breakdowns, a smaller maintenance force and reduced cost of spares. One way of intruducing such a system is to choose an arbitrary time period for minor and major overhauls but, while the simplest, this is not the most economic.

The best procedure is to undertake an initial period of intensive monitoring, whereby the condition of each item of equipment is verified and allowed to run until its performance deteriorates or some part shows signs of distress. An economic time can then be chosen for a group of adjacent items to be maintained.

Sub-area workshop

Each sub-area should be provided with technicians of the disciplines required by the equipment, together with a number of fitters and electricians. Their task would be to carry out the initial monitoring operation and then all the breakdown and preventive maintenance necessary. However, all major overhauls should be directed and monitored by the central base and, as previously stated, complete records kept of time taken, spares and materials used, and any special items of note. In this way, all sub-areas can be co-ordinated and advice given, as problems faced by one sub-area are likely to be repeated in others and avoiding action taken.

OPERATING STATISTICS

Overall statistics of operating machinery and plant are necessary in order to monitor performance over the life of the equipment. These should include all costs, electricity or oil used, repairs, stores, housekeeping and so on. By converting these to basic parameters, a yardstick is obtained whereby station can be compared with station, and falling-off in performance recognised. Fig. 6 gives an indication of one such record, but each situation will need consideration to find the most useful comparisons.

ORGANISATION AND METHODS

With a large number of sections there is a danger that each will spend time and effort determining the correct aids to carry out its tasks. For example, photocopying machines, typewriters, even office furniture. They will also develop individual methods of carrying out similar tasks which may often be found to be incompatible, that is, filing systems, pay methods, protective clothing issues, and so on. The establishment of a small organisation and methods section to carry out this task ensures a minimum of effort on the part of the operating sections, and a uniform approach to common services and equipment.

WORK STUDY AND INCENTIVE BONUS

Dedication to the task by staff on all levels is good in theory, but most people work for reward. The creation of an incentive bonus scheme - if properly managed - can ensure that work being carried out is fairly rewarded.

WELFARE

Organisations often omit the employment of a welfare officer as it is considered that each supervisor, foreman and manager should be concerned with his own staff. I have found, however, that having an independent member of the staff, carefully recruited for their sympathetic manner and approach, has been a great asset. Such an officer can be of particular value in advising on matters not always directly connected with the work of the organisation.

TRAINING

Returning to the introduction of this paper, it is unwise and unfair to expect operatives and maintenance staff in underdeveloped countries successfully to operate modern day plant without adequate instruction and training. Contracts often include a period of time when the contractor is required to operate and maintain his own plant. During this time, he is required to instruct the local staff, but this seldom results in a satisfactory solution. Sometimes, the fault is with the manufacturer's staff not being trained themselves as instructors, or the fault can lie with the purchaser's staff. Training is a continuing process and, therefore, each organisation requires a training section.

However, the problem can be minimised by using one of the training services which now exist. Such authorities as Thames Water, in conjunction with colleges and private companies, operate schemes whereby staff can be trained at home or overseas in every aspect of the water industry's tasks. Use is made of training schools in the UK, and instructors are sent to similar schools all over the world. Professional technician training can be given in British water and sewage treatment works on plant which will be identical to that being constructed. Of even greater long term use, national training officers can, over a period, be taught about the plant itself and the best ways of imparting this knowledge to all levels of staff by using teaching aids, video recordings and sectionalised parts of equipment.

Instruction can also be given to more senior staff, up to director level. They can (under guidance) be allowed to control systems and stations where their mistakes can easily be corrected, which would be more difficult and costly to deal with in their own areas.

A method of introducing new enterprises which is becoming increasingly popular, is where an authority in conjunction with a service company, undertakes to operate and maintain a complete undertaking for a period, taking full responsibility for its performance. They assist in the section of local staff and guarantee to train them during the contract period.

The cost of such a contract is not high when the value of a modern system is considered. An economic balance is required which, on one side, includes the investment in the system added to the cost or effect of a breakdown, and to compare this with the investment on training. The answer is clear.

SALARIES

One important consideration that has a marked effect on the standards reached by operatives and maintenance workers, is their earnings. In many countries the systems are owned and administered by local or central government and this has sometimes led to the workers receiving less than a living wage. Staff can, therefore, be forced to seek an additional job, that is, moonlighting, which can result in them concentrating on this employment (which brings in the extras), rather than their municipal work. In one instance it appeared that the job with the water undertaking was used as a rest period, and the plant and works concerned showed evidence of neglect, despite the fact that more workers were employed than was necessary.

In the UK labour costs for water workers are high - among the top earners of the manual grades. This means that numbers are kept to a minimum - often, it is noticed, a third of those employed overseas.

Many managers recognise this problem but, with national pay scales for government workers, are powerless to correct it. However, there is a solution adopted by some, namely, the privatisation of operation and maintenance. In this way, even though paying the managing contractor, the overall cost of operation and maintenance is reduced.

CONSTRUCTING THE STRUCTURE

With the above information, it is now possible to construct the organisation structure from top to bottom. Fig. 7 gives one possibility to which modifications can be made as required, by the undertaking under review.

NOTES ON FIG. 7

(a) The questions of deputies to managers can be answered in many ways. If the organisation is large enough, the work-load of the state manager is considerable and a full-time deputy handling, say labour matters, is desirable. If the load is not so great, one of the second tier managers can be nominated as deputy, providing there is a substitute for his position.

(b) In Fig. 1 the Operations and Maintenance sections have been separated under different managers. It would be equally correct to combine these sections and divide them into Sub Area 1 - Operations and Maintenance, and Sub Area 2 - Operations and Maintenance.

(c) The services section is becoming more normal in modern organisations, with the need to have specialists in the various subjects. Such sub-sections as organisation and methods, are invaluable to the manager when he wishes to investigate a section without upsetting its manager. Work study and incentive bonus are, equally, a way in which in-depth studies can be made of the way work methods can be improved and high effort rewarded.

(d) It should be emphasised that this paper concerns only the operational and maintenance aspects and has not, therefore, concerned itself with the other duties and professions involved in a complete water undertaking. It fits the complete structure under a Chief Executive (Managing Director or similar title), alongside the other normal departments, say finance, engineering (new works) and overall administration.

CONCLUSION

Special care should be taken in the design and manufacture of plant for use in developing countries and technology not simply transferred. Assistance should be given (and when part of AID package, included in the value) in the initial operation and training of staff at all levels. Without such action the dismal record of failures and wasted finance will continue.

It has been advised in this paper that the managers of young organisations in the water industry should seek advice from the experts in well established water undertakings. It has been noticed that there is sometimes a reluctance of the part of senior management to admit that this could be of benefit. To change this view, consideration should be given to areas such as London, which has had water undertakings for over 500 years. During that time they have made nearly every possible mistake, but it is the knowledge gained from these failures that makes them supreme teachers.

Acknowledgements to Thames Water Authority and Roxby Engineering International Ltd.

FIG. 1

REQUEST FOR SUPPLY (NON-METERED)

Trade or domestic

- Receive request for supply (by letter or telephone)

Plumbing drawings

- Send letter requesting plumbing drawings
- Receive plumbing drawings

Sufficient details

- Send acknowledgement letter if supply process is likely to be delayed.

Site drawings

- Send letter requesting site drawings and/or with drainage marked
- Receive site drawings

Examine drawings

Examine drawings

Sufficient detail

Insufficient detail

- 0 Complete PU.719 for separate report
- Send PU.719 to foreman of Inspections
- Receive PU.719 completed

Trade

- Send drawings to technical if necessary
- Receive information from technical
- Send letter informing applicant of any changes required

- Send details to assessment for decision on metering
- Receive instructions from assessment

- 0 Complete PU.1144 and PU.173
- Send PU.1144, PU.173 and site plans to S.R.E.
- Receive PU.173, PU.1144 and site plans marked up from S.R.E.

Non-metered

Metered

Follow metered supply procedure

FIG. 2

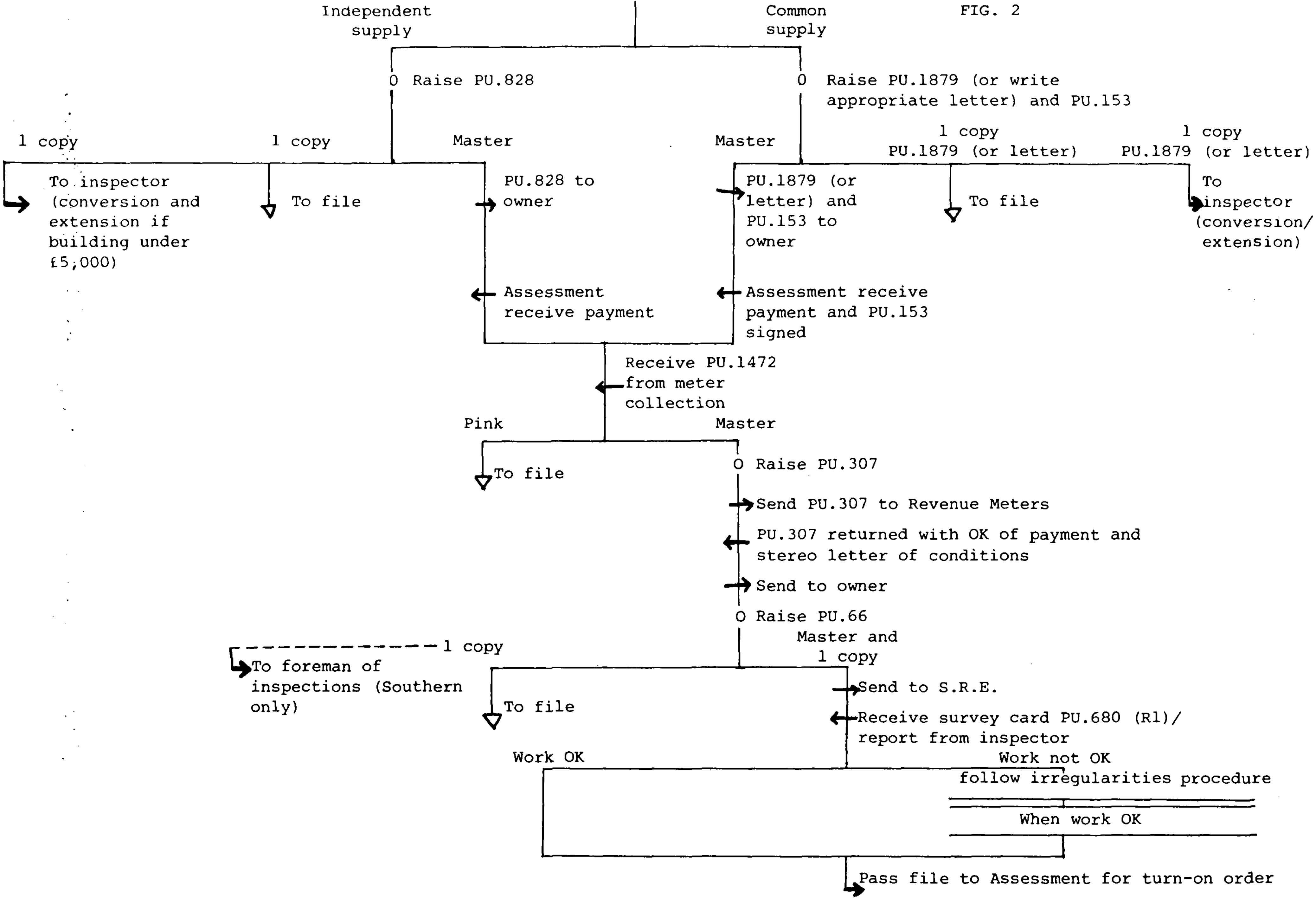

Independent supply
Common supply
0 Raise PU.828
0 Raise PU.1879 (or write appropriate letter) and PU.153
1 copy
1 copy
Master
Master
1 copy PU.1879 (or letter)
1 copy PU.1879 (or letter)
To inspector (conversion and extension if building under £5,000)
To file
PU.828 to owner
PU.1879 (or letter) and PU.153 to owner
To file
To inspector (conversion/ extension)
Assessment receive payment
Assessment receive payment and PU.153 signed
Receive PU.1472 from meter collection
Pink
Master
To file
0 Raise PU.307
Send PU.307 to Revenue Meters
PU.307 returned with OK of payment and stereo letter of conditions
Send to owner
0 Raise PU.66
Master and 1 copy
1 copy
To foreman of inspections (Southern only)
To file
Send to S.R.E.
Receive survey card PU.680 (R1)/ report from inspector
Work OK
Work not OK follow irregularities procedure
When work OK
Pass file to Assessment for turn-on order

FIG.3a

ACCOUNT No:			WORK ORDER
PRIORITY A ☐ B ☐ C ☐ E ☐ S/D ☐			P.E.No............... W.O.No..........
AREA. ...... INST........	ELEC........ SHOP........	PLANT...............DATE......... ORIGINATED BY.................... APPROVED BY.....................	DATE COMPLETED............... FOREMAN SIGN OFF............. PROD.ACCEPT..................

DESCRIPTION OF WORK

ESTIMATE OF MANPOWER AND EQUIPMENT

EQUIPMENT NEEDED	MANPOWER REQUIRED	TIME

FIG.3b

COSTING DATA

TRADESMAN	No.	GRADE	TIME	STORES REQUISTION NUMBERS	MAIN POINTS OF WORKS
MACHANIC					
PIPE FITTER					
WELDER					
INST. MECH.					
ELEC. MECH.					
PAINTER					
MASON					
CARPENTER					
CRANE DRIVER				TOTAL MANPOWER COSTS	
LAGGER					
DRIVER					
HELPER				TOTAL MATERIAL COSTS	
MACHINIST					

REVERSE SIDE OF FIG.3a.

FIG.4

REPAIR REPORT

EQUIPMENT DESCRIPTION ______________________ EQUIP. No. __________

____

WORKS ORDER No. ______________ DATE OF REPAIR ________

REPORTED FAULT: ______________________________

____

____

DESCRIPTION OF FINDINGS: ______________________________

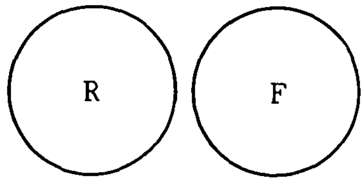
____

____

____

____

____



'AS FOUND' ALIGNMENT

DESCRIPTION OF REPAIRS(INCL.PARTS USED) ______________________________

____

____

____

DETAILS OF 'AS LEFT' CLEARANCES: ______________________________

____

____

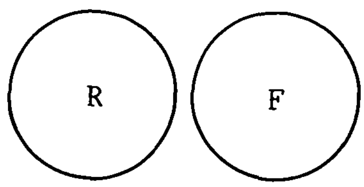
WORK WAS ADEQUATELY PREPARED:

YES: ________ NO: ________

SNAGS ENCOUNTERED: ______________________________

____

____



'AS LEFT' ALIGNMENT

RECOMMENDATIONS FOR IMPROVEMENT: ______________________________

____

DATE:........................ SIGNED.......................

FIG.5

MECHANICAL HISTORY CARD

EQUIP. No..............

DATE	WORK ORDER No.	DETAILS OF REPAIR

PLANT EQUIPMENT DESCRIPTION:	EQUIPMENT NUMBER:

FIG. 6

(Suggested headings)

PERFORMANCE MONITOR

YEAR ENDED: ____________________

OPERATING RESULTS					COSTS				
						WORKING EXPENSES			
STATION	QUANTITY PUMPED PER YEAR	AVERAGE HEAD	UNITS OF ELECTRICITY USED	OVERALL EFFICIENCY	COSTS OF UNITS USED	OPERATOR'S COST	STATION GENERAL WAGES	STORES IN- CLUDING HEATING LIGHTING	UPKEEP OF STATION WAGES and STORES

continued:

COSTS									
REPAIRS		TOTAL ANNUAL COST	PER W Kwh						
			WORKING EXPENSES					REPAIRS	
UPKEEP AND MOTOR	REMAINDER WAGES AND STORES		COSTS OF ENERGY	GROUP OPERATIVE WAGES	STATION GENERAL WAGES	STORES IN - CLUDING LIGHTING AND HEATING	UPKEEP OF STATION	PUMPS AND MOTOR	WAGES AND STORES

continued:

COSTS					MAN HOURS PER Kwh INCLUDING OPERATORS, GENERAL AND REPAIRS
PER W Kwh		PUMPED			
TOTAL EX - CLUDING CAPITAL	TOTAL IN- CLUDING CAPITAL	PER m^3 AT ALL HEADS	PER m^3 AT 1m HEAD		
		COSTS OF ELECT- RICAL UNITS	COSTS OF ELECT- RICAL UNITS	WAGES STORES REPAIRS	

FIG. 7

- MANAGER
  - DEPUTY MANAGER + clerks and assistants
    - Central laboratories
      - Manager
      - Chemist
      - Bacteriologist
      - Biologist
      - Laboratory technicians
      - Labourers
      - Clerks
    - Services manager + clerks and assistants
      - Stores manager
        - Stores assistants
        - Labourers
        - Clerks
      - Establishment officer + clerks
        - Organisation and methods
        - Work study
        - Incentive bonus
        - Personnel
        - Statistics
        - Welfare
      - Training officer
        - Instructor
      - Transport manager
        - Drivers
        - Maintenance staff
        - Labourers
        - Clerks
      - Accounts section
        - Manager
        - Clerks
    - Central maintenance manager + clerks and assistants
      - (1) Sub-area supervisor
        - Technicians
        - Fitters
        - Electricians
        - Instrument mechanics
        - Labourers
        - Clerks
      - (2) Sub-area supervisor
        - Technicians
        - Fitters
        - Electricians
        - Instrument mechanics
        - Labourers
        - Clerks
    - Operations manager + clerks and assistants
      - Sub-area (1) manager
        - Potable water treatment
          - Works engineer
          - Shift charge engrs.
          - Four gang operators
          - Disinfection assistants
          - Station clerk
          - Labourer
        - Distribution
          - Supervisor
          - Main laying, repair, leakage investigation, meter reading gang.
          - Clerk
        - Sewage engineer/ chemist
          - Shift charge engr.
          - Four gang operators
          - Labourers
          - Station clerk
        - Sewer supervisor
          - Sewer gang for cleaning, repairs and connections.
      - Sub-area (2) manager (same as sub-area 1)
    - New works engineers draughtsmen

PAPER 3

THE MANAGEMENT OF WATER SUPPLY AND DISTRIBUTION SYSTEMS

BY

GORDON DEVINE
WRc ENGINEERING
UNITED KINGDOM

INTRODUCTION

The water distribution network represents the largest capital investment of any component part of a water supply system. Yet until recently, it has received little active monitoring and control. The need to minimise costs in terms of energy, leakage, manpower, resource development - now a matter of worldwide concern - has focussed attention on distribution systems. New technology makes it possible to improve the cost-effective use of available assets with the aim of reducing operating costs while maintaining or improving standards of service. Modern technology based systems provide management information which helps to enhance day-to-day water distribution operations as well as other functions such as planning, maintenance, resource allocation, expenditure control and customer relations.

Control of the supply and distribution network will only arise from an improved understanding of its operation and the ability to exercise appropriate policies and decisions to satisfy consumers in terms of quality and quantity. This requires reliable and up-to-date information and the monitoring of certain parameters is the means whereby an indication of the system condition is provided and information is available to take control actions.

IMPROVED MGT AND CONTROL RELIES ON :

i) Information to undertake the day-to-day operations of the water system via effective monitoring and control.

ii) Management information for planning, maintenance, resource allocation, expenditure control and customer relations.

iii) Performance monitoring, optimisation of operations and data for modelling of systems.

The key parameters for monitoring excluding quality aspects, are pressures, flows, levels, pump status and valve status.

The means of control is primarily by using pumps and valves and the control parameters (excluding the treatment process) are the pressures, flows, levels and power consumption.

With current expenditure on power, leakage and bursts in the UK being in excess of £160M per annum, there are very worthwhile savings to be made.

This article outlines a number of the available techniques and indicates some of the advances made in, for example, leakage control methods; future developments in the broad field of water distribution management are also touched upon.

TECHNIQUES AND METHODS FOR MONITORING AND CONTROL

There are certain techniques which can assist operational control and automation of supply and distribution systems:-

Regular scheduling of pumps
Simulation of supply and distribution networks operation
Short term demand prediction
Leakage control
Pressure control

Over the past few years, work by WRc and others has shown that:-

i) Significant reductions in power costs associated with pumping can be obtained by use of the most efficient pumps, making maximum use of existing service reservoir storage in a system, and taking greatest advantage of the electricity tariffs applied by the electricity supply authority.

ii) Reductions in leakage levels are best obtained by the application of monitoring techniques such as district or combined metering schemes.

iii) Simulation of the operation of a system assists in deciding the least cost operating regime.

iv) The application of pressure control reduces leakage and bursts within the distribution system.

These topics are becoming increasingly important as energy costs rise, distribution systems age and are more prone to leakage and new sources of supply are more difficult and expensive to develop.

REGULAR SCHEDULING OF PUMPS

In water supply systems there is some flexibility with regard to choice of pumps, choice of source and pattern of pumping adopted.

The aim of pump scheduling is to minimise marginal costs of supplying water, whilst keeping within physical and operation constraints. Important features of cost are the electricity tariff structure, by pumping more during off-peak periods, the relative efficiencies of the available pumpsets, the head through which they pump and marginal treatment costs. Important constraints include consumer demand, reservoir capacities, abstraction limits, pumping capacity, and treatment works throughput.

Pump scheduling is the process of choosing which of the available pumps within the system are to be used, the periods when the pumps are to be run and the pump speeds. Commonly 24 hours is an appropriate scheduling period in this context.

Ensuring that all the constraints imposed on a large supply system are obeyed and that the pump schedules lead to minimum costs is a difficult task and almost invariably computer methods have to be used. Individual solutions must be tailored to particular supply systems, but a common procedure should be followed:-

- Assess savings
- Model the system
- Choose the algorithm
- Choose implementation style

There is a wide range of options for implementation, and the choice depends on many factors including the savings that may be made, existing computer, telemetry and remote control facilities. For example, a set of guidelines could be developed and implemented by operators and at the other extreme a computer solution is executed automatically each day, with automatic data collection and remote control of pumps.

SIMULATION OF SUPPLY AND DISTRIBUTION NETWORK OPERATION

Network analysis at a single point in time is well established and has been used for many years for design, planning and as an essential source of information for other activities such as pressure control, leakage control, and pump scheduling.

Fig. 1 is part of a schematic diagram showing the network analysis results produced by the WRc interactive-graphics program Watnet.

The use of these techniques in an operational context, as opposed to the design and planning mode, is enhanced by extending the traditional 'snapshot' to simulate the performance of the network over an extended time period. This allows the results of decisions concerning pump usage, for example, to be seen in terms of diurnal variations in pressures throughout the distribution network and reservoir levels.

The simulation capability can be put to advantage in a monitoring and control role to answer more immediate questions such as what will happen tomorrow and what is happening now?

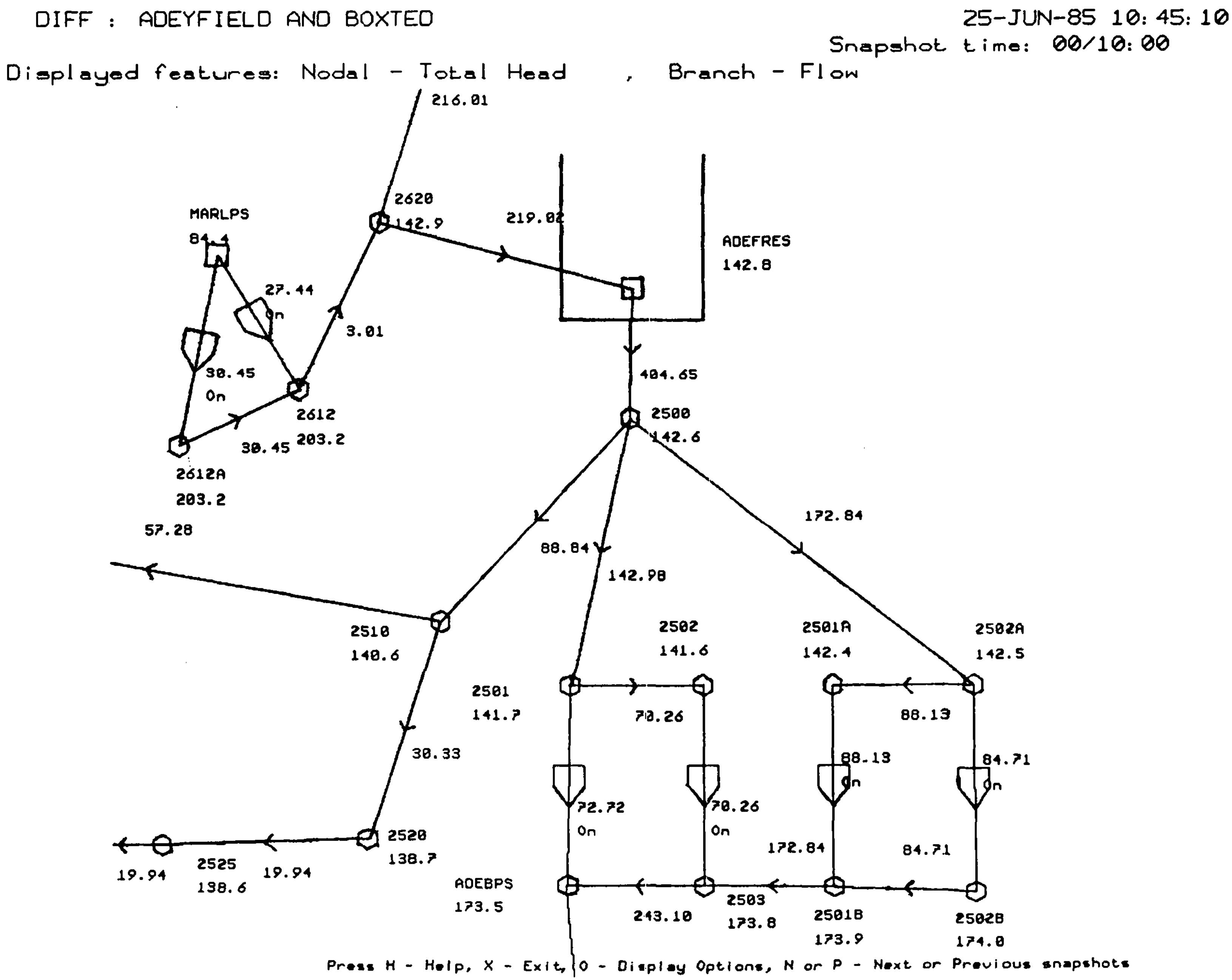


Fig. 1: Network Modelling

Running the network simulation program on a regular daily basis gives three capabilities. The first is to examine the simulation for the coming day for unacceptable operating conditions and potential problems. This is particularly useful when maintenance or unusual operations are planned.

The second capability is to link the simulation to a telemetry and telecontrol system and monitor the system behaviour and provide a means of automatic surveillance. Finally, simulation extends the information available from actual measurement points to providing further values throughout the system which can assist in monitoring levels of service.

SHORT TERM DEMAND PREDICTION

In order to determine optimum pump schedules for a day and also to simulate the operation of a supply and distribution system, consumer demand values have to be provided. The requirement is to predict demand for approximately 24 hours to 1 week ahead. In general the primary data is historical demand values for an area with most weight being given to the most recent data.

The requirements for a demand prediction vary with the area for which the predictions are made and improvements may be possible by the inclusion of meteorological data.

The relationship between storage capacity and demand is the important factor when considering accuracy and the detail needed for pump scheduling purposes. In most water supply systems, storage is equal to between 3 and 24 hours' demand. For very large reservoirs, prediction accuracy is not so important.

However for small reservoirs accurate prediction for small time intervals is necessary so that reservoir level constraints are not violated due to predictor error.

ASSESSMENT OF UNACCOUNTED FOR WATER

The UK report entitled "Leakage Control Policy and Practise" (Ref.1) published in 1980, provides a logical procedure for determining the most appropriate method of leakage control in any distribution system. This procedure is being widely implemented by the UK Water Industry with the result that there is a marked trend towards those methods of active control involving instrumentation, particularly in the context of district metering and combined district and waste metering (Figure 2).

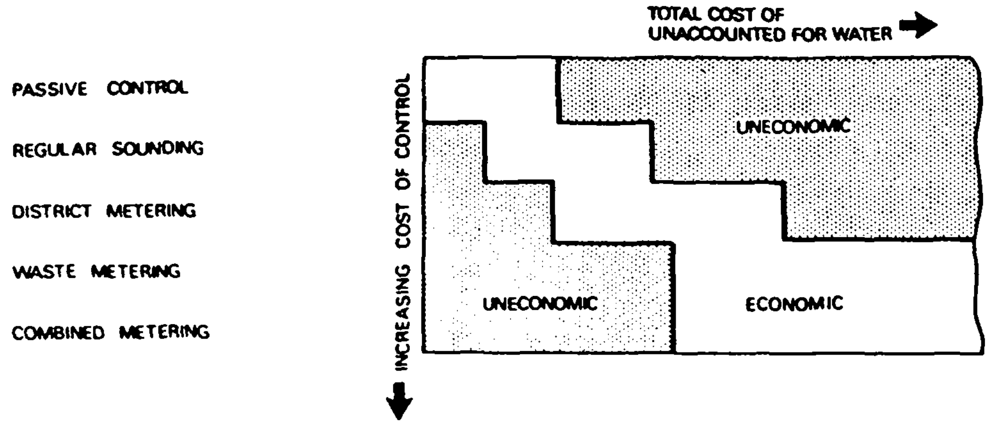


Fig. 2 Schematic diagram to illustrate how the selection of the most appropriate leakage control method varies for different costs of unaccounted for water

CAPITAL COSTS

Cost Savings

A reduction in unaccounted for water from adopting a more intensive control policy will produce savings in operation and also deferment of future demand-related capital schemes. (Fig 3)

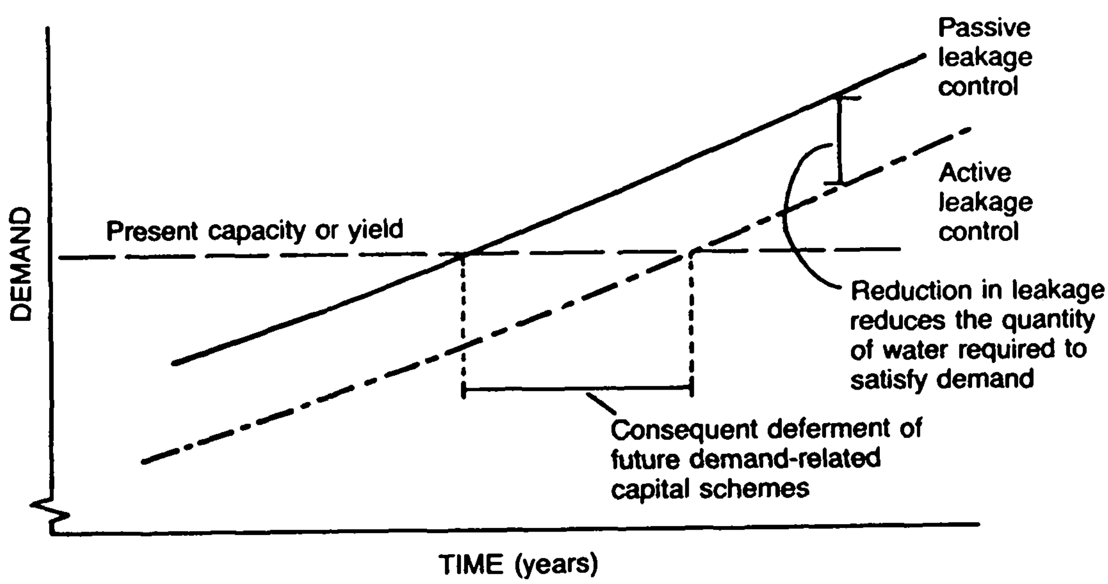


Fig. 3
Diagrammatic representation of the deferment of capital expenditure

District metering involves installing flow meters at strategic points within the distribution system so that areas of about 2000 to 5000 properties are metered continuously and the total quantity of water entering each district is recorded. Combined metering, as defined in 'Leakage Control Policy and Practice', involves the use of additional waste meters downstream of the district meters.

Although in the UK many water utilities regularly monitor the supply into and within their distribution systems, district metering as a method of control was not, until recently, widely practised. In many cases the instrumentation used was inappropriate and the districts too large to facilitate the identification and location of all but large leaks and bursts.

Recent developments in solid state data logging equipment have enabled much more information on daily demand and night flows to be obtained for little additional cost. This permits smaller changes in leakage to be identified more reliably than from simple meter readings.

Such an approach is being actively implemented worldwide and notably in Korea, Brunei and several states in Malaysia. In these countries it is not untypical to find unaccounted for water levels of around 50% and consequently the scope for reduction and the accompanying savings that accrue (and potential increase in revenue) is considerable. Experience has shown that for UFN levels of 80l/property per hour it is possible for this to reduced by some 20l/property/hour. On the economic basis outlined above, the pay back period for schemes which implement a more active control policy can be measured in months.

Further developments will be the linking of meters into a telemetry scheme. This has the advantage that more information can be obtained continuously, rather than intermittently, as from data loggers, and that this information is obtained on demand, so that for example, night flow information can be examined each day.

Depending upon the analysis methods, there are certain data requirements from the meters ranging from simple intermittent recording of minimum night flow, to trend analysis from regular monitoring of full diurnal consumption data.

If the data is telemeteted to a central point for control purposes, there are certain benefits:-

- no manual on-site readings
- wide coverage of the distribution system so that districts can be compared
- results can be presented daily to assist in manpower planning.

- an early alert to potential increases in leakage or bursts is provided.

PRESSURE CONTROL

During recent years it has been demonstrated that the effect of pressure upon leakage is far greater than theory would suggest and for a given reduction in pressure it has been shown to produce a proportionately greater reduction in leakage. Pressure control leads to more consistent standards of service to the consumer and reduces the incidents of bursts especially in the older parts of a distribution system.

There are basically four methods that can be employed to control pressures:-

- valving or zoning
- reducing pumping heads
- break pressure tanks
- pressure reducing valves (PRVs)

and the one with the most flexibility is the pressure reducing valve. It may not be possible to reduce pumping heads into a system and this could conflict with a previous aim of reducing power costs.

Recent developments have led to flow modulating valves which aim to produce a constant pressure at a critical point within the distribution system (Fig. 4). These modulating valves are being developed for automatic operation by loop control and telemetry or controlled locally by a micro-processor which has stored information of the system characteristics.

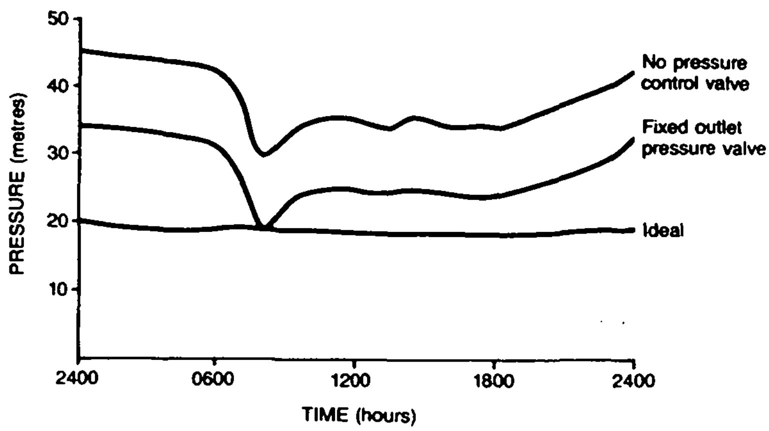


Fig. 4
Pressure at critical point in distribution system

AN INTEGRATED APPROACH TO CONTROL

Modern technology of data gathering, communications and computing can make available detailed monitoring information and enable varying degrees of sophisticated control to be implemented. The individual techniques of network simulation, optimal cost scheduling of pumps and analysis of district meter data are already established.

The integration of the various techniques of monitoring and control involves adopting a systems approach to operational management. This approach is being strongly supported in the UK Water Industry. Such an approach increases the potential for more effective and cost beneficial control and enables the costs of equipment, communications and software to be shared by several activities of modern technology based systems.

WRc have been actively involved in defining the requirements for a telemetry based control scheme in Malaysia where this approach has been used to:

1. Define user requirements to ensure the system supplied meets the operational needs.

2. Develop a functional specification for tender purposes.

3. Define instrumentation requirements.

4. Evaluation and implementation.

A decision support system (DSS) has been designed by WRc to embody the four techniques of cost-effective pump scheduling, network simulation, analysis of data for leakage control and short term demand prediction within a single computer-based system of hardware and software. This support system (fig.5) will possess its own database, interfaces with users and telemetry systems and supervisory software to control its activities.

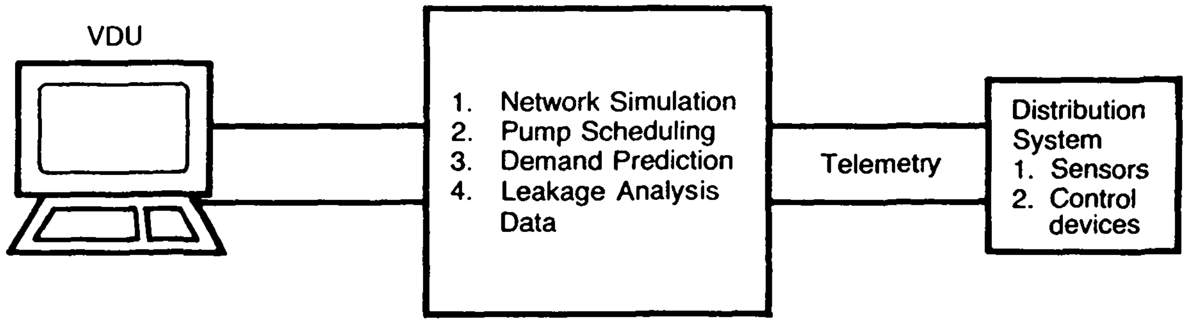


Fig. 5
Decision Support System (DSS)

It is intended to complement a range of telecontrol systems and essentially receives data monitored in water supply by a telecontrol system. The DSS provides appropriate techniques for control (e.g. schedules of pump use) and monitoring (e.g. leakage levels, expected flow and pressure patterns) which can be communicated to a control system or inspected by an operator. It also provides an archive source for general management data and allows "off line" use of techniques for operational design and investigation. A general telecontrol system served by the DSS will have the capability of monitoring appropriate parameters at outstations e.g. pumping stations, reservoirs and distribution sites, and for exercising control, particularly of pumping stations (Figure 6).

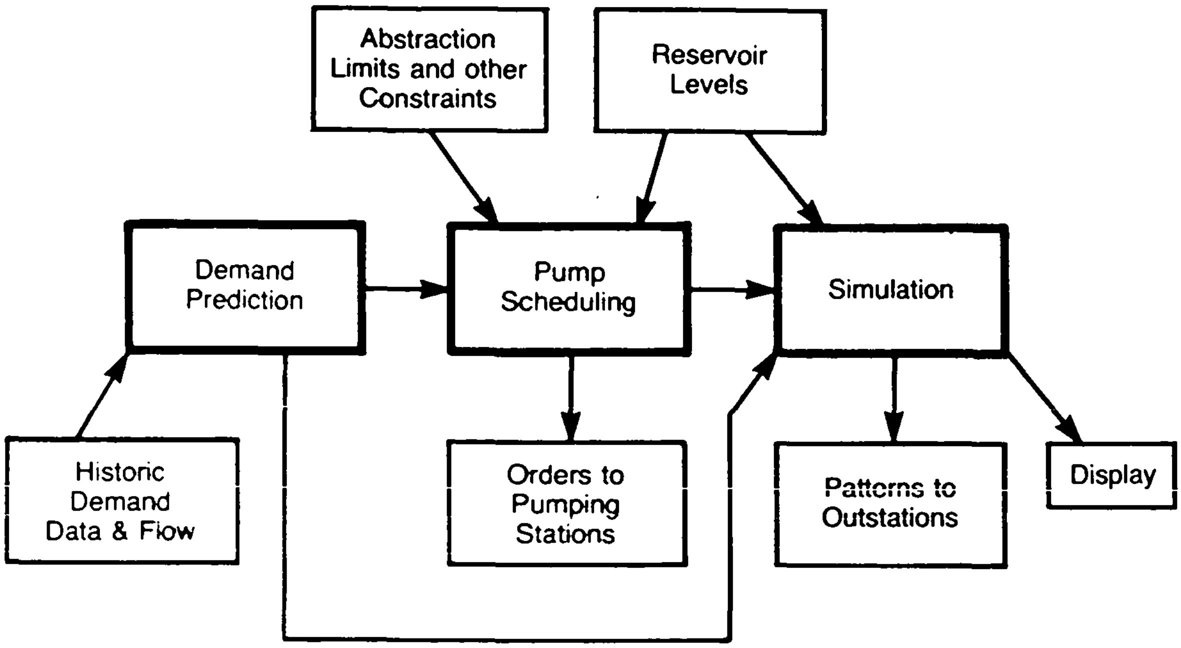


Fig. 6
Decision Support System – Linked Techniques

THE BENEFITS AND FUTURE APPLICATION OF TECHNOLOGY

The growth and influence of micro-technology within the UK Water Industry has been unmistakable. However it has been recognised that this can bring benefits in terms of overall efficiency but it also carries problems if a co-ordinated approach and strategy for its implementation is not adopted. A reduction in unaccounted for water (the components of which are leakage from the distribution system, underecording of meters, and illegal connections) by adopting a more intensive control policy will produce savings in operations and also defer demand related capital schemes.

The preparation of a user requirement specification must be the precursor to the development of functional specification and implementation of modern technology based systems.

The broad objectives and benefits of implementing remote monitoring and control systems with modern technology are seen as:-

i) More efficient deployment of staff

ii) Reduction in power costs by fully exploiting cheaper water sources and optimising pumping operations.

iii) Reduced leakage and greater utilisation of existing resources.

iv) Reduced travel time of staff and better planning for maintenance.

v) Reduced damage from mains failures.

vi) Improved operational flexibility and a more reliable system.

vii) Weaknesses in the system highlighted.

viii) Future forward planning requirements determined and an improved standard of service to the public.

CONCLUSIONS

Operational management is now moving from largely labour-based procedures to higher levels of automation for both monitoring and control. In order to be fully effective and cost-justified, the various components or modules must be flexible to accommodate changes in operational requirements as a result of increased information, knowledge and experience. It is now possible to identify areas where the operation of the supply and distribution system can benefit from the application of remote measurement, control and automation techniques.

Each user will have differing information needs in varying time horizons ranging from real time (now), daily to yearly and these needs should be recognised. Thus it will be necessary to merge data acquired in real-time with relatively static data bases in order to provide managers with timely and relevant information such that control can be maintained and improved in a dynamic environment. An example of this is the developments taking place with regard to digital mapping.

The information provided by existing and proposed ICA systems will become the key ingredients of future Intelligent Knowledge Based Systems (IKBS). Indeed the design of a control system should allow for the future inclusion of 'knowledge based' decision making software and will allow the utilisation of such techniques as self adaptive control and expert systems.

The application and use of the latest development in these technologies is as relevant to the Far East water supply and distribution systems as to any other part of the world. This will provide most benefits in ensuring the cost effective supply of water to the advantage of the consumer and distribution engineer alike.

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PAPER 4

INFORMATION SUPPORT FOR TRANSFER OF WATER TECHNOLOGY IN ASIA

BY

S. G. BHAT, S. K. KESARWANI AND MRS. S. N. SINNARKAR
NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE
NAGPUR-440 020, INDIA

In the wake of International Water Supply & Sanitation Decade concerted R & D efforts are being made to ensure reliable water supply to rural as well as urban communities. In addition to the traditional technologies new technologies including products and processes, related to water supply and treatment are being developed. Maximum advantage of new technologies could be taken , if these could be properly transferred and diffused.

Water Technology Transfer

Technology transfer cannotes the movement of technology from its generation through its dissemination and appropriate adaptation. In the context of water technology the technology transfer consists in the use of newly developed material, methods, equipment or chemicals for providing better or more economic solutions to purification or operational problems.

The process of water technology transfer involves:

i) Identification of relevant technologies in the field.

ii) Creation of awareness about new and improved technologies, their suitability, value etc.

iii) Transferring technology through suitable dissemination mechanism,

iv) Building a feedback system to enable orientation, reorientation or improvement of the transfer process.

For Asian countries there are three sources of technology:

i) Import of Western technology

ii) Development of appropriate technologies

iii) Dependence on traditional technologies

The technologies of developed countries often fail to function when they are transplanted in developing countries without suitable modifications. These technologies often have less relevance to the local needs. However, they could be adapted and assimilated. Transfer of water technology encompasses the collection, documentation and dissemination of water related information such as material required, performance and cost of using specific technology, transformation of research efforts into processes, products and services. The end result of information dissemination is to create awareness and stimulate interest in new technological developments.

Importance of Information

While information has a critical role to play in any field of science and technology its requirement in water related field is as basic as water itself. The communication of information is an essential link in the technology transfer chain. It has an important role in technology transfer by:

i) Contributing to the transfer and development of technology and strengthening the local technological capability and in the generation of local technology.

ii) Assisting in decision making process, research and practical application of technologies developed.

iii) Bridging the technological gap that exists between different countries by exchange of information.

iv) Design, selection installation and improvement of processes, materials, equipment, services and methods.

Information Requirements

Information pertaining to water related technology is required for a variety of purposes, decision making, planning, research, innovation, pollution control, monitoring, designing, operation etc., by a wide variety of personnel involved in different tasks. The various categories of users are:

i) Policy makers in the matters of water supply

ii) Administrators and managers of water supply programmes

iii) Financial and technical co-operation agencies providing advisory services, funding etc.

iv) Researchers, scientists and teachers

v) Products manufacturers

vi) Monitoring and testing personnel

vii) Construction agencies

viii) Consultancy organisations

ix) Maintenance and operational personnel

x) Field and evaluation personnel

xi) Training supervisors in charge of training programmes.

Information Support: Present Situation

Availability of information providing existing knowledge and experience in water supply and sanitation programmes varies widely in different Asian countries. In many cases savings in the use of scarce national resources can be achieved by systematically acquiring information from external sources and by applying this knowledge. Lack of access to information has proved to be an important constraint in water supply development.

The present scene of information support can be summarised as follows:

i) Individual interested in some facet of water technology information may have a difficult time for obtaining desired piece of information as it is scattered in different sources. Much useful information is hidden in published literature existing in diversified publications.

ii) Information about designs and solutions found either in the home country or in the neighbouring country is not readily available. Feasibility study reports, reports of successful projects, state-of-art reports in water supply are compiled, however their existence is not known. Finding out relevant information thus becomes a tiresome job.

iii) Information about drawings, designs, specifications, standards, patents, design models is available in scattered sources.

iv) Certain technologies are utilized while other potential technologies are not used at all. A serious handicap to the development of water supply programme is the lack of information services for the transfer of technical information.

v) Many a times R & D workers in the field are not aware of what others are doing and what has already been done.

vi) Field personnel concerned with water development are absorbed in day-to-day problems and lack necessary time to find pertinent information.

vii) Facilities for documenting the information generated and its dissemination are not available in most of the Institutions.

viii) There is no established mechanism for free flow and transfer of information.

ix) Linkages with other organisations either do not exist or are very poor.

Transfer of Available Technology

Appropriate technologies developed elsewhere have to be utilized and suitably adopted so as to accrue maximum benefit. For example, information about low cost and appropriate solutions available in other developing countries do not reach the actual user in India. Research carried out in developing countries in Asia as well as in other parts of the world are required to be tried in field. Advances in research in Water Supply & Sanitation have not been applied in practice as in the case of waste treatment. While there is lot of talk about simple chlorination devices, use of different material for water distribution, low cost sanitation options, very little has been tried in the field. This is probably due to lack of availability of information.

Similarly many water related technologies have been developed in India and could be tried in other Asian countries. Some important technologies developed in India and other developing countries have been listed in Table I and Table II respectively. The lists are not conclusive but are only indicative.

Strengthening Information Support

All this warrants to take some immediate measures to strengthen information support for transfer of information. Some of the measures are described below.

i) Packaging and Consolidation of Information

Many publications that are intended to provide answer to some specific needs or problems are not in an acceptable format. Many a times they are too technical and cannot be understood by administrators or semi-technical personnel such as operators etc. Information is also scattered in various sources and it is many times necessary to consolidate and repackage. It is felt that while consolidating or repackaging the information, different categories of users may be kept in view and different information packages can be compiled.

These can be supplemented by News Letters, Technical Digests, Capsule Reports, State-of-art Reports, Directories, Handbooks, Buyers Guide etc.

ii) Establishing Documentation Centres

Documentation Centres can be established at various places or at least one in each country which will be charged with the responsibility of collecting, analysis, organising, storing and disseminating information. These centres can collect information from other countries and in turn would disseminate information generated from their own country.

Various services which the documentation centres should try to provide have been given in Appendix I.

iii) Establishing Information Network

In addition to the efforts done by agencies like The International Reference Centre (IRC, The Netherlands), The World Bank (Washington, U.S.A.) and the Environmental Sanitation Information Centre (ENSIC, Bangkok, Thailand) etc., for better technological exchange programmes amongst the developing as also the less developed countries information linkages need to be further strengthened. With wide range of information providers and users the problem of co-ordinating their activities crops up. This can be achieved by establishing a network. The value of such a network for Asian countries is quite necessary as most of theorganisations work in isolation. The network would result in increased availability, accessibility and ultimate utilization of water technological information.

Efforts done at NEERI (India)

National Environmental Engineering Research Institute, Nagpur, India, has been trying to provide information support in the field by undertaking various activities. Some such information activities are highlighted below:

i) Current Awareness Service

"A Guide to Current Literature in Environmental Health Engineering and Sciences". The guide serves as a medium for dissemination of current information about the latest trends and practices in the field. Besides serving as a current awareness tool the guide also serves as an aid for retrieval of relevant information.

ii) Literature Search & Bibliographical Service

Literature searches for finding pertinent information are carried out for R&D personnel. Bibliographical services are also provided both in anticipation and in response to requests.

iii) Selective Dissemination of Information

This is a personalized service through which concerned persons are informed about the existance of the most recent information which would be of relevance to their needs.

iv) Help for Building up a Collection of Documents pertaining to Water Technology.

Help to different organisations in building their collection of environmental documents by suggesting appropriate titles and methodology for proper procurement is rendered. Guidance for setting up "Environmental Libraries" is also provided to organisations approaching for such assistance.

v) Repographic Services

Xerox copies of literature available in NEERI are provided on request at nominal charge.

vi) Literature Search & Documentation Facilities

A rich collection of literature - a fund of well organised information and good back up library service of the Institute has been a boon to industrialists, scientists and research scholars who are availing of this facility extensively against payment.

vii) Indian Literature in Environmental Engineering
A Bibliographical Review

This publication presents bibliographical details of papers published by Indian Scientists in Indian as well as foreign periodicals and also papers presented at various conferences, seminars and symposia both at National and International level. It serves as a tool for retrieving data and information about the R&D interalia. It also serves as a feeder service to International Secondary Information Services.

viii) Research in Retrospect

NEERI is attempting to take stock of the work done in India in the field and has been collecting information about the earlier work done in the country, which is scattered in various reports, periodicals, symposia proceedings etc. As a first step work done by NEERI has been documented in the publication entitled "NEERI Research in Retrospect - 1959-1983 - A Bibliographical Review".

ix) Directory of Environmental Organisations in India.

This directory provides information about organisations which are conducting, promoting or encouraging R & D activities in the field. It has been acclaimed as a usual reference book and is helpful for undertaking well planned and co-ordinated activities.

x) Research Programme in Environmental Engineering & Science in India.

The publication provides information on research being carried out in India and provides detailed information about (a) the projects under progress, (b) investigators and the project on which they are working, (c) Institutions where the work is being carried out and (d) the research sponsored by various organisations. Publication is useful to establish meaningful dialogue amongst R&D personnel to avoid duplication of efforts.

xi) Environmental Pollution Control; A Select Bibliography

Information Resources in the field have been highlighted and is helpful for selecting relevant publications in various areas encompassing environment.

TABLE 1 - WATER RELATED TECHNOLOGIES DEVELOPED IN INDIA

i) Chlorine Cartridge for continuous disinfection of well waters using single pot and double pot earthen wares.

ii) Membrane Filter Papers and Filter Holders.

iii) Nalgonda Technique of Defluoridation of Drinking Water.

iv) Domestic Defluoridation Unit.

v) Defluoron - 2, Synthetic Carbonaceous Sulphonated Material.

vi) Iron and Manganese Removal Unit.

vii) Split Coagulation Package Water Treatment Plant.

viii) Ion Selective Electrode Technique for Measuring Residual Chlorine & Mercury.

ix) Slow Sand Filtration.

x) Chlorine Ampoules

xi) Chlorine Tablets

xii) Package Water Treatment Plants.

xiii) Rural Latrines

xiv) Hand Pumps (India Mark II).

xv) Ceramic Candle Water Filters

xvi) Chloroscope

xvii) Coconut Shell as Filter Material

xviii) Coagulant Aids from Natural Products

TABLE II - WATER RELATED TECHNOLOGIES DEVELOPED BY OTHER COUNTRIES

i) Rainwater Catchment

ii) Low cost Water Jars

iii) Tubewell Hand Setting

iv) Tubewell Casings and Screens

v) Tubewell Sand Boiler

vi) Infiltration Well and Galleries

vii) Alum Dosing Tower

viii) Bamboo Water Pipes

ix) Public Stand Post

x) Bellows Pump

xi) Plastic Taps

xii) Bamboo Water Storage Tanks

APPENDIX

Following are some of the Information Services which should be rendered by the Documentation Centre.

1) Current Awareness Service:

Purpose:- To keep the engineers, technicians, management personnel abreast of current development in the field.

2) Selective Dissemination of Information:

Purpose:- To provide pin-pointed and latest information based on the interest profiles of the users.

3) Digest Services:

Purpose:- To draw attention to solutions found elsewhere for technical problems. The emphasis would be on practicability, cost reduction, simpler techniques and equipment. Similarly, information on measurements, analysis and control methods would be given, besides new applications of materials.

4) Management Information Service:

Purpose:- To disseminate current scientific, technical, commercial and techno-economic information from the management point of view.

5) Data Service:

Purpose:- To collect in a convenient form and disseminate scientific, technical and techno-economic data on different subjects of interest

6) News Brief Service:

Purpose:- To disseminate general information pertinent to Water Supply and Sanitation which would be of interest to various categories of personnel.

7) Package Information Service:

Purpose:- To disseminate Information on a specific topic. This also involves re-packaging information, wherever necessary.

8) Bibliographic Service:

Purpose:- To provide a list of references on a specific topic by carrying out retrospective search.

9) Document Delivery Service:

Purpose:- To provide copies of documents which would be most relevant to the work of engineers and field personnel.

PAPER 5

MAINTENANCE FOR HIGH TECHNOLOGY AND LOW-COST SYSTEMS

BY

JOHN PICKFORD
WEDC GROUP LEADER
LOUGHBOROUGH UNIVERSITY OF TECHNOLOGY
UNITED KINGDOM

INTRODUCTION

In a report to the United Nations General Assembly earlier this year (1) the Secretary-General gave some details of achievements during the first three years of the International Drinking Water Supply and Sanitation Decade. Although there was a disappointing decline in the number of rural people reported to have sanitation, the population with water supplies has increased everywhere. Between 1980 and 1983 an additional 346 million people were provided with water. The statistics, provided by the World Health Organization, show that 1330 million people in developing countries are now served with water supplies.

However, experience in many countries leads to concern about the actual level of service provided. Statistics are one thing; accessible, reliable, year-round, day-long, consistently-safe water is something else. As Mike McGarry wrote nearly a decade ago (2) "administrative personnel are more interested in numbers of facilities installed than in their effective use; seldom are post-project evaluations undertaken". In the past there has been much criticism of international agencies and bilateral donors because they were only concerned with providing funds for capital works - for the initial provision of facilities. Recipients of loans and grants are expected to find the necessary resources for subsequent operation and maintenace.

There is now much greater understanding of recipients' need for help in keeping facilities going after construction. "Operation and maintenance" became catchwords of the Decade no less than "appropriate technology", "community participation" and "institution building". There is increasing consideration of the whole life of a project as a single entity, from the time when it is only a "twinkle in the eye" of those who propose it, through years or decades of useful life.

Hence maintenance as it is considered here includes operation and the management necessary to ensure that water and sanitation continue to be available as originally planned, or as later found to be required. In some cases maintenance may extend to renovation or rehabilitation when wear and tear demand replacement of whole or part of the facilities.

POOR MAINTENANCE

A WHO publication (3) gives the following warning:

> Poor operation and maintenance practices have in many instances largely contributed to a decreased utility, or even to an early failure, of newly constructed water supply and sanitation facilities. Thus, the health and social benefits for which the facilities were designed have not been realised; capital investments have been wholly or partly lost; and scarce resources, which could otherwise have been

utilized for further development, are being expended on the premature replacement of equipment or for the rehabilitation of facilities before they have been in operation for the full span of their useful lives.

Unfortunately, the "many instances" of poor maintenance have occurred in almost every country. Even in the most affluent of industrialized countries things are not what they ought to be. Twenty per cent of the outbreaks of waterborne disease in the United States are due to inadequate maintenance and improper operation of water treatment and supply. In 1971 Arceivala (4) reported that in 80% of Indian water treatment plants not even the alum dosing was being done properly and 50% of sewage treatment plants were completely out-of-order. Recently Strauss (5) reported on a community water supply and sanitation programme in western Nepal: "although two-thirds of project villages had appointed a village maintenance worker, hardly any preventive maintenance was provided".

From my personal experience I could cite examples of bad maintenance from most of the thirty-odd developing countries I have visited. I have no reason to believe that what I have noticed is any different from other people's observations. I have often seen sedimentation tanks completely full of sludge, valves that will neither open nor close, and leaking taps, pipes and tanks. Amongst my most vivid memories are a comparatively new sewage works in Pakistan where only one of five percolating filters was operational, another works in India where the total flow passed so quickly through one of four sedimentation tanks that no sludge settled, and a beautiful little works in Sri Lanka where all the ironwork had been freshly painted (a most unusual sight) but the people in charge had not the slightest idea of the correct mode of operation so a design retention time of several hours was reduced to a few minutes.

When high technology is involved the excuse for badly-maintained equipment is that the operators do not understand it, or that technical expertise and spares are not available locally. However, poor maintenance is at least as frequently found in the most simple of facilities. For example Kerkhoven (6) notes the infrequent removal of the schmutchdecke from slow sand filters - sometimes it is only removed once or twice a year. In some places the filter bed is dug up for cleaning; in others too thick a layer is removed.

From what has been said and written about it, leakage from distribution mains is probably the most serious of maintenance defects. In many a town and city the present shortage of delivered water could be entirely eliminated if there were no leaks. Losses in distribution systems affect the most sophisticated industrial centres as well as small market towns. For example, in Hong Kong 30% of the supply is unaccounted for (7); in Manila during the period 1970-78 the loss was 50% of the supply (8). Hong Kong's losses are partly because in high-rise buildings the water is metered at the outlet from the roof tank. As they do not pay for lost water consumers have no incentive to repair leaks between their plot boundaries and the tanks, even though maintenance of these pipes is their responsibility. In

Manila's water distribution system excessive losses caused low pressure. In unimproved pipes little water was lost through small cracks. However, when a proper maintenance system was instituted and major leakage was cured, the pressure increased. Then a great deal of water escaped from the small and previously unnoticed cracks.

In an attempt to reduce losses from poorly maintained distribution systems many water authorities provide only an intermittent supply. Dr Raman (whose recent untimely death we mourn) wrote in 1978 (9) that intermittent supply was a method adopted by almost all water undertakings in India. For example in Ahmedabad water was only available for 5½-6 hours a day and in Aurangabad for 3½ hours a day. The almost inevitable consquence of intermittent supply in leaking pipes is the ingress of contaminated water. So the consumers not only have the inconvenience of restricted hours of delivery. When water does come from the tap it is unsafe.

Poor maintenance of water supplies is common enough, but generally the maintenance of sanitation is worse. If water pumps fail and no water is delivered there is often so much political rumpus that something is done somehow. If sewage pumps fail nobody seems to bother - a manhole is broken so that sewage escapes and flows down nullahs to form stagnant fetid pools. Worst of all are public and communal latrines, which are often so disgusting that no self-respecting member of the public or community will use them. Strangely, community facilities in refugee camps may be exceptions to the usual deplorable pattern (10).

REASONS FOR POOR MAINTENANCE

The reason most commonly given for poor maintenance is lack of funds. Sometimes this is only an excuse for lack of effort, but in many places - probably in the majority of developing countries - the budget for recurrent expenditure either does not exist at all or is totally inadequate. I clearly remember talking to a sewage works manager some years ago. He was struggling against incredible odds to keep a large and comparatively modern works functioning. He told me that year by year his authority had cut his budget. By the time I met him the annual allocation of funds was only sufficient to pay off the loan repayments. Nothing was allowed for lubricants, spares, materials of any kind, or even for the wages of his workers. Fortunately his sedimentation tanks and sludge beds were still in working order and he was able to sell sufficient dried sludge to farmers to pay some wages and buy a few necessary supplies.

Strauss (5) reported the evaluation of 45 water supply schemes in Nepal and found that 36% had serious shortcomings and 16% were non-operational. He analysed the causes of the defects and found that poor design accounted for 27%, poor construction 78% and natural disasters 11% - obviously some defects had more than one cause. However, failure and unsatisfactory performance are often found when the initial design and construction were good.

At least they were good by accepted international standards, which may not be the same thing.

DESIGN

Designs which result in early failure or diminished usefulness may be intrinsically faulty. Insufficient steel in a reinforced concrete slab can cause failure when heavily loaded whether the structure is in Baltimore or Bangkok.

Other designs are unsatisfactory because they assume that the same conditions apply throughout the world: no allowance is made for differences of climate, or differences in the availability of diesel fuel, electricity, spare parts and skilled labour, or differences in the habits of users. Such designs ignore the comment in an old book about sewage disposal in the tropics (11), "those who are familiar with tropical countries recognize at once that the conditions obtaining in oriental towns cannot be said to resemble those of western cities".

The story is told of a relatively new water treatment plant in the capital city of a developing country. Much of the equipment and instrumentation was inoperative. The resident engineer of the expatriate consultant was asked how the plant would have been designed differently for his own city. Perhaps remembering the international reputation of his firm he proudly replied "we did everything in this plant that we would have done for a plant for ourselves" (12). Unfortunately such disregard of what is appropriate locally is not uncommon, whether the designer is expatriate or indigenous.

A third fault which results in premature failure is disregard of operation and maintenance during the design process. Vertical flow clarifiers are no good if the electricity supply is intermittent (13). Gravity filters are more satisfactory than pressure filters because the operator can see what is happening when a gravity filter is cleaned.

Engineers often ignore post-completion performance. This is partly due to their own education. Civil Engineering students are taught theory and analysis, most now learn something about design, a few hear about construction technology and management, but rarely is anything said about maintenance.

In the real world the actual time devoted to a project before completion is usually quite short - often only a year or two. But the "design life" may be thirty or more years, and the effective working life may be much longer - if proper maintenance is provided.

ACCESSIBILITY AND COMMUNICATION

Too often equipment is inaccessible. Valves are placed in such positions that only a dwarf or a contortionist could operate them. It should be possible to reach sites where maintenance has to be carried out throughout the year. So allowance must be made for seasonal variations of rivers and for swamps that develop following rainfall.

A well-developed communication system is essential. There should be a referral system for back-up services and rapid response to emergency calls for assistance. For good maintenance of high level technology and low-cost systems, and everything in between, it is important to have a policy which clearly defines the distribution of responsibility.

Manufacturers' maintenance manuals for technical equipment should be available where they are needed - near the equipment - and not kept in a far-away office. However, manufacturers' literature often seems to be written so that only the manufacturers' staff can understand it! To supplement such manuals it is well to prepare clear step-by-step instructions in a language which the people on the spot can understand.

RECORDS

Carefully-kept notes of what maintenance is done, when it is done and by whom it was done can be most effective in ensuring that routine maintenance is satisfactory. Records may allow critical examination of performance to facilitate planned maintenance (14). There is, of course, a danger of trying to obtain too detailed records - trying to collect too much information. Whoever has to complete records should understand the reason for providing information and should realize that someone else looks at the records, checks them and makes use of them. Otherwise there is a danger of the often-observed stupidity of "making-up" the records - claiming that work has been done which was not attempted, entering imaginary figures for dial and digital read-outs, and so on. In a high-tech situation information can be recorded automatically, but once again there is no value in keeping records just for the sake of keeping them. A question that should always be asked is "what use is this information?".

MANPOWER FOR MAINTENANCE

After shortage of finance the most common reason given for inadequate maintenance in developing countries is a lack of skilled manpower. To some extent this is valid, particularly in terms of technical skills to cope with technical equipment. Part of the solution to this problem lies in matching equipment to already available skills - making the technology appropriate. This may mean using processes such as slow sand filtration that use unskilled labour for most maintenance tasks. Kelkar (15) reports that only two pump operators, one plumber and some part-time labourers were required for a slow sand filter serving 35 000 people.

In many countries the often-repeated plea that there are not enough trained maintenance technicians of the right calibre is certainly true if electronic and hydraulic controls are part of the equipment for water supplies and sanitation. High technology equipment calls for high technology technicians. The most useful guideline in such circumstances is to plan the maintenance programme to make the most effective use of the time of skilled people. Can more-readily-available clerical staff work with specialist technicians to take over report-writing and the keeping of records?

Over-emphasis on academic ability often obscures the availability of practical skills that can cope with most non-specialist maintenance. There are now few places without local mechanics. They often work in the "informal sector", self-employed or in a small joint venture. Many are excellent workmen but have no paper qualifications. So they may be denied the opportunity of appointment to the establishment of water and sanitation authorities.

Good management can make effective use of whatever skills are available by having

+ clear understanding of all maintenance tasks
+ job descriptions for all posts
+ appropriate tools, plant, transport, fuel, spare parts, chemicals, drawings and detailed instructions available when required
+ adequate supervision
+ adequate levels of pay
+ promotion opportunities
+ an effective training programme

There is danger in making overtime payments to staff called out for emergency work. Routine maintenance may be neglected in the hope that an emergency will arise.

Carefoot has pointed out repeatedly (eg 16) that human resources development (HRD) is not enough. It must be backed by and form part of effective human resources management. Nevertheless, the importance of training is a constant plea by those responsible for high technology and low-cost work alike. When discussing slow sand filtration Kirkhoven (6) commented "although operation and maintenance is relatively simple, it must be properly performed by a caretaker who has sufficient background knowledge and the necessary skills. Obvious as this may seem, the programme has shown this to be one of the major causes of failure - operators have received insufficient training, sometimes none".

Mostertman (17) suggested that training for operation and maintenance has three requirements:

+ trainees should do things with their hands
+ they should learn about organization and management
+ allowance should be made for local conditions

RURAL WATER SUPPLY AND SANITATION

Of necessity most rural facilities come into the "low-cost" category, although the drilling equipment for deep boreholes is sometimes both expensive and sophisticated. Haman (18) reported the use of television for down hole inspection in connection with deterioration of well performance in Sabah, Malaysia. Encrustations caused by iron bacteria were dissolved by acid, especially oxalic acid.

One of the difficulties in providing maintenance in rural schemes that require technically skilled attention is the unwillingness of qualified staff to work away from urban centres where there are greatest prospects for promotion. One idea for overcoming this is to allow technicians to retire early with full pension if they agree to settle in their home rural area. There they maintain the system and train local people.

Rural water supply programmes often consist of a large number of small units, with corresponding difficulties of maintenance. In the Hang Chat District in Lampong Province, North Thailand, with 61 villages and a total population of 42 000, PVC hand pumps were installed for easy maintenance. Seven hundred people were trained in operation and repair over a period of five days (19).

Community responsibility for maintenance is the essence of many rural programmes. In Malawi "a critical element in the maintenance programme is the user's sense of commitment to and ownership of the water system" (20). In few countries is there so great a commitment to community participation as there is in Malawi. There the communities are involved during the planning stage and so are able to influence design to make it appropriate for their ability to maintain. Willingness of communities to participate in maintenance depends on whether the facilities meet their perceived needs in terms of convenience, quality and quantity - for animals and garden watering as well as domestic use. In north Thailand (19) there was an initial refusal by the villagers to realize that they had any water supply problem at all.

In Malaysia it is reported (21) that all the villagers agreed "to work out a maintenance schedule at community and household level ... many of the male users showed a keen interest in learning more about the installation and maintenance of the pumps". It is unusual to read about male users, whereas there is a continuous stream of literature about women and their role in water supply and sanitation.

In Sri Lanka women have been trained as caretakers for several years. They are also manufacturing pumps in a pilot project sponsored by IDRC of Canada and the national Sarvodaya movement, learning new skills that can help them later with maintenance in their own communities (22,23). In Nepal women are encouraged to use pipeline routes as village paths and report leaks to water caretakers (24).

While maintenance is often a community responsibility, there are places where individual householders look after maintenance, and others where the water authority accepts the duty itself. In Bangladesh 1150 rower handpumps were sold in two seasons. Nearly three-quarters of the buyers were able to show that they could carry out routine maintenance on their pumps (25).

The UN Secretary-General's 1985 Decade report (1) notes that "a significant feature of the rural training programmes being developed in China and the Philippines is the definition of accredited skill standards for operation and maintenance against which some thousands of rural operators will be trained, tested and certificated". In northern Ghana (26) and elsewhere a three-tier system has been introduced with bicycle or motor-bike transport at the lowest level, mobile lorry-mounted workshops and well-equipped central workshops. However, the UNDP/World Bank handpump project is firmly wedded to the village level operation and maintenance (VLOM) principle. Only when satisfactory VLOM pumps are available "will it be feasible to transform the maintenance system from a reliance on expensive motorised mobile teams of skilled mechanics paid with government funds to one where the village or group of villages carries out and pays for pump maintenance and repair" (27). It has also been suggested (28) that "it is immediately obvious that the three-tier system has been designed by engineers and economists who have never lived and worked in a village" as it shows no confidence in the ability of villagers to carry out their own maintenance. This article further comments that the stability, continuity and credibility of any community-based programme depends on how much village knowledge, skills and experience are used for the people' own development.

* * * * * *

Whether it is carried out by individual householders, by the community or by government-financed authorities, good maintenance is essential if full benefit is to be obtained from all the new water supply and sanitation schemes being provided as part of the International Drinking Water Supply and Sanitation Decade.

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PAPER 6

ASPECTS OF A MEDIUM SCALE IRRIGATION PACKAGE PROJECT IN THAILAND

BY

J. R. HENNESSY, PARTNER AND J. H. ANDREWS, CHIEF ENGINEER
SIR ALEXANDER GIBB & PARTNERS, CONSULTING ENGINEERS
READING, UNITED KINGDOM

INTRODUCTION

In recent years the Government of Thailand has been giving priority to small and medium scale irrigation projects. One reason is that the potential for the more extensive schemes in the flood plains of the country's major rivers is now limited since the existing water resources have already been largely exploited. Another reason, generally supported by the international lending agencies, is that it has been found from past experience that management problems associated with the larger projects have often led to a shortfall in the expected benefits. More emphasis is therefore being placed on the development of smaller, geographically more diverse projects where water resources are not yet fully utilised, and on improving the efficiency of existing projects.

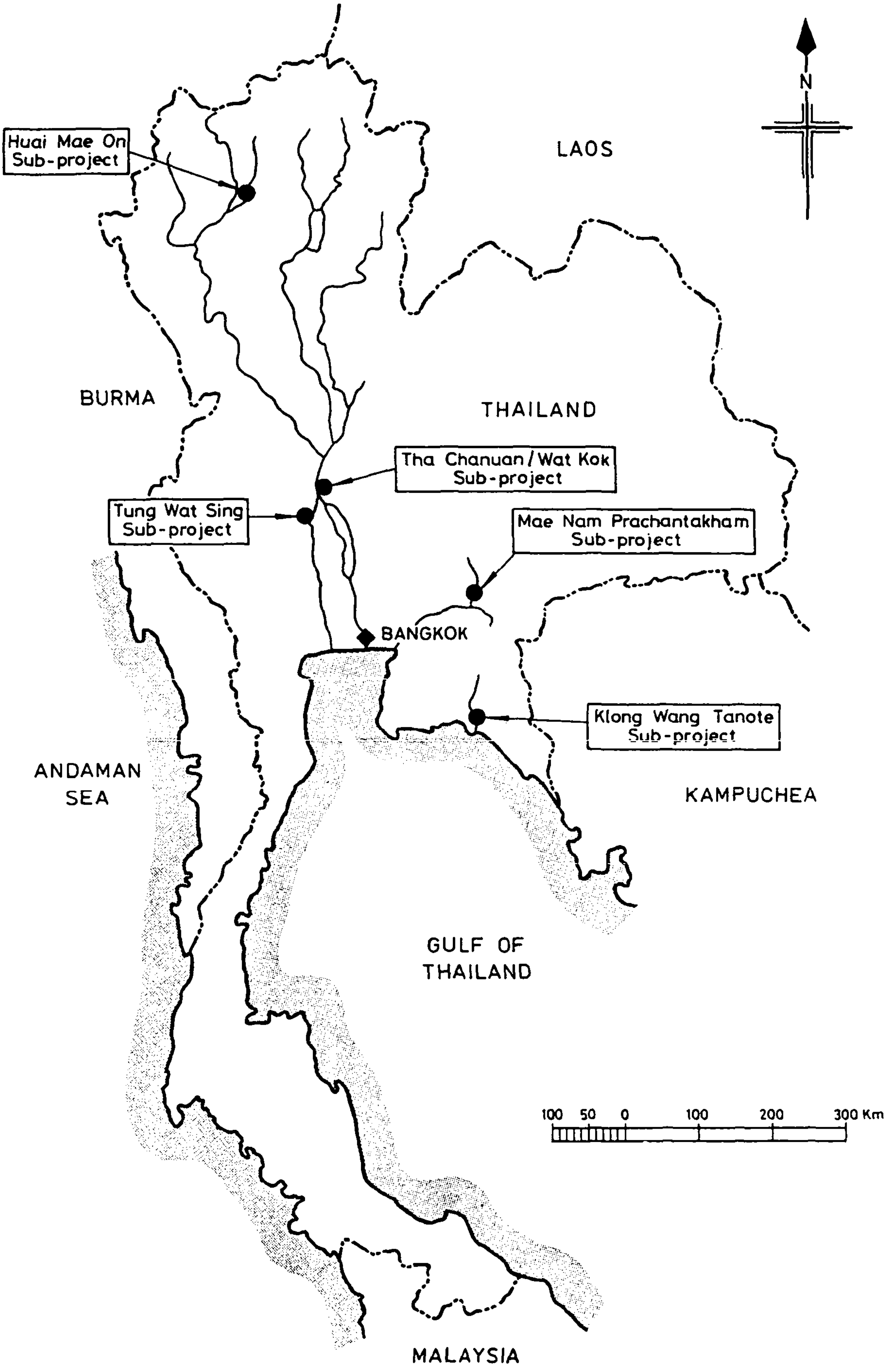
The Royal Irrigation Department of the Thai Ministry of Agriculture and Cooperatives has identified a large number of potential medium sized projects in the country over a wide geographical area. The five schemes forming the subject of this paper were selected as one of the first groups in this major programme to be implemented and, in 1981, under a technical assistance grant from the Asian Development Bank (ADB), a feasibility study of the so-called Medium Scale Irrigation Package Project was carried out by Sir Alexander Gibb & Partners of UK in association with TEAM Consulting Engineers Co. Ltd. of Thailand.

The basic purpose of the project is to increase agricultural output and farm income, generate employment opportunities and improve the living standards of the people in the five sub-project areas whose locations are shown in Figure 1.1. The individual irrigable areas vary from 900 ha to 11 000 ha, with the whole package covering a total area of approximately 19 000 ha and affecting 3 300 families.

After appraisal of the project, the ADB agreed to make a loan to the Kingdom of Thailand for implementation and, early in 1983, the Royal Irrigation Department appointed Sir Alexander Gibb & Partners, in association with ELC Electroconsult Engineering SA and TEAM Consulting Engineers, to carry out detailed design and assist in the supervision of construction of the five sub-projects. The descriptions which follow illustrate the diverse engineering content of the package.

2. DETAILS OF THE FIVE SUB-PROJECTS IN THE PACKAGE

2.1 Huai Mae On Sub-Project



LOCATION OF SUB-PROJECTS

Figure 1.1

2.1.1 Service Area

The sub-project area of about 900 ha lies on both banks of the Huai Mae On river, approximately 20 km east of the town of Chiang Mai and at an elevation of about 400 m above sea level. Mean annual rainfall is 1 100 mm and, during the wet season, dry periods in excess of 10 days are not uncommon and result in a reduced rice crop. During the dry season irrigation is essential for any crop.

The present irrigation system supplies supplementary water for the rainfed crops in about 17% of the sub-project area by means of several weirs constructed in the river. In the remainder of the area, drought conditions occur about once every five years and there are periods of moisture stress every year.

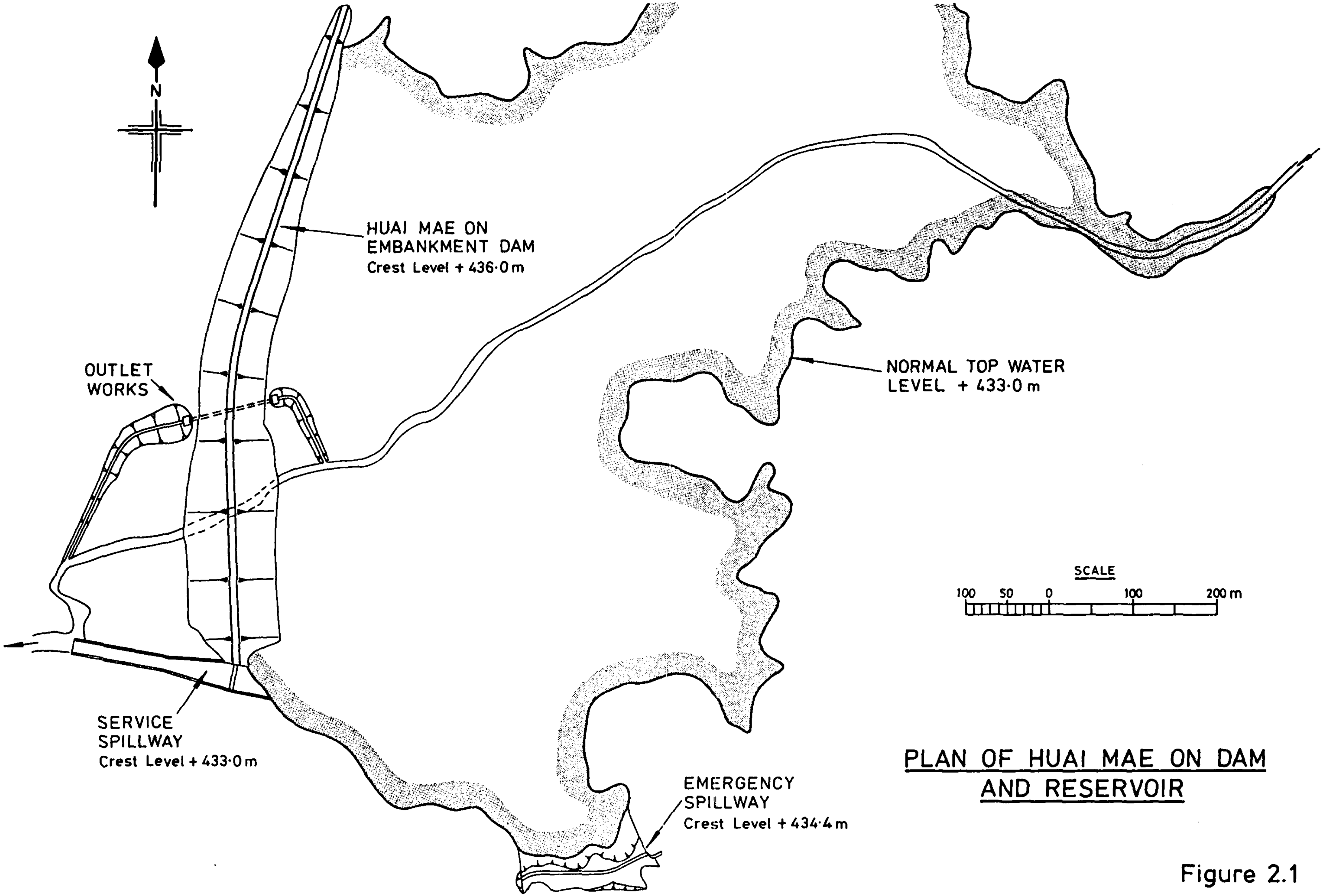
The dominant crop in the wet season cropped area is rice, with tobacco taking up the remainder. During the dry season various crops are grown in the irrigated 17% of the sub-project area, including tobacco, groundnuts, garlic, shallots and chillies.

The purpose of the project is to store water by means of a dam on the Huai Mae On and thereby to provide a supplementary irrigation supply to the whole area in the wet season and to irrigate 75% of the area in the dry season. The reservoir will have a live storage capacity of approximately 4 million cubic metres.

2.1.2 Dam

The dam, which is approximately 800 m long, has a maximum height of 20 m above river bed level. A plan of the dam is shown on Figure 2.1. The type of dam was largely dictated by foundation conditions and the materials available for construction. This has resulted in the choice of an earth embankment dam with a wide core of weathered andesite consisting of silty, sandy clays from the reservoir area, and upstream and downstream shoulders of sand, sandy gravel and gravel from areas near the river.

A typical section of the embankment is shown on Figure 2.2. The crest width is 8 m and upstream and downstream slopes are 1 vertical to 2.5 horizontal. As can be seen, a chimney drain has been provided downstream of the core in order to safely collect any preferential high level seepage which might arise through non-homogeneity in the core fill. In addition, to assist stability during the construction phase, and later during rapid drawdown, the lower part of the upstream slope has been flattened to 1 vertical in 3 horizontal and a series of horizontal blanket drains provided above.



PLAN OF HUAI MAE ON DAM AND RESERVOIR

Figure 2.1

Seepage through the foundations under the dam is mainly controlled by a positive cut-off down to Grade I/II rock level, and a grout curtain below. Due to the expected highly fractured nature of the rock, blanket grouting 3 m deep will be carried out over the full extent of the floor of the cut-off trench.

Two additional features regarding treatment of the core trench are worthy of mention. As a precaution against erosion taking place at the interface between rock and core, provision has been made for sprayed concrete to be applied to the bottom of the cut-off trench over its entire length. In addition, the very uneven nature of the profile of the rock floor of the trench is being corrected where necessary by concrete infilling to eliminate possible causes of differential settlement, arching and cracking of the core.

2.1.3 Appurtenant Structures

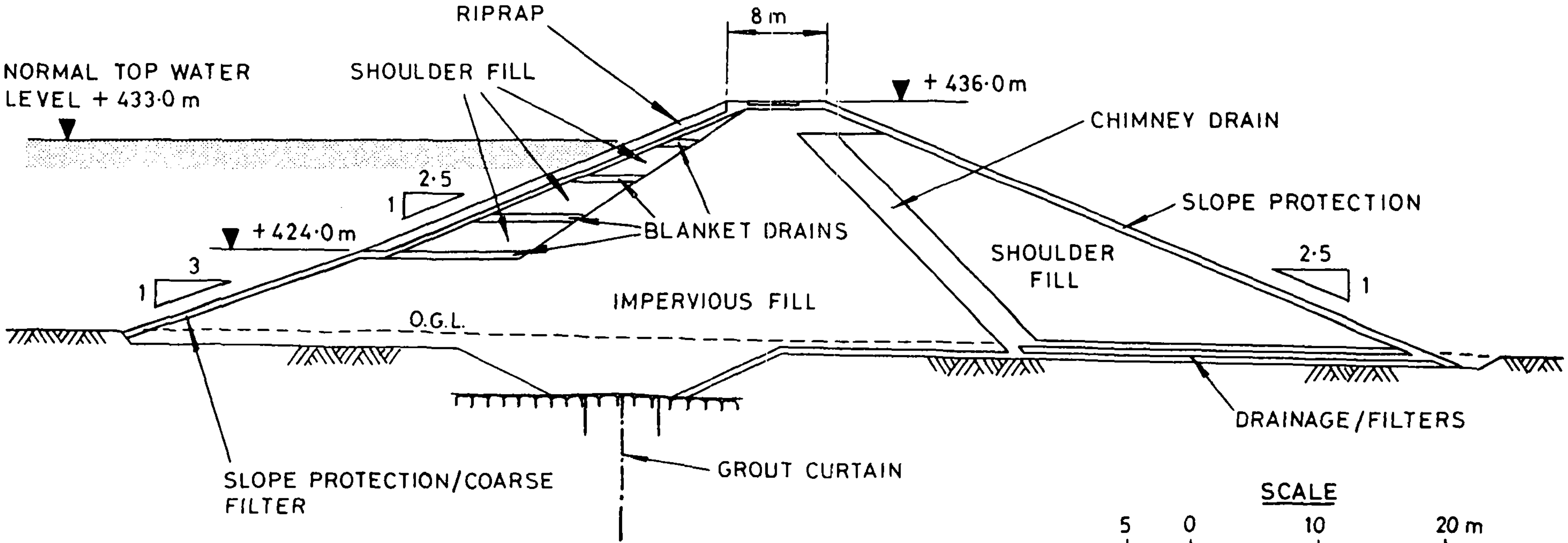
To deal with the passage of floods two separate spillways are provided as shown on Figure 2.1, i.e. the service spillway and the emergency saddle spillway.

The service spillway, consisting of an overflow weir 30 m long and a concrete-lined chute terminating in a flip bucket at the downstream end, is designed to pass, on its own, the 100 year flood of approximately 100 m^3/s. For floods of return period greater than 1 in 100 years, the emergency spillway with its 150 m long crest also comes into play and for the 1 in 1 000 years design flood of 135 m^3/s the emergency spillway passes 15 m^3/s whilst the service spillway takes 120 m^3/s.

As a check, the Probable Maximum Flood (PMF) of 375 m^3/s was routed through the reservoir and the two spillways were found to successfully pass the flood without the dam being overtopped.

The outlet works are located on the right bank of the river and provide for the controlled release of stored water up to design maximum flow of 1.5 m^3/s for irrigation purposes. During construction of the dam, the outlet works provide a 2.2 m square reinforced concrete culvert through which the river is diverted for several months of the dry season whilst the river bed portion of the dam is built. On completion of the dam to crest level the culvert will be closed by means of stoplogs and a concrete plug. A 600 mm diameter steel pipeline will then be installed in the culvert to pass irrigation flows and to enable the reservoir to be drawn down in emergencies.

An interesting aspect of the outlet works is that these have been designed with possible future hydro-electric generation in mind. Although the flows are small, a considerable amount of energy has to be dissipated before the released water can be used for irrigation.



HUAI MAE ON DAM - TYPICAL CROSS-SECTION

Figure 2.2

2.1.4 Irrigation Works

A total of 11 weirs and their associated irrigation channels presently serve the area. The Huai Mae On dam will affect about half of these and appropriate arrangements have been made to adapt them to the new regime by re-routing channels, connecting them to the dam outlet works, etc. In addition, one temporary weir is being replaced by a permanent concrete structure. It is not considered necessary for any in-field works to be carried out on this sub-project.

2.1.5 Construction Contract

A contract for construction of the Huai Mae On embankment dam and appurtenant works was awarded in January 1985, valued at approximately US$ 2.1 million, and construction is currently in hand.

2.2 Tung Wat Sing Sub-Project

2.2.1 Service Area

The sub-project area of approximately 11 000 ha is on the right bank of the Chao Phya river and on the west bank of the existing Makham Thao U-Thong irrigation canal at an elevation of about 20 m above sea level. The area was excluded from previous development of the lower Chao Phya basin as the land is too high to be commanded by gravity. Mean annual rainfall is 1 170 mm with about 80% occurring in the wet season. Despite this there are frequently drought periods causing damage to the wet season crops and, in addition, damage by flooding results from blockage of the natural drainage from the west by the existing Makham Thao U-Thong canal.

The sub-project area is at present dependent on rain-fed agriculture with some local wet-season pumping on a small scale. Virtually all of the cultivated area is paddy.

The new works will provide pumped irrigation water from the Chao Phya river to the whole area and in the wet season the full irrigation demand can be met. However, in the dry season only about 60% of the area can normally be supplied due to the general shortage of water in the Chao Phya basin and therefore some form of control will be required. The layout of the sub-project works is shown on Figure 2.3.

2.2.2 Pump Station

The pump station, which has a 900 m long approach channel, contains seven identical electrically operated vertical axial flow pumps (six service plus one standby), each with a capacity of 2.2 m^3/s against the maximum static head of 8.5 m. Two basic alternative pump station arrangements were studied, one with inclined axis pumps and one with vertical axis pumps.

A vertical pump arrangement, with permanent overhead gantry crane, was chosen as being most appropriate in this case.

On the delivery side of each pump there is a 1 m diameter steel pipeline which carries the flow up into the main canal which is on a 6 m high embankment at this point. The pipe outlets are fully submerged at all times thereby achieving maximum economy in the energy required for pumping. Siphon breaker/air valves are of course fitted. The configuration of the pump station and delivery pipes is shown on Figure 2.3.

2.2.3 Irrigation Systems

As shown on the layout on Figure 2.3 the main canal, whose design capacity is approximately 13 m^3/s at the upstream end, runs the full 35 km length of the western boundary of the sub-project area. A total of twelve secondary canals, with maximum capacities varying from 3.8 m^3/s to 0.2 m^3/s branch off the left side of the main canal.

The main and secondary canals are concrete lined throughout. For the upstream 3 km of the main canal, where it is constructed almost entirely in fill, pre-loading has been specified to avoid problems with differential settlement causing possible cracking of the concrete lining. The embankment is required to be constructed to full height and allowed to settle for at least four months before excavating the canal in it and placing the lining.

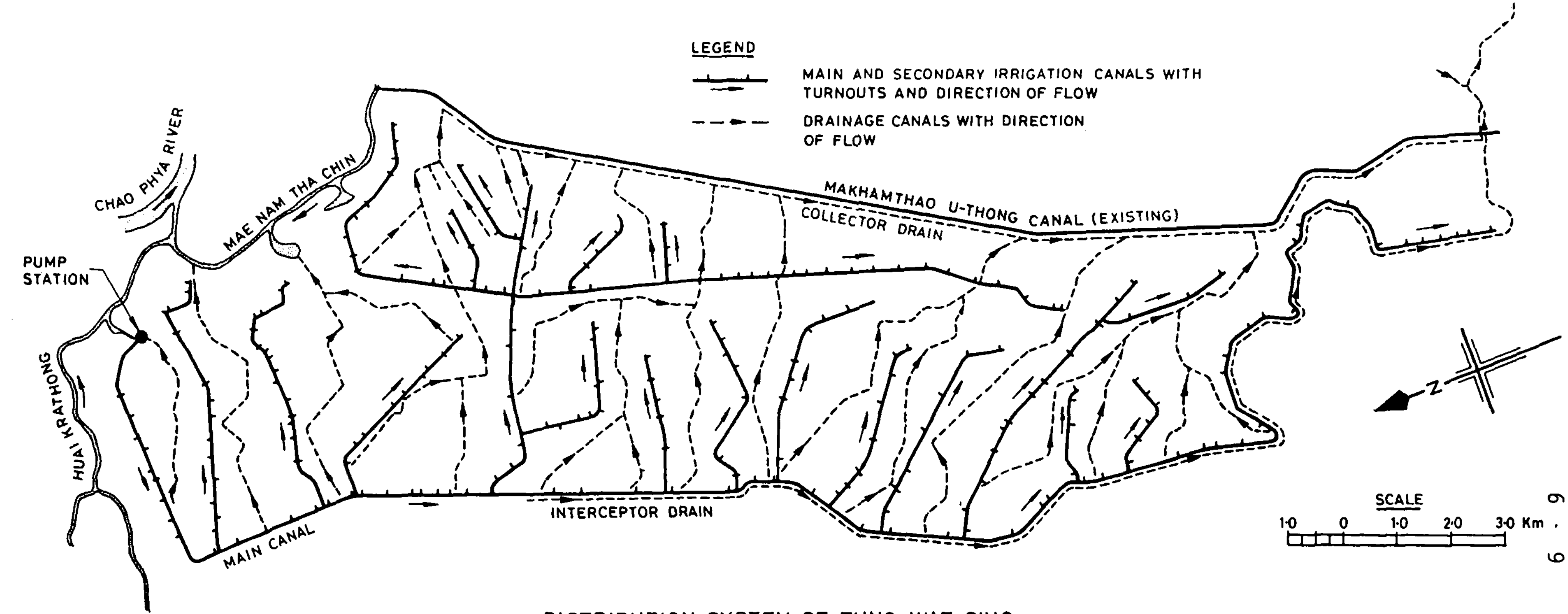
The whole sub-project area is divided into service units (chaks) of approximately 50 ha within which irrigation will be carried out by rotation. The turnout to each chak is in the form of a double-gated constant head orifice.

A 100 ha pilot area will be prepared and operated in advance of completion of the whole sub-project in order to demonstrate to the farmers the advantages of employing such techniques as land consolidation, land planing, etc.

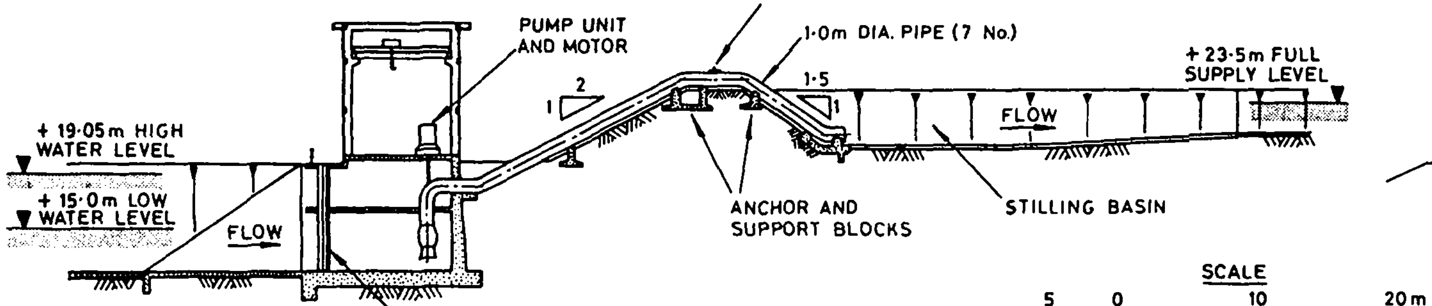
2.2.4 Drainage System

As mentioned in 2.2.1 above, external drainage from the west regularly causes flood damage in the sub-project area. To prevent this a large interceptor drain, of which the right bank of the main canal is an integral part, has been provided. The interceptor drain, designed to cater for a 3-day rainfall with a 5-year return period, will have a capacity of 135 m^3/s at its downstream end. The majority of this flow will be discharged into the existing Huai Tanote stream whose structures will be enlarged where necessary.

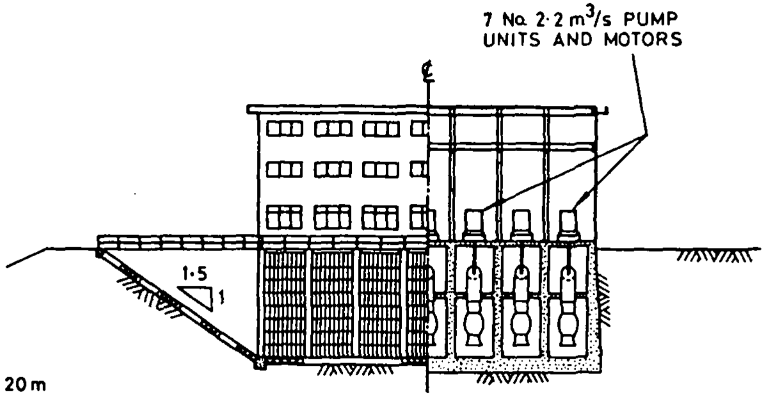
Drainage provisions within the sub-project area itself are catered for by a reticulation of drainage canals leading into a collector drain running parallel to the right bank of the existing Makham Thao U-Thong canal and eventually discharging into the Huai Tanote.



DISTRIBUTION SYSTEM OF TUNG WAT SING



LONGITUDINAL SECTION THROUGH PUMP STATION



ELEVATION/SECTION OF PUMP STATION

2.2.5 Construction Contracts

Because of the size of the Tung Wat Sing sub-project, construction work has been split into two main contracts. Contract No. 1 includes the pump station and the irrigation and drainage canals for about 40% of the sub-project area, whilst Contract No. 2 includes the irrigation and drainage canals for the remaining 60% of the area, together with the interceptor drain and Huai Tanote works.

The first contract, valued at approximately US$ 4.8 million, was awarded in January 1985 and construction is currently proceeding. It is expected that the second contract, whose value is estimated to be approximately US$ 7.2 million, will be awarded before the end of 1985.

2.3 Tha Chanuan/Wat Kok Sub-Project

2.3.1 Service Area

The sub-project area of approximately 3 500 ha is on the left bank of the Chao Phya river upstream of the Chao Phya dam but too high to be commanded by gravity. The area is divided into two parts by the existing Manoram canal, with the Tha Chanuan part occupying about 80% and Wat Kok the remaining 20%. Ground elevation is approximately 20 m above sea level.

The rainfall pattern is similar to that in the Tung Wat Sing sub-project, with a mean annual rainfall of 1 170 mm, 80% of which occurs in the wet season. Drought periods and flooding frequently cause damage to the wet season rice crop. In some years, additional dry season crops have been grown with the aid of extensive temporary pumping after substantial losses occurred in the wet season.

Again, as for Tung Wat Sing, the new works will provide pumped irrigation water to the whole area, meeting the full irrigation demand in the wet season but normally only permitting part of the area to be irrigated in the dry season. Flood banks along the left bank of the river will be heightened and improved.

2.3.2 Pump Stations

Separate pump stations, P.S. No. 1 and P.S. No. 2, serve the two areas of Tha Chanuan and Wat Kok respectively. Both pump stations, which have electrically operated vertical axial flow pumps and a permanent overhead gantry crane, are sited on the left bank of the Chao Phya river.

P.S. No. 1 contains three identical pumps, each with a capacity of 1.1 m^3/s against a maximum static head of 5.2 m whilst P.S. No. 2 has two pumps each of 0.45 m^3/s capacity and a maximum static head of 4.2 m.

Longitudinal sections through the two pump stations are shown on Figure 2.4. As can be seen, the general arrangement is similar for both, with the pump outlets discharging into rectangular reinforced concrete stilling basins, each with a rock-filled baffle type energy dissipator. Poor sub-soil conditions have dictated the use of a concrete piled foundation in the case of P.S. No. 2.

2.3.3 Irrigation System

The layout plan of the irrigation system for the Tha Chanuan and Wat Kok areas is shown on Figure 2.4.

In the Tha Chanuan system, the 3.3 m^3/s maximum flow from P.S. No. 1 divides, after 120 m, into the Left and Right Main Canals whose design capacities are 0.5 and 2.8 m^3/s respectively. The total length of the Left Main Canal is 4.8 km, with one secondary canal of capacity 0.1 m^3/s branching off it, whilst the Right Main Canal is 14.3 km long with a total of five secondary canals branching off it, with capacities varying from 0.2 to 0.6 m^3/s. The main and secondary canals are concrete lined throughout.

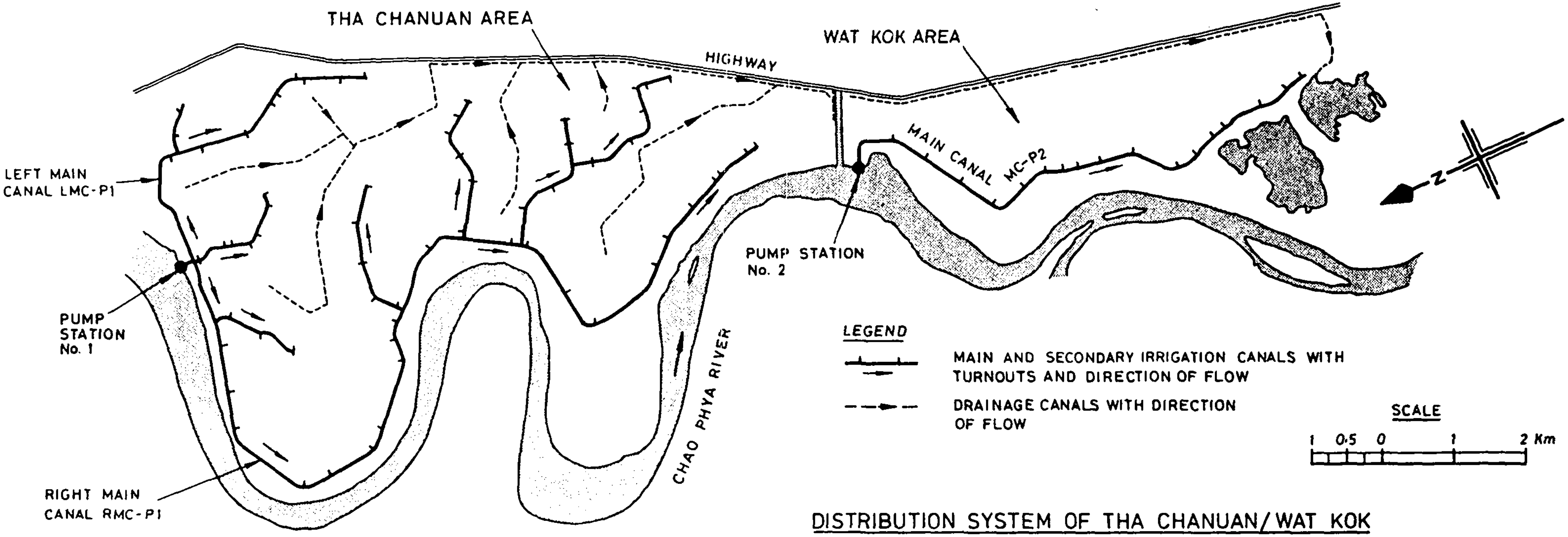
In the Wat Kok system the main canal is 7.5 km long and has a maximum capacity of 0.9 m^3/s. There are no secondary canals off this main canal. The main canal is concrete lined except for the first 200 m where it is clay lined and constructed entirely on embankment on foundation soils whose bearing capacity is low. As a precaution, the embankment there has been made very wide, with substantial berms above both toes. Additionally, the embankment is required to be constructed at least six months in advance of canal excavation to allow foundation settlement to take place. This technique is similar to that used at the upstream end of the Tung Wat Sing main canal, as mentioned in 2.2.3 above.

The whole sub-project area is divided into service units (chaks) of approximately 50 ha each, within which irrigation will be carried out by rotation. Turnouts to the chaks are in the form of double-gated constant head orifices.

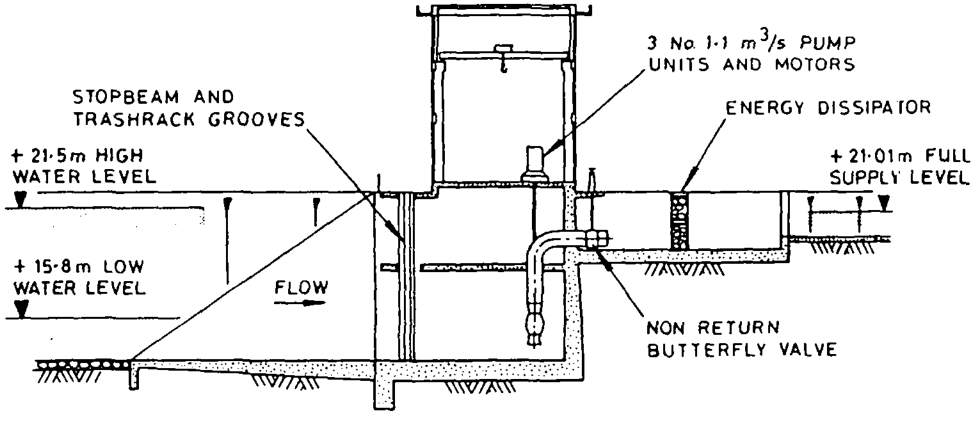
As at Tung Wat Sing, a 100 ha pilot area will also be prepared and operated at Tha Chanuan in advance of completion of the whole sub-project.

2.3.4 Drainage System

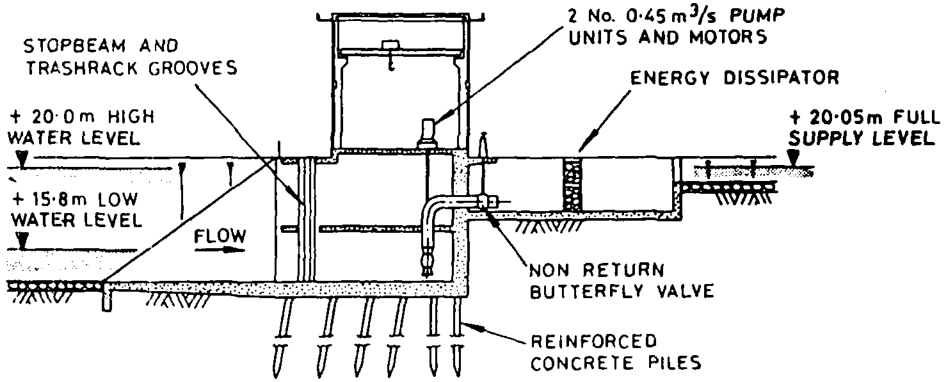
As shown in Figure 2.4, drainage within the sub-project area is catered for by a number of drainage canals, generally following existing natural drainage channels eastwards into two collector drains flowing south along the Phahon Yothin highway.



DISTRIBUTION SYSTEM OF THA CHANUAN/WAT KOK



LONGITUDINAL SECTION THROUGH
PUMP STATION No. 1



LONGITUDINAL SECTION THROUGH
PUMP STATION No. 2

Figure 2.4

Flood waters from the Chao Phya are excluded by raising and improving the existing flood dykes on the left bank of the river and also by utilising certain lengths of the right bank of main canals RMC-P1 and MC-P2 as additional flood dykes.

2.3.5 Construction Contract

A contract for construction of the Tha Chanuan/Wat Kok works was awarded in February 1985, valued at approximately US$ 3.5 million, and construction is currently in hand.

2.4 Mae Nam Prachantakham Sub-Project

2.4.1 Service Area

The sub-project area of approximately 2 600 ha is located on both banks of the Mae Nam Prachantakham and is fed by gravity from a river regulator structure at the northern end. Ground elevation is approximately 12 m above sea level.

The mean annual rainfall is 2 040 mm but there is a wide variation and the 1 in 10 year rainfall is as low as 1 000 mm. The project will provide wet season irrigation only since there is little flow in the river in the dry season and no possibility of providing significant storage. Since there is little opportunity for use of water downstream of the sub-project, unrestricted use can be made of the wet season flows.

Although no direct protection is practicable against flooding from the river, some protection against the overland flows from the high ground on either side will be provided by the banks of the main canals and the drainage system and culverts.

2.4.2 River Regulator Structure

As shown in the plan view on Figure 2.5, the regulator is sited within a large meander of the river, thus enabling the structure to be built in the dry before the diversion channel is excavated and the river closure dam constructed. Figure 2.5 also shows a longitudinal section through the regulator, which consists of a reinforced concrete structure with three 6 m wide openings, each controlled by an electrically operated radial gate 6.5 m high. Two rows of steel sheet piling reduce seepage under the structure.

In the embankments on either side of the gated regulator, intake structures to the Left and Right Main Canals are incorporated. In addition, an emergency spillway has been provided to alleviate the effects of flood discharges greater than the 1 in 25 year design flood.

2.4.3 Irrigation System

The layout of the irrigation distribution system is shown on Figure 2.5. The Right Main Canal, of maximum capacity 2.4 m^3/s, is 9.3 km long and has three secondary canals branching off it. These total 11.7 km in length and their capacities range from 0.2 to 1.0 m^3/s. The Left Main Canal has a capacity of 0.8 m^3/s, is 7.3 km long and has one 2.9 km long secondary canal of 0.4 m^3/s capacity. The main and secondary canals are concrete lined throughout.

As is the case with the other sub-projects already described above, Mae Nam Prachantakham sub-project is also divided into service units of approximately 50 ha each, within which irrigation will be carried out by rotation. Similarly, a 100 ha pilot area will be prepared and operated in advance of completion of the whole sub-project in order to demonstrate various techniques to the farmers.

2.4.4 Drainage System

Figure 2.5 shows the drainage canal network within the Mae Nam Prachantakham sub-project area. Generally these canals follow the existing natural water courses. Overland flooding from the high ground to the north-west will be alleviated by being retained by the main canal banks and discharged in a controlled manner through drainage culverts.

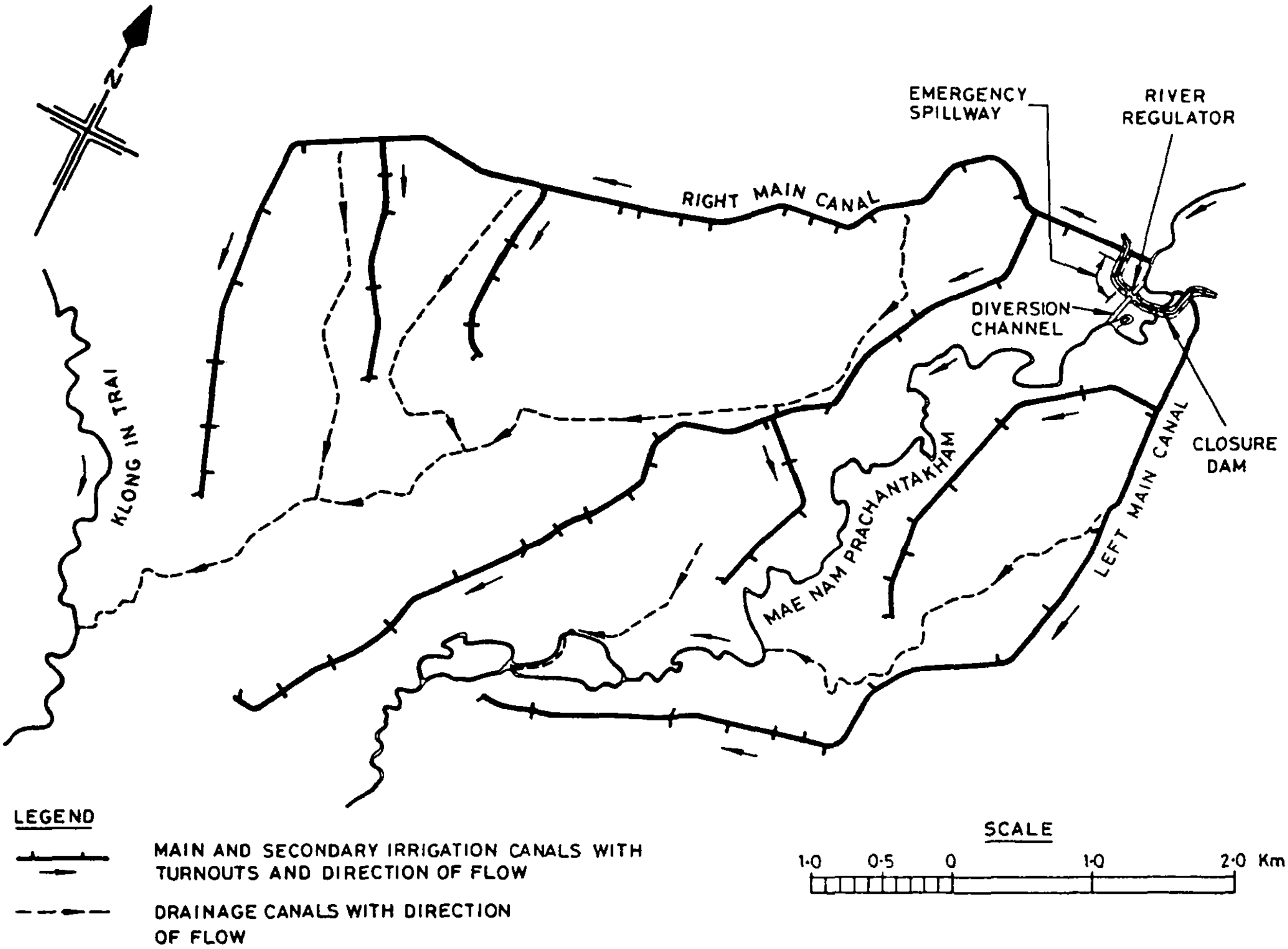
2.4.5 Construction Contract

A contract for construction of the Mae Nam Prachantakham works was awarded in September 1984, valued at approximately US$ 3.4 million, and construction is currently in hand.

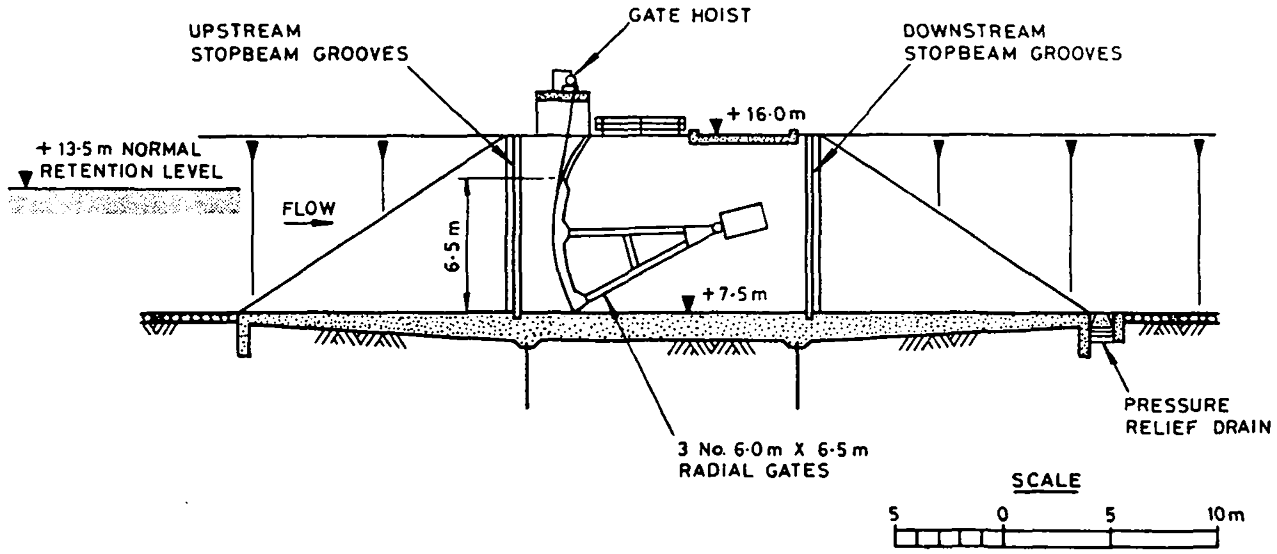
2.5 Klong Wang Tanote Sub-Project

2.5.1 Service Area

The sub-project area, which has a mean annual rainfall of 3 050 mm, is located on both banks of the lower reaches of the Klong Wang Tanote on the south-east coast of Thailand. Many farmers already pump water from the river to irrigate rice and tree crops, but infiltration of sea water into the river channel at periods of low flow restricts the use of water in the dry season. Temporary weirs have been constructed annually to try to restrict the upstream movement of the salt. The low-lying paddy lands at the southern end of the sub-project are also frequently flooded by sea water at high tides.



DISTRIBUTION SYSTEM OF MAE NAM PRACHANTAKHAM



TYPICAL SECTION THROUGH RIVER REGULATOR

Figure 2.5

As well as providing two new tidal regulators and a coastal embankment, it was originally planned to provide an irrigation and drainage network including a number of small pumping stations to serve an area of approximately 1 000 ha of paddy. However, in view of the local preference for fruit tree farming and the recent addition of several pumping stations and pipe systems built with the cooperation of the farmers and the provincial administration, it has been decided to build only the tidal regulators and coastal embankment under this package project. A usable reservoir storage volume of 6.8 million cubic metres will be retained by the regulators.

2.5.2 Tidal Regulators

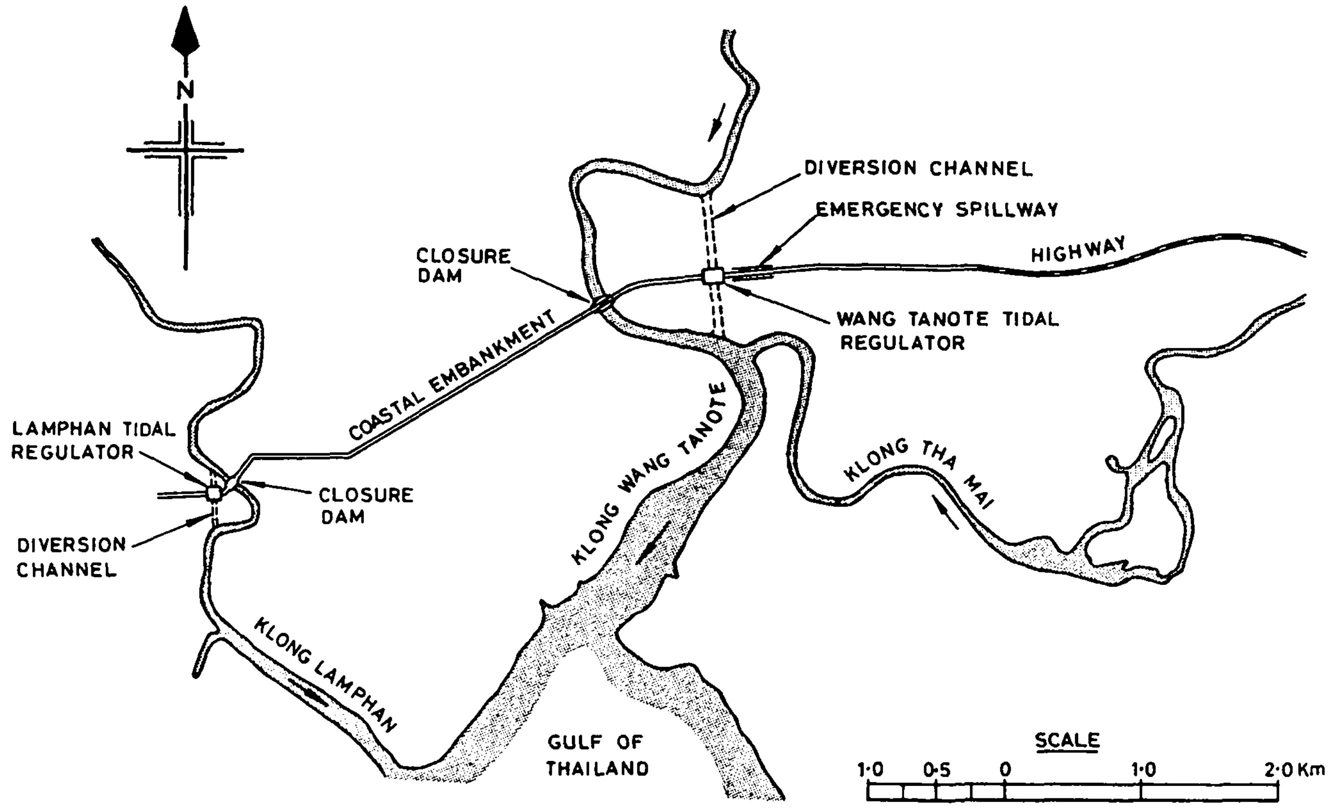
The location and layouts of the two tidal regulators are shown on Figure 2.6. The main regulator, on Klong Wang Tanote, is a reinforced concrete structure, founded on concrete piles. It has five 6 m wide openings, each controlled by a 6.7 m high electrically operated radial gate, and can pass the 1 in 25 year design flood of 420 m^3/s. Floods of greater magnitude will be discharged over an emergency spillway on the adjacent left hand embankment.

The regulator is sited within a meander in the river, thus enabling construction in the dry before the diversion channel is excavated and the closure dam placed.

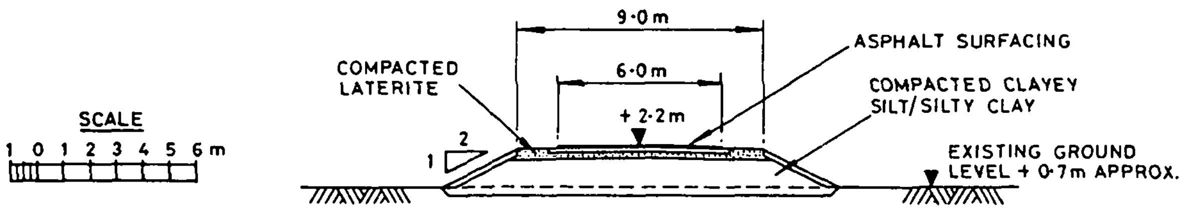
A feature of the design is that the radial gates must be capable of resisting water pressure in both directions. Normally the gates retain the fresh water reservoir on their upstream sides, at +1.0 m in the dry season and at +0.7 m for most of the wet season to allow wet season rice to be grown on the fringes of the reservoir. However, at times of high tide, sea level can exceed the reservoir level by several metres, with the corresponding load acting on the back of the gates. Stainless steel has been specified for many of the radial gate components and special attention has been paid to the gate pivots to ensure trouble-free working in the corrosive tidal environment.

In order to avoid salt intrusion into the reservoir at times of high tide, upstream and downstream water level pressure transducers will transmit water level information to the control building and an alarm will be sounded if the downstream level approaches the upstream level whenever any one of the regulator gates is open.

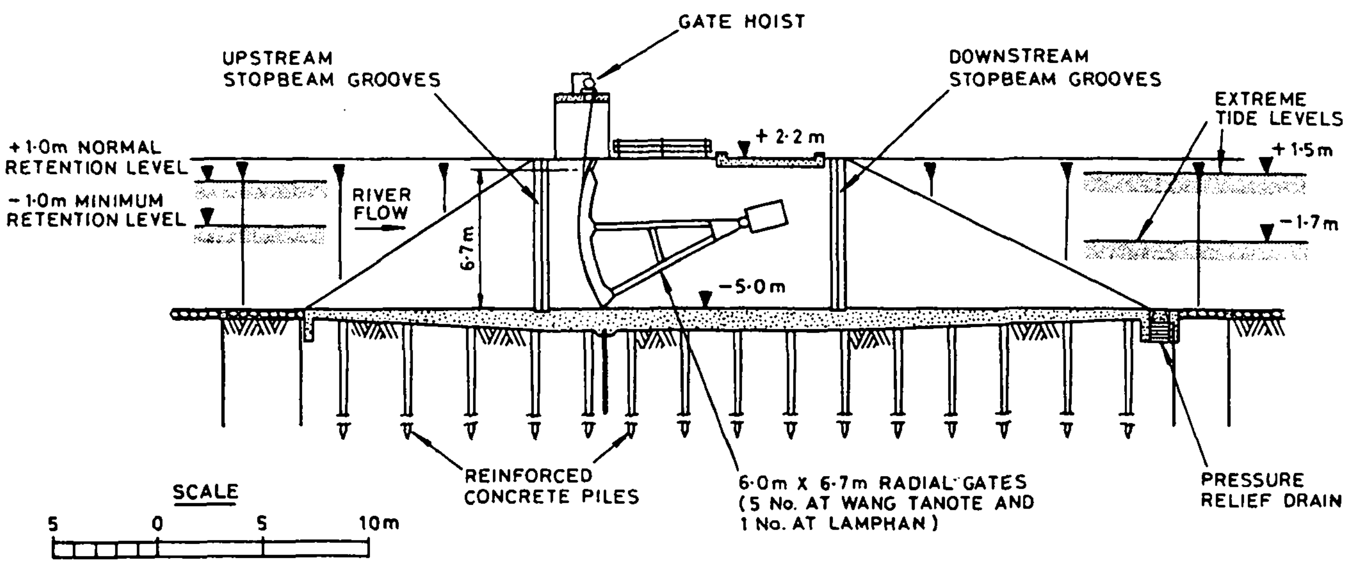
The regulator on Klong Lamphan is similar in concept to the Wang Tanote regulator but it contains only one radial gate, which is manually operated in this instance. No emergency spillway is provided at Lamphan since at high levels the two reservoirs are connected and excess flows will pass over the Wang Tanote spillway. A telephone line will be provided for communication between the operating staffs at the two regulators.



KLONG WANG TANOTE SUBPROJECT - LAYOUT



TYPICAL SECTION THROUGH COASTAL EMBANKMENT



TYPICAL SECTION THROUGH TIDAL REGULATOR

(REGULATOR SHOWN IS AT WANG TANOTE)
(REGULATOR AT LAMPHAN IS SIMILAR)

Figure 2.6

2.5.3 Coastal Embankment

A 10 km long embankment, whose average height is less than 2 m, seals off the low-lying land between the regulator structures and the higher ground - see layout on Figure 2.6. A typical section of the embankment, which will carry a 6 m wide roadway, is also shown on the figure.

The terrain traversed by the coastal embankment is generally difficult and includes sections of mangrove swamp. Stripping of all roots and organic matter from under the embankment will therefore not always be possible and a limited specification is applied, requiring only the cutting down and removal of all surface vegetable growth on difficult areas. It is felt that this pragmatic approach is the correct one here where the hydraulic gradients across the embankment will rarely reach 1 m.

Where the embankment crosses the Wang Tanote and the Lamphan, i.e. at the closure dams, a very wide cross-section (over 100 m) has been specified where the bulk of the fill has to be placed underwater and where compaction will generally not be possible. Strict limits are set as to the state of the tide when closure dam filling operations can take place.

Gated culverts are provided at a number of low points along the line of the embankment to allow drainage from inland to take place at low tide. The gates of course must be shut whenever tide levels are such that salt water could flow inland.

2.5.4 Construction Contract

A contract for the construction of the Klong Wang Tanote Sub-Project works was awarded in September 1984, valued at approximately US$ 2.2 million, and construction is proceeding.

3. COMMENTS ON THE PACKAGE CONCEPT

As mentioned in the introduction, the five medium-scale irrigation sub-projects described above were grouped together to form a package financed under an Asian Development Bank loan. The five schemes are widely separated geographically as shown in Figure 1.1, being distributed over four provinces and coming under the control of four separate regional offices of the Royal Irrigation Department of Thailand.

The main reason for the grouping was that these schemes were selected as having similar priorities and hence implementation of all was required more or less simultaneously and a single financial package arranged accordingly.

For the consultant's study and design team based in Bangkok, the geographical spread of the schemes raised one or two problems. Site visits has to be co-ordinated with the different regional offices and no more than two sub-projects could be visited within one day. Visits to Huai Mae On in the north were generally made by air whilst the other four sub-projects were reached by road.

The different locations, with their widely differing soils and rainfall patterns, each required a different set of irrigation and drainage design criteria to be produced, thus involving some duplication of effort.

A certain amount of standardisation of irrigation and drainage design details was obviously possible, but the technical diversity of the sub-projects meant that many "one off" designs also had to be produced by the single team of engineers.

In the same way, certain similarities existed in the contents of some of the contract documents, but separate sets of documents including bidding forms, contract provisions, technical specifications and bills of quantities were required for each sub-project. There was also the added complication that several of the contracts were open to international bidding and several were for local contractors only. The tight programme for issue of bidding documents meant that the documents for several contracts were being prepared concurrently, as were the sets of contract drawings.

During the current construction supervision phase, whilst the consultant has one construction engineer acting as observer on each site, the main coordinating effort is in Bangkok and much travelling is involved in attending regular site meetings with each of the different contractors and dealing with specific technical problems at the various sites.

Despite the minor reservations mentioned above, it has clearly been demonstrated that control of the design and construction supervision of such a diverse group of medium sized irrigation projects by a single consultant team is feasible. This has obvious advantages for the client who had already grouped the sub-projects into a single package for funding purposes.

4. ACKNOWLEDGEMENTS

The authors are grateful to the Director General of the Royal Irrigation Department of Thailand for permission to publish this paper. They also wish to acknowledge the continuing friendly cooperation and assistance received from the Department's staff in carrying out the project.

PAPER 7

SINKING OF DEEP TUBEWELLS IN NORTHERN BANGLADESH - A CASE STUDY

BY

MOHAMMAD AKBAR HOSSAIN AND DR. SALEEMUL HUQ
ASSOCIATED ENGINEERS & DRILLERS
DHAKA, BANGLADESH

capillary rise, effluent flow to rivers, ground water extraction and transpiration by deep rooted trees.

CULTIVATION

The existing cultivation, irrigated under rainfed conditions consists of a rice crop (Boro) grown during the months of January to May and a further rice crop (Aman) during the months of July to October. During the dry, winter season the land is left fallow or some hardy dry season pulse crops may be grown. Where the ground water irrigation has been made available a further rice crop (IRRI) or wheat crop is grown during the winter months.

GROUND WATER EXTRACTION

Ground water extraction consists of Shallow Tubewells (STWs) and Deep Tubewells (DTWs). Shallow Tubewells consists of 4 in diameter Galvanised Iron (G.I.) pipe sunk to a depth of 100 to 150 feet with 30 to 40 feet of screen (G.I. Core Brass Screen). These are sunk by percussive drilling manually using a bamboo frame. Deep Tubewells consists of 6 in diameter screen and lower well casing to a depth of 250 to 350 feet and 80 - 96 ft upper well casing (14 in diameter). The upper well casing consists of locally manufactured Mild Steel pipe and the lower well casing of G.I./M.S. pipe to be locally produced. Screen consists of imported continuous wirewound stainless steel as well as fibre glass slotted screen. Drilling is done by reverse circulation / Water jet with a borehole of 22 in diameter.

DESIGN DATA

The location ana maximum depth of each tubewell is shown in Figure 2 and the length of screen used is shown in Table 1. The depth of the tubewells ranged from a minimum of 108 ft to a maximum of 198 ft while the length of screen used ranged from 40 ft to a maximum of 90 ft.

The tubewells were tested and developed at 3 cusec capacity for 4 hours. The static water level and pumping water level were recorded and the specific drawdown calculated in each case. The static water level ranged from 10.15 ft to 22.58 ft with a mean value of 13.68 ft while the pumping water level after 6 hours at 3 cusec ranged from 21.88 ft to 46.04 ft with a mean of 31.68 ft.

A number of selected wells were used for long term test pumping for 72 hours at 3 cusec capacity. The effect on the water table at various distances from the well were measured by deep and shallow piezometers (Figure 3). The type of soil found at the different depths are also shown. This ranged from grey brown clay at the top to very fine sand: grey at the bottom.

The pumping water level after 72 hours at 3.0 cusec capacity was 35.49 ft (from a static water level of 14.6 ft). The levels in the different piezometers gave readings of 20 ft at 80 ft distance from the well, 18.8 ft, 50 ft from the well, 16.9 ft, 200 ft from the well and 16.1 ft at 500 ft from the well.

INTRODUCTION

In 1975 the Bangladesh Agricultural Development Corporation (BADC) received project finance from the International Development Association (IDA) of the World Bank to sink 3000 Deep Tubewells in the north western region of Bangladesh. The World Bank appointed Consultants were Sir Macdonald and Partners of the U.K. After competitive international bidding the contract was divided and awarded to seven drilling companies both Bangladeshi and foreign. Associated Engineers and Drillers was awarded a contract to sink 300 Deep Tubewells in Bogra district. The work was started in 1975 and completed in 1978.

STUDY AREA

We have conducted a study of 52 tubewells sunk in 1975 in an area of 70 sq miles (Nandigram Thana) in Bogra district which lies within Rajshani Division in the north western part of Bangladesh (Figure 1). The area is part of an extensive flood plain of the river Ganges with an average gradient of less than 0.27 m/Km rising from 6 m to 100 m above sea level. The alluvial plain contains a network of river channels, both active and passive. During the monsoon large areas are flooded but during the dry season the majority of the areas dry out and cultivation is limited to areas adjacent to surface water.

CLIMATE

The climate is tropical and humid with a wet south-west monsoon from June to November. During the remainder of the year a cool, dry north-east wind blows from central Asia, bringing the lowest temperatures and humidity around November and December.

The climate gives rise to 3 main seasons:

1. Winter (November to February) : Dry, cool (Temp 7°-29°C)
2. Summer (March to May) : Dry, hot (30°-40°C), humid (60% - 85%), stormy
3. Monsoon (June to October) : Heavy rainfall, hot, humid

AQUIFER

The aquifer consists mainly of sands and coarser sands overlain by a semi confining bed of finer grained mixed materials with generally low permeabilities. In a few places the aquifer is not thick enough or of such a low permeability that it is incapable of supporting large scale tubewell development. However, these areas are small and relatively well defined. The various aquifer deposits are considered to be in hydraulic continuity throughout the region.

The most important source of recharge of the aquifer is from rainfall while the main components of ground water loss are from

CROPS

The area irrigated by a single tubewell (Command area) in the study ranged from 40 to 110 acres with an average of 62 acres and the tubewells were found to be used during the dry winter months from November to February. The availability of ground water for irrigation from the tubewells has enabled the farmers to grow a third cereal crop in addition to the two normal crops grown under rainfed conditions. Our survey showed 5 tubewells being used were primarily for high yielding varieties of rice while the remaining 47 tubewells were being used for irrigating wheat. In all cases the farmers reported substantial increases in yield due to the availability of water for irrigation from the deep tubewells.

CURRENT SITUATION

In 1983 we took another look at the situation in Nandigram and found that there were now a total of 93 deep tubewells and 920 shallow tubewells in operation. We also measured the static water table, pumping water table and calculated the specific draw down for the 52 deep tubewells originally sunk by us (Table - 1). We were surprised to note that there had been a sharp fall in the static water table of over 12 ft with an average fall of 8.5 ft. The pumping water levels and specific draw down showed a similar effect (Table-1).

CONCLUSION

The sinking of deep tubewells in the alluvial soil of North Bangladesh where the aquifer is within the depth of 200 ft is fairly simple operation using reverse circulation rotary drilling rig. The tubewells have been shown to have increased the crop production within the command areas and have proved popular with the farmers. However, the sinking of 93 deep tubewells and 920 shallow tubewells in Nandigram over the last 8 years seems to have caused a substantial decrease in the water table and hence effected the draw down. This has already begun to effect a number of shallow tubewells in the vicinity. It is, therefore, imperative to make a thorough study of the characteristics of the ground water reservoir including its rate of recharge before sinking more tubewells. It is also necessary to work out the optimum mix of deep and shallow tubewells or perhaps designate specific areas exclusively for one type or the other.

Table - 1 : Design and Test Data of 52 Deep Tubewells in 1975 and 1983

Sl No	Well No	Screen (ft)	Total Length (ft)	Static Water Level (ft) 1975	1983	Change over 8 years	Specific Draw Down (ft/Cusec) 1975	1983	Change over 8 years
1	B- 1	40	138	11.80	23.00	11.20	5.29	6.59	1.03
2	B- 2	60	138	14.27	22.00	7.73	5.69	5.88	0.19
3	B- 3	30	108	18.00	23.00	5.00	11.22	9.67	-
4	B- 4	60	128	14.08	20.50	6.42	5.08	8.13	3.05
5	B- 5	80	178	13.50	23.67	10.17	4.71	8.73	4.04
6	B- 6	60	138	19.70	21.58	1.88	5.77	7.84	2.07
7	B- 7	70	188	11.16	21.75	10.59	3.72	7.42	3.70
8	B- 8	60	138	14.38	21.42	7.04	5.22	6.13	0.91
9	B- 9	40	108	12.42	22.50	10.08	10.02	9.34	-
10	B-31	60	128	17.40	22.17	4.77	5.90	6.08	0.18
11	B-32	60	138	15.16	22.00	6.84	5.56	5.79	0.23
12	B-33	50	128	13.16	21.50	8.34	7.50	6.42	-
13	B-34	60	128	12.50	22.38	9.88	6.46	7.63	1.17
14	B-35	60	128	16.85	22.25	5.04	6.14	6.96	0.82
15	B-36	50	178	13.25	21.92	8.67	6.06	7.94	1.88
16	B-37	60	168	13.32	22.42	9.10	6.85	8.38	1.53
17	B-38	80	188	14.66	22.17	7.51	4.89	8.04	3.15
18	B-39	80	178	13.50	21.42	7.90	5.16	7.38	2.22
19	B-40	60	188	13.32	22.25	8.93	4.12	8.67	4.55
20	B-41	90	188	13.56	21.42	7.86	4.47	7.92	3.45
21	B-42	70	198	11.75	21.79	10.04	4.83	7.27	2.44
22	B-43	80	188	12.50	21.58	9.08	4.79	7.44	2.65
23	B-44	70	198	11.84	22.63	10.79	3.94	7.31	3.37
24	B-45	70	198	15.56	21.83	6.27	3.93	7.30	3.37
25	B-46	40	128	12.06	20.83	18.77	7.99	6.67	-
26	B-47	80	178	10.18	22.83	12.65	3.39	7.31	3.92
27	B-48	70	168	10.15	21.46	11.31	4.91	7.31	2.04
28	B-49	60	178	11.08	22.00	10.92	3.69	8.42	4.73
29	B-50	50	138	14.39	22.25	7.89	7.75	6.67	-
30	B-51	50	118	14.33	20.83	6.50	6.91	7.17	0.29
31	B-52	50	118	11.30	23.67	12.37	5.99	4.92	-
32	B-53	50	128	13.33	22.25	8.92	7.72	6.50	-
33	B-54	60	148	22.58	22.67	0.09	5.57	7.42	1.85

(Table - 1 continued)

34	B- 55	80	168	13.16	22.50	9.34	4.47	6.65	2.18
35	B- 56	50	138	11.86	21.71	9.85	6.63	6.65	0.02
36	B- 57	60	138	13.19	22.25	9.06	5.95	5.96	0.01
37	B- 58	60	138	13.80	23.17	9.37	5.60	6.02	0.42
38	B- 59	50	138	13.79	22.17	8.38	6.58	7.67	1.09
39	B- 74	50	138	14.60	23.25	8.65	6.96	7.71	0.75
40	B- 75	40	118	15.90	22.00	6.01	7.93	8.00	0.07
41	B- 82	50	138	14.00	20.75	6.75	6.43	5.63	-
42	B- 85	50	128	12.87	22.63	9.76	7.14	8.31	1.17
43	B- 86	60	138	14.29	23.00	8.71	6.56	5.17	-
44	B-144	70	188	12.58	22.63	10.05	6.60	8.27	1.67
45	B-146	70	148	11.32	23.17	11.85	4.75	7.42	2.67
46	B-147	90	178	11.50	22.42	10.92	4.48	7.56	3.08
47	B-148	70	188	12.50	21.75	9.25	6.19	7.59	1.04
48	B-149	60	128	17.40	23.75	6.35	6.90	6.88	-
49	B-211	80	198	13.56	21.92	8.36	5.24	6.69	1.45
50	B-212	50	128	12.66	22.50	9.84	7.11	4.88	-
51	B-213	70	168	12.17	12.17	9.00	5.19	8.79	3.06
52	B-214	70	148	13.00	21.50	8.50	5.68	5.63	-
Mean		60	152.6	13,68	22.16	8.48	5.91	7.18	1.21
Maximum		90	198	22.58	23.75	12.65	11.22	9.67	-
Minimum		40	108	10.15	20.50	0.09	3.39	4.88	-

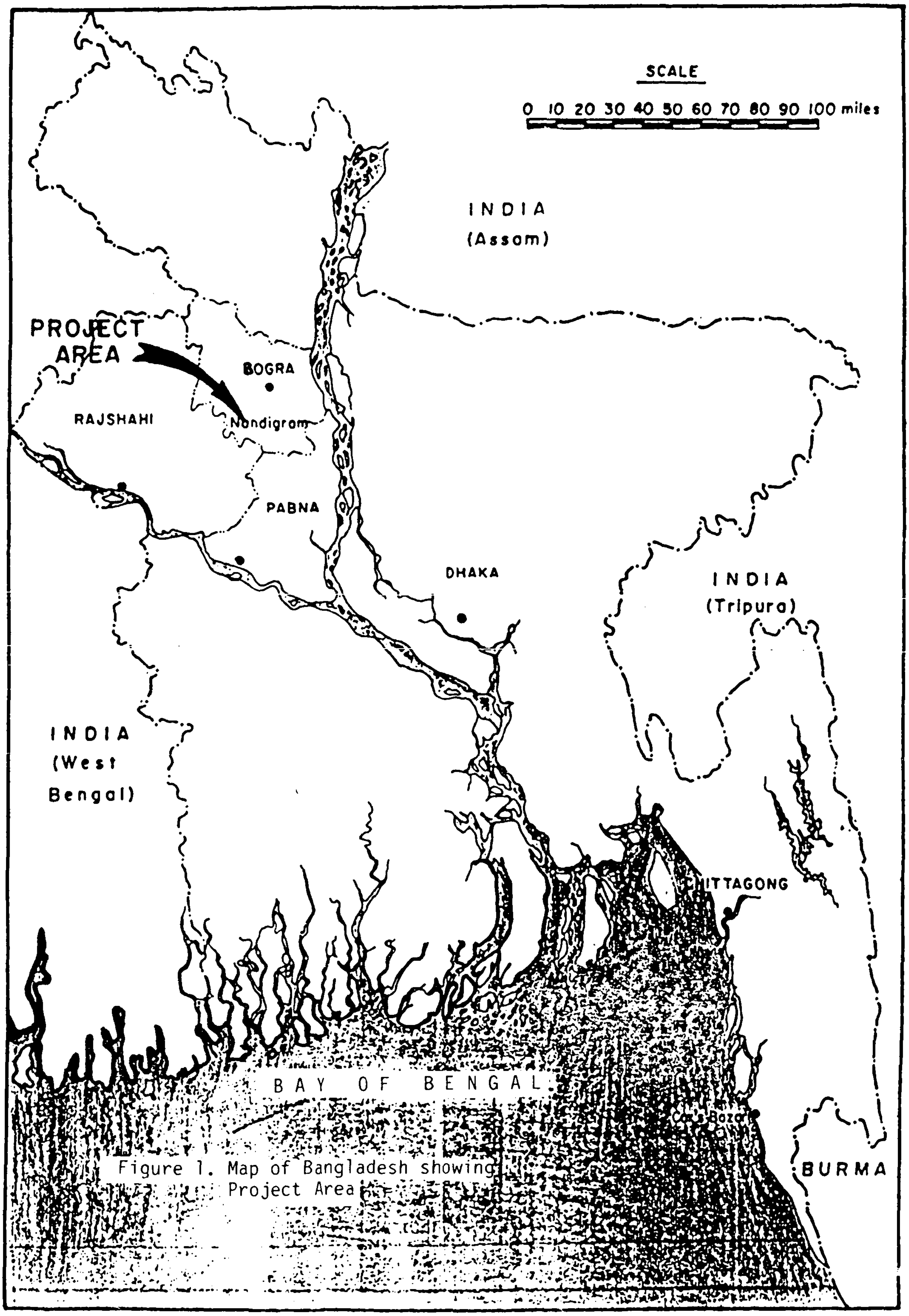


Figure 1. Map of Bangladesh showing Project Area

Figure 1

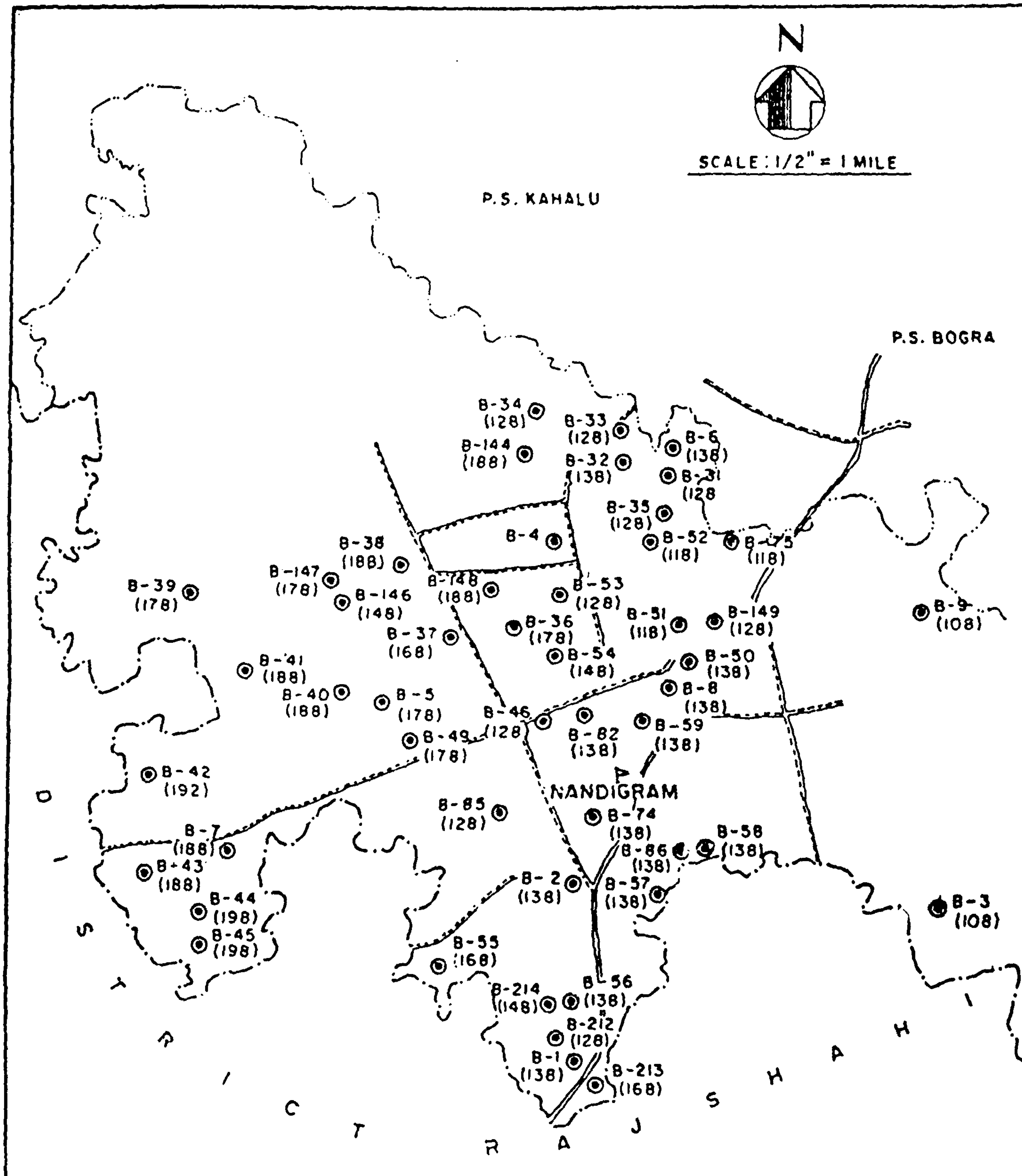


Figure 2 : Nandigram Study Area showing Location of Deep Tubewells.
Figures In Brackets indicates Depth of the Tubewells in feet.

SKETCH SHOWING THE LITHOLOGY OF THE GEOLOGIC FORMATION AND LOCATION OF SCREENS OF PIEZOMETERS AND MAIN TUBEWELL B-74

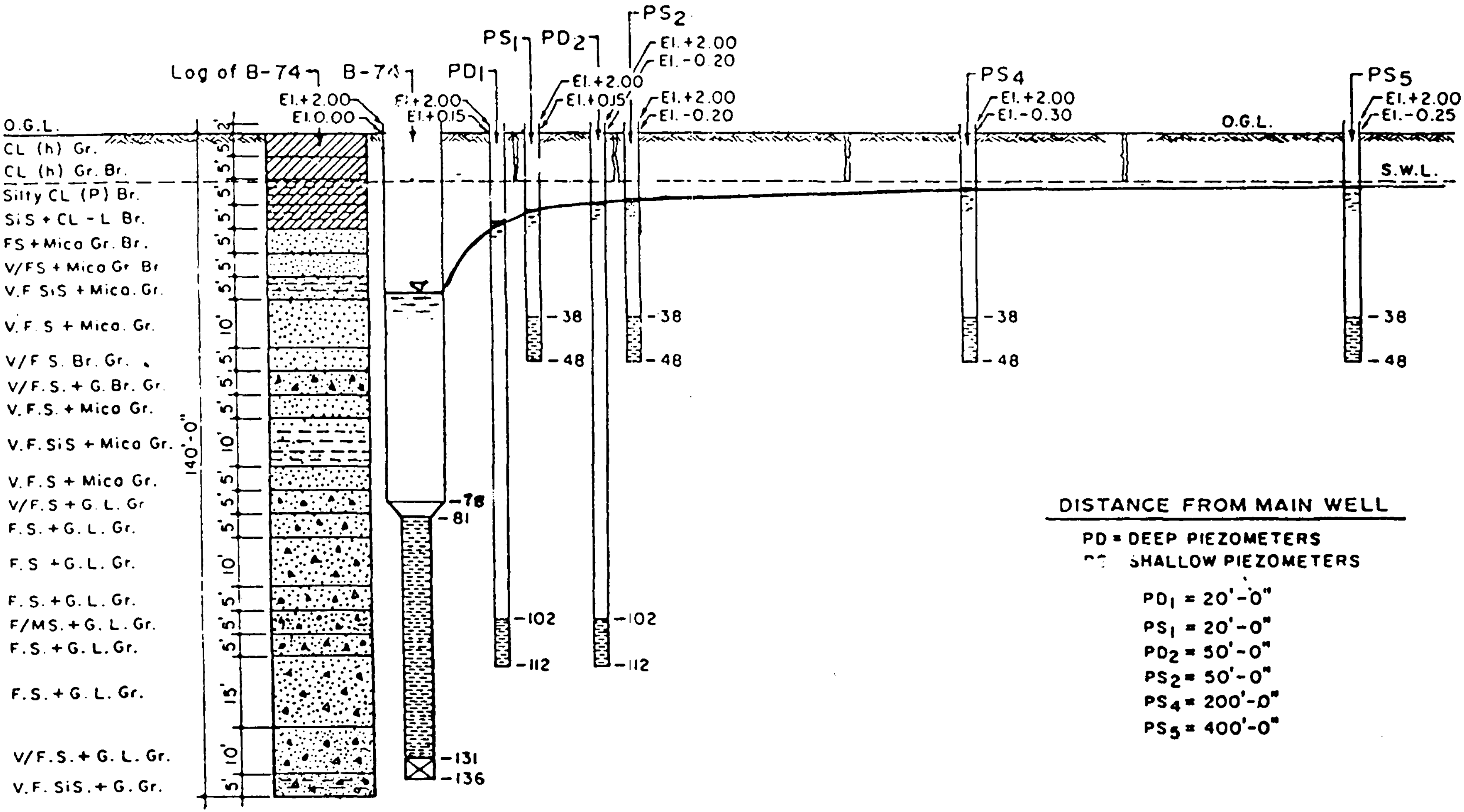


Figure : 3

PAPER 8

A RURAL IRRIGATION PROGRAMME IN INDONESIA

BY

INVITED SPEAKER

PAPER NOT AVAILABLE AT TIME OF PREPRINTING

PAPER 9

THE UNITED NATIONS INTERNATIONAL DRINKING WATER SUPPLY AND SANITATION DECADE: A BIRD'S-EYE VIEW

BY

YOON YUL KIM
UNITED NATIONS DEVELOPMENT PROGRAMME
MALAYSIA

PART I : INTRODUCTION

The Mar del Plata Action Plan 1/, drafted and approved at the UN Water Conference in 1977, recommended the Decade 1981-1990 to be designated as the International Drinking Water Supply and Sanitation Decade (IDWSSD) 2/. At its 108th Plenary Meeting in November 1979 the General Assembly of the United Nations endorsed this recommendation as well as the Economic and Social Council of the United Nations (ECOSOC)'s resolutions on the follow-up activities for implementing the Mar del Plata Action Plan. The General Assembly of the United Nations proclaimed the Decade at its 55th Plenary Meeting, 10 November 1980 3/.

Let us look at the situation that prompted such a high level global campaign.

A. The Needs 4/.

Due to the high birth rate in developing countries, the number of people without water and/or sanitation facilities has been growing in both urban and rural areas. There are now more than 1000 million people in developing countries - about half the population of the world. Some 70 percent live in rural areas. At least 50 percent are children, or young people under the age of 18.

Figures for 1980 indicate that approximately three out of five persons in developing countries do not have easy access to safe drinking water. Three out of four persons in these countries do not have any kind of sanitary facility, not even a pit or bucket latrine.

Rural areas are most severly affected. While approximately 75 percent of the minority living in urban areas of the developing world receive some form of safe drinking water, either through house connections or standpipes, only 29 percent of those in rural communities have access to clean water.

On the sanitation side, 53 percent of the combined urban population of developing countries have adequate facilities while only 13 percent of the rural people have access to such facilities.

The impact of these figures on health and social welfare is huge and statistics imply disastrously inadequate living conditions for millions of people. For example, UNICEF estimates that about 15 million children below the age of 5 die in the developing countries every year. The absence of safe water and sanitation is a major cause.

If everyone had access to safe drinking water and sanitation, infant mortality could be cut by as much as 50 percent worldwide. According to the World Health Organisation, approximately 80 percent of all sickness and disease in developing countries can be attributed to inadequate water or sanitation, accounting for between 10 and 25 million deaths each year 5/.

Quite aside from the personal and social consequences of ill health there are tremendously high economic costs resulting from water and sanitation deficiencies, such as loss of productivity and income, with their further effects up on the Gross National Product and National development in general.

There are also less obvious consequences generally borne by women and children. In some places, mothers use up to half their day's time and energy to get water and children may not go to school because they have to help their families in fetching water. The Decade aims to assist in solving problems such as these, through the provision of water supply and sanitation.

B. The Strategies of the Decade

The UN Water Conference recommended the following priority actions in order to implement the targets of the Decade 6/.

The main area of priority will be to create general awareness of the problems at hand, and accordingly to encourage Governments to commit themselves to make special efforts towards developing adequate water supply and sanitation. Especially attention should be paid towards the poor and less privileged and to water-scarce areas 7/.

Water and sanitation programmes should be introduced in an integrated fashion, and both should be made socially acceptable and affordable 8/. Community involvement will be promoted; users have to be involved at every level of the programme, from the planning up to the maintenance and safe-guarding of water quality stage 9/. Given these requirements, manpower constraints constitute a major problem. Therefore, training is necessary, specifically at the intermediate and lower levels.

Human resources development plays a major role in the Decade, to create and maintain the technical, scientific and managerial competence necessary to ensure the targetted drinking water and sanitation facilities by 1990 10/. It is obvious that a parallel requirement for the above will be upgrading and strengthening of institutions, governmental or non-governmental.

Even when a community does get safe drinking water and sanitation, water-related diseases may persist. Therefore these programmes should be integrated with other community development projects, for instance, hygiene education and primary health care 11/.

The Action Plan recommended that a National Action Committee be established at the national level in which different ministries and national agencies concerned with the development of drinking water supply and sanitation should participate 12/.

At the international level a Steering Committee for Co-operative Action was established to enhance co-operation among UN agencies in the field of drinking water supply and sanitation. The following eleven UN agencies participate in it: WHO, UNICEF, ILO, UNEP, FAO, IBRD, UNESCO, United Nations Department of Technical Co-operation for Development, UNCHS, UN International Research and Training Institute for the Advancement of Women and the UNDP, which chairs the Committee. The WHO Unit for Global Promotion and Co-operation in Water Supply and Sanitation provides the Secretariat to the Steering Committee. The Committee maintains close links with the National Action Committees, through the UNDP Resident Representatives 13/. At all other levels, financial institutions, NGOs, the business community, industries and the media are called upon to assist in achieving the objectives of the Decade.

C. Costs of the Decade

Meeting even the Decade's basic objectives will be an ambitious and costly task: new water supply and sanitation facilities will have to be provided for half a million people every day during the Decade. The World Bank and UNDP have made some calculations based on less sophisticated and lower cost technologies, which will provide an adequate level of service in both urban and rural areas. It further takes into account a wider mix of service levels and an 80 percent level of coverage by the Decade's end. This figure is $300,000 million or $30,000 billion per annum. Since external sources can provide only about $2,300 million a year, the major share of funds must come from internal resources, provided by the developing countries themselves. On the average, external support thus forms only 20 percent of the total sector investments, while for less developed countries this can run up to 70 percent 14/.

In order to receive more foreign assistance to meet such needs, developing countries should shift their priorities towards the water and sanitation sector. It has been suggested that National Decade Plans emphasise this. Developing countries should also be assisted in the project identification and preparation phase, so that potential donor countries can be presented with well-defined aid requests. An excellent tool therefore is the Project and Programme Information System Data Sheet 15/, which presents Decade-Aid requests.

PART II : UNDP AND THE DECADE

A. World-wide Distribution of Activities

Water and sanitation programmes have always been an integral part of UNDP's technical assistance programme. From the 1960's to the proclamation of the Decade, UNDP financed about 80 projects, most of them executed by WHO. Since then, UNDP has financed 123 global, interregional, regional and country projects amounting to some US$152 million. (Co-financiers are the UN Capital Development and United Nations Sudano-Sahellan office (UNSO)).

These projects are particularly focussed on the development and use of the full range of water resources, training, health education, institutional development, and technology development. Priority, however, has been given to projects or components thereof for drinking water supply for providing coverage to rural areas, introducing technologies and for human resources development. Each project usually is involved in more than one area of activity 16/.

By region, Africa has the most projects (39%) and the largest share of funds (37%). The Asia and Pacific region has the second largest number (30%) and receives the second largest share of total funding (30%) followed by the Arab states with 12 percent of the projects and 12 percent of the funding. Latin America has 4 percent of the funding and 9 percent of projects, and the global/interregional programme 5 percent of the projects and 11 percent of total funds.

At the country level, UNDP is responsible for assisting the Governments in chairing technical support teams, consisting of members of various UN agencies present in the country. As mentioned before, the Resident Representative of UNDP maintains close links with the International Steering Committee and e.g. with the Informal Working Group to identify water and sanitation areas needing international research and development and informational inputs.

B. Global and Interregional Projects

At the moment UNDP is financing one global project on Research and Development in Integrated Resource Recovery, which is executed by the World Bank. The project focusses on low-cost water recycling and collecting systems and their economical and institutional feasibility through case studies and pilot plants.

Of the five current UNDP-financed interregional projects, three of them are executed by the World Bank. These are mainly concerned with the development and implementation of appropriate technology for low-cost sanitation and water supply; and their background philosophy derives from the fact that in previous times, many water and sanitation systems in developing countries mistakenly adopted high-cost western designs, which also required expatriate technical expertise.

Technology must now be adapted to fit the prevailing realities and resources, and thus be cheaper to produce and easily maintainable by the community using it. Therefore, main activities of these projects are laboratory and field testing of rural water supply handpumps, informing and training of local communities on the use of low-cost sanitation facilities and advising Government policy-makers on project designs reflecting local environment, health and social conditions 17/.

Another activity of UNDP at the interregional level is the promotion and support for women's participation in the Decade's activities on behalf of increasing the well-being of women themselves and their families. The project will establish a sound data-base for increasing women's effective participation in water supply and sanitation programmes at all stages. The project will establish linkages with many country projects especially in the fields of health education, training, field testing and institutional development.

Also executed by the UNDP Office of Project Execution is the project on Programme Development and Information/Communication on NGO Support for Decade's activities. The long-term objective is the attainment of support for Decade's goals through selected public groups, influencing water supply and sanitation programmes in developing countries. Its short-term objectives are programme development to include women and NGO's in Decade programmes, information distribution and technical co-operation activities among developing countries through the exchange of experiences. Also of considerable importance, the project assists in attracting the financial and other resources needed to obtain the Decade goal. In this region, a South Asia NGO Collaboration Programme for the Decade is being executed under it, as well 18/.

PART III : UNDP AND THE DECADE IN ASIA AND THE PACIFIC

A. Introduction

UNDP has allocated more than US$45 million on behalf of water and sanitation programmes in this region. Countries which receive the biggest share are Bangladesh, India and Indonesia. The majority of the projects in the region have an institution-building character or are actually involved with the implementation of water supply and sanitation facilities. Other activities are study and research of surface water control, hydrology, system engineering, water balance studies and manpower training. The average duration of the projects is four years. The majority of the projects is in the range of US$500,000 and US$1,000,000 while especially the three biggest recipient countries do have projects with inputs higher than US$1 million. Besides Government inputs in kind, the projects are co-financed by UNICEF or bilateral development assistance agencies.

B. Regional Projects

A small amount of the funds allocated for the Asia region have been spent on the following three projects:

i) Diarrhoeal Diseases Control Programme:

A regional training support project executed by WHO which started in 1979. The project's long-term objective is to adopt and promote known and new strategies for treatment and prevention of diarrhoeal diseases as part of primary health care. In the short-term, the project supports national institutions in research and training activities and in organising intercountry and national training courses for trainers and health workers.

Another important feature of the project is the fact that it disseminates knowledge about diarrhoeal diseases control within Asia, in the context of Primary Health Care and the Decade. The project has strengthened the International Centre for Diarrhoeal Disease Research (ICDDR) in Dacca, Bangladesh; the National Institute for Cholera and Enteric Diseases in Calcutta, India; and the King Edward Medical College in Lahore, Pakistan. The participating countries include Bangladesh, Burma, China, India, Indonesia, Laos, Malaysia, Nepal, Pakistan, Papua New Guinea, Philippines, Sri Lanka, Thailand, Vietnam.

Secondly, a World Bank-executed project on the Preparation of Water and Sanitation Projects, started in 1982, is active in the following countries: Bangladesh, Bhutan, Burma, China, Maldives, Malaysia, Nepal, Philippines, Sri Lanka, Thailand and Indonesia.

A technical team has visited the participating countries to assist Governments and national institutions with the preparation of projects and the identification of funds sources. The team pays special attention to low-cost technology and projects which can be widely replicated. Projects have been formulated in Malaysia, Nepal, Sri Lanka and Thailand and for some funds have been located. Training is performed through seminars in e.g. Philippines, India, Thailand and Sri Lanka, Burma, Malaysia.

Another WHO-executed UNDP-financed regional project is assisting the Governments of Indonesia, Malaysia, Maldives, Nepal, Papua New Guinea, Philippines, Sri Lanka, Thailand and Tonga in the setting of guidelines, criteria and procedures for Planning on Water Supply and Sanitation and the strengthening of participating institutions through case studies.

The project also pays sufficient attention to important components such as community education and participation, human resources development and choice of appropriate technologies. An important feature of the project will be the networking of national collaborating institutions. Workshops are organised to exchange the data on the several case studies and close contacts are maintained with multi- and bi-lateral aid agencies engaged in Decade activities.

Some examples of ongoing case studies include a study on human resources development for Water Supply and Sanitation field workers in Indonesia; in Nepal, a study on Institutional Development for Rural Water Supply and Sanitation; in Papua New Guinea, a solar river-pump for village water supply, while the Philippines has a study on appropriate technology for flow restructure devices in rural water-supply.

The resulting guidelines, criteria and procedures will be developed and used for training of senior government staff, which will lead hopefully to a strengthening of water supply and sanitation project planning.

C. Malaysia and the Decade

The concepts of the Decade are incorporated in the Fourth Malaysia Plan, 1982-1986. Its Mid-Term Review of March 1984 further stated that "Water supply, sewerage, urban drainage and flood mitigation programmes will be expanded to improve the quality of life."

In effect, the Government of Malaysia started its Decade activities as early as October 1979, with the implementation of a National Water Resources Policy Study by a Japanese International Co-operation Agency (JICA) study team, which produced a set of detailed recommendations dealing with domestic and industrial water supply irrigation, hydropower, sewerage systems, water treatment, floods, river utilisation and water pollution. Proposals were also made to reorganise financial, administrative institutional and legal studies 19/.

The Government gives with the initiation of new projects, priority to water supply. Emphasis will be given to water conservation, through the scheduled installation of spring-loaded taps, downstream storage facilities and ground water exploitation. The figures for 1980 show that in urban areas, 89 percent of the population is covered by water supply services, while for rural areas only 43.2 percent is covered. The targets for the Decade are respectively 100 percent and 83 percent. Sanitation facilities are so far under-developed, only 3.2 percent of the population has been provided with a central sewerage system. This will be considerably more for the urban areas towards 1990. In 1983, 12.5 percent of the population (all in the rural areas) did not have any excreta disposal facility, while others (about 85 percent of the population) make use of buckets, pits, hanging latrines and pour-flush toilets 20/. In 1990, however, 100 percent of the urban and 66 percent of the rural population will be provided with sanitation facilities.

UN Assistance in the water and sanitation sector has been provided to Malaysia from 1966 onwards, e.g. by UNDP, WHO, FAO and the World Bank. Presently on-going projects include MAL/82/011: Training in Water Systems Technology (US$286,000) through which the Water Division of the Public Works Department is being assisted from February 1985 by two UNDP financed experts for a period of two years. This WHO-executed project will help increase the training capacity in Peninsular Malaysia for all technicians working in the water and sanitation sector, leading to an improvement of the operation and maintenance services of water and sanitation systems.

Furthermore, the Government of Malaysia is participating in a regional UNDP-financed, World Bank-executed project on Preparation of Water and Sanitation Projects (see p.9-6), which for Malaysia is essentially focussed on project designs in the states of Johore and Selangor.

The Johore project for expansion of water production and main distribution facilities, was identified during a joint UNDP/ World Bank mission. Its total cost will amount to US$149 million, US$73 million of which is to be in foreign currency. The Government of Malaysia has submitted a request for a loan to the World Bank.

The Selangor State project would supply water to approximately 2 million people in the Federal Territory of Kuala Lumpur and adjacent areas in Selangor State, at an estimated total cost of about US$450 million. The UN team assisted the Public Works Department in the preparation of the project, which will be submitted for IBRD appraisal early in 1986.

Malaysia is also participating in the regional Decade Advisory Services Project, described on p.9-7. The case study exercise for Malaysia took place in the Lundu district of Sarawak, East Malaysia. This study intends to document the institutional development of rural water supply and sanitation sectors in East Malaysia and to integrate Primary Health Care with rural water supply and sanitation. A drinking water quality surveillance manual and preventive maintenance manual will be field-tested and modified.

In addition to the above-mentioned UNDP technical assistance, Malaysia is receiving bilateral assistance covering a wide range of activities from consultancies regarding the construction of dams to the provision of small-scale handpumps in rural water supply projects. A substantial loan of US$24.5 million has been received by the Malaysian Government from the Asian Development Bank for the construction of a new water supply scheme in Kedah State, in northern Malaysia. The scheme will consist of a raw-water pumping station, a treatment plant, five water reservoirs and a network of 73 km of pipelines.

PART IV : THE DECADE IN 1985

The Decade has helped create a worldwide awareness of the lack of safe water supply and sanitation for two-thirds of mankind. More important, it has converted this awareness into some positive actions undertaken by developing as well as developed countries and international aid agencies. More than 70 developing countries have drawn up their detailed Decade plans and targets, and brought better quality projects forward to donors who as a result have increased their allocations for Decade programmes. Satisfactory progress has also been made in the production and application of low-cost materials for water supply and sanitation, which being locally manufactured and user-accepted, are easier to operate and maintain 21/.

During the first three years of the Decade, some 345 million people gained access to safe water supply and 140 million obtained sanitation facilities 22/. The most significant progress has been made in South East Asia mainly because of its relatively high economic growth rates and the successful introduction of selected low-cost technologies. In Bangladesh, India and Indonesia alone, 130 million people gained access to safe water supply 23/.

The Decade programme as a whole, however, has faced many constraints which will likely prevent it from reaching its original target of "safe water and sanitation for all people by 1990." In fact, even if the required funds were available, the target probably could not be reached by 1990 due to the developing countries' lack of capacity to absorb the resources. This in turn is mainly due to inadequacies in infrastructural and institutional development, and lack of skilled manpower. Furthermore, water and sanitation programmes have to compete with other development sectors and often do not receive high enough priority from the policy-makers. A closely related factor is the low costs-recovery ratio of water and sanitation facilities, and their operation and maintenance.

Progress in reaching the Decade's targets is also hampered by the lack of community participation and integration with other development activities. Even water and sanitation programmes themselves are sometimes implemented separately. Interlinked herewith is the fact that the provision of water supply receives priority above sanitation projects, while urban areas are more favoured than rural areas. As a result, at the global level the percentage coverage of sanitation in the rural areas has deteriorated by 2 percent.

Besides the above-mentioned policy-related problems, three major external factors negatively affect the Decade progress: the high rate of population growth, the reduced physical supplies of water and the World recession responsible for the deterioration in the resource situation 24/.

As from 1986 still 1200 million people will be refrained from safe water supply and 1900 million from adequate sanitation. It is not possible for all of them to be granted these facilities before 1990, but that should not be a reason to give up the Decade programme; what we have to give up is the concept of reaching the target in one decade.

Out of the experience gained from the Decade so far some revised policy lines have been established, which might accelerate the Decade programme and will improve its quality 25/.

One of the most important is that programmes should be executed with the assistance of the intended beneficiaries, locally manufactured equipment should be used and preferably financed by local money. The emphasis has to be shifted from big scale (western) engineering undertakings to decentralised, community-level water and sanitation projects, preferably executed in close connection with each other and with Primary Health Care and Health Education Programmes. Special attention has to be paid to the strengthening of institutions, human resource development, improvement of cost-recovery and the involvement of women and non-governmental organisations.

In addition to this, Governments and donors have to be kept continuously interested in the Decade's objectives. Hopefully, the growing visible social, health and economic improvements in the lives of millions, resulting from the new availability of water and sanitation facilities, will keep the stream of progress moving.

1/ Report of the United Nations Water Conference, Mar del Plata, Argentina, 14-25 March 1977. UN Publications, Sales WO E.77-11.A.12.

2/ Other International Conferences which have agreed on concerted actions to meet water supply and sanitation needs are;

- United Nations Conference on Human Settlement (Habitat), Vancouver, Canada, 1976;
- WHO-UNICEF sponsored Conference on Primary Health Care, Alma Ata, USSR, 1978;
- The World Conference of the United Nations Decade for Women's Equality, Development and Peace, Copenhagen, Denmark, 1980.

3/ World Water, D-day for the Water Decade;

A special reprint of articles from World Water in November and December 1980 produced for UNICEF and UNDP to commemorate the launch of the United Nations International Drinking Water Supply and Sanitation Decade.

4/ Decade Dossier, published by UNDP Division of Information;

Water and Sanitation for all? Earthscan Press briefing document no. 22, New York, November 1980;

UN Secretary-General, Kurt Waldheim, Keynote Speech, United Nations General Assembly, 10 November 1980.

5/ Diarrhoea directly kills six million children a year and contributes up to the deaths of up to 18 million people.

Trachoma affects 500 million people at any age, often causing blindness;

Parasitic worms infect nearly one half of the entire population of the developing countries; 200 million people in 70 countries suffer from schistosomias;

Malaria kills yearly one million children below the age of two in Africa, below the Sahara alone.

6/ International Drinking Water Supply and Sanitation Decade (1981-1990), Briefing Document, United Nations WHO, Geneva, June 1980 (EHE/80.8).

7/ Decade Action Guide, United Nations Development Programme, Division of Information.

8/ Appropriate Technology for Water Supply and Sanitation World Bank Technical Papers, The World Bank, Washington D.C., 1976-1984;

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9/ Anne Whyte, Guidelines for Planning Community Participation in Water Supply and Sanitation Projects, Institute for Environmental Studies, University of Toronto. WHO publication, ETS/83.8; Maintaining the system: Barefoot Engineers, UNDP Case History No. 4;

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10/ Basic Strategy document on Human Resources Development, Recommendations of the Task Force on Human Resources Development of the International Drinking Water Supply and Sanitation Decade Steering Committee for Co-operative Action, WHO, Geneva, April 1982.

11/ Drinking Water and Sanitation, 1981-1990, A way to health, WHO, Geneva, 1981;

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12/ Project and Programme Information System, IDWSSD, Publication no. 1, WHO, Geneva, Revision April 1983.

13/ Further the Action Plan recommends the Inter Secretariat Co-operation at the Regional Level; The Institution of Designated Officials for Environmental Matters and the Inter Secretariat Group for Water Established by ECOSOC's Administrative Committee on Co-ordination. See: United Nations Water Conference, 1977, The United Nations Organisations and Water, Briefing Note; Prepared by the Intersecretariat Group for Water of the Administrative Committee on Co-ordination, United Nations, New York, 1982.

14/ The International Drinking Water Supply and Sanitation Decade, Review of National Baseline Data (as at 31 December 1980), WHO offset Publication No. 85, WHO, Geneva, 1984.

15/ Also useful are:

Catalogue of External Support, IDWSSD, publication no. 3, WHO, Geneva, second edition April 1983;
The International Drinking Water Supply and Sanitation Decade Directory, World Water Magazine, WHO, London, first edition June 1984;

Grover, Burnett, McGarry, Water Supply and Sanitation Project Preparation Handbook, World Bank Technical Papers, The World Bank, Washington, D.C., 1983.

16/ Catalogue of projects, related to the International Drinking Water Supply and Sanitation Decade and supported by the UNDP and UNDP-associated Programmes, UNDP Division of Information, New York, November 1984.

17/ The World Bank/UNDP Water Decade Programme, a report on the Status of Research and Development of Low-Cost Technologies, Water Supply and Urban Development Department, World Bank, Washington D.C., January 1985.

18/ Building Bridges, Collaboration with NGO's in South Asia, IDWSSD, Department of Public Information, UNDP, New York.

19/ Government of Malaysia National Water Resources Study, Malaysia, Main Report Vol. I Master Action Plan, Vol. 2 Water Resources Development and Use Plan, Japan International Co-operation Agency, October 1981.

20/ Mid-Term Review of the Fourth Malaysia Plan, 1981-1985, Kuala Lumpur, March 1984;

African and Asian Water & Sewerage, Vol. 3 No. 3, Industrial and Marine Publications Ltd, September 1984.

21/ International Drinking Water Supply and Sanitation Decade, Decade Watch, Vol. 2, No. 3, July-September 1983, UNDP, New York;

Decade Watch Sanitation Special, Vol. 2, No. 4, December 1983, UNDP, New York.

22/ Rural and urban water coverage grew with 14 and 1 percent, rural sanitation deteriorated with 2 percent, while urban sanitation grew with 14 percent;

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PAPER 10

URBAN DRAINAGE AND SEWERAGE IN KUALA TERENGGANU, MALAYSIA

BY

A RASHID ARAFFIN
BINA RUNDING SDN. BHD.,
MALAYSIA
R J OWENS
JOHN TAYLOR AND SONS,
UNITED KINGDOM

1.0 INTRODUCTION

1.1 Scope of Paper

This paper includes in general terms a description of the design of the proposed Urban Drainage and Sewerage Scheme being undertaken by the Majlis Perbandaran Kuala Terengganu on behalf of the State Government of Terengganu.

1.2 Background

Kuala Terengganu is situated on the East coast of Peninsula Malaysia on the mouth of the Sungai Terengganu. The climate is typically tropical with average monthly temperatures ranging between 25°C and 28°C and consistently high relative humidity. Total annual rainfall is approximately 2,600 mm. most of which falls in the monsoon season between November and February. The topography is extremely flat, apart from a couple of small hills it rises less than 10 m above sea level.

The total area eventually to be served by the Urban Drainage and Sewerage Scheme is within the jurisdiction of the Kuala Terengganu Municipality and the estimated present population is 205,000, predicted population by the year 2000 is 350,000. Current development within the town comprises a densely populated town centre, an area of light industry along the Southern Bank of the Sungai Terengganu to the West of the town centre and low to medium density residential areas to the South and West of the town centre. (Fig. 1). The remainder of the Majlis Perbandaran Kuala Terengganu area is largely rural with scattered kampung development.

Like other major towns in Malaysia, development in Kuala Terengganu is proceeding rapidly to support the pressing and increasing demands of rising population. In addition, in Terengganu,there is the influence of tourism, the new offshore oil industry and the increasing affluence and expectations of the community at large. Such development is putting severe pressure on the infrastructure and Local Government administration.

Existing sewage disposal and drainage systems are inadequate. Sullage water flows onto open ground or into surface water drains and ground water is contaminated. Solid waste accumulates on open ground, beside roads and in surface water drains. The extent and frequency of flooding due to an inadequate and frequently blocked existing drainage system is a serious nuisance. Storm flows will increase, particularly within the town as development increases the impermeability of the area. Inundation from the river has significantly decreased as predicted since the construction of Kenyir Dam on the Sungai Terengganu was completed about two years ago.

A Master Plan (Ref 1) for sewerage and drainage for the whole of the Municipality was prepared in 1983. This identified the scope of the sewerage and drainage works necessary and made recommendations for the staged construction of the proposed works. In October, 1984, Bina Runding Sdn. Bhd. in association with John Taylor & Sons, Consulting Engineers of London, U.K., commenced work on the review and up-dating of the Master Plan prior to detailed design. The review was completed in December, 1984 (Ref 2) and the detailed design and preparation of tender documents for the first stage of construction of the drainage and sewerage scheme commenced. At the time of writing this paper (June, 1985) the designs are essentially completed, draft documents are under consideration by the Majlis Perbandaran Kuala Terengganu and the necessary land acquisition procedures have commenced.

1.3 Objective

The technical and other problems met during design work and the solutions found are not new or specific to Kuala Terengganu. The object of presenting them is to generate interest and hopefully to provoke some discussion and interchange of ideas between others who have experienced similar problems.

The body of the paper is arranged in five main sections dealing respectively with:

(1) the designs of the sewerage and sewage treatment facilities
(2) the designs of the drainage network
(3) materials and methods of sewerage construction
(4) planning and building controls and their effect on project design and implementation
(5) the effects of the project on staffing within the Majlis Perbandaran Kuala Terengganu.

2.0 SEWERAGE AND SEWAGE TREATMENT

2.1 Scope of Stage 1 Construction

The area to be sewered under stage 1 (Fig. 2) is approximately 1,000 hectares and comprises the town centre, the industrial area and surrounding area of residential development immediately to the West of the town and the existing residential development to the South of the town. The future population of this area is expected to rise to about 100,000.

The proposed sewer network comprises approximately 35 km of trunk sewers with diameters varying from 225 mm to 1,500 mm. In addition there is expected to be approximately 20 km of branch sewers and property connections in minor roads and back lanes. Five pumping stations are included, four area stations located within the sewerage network and one main lift station at the sewage treatment works. The sewage treatment works, comprising anaerobic, facultative and maturation ponds, is sited on the North bank of the Sungai Ibai, approximately 6 km. South of the town centre.

2.2 Design Criteria

Due to the flat topography, minimum gradients are the critical factor in determining sewer sizes and depths. The methods proposed by the United States Environmental Protection Agency (Ref 3) were used to ascertain minimum gradients required to prevent high concentration of H_2S in sewers. These were compared with the minimum gradients required to obtain a full bore velocity of 0.6 m per second and the steeper gradient for each diameter of sewer used as the minimum design gradient (Table 1). The effect of these gradients on subsequent design and choice of sewer pipe material is discussed later in this paper.

Sewage flows originate from three contributing sources, domestic, industrial and infiltration. Sewers are designed to carry the accumulative peak flow from these three sources.

Infiltration allowance is a constant 6 cu. m. per hectare per day from the developed area to be sewered.

For industrial areas an average flow of 20 cu. m per hectare per day has been allowed. This future average industrial water consumption was based on measured present water consumption. Peak flows from industrial areas were assumed to be twice the average flow.

Domestic flows were based on average per capita sewage flow of 225 litres per head per day increased to 244 litres per head per day to allow for additional flows from local schools, commercial and institutional buildings within primarily residential areas. The factor used to obtain peak domestic flow from average flow was $\frac{4.8}{P^{0.125}}$ where P is the equivalent population in thousands.

Selection of trunk sewer routes was based on comprehensive ground level surveys. Design flows, pipe size and gradient for each sewer length between manholes was calculated in-house by computer using a programme developed for this scheme by Bina Runding Sdn. Bhd.

Structural design of pipelines was based on the procedures recommended in 'A Guide to Design Loadings and Buried Rigid Pipes' prepared by the Transport and Road Research Laboratory, Department of Transport, U.K. (Ref 4). "Wide trench" conditions were assumed throughout as site investigation indicated that stable trench sides were unlikely to be achieved.

2.3 Pumping Stations

Five sewage pumping stations are to be constructed in the Stage 1 scheme, three in the developing town area, one approximately 3 km South of the town centre and on the main trunk sewer to the sewage treatment works and one at the sewage treatment works. The five pumping stations include:

- One station with electrosubmersible pumps in wet sump.
- Three wet well/dry well stations with rotodynamic pumps in the dry well shaft driven by motors at ground level.
- One archimedean screw station

All stations are of conventional design incorporating standby pumps, automatic (or manual) operation with pump start/stop control by sewage level sensors in the wet sump. Sewage flows, to the three stations situated in the developed town area, are expected to build up rapidly after commissioning of the sewerage system. The full complement of pumps will therefore be installed during station construction. The screw pumping station and the lift station to the sewage treatment works have capacity reserved for future development. In each case space has been allowed for installation of additional pumps in the future when increasing sewage flows dictate.

Diesel driven generators will provide standby power in case of failure of mains supply at the sewage treatment works station, the screw station and the largest of the three town stations. At the two smaller town stations, in case of power failure, standby pumping will be provided by mobile deisel driven pumps. These pumps can be made available for maintenance duties on sewers and drains emptying ponds for desludging at the sewage treatment works and over-pumping manholes for sewer maintenance and clearing blockages.

2.4 Sewage Treatment

The form and arrangement of the treatment works is a sequence of three ponds in series designated anaerobic, facultative and maturation. (Fig. 3). The anaerobic ponds are 3 m deep and give a retention time of 2.5 days. Subsequent assessment of the sizes of the facultative and maturation ponds assume a BOD reduction of 60 per cent in the anaerobic ponds. The area of facultative and maturation ponds together is based on a BOD load onto the ponds of 225 kg/ha/d. The maximum loading of the facultative ponds, assuming a lowest mean temperature of 25°C, has been taken as 380 kg/ha/d.

In facultative and maturation ponds it is generally recognised that BOD reduction follows first order kenetics; that is, the rate of BOD reduction decreases in proportion to the concentration remaining. Using the above design parameters the sewage treatment works is expected to produce an effluent with BOD better than 22 mg/l. (Table 2). Optimum sizing of facultative and maturation ponds, to maintain anaerobic conditions and avoid odour problems, is related to surface area and depth depending on exposure to the atmosphere and solar radiation. At the chosen optimum depth of 1.5 m the retention times are 3 days and 2.1 days for the facultative and maturation ponds respectively.

An effluent quality better than 50 mg/l BOD is predicted after the facultative ponds (without final treatment in maturation ponds). This quality complies with Malaysian Ministry of Health requirements (Ref 5) and it could be concluded that the maturation stage of treatment is unecessary. However, this prediction allows little margin for unexpected variations in flow or possible reduction in anaerobic pond performance. Additionally there are other benefits from maturation pond treatment including enhanced suspended solids reduction, pathogen reduction, and oxygenation, the latter limiting the

Table 1. Minimum Sewer Gradients

Sewer dia (mm)	(1) Minimum gradient required for velocity of 0.6 m/s	(2) Gradient required to ensure minimal formation of H_2S	(3) Gradient required to prevent high concentrations of H_2S*	(4) Ruling gradient (steeper of column (1) and column (3)
150	210	250	340	210
225	360	375	460	360
300	525	490	610	525
375	714	600	720	714
450	897	700	880	880
525	1 094	800	1 040	1 040
600	1 380	900	1 200	1 200
675	1 500	990	1 360	1 360
750	1 720	1 080	1 490	1 490
900	2 175	1 250	1 750	1 750
1 050	2 632	1 400	1 980	1 980
1 200	3 115	1 560	2 220	2 220
1 350	3 582	1 670	2 420	2 420

* Based on methods published by the United States Environmental Protection Agency in "Sulphide Control in Sanitary Sewerage Systems".

Sewage temperature 28°C

BOD 225 mg/1

Source: Master Plan (1983)

Table 2 Sewage Treatment Works Performance

Average Flow	Design Flow		Design Flow minus Infiltration	
	52 491 cu m/d		44 036 cu m/d	
	BOD_5 Load	% Reduction	BOD_5 Load	% Reduction
Average Sewage Load	209		249	
		60		60
Anaerobic Ponds Effluent	84		100	
		54		58
Facultative Ponds Effluent	39		42	
		44		48
Maturation Ponds Effluent	22		22	

extent of oxygen sag in drought conditions in the Sungai Ibai with subsequent benefit to aquatic life.

Most sewage arriving at the treatment works will have passed through coarse screens at the pumping stations. The provision of additional screens at the treatment work is therefore questionable. However, they have been included to minimise the possibility of floating solids effecting the flume (flow) measurements or passing through the ponds and reaching the river.

The total pond treatment capacity is split into eight treatment lines each comprising an anaerobic pond, a facultative pond and a maturation pond in series. Four lines of ponds representing 50 per cent of the ultimate treatment capacity are to be constructed in Stage 1. The total area required for the ultimate works capacity will be approximately 45 ha. of which about 25 ha. is required for the Stage 1 works.

2.5 Contract Packaging and Cost

The stage 1 sewerage and sewage treatment system is to be constructed under three separate contracts. It is hoped that construction may start in mid-1986 and finish in 1989. The first contract will include the sewage treatment works and the sewers serving the newer development South of the town centre. The second contract comprises the sewerage of the town centre. The third contract comprises the sewerage of the industrial and residential development West of the town centre. The estimated cost of construction of Stage 1 sewerage work is R$80 million.

Each contract will be an "all in" contract and therefore includes the manufacture, supply, erection and commissioning of the mechanical and electrical equipment for the pumping station as well as civil engineering construction.

3.0 DRAINAGE

3.1 Scope of Works

The area to be served by the Stage 1 drainage system includes the town centre and urban development areas to the West and South of the town bounded by the Sungai Terengganu, the South China Sea and the Sungai Ibai. (Fig. 4). The proposed drainage system comprises approximately 40 km. of earth and concrete channels and culverts with associated road and foot bridges, outfall tidal gates and river flood protection bunds. The natural slope of the land in most of the Stage 1 area generally dictates that rain water run-off flows towards the South and discharge to the Sungai Ibai. The Northern part of the area drains towards the Sungai Terengganu. The total drainage catchment area for Stage 1 is approximately 2,900 ha.

Existing flooding problems are primarily because storm flows cannot get into the drains and existing drains cannot cope with flows during a typical storm. There are a number of contributing factors; some can be avoided by improved design of road drains including number and location of kerb outlets, road surface profiles, improved maintenance and cleaning of drains. Platform levels should be established for development of all areas so that filling prior to construction is to consistent planned levels above datum.

To ensure that surface water can get into the system the design and implementation of the Stage 1 drainage network has been split into two components; the primary network comprising the main drain and outfalls and a network of secondary drains to collect and carry run-off into the main system.

and carry run-off into the main system.

3.2 Design Criteria

Procedures for the estimation of storm run-off and design of drainage systems have been prepared by the Drainage and Irrigation Department and published in the form of various hydrological procedure booklets. (Ref 6). In general these recommended procedures and parameters have been adopted in design.

Different storm return periods have been adopted for various types of land use. Drains in commercial and industrial areas are designed to cater for a 5-year storm. Drains in residential areas are designed to cater for a 2-year storm. Partial submergence of agricultural areas (padi) has been allowed but limited to a period, for design, of 72 hours.

A new procedure for the design and analysis of urban drainage systems in the U.K. has been prepared by the Department of Environment, U.K. (Ref 7) and was published in 1981 as the Wallingford Procedure. The procedure is more complex than the previous TRRL and Rational methods and requires more initial data to be collected. In particular, measured storm profiles or hyetographs are needed for the best use to be made of the Wallingford Procedure. The Procedure was developed to fulfil the need for detailled analysis and understanding of the performances of a drainage system for the most cost effective design of drainage systems in urban areas.

A variation of the procedure for use outside the U.K. has been developed and has been available since 1983. There is insufficient meteorological and hydrological data currently available for Kuala Terengganu to enable the overseas version of the Wallingford Procedure to be used effectively for the design of the proposed drainage system. Although the current Malaysian standard procedure, based on the Rational method, tends to over-estimate downstream flows for larger catchments, it is questionable whether significant cost savings would have been obtained. Even if the resulting marginal decrease in downstream drain sizes would have been desirable, the degree of protection against flooding given by the use of two and five-year design storms is by no means excessive for such a flat area.

3.3 Alternative Solutions

Stage 1 drainage area is sub-divided into several discreet catchments each to be served by its own network of primary and secondary drains. Various conceptual and routing alternatives were considered, where appropriate, for each catchment; the following being worthy of note.

The majority of the catchment directly South from the town centre is bounded by a sandy ridge along the coast which effectively prohibits natural run-off over the beach to the sea. The catchment will therefore be served by a drain running approximately North-South through the centre of the catchment discharging to the Sungai Ibai. High tide levels during the monsoon in the Sungai Ibai dictate that the outfall will be tide-locked and submerged. To restrict the drain and outfall size, 145 ha. of low-lying undeveloped land immediately to the North of the outfall has been reserved as a "ponding area" (informal balancing lagoon). This area provides storage for the volume of run-off that cannot be discharged to the Sungai Ibai during the tide-locked period. It is an integral part of the drainage system for this catchment and the area must be permanently maintained free of filling and development.

As an alternative to the provision of a ponding area, a scheme replacing the flood tidal gate with a screw pumping station was considered. The flow from the design storm would require a pumping capacity of about 37 cu.m./sec, flooding would still have occurred during more severe storms. It was considered that the value of the land that could have been released for development did not warrant the expenditure on such a scheme and the pumping alternative was therefore rejected.

A second alternative involving the construction of a deep interceptor culvert from the centre of the catchment area crossing the coastal ridge and discharging to the beach and sea was also considered. This would have reduced the size of the main drain to the South downstream of the interceptors and the extent of the area for ponding. The existing drains collect sullage water, and sewage discharged from septic tanks. In addition rubbish and domestic solid wastes are illegally dumped into the drains. The interceptor scheme would therefore have led to beach pollution in an area of considerable amenity value unless a long submerged outfall was constructed to carry surface water flows well away from the shore.

Natural drainage outlets to the sea along the East coast of Peninsula Malaysia are effectd by littoral sand movement which can form sand bars which totally block the outlets. No data currently exists on sand movement behaviour off Kuala Terengganu. A hydrographic study to observe the pattern of sea bed movement and to assess how this natural phenomenon might change if interrupted by an outfall structure would be necessary. The potential saving in cost due to the decreased size of drains and ponding area downstream of the interceptor was outweighed by the cost of the interceptor itself, the outfall structure and the hydrographic survey. This together with the potential pollution problems did not justify the proposed interceptor and this alternative was therefore rejected.

Of particular significance in the choice of drain type in urban areas was the cost and difficulty of land purchase. Private land in Kuala Terengganu is split into many small individually owned lots. The difficulties of land acquisition in such circumstances are well known and the choice of drain type, route and profile was therefore often influenced by land acquisition considerations.

In some areas the final drainage configuration could only be arrived at by trial and error. An initial drain route based on engineering and technical design parameters was prepared avoiding the more obvious obstructions such as concrete buildings then scrutinized in conjunction with the client to obtain the benefit of his local knowledge. The options then considered included:

(a) decreasing bend radii below initially assumed design values with significant increase in head losses and impairment of hydraulic characteristics.

(b) changing to a different form of drain construction e.g. from trapezoidal to U section.

(c) re-routing individual drain lengths.

(d) deferring construction until road reserves were widened thus allowing construction in the future.

(e) construction of buried culverts within existing narrow road reserves instead of the preferred open drain.

(f) reassessment of the entire localised drainage regime to reduce land acquisition requirements in specific areas.

In many cases the final design and route was a compromise between engineering design principles and the potential cost and delays due to land acquisition.

Trapezoidal earth drains require the acquisition of wide drainage reserves; although cheaper to construct than concrete lined drains they require more frequent maintenance.

Construction cost in Malaysia are not increasing significantly at present but land values in Kuala Terengganu have recently increased considerably and are expected to continue to do so. The difference in total cost between earth and concrete drains will therefore decrease with time. Extensive use has been made of concrete lined drains in urban areas.

3.4 Contract Packaging and Costs

The Stage 1 system of primary drains will be constructed under three separate contracts running concurrently, with construction expected to start at the end of 1985 and finish at the end of 1988. The total Stage 1 area has been divided geographically with the priority town area drainage in the first contract , the large catchment to the South of the town area in a second contract, and the industrial and residential area to the West of the town centre in a third. The estimated cost of construction of Stage 1 of the primary drainage system is R$50 million. The secondary drains will probably be constructed by local contractors under a series of small value contracts.

4.0 MATERIALS AND METHODS OF SEWER CONSTRUCTION

Given the topography and the high ambient temperature, the expected slow build up of the sewage flows in the early stages, lengthy retention periods, lengthy retention periods in the sewers and the risk of sedimentation, the formation of H_2S in the sewers is predictable. It is of paramount importance therefore that the material chosen for sewer and manhole construction be highly resistant to H_2SO_4 corrosion. An initial assessment of sewer pipe materials based on availability, cost and suitability indicated that VC, HDPE and uPVC lined RC were likely to be the most suitable. None are currently available in all the diameters needed. None had a clear cost advantage over the others. RC pipes with HA lining were not considered as HA cement is not resistant below pH4 and lower pH's can be expected.

HDPE pipes are flexible and carry superimposed loads by a combination of pipe hoop strength and mobilization through pipe deflections of reactions from the bedding and soil around the pipe to maintain the circularity of the pipe. Stability of the bedding and surrounding soil must therefore be guaranteed, for the duration of the life expectancy of the pipeline, if pipe deflection limits, to avoid collapse or impaired hydraulic characteristics, are not to be exceeded.

The subsoil investigation that has been carried out indicated that the material at depths where the sewers will be laid is usually very loose, fine to medium sand and occasionally very soft grey clay. The ground water level is generally within 2 m of the ground surface.

These conditions are outside the limits normally required to ensure stability and give proper support to a flexible pipeline laid in a granular bedding material. It was therefore considered inappropriate to use flexible pipes for the Kuala Terengganu sewerage project.

Concrete pipes are rigid, the structural design procedures well known and the long term structural performance proven. Concrete pipes with an integral uPVC lining are currently manufactured in Malaysia in diameters large enough to admit a man to enter the pipeline after it has been laid and protect the exposed concrete of the joints by welding a strip of PVC lining material across the joint. These pipes will be used for sewers over 600 mm diameter, At the time of writing no suitable system of protecting the joints from corrosion is commercially available for small RC pipes.

VC pipes in diameter up to and including 600 mm are available from several sources in Australia and Europe and it is understood that the VC pipe factory in Johore Bharu is intending to extend its manufacturing capabilities to include pipes larger than its present limit of 300 mm diameter. VC is resistent to corrosion associated with sewage and will be used for all pipes up to and including 600 mm diameter.

Concrete surfaces inside manholes are equally at risk to attack from an accumulation of H_2SO_4. HA cement mortar rendering will not be used for the reason previously stated. Epoxy coatings are not considered suitable because although resistant in themselves to attack they do not adhere well to concrete in the long term. GRP liners have been used successfully in the

Middle East and give good resistence to corrosion, to damage from impact or wear from use of maintenance equipment. In in-situ manholes it can be applied as a non-structural liner fixed to the international faces of formwork or used as the inner formwork itself. It is readily formed to the required shape. GRP liners can also be readily fixed to the inside face of precast manhole sections leaving only the joints between section to be made good with a fibre mat and resin. GRP will therefore be used to protect the internal concrete surfaces of manholes in the Kuala Terengganu sewerage system.

PVC and PE sheets can also be used but are not rigid and must be positively fixed to the framework with nails and the holes subsequently located and sealed. They are more easily damaged after installation.

Sewers are to be laid at depths ranging between 2 m and 8 m, often along narrow streets congested with other services. The water table is consistently high and the ground, normally very loose, is sand or very soft, fine clay. During the early stages of design pipe jacking and tunnelling construction methods were considered. Methods used in Butterworth and Singapore were investigated. It was found that these systems, using techniques to allow for the particularly poor ground conditions in Kuala Terengganu, were likely to be appropriate and possibly cheaper than sewers in open excavation where the only feasible means of trench support was continuous steel sheet piling. (Fig. 5). The contract documents acknowledged the possible suitability of alternative methods of sewer construction and specifically allowed for pipe jacking proposals.

5.0 PLANNING AND BUILDING CONTROL

Sewage flows are directly related to existing and future land use, population densities and supply of potable water. For designs to be cost effective it is desirable to minimise the need for sweeping assumptions as to future land use and population densities which are of necessity conservative and thus lead to over design. A structure plan should be prepared as this is most important before detailed planning of sewerage and drainage networks. The adopted structure plan can then be used as a basis for more detailed development plans, preferably for all the area of the structure plan and define the limits and types of development, future road networks and platform levels for future land development. Existing legislation gives sufficient powers to local authorities to amend or reject planning applications to ensure their compliance with the overall structure plan.

There is a structure plan for Kuala Ternegganu and some localised development plans. Planning co-ordination, to include all infra structure is therefore most important with plans in sufficient details for both general planning and detailed design of sewer and drain systems as well as other services.

There are problems related to provision of sewer connections to existing properties. For example in some cases, in particular terraced residential or shop-house development, buildings have been constructed up to rear plot boundary and apparently this is legal. Sewage discharges or septic tanks are at the back of the property and when owners of adjacent land wish to redevelop they are required to provide and surface an access road along rear of the terrace. Such re-development may not take place for many years. Thus many existing terrace buildings in such areas cannot be connected to the sewers for some considerable time. One solution is to purchase the landrequired for back lanes. This is obviously an undesirable precedent; it is a lengthy process, would involve Government expenditure and would appear unecessary as the land and the back lane access has to be provided free of charge by the adjacent land owner when he chooses to develop or redevelop, Some local planning rules or regulations are desireable to deal with this type of problem.

Illegal temporary structures are also a problem. They have proliferated as hitherto they have caused no direct nuisance. Also additional staff would be needed by the local authorities to identify and process the documentation for their subsequent removal. Many of these structures have now to be removed for the construction of the sewerage and drainage networks. Although the local authority is entitled to remove such buildings it takes time to accomplish and is always, under-standably, a sensitive local issue.

6.0 STAFFING AND TRAINING

This year the Majlis Perbandaran Kuala Terneggaṅu set up a division specifically to deal with all aspects of existing and future sewerage and drainage facilities. Previously these functions were handled by several departments; resources including staff, particularly experienced engineers, were inadequate to deal satisfactorily with the work load. The new division will be sub-divided, one dealing with drainage, the other sewerage systems. Each sub-division will have a "new works" section and an "operation and maintenance" section. The function of the new works section would be initially to liaise with the consultant during the construction and commissioning of the new systems and subsequently to programme, plan, design, prepare contract documents and supervise the construction of extensions to the system.

In particular the sewerage new works section would be responsible for the scrutiny of developers proposals for future building and to supervise the construction of property connections to the sewers. The drainage new works section would similarly identify the need for, then prepare design and contract documents for extensions to the system as development proceeds and supervise repair work to existing drains as well as new construction work.

The sewerage operation and maintenance section would ensure the proper operation of the new sewerage and sewage facilities and also continue with the systematic emptying and maintenance of existing septic tanks and solid waste disposal. Of fundamental importance to the success of these operations is the appointment of sufficient senior staff for planning and programming of both new work and operation and maintenance procedures and to enforce their implementation. It is ineffective and counter-productive to leave supervision of implementation in the field in the hands of unskilled supervisors.

It is proposed that training be aimed primarily at senior staff and the recruitment of suitable staff be started during construction of the new systems so that initial training and familiarization with the systems can be obtained by these senior staff by participating in the supervision of construction along with the consultant's site supervisory staff. It has also been proposed that a project manager be appointed to co-ordinate construction supervision of all concurrent contracts and that one of his primary duties should be to prepare and advise the Majlis Perbandaran Kuala Terengganu of suitable operation and maintenance programmes and procedures, arrange on-site training seminars and advise on recruitment programming.

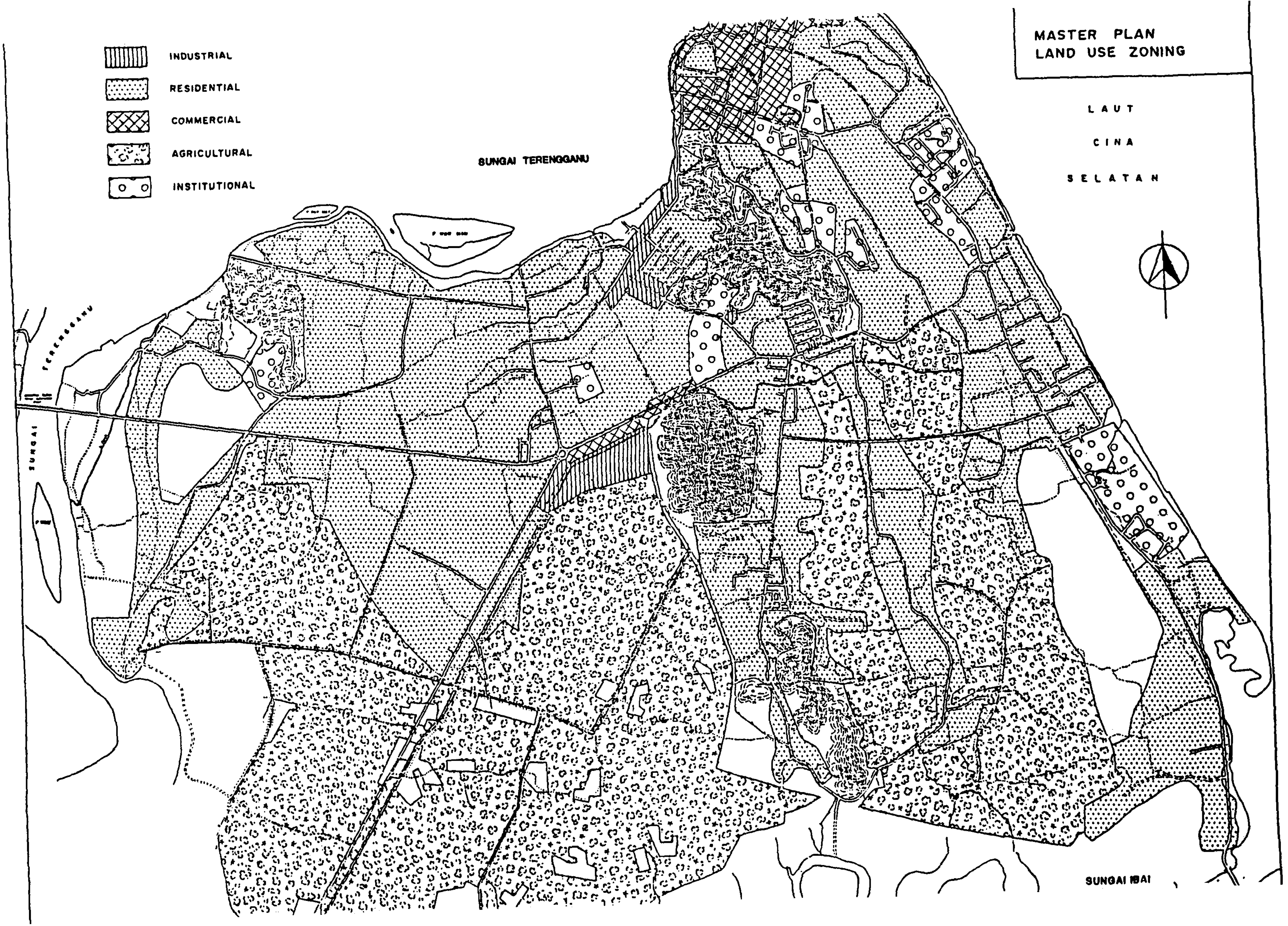
Facilities for additional training have been allowed for under the sewerage construction contracts in a number of ways.

(a) The contractors will arrange for representatives from the Majlis Perbanaran Kuala Terengganu to attend short-term management, planning and relevant technical courses at colleges both in Malaysia and overseas.

(b) The contractors shall also be responsible for arranging visits by MPKT staff of three months duration to the place of manufacture of the mechanical and electrical equipment during which the staff member will receive advice and practical experience on the manufacture of the machinery.

(c) Short-term training sessions and site experience will also be given during erection and commissioning of the machinery.

Finally, the contractors are required to operate and manage the whole of the completed works for a period of six months after completion of construction. During this period the contractors are to supply all labour necessary to fully operate and maintain the whole of the constructed works including all regular maintenance items such as greasing of machinery and grass cutting, the contractors will also be responsible for compiling suitable operation and management programmes and procedures in the light of operating experience gained. This period gives the Majlis Perbandaran Kuala Terengganu a six month lead-in time for staged recruitment of the full complement of operating staff needed and allows for staff from the Majlis Perbandaran Kuala Terengganu to work together with contractor's staff while gaining the necessary expertise for full operation.


MASTER PLAN
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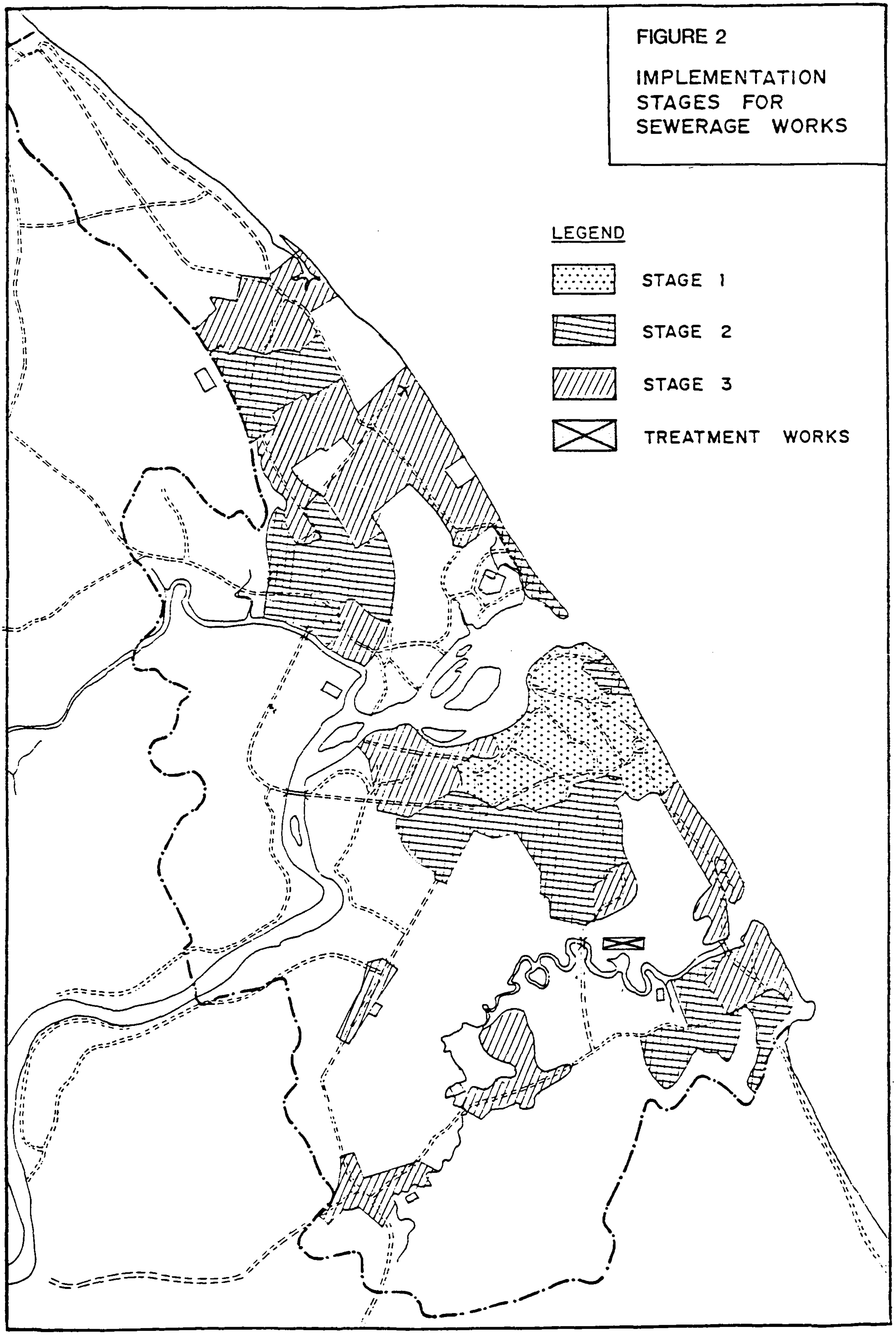


FIGURE 2
IMPLEMENTATION STAGES FOR SEWERAGE WORKS
LEGEND
STAGE 1
STAGE 2
STAGE 3
TREATMENT WORKS

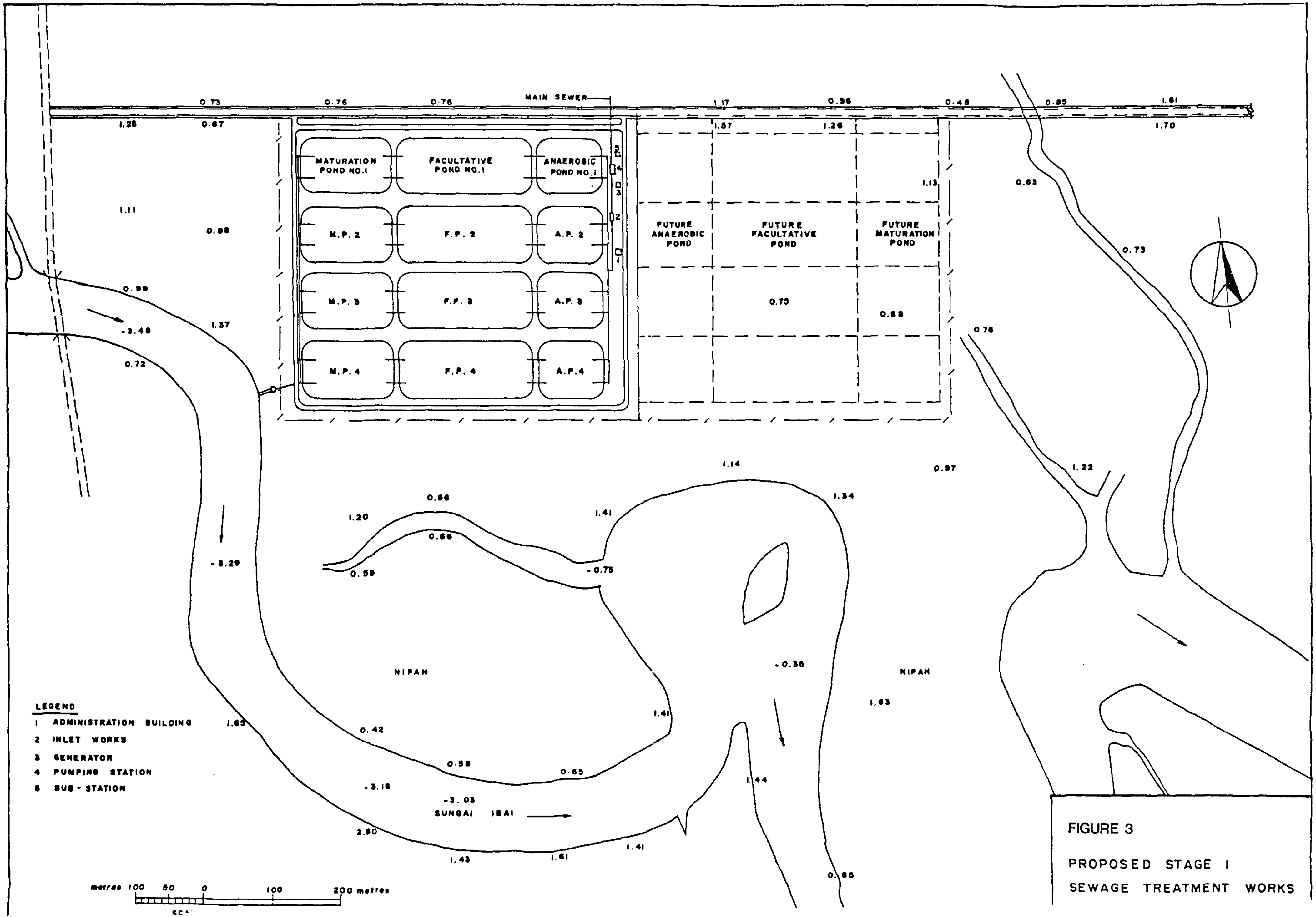


FIGURE 3

PROPOSED STAGE I SEWAGE TREATMENT WORKS

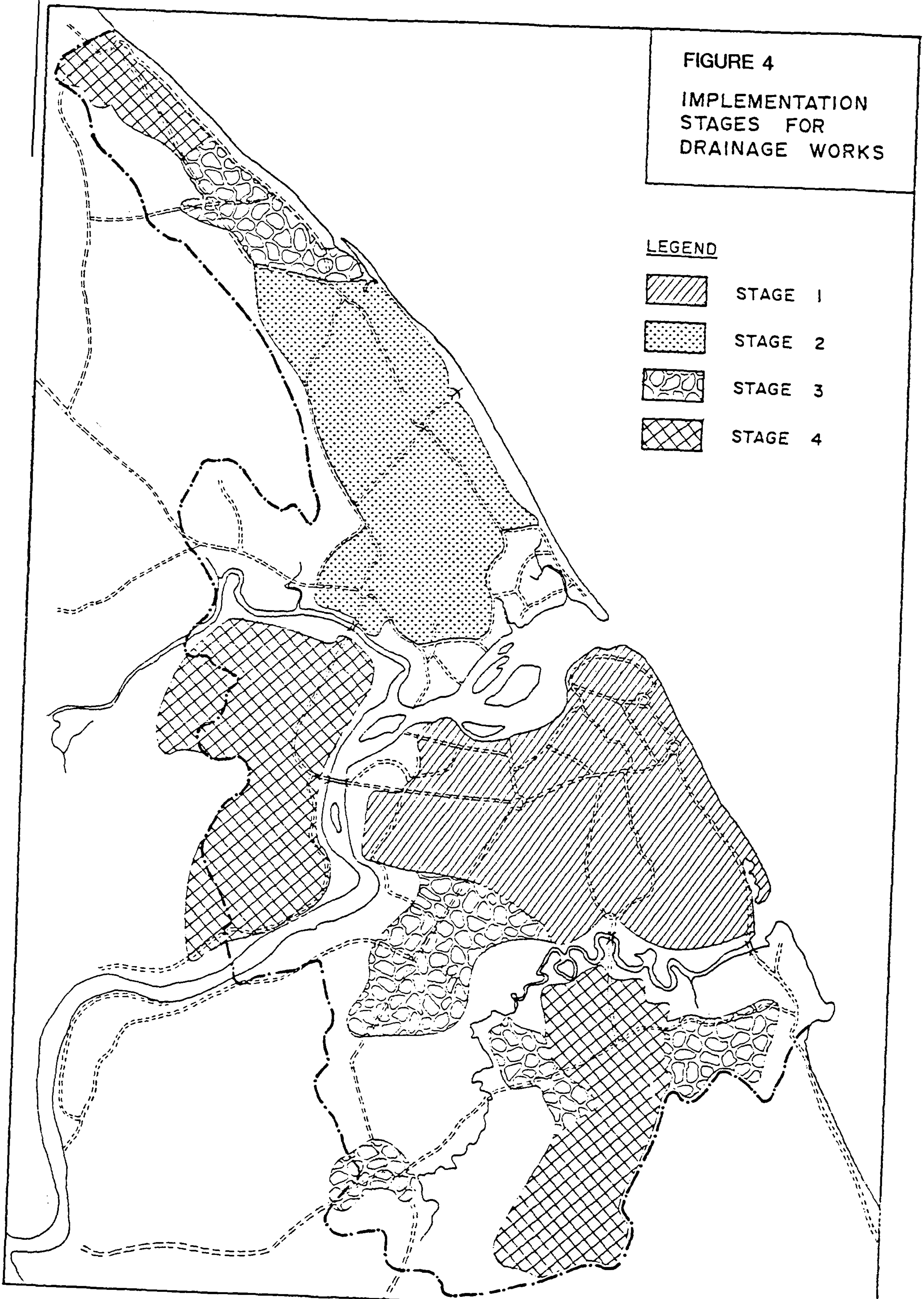
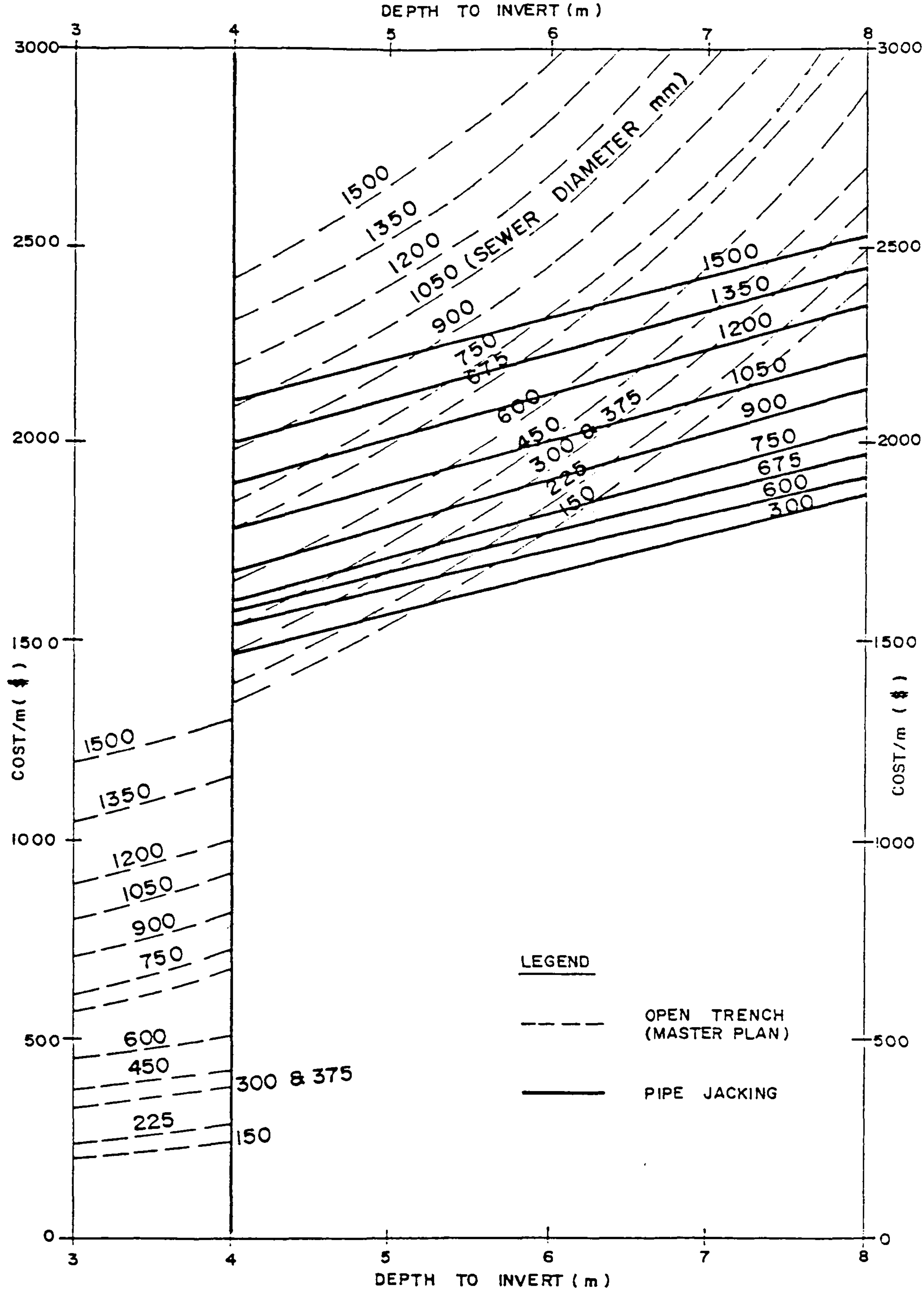


FIGURE 4
IMPLEMENTATION STAGES FOR DRAINAGE WORKS
LEGEND
STAGE 1
STAGE 2
STAGE 3
STAGE 4



OPEN TRENCH AND PIPE JACKING COST COMPARISON

FIGURE 5

PAPER 11

THE DESIGN, CONSTRUCTION AND OPERATION OF WASTE STABILISATION PONDS AND THE RE-USE POTENTIAL OF THEIR EFFLUENTS

BY

W J MAIDMENT
P A R SCOTT
SCOTT WILSON KIRKPATRICK & PARTNERS
UNITED KINGDOM

BACKGROUND

In Europe and the USA the development of modern-day sewage treatment practices evolved over a considerable period. With the advent of the industrial revolution there was a rapid increase in urban population. This increase in the urban population caused overloading of existing water systems which were becoming heavily contaminated by wastes since the traditional methods of waste disposal were inadequate. The solution adopted was simple, though costly, in that waste water was transported out of the urban areas via underground sewers to discharge into the nearest river system. This led to gross pollution of the receiving waters and the outbreaks of disease from the use of these waters became ever more commonplace. It was public concern that led to the appointment in the UK of a number of Commissions to review and to make recommendations for the alleviation of the problem. This resulted in the establishment of 'sewage farms' in many towns, but it was the reports of the Royal Commission on Sewage Disposal, sitting from 1898 to 1915 that formed the basis of much of the present day sewage treatment practices and resulted in the Royal Commission Standards for effluent quality, standards which are frequently applied in many parts of the world. In the USA sewage treatment fared little better since receiving waters and land areas were very large. However, by the early 1900's nuisance and health conditions were such that there was an increasing demand for more effective wastewater treatment.

The high cost of land in Europe and the USA combined with the impracticability of acquiring ever larger areas for sewage treatment led to the development of more intensive systems with the resulting evolution of present-day sewage treatment processes. These processes, developed in the industrial north with its generally temperate climate, include:

- activated sludge
- percolation filters
- oxidation ditches/extended aeration
- package plants

However, in developing countries the conditions under which the problem of how to treat sewage are not the same as those that faced the industrialised north at the start of its development.

Populations are generally considerably larger in developing countries compared with those in the now industrialised northern nations at the time of their development. Urbanisation has been more rapid and has resulted in far higher population densities. The problem is compounded by the high population growth rate due in part to improved medical care. Many of the developing countries have far fewer natural resources.

Some even suffer from a shortage of that most basic resource - clean water. Generally developing countries are in the tropical and sub-tropical zones of the world and consequently their climate is very different to that in the industrialised north. In these warmer climates the number and variety of faecally transmitted diseases is greater. The hot humid conditions are conducive to pathogen survival, which adds to the morbidity in these regions. Thus the reduction of pathogens should be one of the primary objectives of any waste disposal system.

In many developing countries compost, manure and human waste have retained their value as fertilisers and consequently the ability to re-use these wastes is important. Finally, land is frequently available at low prices. Thus it can be seen that the problems facing the developing countries are more acute than those that faced the industrialised north at the start of their development. So it is unlikely that the processes that have evolved in the resource wealthy, less populous and cooler north will be suitable for the poorer, high density and warmer developing countries.

Waste stabilisation ponds are, and have proved to be, a very efficient and reliable method of sewage treatment in the conditions experienced in many of the developing countries particularly in respect of pathogen removal. They should be the first choice for sewage treatment in tropical and sub-tropical regions especially where land is freely available.

INTRODUCTION TO WASTE STABILISATION PONDS (WSP)

Historically, ponds were used to relieve existing mechanical intensive sewage works by operating virtually as storage reservoirs. Gross overloading of these reservoirs resulted in offensive odours and contributed to the unpopularity of this form of treatment. At Santa Rosa in 1924, it was found by coincidence that a sewage impounding reservoir could work efficiently and be free from nuisance providing that the reservoir or pond was not overloaded. Since then much research has been carried out into the operation of ponds and it is widely accepted that tropical and sub-tropical climates provide an ideal environment for the treatment of sewage by this method.

A typical pond arrangement is shown in Figure 1 and the flow pattern through this pond system in Figure 2.

MECHANISM

There are three main categories of sewage stabilisation ponds: anaerobic, facultative and maturation, usually acting in series and each having a specific function. Anaerobic ponds are used for the pretreatment of strong wastes; facultative ponds for the major part of the removal of the BOD; and maturation ponds for the destruction of faecal pathogens.

Anaerobic ponds essentially act as septic tanks. The removal of BOD and suspended solids is due to the settlement of the sewage solids which undergo intense anaerobic digestion. Provided that the volumetric BOD loading is below 0.4 $kg/m^3/day$ and that the waste has a sulphate concentration below 100mg/litre, then a stable alkiline fermentation with evolution of methane occurs which does not give rise to odour problems. If the BOD loading is too low it is difficult to maintain anaerobic conditions.

Facultative ponds are used to treat either raw sewage or settled sewage from anaerobic ponds and both aerobic and anaerobic conditions exist in them. Aerobic conditions are maintained in the upper layers whilst anaerobic conditions prevail towards the bottom of the ponds. The level of the oxypause, that is the level at which the dissolved oxygen concentration falls to zero, fluctuates due to the photosynthetic activity of the algae during the day.

The oxygen necessary for the stabilisation of the wastes by bacteria can come from four sources:

(a) dissolved oxygen in the waste liquid
(b) the atmosphere by surface aeration
(c) oxygen split from nitrates and sulphates and
(d) photosynthetic activity of algae

The oxygen available from sources (a) and (b) is small, and to utilise the oxygen from nitrates and sulphates, anaerobic conditions must prevail. The main source is photosynthesis which ceases during the night causing the dissolved oxygen concentration to fall and the oxypause to rise. Facultative bacteria, which predominate, can obtain their oxygen from the free oxygen where aerobic conditions exist or by splitting the oxygen from nitrates and sulphates where anaerobic conditions exist.

The facultative bacteria utilise the oxygen produced by the algae to oxidise the organic waste matter, producing new bacterial cells, water, carbon dioxide, phosphate, ammonia etc. The carbon dioxide is utilised by the algae during photosynthesis since there is insufficient available from the atmosphere. The beneficial interdependence between the algae and bacteria is called symbiosis.The utilisation by the algae of the carbon dioxide can exceed the rate at which it is replaced by bacterial respiration. To provide more carbon dioxide the bicarbonate ions present dissociate producing carbon dioxide and the hydroxyl ion which increases the pH. There is therefore a cyclic variation in the pH of the pond. At the bottom of the pond, anaerobic digestion of the sludge continues in the absence of oxygen.

Figure 3 illustrates the symbiotic relationship between the algae and bacteria and Figure 4 shows the pathways of BOD removed in facultative stabilisation ponds.

Maturation ponds are used subsequently to facultative ponds and are aerobic throughout their depth. Pathogens are destroyed due to the hostile environment - starvation, temperature, predators, ultra violet radiation and algal concentration. Detention time is the key factor in pathogen concentration are also important factors in bacterial removal rates. Increases in these factors leads to an increase in the removal of faecal bacteria. Thus the high temperatures encountered in the tropical and sub-tropical countries will enhance the bacterial quality of the final effluent from waste stabilisation ponds.

EFFLUENT STANDARDS

As previously mentioned, the Royal Commission on Sewage Disposal laid down quality recommendations for sewage effluent and among its recommendations were that BOD should not exceed 20 ppm (or mg/l) at 65^{o}F and that suspended solids should not exceed 30 ppm (or mg/l) where there was at least an eight-fold dilution at the point of disposal . This standard applies to the discharge to rivers in temperate climates but is frequently used in other countries where the conditions are very dissimilar. The criteria for deciding on effluent standards should take into account the proposed method of discharge of usage of the final effluent. If the effluent is to be discharged to an aquifer then bacterial quality is important, or if it is to be re-used for irrigation then both BOD and bacterial quality are the main criteria.

Ponds can be designed so that the quality of effluent is such that it can be used without any additional treatment for unrestricted irrigation. On the other hand they can be designed so that there is no effluent discharge because all the effluent is lost through seepage and evaporation. However, there are draw-backs in the latter case because there will be an accumulation of dissolved salts which may become toxic to the algae and the effluent which percolates into an aquifer may give rise to groundwater pollution.

Recommended irrigation and discharge standards are given in Table 1.

METHOD OF RE-USE	BOD (mg/l)	FAECAL COLIFORMS (No/100 ml)[1]
Irrigation of trees, cotton and other non-edible crops	60	50,000
Irrigation of citrus, fruits, trees, fodder crops and nuts	45	10,000
Irrigation of deciduous fruit trees,[2] sugar cane, cooked vegetables and sports fields	35	1,000
Discharge to a receiving stream[3]	25	5,000
Unrestricted crop irrigation including parks and lawns	25	100

1. These concentrations should not be exceeded in 80% of samples
2. Irrigation should stop two weeks before picking and no fruit should be picked from the ground
3. Depends on dilution available; effluent should contain less than 10^5 algal cells/ml

Note: These figures represent rough guidelines. Effluent quality may have to to satisfy other standards in different countries or under particular circumstances or conditions

Table 1. Recommended Irrigation and Discharge Standards.

The standard for algal concentrations in effluents to be discharged to rivers is based on the finding that the oxygen content of the receiving waters would deteriorate if the algal concentrations were to exceed 1×10^5 cells/ml. However, algae are usually an important link in the food chain and there is no evidence that algal blooms in receiving waters are due to the discharge of algae but rather due to the entrophication of limiting nutrients such as nitrogen and phosphorus. In fact, an intensive study in California's Nappa Valley showed that waste stabilisation pond effluent contributes a highly stabilised effluent with a complex biological community that augments the receiving water community. When effluents are used for irrigation, the standards for algal concentrations given above may require amendment since a high algal concentration may cause clogging of drip irrigators. However, in a well designed pond system, the effluent algal concentration should be below 1×10^5 cells/ml.

There are no recommended standards for water quality when ponds are used for pisciculture. However, there must be some dissolved oxygen all the time and ammonia concentrations may well prove to be the limiting factor.

Chlorination of final effluents is practised in a number of countries, notably in the USA. With well designed waste stabilisation ponds, chlorination is neither necessary nor desirable. Figure 5 shows the rapid re-growth of coliforms in an effluent after chlorination. Apart from cost and maintenance considerations, there is a risk of formation of carcinogenic chlorinated hydrocarbons and many faecal bacteria are resistant to chlorine which results in aftergrowth. Very high chlorine concentrations are required to kill viruses, protozoa and helminths.

It should be noted that a well designed pond system can produced an effluent with less than 100 faecal coliforms per 100 ml which is suitable for unrestricted irrigation.

DESIGN CONSIDERATIONS

The main factors that must be taken into account when designing waste stabilisation ponds are:-

- ambient and/or water temperature
- wind velocity and direction
- solar radiation and cloud cover
- strength and quality of wastewater to be treated
- final effluent quality required
- area of land available
- water losses through percolation and evaporation

In cases where there are industrial discharges to the sewerage system, the nature of the discharges should be established especially where industrial discharges form a significant portion of the total sewerage flow.

Methods for the design of ponds are based on, or indirectly based on, the effect of temperature. Generally sewage temperatures will be about 3°C above ambient temperatures.

Anaerobic Ponds

Anaerobic ponds should be designed on the basis of a volumetric organic loading of between 0.1 and 0.4 kg $BOD/m^3/d$, the lower value being used when the ambient temperatures in the cold season fall to around 12°C, and the higher value when the ambient temperatures are fairly uniform throughout the year at around 27° to 30°C. For minimum ambient temperatures between these two extremes, it is suggested that it is reasonable to assume a linear relationship.

The successful operation of anaerobic ponds depends on maintaining the balance between acid-forming bacteria and methanogenic bacteria. In anaerobic digestion sewage solids are broken down in two stages by these two groups of anaerobic bacteria. First, organic compounds are oxidised to acetic acid and other fatty acids and then these acids are converted to methane. The methanogenic bacteria are sensitive to acidic conditions and for this reason the pH should be maintained in excess of 6 and preferably around 7.

Temperature is also important since most bacteria have a maximum growth rate at temperatures of between 20°C and 38°C. Temperatures in excess of 15°C are necessary and the rate of digestion increases sevenfold for each 5°C rise. At temperatures below 15°C anaerobic ponds act simply as sludge storage ponds. At the higher temperatures sludge accumulation is minimal and desludging, which should be undertaken when the pond is half full of sludge, is only necessary every 3 to 5 years.

Retention times should normally be between 2 and 5 days and the depth of the ponds should generally be between 3 and 5 metres. Toxic or inhibiting substances which may be discharged from various industrial processes should, in general, be excluded.

The BOD removed from anaerobic ponds varies between 50% and 70% depending on the retention time, 50% being removed when the retention is 1 day and 70% after 5 days. Because of their high BOD removal rate the inclusion of anaerobic ponds will substantially reduce the size of facultative ponds.

Facultative Ponds

Facultative ponds depend on the symbiosis between bacteria and algae. Many different methods are available for the design of facultative ponds and they are generally based on empirical formulae, statistical analyses and rules of thumb. The design methods in most common use are:-

- Global Environmental Design Basis
- Gloyna's Empirical Formula
- First Order Kinetics
- Indian Approximate Procedure
- Solar Radiation Method
- Thirumurthi Method
- McGarry and Pescod Formulae

These various design methods, being based on observed performances, produce different results which may be the result of variations in local conditions.

First order kinetics is becoming accepted as a rational approach to the design of facultative ponds. It assumes that the pond is a completely mixed reactor in which BOD removal follows first order kinetics. This is shown in the following equation:-

$$\frac{L_e}{L_i} = \frac{1}{1+k_1 t^*}$$

where:

L_e = effluent BOD mg/l

L_i = influent BOD mg/l

k_1 = rate constant for first order removal of BOD, d^{-1}

t^* = retention time in days

To ensure facultative ponds operate satisfactorily L_e should be in the range 50 - 70 mg/l for ponds 1 - 1.5 m deep. The value of k_1 is about 0.3 at 20°C and its variation with temperature is given by:

$$k_1 \ (T) = 0.3 \ (1.05)^{T-20}$$

where T is the varied temperature which is taken as the mean temperature of the coldest month.

Facultative ponds should not be built in sheltered areas as wind action induces vertical mixing. Mixing plays a significant role by minimising short circuiting, preventing stagnant areas from forming and by carrying up non-motile algae to the photic zone because algae can only produce oxygen where there is light. Mixing also carries oxygen down to the lower levels of the ponds and also prevents the formation of a thermocline. If there is no mixing then the non-motile algae will settle out, the motile algae will move away from the hot surface layer and form a dense layer some 300 to 500 mm below the surface. The settled non-motile algae will exert an additional BOD and simultaneously there will be less oxygen produced as there are fewer algae, thus reducing the rate of waste stabilisation.

The sludge layer that forms on the bottom of facultative ponds undergoes anaerobic fermentation with the production of methane. The methane can cause the sludge to rise resulting in the formation of floating mats which prevent the penetration of light into the photic zone. Consequently these mats should be removed. If the ponds are treating effluent from anaerobic ponds this problem should not occur.

Facultative ponds in general should be between 1 and 1.5 m deep, although they can be deeper to reduce losses through evaporation, and in cold climates, to retain as much as possible of the thermal energy of the sewage. A minimum depth of one metre is essential to prevent the growth of vegetation which if allowed to grow makes suitable conditions for the breeding of various insects, snails etc.

Maturation Ponds

The principal purpose of maturation ponds is the destruction of faecal pathogens since the major part of the BOD has been removed in the anaerobic and/or facultative ponds. They are aerobic throughout their depth. The design of maturation ponds, then, is based on the removal of faecal coliforms and can be satisfactorily represented by a first order model:

$$N_e = \frac{N_i}{1+k_b t^*}$$

where N_e = a number of faecal coliforms per 100ml of effluent

N_i = number of faecal coliforms per 100 ml of influent

K_b = first order rate constant for faecal coliform decay, d^{-1}

t^* = hydraulic retention time in days

The value of k_b is highly temperature dependent and is given by:

$$K_{b\ (T)} = 2.6\ (1.19)^{T-20}$$

for values of T between 2°C and 21°C and where $K_{b(T)}$ = the value of K_b at T°C.

For a number of maturation ponds in series, the concentration of faecal coliforms in the final effluent is given by:

$$N_e = \frac{N_i}{(1+K_b t_1^*)\ (1+K_b t_2^*)\dots(1+K_b t_n^*)}$$

where t^*_n = hydraulic retention time in the nth pond (in days).

From this formula it can be shown that a higher faecal coliform removal is achieved by having a number of smaller ponds rather than just one large pond. Additionally, it can be shown that the most efficient system is one in which the maturation ponds have equal retention periods.

Maturation ponds should be between 1 and 1.5 m deep. They can be deeper if the pressure for land is great but should not be less tha 1 m in order to prevent the growth of vegetation. Viral and bacterial removal are marginally better in shallow ponds than in deep ponds.

In facultative ponds, algae are numerous partly as conditions are not conducive to the development of algal predators. However, in maturation ponds the algal numbers decrease due to the establishment of an extended food chain of protozoa, rotifers, crustacea and fish and to the reduction in concentrations of dissolved nutrients.

POND CONSTRUCTION

Ponds can be of any shape, and sometimes it is economic to design them to suit the topography of the site. Length to breadth ratios shoud be 2 or 3 to 1 and the long side should be aligned with the prevailing wind to achieve good mixing. They should be sited away from centres of population preferably at sites where there is sufficient land available to permit extensions to the system.

Generally it is recommended that pond systems are at least 500 m away from the nearest residential area, and where anaerobic ponds are used 1,000 m is recommended. However, there are many instances where people are living much nearer without suffering any nuisance. Figure 6 shows Gabarone, the capital of Botswana. Three sets of ponds have been constructed to serve different sections of the capital as it has developed. Stage 1 of pond system 3 was designed by Scott Wilson Kirkpatrick & Partners and constructed in 1975. The site was chosen because the majority of the sewage could gravitate to it, it was far enough away from any proposed development, sufficient land was available for duplication and because it was close to the Segoditshane river into which the final effluent is discharged.

Generally pond bases should be impermeable, although the sludge does tend to seal the base with time. Sealing the ponds can be achieved using clay, bitumen, ashphalt, blinding concrete or polythene sheeting suitably protected with sand.

Embankments usually have slopes of about 1 in 3 but this can vary depending on the soil conditions. Erosion is prevented by placing precast concrete slabs or rip-rap at top water level. The top of the embankment should be at least 500 mm above top water level and the concrete or stone protection should extend over that portion of the embankment likely to be affected by wave action. The use of precast concrete slabs also serves the additional function ofpreventing weed growth around the margins thus removing the conditions necessary for the breeding of snails and mosquitoes. In Figure 7 the precast concrete slabs at top water level can clearly be seen and Figure 8 shows grass stopping at the water level due to the presence of precast concrete paving slabs and both figures show the formation of a sludge mat which should be removed during normal maintenance operations.

All pond systems should have some form of flow measurement at the inlet and outlet to enable the performance of the system to be checked.

In order to prevent the formation of a sludge bank at the inlet to anaerobic and facultative ponds, the inlet pipe should be taken some distance out from the edge of the embankment. Additionally there can be local deepening of the pond in the area of the inlet which will act as a store for non-degradable solids such as grit and sand which tend to be a major constituent of the sludge banks.

The typical details of an inlet are shown in Figure 9.

Figure 10 shows what can happen when the raw sewage is discharged directly into a facultative pond at its edge - a sludge bank forms which prevents the influent getting into the pond freely and additionally provides suitable conditions for vegetation to grow which provides a habitat for insect breeding.

The are numerous types of interpond connection and Figures 11 and 12 show two different types that have been used. Refinements can be made, such as providing variable level draw offs and these may well prove worthwhile for larger systems which are permanently manned.

The size of the pipework for the interpond connections should be kept to a minimum so as to attenuate peak flows.

For larger systems it is desirable to provide screening and grit removal facilities and the degree of automation and sophistication of these facilities will depend on the size of the pond system and the availability of skilled or semi-skilled labour.

SLUDGE

In conventional sewage treatment works, one of the major problems is the treatment and disposal of the sludge that is produced daily. t also accounts for a large proportion of the operation and maintenance cost of the works. In stabilisation ponds this is a relatively minor problem. Anaerobic ponds require desludging every 2 - 5 years, facultative ponds every 20 to 40 years and maturation ponds probably never during the lifetime of the system. The sludge once removed can be dried on sludge drying beds or in the pond itself and then used as a fertiliser. To assist in sludge removal, facilities for draining down the ponds and for by-passing them should be provided. They do not, however, need to be provided for maturation ponds. If it is intended to allow the sludge to dry in the ponds, then access ramps should be provided to allow vehicular access for the excavation of the dried sludge.

Duplication of ponds and well laid out interconnecting pipework will enable desludging to be carried out with the minimum of overloading to the remainder of the ponds in the system.

UPRATING POND SYSTEMS

Pond systems should be constructed to treat the present and the immediate future flows rather than to the 20 or 30 year design horizon, mainly on economic grounds but partly because if they are extremely large they will take a substantial time to fill and consequently there will be no effluent available for irrigation for some time.

Pond systems can be extended simply by the addition of a second stream in parallel. This process may be repeated a number of times provided that sufficient land is available. Another alternative is to construct facultative and maturation ponds initially, and when they become overloaded, to construct an anaerobic pond prior to the facultative ponds. These alternatives are illustrated in Figure 13.

Other methods of uprating pond systems include the construction of aerated lagoons after anaerobic ponds but before facultative ponds or the installation of aerators in the facultative pond. Aeration however alters the biological processes as oxygen is supplied by the aerators resulting in the disappearance of algae and the facultative pond now operating more as an activated sludge system. Another alternative is high rate ponds which could be used to reduce the loading on facultative ponds. They are very shallow 20 - 40 cms, and the photic zone extends virtually for the full depth of the ponds. The conversion of sewage nutrient to algae is very rapid, and the large amounts of algae produced have to be removed. However, it is the lack of a suitable algal removal system that has limited their use at present.

ALGAL REMOVAL

Algae in the effluent not only increase the concentration of the suspended solids but also increase the BOD value. It has been suggested that up to 62% of the BOD of the effluent from a facultative pond is due to algae. Clearly the removal of algae would have a dramatic influence on the quality of the final effluent. The removal of algae can, as previously stated, be partially achieved by increasing the number of maturation ponds but this does not appear to be very efficient.

Numerous methods of algal removal are available and vary widely in complexity, cost and effectiveness. However, if the effluent is to be used for irrigation, then provided the algae do not clog the irrigation system it can prove advantageous because the algae provide a source of nutrient.

MAINTENANCE

Pond maintenance, apart from desludging, consists mainly of cutting grass around the ponds, the breaking up of algal mats and the removal of any floating debris and scums. Scum should not be removed from anaerobic ponds but it may be necessary to spray the scum with insecticide to prevent the breeding of flies. The use of insecticides is however not generally necessary or recommended as it may inhibit the biological process in the stabilisation ponds. It is worth noting that waste stabilisation ponds do not rely on skilled operators or on a large array of electrical machinery or controls which have to be maintained at a high level for satisfactory operation of the plant. Waste stabilisation ponds are intrinsically fail-safe in their operation andprovided basic maintenance is carried out will operate satisfactorily with the minimum of attention.

RE-USE

One of the ways to re-use the final effluent is to use it for irrigation. The main methods of irrigation are:-

(a) furrow irrigation which is widely used in South Asia;

(b) flood irrigation which can lead to helminth infections such as schistosomiasis;

(c) sprinkler irrigation which may lead to the spread of of diseases caused by the dispersion of aerosolized pathogens; and

(d) drip and bubbler irrigation which overcome the problems associated with sprinkler irrigation by applying the effluent directly to the roots of the system and which results in a lower water use although the system is capital and maintenance intensive.

Although pathogen removal in waste stabilisation ponds is very good it is not complete and unless some form of tertiary treatment is carried out some pathogens may survive long enough to infect vegetable crops that are eaten raw. If, however, restrictions are applied to what crops are irrigated, then the risk of infection can be eliminated.

In many parts of the world, especially the Far East, fish culture has been carried out for many centuries and fertilisation of fish ponds with fresh night soil is commonly practised. The rearing of fish is also carried out in waste stabilisation ponds and much scientific investigation has been carried out on this method of fish culture. The object is generally twofold:

(i) that of rearing fish; and

(ii) of improving the quality of the final effluent.

Due to the presence of the fish, the concentration of algae and suspended solids in the final effluent is reduced as is the number of faecal coliforms. The fish are not susceptible to human pathogens and those that have been identified have been in the gut which can be cleared by depuration.

The sludge that is produced in waste stabilisation ponds is well mineralised and is a valuable resource. It is a good fertiliser and using it on agricultural land is an economical method for its disposal.

There is clearly scope for the integration of both fish farming and the re-use of the final effluent for agriculutral and beautification purposes as well as for using the sludge produced as an agricultural fertiliser all of which will improve the overall economic feasibility of a pond system.

As regards the health aspects of wastewater re-use it has been proposed that it is the actual risks rather than the potential risks of wastewater re-use that ought to be considered. The risk to health depends on the pathogen and its properties - the concentration of the pathogen in the effluent and that necessary to cause morbidity, its survival time under the relevant conditions, its life cycle and the extent to which people become immune. Thus if a pathogen is transmitted to young children and as a result they gain long lasting immunity, then the older population will be immune and the presence of even high concentrations of the pathogen in the wastewater will cause no increased incidence of the disease to the community. Similarly, if there are many different routes by which the disease is spread then the presence of the relevant pathogens in the wastewater is unlikely to be a significant additional risk. On the other hand if it is the only route for the transmission of the disease then all the incidence of the disease will be attributable to the wastewater.

A World Bank study on wastewater irrigation gives guidance on the risks associated with wastewater irrigation and gives advice on how to reduce these risks. Among the precautions that can be taken are restricting the type of crop irrigated, improving the hygiene of those likely to come into contact with the wastewater and a number of other measures. The most effective measure however is to improve the wastewater treatment. The treatment process should achieve the maximum removal of helminths and reduce the number of bacterial pathogens as well as being free from odour and nuisance. The World Bank study concludes that waste stabilisation ponds with anaerobic pre-treatment followed by four main ponds with a minimum retention time of 20 days achieves these criteria.

ECONOMIC AND FINANCIAL COST COMPARISONS

The basic criterion in determining whether a particular method or system of sewage treatment is efficient or not is to make comparisons between the economic costs of each alternative in achieving the same purposes. It should be appreciated that it is not possible to generate an economic model that will apply to all countries and provide the necessary information to make sound judgements. For example, land, labour, capital, power and water costs vary from one country to another. However, the World Bank in its Technical Paper Number 7, published an economic cost comparison between four different systems of sewage treatment, viz:-

- waste stabilisation ponds
- aerated lagoons
- oxidation ditches
- biological filtration

The basic parameters used in the comparison included:-

o contributing population	250,000
o per capita BOD	40 g/d
o controlling temperature	20° C
o effluent standard	25 mg/l BOD: 10,000 FC/100 ml

Capital costs included land, earthworks, structures and equipment and recurring costs of power, labour and maintenance. It is not clear whether shadow prices were included in the economic analysis. The result of the World Bank's analysis is shown in the graphs of Figure 14 for discount rates of 5, 10 and 15% and varying land costs. These graphs indicate that waste stabilisation ponds would be the least cost alternative when land costs are less than 15 US$/m^2, 9.7 US$/m^2 or 5.4 US$/m^2 for discount rates of 5%,10% and 15% respectively. In some cases it could prove economic to convey sewage from an area where land is relatively expensive to an area where land costs are minimal.

For controlling temperatures above 20° C, waste stabilisation ponds will become even more economic. It is also clear that in situations where land is relatively cheap and temperatures high the economic case for using waste stabilisation ponds becomes very strong. However, each case must be taken on its merits and the judgement and assumptions involved in any economic analysis must be carefully made.

CONCLUDING COMMENTS

Waste stabilisation ponds are ideally suited for use in tropical and sub-tropical countries. In most areas the skies are clear for much of the year with high mean temperatures.

Pond systems are cheap to construct, easy to extend, require no power and very little maintenance. They require desludging at very infrequent intervals whereas sludge treatment and disposal is a major element in conventional sewage treatment processes.

Contrary to popular belief, pond systems, when operated only moderately well produce less odours than conventional systems partly because of the quiescent conditions. Anaerobic ponds, provided they are operated correctly will also operate very efficiently and be odour free. The performance of large pond systems can be improved by the incorporation of mechanical equipment such as automatic screens, macerators and detritus tanks. Various level draw-offs may afford a simple method of improving the quality of the final effluent especially if they can be linked to a detection system that enables the best quality effluent to be passed on to the subsequent pond.

When considering effluent re-use for agriculture and beautification purposes, it is the actual health risks that ought to be considered rather than the potential health risks. Effluent standards should be based on the concentration of faecal coliforms and on BOD, the determination of which should be carried out on filtered samples.

Finally sewage should be considered as a valuable resource and pond systems should be developed in such a way that full use is made of this resource. Where possible integrated systems should be developed that make provision for fish farming and irrigation as well as using the sludge as an agricultural fertiliser.

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FIGURE 1. TYPICAL WASTE STABILISATION POND ARRANGEMENT

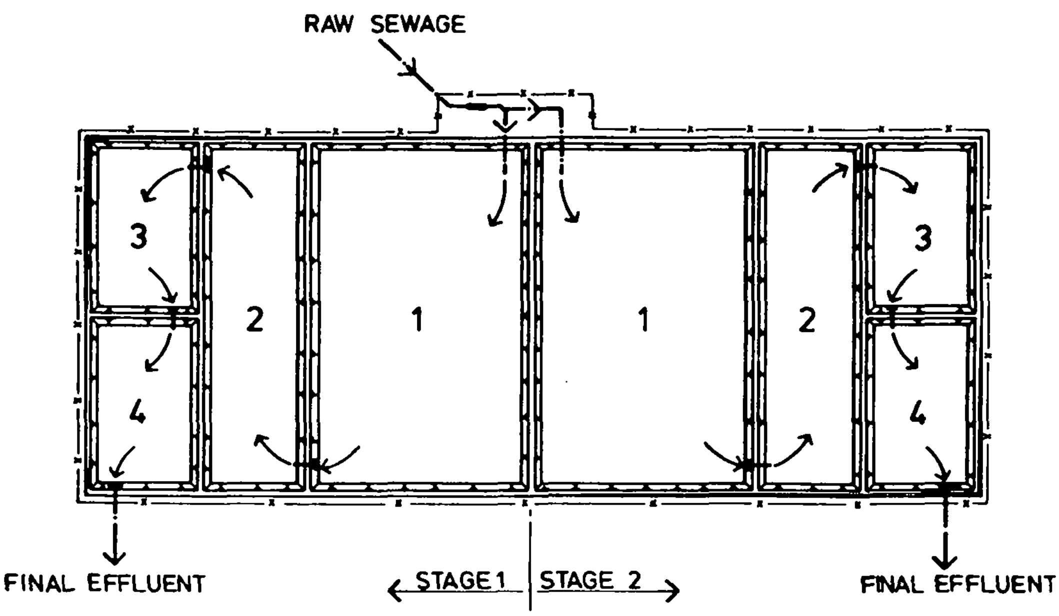

FIGURE 2. FLOW PATTERN THROUGH POND SYSTEM SHOWN IN FIGURE 1

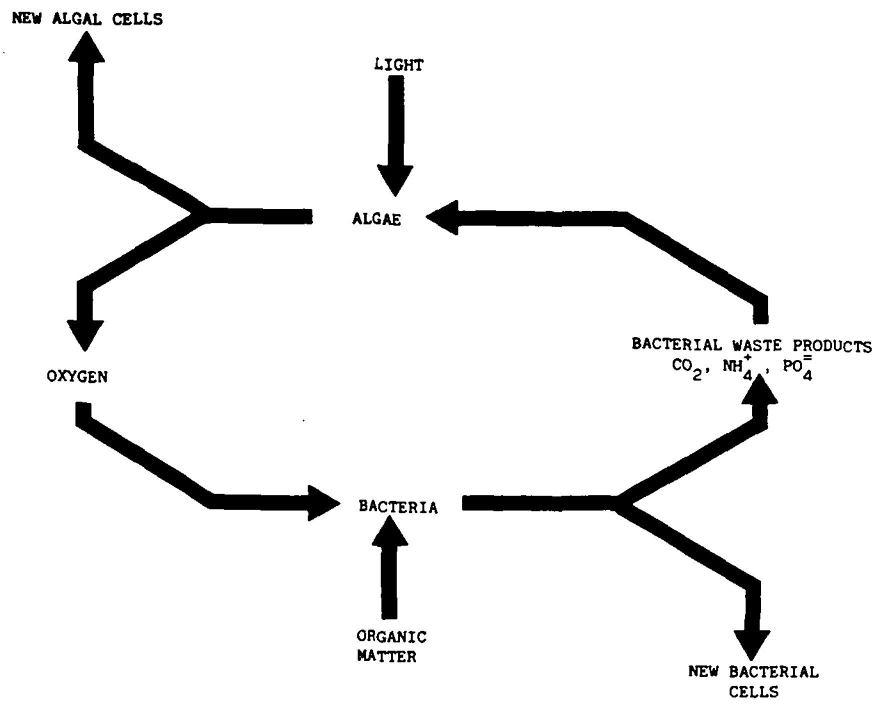

FIGURE 3. SYMBIOSIS BETWEEN ALGAE AND BACTERIA IN FACULTATIVE PONDS.

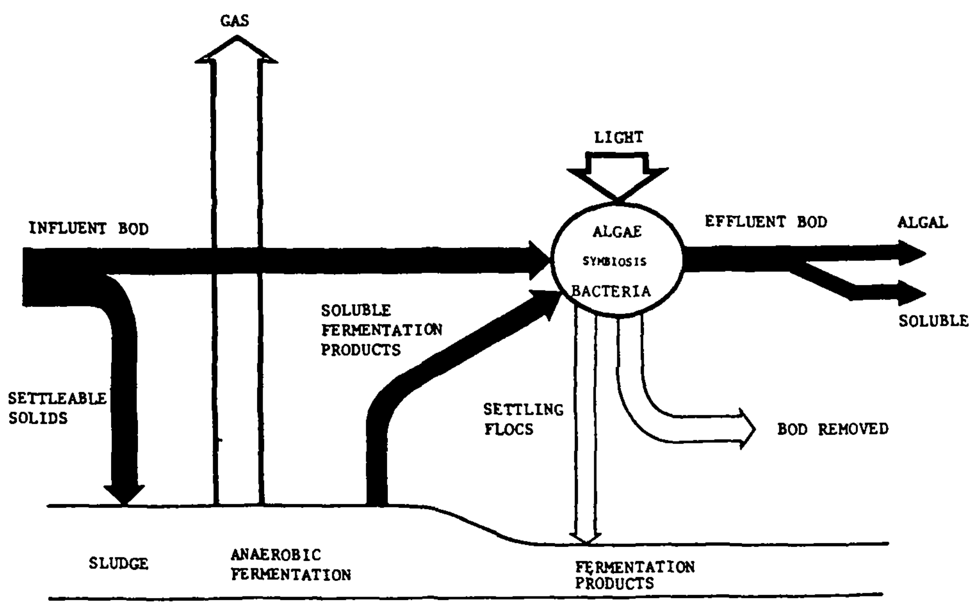

FIGURE 4. PATHWAYS OF BOD REMOVAL IN FACULTATIVE PONDS

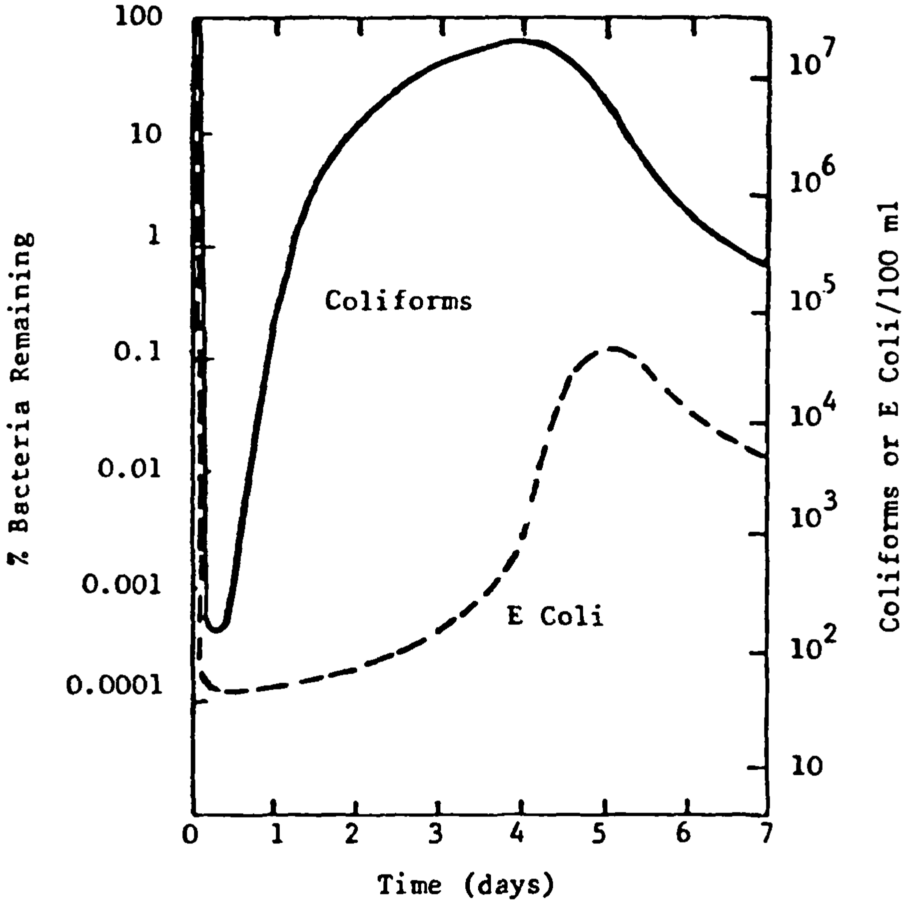

Figure 5 . Regrowth of coliforms and E coli in effluent at 20°C after inactivation with 5 mg/l of applied chlorine and no dechlorination (6)

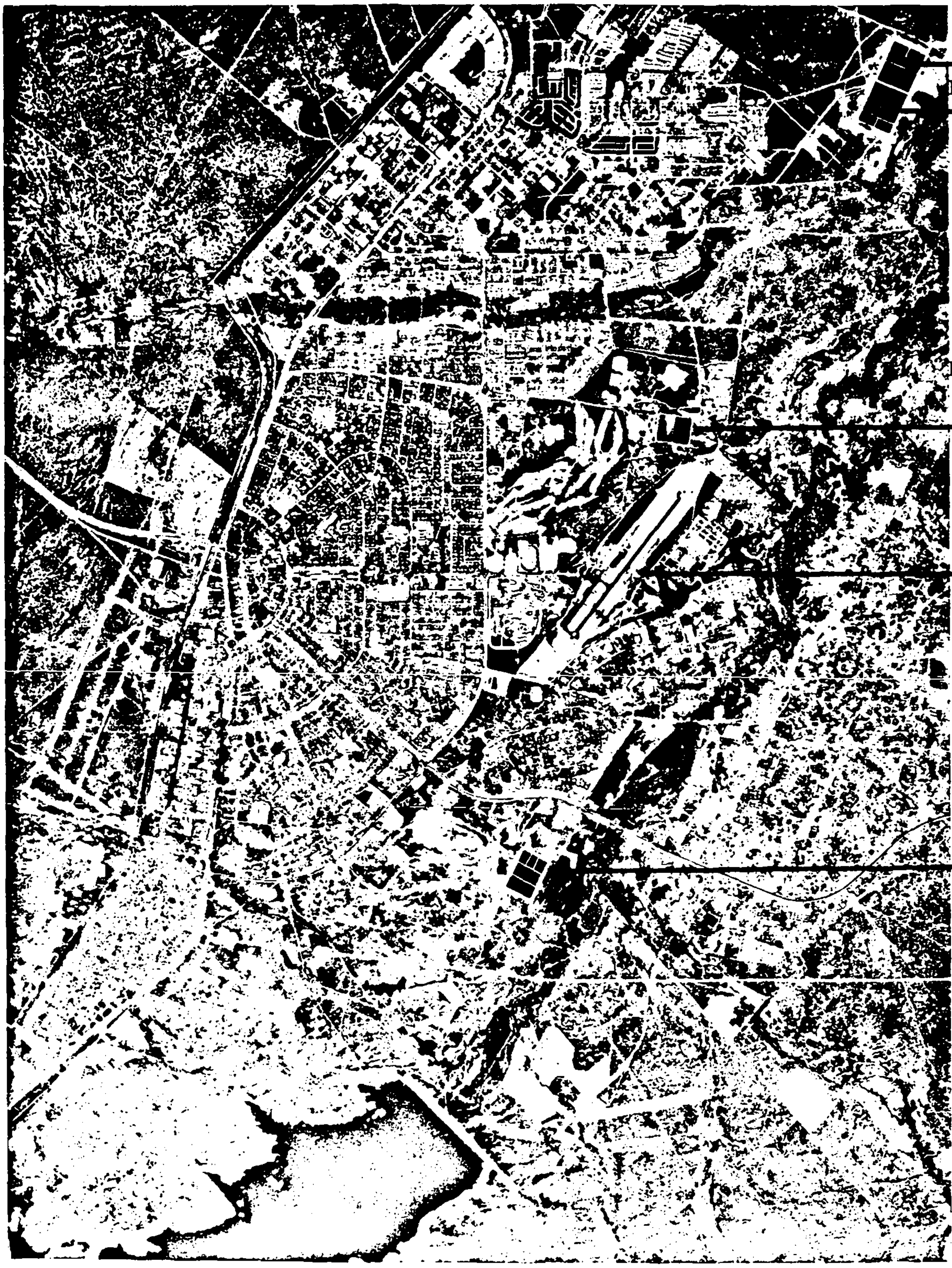

FIGURE 6. POND SYSTEMS, GABORONE, BOTSWANA, JULY 1982

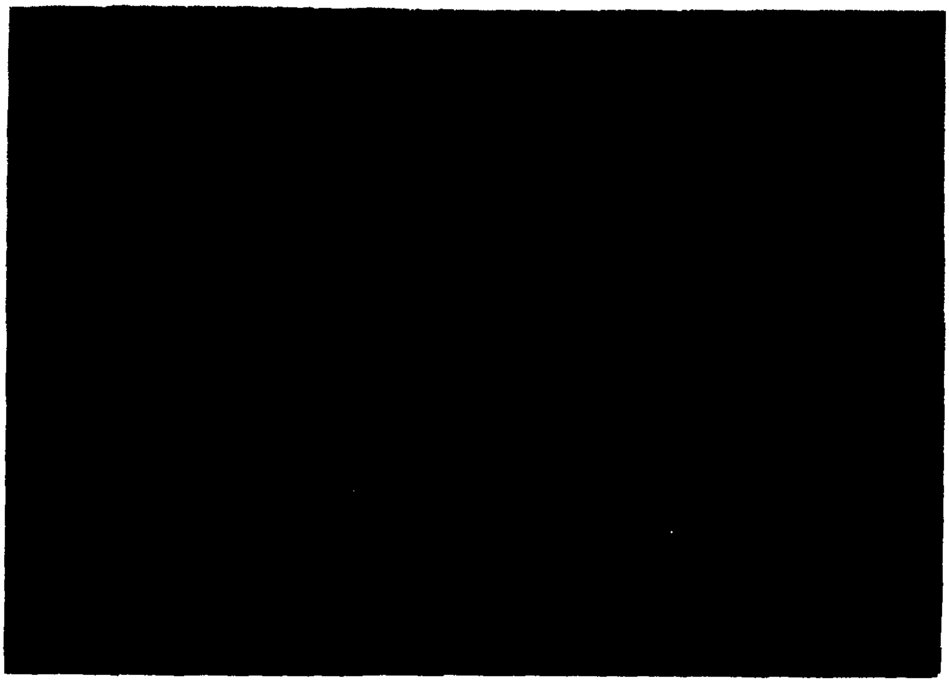

FIGURE 7. EMBANKMENT PROTECTION USING PRECAST CONCRETE SLABS

FIGURE 8. GRASS CURTAILMENT AND SLUDGE MAT

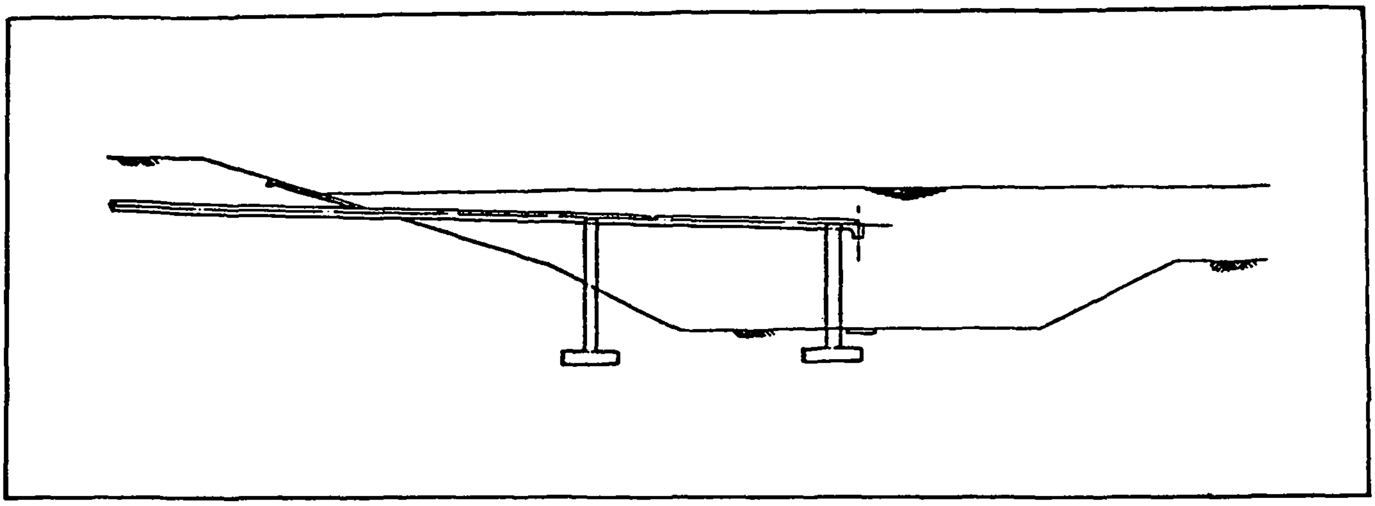

FIGURE 9. INLET ARRANGEMENT 1

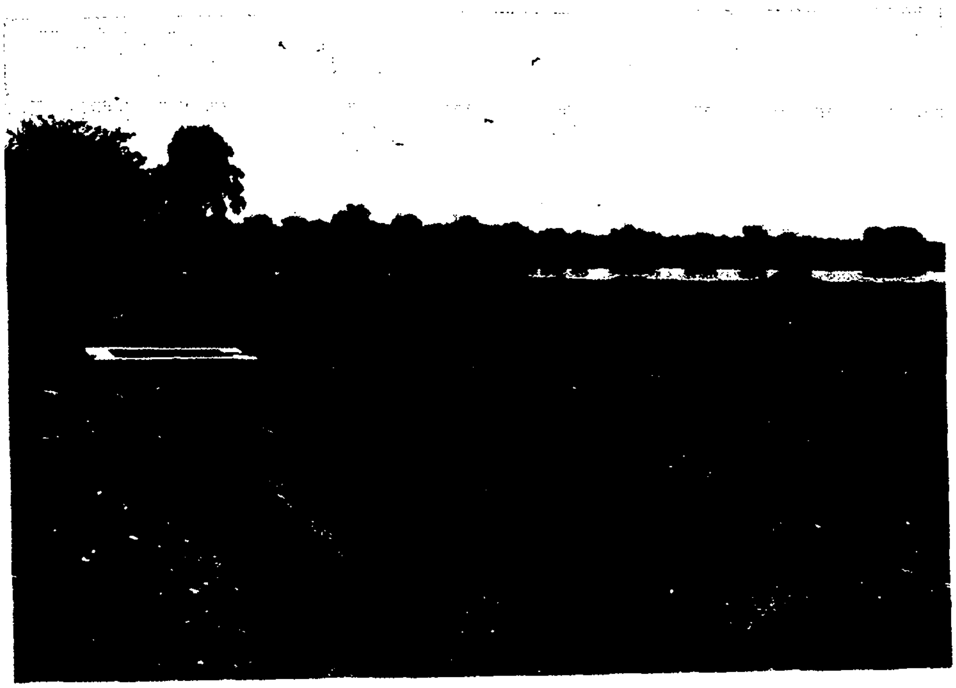

FIGURE 10. SLUDGE BANK FORMATION

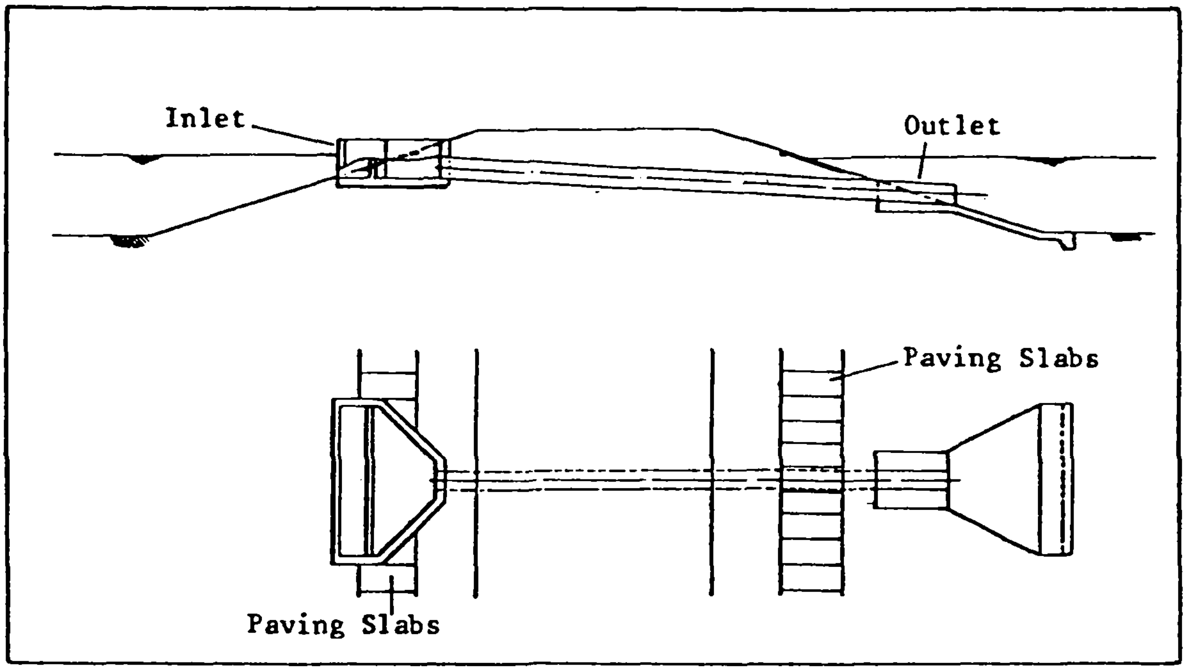

FIGURE 11. INTERPOND CONNECTION 1.

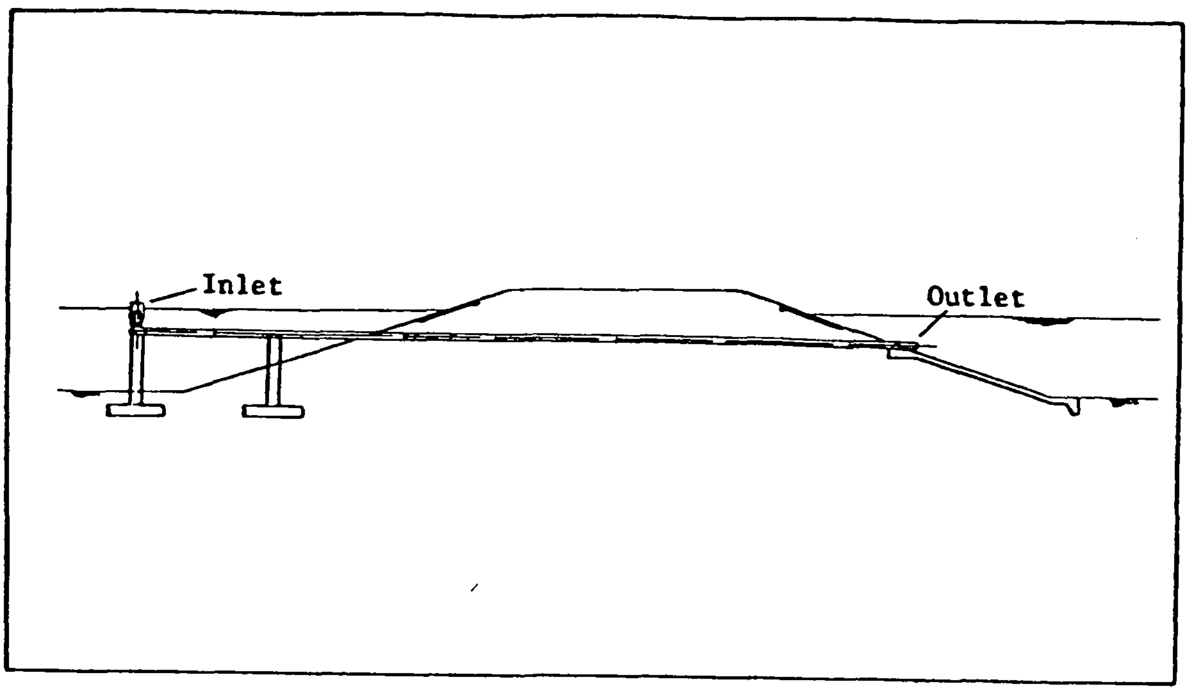

FIGURE 12. INTERPOND CONNECTION 2.

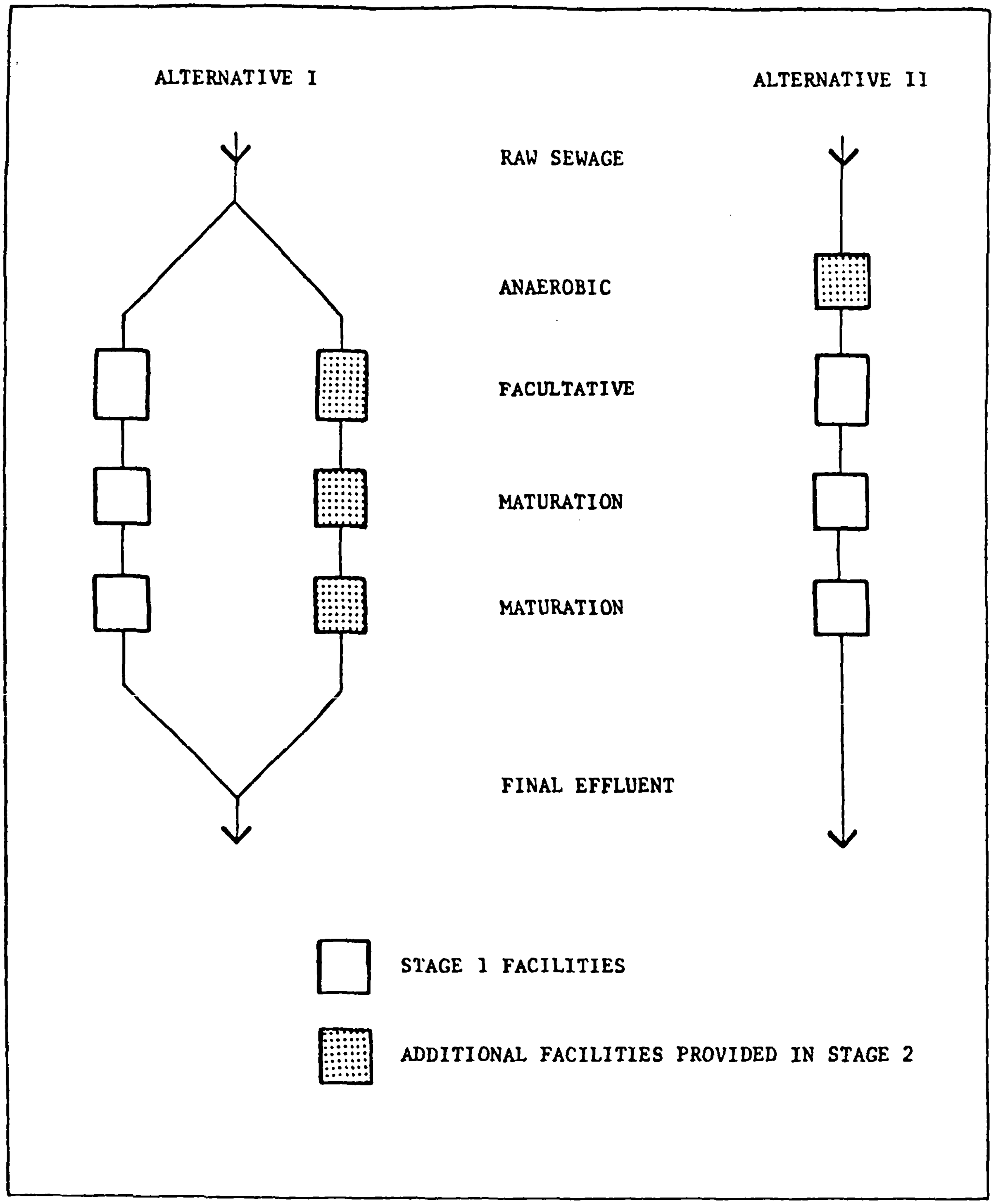

FIGURE 13. UPRATING POND SYSTEMS

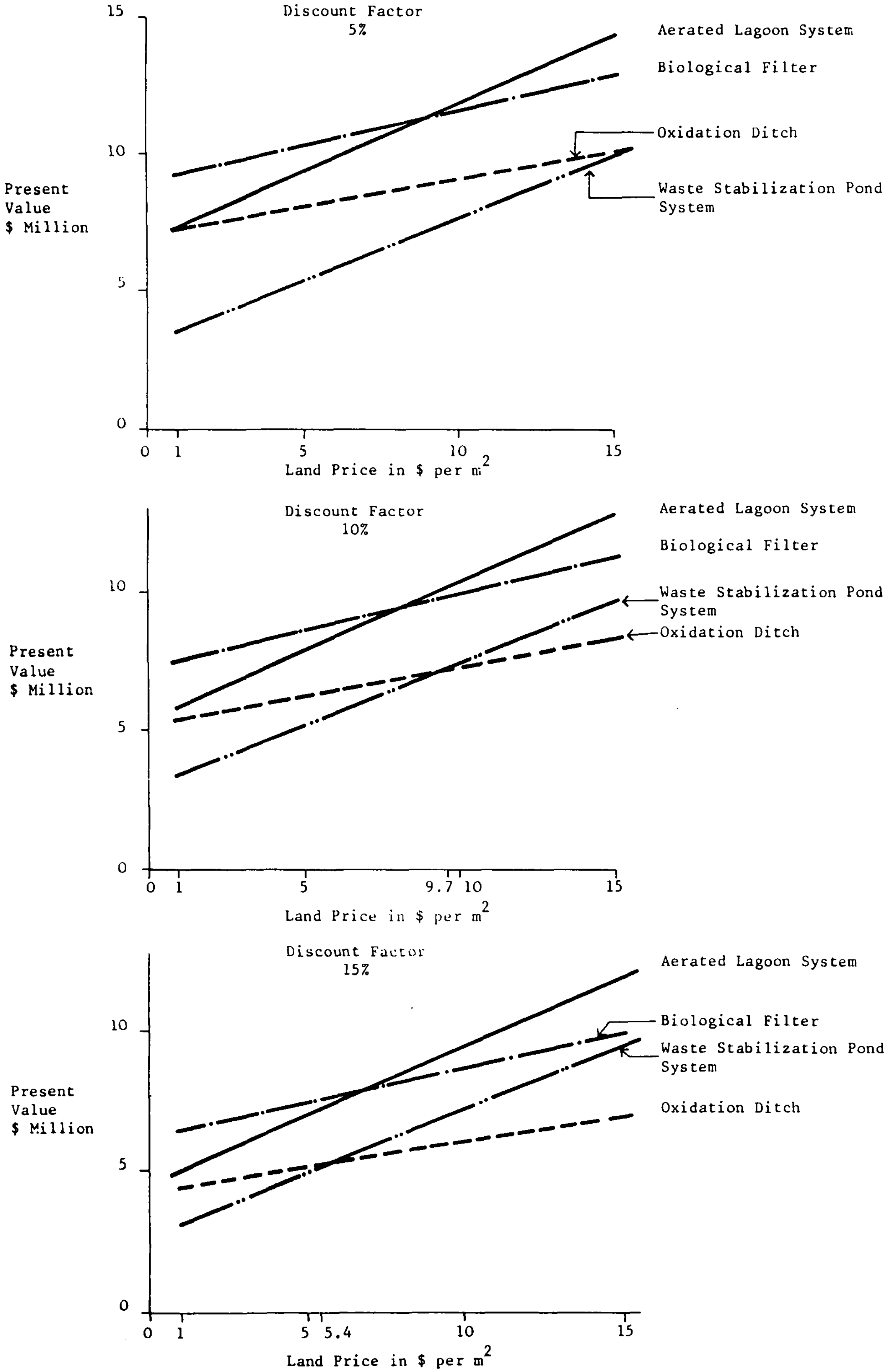

FIGURE 14. ECONOMIC COMPARISONS

PAPER 12

SEWAGE SLUDGE IN ASIAN METROPOLITAN AREAS - A WASTE OR RESOURCE?

BY

A J STARMER
BALFOUR INTERNATIONAL
UNITED KINGDOM
C J OSBORNE
ALAMRUNDING SDN. BHD.
MALAYSIA

SUMMARY

In general the climate of Asia together with favourable land costs lends itself to the use of oxidation ponds for treatment of sewage. However, in metropolitan districts, the large areas of land required for this type of process are costly, even if they are available, and more sophisticated intensive types of plant are used to treat liquid wastes.

These plants generate considerable quantities of sludge requiring disposal and some form of treatment is frequently required if disposal is to be environmentally acceptable and not cause offence. Treatment methods utilised include the following, often in various combinations :

- digestion
- chemical conditioning
- dewatering
- incineration

Where final disposal to land is practised, the treatment should include digestion to control the spread of pathogenic organisms which would otherwise be returned to the community by contact directly or indirectly through crops or animals. There are also other reasons why digestion can be desirable prior to disposal to land or sea. The digestion process has the effect of reducing the mass of sludge available for disposal by breakdown of the organic content releasing gas in the process. The gas produced can be collected for utilisation as a fuel source. The largely disinfected sludge resulting can be utilised as a soil conditioner provided it is stabilised.

The benefits which can thus be obtained from processing the sludge prior to disposal call into question whether sewage sludge in an Asian metropolitan environment is indeed a waste or a resource for the community.

Experience in Singapore has shown that the benefits are quantifiable and are real. The authors have been involved with development of three works in Singapore where sludge gas is used as a resource for power generation.

GENERAL

The treatment of domestic sewage, whilst eliminating one aspect of environmental pollution, creates an organic waste problem.

When first drawn-off, sludges can vary in solids content from 0.5-5% and subsequent processes are designed to lower the moisture content to an extent compatible with the final method of disposal. Disposal methods may be categorised as follows:-

1. Landfill alone
2. Landfill together with refuse
3. Disposal to sea
4. Agricultural use
5. Incineration

In practice, disposal to land is most common, usually in the form of dried cake. Where this occurs as landfill, the sludge can be classified as a resource of the same value as fill material. However disposal to sea and incineration are methods which consider sludge as waste.

The costs of disposal are largely influenced by the transport costs of the sludge from the treatment works site to the disposal site. Sludge is usually treated prior to disposal and is likely to involve thickening of the sludge to reduce the quantity of sludge being transported. Similarly, the disposal method may require adjustment of the moisture content to suit the process being used. For example, incineration may require the moisture content being reduced to about 70% to be autothermic. Furthermore, in the case of incineration, the calorific value of the sludge will be reduced if digestion has taken place or if an inert conditioning chemical such as lime has been added.

Where final disposal to land is practical, anaerobic digestion of the sludge is advisable to reduce the spread of pathogenic organisms which could otherwise be returned to the community by direct contact with the sludge or contact indirectly through crops or animals. During digestion, anaerobic micro-organisms break down complex organic compounds such as carbohydrates, proteins and fats into simple, more stable substances, including water and methane gas. The rates of reaction are directly affected by temperature and are normally considered to be at a maximum in the mesophilic range (15°C - 38°C) and in the thermophilic range (45°C - 65°C). Operation in the thermophilic range requires considerable external heat and is not normally considered for treatment of domestic sludges. In temperate climates, the temperature range 30 - 35°C is considered as optimum and heating of sludge digesters is carried out to maintain the process within this temperature range. In South East Asia, the digesting sludge temperature can be maintained approaching the optimum range without recourse to additional heating. It is not normally economic to attempt to achieve the marginal increase in gas production at the expense of significant additional capital and maintenance costs. In addition to the advantages of disinfection and gas production, the digestion process reduces the sludge mass by up to 30%.

Frequently in Asia, sewage treatment facilities have been based on the oxidation pond principle where sufficient land has been available. In such situations, treatment facilities have low running costs and moderately low capital costs. In metropolitan areas however, the cost and availability of land often dictate that an intensive form of sewage treatment is adopted. Table 1 indicates the amount of land required for alternative types of treatment (1).

Table 1 - Areas of land required for sewage treatment works expressed in hectares per 10 000 persons

Treatment	Population			
	20 000	50 000	100 000	200 000
2-stage oxidation ponds	4.25	3.80	3.40	3.15
aerated lagoons	1.45	0.88	0.68	0.59
coventional activated sludge	0.76	0.68	0.62	0.55

By comparison, intensive sewage treatment schemes in Singapore and Hong Kong, serving populations in the range greater than 200 000, have been achieved at utilisations of 0.40 and 0.30ha/ 10 000 persons respectively. In these schemes, separate units have been provided for inlet works, primary settlement tanks, aeration tanks, final settlement tanks, return activated sludge pumping stations, sludge digesters, gas holders, power stations and sludge dewatering complexes.

Sludge treatment and disposal is often given limited consideration when oxidation pond schemes are being planned. However, at some stage, perhaps after 10 years or more, desludging of the ponds will be necessary and the actual removal of large quantities of sludge whilst maintaining satisfactory treatment of the sewage flow together with the subsequent disposal of the sludge should not be underestimated when considering overall running costs. The actual direct costs of such a desludging operation will be significant but furthermore, as these oxidation ponds are often constructed relatively close to housing areas, considerable effort will be necessary to ensure that the environment of the local residents is not disturbed.

EXPERIENCE IN SINGAPORE

a) Design

The three Singapore Sewage treatment works designed by Balfours, namely Kranji, Seletar and Juron, were based on a similar design philosophy for sludge treatment, details of which are given below:

	KRANJI	SELETAR	JURONG
Av. design sewage flow (m 3/d)	38000	57000	82000
Primary sludge production (kg/d)	6720	10100	18900
Secondary sludge production (kg/d)	6045	9100	16900
Digester retention Period (days)	30	30	27
Gas production (m^3/d)	4300	6300	11800

Primary sludge was designed to be drawn-off from the settling tanks and thickened in circular gravity consolidation tanks equipped with picket fence stirrers together with waste activated sludge, previously thickened in dissolved-air-flotation units, and pumped to fixed-roof concrete digesters. Due to the ambient temperature only varying between 22° and 33°C, no additional heating of the sludge was provided for. Mixing of the sludge in the digesters is achieved by gas lift, excess gas being stored in water-sealed, floating roof gas holders before passing to the on-site power generating station.

To utilise the sludge gas, compression-ignition dual-fuel engine generator sets were provided. The engines are of the pressure-charged type and water-cooled gas compressors are located in the power stations.

The engines utilise a small amount of pilot fuel whilst operating on sludge gas, but may also operate completely on fuel oil if required. Bulk fuel oil storage tanks have been constructed for this eventuality. Details of the installations are given below:

	KRANJI	SELETAR	JURONG
Digesters (No)	2	3	6
Digester total capacity (m^3)	9600	14400	24282
Gas recirculation compressors (m^3/min)	8.5	8.5	8.5
Engine (No)	4	3	3
Engine (KVA each)	650	800	915

Following digestion, sludge is dewatered using filter plate presses fed by reciprocating sludge pumps. The plants were designed for sludge conditioning using lime and ferrous sulphate or ferric chloride. Provision was also made for sludge elutriation using effluent prior to conditioning in order to reduce the chemical dosage.

Following dewatering, the sludge was to be stored on site in windrows for a short period before being used as a soil conditioner for tree planting and turfing of various areas of the island.

b) OPERATIONAL EXPERIENCE

Kranji and Seletar receive flows of primarily domestic origin at levels considerably below design. Seletar operational data has been used to represent both works. Jurong receives flow mainly of industrial origin and presently runs at about 70% of design capacity.

Seletar Sewage Treatment Works

At Seletar, the primary tanks are desludged 3 times per day and a sludge of moisture content 96-97% is obtained. From the primary tanks, sludge gravitates to the consolidation tanks where it is mixed with waste activated sludge, thickened to 96% in flotation thickeners, and pumped to the sludge digesters.

Digested sludge is dewatered using plate presses which were commissioned using lime and copperas (ferrous sulphate) as the conditioning chemicals as designed. Subsequently, operating staff have found polyelectrolytes at a dose of 0.5% to be the most cost effective conditioning agent. Polyelectrolytes have the further advantage of reducing the quantity of sludge to be removed from the site as the additional chemical bulk introduced into the sludge is negligible. Using polyelectrolytes has also reduced the pressing period from 4-5 hours using lime and copperas to about 3 hours, thereby increasing the potential throughput of the plant.

It is interesting to note that there is considerable difference in the relative costs of polyelectrolyte to lime and copperas between Europe and Singapore as shown by the typical current costs given below.

	Lime	Copperas	Polyelectrolyte
Singapore	M$255/tonne	M$290/tonne	M$5.90/kg
Europe	M$175/tonne	M$127/tonne	M$9.40/kg

Relative costs in Singapore at design stage were

M$320/tonne	M$530/tonne	M$11.70/kg

Filter pressed sludge at a moisture content of about 70% is readily sold as a soil conditioner to landscape contractors for mixing with top soil and for tree planting at a price of M$3.30/$m^3$.

In 1984, the incoming flow averaged 19060m^3/d compared to the design flow of 57000m^3/d. Gas production for 1984 averaged 1592m^3/d which generated 3002kWH/d as compared to a total power requirement to the works of 13857kWH/d.

At the present time, the incoming flow is about 80% of the design flow, a significant increase over the 1984 figures due to several flow diversions for the works.

Jurong Sewage Treatment Works

At Jurong, the primary settlement tanks were provided with automatic desludging system. Timers are used to open the sludge valves at preset time intervals and remain open for a fixed time. At present, desludging is carried out at 2 hourly intervals for a period of ten minutes. Another set of valves controls the flow rate of sludge leaving the desludging chambers. When the sludge viscosity decreases during desludging, the sludge level in the chambers rises and causes the sludge valves to be shut off automatically. This system enables the moisture content of the primary sludge to be regularly maintained at 96%.

Whilst the six digesters were designed to provide the facility of primary/secondary operation, it has been found in practice that maintaining purely primary operation has not resulted in a significantly reduced gas yield. Each gas recirculation compressor operates a total of 16 hours a day and apparently results in satisfactory sludge mixing and gas release.

The incoming sewage flow for 1984 averaged 58055m^3/d compared to the design flow of 82 000m^3/d. Gas production for 1984 averaged 6708m^3/d, compared to the 8354m^3/d which the design predicted for this flow. The lower production rate is attributable to the fact that the incoming sewage strength is only 80% of design. As stated earlier, a large proportion of the flow arriving at the Jurong Works is from industrial sources and, since the time of design, the emphasis of industrial development has changed towards lighter, more value-added industry with weaker effluents.

The gas produced in 1984 generated 12711kWH/d as compared to the total power requirement for the Works of 19657kWH/d., i.e. about 65% of the works power load was generated with sludge gas.

Sludge from the digesters is passed to the elutration tanks, currently used as thickening tanks to decrease the moisture content of the digested sludge from 96% to 94%. As at Seletar, lime and copperas were used at commissioning but operation is now with polyelectrolyte at a dose of 0.4% resulting in a sludge cake moisture content of 65-70% after 2 to 3 hours pressing.

Sludge from Jurong, as at Seletar, is sold at a price of M$3.30/m^3 but has proved less popular presumably due to the higher industrial content. Although this cost recovery is relatively small compared with the cost of sludge treatment, it does produce a recovery unlike many metropolitan works where disposal adds to the works operating cost.

EXPERIENCE IN HONG KONG

The combined factors of higher land costs than in Singapore and the need for nitrogen removal from the effluent resulted in a more compact design of works being adopted at Tai Po works in Hong Kong, which is currently under construction.

Rectangular primary settlement tanks were selected due to space requirements and diffused air secondary treatment was adopted, for process reasons, and to allay possible future complaints of spray nuisance to a brewery had surface aeration been adopted. The combined sludges are to be digested in concrete digesters with internal gas lift circulation incorporating heating facilities. The heating facility is required to maintain digester temperatures in winter and utilises waste heat from the dual-fuel engines. The engines utilise gas recovered from the digesters and drive blower units via gearboxes to provide air for the aeration process.

Digested sludge is to be dewatered using belt presses before disposal to land. At present, there is no obvious market demand for sludge, being a relatively new product available on a market which has not readily accepted compost. Agricultural land use in Hong Kong is such that large markets for sludge as a soil conditioner are not likely to be readily found and so, although the resource is available, it appears unlikely to be utilised in the near future.

RECENT DEVELOPMENTS

The potential energy available from the utilization of gas produced by the digestion of sewage sludges has long been recognized. It was reported that in 1985 Donald Cameron illuminated the septic tanks at Belle Isle, Exeter, UK with the gas generated therein. (2)

In the past, it has been considered that only in the case of treatment works with equivalent populations in excess of 100 000, has sludge digestion with energy recovery been worthwhile. This philosophy was based on consideration of digesters with long retention periods and dual-fuel engines by specialist manufacturers requiring skilled and experienced operators.

It is also well known that developing countries such as India, China, Thailand, Malaysia, Korea, Taiwan etc. have pioneered the development of small scale rural biogas plants and it is reported that there are over 7 million plants in China alone. (3) These small scale units provide gas for cooking, waste heating and small scale electricity generation.

More recently, interest has been shown in Europe for smaller package digestion units with associated energy recovery systems. Direct use of the methane in petrol and diesel engine road vehicles has proved possible following pressurised water scrubbing. In petrol engines, operation purely on methane is possible but use in diesel engines is limited to a 65%/35% diesel/methane proportion to avoid precombustion problems.

On-site use of methane is now considered viable for works with population equivalents as low as 10 000. Mass production small engine manufacturers such as Fiat, Ford and Land Rover have developed engines suitable for running on sewage gas. Noone et al (4) have reported on the use of a 20kw engine developed for use in the petroleum industry and found this to be financially worthwhile.

Sewage sludge may also be considered as a source of protein and extensive research and development is taking place at the present time to perfect commercial methods of separating the protein. Naturally, one of the main areas of concern is to maintain a sterile end-product to ensure that no disease enters the food chain or results in any adverse effects.

Trials have been successfully carried out feeding protein extracted from sludge as a food supplement to trout and feeding a proportion of dried sludge to poultry.

Of course, historically in Asia and other tropical areas, fish ponds have received both human and animal waste materials as a nutrient source for centuries. This simple practice has remained as a good example of utilization of the resources nature has provided. However, in Metropolitan Areas this is no longer a practical option.

CONCLUSION

Removal of large amounts of water borne pollution in Metropolitan areas gives rise to large amounts of sewage sludge requiring disposal. Although several disposal methods are available, disposal to land is most commonly practised and, to control the spread of pathogenic organisms, digestion of the sludge before disposal is recommended.

With the benefit of warm climates for most of the year, Asian sewage treatment works are able to capitalise on the resource of gas produced during the digestion process which would otherwise have been utilised in heating to maintain the digestion process. The gas available can be converted to power, thereby reducing the demand for other fuels and offsetting the operating costs of sewage treatment which continue to increase. The digested sludge can then be disposed of to land either as a liquid, if sufficient land is available, or as a solid after dewatering.

Sludge cake can be classed as a resource, at least equal in value to the cost of fill material, where it is used to benefit land in landfill and restoration projects. Mixed with topsoil, it has much benefit as a soil conditioner, particularly where light, sandy soils are prevalent. In this application, it has a small saleable value but, nevertheless, a positive value as a resource, not a waste.

ACKNOWLEDGEMENTS

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PAPER 13

THE APPLICATION OF MEMBRANE SEPARATIONS TECHNOLOGY FOR WATER EFFLUENT TREATMENT

BY

PETER S. CARTWRIGHT
PRESIDENT
C_3 INTERNATIONAL
UNITED STATES OF AMERICA

INTRODUCTION

Whereas water purification applications have been the dominant markets for membrane separation technologies to date, effluent treatment applications offer outstanding potential for the future.

Today, opportunities abound for existing membrane polymers and configurations, but a very real "knowledge gap" has prevented greater use of these technologies in effluent treatment applications.

This paper will attempt to provide a level of understanding with regard to both technical considerations and specific effluent applications.

BACKGROUND

"Effluent" can be defined as a waste component from a manufacturing or processing activity.

The reasons for considering waste treatment are many and varied:

1) Government Regulation -

The U.S. Federal Resource Conservation and Recovery Act (RCRA) identifies many water borne contaminants which are considered to be health risks and regulates their discharge. The list of pollutants suspected of causing cancer, birth defects or other toxic reactions is getting much longer and will continue to grow.

2) Environmental Pressures -

Powerful voices throughout the world are being heard clamoring for even tighter and more restrictive discharge regulations. Although many of these concerns are not founded in fact, however, they represent a persuasive lobby and are expected to further exacerbate the rush towards more tighter discharge regulations.

3) Solute/Solvent Recovery -

There are numerous cases of economic benefit provided by the recovery of dissolved or suspended materials from the effluent stream, as well as the recovery of the solvent itself. With the increasing scarcity of raw materials, the concept of reuse or recovering and selling the solute commands serious consideration. In addition, as high quality water becomes increasingly scarce, it will become more costly to purchase, thereby providing incentive for water reuse also.

4) Technology Benefits -

The membrane separation processes offer the following advantages when compared to other means of separation:

- Low energy utilization - no phase or temperature change involved
- Continuous process - providing the advantages of automation and uninterrupted operation.
- Low maintenance with a minimum of moving parts - the systems are easy to operate and maintain

MEMBRANE TECHNOLOGY REVIEW

The four membrane separations technologies addressed in this paper include:

- Microfiltration
- Ultrafiltration
- Reverse Osmosis
- Electrodialysis

Although they all accomplish separation of liquid borne contaminants from the liquid, each utilizes a different separation mechanism and each has specific advantages and disadvantages when compared to the others. In spite of the difficulties in generalizing an attempt will be made to address these technologies in terms of their effectiveness in treating effluent streams from a number of specific industries.

Figure 1 depicts the mechanism of microfiltration. Generally, microfiltration involves the removal of particulate materials ranging in size from 0.1 to 10.0 microns (1000 to 100,000 angstroms).

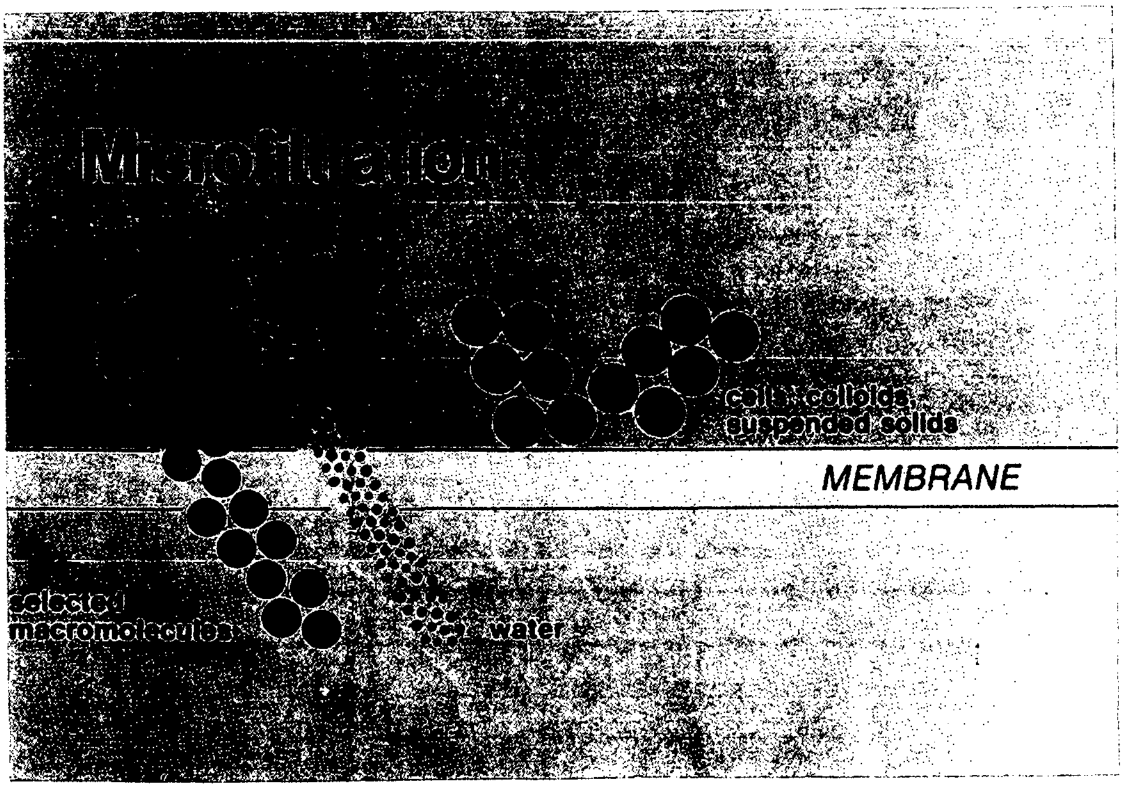


Figure 2 depicts ultrafiltration, which is used to separate materials in the 0.001 to 0.1 range (10 to 1000 angstroms). Basically, ultrafiltration is used to remove dissolved materials while the suspended solids are removed by microfiltration.

Figure 3 illustrates reverse osmosis which typically separates materials less than 0.001 micron (10 angstroms in size). Reverse osmosis offers the added advantage of rejecting ionic materials which are normally small enough to pass through the pores of the membrane. As with ultrafiltration, reverse osmosis is used to remove dissolved materials.

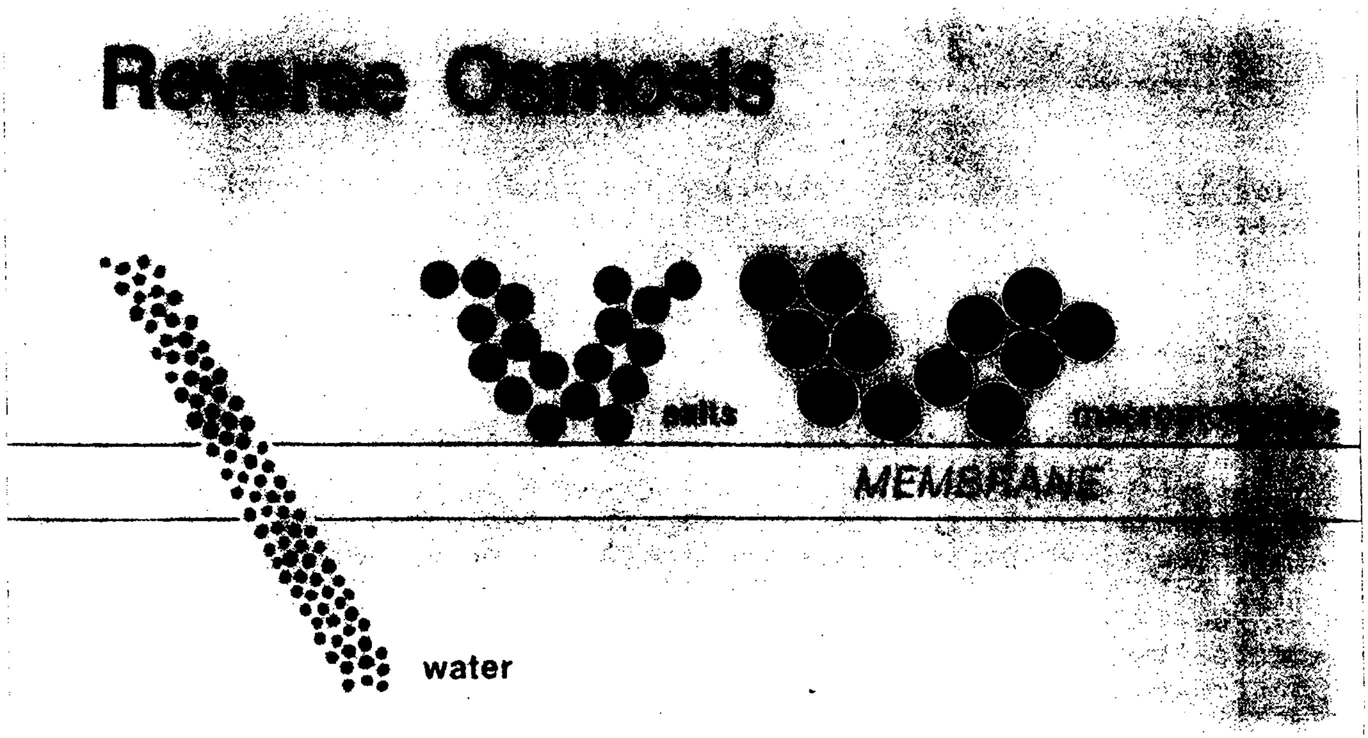
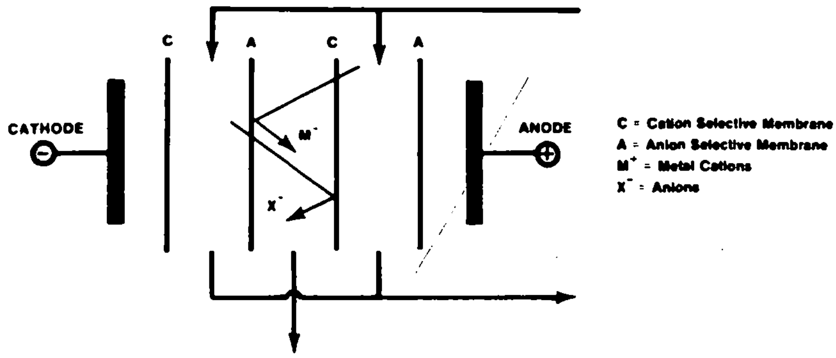


Figure 4 depicts electrodialysis which utilizes permeable membrane as well as an anode and cathode to effect separation. Instead of driving pure water through the membrane and leaving contaminants behind, as in the case of the other membrane processes, electrodialysis utilizes membranes which selectively allow either the cationic or anionic solute to pass through in response to the electrical charges imposed by the anode and cathode.



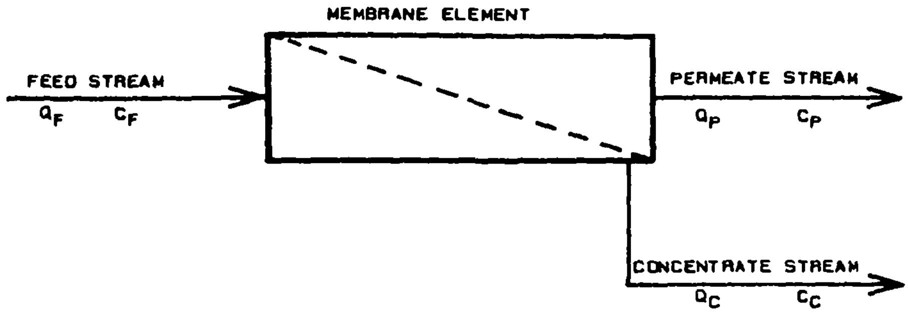
SYSTEM DESIGN CONSIDERATIONS

In order to treat an effluent stream, it must be thoroughly analyzed for the following data:

- Total solids content
  - Suspended (TSS)
  - Dissolved organic (TOC)
  - Dissolved inorganic (TDS)
- Specific chemical constituents
  - Oxidizing chemicals
  - Organic solvents
- pH
- Operating temperature

Usually, the goal is to "dewater" the feed stream as much as possible; that is, to remove solvent to facilitate either reuse or removal of the concentrated solute. Of secondary importance is the possible reuse of the purified solvent (usually water). These two considerations are significant in determining both the process and membrane device to be used.

Figure 5 depicts a general schematic for the membrane processes of microfiltration, ultrafiltration and reverse osmosis. In these technologies, the implication of increasing the dewatering process is described by the term "recovery," which is defined as the permeate volume divided by the feed volume, in other words, the percentage of the feed flow which is pumped through the membrane. Typically for effluent treatment applications, the recovery figure is at least 90%. As recovery is increased (to decrease concentrate volume), the concentration of solute and suspended solids in the concentrate stream increases.



Q_F - Feed flow rate

C_F - Solute concentration in feed

Q_P - Permeate flow rate

C_P - Solute concentration in permeate

Q_C - Concentrate flow rate

C_C - Solute concentration in concentrate

$$\text{RECOVERY} = \frac{Q_P}{Q_F}$$

(Expressed as percent)

Figure 5, Membrane Processing Schematic

For the processes of ultrafiltration and reverse osmosis which deal with dissolved materials, a property of the solution known as "osmotic pressure" becomes a limiting factor. Osmotic pressure is a characteristic of all solutions, and is loosely defined as the resistance of the solvent portion of the solution to freely passing through the membranes. Osmotic pressure is a function of both the particular solute as well as its concentration.

The recovery of a system can be controlled by restricting the quantity of flow in the concentrate stream, normally through the use of a concentrate valve. As recovery is increased, with the resulting decrease in concentrate flow, the concentration of solute in the concentrate stream increases, which results in an increased osmotic pressure.

No membrane is perfect in that it rejects 100% of the solute on the feed side; this solute leakage is known as "passage." Expressed as "percent passage," the actual quantity of solute which passes through the membrane is a function of the concentration of solute on the feed side. Under high recovery conditions, the concentration of solute on the feed side is increased and therefore the actual quantity of solute passing through the membrane also increases. Because most effluent applications demand that, in addition to a minimum concentrate volume, the permeate quality be high enough to allow reuse or to meet discharge regulations, the "Catch-22" predicament of permeate quality descreasing as recovery is increased can impose design limitations. Additionally, the increased osmotic pressure resulting as recovery is increased also imposes a design limit. Generally, pumping pressures in excess of 1000 psi are impractical for most applications.

Electrodialysis systems separate ionic species from water and other dissolved materials by attracting the salts through the membrane. Because pumping energy is not used to effect the seperation, osmotic pressure is not a factor; however the conductivity of the solution is important and becomes a factor limiting the degree of purification that can be accomplished. The maximum concentration that can be obtained is generally limited by practical considerations of membrane surface area required and equipment costs. When comparing electrodialysis to reverse osmosis, the former process can generally produce concentrate streams ten times the concentration of reverse osmosis; however, non-ionic solute cannot be concentrated and the permeate is not as pure in dissolved ionic concentration as that produced by reverse osmosis.

With regard to membrane element configuration, Table 1 lists the important physical characteristics of the various membrane element device configurations available today:

TABLE 1

Elemert Configuration	Packing Density*	Suspended Solids Tolerance
Spiral wound	High	Fair
Tubular	Low	High
Plate and frame	Low	High
Hollow fine fiber	Highest	Poor
Electrodialysis stack	Low	High

*Membrane area per unit volume

Because of the propensity of suspended or precipitated materials to settle out on the membrane surface and plug the membrane pores, turbulent flow conditions must be maintained (Reynolds numbers in excess of 2000). For high recovery systems, this usually requires recycling a significant percentage of the concentrate back to the feed side of the pump. The addition of this concentrate stream into the feed solution obviously increases the dissolved solids concentration further increasing osmotic pressure.

TESTING CONSIDERATIONS

All of these factors: recovery, osmotic pressure, permeate quality, recycle etc., serve to underscore the value of testing the specific waste stream as thoroughly as possible. Because effluent streams often vary in analysis as a function of time, it is important that either a composite of a "worst case" sample be obtained for test purposes.

One or more of the following test procedures should be utilized when evaluating membrane technology with particular effluent stream.

Cell Test - Utilizing small (approximately 15 square inches) cut pieces of sheet membrane mounted in a "cell" that exposes the membrane to the test solution using the cross-flow mechanism. This test is effective for quick evaluation of a number of different membrane polymers to determine degree of separation.

Advantages : Fast
Inexpensive equipment involved
Only small quantities of test solution required

Disadvantages: Cannot indicate long-term chemical effects of solution on polymer
Does not provide engineering scale-up data
Gives no indication of optimum membrane element configuration
Does not provide data on fouling effects of test solution

Applications test - Typically involves the evaluation of a 30-50 gallon sample of solution on a production-sized membrane element. The element is mounted in a test machine with the engineering features of production systems. For a given element, the test can be completed within 1-2 hours. Figure 6 details the applications system design.

Advantages : Fast
Provides scale-up data (flow, element efficiency, osmotic pressure as a function of recovery, pressure requirements, etc.)
Can provide an indication of membrane stability

Disadvantages: Does not indicate long-term chemical effect
Does not provide data on fouling effects of the test solution

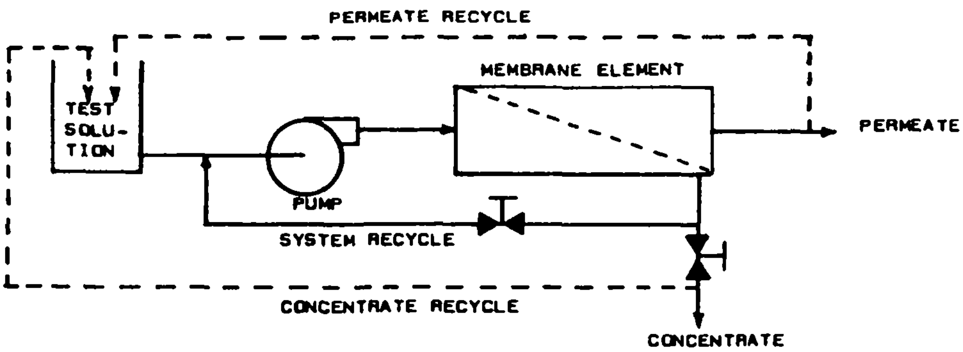


Figure 6, Applications test schematic

Pilot test - Usually involves placing a test machine (such as that used for the applications test) in the process operating on a "side-stream" for a minimum of 30 days.

Advantages : Accomplishes all of the functions of the applications test plus provides long-term membrane fouling and stability data

Disadvantages: Expensive in terms of monitoring and time requirements

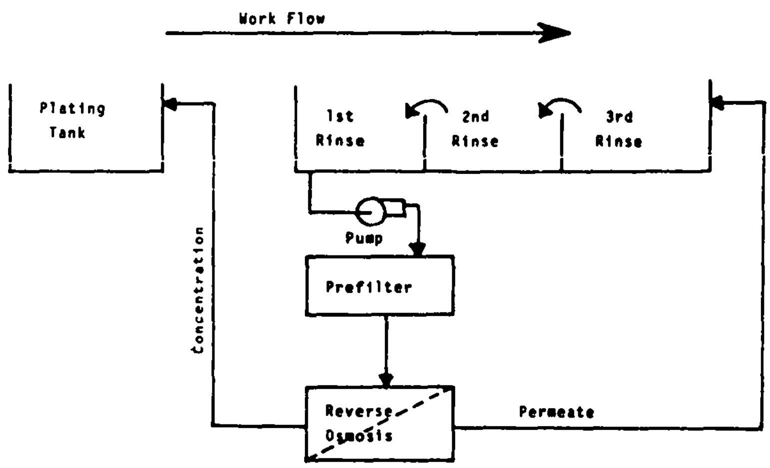
APPLICATIONS

Metal Finishing

1) Electroplating solute recovery ("zero discharge") reverse osmosis recovery of plating salts from electroplating rinses; return of the concentrate to the plating bath and permeate to the last rinse. (Figure 7)

BATH TREATED	NUMBER OF EXISTING SYSTEMS
Nickel	150
Acid Copper	12
Acid Zinc	1
Copper Cyanide	1
Hexavalent Chrome	1

Feed TDS: 2-3000 ppm
Typical feed rate: 2-10 gal/min
Present market potential: $5-10 MM/yr
Projected growth rate: 10%/yr



Electrodialysis recovery of plating salts from "drag-out" or stagnant rinse tanks preceding flowing counter-current rinses. (Figure 8)

Number of existing systems: 35
Feeds TDS: 4-5000 ppm
Typical feed rate: 5-20 gpm
Present market potential: $1-2 MM/yr
Projected growth rate: 30-40%/yr

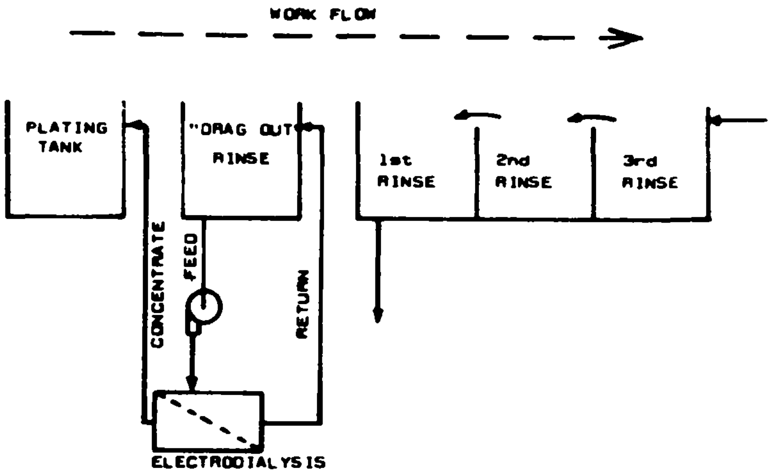


Figure 8, Electrodialysis recovery of plating salts

2) "End of Pipe" Effluent Treatment - the use of membrane technology to dewater mixed plating rinse streams:

   a) Reverse osmosis prior to chemical precipitation/ clarification to reduce hydraulic loading to the clarifier (Figure 9)

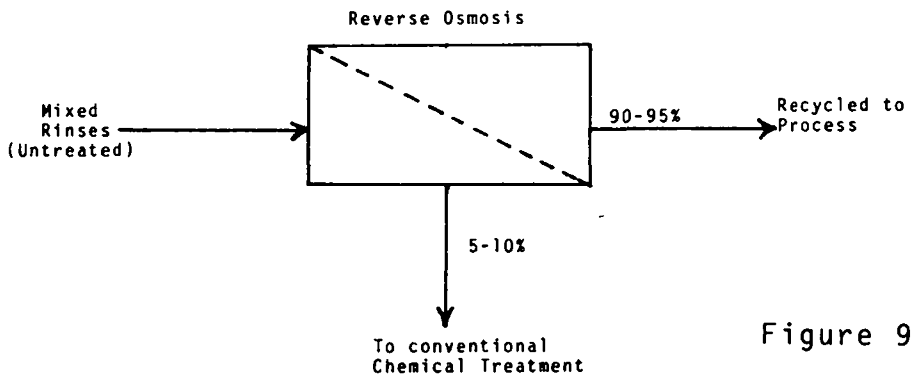


Figure 9

   b) Reverse osmosis on clarified effluent to ensure toxic metals compliance. (Figure 10)

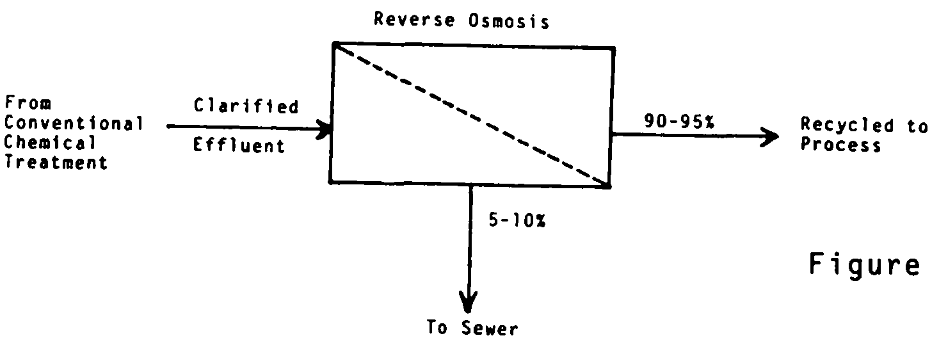


Figure 10

c) Microfiltration on total effluent immediately following precipitation step to pre-dewater sludge prior to filter press (Figure 11).

Feed TDS: 1000-10,000 ppm
Toxic metals concentration: 1-100 ppm
Number of existing systems: 10-20
Present market potential: $7--15 MM/yr
Projected growth rate: 10-15%/yr

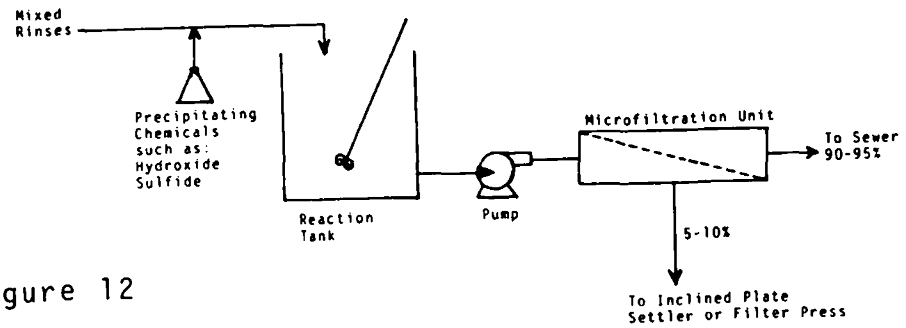


Figure 12

Dissolved or emulsified oils can be separated from water through the use of ultrafiltration. Typically, the oil-rich concentrate is recycled to the feed tank until the oil concentration is high enough to allow it to be incinerated for the BTU value (60-70%). Figure 12 schematically represents this process. Following are three present applications for this technology:

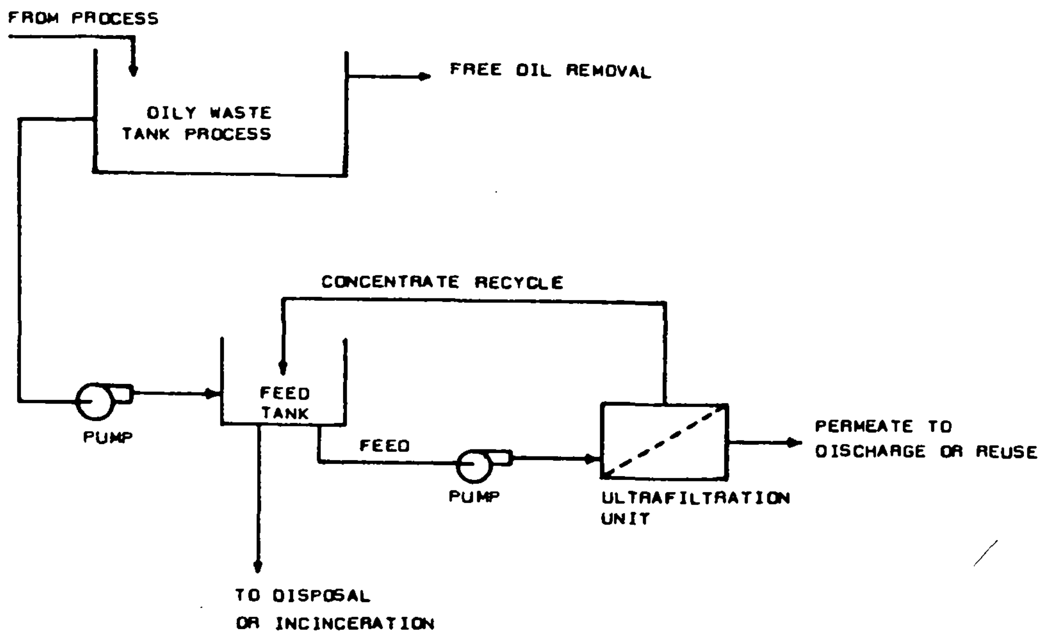


Figure 12, Oily waste treatment

3) Oily waste treatment of can forming rinse waters - ultrafiltration to remove drawing and forming oils from one-piece can cleaning rinse waters.

Permeate can be recycled as rinse water; concentrate hauled or incinerated

Typical feed stream COD: 2000-5000 ppm
Approximately 5 systesm presently operating
Typical feed rate: 10-20 gpm
Present market potential: $3 MM/yr
Projected growth rate: 10-20%/yr

4) Oil waste treatment of coil coating rinse waters - use of ultrafiltration to remove rolling oils from aluminum and steel coil cleaning rinse waters. In some cases the valuable detergent is recovered and the permeate is reused; concentrate is hauled or incinerated.

Typical feed stream COD: 10-20 ppm
Approximately 5 systems presently operating
Typical feed rate: 10-20 gpm
Present market potential: $2 MM/yr
Projected growth rate: 10%/yr

5) Oil waste treatment of rinses from automotive and aircraft cleaning - use of ultrafiltration to remove oil from detergent cleaning rinse waters; permeate can be recycled, concentrate hauled or incinerated.

Typical feed COD: 2-10,000 ppm
Approximately 15 systems presently operating
Typical feed rate: 20-50 gpm
Present market potential: $5-10 MM/yr
Projected growth rate: 20-30%/yr

6) Electrodeposition paint bath dewatering - continuous "side stream" ultrafiltration of electrodeposition paint bath to remove water and contaminants. Concentrate is returned to the bath; permeate is used as first rinse or discharged. (Figure 13)

This is a mature market (if not saturated) and is dependent on the automotive and appliance markets.

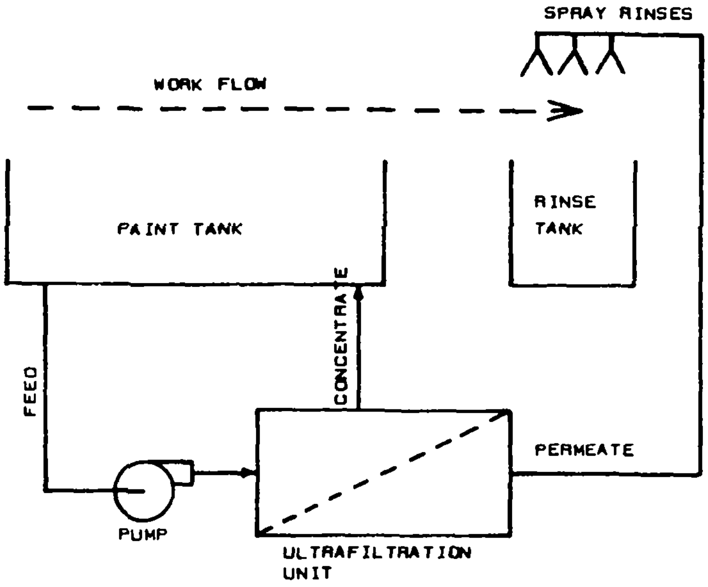


Figure 13, Electrodeposition paint dewatering

FOOD PROCESSING

Membrane technology offers potential in many diverse food processing applications such as those requiring separation at ambient temperatures, continuous operation, fractionation, etc. In general, with the exception of cheese whey application, these are just now being investigated and there are only pilot installations in operation.

1) Cheese whey dewatering or fractionation - reverse osmosis to concentrate whole whey prior to spray drying, ultrafiltration to fractionate whey to recover lactalbumin protein and electrodialysis to de-ash ultrafiltration permeate.
   Approximately forty systems installed in the United States since 1981.
   Total sales to date: $22 MM
   Equipment requires USDA 3A Dairy construction and FDA approved membrane elements.
   Market potential depends upon federal government decisions regarding "standards of identity." If changes are mandated, a potential exists of $10-12 MM/yr; if not, potential is $1-2 MM/yr.

2) Distillery "stillage" dewatering - utilization of membrane technology to concentrate organic material left over after the alcohol distrillation process in the production of ethyl alcohol. The concentrate is used as animal feed and permeate can be used as boiler feed. Typical feed stream characteristics:

TDS: 30-40 ppm
Suspended solids: 5000 ppm
Bod: 20,000 ppm
Present market potential: $1-2 MM/yr
Projected growth rate: 10-30%/yr

3) Brewery waste treatment - use of membrane technology to:
   a) Recover valuable enzymes such as isohumulone
   b) Remove color and enhance flavor
   c) Concentrate hops for reuse
   d) Provide "end-of pipe" effluent dewatering
   Typical feed stream characteristics:
   TDS: 30-40 ppm
   Suspended solids: 500ppm

4) Wine processing - use of microfiltration and ultrafiltration to:
   1) Remove bacteria (cold sterilization)
   2) Improve color, enhance flavor
   Typical feed stream characteristics:
   TDS: 50-60,000 ppm
   Suspended solids: 500 ppm
   BOD: 12,000 ppm
   Present market potential: $1-2 MM/yr
   Proejcted growth rate: 5-10%/yr

5) Meat processing - use of membrane technology for:
   a) Protein recovery from total effluent
   b) Blood plasma fractionation
   c) Gelatin recovery/purification
   d) Pork pickling (curing) brine recovery
   Typical feed stream characteristics
   TDS: 3-5 ppm
   Suspended solids: 2-3000 ppm
   BOD: 2-3000 ppm
   COD: 5000 ppm
   20% Sodium Chloride Concentration
   Protein molecular weight about 5000

6) Grain seed oil processing - ultrafiltration to separate oil from extracting solvents:
   Typical feed stream characteristics:
   Molecular weight of oil: 1-2000 daltons
   Typical feed rate: 50-100 gpm
   Present market potential: $2-3 MM/yr
   Projected growth rate: 10-20%/yr

7) Sugar processing - membrane technology to remove color from liquid sucrose:
   Typical feed stream characteristics: Temperature of 70 C
   Typical feed rate: 50-200 gpm
   Projected growth rate: 10-20%/yr

8) Fruit juice clarification - microfiltration and ultrafiltration to remove colloidal contaminants:
   Approximately 15-20 systems operating worldwide
   Typical feed rate: 10-300 gpm
   Present market potential: $5-10 MM/yr
   Projected growth rate: 10-20%/yr

9) Juice processing - ultrafiltration and reverse osmosis to:
   a) Preconcentrate (dewater) tomato, orange, apple, beet, lemon, etc. prior to evaporation
   b) Fractionate fruit juices to remove pectins

   Typical feed stream characteristics:
   High suspended solids (pulp) which must remain
   Typical feed rate: 100-500 gpm
   Present market potential: $10-30 MM/yr
   Projected growth rate: 30-50%/yr

10) Corn sweetener concentration - ultrafiltration to concentrate dextrose from 4-6% to 25-30%

   Typical feed stream characteristics:
   Molecular weight of dextrose - 180 daltons
   Temperature of feed 80 C
   Typical feed rate: 50-200 gpm
   Present market potential: $2-3 MM/yr
   Projected growth rate: 20-30%/yr

PHARMACEUTICAL/BIO TECHNOLOGY APPLICATIONS

The use of membrane technology in these industries offers much promise. Such critical and diverse requirements as low temperature concentration, solute fractionation and continuous processing provide outstanding opportunities for all four membrane separation technologies.

Other than the purification of water for product rinsing or medication preparation, these technologies have been used sparingly to date; however, the rapid growth of the biotechnology industry will require significant utilization of all membrane technologies as large-scale manufacturing processes evolve from the present laboratory preparation procedures.

Possible applications include:

- Continuous bio-reactor
- Product concentration/dewatering
- Fractionation/purification
- Cold sterilization
- Solvent reuse

By 1990, the membrane technology market is expected to total $100-150 MM/yr, with a projected growth rate of 60%/yr.

BRINE WATER TREATMENT

Reverse osmosis or electrodialysis to dewater high TDS waters brought to the surface in oil and gas drilling operations.

Typical feed stream characteristics:
TDS: 50-350,000 ppm
Typical feed rate: 10-50 gpm

BOILER/COOLING TOWER BLOWDOWN

Reverse osmosis to dewater blowdown from boilers and cooling towers.

Blowdown may contain chromates (toxic waste)

Typical feed rate: 1-100 gpm

TANNERY WASTE TREATMENT

Reverse osmosis to dewater effluent from leather tanning operations.

Typical feed stream characteristics:
pH: Approximately 12
BOD: 14,000 ppm
COD: 30,000 ppm

Possible trivalent chrome present

TEXTILE WASTE TREATMENT

1) Dye recovery - use of membrane technology to concentrate dye to return to the dye vat; permeate reused for rinsing.

   Typical feed stream characteristics:
   TDS: 2-15,000 ppm
   Suspended solids: 100 ppm
   BOD: 300 ppm
   COD: 1500 ppm
   pH: approximately 12
   Typical feed rate: 50-300 gpm
   Present market potential: $5-8 MM/yr
   Projected growth rate: 20-30%/yr

2) Sizing recovery -ultrafiltration to recover polyvinyl acetate compounds from rinses for reuse. Permeate can be recovered for rinsing.

   Typical feed stream characteristics:
   TDS: 10-20,000 ppm
   Suspended solids: 1000 ppm
   COD: 30,000 ppm
   pH: Approximately 6
   Typical feed rate: 50-300 gpm
   Present market potential $5-8 MM/yr
   Projected growth rate: 20-30%/yr

PULP AND PAPER WASTE TREATMENT

Ultrafiltration recovery of lignosulfonates from spent sulfite liquor.

Typical feed stream characteristics:
TDS: 90-120,000 ppm
Wood sugar: 20-40,000 ppm
Lignosulfonates: 40-80,000 ppm
pH: 3-4
Typical feed rate: 100-1000 gpm
Present market potential: $6-10 MM/yr
Projected growth rate: 1-5%/yr

DEWATERING PHOTOGRAPHIC RINSES

Use of reverse osmosis to concentrate ferrocyanide, thiosulfate and silver salts in photo processing rinse water. Concentrated silver can be easily recovered electrolytically and thiosulfates oxidized with ozone to facilitate discharge.

Typical feed stream characteristics:
BOD: 1200 ppm
COD: 2000 ppm
Silver: 30 ppm
15 systems currently installed in United States
Typical feed rate: 5-20 gpm
Present market potential: $1.5-2 MM/yr
Projected growth rate: 10%/yr

SUMMARY

This paper has attempted to identify some of the opportunities offered by membrane processes in effluent treatment applications, but there are no easy answers; no single technology is the solution for all problems.

Certainly, the requirement for testing cannot be emphasized enough; however, for those applications which testing indicates can be effectively treated with membrane technologies, they can provide outstanding performance.

Some experts predict that, within 10-20 years, effluent treatment, along with food and chemical processing, will represent 80-90% of the total membrane processing market.

PAPER 14

RODENT CONTROL IN SEWERS

BY

Roger Harris, Manager and Norman Crane, Specialist Adviser
Howard Humphreys OMT Division
United Kingdom

INTRODUCTION

It is important that engineers involved with the operation and maintenance of sewerage systems remain aware of the damage that can be caused by rodent infestation and the facilities available to effect control. Among the Reference Manuals to assist in this respect is one published in UK by the Ministry of Agriculture, Fisheries and Food in co-operation with the Local Government Training Board. A considerable amount of research on rats and mice has been carried out over the years and a large volume of documentation published. Probably the most comprehensive bibliography available regarding the subject will be found in a recently published reference book, (1) which contains over 1300 references and brings together all recent information related to control. A much briefer list more relevant to the specific aspect of sewer rat control is included at the end of this paper.

Sewers, particularly if poorly maintained or badly designed/ constructed, provide rats with their two essential basic requirements, shelter (or harbourage) and food. In addition the sewer systems provides an underground highway network connecting all parts of a district thus helping to spread the infestation to the surface. The air temperature in sewers is favourable to rats being warmer than above ground in cold weather and cooler during hot weather. The rat most commonly found in sewers is the Common Rat (brown, 'Norway' or sewer rat) its scientific name is Rattus norvegicus; it lives anywhere offering food and shelter predominantly though in sewers. The Ship Rat (black or roof rat) Rattus rattus lives largely indoors, mainly in the Port areas but is found in sewers in some parts of the world.

BIOLOGY OF THE RAT

The word rodent comes from a Latin word that means to gnaw. Rodents gnaw with their paired incisor teeth. The front suface of these have a thick layer of enamel, giving the teeth hard cutting edges which will cut through soft metals such as lead and some grades of aluminium. The incisors are used for biting and holding food, fighting and to excavate burrows. Behind the incisor in each jaw there is a gap with no teeth, through which they are able to spit out soil or inedible materials while gnawing. This means many chemical repellants designed to prevent gnawing often fail to discourage rats, since they are able to gnaw the treated material and at the same time reject the chemical repellent.

An adult common rat may weigh from 100-500 gm. The head and body varies in length from 200-270mm, and the tail which is shorter than the head and body, measures between 165 and 205mm.

Common rats are very efficient burrowers, and their burrows may extend several metres, horizontally. They are also good climbers, and have no difficulty in travelling by way of pipes or beams, and can climb vertical walls if the surface is rough enough. Rats can chimney up between walls and drain pipes, and even inside vertical pipes if the diameter is not more than 100mm. They can jump about 600 mm, and are reasonably good swimmers although they do not like going into the water.

Rats breed throughout the year and multiply so fast under favourable conditions that colonies can increase by 3-9% per week. Female rats have their first litter at about 4 months of age and may have up to 5 during their lifetime. Litters range from 2-14 young with an average of 8 per litter for common rats. Their life expectancy is about one year.

They are active mainly at night, when they feed, thus a sewer is an ideal abode for them. The distances they move depend on how far they have to travel to find food or water. Rats in well established colonies usually set runs between their living quarters and their food supply. Young rats that are leaving their parent colonies may travel considerable distances before they settle and start new colonies. Mass migration of whole rat colonies have occasionally been reported, but these reports have never been authenticated.

Their diet consists of many kinds of food, animal or vegetable, but they generally prefer cereals, consuming about 10% of their own body weight in food each day. Rats also need to drink water, and can only live a few days without it.

DISEASES TRANSMITTED BY RATS

Rats carry many diseases, of which the most important is Weil's Disease (leptospirosis). The causal organism lives in the kidneys of the rats but apparently has little effect on the rats themselves. About 40 per cent of rats carry the organism which is excreted in their urine.

In the damp or wet conditions found in sewers the organisms can survive for several hours. Men working in rat infested sewers are exposed to the risk of contracting the disease, which can be fatal in up to 20 per cent of cases. Weil's Disease is difficult to diagnose clinically, since the early symptoms may resemble those of 'flu'.

Employers should provide a special card for their operational staff to hand to their doctors should they feel unwell in order to alert the doctor to the possibility of Weil's Disease. Otherwise many doctors without experience of the disease may well not take it into account. The card should give information about the disease together with safety precautions and instructions to the card holder.

The safety precautions are relatively simple: since the main route of entry of the bacteria into the body is by penetration of the skin in scratched and abraded areas, all cuts and scratches should be treated promptly and suitable clothing, such as boots and gloves should always be worn. There is also some evidence to sugest that infection can result from ingestion of the organism, therefore those exposed to infection should wash their hands thoroughly after work and always before eating, drinking or smoking.

Apart from Weil's Disease it should not be forgotten that the rat carries numerous other diseases, notably salmonellosis and rat-bite fever which may also be transmitted to man.

DAMAGE CAUSED BY RATS

The common rat is a burrowing animal and because of this habit it may exploit any defect in the sewer wall or in the drainage connections by burrowing into the surrounding soil. This results in soil falling into the sewers or drains which interferes with the flow and causes blockages. If the burrowing activity is sufficiently extensive it may cause, or at least contribute to, road collapse and further damage to the sewer. This may seriously interfere with the traffic and the efficient functioning of the sewer, as well as causing hazards to safety and health and incurring high repair costs.

Frequently, insufficient attention is given to the part played by rats in contributing to the structural damage to sewers.

Sometimes when an urban area is redeveloped it becomes subject to invasion by rats. This is caused by rats coming from defective or disused drains which have been left connected to the main sewer instead of being removed or backfilled.

PREPARING FOR A CONTROL PROGRAMME

Rats gain entrance to sewers through broken pipes or covers, and laterals that are abandoned or exposed in rat-infested neighbourhoods. These openings must be located and closed to rodent travel when initiating a rodent control programme.

Many openings and rat burrows connected to sanitary sewers can be detected through smoke testing of sewers. Other passageways can be identified by the presence of rat droppings or by reports from individuals living in or near rat-infested neighbourhoods.

A key requirement for preparing and executing a rodent control plan is a set of up to date record drawings of the sewer system.

ASSESSMENT OF INFESTATION

The location and assessment of the scale of sewer infestation is caried out by test baiting. Specific weights of wheat or other bait are placed in manholes then checked daily for a predetermined period and the amount eaten recorded. After the subsequent poisoned baiting programme the above technique may be utilised to assess the success of the baiting programme.

One of the problems encountered using test baiting to assess sewer rat infestation is the "wash off" of bait by water flowing in the sewer. Thus, on re-inspection, the bait is wrongly recorded as having been eaten by rats. To avoid mistakes of this kind it is advisable to put a small pile of wood shavings beside the bait in the manhole. The shavings are not attractive to rats, and do not get eaten. Thus, if on reinspection both the bait and wood shavings have gone, both can be assumed to have been washed off. Wood shavings have been found particularly useful when test-baiting for the first time in new systems.

METHODS OF CONTROL

There are some unusual methods of control utilised in different parts of the world. In some parts of the Philippines rats are eaten! Bounty payments is a method sometimes used and this approach was recently employed in Penang, Malaysia following the success of a similar campaign to effect crow control. In an area of West Java a prospective bridegroom must kill 50 rats before permission to marry is granted. Other control methods that have been advocated in the past are gassing, flooding, the use of poisoned "sticky boards" and the laying of poisoned foam on the benching of manholes. Trapping is fairly widely used.

However, the principal and most effective current method of control is through carefully planned baiting campaigns employing proven rodenticides.

Effective control is an integration of sound fieldwork and efficient plotting of all results on a layout plan of the area or alternatively on a computer programme.

The techniques used today to successfully control rodent infestation owe a great deal to the research work carried out in the UK between 1950-70. The key technical papers produced in this period are listed at the end of this paper.

RODENTICIDES

Basically there are two groups available, first a chemically heterogeneous group known as 'acute' or quick acting poisons, and second, the chronic slow acting anti-coagulant poisons.

Acute poisons are divided into two further groups. Compounds in the first group, include zinc phosphide, arsenious oxide and norbromide, have a particular disadvantage in not being very acceptable to rats, therefore acute poisons of this first group cannot be recommended for sewer rodent control. The second group of acute poisons includes fluracetamide (1081) and thallium sulphate. These compounds are very much more accepted by rats than are acute poisons of the first group, and they can therefore be included in bait at relatively high concentrations. The high toxicity of baits containing these poisons means that a very small dose will be lethal to a rat and consequently the maximal effect can be obtained. Their use, has however, been banned by some authorities who consider them highly dangerous for the sewer operatives and the pest control officer to handle.

Anti-coagulant rodenticides including warfarin, diphacinone, or difenacouns baits, exert these effects by preventing the blood from clotting, thus causing death from haemorrhage. They are probably the most effective of all rodenticides. In order to be lethal however they must be eaten for several successive days. To be successful therefore it is essential to maintain a surplus of bait in the manholes by replenishing it at intervals until all takes cease. This usually takes two or three weeks, but may take as long as five. Anti-coagulants sometimes tend to give poor results in very wet manholes where it is difficult to keep the bait in good condition for the required period. Even in normal conditions it is usually necessary to include a fungicide in order to ensure that the keeping qualities of the bait are satisfactory. Resistance to anti-coagulant rodenticides in rats does occur.

When any poison is added to a bait the fermal mixture must be sufficiently attractive to draw rats away from their normal food. Rodents are attracted to practically any human food, but because they are basically grain eaters they usually prefer cereals. Baits must be a texture that will mix evenly with poisons. Ground cereals like medium oatmeal are the most practical to use, because they can be directly mixed with most master mixes. Damp baits are generally more attractive to rats than dry or oily baits. Their main disadvantage is that in most situations they tend to dry out or go mouldy so have to be replaced frequently. They are therefore less practical to use with anti-coagulant poisons which have to be left down for comparatively long periods.

SEWER MAINTENANCE

The major damage to sewer structure by rats results from their exploring the weaknesses of defects and burrowing through some to make nests. The magnitude of defects in existing sewer systems is often not appreciated and this was highlighted by a recent sewer survey of six kilometres of sewers of various ages and at various locations in the UK (17). The results are summarised in the table below, reproduced from the study.

FREQUENCY OF DEFECTS OBSERVED IN 6KM OF SEWERS

Total length surveyed 6090 m   Total number of pipes 7665

Defect	Number of defects	Percent of total defects	Length affected by each defect (m)	Percent of defective length with continuous defect*
Structural :-				
Cracked - longitudinal	418	6.4	245	60
Fractured - "	37	0.6	23	31
Broken - "	5	0.1	2	2
Cracked - circumferential	168	2.6	131	0
Fractured - "	30	0.5	26	0
Broken - "	5	0.1	5	0
Cracked - multiple	108	1.7	89	68
Fractured - "	40	0.6	32	52
Broken - "	12	0.2	9	12
Deformed	23	0.4	17	15
Joints displaced	3753	57.3	2953	92
Joints open	42	0.6	39	0
Service :-				
Roots	190	2.9	146	26
Infiltration	244	3.7	216	59
Encrustation	296	4.6	277	7
Obstruction	11	0.2	8	0
Debris	831	12.7	683	95
Change in level	212	3.2	846	0
Change in line	30	0.5	26	0
Construction :-				
Junction	45	0.7	35	-
(Sound junctions)	(545)			
Connection	49	0.8	36	-
(Sound connections)	(94)			
TOTAL	6549	100	5842	

* A continuous defect is one affecting two or more consecutive pipe lengths.

Some key points to observe when maintaining sewers are:-

1. Ensure sound joint when making drain connections.
2. Check pointing in old brick lined sewers.
3. Note flow over invert of old sewers, if insufficient to cover invert, check if rat droppings or fur (from preening) has recently been deposited.
4. Likewise in all side entrance manholes.
5. Regularly remove detrited matter.

Rats travel along working sewers when scavenging for food, but need dry undisturbed places for nesting. It is known that they frequent disused lengths of sewer for this purpose and it is therefore important that they should be denied access to any such disused or "dead" lengths. It is accordingly recommended that when new sewers are laid, all old sewers which are abandoned should be either grubbed up and the ground made good with hard filling, or, if this is impracticable, filled solid with weak concrete.

Malpractices which encourage rat infestation included straight pipes used to make a "bend" in a drain, open junctions, no taper pipes used to join two pipes of varying diameters and holes knocked into the crown of a large sewer to take a connection from a smaller drain.

It should be mentioned that modern materials such as PVC provide no barrier to the rat. Within a short time a rat can gnaw through a PVC pipe to gain access to a source of warmth, food, water, security and harbourage for breeding.

SAFETY CONSIDERATIONS

A number of potential hazards face rodent control operatives and sewermen working in sewer systems. It is, therefore, essential that they have a proper understanding of these hazards, receive adequate safety training and take the recommended precautions related to entering sewers (3).

Sewers are a hazardous working environment presenting dangers from sewer gas and other chemicals, rapid flooding due to heavy rain and risk of physical injury due to falls and abrasions, as well as disease risks.

Many sewer rat control operations, however, do not involve descending into the sewers but are carried out from the surface. Here, a major risk is the possibility of road accidents and special care must be taken to control and direct traffic in the vicinity of the manholes when baiting is in progress. A further hazard is that of physical injury associated with the lifting of the heavy manhole covers. In order to minimise these risks sewer baiting should be carried out by a team of at least two and preferably three men provided with the necessary equipment. A vehicle is required equipped with a full range of tools, traffic signs, hand washing facilities and a first aid kit.

For those who are required to prepare or handle the poisoned bait special training is required, with particular reference to safety. Anticoagulant rodenticides, of which warfarin is the most widely used are generally considered to present minimal risk. They are safe to use provided that elementary safety precautions are observed, such as avoiding all contact by mouth, preventing spillage, and the washing of hands and exposed skin before meals and after work. The other main type of rodenticide used in sewers, acute poisons, are highly toxic and their use is generally severly restricted to heavily infested systems and sewers where excessively wet conditions severly reduce the efficiency of anticoagulants. Before using acute poisons such as fluoroacetamide the personnel concerned must be specially trained in its safe use.

SOME INTERNATIONAL CASE BOOK EXAMPLES

Rodent control in sewers often attracts an 'out of sight - out of mind' attitude. Major problems exist all over the world and are dealt with in different manners. The main reasons for the failure to keep rodents under control in many countries are lack of action at government level, ignorance among urban and rural citizens and the inadequate performance of some rodenticides. Additionally the failure to follow up a campaign by a structured maintenance operation will allow the rat population to recover and the achievements of the main campaign will be lost. Some experiences related to different countries are quoted below in order to highlight certain points.

The World Health Organisation often assists countries by arranging for expert advice to be given by a specialist consultant. A study in 1977 in Amman, Jordan, indicated that although the City dated back to 1878 a major problem through sewer infestation did not occur until about 1970. The pilot field trials identified the scope of the problem and identified an effective rodenticide. The studies revealed that in any larger scale programme the problem of re-infestation would have to be overcome and showed various ways of achieving this including the timing of hygiene improvements, initial deployment of more manpower, use of permanent poison bait stations and improved co-operation of local people through a publicity campaign.

The rodent infestation problems of another Middle East country, Egypt, incurred a great deal of publicity in the mid 1970's. A major campaign launched in 1978 failed due to lack maintenance/follow up and a further major campaign is currently underway as part of an aid programme. The early campaign used an acute poison but bait shyness developed and subsequently only anticoagulents have been used. It is interesting to note that a major environmental change could have assisted the rapid recovery of the rat population following the first campaign. This was the construction of the Aswan High Dam which stopped the annual Nile floods and thereby prevented the yearly drowning of many rats.

A WHO sponsored rodent infestation study of Karachi, Pakistan (6) revealed that the major rodent present was R. rattus as opposed to the normally encountered common rat and that the principal method of control being used was trapping. There are about 1500 km of sewers and 500km of open drains in the city. Much of the piped drainage system was found to be defective and it was determined from surface signs that the sewerage system was the major source of infestation. The emphasis of control in the past had been in the agricultural sector and the environmental health sector had been largely neglected. The study set out a major training programme in addition to providing specific technical guidance related to control procedures.

A report by the Health Department of Fiji (5) on their first major campaign in the 8 square mile city showed that 6164 rats were recovered after the campaign and of these the higher percentage was of the common rat. The city was divided into four zones and in each a supervisor and nine operatives laid the baits. The campaign lasted nine weeks and used approximately 500 lbs of poison and 2.5 tonnes of cereal.

RESEARCH

Research has established that the use of poisoned baits, coupled with careful, detailed planning of treatments and efficient implementation can maintain very low levels of infestation in sewers.

Among the alternative methods of control one that has been the subject of considerable research in recent years is the use of chemosterilants. In a recent trial (4) a single application of a male chemosterilant to a problem sewer rat infestation resulted in reductions of rat numbers and distribution which was comparable to effects of warfarin baiting methods. The research showed that the particular chemosterilant, Alpha-chlorohydrin could be a useful addition to the arsenal of rat control agents.

CONCLUSION

Whilst the overall responsiblity for rat control generally lies with the health departments of municipal authorities the engineer and other personnel involved in the operation and maintenance of sewer systems have a significant contribution to make in the execution of effective rodent control programmes.

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PAPER 15

THE APPLICATION OF THE OXYGEN ACTIVATED SLUDGE PROCESS FOR THE TREATMENT OF BREWERY WASTE WATERS

BY

ABDUL MANAF BIN ISHAK
BUMI WATSON
MALAYSIA

AND

K. H. ALLUM
WATSON HAWKSLEY
UNITED KINGDOM

INTRODUCTION

Brewing has been practised since time immemorial by virtually all the races of mankind. The ancient Egyptians brewed beer from barley, and to this day barley malt has remained the basic ingredient of beer. Hops were used much later in medieval times for preservation, and their bitter flavour is now part of the essential character of beer.

Whilst no doubt wastewater was of little consequence in ancient times it is recognised that the modern brewing process produces large volumes of wastes often running into an order of magnitude greater than the volume of beer bottled. These wastewaters originate primarily in the brewing process itself, and include tank bottoms, excess yeast, spent hops and entrained wort, as well as bottle and keg washwaters. As a consequence the wastewater strength and its pH is highly variable. The waste is also deficient in the essential bacterial nutrients, nitrogen and phosphorus. On storage, bacteria and yeast which are present naturally in the wastewater rapidly deplete any dissolved oxygen and the wastewater becomes anaerobic. Under these conditions hydrogen sulphide is released which causes odour and corrosion problems.

The volume and strength of the wastewater depends upon the nature of the process used, the type and volume of beer produced, and perhaps most important of all, the quality of plant operation and management. Pollution loads per hectalitre (100 litres) of beer produced range between 0.13 to 1.3kg BOD and 0.06 to 0.6kg SS. Wastewater flows vary between 0.1 to 2.4m^3/hl. Reported pollution loads and flows from 15 breweries indicated that the strength averages about 1 000mg/l and 500mg/l for BOD and SS respectively. However, in modern breweries where water saving is practised wastewater BOD is often in excess of 200mg/l.

A wide range of processes have been used to treat these highly polluting wastewaters, and in this paper the authors report on two studies carried out for the three breweries at Tadcaster, England and the Guiness Petaling Jaya Brewery, Malaysia.

Tadcaster Treatment Plant

Tadcaster is a small town in the north of England with a population of 8000. In the 19th Century the town began to expand with the development of the malting and brewing industries. The breweries used locally grown barley and drew water from the magnesium limestone strata beneath the town, and their wastewaters discharged into the River Wharfe.

As early as 1906, in an attempt to alleviate pollution problems in the river, a sewage works was built on part of the present day site to treat combined domestic and brewery flows from the town. In common with many works of that period, treatment consisted of chemically (lime) assisted sedimentation and land irrigation; the resulting sludges were lagooned. In later years, low-rate biological filters replaced the lime and land treatment processes. However, considerable volumes of brewery wastewater still continued to discharge directly into the river from numerous private outlets.

During the early seventies the local Council built separate sewers to convey the wastewater from the three major breweries in the town to the treatment works, and the private outlets were abandonned. But the capacity of the existing works was inadequate and most of the wastewater received only sedimentation before discharge to the river.

At that time the Council intended to extend the existing biological filter works to treat all the brewery waste water flows. However, the brewers were not satisfied with technical aspects of the plant and appointed the consultants, Watson Hawksley, to assess the design. Following reorganisation and the formation of Water Authorities the Yorkshire Water Authority appointed the consultants to design and supervise the construction of the new treatment works.

Brewery Surveys

As part of the study the consultants investigated the sources and characteristics of internal wastes on two of the three breweries; the third brewery carried out an independent study of its wastewaters. The studies assessed the combined pollution load, examined possible means for balancing and reducing flows and pollution loads within the individual breweries, and attempted to project future pollution loads.

It was found that one brewery discharged wastewater at a rate equivalent to $0.643m^3$ and 0.47 kg BOD per hectalitre of beer brewed; the other brewery produced $0.74m^3$ and 0.41kg BOD per hectalitre. Studies indicated that by quite simple process modifications and implementation of good housekeeping practises the former brewery could reduce pollution loads by 20-25 per cent, and the latter by about 10 per cent.

The first studies were carried out in 1973, and then repeated in 1976 when the flows and loads then projected to 1986 were used for design. These are shown in Table 1 with a comparison of earlier estimates and projections, as well as the average daily analyses recorded during 1983.

It is interesting to note that the actual 1983 flows and analyses correlate more accurately with the 1977 estimates rather than the later 1976 values, when there was unrealistic optimism that annual beer sales would continue increasing well into the eighties. Furthermore, the 1983 data reflect the effects of recession and resulting drop in beer consumption rather than waste saving measures within the breweries.

Table 1

Tadcaster Breweries - Wastewater Flows and Pollution Loads

	Estimated 1973	Projected 1983	Estimated 1977	Design* Basis 1986	Recorded Average 1983
Average daily flow Ml/d	5.86	8.41	6.88	10.86	7.37
BOD - kg/d	5865	9600	9860	15136	8830
- mg/l	1000	1140	1400	1400	1196
SS - kg/d	2463	5480	5247	7990	-
- mg/l	420	650	760	735	-

* Maximum design value

Site Constraints

Whilst there was sufficient land area available on the existing site to suit a wide range of treatment processes, the site is exposed and clearly visible from Tadcaster. For this reason local planners demanded much attention to plant appearance, and the brewers agreed to pay the additional costs for facing all the main buildings with local stone. To ensure that no adverse noise reached the nearest houses 500 m distant, noise levels had to be kept within 55dBA at the site boundary. Extensive use of acoustic hoods and silencers was made to achieve these limits. In addition, potentially malodourous treatment units had to be covered and provision made to deodourise the vent gases.

Discharge Standards

The River Wharfe upstream of Tadcaster is within class 2 (DO greater than 40% saturation, BOD less than 9mg/l) and it is the Authorities policy to maintain this standard throughout its length. Initially it was thought that the effluent would have to comply to a 30:20 (SS:BOD) standard, but on review of the projected pollution loads, the standards were revised to 100:50 and 60:40 for the brewery and domestic wastewaters respectively.

Process Selection

Initially it was proposed to treat the brewery wastewater after screening, pH control and nutrient addition by high-rate biological filtration. The partially treated effluent would be mixed with settled domestic sewage and treated on a second stage alternating double-filtration process to produce a 30:20 standard effluent. Sludge after thickening would be tankered away for disposal to land or sea.

However, later discussions with the brewers revealed that the revised projections for beer and lager production would result in a 30 percent increase in volume and a 60 per cent increase in BOD load by 1986. Because of this substantial increase in load and the availability of 'new processes' it was decided to review the process design. In particular the oxygen activated sludge process (Wimpey-Unox) and Deep-Shaft process (ICI) were assessed by pilot plant and laboratory scale studies. Unfortunately at that time anaerobic processes capable of treating comparatively cool, low strength wastewaters had not been developed sufficiently for inclusion in the study. The experimental work carried out included sludge thickening and stability (odour, H_2S and COD release) assessments. Boreholes were drilled to ascertain the costs of drilling the large shaft required for Deep-Shaft process.

The estimated capital and operating costs using 1976 prices but based on 1986 pollution loads are shown in Table 2.

Table 2

Tadcaster - Estimated Costs of Alternative Biological Treatment Systems (2)
(1976 prices)

	High-Rate Filter	Oxygen Activated Sludge	Deep-Shaft
Total capital cost	3 606 000	2 608 000	2 772 000
Annual repayment/loan charges	457 000	338 000	350 000
Annual power costs	62 000	107 000	73 000
Annual sludge disposal (tankering) costs	308 000	251 000	288 000
Total annual operating costs	538 000	566 000	563 000
Total annual costs	£ 995 000	£ 904 000	£ 913 000

Whilst the costs showed a small advantage in favour of the oxygen process over the Deep-Shaft, this could be accounted for by the difficult geological conditions for drilling the shaft. Apart from the overall cost advantages, the activated sludge processes were favoured as they are compact, being less visually intrusive on the landscape. Also experimental work showed that surplus activated sludge was more stable than high-rate filter sludge. Another advantage was that the processes produced much lower volumes of vent gases requiring deo-dourisation.

After considerable discussion and process review with the brewers and the Authority (the review included visits to a number of oxygen plants treating brewery wastewaters), the oxygen process was selected in preference to the Deep-Shaft, During the tour the study group had been impressed by the robust nature of the oxygen process, particularly where operational skills were less evident and little preventative mechanical maintenance practised.

Process Design

From the outset the decision had been taken to treat the domestic sewage from the town on the existing biological filter plant. For whilst it was recognised that separate treatment of the brewery and domestic wastewaters resulted in the loss of valuable nutrients present in the domestic wastewater, it was considered that the advantage of lower hydraulic loadings and the greater simplicity in allocating capital and operating costs to the three breweries more than offset any increased chemical requirements.

Many of the process design parameters for the activated sludge and thickening units were derived from the original pilot plant work and supplemented by the consultants and Wimpey-Unox's know-ledge of brewery treatment processes. A computer model was prepared of balancing tank performance (BOD/pH, flow, etc.) and used to determine the most economic design; data derived from this model were also used to establish flow and load peaking factors for the oxygen process. Analysis of flow and pH records, as well as typical titration curves, were used to size the neutralising chemical storage tanks and pH control system. Respirometer studies carried out at Newcastle University on samples of mixed brewery wastewaters established the most economic nutrient dosing levels.

An outline schematic and layout of the treatment process is shown in Figure 1 and details of plant dimensions and capacities are given in Appendix 1. Brewery wastewater is pumped to the works. Flows are measured by a magnetic flow meter and then pass to cup screens fitted with 10mm mesh which remove large solids. The screenings are washed from the screens by pressure jets and con-veyed by launder channels to a rotary sieve; solids are discharged to a skip and washwater is returned to the main flow. The screened flow discharges to balancing tanks.

Two balancing tanks provide an average four hours retention for the screened flows, and are completely mixed and aerated by jet eductor aerators. To maintain a minimum dissolved oxygen level in the tanks the aerator power is varied automatically by controlling the flow from recirculation pumps. Outlet flows are controlled at a preset maximum rate, typically 1.4 times average flow, by a programmable logic controller (PLC). The tanks are covered and vented to the deodourisation plant.

After pH control using concentrated sulphuric acid or sodium hydroxide as required, and then dosing nutrients in the form of anhydrous ammonia and phosphoric acid, the flow discharges into two covered aeration tanks. Each tank is divided into three pockets which are fitted with surface aerators. Oxygen enriched air (typically 90 per cent oxygen) is supplied from a pressure swing adsorption (PSA) generator; liquid oxygen stored in a cryogenic vessel may be used to supplement supply or provide for emergency use.

Mixed liquor from the aeration tanks is settled in two circular tanks which are fitted with half-bridge blade scrapers. Provision has been made to dose polyelectrolyte at the aeration tank outlet to improve sludge settleability if bulking proves to be a problem but to date this has not been required. The treated effluent is discharged to the River Wharfe.

Settled activated sludge is returned to the aeration tanks using two variable-speed axial flow pumps and surplus sludge is pumped to two covered tanks fitted with picket fence thickeners. Supernatant liquor from these tanks is returned by gravity to the inlet of the activated sludge reactors and thickened sludge is pumped to two covered storage tanks. Sludge is pumped from the storage tanks through an overhead gantry to tankers for off-site disposal.

Process Control

To ensure consistent and reliable process performance as well as minimising manpower requirements, a fairly high degree of plant automation has been provided. Two PLCs maintain all the plant functions (apart from the PSA unit), and a host computer is used for data logging and processing duties. The oxygen generation plant has its own dedicated PLC. The control system is described in greater detail in Appendix 2.

Staffing Levels

A total staff of six operate the brewery wastewater and domestic sewage treatment plants. A superintendent controls daily operations and is supported by two technical-grade craftsmen (one mechanical, one electrical) and three operators. The plant is attended during weekdays only, for a total of 40 hours per week.

Training

Considerable attention was paid to staff training. This training was divided into three parts:

- The superintendent and craftsmen were appointed well before the plant was commissioned so that they could observe the installation and commissioning of the mechanical and electrical plant
- The consultants provided a comprehensive operating and maintenance manual, and arranged for specific training to be provided by individual plant suppliers.
- Training sessions were given describing the principles of maintenance and operation for the instrumentation, micro-processor, oxygen generation and aeration processes.

Capital Costs

The plant was commissioned in November 1982. After including the costs for various ancillary works (administration buildings and workshops for example) and professional services, the total capital costs for the Tadcaster Plant amount to £4.25 million These costs (largely as a result of inflation during the design and construction period) represent an increaseof about 63 per cent compared with the 1976 estimates. Further details of the costs for principal civil engineering and mechanical plant works are given in Table 3.

TABLE 3

TADCASTER - Principal Contracts and Capital Costs

Description	Contractor	Completion Value (£)
Oxygen production/ dissolution equipment	Wimpey Unox Ltd	750 000
Civil Engineering	Tilbury Construction Ltd	2 250 000
Screening/dewatering equipment	Hawker Siddeley Brackett Ltd	26 000
Pumping Equipment	Sigmund Pulsometer	219 000
Scrapers/picket fence thickeners	Powell Duffryn Pollution Control Ltd	97 000
Chemical storage/ dosing equipment	Wefco (Gainsborough)	120 000
Electrical supply/ control equipment	Holiday Hall Co Ltd	606 000
GRP tank covers	R.P. Structures Ltd	102 000
Odour Control/ ventilation equipment	Rigidon (UK) Ltd	76 000
	TOTAL £	4 246 000

Operating Costs and Data

In 1983/84 the plant operating costs were about £600 000 per annum of which about half was attributable to the costs of tankering sludge from the site. It has been estimated that for design flows and loads the annual operating costs would be in excess of £1 million.

The power requirement for oxygen production was measured at about 500 kWh/tonne oxygen at average demands, reducing to 410kWh/tonne at higher outputs. In 1984 the total cost (including loan repayments) for generating oxygen averaged £31/tonne, which compares favourably with liquid oxygen costs of £43/tonne delivered to site. (3).

Production of thickened sludge during 1983 averaged about $1050m^3$/week, and the 1984 costs for disposal of liquid sludge to sea amounted to about £5.20/m^3 (3). This involves an average 50 tanker movements per week. Sea disposal has proved to be satisfactory, but expensive, and it is hoped that in the future the major outlet will be to farmland in the locality.

Commissioning and Operating Experiences

Not surprisingly for such a complex plant a number of operation andmechanical problems occurred during the initial commissioning and operating period. However, apart from inadequate mixing characteristics of the aerators, all these problems were quickly resolved.

From the outset the operation of the surface aerators proved troublesome. During the aeration trials conducted by the Authority and supervised by the consultants, at certain depths of aerator immersion, hydraulic surging caused cyclic variations in power demand and reduced the aerator efficiency. The contactors, Wimpey-Unox, proposed various modifications to the internal tank baffling arrangements to overcome this problem. But in operation it soon became apparent that oxygen was in limitation in certain parts of the tank, and also that considerable quantities of sludge were accumulating in the primary aeration pockets. Whilst it was found that reversing the direction of rotation of the aerators for short periods resuspended the solids, the displaced solids then created problems with rising sludges in the final settling tanks.

It was quite clear in the aeration trials that mixing had been entirely adequate with clean water and that some other factor was affecting the aerator performance. Detergents were suspected and surface tension measurements confirmed this. But the solution to the problem proved more difficult, the brewers could not be persuaded to change their detergents or heading agents, and modified baffle arrangements and fitting uptake tubes to the aerators were not particularly successful.

As a final resort, a submersible mixer of low power was tried in one of the tanks, and immediately improved mixing efficiency. Bottom mixers (which each absorbed about one kW) were fitted to the aerators and this finally resolved the problem.

Except for specific problems in some control loops, the works control system has operated well. Relatively few of the electrical and electronic problems which have developed have required specialist repair. However, failure of a PLC led to problems when the plant (which is designed to respond to continually changing operating conditions) had to be operated under 'hand control' only.

Certainly the information produced in the data logging system about operation and maintenance requirements is leading to a better understanding of operational regimes, and the client firmly believes that PLCs provide a degree of flexibility for operational control which was never available with 'hard-wired' systems used in the past.

GUINNESS MALAYSIA BERHAD TREATMENT PLANT

In 1977 Bumi Watson (Malaysia) Sdn were engaged by Guinness Malaysia Berhard to undertake a study at their Petalung Jaya Brewery. At that time the brewery operated continuously throughout the year with staggered breaks in the three brew-houses when the workers took their annual leave. The waste-water from the production of high-gravity stouts and lagers drained to a combined system which discharged at a number of points into an already highly polluted culvert passing through the brewery grounds.

The study was completed in early 1978 and included:

- A brewery survey to establish wastewater flows and pollution loads
- Layout designs for modifications to the brewery system to separate domestic, industrial wastewater flows and surface waters.
- Recommendations for production plant modifications and 'good housekeeping' measures to reduce wastewater discharges
- Evaluation of wastewater treatment processes to comply with the Government's proposed regulations for effluent discharges.
- Comparison of alternative treatment plant sites.

Even after making allowance for the high specific gravity beers and the high proportion of product bottled, the survey revealed that the wastewater flows and pollutionloads were high. The wastewater discharged per hectalitre of beer averaged 1.4m^3 and contained 3.9kg BOD. The combined flows averaged 1400m^3/d with

2800mg/l BOD and 1000mg/l SS content, and peak daily flows and pollution loads were more than twice the average values. A number of recommendations were made to reduce these pollution loads.

In common with the Tadcaster plant it was proposed that after pretreatment consisting of screening, balancing, pH control and nutrient addition, the wastewater would be biologically treated to a 50:50 (SS:BOD) standard. Surplus sludges would be consolidated and then dewatered by centrifuge.

Four biological treatment processes were evaluated and costed:

- High-rate biofiltration (using plastics media) followed by activated sludge treatment.
- Oxygen activated sludge (Wimpey-Unox process).
- Multi-stage biofiltration.
- Deep-shaft (ICI process)

The estimated capital and operating costs for the various schemes are summarised in Table 4; capital costs include for drainage work and professional fees.

Table 4

1978 Cost Estimates (Million M$)

Scheme	Biofiltration/ Activated Sludge	Oxygen Activated Sludge	Multi-stage Biofiltration	Deep Shaft
Capital cost	7.85	4.04	7.82	5.66
Annual Operating Cost	0.81	1.98	0.76	0.86

Even though the capital cost of the oxygen process was significantly less than its nearest rival, the Deep Shaft process, the high running costs associated with the oxygen process allied to the concern over the operational reliability of the relatively complex oxygen generation plant resulted in consultants recommending the Deep-Shaft process. Of course this recommendation was subject to borehole investigations. In the event of unsatisfactory ground conditions multi-stage biofiltration was the next choice.

Land area for a treatment plant on the brewery site was very limited; the sites available included one end of a football pitch and a car park. The rather unpopular decision was taken to site the plant on the football pitch.

As it was considered most unlikely that the Government would insist on the immediate construction of a treatment plant, the consultants recommended a phased programme. The programme included resewerage to separate surface water and wastewater discharges, modifications to plant and operation practices in the brewery to reduce pollution loads, and a trial borehole for the Deep-Shaft process.

Phase 2

By 1980 the brewery had completed the resewering and at least some of the 'good housekeeping' measures. A second survey was completed to establish pollution loadings and project future loads. The treatment process was reassessed, with particular reference to treatment of future waste flows and loads to various standards.

A trial borehole showed bed rock only 13.5m below ground level, so it was quite clear that the Deep Shaft process was impractical on this site. Since the time of the first study there had been increasing concern over the risk of odour from the bio-filtration process. Also, in view of increasing cost of plastics media and the high capital and operating costs for the deodourisation facilities needed, the decision was taken to review the oxygen activated sludge process once more, and also to consider the use of an extended-aeration process.

To minimise site land area requirements the proposed extended-aeration process use a 6.0m deep aeration tank with submersible, static aerators. To reduce the risk of bulking activated sludge the process incorporated a contact zone where the return activated sludge was subjected to a high substrate concentration by admixture with the wastewater before discharge to the aeration tank.

The study showed that the capital and running costs for the two processes were similar. Whilst it was recognised that the extended-aeration process would be simpler to operate and maintain, land was at a premium, and this factor ruled in favour of the oxygen process.

Process Design

In common with the Tadcaster plant the oxygen process was designed to treat crude wastewater after screening. This eliminated the need for primary sedimentation tanks, with resulting savings in capital costs amd the reduction of odour associated with their operation and disposal of primary sludge. As most of the BOD in brewery wastewater is in soluble form, feeding unsettled waste only requires a marginal increase in the size and consequently costs of the aeration stage. In addition, the solids in the feed tend to act as a weighting agent both improving the settleability and dewatering characteristics of the activated sludge.

However, it was considered that it should be possible to utilise more effectively the oxygen processes capacity to absorb shock loads whilst still operating at very high process loadings. Of course, such process modifications should result in reduced construction costs , simpler operation and lower land area requirements.

It was evident from the surveys, that unlike Tadcaster, peak flows and loads lasted rather longer than just a few hours. An extremely large balancing tank with one or more days capacity would have been required. Consideration was given to omitting the balancing tank stage. This had the benefit of reducing potential odour problems, restricting growth of undesirable microorganisms, as well as eliminating the power demands and maintenance requirements associated with the balancing tank mixing system. Nevertheless, simplification has some cost as the treatment of unbalanced flows requires more powerful oxygen generation and dissolution systems, and slightly larger final settling tanks.

The design philosophy adopted was to select a sludge loading which under peak loading conditions (lasting no longer than 1 or 2 days) just ensured that effluent quality was maintained and sludge quality did not deteriorate. Knowing the sludge quality it was then possible to define the size of the oxygen reactor and the peak oxygen transfer rates needed. Of course lower loadings could be readily accommodated by the automatic control systems used for the oxygen process. Nutrients and pH control agents could be dosed into the primary aeration pocket.

By carefully selecting the reactor configuration it was possible to design a plant which required little additional oxygen to be supplied when operating under peak loading conditions. For under these conditions, the specific oxygen requirement per unit weight of BOD removed decreases and hence the yield of carbon dioxide per unit of flow also tends to decrease. If at times of peak loads dissolved oxygen level in the mixed liquor was allowed to drop from 6mg/l to 1mg/l, this in association with less carbon dioxide released to the gas phase results in a higher oxygen utilisation efficiency. The combination of less oxygen per unit weight of BOD and a greater oxygen utilisation efficiency 'balances' out the increased BOD load.

Even without balancing, calculations showed that it would be possible to use the same size of aeration tank withonly a slight increase in the maximum oxygen demand. The fairly marginal increase in cost for the oxygen generation and dissolution plant was more than offset by the elimination of the balancing tank and its associated mechanical plant.

Another feature of the oxygen process (which is associated with the good settling properties of the activated sludge) is the ability to operate with high mixed liquor solids contents and low recycle ratios. As a result, return and surplus sludges typically contain 1.5 to 2 per cent dry solids. With this level of solids it was possible to dewater the sludges directly without an intermediate thickening stage. Using decanter centrifuges with polyelectrolyte dose rates of the order of 3kg/tonne dry solids, high solids recoveries and sludge cake with a 12 per cent dry solids content can be obtained.

An outline schematic and layout of the treatment process is shown in figure 2, and details of the plant dimensions and capacities are given in Appendix 1.

Staffing

The simplicity of plant operation and routine maintenance requirements are reflected in the staffing levels. Permanent staff on plant are one operator and labourer who are supported as required by an engineer and technician.

Capital Costs

The plant was commissioned in December 1983. The total capital costs including costs for various ancillary works and professional services amount to about M$ 4.4 million. As all the mechanical and electrical (M & E) plant was supplied as a complete turnkey package by Wimpey Unox Ltd. it is not possible to give costs for the individual M & E systems. The details of the costs for civil and M & E plant are given in Table 5.

Table 5

GUINNESS MALAYSIA - Capital Costs

Description	Contractor	Completion Value (M$)
Civil Engineering	Tean Two Construction	1 400 000
Mechanical and Electrical Plant	Wimpey Unox Limited	2 980 000
	APPROX TOTAL (M$)	4 380 000

Commissioning and Operation

It is rare to find an industrial treatment plant which, on commissioning, works absolutely perfectly. This plant proved to be no exception to the rule. Waste saving measures carried out in the brewery during the plant construction period had reduced water consumption but had little effect on pollution loads. As a result waste strength had increased and temperature risen to well over 40°C. Nevertheless, in operation the process has tolerated high peak loadings, discharges of hot wastewaters, and operation over a wide range of pH values with remarkably little effect on sludge or effluent quality.

It is interesting to note that the PSA operation has proved to be rather more reliable than at Tadcaster. odour levels around the plant are better than, or atleast comparable with, the Tadcaster plant. But without any specific precautions being taken noise levels are much higher. However, it must be borne in mind that these higher noise levels are more acceptable in an industrial environment.

The sludge dewatering plant has proved simple to operate and reliable in operation, producing a 12 per cent dry solids cake at the specified loadings. Unlike Tadcaster there is a local demand for sludge and the cake is removed at no cost from the site by farmers who use it as a feed supplement for their pigs.

Corrosion induced by high oxygen and carbon dioxide levels has generally been within acceptable levels. But after about one year's operation, it was noticed that the final tank scraper rubbers were wearing very badly. On draining the tank it was found that the floor had been badly corroded and the aggregate was exposed; the exposed aggregate had been wearing the scraper blades.

At the time of the plant design it was recognised that, in the presence of high dissolved carbon dioxide levels, the surface layers of concrete are rapidly carbonated, But providing a good dense quality of concrete is used and there is adequate cover for the reinforcement, the rate of penetration of carbon dioxide rapidly slows down. As a result the rate of carbonation soon declines. In this case the problem may have been caused by either physical abrasion resulting from the scraper action which removed the less tenacious carbonated layer thus allowing the reaction to proceed, or alternatively, a poor grade of concrete (for example too high a cement: water ratio) had been used for the screed allowing rapid penetration and failure.

As a precaution core samples were taken from the settling and aeration tank walls and tested for carbonation. All samples were within acceptable levels. The existing screed was broken out and replaced by an epoxy mortar screed and since that time the tank has performed satisfactorily.

Conclusions

Process evaluations and operating experiences at Tadcaster and Guinness-Malaysia have established the oxygen-enriched activated sludge process as a cost effective and reliable system for treating brewery wastewaters. The process is particularly suited to sites where land is at a premium.

Much has been written about the complexity of PSA oxygen generation, and no doubt the equipment is more complex than plant generally associated with wastewater treatment. Nevertheless, properly trained operators and maintenance staff soon adopt to the 'new' process and the PSA unit generally becomes one of theless troublesome items of equipment on the treatment works.

All processes have their vices and virtues and it behoves the design engineer to minimise the former and utilise the latter. At Guinness Malaysia full advantage has been taken of the oxygen processes capacity to treat very high pollution loads, and elimination of the balancing tank has simplified plant operation and reduced potential odour problems.

Treatment and disposal of sludges from high-rate processes is always likely to prove somewhat troublesome. However, the authors believe that Malaysia's disposal technique of feeding surplus sludge (which after all is a very valuable source of protein) to pigs, is somewhat better than Britain's indirect and rather costly method of feeding fish in the North Sea!

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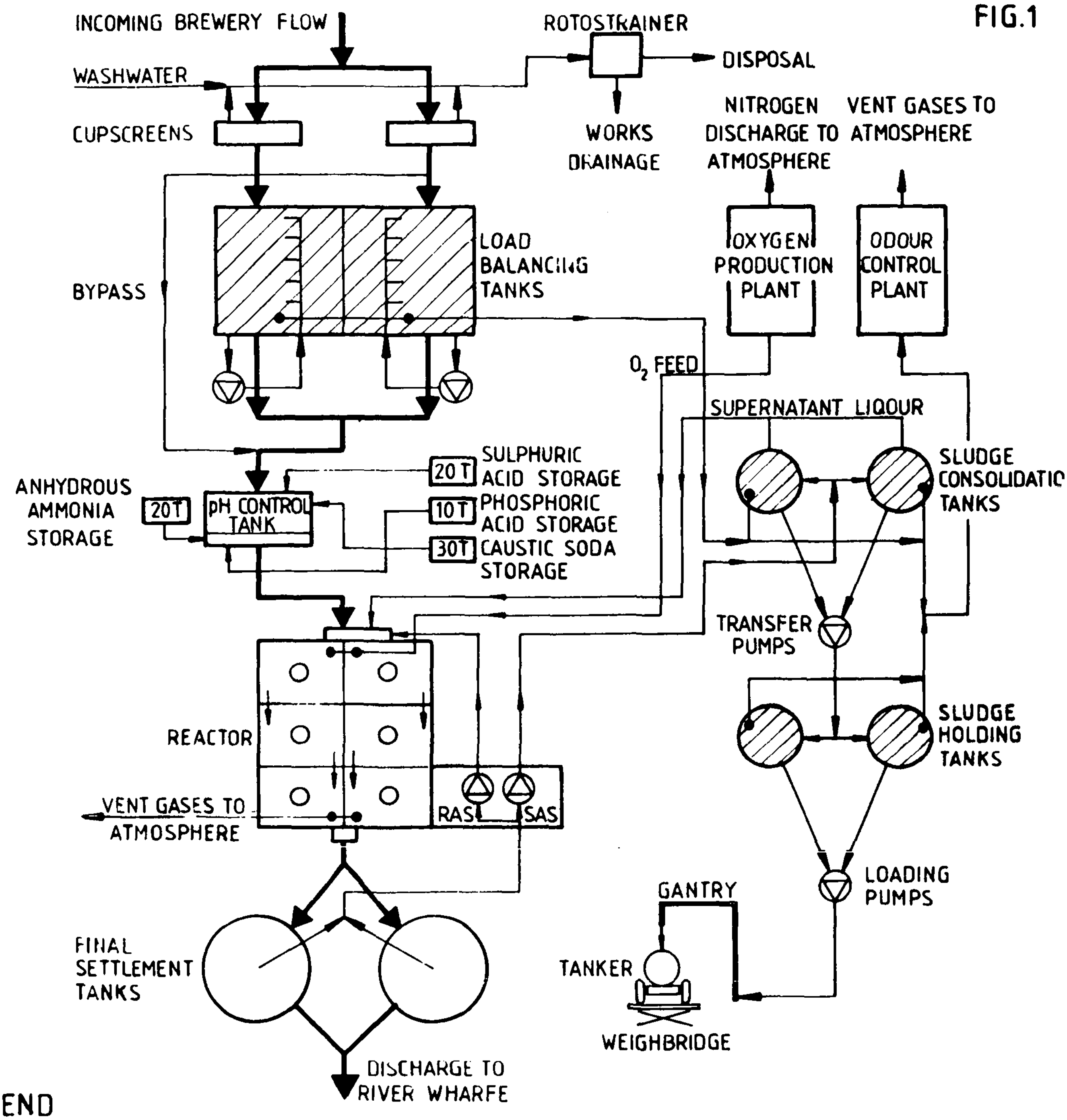
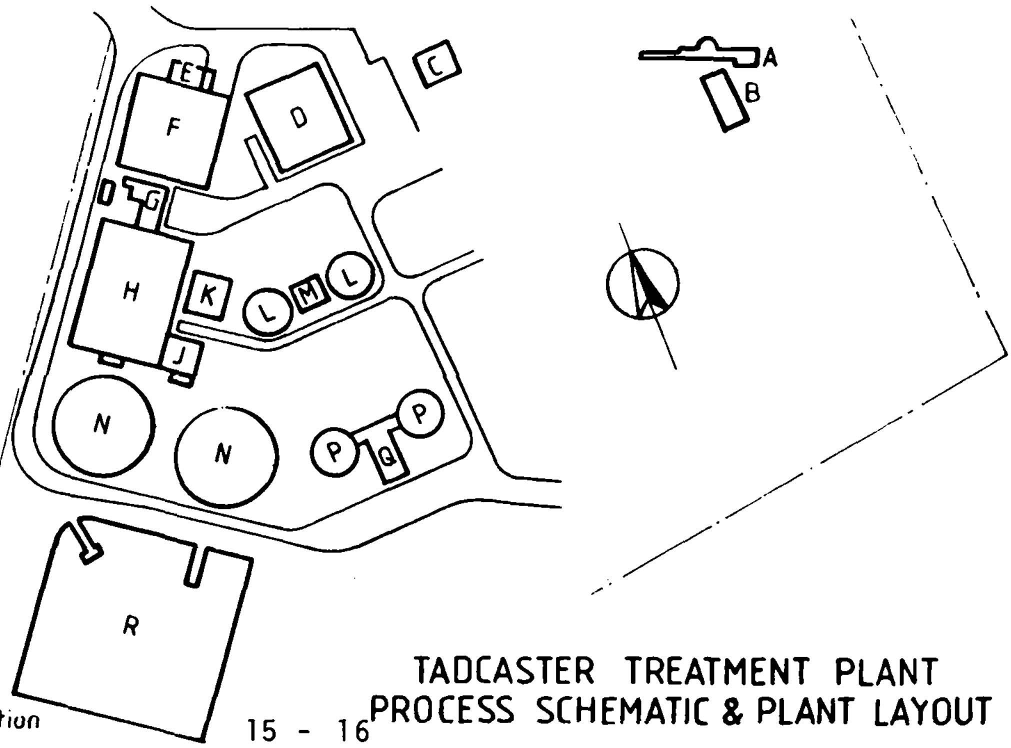
FIG.1



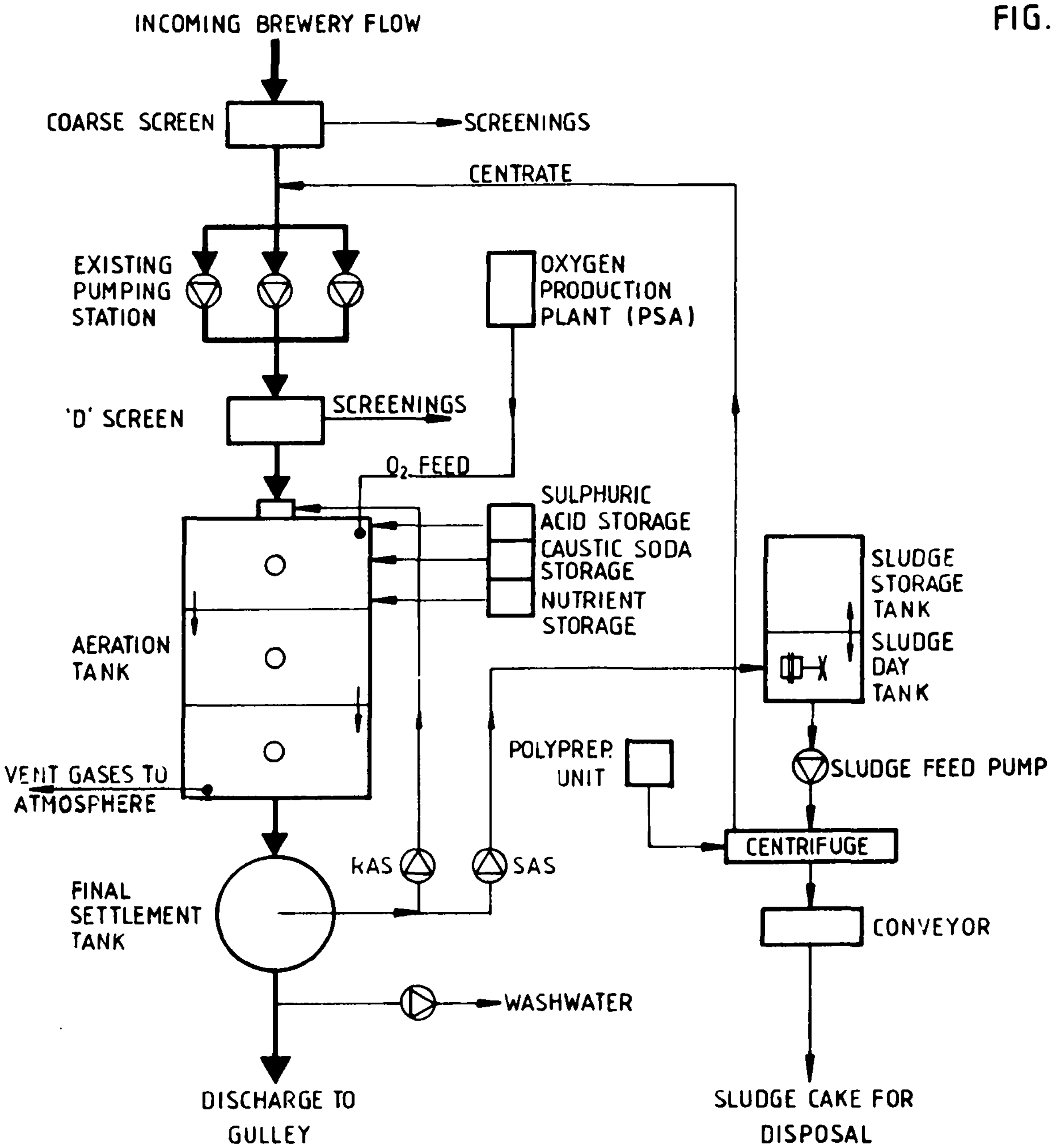
LEGEND

- Covered Vented Units
- Pump
- A Domestic Inlet Works
- B Screenings & Grit Bay
- C Admin. Building
- D Oxygen Production Plant
- E Inlet & Screens
- F Load Balancing Tanks
- G pH Control
- H Reactor
- J RAS / SAS Pumping Station
- K Odour Control Plant
- L Sludge Consolidation Tanks
- M Sludge Transfer Pumping Station
- N Final Settling Tanks
- P Sludge Holding Tanks
- Q Sludge Loading Pumping Station
- R Sludge Lagoon



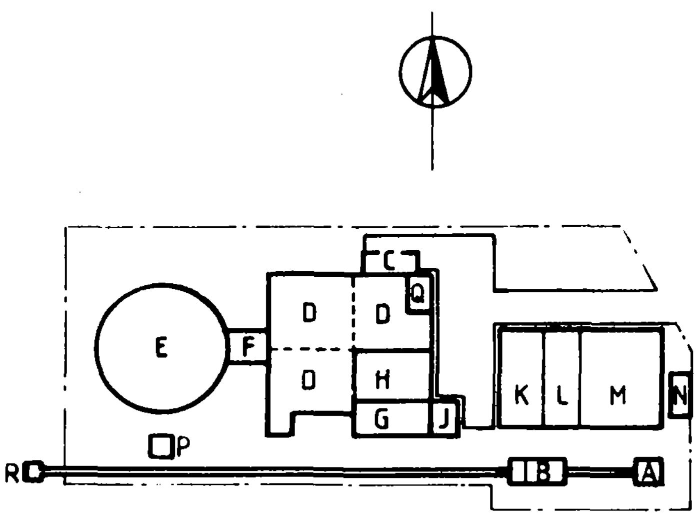
TADCASTER TREATMENT PLANT
PROCESS SCHEMATIC & PLANT LAYOUT

FIG.2



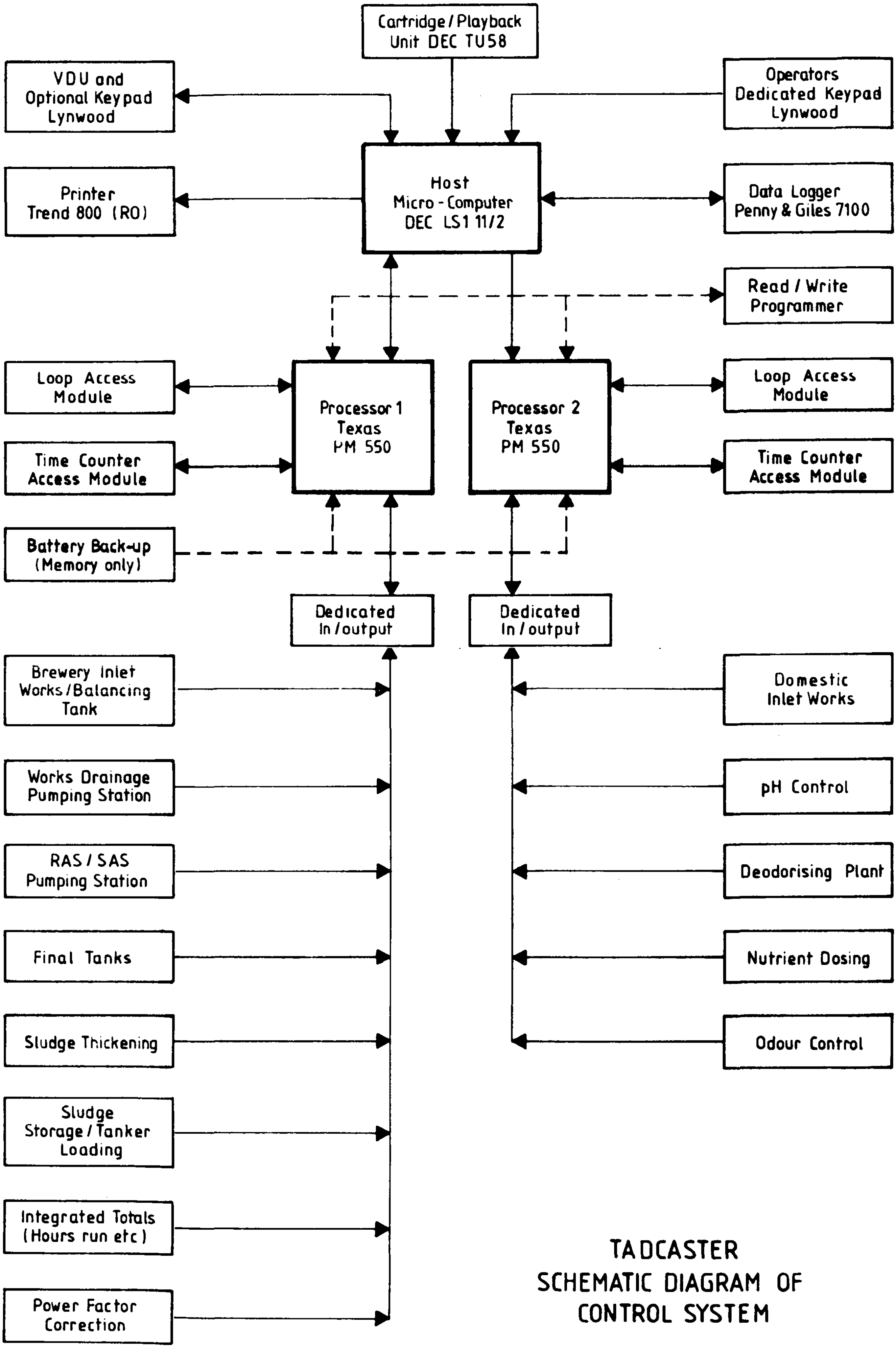
LEGEND

- Pump
- Mixer
- A Coarse Screen
- B Existing Pumping Station
- C Chemical Storage Plant
- D Aeration Tank
- E Final Tank
- F RAS/SAS Pumps
- G Sludge Day Tank
- H Sludge Storage Tank
- J Sludge Feed Pumps
- K Dewatering Plant
- L Laboratory/Store
- M PSA Plant
- N LOX Storage
- P Sampling Chamber
- Q Screen
- R Discharge to Gulley



GUINNESS MALAYSIA BERHAD
TREATMENT PLANT
PROCESS SCHEMATIC & PLANT LAYOUT

FIG. 3



TADCASTER
SCHEMATIC DIAGRAM OF
CONTROL SYSTEM

APPENDIX 1

DETAILS OF PLANT DIMENSIONS AND CAPACITIES

UNIT	PLANT			
	TADCASTER		GUINNESS MALAYSIA	
	Description	Capacity	Description	Capacity
Brewery Inlet Works				
Screens	2 cup screens, 10mm mesh	250l/s, 0.75kw	1, 'D' screen, 6mm mesh	
Washwater	3 jets/screen	1.8l/s @ 1.7bar	-	-
Screening dewaterer	1 Rotostrainer	4.8l/s, 0.38kw	-	-
Balancing tanks	2 tanks, 19.7 x 11.5 x 4m	Each 226 - 905 m^3	-	-
Eductors	12 x 2 Flygt type	Air $88m^3/h$	-	-
Recirculation pumps	2 centrifugal, 100 mm delivery	234 - 360l/s, 17 - 56 kw	-	-
Oxygen A.S. Plant				
Reactor tank trains	2 No. 32.7 x 10.9 x 3.2m (3 pockets)	$2300m^3$ Av. retention 5.1h loading 6.6kg BOD/m3	I No. 27.6 x 8.6 2.8M	$711m^3$ Av. retention 7.1h Peak loading 6.8kg BOD/m^3

UNIT	PLANT			
	TADCASTER		GUINNESS MALAYSIA	
	Description	Capacity	Description	Capacity
Aerators	6 No. 2m dia, 52 rpm	Total 178kW	3 No. 1.9/1.8m dia 52/47 rpm	Total 48.5kW
Oxygen Supply System				
PSA sieve vessels	3 No. 2.9m dia x 5.0m	16.1 tonne/d @ 90% purity	3 No.	3.5 tonne/d @ 80% purity
Main compressors	3 No. reciprocating, 3.1 bar	123kW, 1750m^3/h	2 No. reciprocating	87kW, 1240m^3/h
Lox storage	1 No. cryogenic vessel	32 tonnes	1 No. cryogenic vessel	13.1 tonnes
Lox vaporisers	4 No.	250m^3/h	1 No.	127Nm^3/h
Final Tanks				
Tanks	2 No. 25.2m dia x 2.5m deep	1250m^3 each av. UFV 0.45m/h	1 No. 18.0m dia x 2.5m deep	640m^3 av.UFV 0.4m/h
Scrapers	2 No. speed 2m/min	0.25kW	1 No. speed 2m/min	0.25kW
RAS pumping	2 No. 30 - 1411/s	436/1450rpm 9.6 - 22kW	RAS/SAS 2 No. 211/s	
SAS pumping	2 No. 5.8 - 8.81/s	260 - 420rpm 5.5kW	-	-
Sludge Handling				
Thickening tanks	2 No. 11.2m dia x 3m deep	343m^3 each	-	-
Picket fence	2 No. peripheral speed 1.75m/min	0.25kW	-	-

UNIT	PLANT			
	TADCASTER		GUINNESS MALAYSIA	
	Description	Capacity	Description	Capacity
N/P Nutrients	-	-	1 No. $5m^3$	
Sulphuric acid	1 No. 2.2m dia x 3.7m	20 tonnes, 96%	1 No. $0.5m^3$	0.9 tonnes, 96%
Sodium hydroxide	1 No. 3.0m dia x 3.6m	30 tonnes, 47%	1 No. $0.5m^3$	0.6 tonnes, 47%
Odour Control Plant				
Fans	2 No. 2750 rpm	$4700m^3/h$, 11kW	-	-
Wet scrubbers	2 No. 1.0m dia		-	-
Activated carbon column	1 No. 2.5 dia		-	-
Control System				
Microprocessor unit	2 No. Texas PM 550		1 No. Texas 5TI	
	1 No. Texas 5TI			
Host computer	1 No. DEC LSI 11/2		-	
Data logging	1 No. Penny & Giles 71000		-	
Visual Display Unit	1 No. Beta Lynwood			
Printer	1 No. Trend Model 800		-	

UNIT	PLANT			
	TADCASTER		GUINNESS MALAYSIA	
	Description	Capacity	Description	Capacity
'Day' tank	-	-	1 No. 9.2 x 3.0 x 2.8M	$77m^3$
Submersible mixer	-	-	1 No. Flygt 4400	0.9kW
Holding tanks	2 No., 12m dia x 5.2m	$596m^3$ each	1 No. 7.2 x 9.2 x 2.8M	$185m^3$
Sludge lagoon	1 No. 30 x 30 x 3m	$4300m^3$	-	-
Tanker weighbridge	1 No. 15m x 3m wide	40 tonne	-	-
Centrifuge feed pumps	-	-	1 No. progressive cavity	71/s
Centrifuge	-	-	1 No. Pennwalt PM3500	
Polyprep plant	-	-	1 No. Allied Colloids	
pH Control				
pH control tank	1 No. 3.85 x 3.85 x 3.8m	$58m^3$	-	-
Mixer	1 No. 1.5m dia, 48 rpm	$116m^3$/min, 7.5kW	-	-
Chemical Storage Tanks				
Phosphoric acid	1 No., 1.8m dia x 3.1m	10 tonnes	-	-
Anhydrous ammonia	1 No. 2.6m dia x 7.2m	20 tonnes	-	-

APPENDIX 2

Tadcaster - Instrumentation and Control Systems (4)

With the exception of the PSA plant all the functional units are controlled by two PLCs (Texas Instruments PM 550); the PSA plant has its own dedicated PLC (a Texas 5TI). All the process units apart from the PSA plant can either be operated by hand or by the centralised PLCs. The control is segregated into discrete sections, namely chemically related inputs and flow control. The PM 550 processors communicate with the plant through dedicated analogue and digital input/output (I/O) modules. Direct access to memory is provided through dedicated loop access module (LAM) and time counters and access module units (TCAM) associated with each processor. This system allows the operators to establish control parameters for the plant. A schematic diagram of the central controller is given in Figure 3.

The proportional integral derivative (PID) control loops include: balanced flow rate, pH control, nutrient addition, ammonia tank pressure control, returned activated sludge (RAS) and surplus activated sludge (SAS) flow rates. A host micro-computer (DEC LSI 11/2) records, analyses, stores and presents data through a VDU or printer. The PLCs initiate alarm signals and the micro-computer monitors, records and displays these, and in the event of failure can call for assistance. In all there are 326 digital inputs with 66 outputs and 48 analogue inputs with 13 outputs.

The cost of instrumentation at 1982 prices was about £60 000, and the microprocessors, computer and software about £55 000. As such this represented about 2½ per cent of the total capital costs.

PAPER 16

REVIEW OF A SUCCESSFUL RURAL WATER SUPPLY PROGRAM

BY

Somnath Som
Team Leader
Sheladia Associates, Inc.
Philippines

INTRODUCTION

The project to be discussed here is known as Barangay Water Program (BWP) in the Philippines. This is a potable water supply project for rural households, administered by the Government of the Philippines (GOP), through the local government units (LGU). United States Agency for International Development (USAID) is involved in the main funding source. It pays for the construction cost on a fixed amount reimbursable (FAR) basis as loan money and for some trainings and technical assistance as grant money. Lately, loan money has been used to purchase equipments and also to pay for some technical assistance services. BWP pays for personnel, some training and other operational costs to support the program at both the national and local government levels.

ACHIEVEMENT

It is to be mentioned here that the responsibility of all the opinion expressed herein lies with the author only; the numbers, procedures and other facts described later are obtained from BWP's internal records though.

At the outset, let it be explained why the author considers this Program a "successful" one. Under this program, water supply services has been extended to approx. 600,000 people all over the country through more than 1,100 projects at a cost of ₱ 162 M (US$ 11.5 M) over the last 6 years. This year, BWP expects to add 160,000 more people within it's service area by completing 150 more projects at a cost of ₱106 M (US$ 6.0 M). Table I, "BWP Summary", shows all the relevant data. It will be noted that this was achieved, for Lv II, at a relatively low per capita cost of P382 only. In addition, more than 22 explotory test wells have been built in the second-half of 1984 and 60 more is expected to be completed before the end of the project (Dec/85).

On the institutional side, 83 local government units(provinces or cities) have joined BWP. A total of 694 meetings were conducted with the barangay people resulting in the formation of 366 rural waterworks and sanitation association (RWSA). More than 310 post-completion training in the operation, maintenance, bookkeeping and record maintenance were also conducted. Table II, "BWP Training Summary", shows a list of various trainings.

The author feels that this is a rather good performance, hence he chose to report it as a "successful" program. No doubt the program has experienced its share of failures and frustrations which will be discussed in appropriate places later.

Let us proceed now to discuss the features that made the program work reasonably well. In the following discussion the author has tried to omit those details which are essentially program-specific, unless they have been mentioned to explain certain points, so that more people can appreciate the basic programme without getting buried in all the details.

BACKGROUND & HISTORY

BWP is in operation since 1978. From 1978 to 1981 it was known as BWP I and since '81, BWP II. BWP had both short term and long term goals. The short term or immediate goal was to develop national and local government capacity to plan, design, implement, manage, operate and maintain small domestic water systems. The long term objective was the proliferation of water system and facilities accross the country. The users were to repay, according to their abilities a portion (0% to 100%) of the capital cost and eventually own the water system.

Before launching the full scale BWP I in 1978, a 'pilot' scale program was run during 1977 involving 4 provinces. The purpose was to test the validity and responsiveness of the proposed institutional structure with its attendant operational procedures and policies. During this phase many assumptions were tested and design data were gathered. The entire effort was funded by GOP with USAID providing technical assistance only. It will be interesting to note that three out of these four projects are still in operation with a higher level of service; the fourth one is a victim of local politics for last one year. BWP I ('78-'81) saw procedural refinement and programme expansion. The procedures were improved to establish an institutional structure able to carry out the program. The program was expanded to 59 LGUs. BWP II ('81-'85) phase was designed to be for institutional refinement and program expansion. During this phase attempts were made to strengthen the institutional capability at the various administrative l evel and develop sufficient capacity of the LGUs to attract follow-on funding from other donor agencies. The program has been extended to 83 interested and eligible LGUs.

PROJECT PARAMETERS

BWP projects are grouped under three different types (levels) of services. Level I services are strategically located handpumps fitted to a well (shallow or deep) serving 5 - 15 households (30-120 people) in thinly populated areas. Level II services are community water systems with storage, distribution pipelines and community faucets serving up to a population of 10,000. Level III services supply water to individual households. A modified Level III, termed as Level III-A, supplying low pressure water at extremely low rate (0.4 liter/min) to individual households were also tried but later abandoned. BWP systems are designed to supply 60 and 100 liters per capita per day for Lv II and Lv III systems respectively. Design periods for different components vary between 5 and 20 years. As evident from Table I, Lv II projects were the mainstay of the program. Only recently more Lv II projects are being built.

PROJECT IMPLEMENTATION STEPS

An introduction to various entities involved in the program is in order here. 'Barangay' is the smallest political unit for which this program is geared for. 'Barangay Captain' is the chief of the Barangay. 'Rural Waterworks and Sanitation Association (RWSA)' is the association formed by the consumers to run, and eventually own, the water system. 'Local government units (LGU)' are the provincial and city governments. 'Ministry of Local Government (MLG)' is the line ministry of the national government with the responsibility to carry out this program. 'Barangay Water Program (BWP)' is a special project of MLG. The program management group is also referred as BWP. The BWP staff are divided into three groups - engineering, training and monitoring. They travel throughout the country from their headquarter in Manila. 'Sheladia Associates, Inc. (SAI)' is an USA based consulting engineering firm retained by USAID as engineering consultant to the program. 'Techniks Corporation (Techniks)' is a local consulting engineering firm retained by GOP to provide engineering and field supervision services to BWP. 'professional Rural & Urban Consultants, Inc. (RURBAN)' is also a local consulting firm providing institutional services to BWP under contract with GOP. 'Heads Consultants (HC' also provide individual consultants on training and monitoring to BWP.

Following is a simplified description of the step-by-step development of each project.

1. Barangay people recognize the need for a water system and inform the next higherlevel of government authority through their barangay captain. (This authority may be either the city government or the provincial government).

2. City or Provincial Developmental Staff (C/PDS) then prepares a feasibility study and a preliminary engineering report to determine the feasibility and viability of the project. If the determination is affirmative then those documents are submitted to BWP for review and approval.

3. Barangay people are informed, through a series of meetings, about BWP, it's policies and methods, and the benefits and responsibilities of the users under this program. They are told about structural survey (SS), feasibility studies (FS) andpreliminary engineering report (PER) which are needed to join the BWP. They are also informed about the findings of these studies. Financial aspects are explained too: the consumer association would have to assume a loan of at least a portion of which must be paid back for next 20 years; the consumers must pay a minimum monthly fee, etc. Groundwork for the formation of RWSA is done at this stage. These activities are organized by the LGU and BWP with help from Rurban and HC.

4. Upon the approval of BWP, the project is included in the annual implementation plan (AIP) of the LGU. Action is initiated to provide budgetary allocation at the LGU level.

5. City or Provincial Engineering Office (C/PEO) starts preparing detail engineering design, drawing and specifications. If needed they are assisted by engineers from BWP, Techniks or SAI.

6. In the meantime, the potential consumers form an association, pay their initial membership fees, applies for registration of the association as a non-stock non-profit company (i.e. RWSA) under the laws of GOP. The registration related documents and a bank certificate stating that the RWSA has opened an account with a minimum deposit of ₱2,500.00 are submitted to BWP.

7. BWP reviews the RWSA registration related documents, the final engineering design and other relevant materials. If no further actionis needed, BWP issues a notice to the LGU to initiate construction proceedings. If the documents are incomplete or need modifications, they are returned to the proper authorities for corrective actions.

8. Around this time the RWSA enters into an agreement with the LGU to accept the project when completed and amortize the cost of theproject according to their ability. The amortization usually amounts to a percentage (less than 100) of the construction cost.

9. The C/PEO lets the project out for bid usually among a group of prequalified contractors; selects and negotiates a contract with the winning bidder; issues work order. If the project is to be built by the administration, C/PEO starts procurement and other necessary activities.

10. The construction activities start. During the construction period, the LGUs are to provide regular supervision. They are assisted by the engineers from BWP, Techniks, SAI and USAID.

11. After the completion of construction, final inspection is conducted jointly by the representatives from the contractor, LGU, BWP, Techniks, USAID and the RWSA. The project is accepted by the LGU, BWP, and USAID, if built as per BWP specification.

12. RWSA officials and operators are given post-completion training in the areas of operation, maintenance, dues collection, bookkeeping etc.

13. The project is turned over to the RWSA, usually through a formal ceremony. The officials of the RWSA signs the acceptance of the project.

14. RWSA starts managing the water system.

SPECIAL FEATURES

Let us now review the key features which helped in the implementation of the programme:

1. Community participation: The community participation has been one of the major cornerstones in the development of the programme. The community is an active participant is almost all phases of the work. They recognize the need of the project; contacts the LGU to perform the necessary studies; donates land for the well, storage tank and the office building; acts as unofficial agent of the LGU during construction by providing alert supervision; participates in the election of managers; and above all pays their monthly bill regularly. The interest and alertness of the community help the managers to deal with the exceptional delinquencies effectively.

2. Community Development: BWP is more than the physical installation of water systems in rural communities. One of the main objective of BWP was community development by harnessing and mobilizing the leadership potential as well as managerial and fiscal capabilities of local groups. The water system and the attending RWSA is merely the vehicle of securing technical, financial and organizational assistance from various government agencies. Many of the RWSAs have taken the objectives (and often provided managerial functions too) to improve their services by upgrading the level of service, to extend services to new areas and new members, and to contract outside contractors to perform maintenance and repair works. They have handled the sensitive issue of raising the monthly fees according to the needs, which usually have been more than what BWP prescribes. In one case the RWSA has taken the lead to open a cooperative grocery store. This enlightenment and improvement in the capabilities of the local people is a major asset for the achievement of the project.

3. Training: One of the foundations on which BWP has been built is proper and adequate training. Training includes meetings and discussion to expose an idea; seminars to explain various topics; helps to organize meetings; and of course, formal class room type lectures and workshops. BWP has conducted more than 775 training seminars on various topics. Table II, "BWP Training Summary", shows the list of trainings, in generic terms, with the number of participants. In most cases the training and the participants have been repeated to provide a long lasting result. The scope of the trainings has ranged from rather sophisticated hydrogeological investigation or looped network distribution analysis to elementary bookkeeping or simply record keeping. The participants have come from almost all levels of involvement: from city or provincial development coordinators to the operators and bookeepers of the association. In addition informal training is provided continuously to the LGU and RWSA personnel through the field visits and other meetings with staff of BWP and their various consultants.

4. Decentralization: BWP activities and decision making authorities have been extended to a large number of offices. The selection of a project is not decided at a central location. Priorities are determined by various LGUs. This approach helped in enlisting the capabilities of a large number of trained and experienced people from the LGUs. It also eliminated

the need of creating a new mammoth, and possibly top heavy, organization. Only about 80 persons, including secretaries and outside consultants, help run the program.

5. Financial Arrangement: As mentioned before, USAID is the ultimate source of funding of this program. GOP shares a substantial burden also. But various agencies shoulder the financial responsibility at different stages of a project. The LGUs first bear the cost of conducting the initial studies and developing final project documents. When BWP issues the "proceed to construction" notice, approx. 15% of the estimated construction cost is given to the LGUs by the GOP through BWP. This money is called the 'seed money'. Then during construction the financial burden is borne by the contractors. The cost of 'administration built' projects are of course shouldered by the LGUs. After final inspection and acceptance of the project, the contractors are paid by the LGUs. LGUs are then reimbursed by the GOP through BWP. Subsequently, GOP asks for, and receives, reimbursement from USAID. The amortization monies coming from the RWSAs go to the LGUs. Under this mechanism the LGUs have a good incentive to build more projects at shortest possible time. This worked very well until last year when GOP financial problems slowed down the flow of money, thereby slowing down the construction activities.

6. Monthly Fees: This is the key element for the survival of the project. BWP guidelines put enough stresses on this point. A project is not considered viable unless the community is able to pay for its operations at least. (The amortization may be 0%). The ability of the community is determined during the initial structural survey and feasibility study by means of estimating their income. The structural survey is a method, adopted by BWP, of estimating the income of a community based on the types, sizes, numbers and the conditions of dwellings there. The dwellings are divided in 10 categories whereas the condition is determined in 3 levels. During the pilot phase and the BWP 1 phase correlation were established between adjusted structural value and income level of a barangay. BWP do not want the monthly fee to be more than 5% of the monthly income or ₱ 20 which ever is lower. Of course, a community may raise its fee if the participants are willing to do so. Presently many communities charge their members a fee of ₱ 30 or more.

7. LGU participation criteria: In order to make the program successful, certain criteria were laid down for the LGUs to meet before they can be part of the program. These criteria made sure that the LGUs maintain certain capabilities at the time of incorporation into the program and continue to meet those and other necessary ones in the future. The LGU must have a functional development staff and an engineering office. They must also have a local development investment plan and a current annual budget allocation. In case funding for waterworks were not included, a supplementary budget must be executed by the LGU. If a willing LGU lacks any of these criteria,

BWP helps in rectifying them. For the future, the LGU has to form a city or provincial evaluation team (C/PET) to monitor and evaluate the performances of the operating systems every three months for the first year and once a year for the next four years. The evaluation group will also provide technical, institutional and other advisory services to the operating systems. BWP conducts an annual recertification survey of all particpating LGUs to verify adherance to these criteria. BWP refuses to have an erring LGU in its fold if the deficiencies are not rectified within a specified period.

8. Simplified engineering design: Many components of the water system are pre-designed. For example, elevated water storage tanks of many sizes and heights were designed in detail and has been distributed to the LGUs. Tables showing friction losses for various combination of flow and pipe sizes have been developed. A group of standard design and drawings helped in the quick and judicious preparation of the project documents. Several seminars were held for BWP and LGU staff on different design and construction topics and methodology. This approach reduced the design time considerably while improving the quality and safety of the structures.

9. Forms and procedures: In order to make the implementation of the project quick and simple, BWP standardized and used many forms designed for specific activities. This has been very helpful to the project specially because BWP staff, both at the national and LGU levels,were rather young and inexperienced.

EXPERIENCES TO THINK ABOUT

BWP has gained very valuable experience over the last several years. They have learned a few bitter lessons too. BWP has been able to address to some of them already. The author feels a brief discussion on them may help others to chart a successful course and to avoid or minimize the same or similar pitfalls.

1. All the trainees must be exposed to multiple trainings to be able to retain and use their acquired knowledge. Learning is a slow and time consuming process. It takes a while to absorb something and put it to practice.

2. Lack of proper construction equipment is a severe hindrance in the implementation of any program. Without proper equipment the quality of work suffers; more time is consumed; more money is spent. Absence of proper well drilling rigs is a case in point.

3. The life and well being of the physical structures of a project depend on the quality of its construction. This cannot be overemphasized. Unfortunately, too often proper supervision is lacking. The people responsible for regular supervision must be made to realize the importance of their task. They must, of course, be provided with the necessary logistical supports, i.e. vehicle and fuel, to render their services.

4. As people get used to using water their consumption increases. Systems designed without this consideration cannot provide good services after a few years. The level of service also determines the amount of water expected to be used by the consumers. A level II system will eventually be converted to a level III system; substantially so if not completely. Our experience shows that per capita consumption for a Level II system increased from 25 to 40 liters over a period of four years; for Lv III the increment was from 30-80 liters over 2-3 years.

5. The type of service must be acceptable to the users. As mentioned earlier, BWP tried to introduce a modified Lv III, termed as Lv III-A, in which each household would have individual connection. The water would come at a low pressure at a flow rate of 0.4 liter/min. This would be be achieved by using a restrictor. Even though, this rate would supply enough water to everybody's needs and at a very low cost, people rejected it. In a society like the Philippines, where people are exposed to television and running water, such a diluted system will not be acceptable.

6. The sources of water must be developed to its fullest capabilities. This is specially important for the well sources. The wells built during the initial period of BWP had many defects. Not only that they were not constructed properly, they were not developed to their full potential either. In the course of subsequent 3,4 or 5 years, these wells needed remedial actions. The additional cost, let alone the discomfort and loss of service to the consumers, is much more than what was saved initially.

7. Cost of electricity is becoming the crucial element in the survival of the systems. The cost has gone up by 2-3 times in the last 2 years. Unfortunately the incomes of the users have not gone up. The consumers are finding it very difficult to pay their bills regularly. Many RWSAs have raised their minimum monthly fees to ₱30 or more per month. Even then they are having difficulty in meeting the monthly operating expenses. This high cost has become the most critical factor in the survival of a water system. In order to cut down the cost of operation, they are cutting down the services. This may eventually lead to the collapse of the system. Design should try to reduce the operating costs.

IMMEDIATE FUTURE

BWP II is scheduled to be phased out by December '85, which was the original project assistance completion date. Moreover, BWP is not considered an unblemished success story. In several areas, it's performance has been less than expected. Of course that does not necessarily reflect a very poor performance; rather it shows a "poor percentage" accomplishment. BWP II expects to spend only up to US$ 11.5 M (depending on GOP appropriation) out of a US$ 19.6 M loan amount. A main reason is of course a very precarious financial position of GOP for the last 2 years. The performance on many of the RWSAs are also below expectation. Majority of them are continuing to depend on the LGUs for technical and financial help for major maintenance and repairs. They are unable to pay regularly their amortization bills. Again the main cause is the overall decline in the national economy. Nevertheless, these lapses (whether due to changed conditions or too much expectation) in the performance of BWP require a thorough review of the present program.

At the time of this writing (June '85), USAID, with the knowledge of GOP, has engaged a team of experts to do a thorough review of the program. They are also to recommend whether to revamp this programme or develop a new program.

CONCLUSION

This paper described the key features of a rather successful rural water supply program. BWP can be proud of completing more than 1,100 water supply projects and satisfying one of the major basic needs of about 600,000 people. BWP will have the potential to reach as many as 1.2 M people. The author hopes that something from this paper will help somebody in developing a successful program.

TABLE I

BWP SUMMARY

1. Program Period — 1978 - 1985

2. Program Budget

USAID	- US$ 25.6 M	-	Loan
	- US$ 2.7 M	-	Grant
GOP	- US$ 13.1 M (in Pesos)		Support

3. Completed Projects (As of December 1984)

	Nos.	Cost (PM)	Beneficiaries (000)
Lv I	814	15.6	90
Lv II + III	310	146.7	493
Total	1124	162.3	583

4. Projects expected to be completed by Dec '85

	Nos.	Cost	Beneficiaries
Lv I	94	5.2	8
Lv II + III	62	101.0	156
Total	156	106.2	164

5. Exploratory Test Wells completed by Dec. '84 — 22 — 1.6

6. Test wells expected to be completed by Dec '85 — 60 — 5.6

7. Potential Total Beneficiaries — 1.2 M

8. Capital Cost/Beneficiary (upto Dec. '84)

	Lv I	P212	US$ 11.8
	Lv II + III	P382	US$ 21.2
'85 Cost (avg)	Lv III	P1018	US$(59.0)

9. Average Construction time - LV II + III

By Administration	- 16.1 months
By Contract	- 10.2 months

10. Total Nos. of Participating LGUs — 83

Total Nos. of organizes RWSA — 366

Total Nos. of Registered RWSA — 234

11. Nos. of people involved in the program management — 81

BWP - Monitoring (incl. Proj. Manager)	10)
- Training	10)
- Engineering	17)
- Secretary	7)
USAID	3
Techniks	16
Rurban	9
Sheladia	3
Heads	2
Secretaries	5

Notes:

(1) All data upto December 1984 unless otherwise mentioned
(2) USAID participation is expected to be phased out by Dec. '85
(3) Peso-Dollar (US) exchange rate varied over the Program period It was US$ 1 = P7.50 in 1979. Concurrently US$ 1 = P18.50 (since mid 1984). All US$ conversions are made at current rate
(4) Estimated due to incomplete data
(5) Includes 12 Level III-A projects
(6) Activity started in mid 1984 only
(7) Includes 10 year growth for all the members within the boundaries of the service areas.
(8) Includes cost of individual meters
(9) Considering data upto 1983. 1984 data incomplete
(10) See page 2 for their roles

TABLE II

BWP Training Summary [1]

	Training Description [2]	Primary Target	No of Times	Total Participation
1.	BWP Policy Methodology (2-3 days)	LGU	5	296
2.	Water Resources Development Planning	LGU	5	242
3.	Structural Survey, Feasibility Study, Preliminary Engineering Report (5 days)	LGU	6	218
4.	BWP Consultive Conference for Program Performance Evaluation and Future Course of action (3 days)	LGU	4	414
5.	Water System Design and Construction (5 days)	LGU	7	354
6.	Hydrogeological training (5 days)	LGU	5	126
7.	Trainors Training for Waterworks Association, Policy and Formation (5 days)	LGU	7	346
8.	Special Skills for Waterworks Technician (5 days)	LGU	5 [3]	201 [3]
9.	Seminar for Prime Contractors (3 days)	Contractor	2	107
10.	Miscellaneous (1-5 days)	LGU		224
11.	Leadership and Management Development (2-3 days)	RWSA	13+ [3]	300 + Brgy. representative [3]
12.	Specialized Bookkeeping Course (1-2 days)	RWSA	13+ [3]	345 + [3]
13.	Community Trainings e.g. (5 days) Pre-Feasibility Studies, Pre-Operational Post-Completion, etc.	RWSA	694	several thousands
14.	Identifying & Solving operational and management problems of operating system (2-3 days)	RWSA	12+ [3]	252 RWSAs

Note: (1) Only Major trng. activities are listed.
(2) Generic description only
(3) Incomplete records