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Urban Waste Water Facilities in Libya

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INTRODUCTION

This paper is concerned with the development of sewerage and sewage-treatment facilities during the past twenty-three years in six major towns and cities in Libya. The paper is based on projects undertaken by Howard Humphreys in Tripoli (the capital), Benghazi, Derna, Misurata, Tobruk and Sebha.

BACKGROUND

Libya covers an area of 1.8 million square kilometres and is situated on the north coast of Africa. It comprises three regions: the Western, Eastern, and Southern Provinces, formerly known as Tripolitania, Cyrenaica, and Fezzan respectively. Tripoli and Benghazi are the principal cities.

Sand and rock deserts are the predominating features of much of the country, the southern part of which lies within the Sahara Desert. The coastal regions of much of the Western Province and part of the Eastern province are comparatively fertile, these areas being separated by the Sirte Desert.

The greater part of the country has a hot and arid desert climate, however, along the Mediterranean coast the climate is more temperate. Rain occurs mainly between October and March, June, July, and August are generally dry and there are no permanent rivers. Temperatures range from a daytime 44^{o}C in summer to near freezing at night in winter.

The present population of Libya is about 3.2 millions, 95% inhabiting the more temperate coastal regions. The current population growth rate is 4.2% per annum.

Libya gained its independance in 1951 and was a monarchy until 1969 when the Libyan Arab Republic was established. In 1977 the country was renamed the Socialist People's Libyan Arab Jamahiraya.

Libya is a major oil producer with an economy dependent entirely upon oil. Revenue from oil sales has enabled the Government to embark on large development programmes including the construction of waste-water facilities which had previously hardly existed. Funds are provided by the Central Government to local Municipalities on a direct-grant basis to cover the full capital cost of all infrastructure development.

Despite the comparatively-high oil revenues, programmed expenditure often outstrips available resources. In recent years a reduction in oil revenue has delayed the implementation of development projects with drainage projects suffering along with other infrastructure work.

HISTORY OF SEWERAGE AND SEWAGE TREATMENT IN LIBYA

In 1961 the inadequacy of existing waste-water facilities prompted the Government to embark on a programme to provide complete sewerage and sewage treatment for the two main cities, Tripoli and Benghazi, the three coastal towns of Derna, Misurata, and Tobruk and the oasis town of Sebha in the Sahara Desert.

At that time there existed an old combined system in central Tripoli and an overloaded foul system in central Benghazi. Both discharged to the sea through short outfalls, most of which were situated close to built-up areas. Tobruk had a limited foul-sewerage system serving an army barracks and discharging to a small treatment plant. Main drainage did not exist in Derna, Misurata, and Sebha which relied on cesspits and septic tanks.

Apart from the obvious public-health problems, the Government was concerned at large volumes of water being discharged to the sea in a country where water was a limited and valuable resource. Their terms of reference, therefore, provided for the treatment of sewage to a standard which would permit the use of the effluent for irrigation.

Initial phases of the sewerage projects were implemented over the period 1961 to 1977 during which time a total of 548 km of sewer was designed and constructed together with 49 pumping stations, and treatment works for each town ranging in capacity from 1.4 to 27 Ml/day. The first-phase projects were all affected to some extent by labour problems, unsettled political conditions in the Middle East, and general administrative difficulties. In Benghazi, these factors led to delays totalling some seven years on an original contract period of four years.

The initial phases of the sewerage projects started in the 1960s have been continued. Master Plans to suit revised development plans and changing economic expectations have been drawn up: Benghazi in 1974 subsequently revised in 1978; Tobruk in 1974; Tripoli in 1977; and other towns also during this period.

The situation in Benghazi demonstrates the advantages of flexibility in Master Planning and the ability to be able to amend drainage systems to suit changing circumstances.

In 1978 the authorities in Benghazi decided severely to restrict development in areas on the periphery of the city and to concentrate sewage treatment at one works rather than the two determined by the 1974 Master Plan. The inherent flexibility of the 1974 Master Plan allowed these changes to be accommodated without any existing sewers or pumping stations being abandoned and with a minimum of redesign of projects to be constructed. Only one project under construction was affected to any extent with delays due to sewer redesign in a limited area and re-routing of pumping mains.

Further design projects followed from these Master Plans and the ensuing construction contracts are still being let. The result is that today complete sewerage systems have been designed for all the major cities and towns in Libya and that construction is taking place as quickly as economic circumstances allow. Sewage-treatment plants to treat the flows anticipated up to the mid 1990's have been designed and construction is either completed or underway.

In more recent years the emphasis has been placed on the smaller towns and villages. Projects have been drawn up for many communities with populations from 1,000 to 20,000, and it is anticipated that eventually all but the smallest village will have main drainage and sewage treatment so that effluent can be reused for agricultural purposes.

SEWERAGE SYSTEMS IN LIBYA

Sewerage systems in Libya, in general, have been designed on a separate basis. In Tripoli the old combined system was retained and extended but elsewhere separate provision has been made for foul-sewage and stormwater runoff.

Foulwater sewer systems

The towns and cities in question have a high density of development. All properties have a piped water supply and most have modern bathroom and toilet facilities. The per capita water consumption is as much as 300 litres per day in the cities and around 150 litres/day in the villages.

Development in the cities and main towns of Libya is very varied, ranging from intensive multi-storey apartment blocks to extensive villa development. The following distribution of development is found in Benghazi.

Development Type	Number of Floors	Population Density per gross hectare	Percentage of Population housed
Multi-storey Apartments	5 - 16	550	10%
Apartment blocks	3 - 9	275 - 575	13%
Hausch and Row Housing	2 - 3	330 - 620	54%
Villas	1 - 2	100 - 150	14%
Government housing	-	-	9%

In Tripoli the development is generally less intensive with densities rarely exceeding 350 persons/hectare; Tobruk is similar to Tripoli. Although the types of development vary through the country the general standard of housing is high and most have modern plumbing and sanitary fittings. Sewage flow per capita tends to be fairly constant irrespective of development, although as would be expected it is above average in the villa areas. Water demand per capita is very much higher than the sewage flow due to the extensive watering of private and public gardens and washing down of verandas and other paved areas.

In Benghazi and Tripoli the author's firm has adopted per capita sewage-flow figures of 270 l/hd; present-day figures for both towns are on average over 200 l/hd and rising.

Although separate foul sewers are not intended to accept surface water they invariably do and this is the case in Libya. It is mainly the inner court-yards of houses which are connected to the foul sewer and consequently there is a considerable increase in flow during wet weather. To allow for this a peaking factor of 6 for sewers of 500 mm and smaller has been adopted on Howard Humphreys' designs for Libya; the factor is reduced to 4 for larger sewers.

The problem of sewer corrosion is one which has not arisen in Libya. Lined asbestos-cement pipes have been used since the start of Phase I without any major corrosion problems. This can be attributed to a number of points:

The relatively weak sewage in Libya, BOD strengths exceeding 200 mg/l are uncommon. This is due to low BOD per capita figures of under 40 g/day and relatively high sewage flows per capita.

Minimum sewer velocities of 1.0 m/s have been adopted ensuring all sewers are self-cleansing.

Good ventilation has been provided throughout the system.

It should be noted that sewage temperatures range from 18°C in winter to 30°C in the summer.

Howard Humphreys' general philosophy with regard to sewer design has been to minimise maintenance problems by ensuring good velocities, easy access to the system (manholes every 50 m maximum), standby and maintenance pumps at pumping stations, chambers on all house connections and, where possible, connecting laterals to manholes, not directly to the sewer via risers and saddles. However, problems have arisen in the operation and maintenance of the systems. Blockages occur due to the disposal of garbage to the sewer and these often take a long time to be cleared. The maintenance depart-ments tend to be understaffed and suffer from a shortage of equipment, spare parts and consumables.

Stormwater sewer systems

The extent of the stormwater systems in Libya varies from city to city and town to town depending upon the topography and proportion of impermeable area. It should be noted that the natural ground in the locations under discussion is relatively impermeable and even in its undeveloped state suffers from flooding in the winter for extended periods.

In Benghazi, where slopes are gradual and development relatively intensive, complete storm-sewer systems have been constructed. The absence of natural drainage channels has meant that box culverts have been built as the main conveyors of stormwater runoff to the sea. In low-lying areas stormwater pumping has been required although this has been minimised. Proposals to reduce sewer flows by limited surface flooding and detention basins were considered, but the authorities rejected the proposals because of possible health, environmental and maintenance problems.

In Tobruk less-complete stormwater systems have been designed as the slopes are steeper. The concept adopted is to allow stormwater to run down roads to main gulley inlets which collect the runoff and discharge it to the sewer system. As in Benghazi, stormwater is discharged to the sea there being no natural watercourses.

Stormwater sewer design by the author's firm has been undertaken using the hydrograph method. A once-in-two-year, two-hour storm was used for design in the larger cities and a one-year storm in the smaller towns. Rainfall data available in Libya and supplemented by the British Meterological Office was used in assessing rainfall depths. Storm profile shapes similar to the fifty percentile British summer storm were considered appropriate. Annual rainfall on the coast varies from 200 mm/annum to 350 mm/annum, it being higher in the west; a typical hourly 2-yearly rainfall depth would be 15 mm.

Major flooding problems in Benghazi have been caused by overland flow, and the overflow from channels intended to intercept it, entering development from outside. Remedial measures have been taken to overcome this problem; channel capacities have been increased and special inlets to trunk storm sewers constructed at the limit of development.

SEWAGE TREATMENT

It is policy in Libya to conserve water and to re-use sewage effluent for irrigation. This necessitates a high standard of sewage treatment and requires that sewage-treatment plants be located reasonably close to the areas allocated for irrigation.

Within the constraints imposed by the required effluent quality and by the land available, the principal criteria for design have been reliability and ease of operation and maintenance.

These considerations led to the provision, in each of the six towns (Tripoli, Misurata, Benghazi, Derna, Tobruk and Sebha) covered by phase 1, of a single sewage-treatment plant supplied from a main town pumping station through a pumping main between three and eight kilometres long. The treatment plants were of conventional design with the following treatment processes.

Preliminary treatment	-	comminution
	-	detritus tanks
Primary treatment	-	sedimentation tanks
Secondary treatment	-	biological filters
	-	recirculation
	-	humus tanks
Tertiary treatment	-	rapid gravity sand filters
	-	chlorination
Sludge treatment	-	sludge digestion (heated at Tripoli and Benghazi, cold elsewhere)
	-	sludge-drying beds (with underdrains except at Sebha)

In all cases full standby generation facilities were provided and in Benghazi it was necessary to generate all electricity on site.

The rapid growth of the towns of Tripoli and Benghazi necessitated the design of extensions to the treatment plants during the 1970's. For a variety of reasons the design for Benghazi was substantially different from that for Tripoli.

The phase-1 plant at Tripoli had been in operation for some years and the filter process was functioning well; however the skilled operators necessary to run the sand filters proved impossible to find and great problems were being encountered in finding labour to lift sludge from the drying beds. The planned extension was large and the town of Tripoli was rapidly approaching the treatment plant site, thus placing land at a premium. It was decided, therefore, that a conventional activated-sludge process was the only practicable form of treatment, it being considered that the operating experience gained would permit successful operation of the process. The extension was designed with microstrainers in place of sand filters for tertiary treatment. However the agricultural authority subsequently decided that the effluent would be adequate without tertiary treatment and these were deleted. Following trials the sludge-drying beds were designed with concrete floors and no media, to permit sludge lifting using a mechanical shovel.

A second treatment plant for Tripoli, at Ain Zara, has since been designed using the same processes.

At the same time the treatment plant at Benghazi, although completed, had not yet commenced operation and no operating experience was available. The planned extension was smaller than for Tripoli and the treatment plant remote from the town with ample space for extension. It was decided, therefore, to retain the filter process (which had proved successful in Tripoli) for the extension but with the use of microstrainers for tertiary treatment and concrete-floored drying beds as in Tripoli.

The space required for filters and the difficulty of obtaining suitable media in large quantities preclude the use of filters for very large plants; and, as the price of electricity in Libya is relatively low, a further extension to the plant at Benghazi, which has recently been designed, utilises the extended aeration process with no primary treatment and no tertiary treatment except chlorination, it being considered that the extended aeration process will provide an effluent fo adequate standard (10:10 average).

In recent years emphasis has been placed on the development of rural areas and the authors' company has recently completed the design of drainage projects for eighteen small towns with populations between 500 and 8,000, and for one town with a population of 12,000, all in eastern Libya. In line with Libyan policy the treatment plants are designed to produce an effluent suitable for irrigation with an emphasis on reliability and ease of operation and maintenance. To achieve this the smaller treatment plants use Imhoff tanks, rotating biological contactors with integral drum screens and chlorination by means of solid hypochlorite tablets. It is intended that after digestion in the Imhoff tanks the sludge be tankered to land. The plants are designed for maintenance from a few central depots and use, so far as possible, standard components. The largest town will be served by an extended aeration plant with primary screens, an aeration tank with horizontal axis aerators, final settlement and chlorination. In this case sludge will be thickened and dried on beds. All the plants are provided with standby generation.

<u>Operation and maintenance</u>

Prior to the commissioning of the plant at Tripoli in 1971 there was no experience in the operation of sewage-treatment plants in Libya. Inevitably, in a country undergoing rapid development, there is a severe shortage of skilled labour and sewage-treatment plants are not given priority in the allocation of available resources.

When commissioned the phase-1 plant at Tripoli was operated by a mixture of expatriate and local staff under the supervision of an expatriate manager. The plant is now managed by a Libyan engineer. Generally, treatment quality has been good despite problems with the sand filters. Problems have also been encountered with the operation of the sludge digestors, which are currently blocked with grit and out of commission, and with sludge handling. The phase-2 extension, although complete has not yet been commissioned.

The phase-1 plant at Benghazi was operated for an initial two-year contract period by a local company employing expatriate staff. The plant is now operated by a Libyan manager with a mixture of local and expatriate staff.

Problems have been experienced with sand filters and drying beds as at Tripoli, but otherwise the plant, although by now overloaded, performs well.

RE-USE OF TREATED SEWAGE

General

In Libya water is at a premium there being low rainfall, no rivers and limited groundwater resources in most areas. In spite of this agriculture was important in times past. With the advent of oil the drift from agriculture accelerated, but Government policy is reversing this trend and agricultural development is a very high priority.

Policy, therefore, is to conserve water resources and the question of re-use is important. Part of this policy is to use treated sewage for irrigation purposes and, where possible, farms have been established near to sewage-treatment works as part of the general countrywide farm-development programme. The six phase-1 works and extensions, therefore, were all designed with this in mind and subsequent extensions continued this policy.

The authors knowledge of irrigation in Libya is based on Tripoli and Benghazi where somewhat different conditions and policies are to be found.

Benghazi

Sewage effluent treated to 10/10 standard and chlorinated is used to irrigate animal feed crops, principally alfalfa, corn, barley and pasture. As far as is known crops for human consumption are not irrigated.

The main problem in using the Benghazi effluent is its high salinity (chlorides have averaged in excess of 1400 mg/l and conductivity in excess of 4500 mmhos/cm 25^{o}C). The high salinity is mainly due to the water-supply quality but is increased by infiltration to the sewer system. This high salinity has resulted in effluent being applied to irrigated areas at a high rate to prevent the accumulation of salts in the root zone. However, this has caused a rise in the water-table level even though under drainage is provided in the irrigated areas.

Tripoli

Although bacterological effluent quality is similar to Benghazi the restriction of its use to the irrigation of fodder crops is not the case. Vegetables which are cooked such as potatoes, carrots and aubergine and salad crops such as lettuce and cucumber are irrigated as well as fruit trees and fodder crops. The vegetable crops are grown on small private farms, and although the authorities recognise there is a health risk they are reluctant to act as there is no proof of the spread of disease through this vector in Tripoli.

In Tripoli the salinity is much lower than Benghazi (chlorides 300 mg/l and conductivity 1500 mmhos/cm at $25^{o}C$) and vegetable crops yields are typically 10-15 tonne/hectare year.

CONSTRUCTION

This cannot be dealt with to any significant extent; however the following summarises some of the authors' experience based on contracts in Benghazi.

The original phase 1 of the sewerage and sewage treatment was let as one civil contract and a number of separate mechanical and electrical contracts. The problems of co-ordination were enormous and most had to be sorted out by the supervisory staff. The result of the experiences on phase 1 has led to the use of a single contract covering civil, mechanical and electrical work with the Contractor having either to demonstrate his own ability to coordinate the various aspects of the works or having to appoint a separate Co-ordinator. This arrangement has worked well and has been adopted for all our Libyan projects.

Construction has not posed many technical problems and conventional techniques have been employed throughout. Almost all delays have been due to poor management, cash-flow problems or political events.

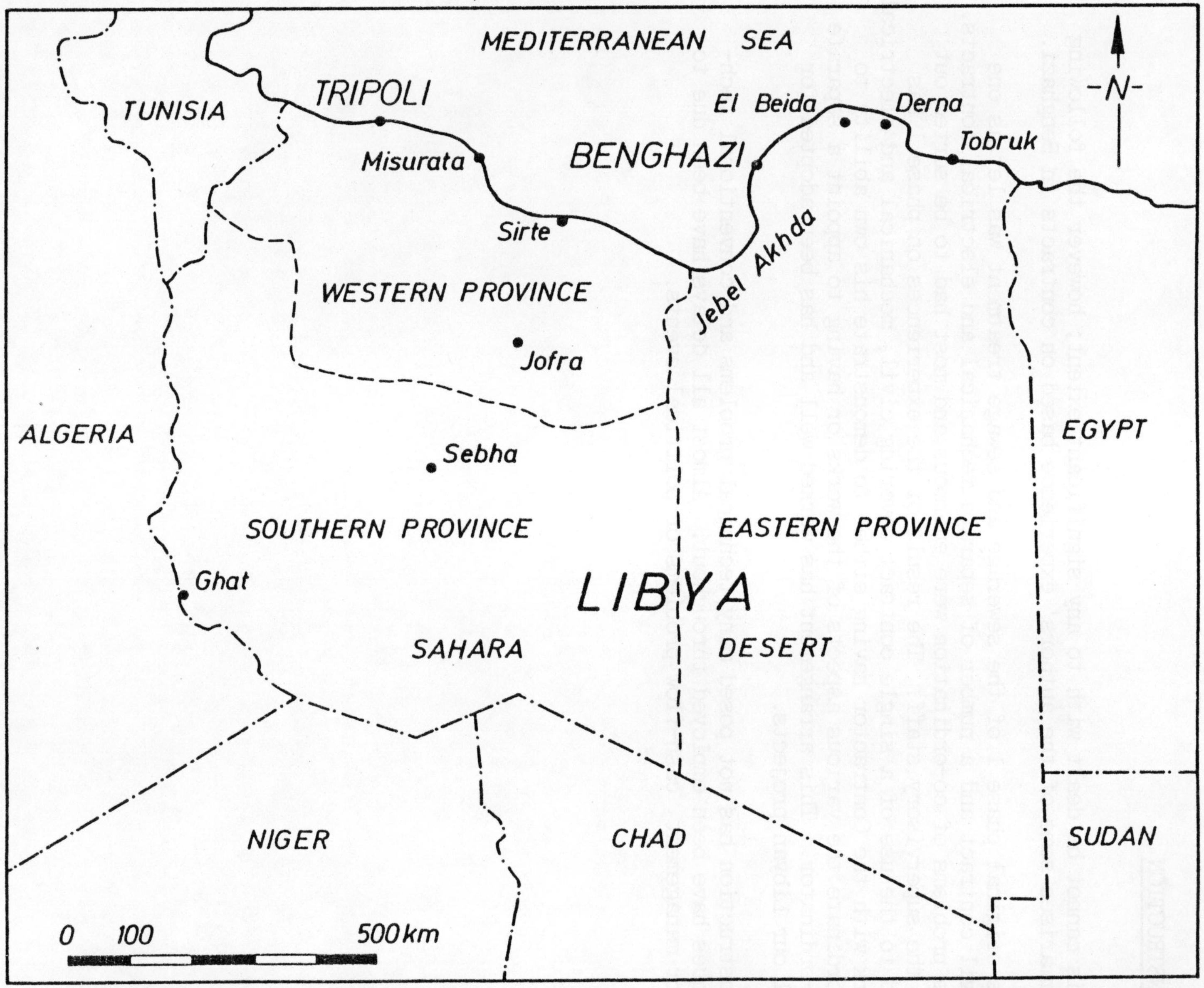

Figure 1 Map showing the territory of Libya, its provinces and main towns

Figure 2 Primary sedimentation tanks at Guarchia Sewage Treatment Works Benghazi, Libya.

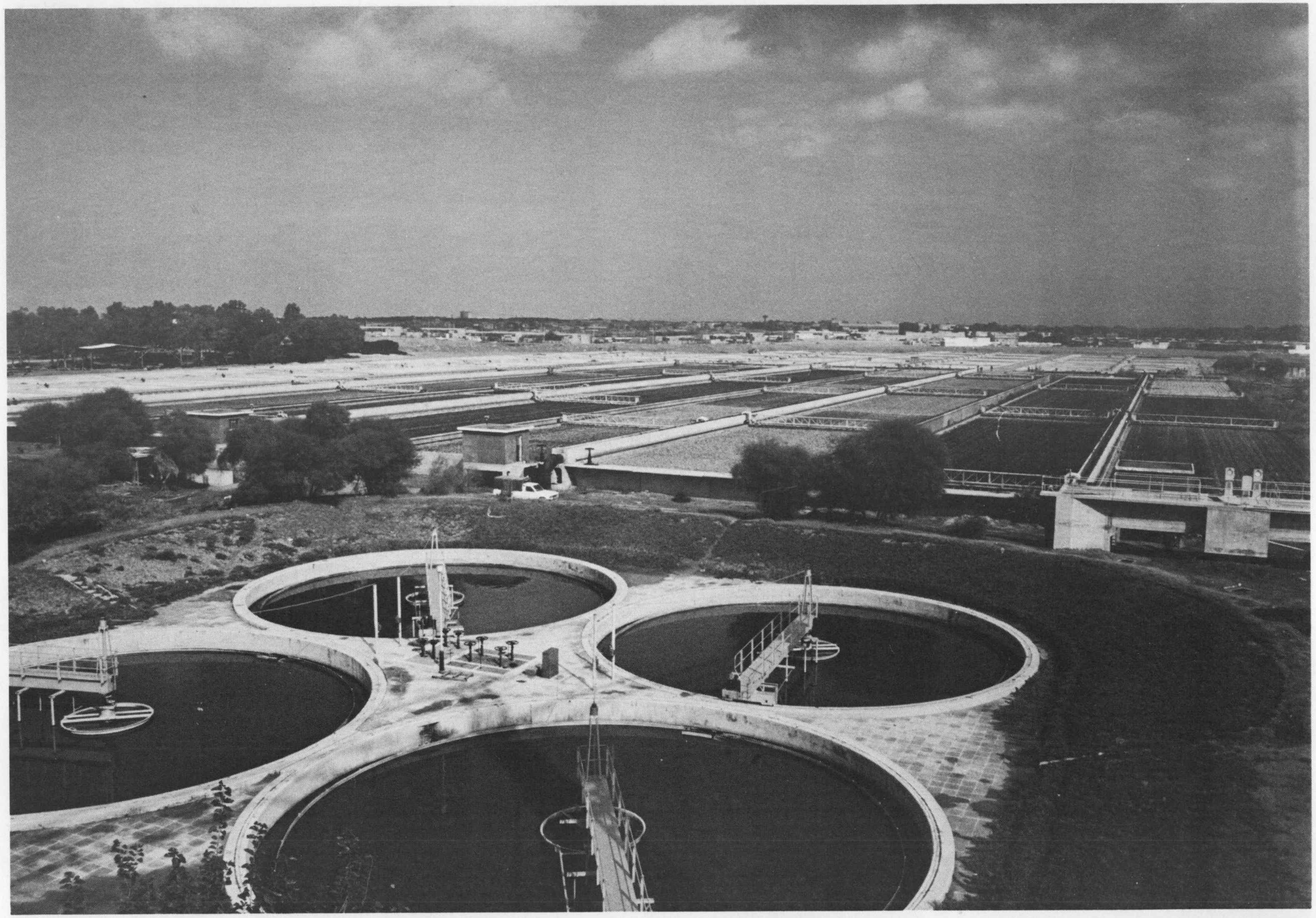

Figure 3 Central Sewage Treatment Works, Tripoli, Libya. Humus tanks with rectangular filter beds in the background.

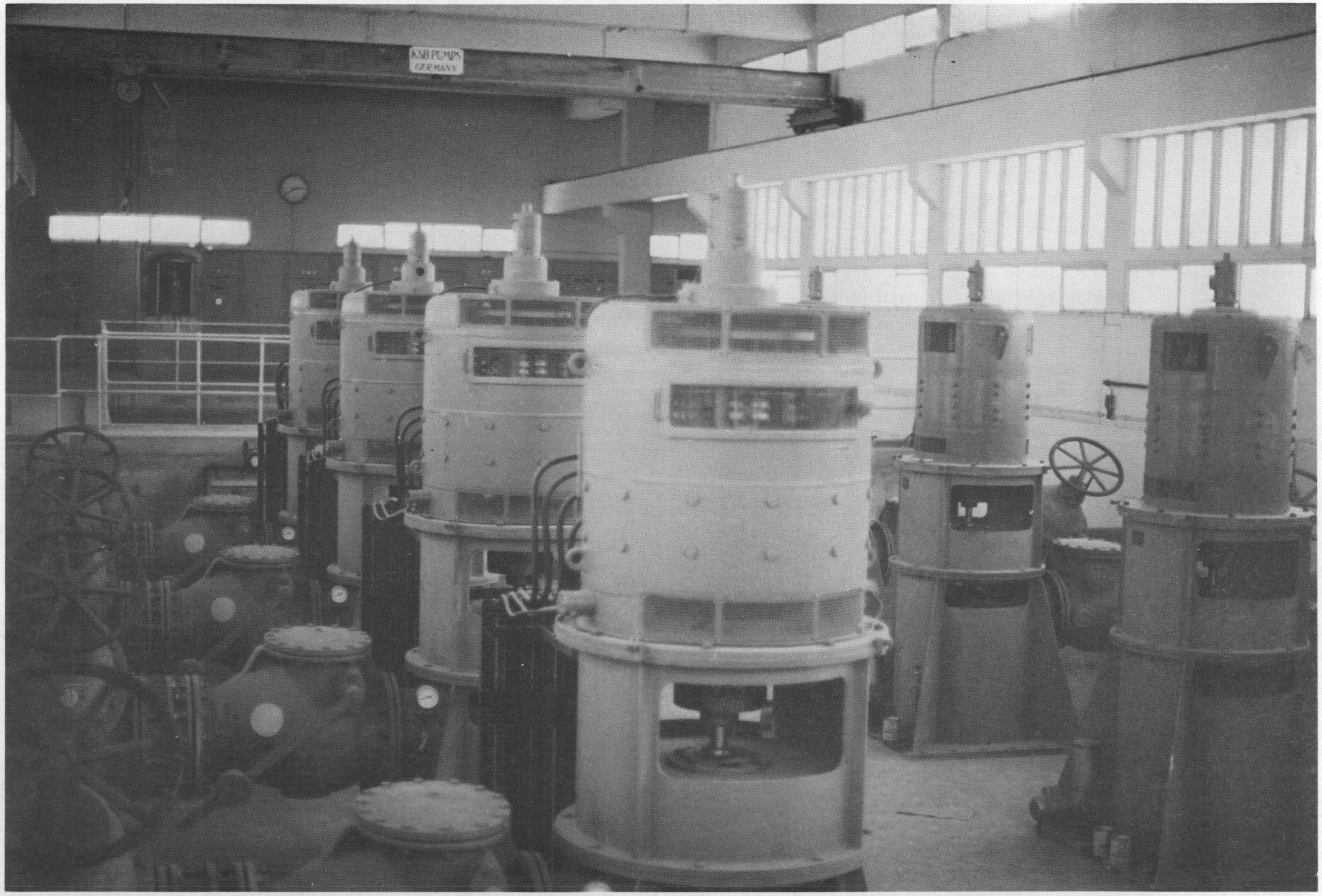

Figure 4 Electrically-driven vertical-spindle pumps, Benghazi Sewage Treatment Works, Libya.

Figure 5 Twin 4 m x 2½ m reinforced concrete stormwater culvert under construction in Benghazi, Libya.