Pergamon

Wat. Sci. Tech. Vol. 32, No. 9-10, pp. 115–124, 1995.

0273–1223/95 $9·50 + 0·00

PII:S0273-1223(96)00082-0

EFFLUENT RE-USE IN A TOURIST RESORT - LARNACA SEWAGE TREATMENT AND IRRIGATION PROJECT - CYPRUS

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ABSTRACT

Designs for sewerage, sewage treatment and effluent disposal prepared in the 1980's, included for marine disposal of secondary treated and disinfected effluent via a 1.5 km long sea outfall. A reappraisal of the scheme in 1990 reviewed alternative options with a view to reducing costs and utilising effluent.

An economic comparison showed that effluent storage and irrigation was an attractive alternative to marine disposal.

A scheme was designed whereby all effluent will be given secondary treatment, stored in reservoirs until required for irrigation, withdrawn through sand filters, disinfected and pumped to an irrigation distribution system serving public amenity areas throughout Larnaca, including parks, gardens, road verges and hotel areas. A sea outfall will not be provided.

The advantages of the scheme are conservation of water, improvement to the environment and prevention of marine pollution at a reduction in cost compared to the originally proposed scheme.

KEYWORDS

Effluent Irrigation, Sea Outfall, Sewage Treatment, Reservoirs.

INTRODUCTION

In the Larnaca region the average annual rainfall is only 350mm and the annual evaporation is in excess of 2000mm. Hence there is an acute need for water, not only for domestic and agricultural purposes but also for landscape greening to provide an agreeable environment to the local population and the increasing tourist industry.

An increasing number of small wastewater treatment plants have been constructed by hotels. In general such treatment plants, built to a standard design by specialist companies in Cyprus, are well constructed and produce tertiary effluent. The hotels use this effluent for the irrigation of lawns, trees and shrubs to

create a more attractive environment for tourism. Although the treatment process provides an acceptable use of waste water, and at a cheaper price than the scarce domestic supply, maintaining the standard and quality is invariably difficult.

Disposal of treated sewage effluent to the sea is considered undesirable due to the harmful effect on marine life and sea pollution which could affect the valuable tourist industry. Hence it has become desirable to make the best possible use of treated effluent on land.

The Larnaca Sewerage and Effluent Re-use Project provides "first time" sewerage and sewage treatment to the coastal strip of Larnaca and utilises treated effluent for irrigation of amenity areas within and close to Larnaca.

BACKGROUND

In November 1982 a Canadian Consultant presented a Master Plan Study and Feasibility Report on Stormwater Drainage and Sanitary Sewerage Systems for the town of Larnaca. This included investigations into reusing treated effluent for irrigated agriculture in areas west and north of Larnaca. Investigations also included effluent disposal by recharge into the Kiti aquifer.

The case for utilisation of effluent for agricultural purposes was not proven and final designs and Bid Documents were prepared for a scheme comprising:

- Sewerage to the coastal strip of Larnaca
- 12 sewage pumping stations
- A secondary treatment works located south of the airport
- A sea outfall for effluent disposal.

A subsequent investigation by the Fisheries Department of the Ministry of Agriculture and Natural Resources identified the need to extend the outfall beyond the original 1.5 km length in order to prevent pollution of bathing waters in the shallow sea in the vicinity of the airport.

In August 1990 Howard Humphreys & Partners Ltd, England, in association with J A Theophilou, Cyprus, were appointed to carry out a review of the existing designs. The re-appraisal report was presented to the Larnaca Sewerage and Drainage Board in January 1991. Included in this review was a feasibility study on the alternative methods of effluent disposal so as to:

- avoid marine pollution
- conserve water
- improve the environment

The area served by the sewerage system is identified in Fig. 1 and comprises the low lying coastal strip extending from the airport in the south to the hotel area in the north, being between 300 and 2000 metres wide and some 12 km long, together with a number of Governmental Refugee Estates.

The population of the sewerage area is estimated as 46,300 in the design year of 2010 (currently about 40,300) of which a substantial number (around 30%) are tourists, either foreigners visiting hotel and apartment blocks or Cypriots from Nicosia staying in holiday villas or apartments.

The sewage flows are estimated to vary according to season as indicated on Fig. 2.

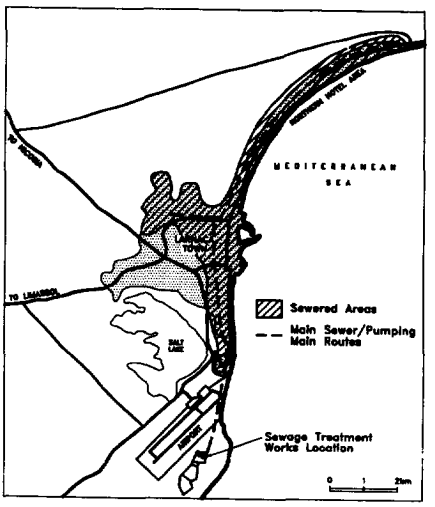

FIG.1 SEWERED AREAS

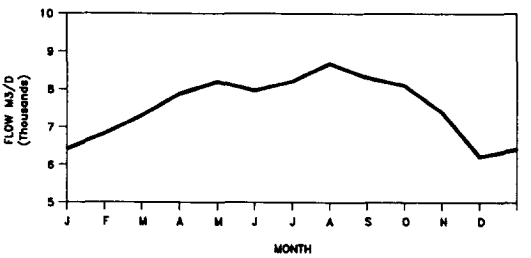

FIG.2 AVERAGE DAILY SEWAGE FLOWS YEAR 2010

OPTIONS FOR SEWAGE TREATMENT AND EFFLUENT DISPOSAL

The Reappraisal Study examined options for sewage treatment and effluent disposal including:

- Sewage treatment at 2 different sites, one north of Larnaca, one south of Larnaca (adjacent to the airport) and a combination of both.
- Waste stabilisation ponds and extended aeration as alternative methods of treatment.
- Effluent disposal to sea, to agricultural re-use and to amenity re-use.

Costed alternatives were developed for each.

Treatment Works Locations

It was found that a single treatment works adjacent to the airport offered the most economic and politically acceptable scheme.

Sewage Treatment

The location of the treatment works appeared to be well suited for the construction of waste stabilisation ponds which offered the most economic method of treatment to produce effluent suitable for sea disposal or effluent re-use. However, this solution was politically unacceptable due to a history of problems with poorly designed and grossly overloaded ponds elsewhere in Cyprus. In addition, further land acquisition would have been required and the volume of water available for re-use (if required) would have been reduced due to evaporation.

Treatment by extended aeration followed by disinfection was therefore agreed upon.

Marine Disposal

The coastal waters of Cyprus are of very high quality with virtually no pollution from sewage or sewage related activities. The terms of reference for the re-appraisal called for the 'elimination of the adverse effects of pollution'.

A study carried out by the Fisheries Department of the Ministry of Agriculture and Natural Resources highlighted the existing pollution-free water quality and the adverse effects likely from the proposed outfall, even if it was extended beyond the previously designed length of 1.5 km.

The estimated cost of the originally designed outfall was in excess of that of the alternative irrigation re-use scheme examined under the Re-appraisal Study, and further consideration was not therefore given to a marine disposal option.

Agricultural Re-use

Previous studies had examined the opportunities for agricultural re-use which was essentially based upon irrigation of agricultural areas in the Dhromolaxia area to the west of the Airport. The schemes required the construction of a lined reservoir and transmission mains at estimated costs varying between US $16000 and US $23000 per hectare and were based on higher effluent flows than are now estimated. There was no history of extensive irrigation in the area, nor any of effluent re-use, and the success of the scheme was doubtful in terms of guaranteeing the usage of all of the effluent.

The economic cost of the water supplied would have been in excess of that which could be justified on a purely agricultural economic basis, which was estimated in the Re-appraisal Report as:

	US $/m^3
Lucerne	0.14
Alfalfa	0.10
Beans	0.12
Wheat	0.02
Barley	0.04

Amenity Irrigation

Larnaca has primarily a tourism based economy with the vast majority of the tourists arriving during the summer months which are hot and dry.

There is a natural demand to create attractive surroundings for the tourist environment including trees, lawns and gardens both in the municipal areas and at the hotels.

Larnaca Municipal Area

The Landscaping Department of the Larnaca Municipality started in 1987 with a staff of 8 and by 1990 had 34 people, at which time approximately 10 ha around the city were being irrigated with about 520 m^3/day of water obtained from wells, tankers and taps, plus some sewage effluent.

The main areas being watered were the Municipal Park, trees and shrubs along major roads, the marina, the sea front, etc. The methods of irrigation consisted of buried pipelines and drip irrigation to trees and shrubs along central road reservations, sprinkler irrigation and hand held hoses.

The Landscaping Department had plans for expanding the areas to be watered to a further 230 ha, thus improving the overall green effect of the city.

Hotels and Apartment Blocks

A number of hotels and apartment blocks have been developed along the north coast in recent years

All the hotels and large apartment blocks, together with a beach restaurant area near to the airport, dispose of their raw sewage and wastewater through Biological Treatment Plants constructed below ground level within the grounds of the properties, generally underneath car parks. The plants are based on the extended aeration process to provide secondary treatment. Additionally, some of the plants have been designed to provide tertiary treatment using advanced methods such as flocculation, pre and post chlorination and 2-stage pressure filtration so that effluent can then be re-used for the irrigation of lawns, trees and shrubs within the grounds of the properties.

The quality of the tertiary effluent after this double filtration system is designed to be 5:5 mgl (BOD_5:SS).

The average cost for running a small treatment plant amounted to about US \$0.36 per m^3. This compared favourably with the cost of US \$2.0/m^3 for transporting water by tanker (fresh or foul). The cost of fresh water for irrigation purposes amounted to US \$1.0/m^3.

Although the majority of plants were operating successfully, a number of operational problems were identified, including the significant maintenance time required, up to 8 - 10 hours per week; the variability in hotel occupancy rate causing variations in treatment performance; inadequate means of disposal so that at times surplus effluent had to be tankered; inability to match irrigation demand to effluent production; chemicals deposited into the system by hotel staff seriously disrupting the biological processes; the need to remove effluent by tanker during breakdowns, and sludge removal and disposal.

The treatment plants generally have a useful life of 10 to 15 years and many of these plants were already 6-8 years old and would need to be replaced in the near future. Hotel owners generally expressed a wish to join a new centralised system, provided they had a treated effluent supply for irrigation purposes at reasonable cost.

Irrigation with sewage effluent had achieved encouraging results: expansive lawns, trees, shrubs and flowers all appeared to be healthy and thriving, and there was no evidence of any salinity build up. Irrigation methods generally employed consist of drippers on polythene tubing for trees and shrubs and mini-sprinklers on portable hoses for lawns and flowers.

Irrigable Areas

It was evident that there was a substantial demand for water for irrigation of amenity areas.

The potential areas, including existing, which could be served by treated effluent, if available in sufficient quantities, were:

-	Airport and environs	110 ha
-	Larnaca including Parkland	80 ha
-	Long term Parkland west of Salt Lake	150 ha
-	Northern Coastal Hotels and Apartments	56 ha
	Total	396 ha

This area exceeds that for which sufficient effluent is available, and thus disposal of the effluent could be assured.

FINANCIAL COSTS AND BENEFITS

Various options for the provision of irrigation facilities from each of the alternative sewage treatment sites were investigated and costed. Annual costs for the provision of irrigation water from the treated effluent were calculated on a discounted basis (capital, operational, maintenance) inclusive of effluent distribution, storage reservoirs, pumping facilities, distribution pipelines and portable irrigation equipment.

Criteria

To justify the investment costs for provision of a treated effluent supply for irrigation purposes it is necessary to establish and quantify the benefits to the community.

Landscape greening is an obvious attraction to both residents and tourists in an area which is completely dry and arid in the hot summer months. There are numerous difficulties in quantifying a 'greening' benefit especially if the end result is considered where a tourist may stay in an area which is pleasantly green with trees, shrubs and lawns but not in surroundings which are completely barren. Without such greening, the tourist trade could be in some jeopardy. Accordingly this intangible benefit would be substantial but there are no simple ways to quantify it.

A more tangible method however is to consider that without treated sewage effluent landscape greening would have to be undertaken by using fresh water supplies.

The benefit of using treated effluent can then simply be considered as the difference in cost between fresh irrigation water supplies and the cost to produce and pressurise treated effluent from a centralised source.

The average cost of fresh irrigation water charged by the supply authority was about US \$1.0/m^3.

The estimated cost of provision and operation of effluent re-use facilities amounted to US \$0.35/m^3 thus giving a unit benefit of US \$0.65/m^3. Based on an availability of 2,271,000m^3/year (after evaporation losses) the benefit of the irrigation scheme would be US \$1,476,000 per year.

The capital cost of the irrigation scheme was also less than that of the alternative sea outfall option, and had the additional benefit of prevention of pollution of the sea.

The irrigation scheme was therefore adopted.

WATER BALANCE

Irrigation Demands

Based on climatic data for the area, net crop water requirements are summarised below.

Crop Water Requirements
(mm/month)

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Grass & Alfalfa	-	-	25	77	140	194	212	197	165	72	21	-	1103
Trees & Orchards	-	-	-	53	133	194	212	187	149	58	7	-	993

Landscape greening will mostly consist of lawns with flowers and shrubs. An overall water requirement of 1103 mm/year was therefore considered to be appropriate for this re-use scheme.

Irrigation methods adopted in Cyprus consist of drip, pop-up sprinkler, mini-sprinkler and conventional sprinkler. An average application efficiency of 75%, and transmission efficiency of 95% giving an overall 71% efficiency has been adopted for design purposes. Design requirements on an average monthly basis were therefore calculated to be:

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Duty l/s/ha	0.13	0.42	0.74	1.05	1.11	1.04	0.90	0.38	0.11

Areas to be Irrigated

Based on an assessment of annual water demand and availability, a schedule of areas to be irrigated by staged development was drawn up. The initial (1995) area of 30 hectares would be expandable to 142 hectares by the end of construction and commissioning of the scheme.

The areas were identified on the basis of overall priority and the programme of sewerage construction as the irrigation mains were to be constructed at the same time as the sewers.

Fig. 3 shows the areas selected for irrigation which comprise parks, gardens, road verges, playing fields and hotel areas.

Effluent Storage

A key element of the scheme is an effluent reservoir designed to hold winter effluent flows until required for summer use.

On the basis of inflow/demand/evaporation loss calculations a total storage requirement of 960,000m^3 was established. This was provided by the construction of reservoirs on land adjacent to the sewage treatment works.

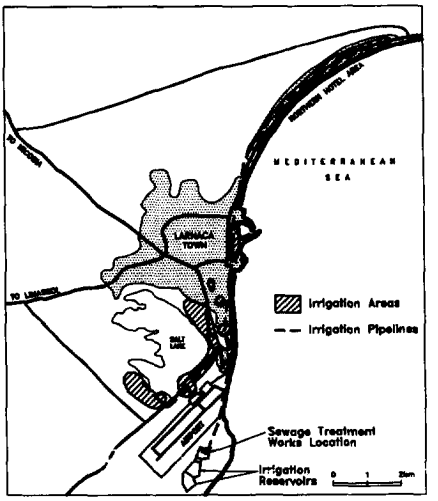

FIG.3 AREAS TO BE IRRIGATED

SCHEME FEATURES

Sewerage

The areas to be sewered are low lying (generally less than 5.0m above sea level) with high ground water levels, generally saline where below sea level.

The sewerage system was redesigned so as to reduce the depth of the sewers and thus reduce costs and ease construction problems, but also to avoid infiltration problems by locating the sewers above ground water level where possible. The sewers, 90% of which are 150mm diameter, were laid at comparatively flat (1 in 250 for 150mm dia.) gradients based on liquid shear stress and sediment transport considerations. A number of additional pumping stations were introduced into the system so as to limit the depth of sewers. The overall effect was to reduce the average depth of sewers from around 3.0m to about 1.5m and the maximum depth from about 7.0m to 3.5m.

The flat gradient and long sewer lines together with frequent pumping are all conducive to hydrogen sulphide generation and the system has therefore been designed to cater for this.

Sewage Treatment

Sewage is to be treated by a crude sewage extended aeration system constructed under a turnkey design and construct contract. The plant features:

- Totally enclosed pre-treatment facilities (screening/grit removal) with odour control
- 2 No. surface aeration oxidation ditches
- 2 No. final settlement tanks
- Sludge thickening
- Aerobic sludge digestion
- Open sludge drying beds

Effluent from the treatment plant which was specified as 20 : 30 (BOD:SS) standard will be pumped to adjacent storage reservoirs.

Effluent Reservoirs

Two storage reservoirs of a total storage capacity of 980,000m³ and having a full storage depth of 4.0m have been provided. Normally the reservoirs will operate in series via an interconnection with filling of one and withdrawing from the other, but each can be operated individually for maintenance purposes. The reservoirs are constructed from 'as dug' earth embankments with HDPE lining. The lining is necessary both for waterproofing and to prevent migration of salinity from the soil into the effluent.

Tertiary Treatment

Effluent from the reservoirs will be withdrawn through 4 rapid gravity sand filters and a chlorine gas disinfection facility. The required effluent standard after tertiary treatment is 10 : 10 (BOD:SS) with faecal coliforms not to exceed 100 per 100 ml. This is in accordance with the Cyprus standards of effluent quality for re-use purposes.

It is expected that the effluent storage reservoir will significantly reduce faecal coliforms thus reducing the requirements for chlorination, but no improvement in quality has been assumed in the design.

Irrigation Pumping

Effluent will be delivered to the distribution system by an irrigation pumping station arranged to supply effluent 'on demand' and maintain a minimum pressure of 5 bar at the pumping station by a selection of combinations of pumping units and a pressure vessel. The pumps are rated for a maximum demand of 324 l/s.

Irrigation Distribution System

The irrigation distribution system is being constructed concurrently with the sewers under three phased construction contracts comprising 'southern', 'central' and 'northern' components of the system.

The irrigation trunk main varies from 500 mm diameter to 250 mm diameter and extends approximately 15km from the treatment works to the northern end. Branches serve the various areas to be irrigated, including a 4km branch to the airport and Hala Sultan Mosque picnic area to the south of the salt lake.

Metered offtakes are being provided for users who will be required to provide their own systems for distribution of the effluent within their lands.

CONSTRUCTION

The sewerage, sewage treatment and effluent re-use facilities are being constructed in four contracts:

No. 1 - Sewage treatment plant, effluent reservoirs, sand filters, irrigation pumping facilities

Nos 2, 3 and 4 - Sewers, irrigation mains and pumping stations (southern, central and northern areas respectively)

Contracts 1 and 2 commenced in 1993 and are due for completion and commissioning in March 1995.

Contract 3 is due to commence early 1995 and Contract 4 in October 1995 with scheme completion due in 1998.

The making of property connections is to be the responsibility of the property owners and to the approval of the Larnaca Sewerage and Drainage Board. In view of the considerable sums currently being expended on tankering of sewage from the larger developments in the central area of the town it is anticipated that the majority of owners will be keen to connect, although there may be some resistance from single householders where the existing arrangement (mostly septic tanks with soakage areas) work adequately.

OPERATION

Initially the irrigation facilities will be operated by the Larnaca Sewerage and Drainage Board who will be responsible for managing the system including agreeing with users the quantities of effluent to be withdrawn and for charging them on the basis of quantities used.

It is expected that ultimately the operation of the scheme will be taken over by a new department to be set up by the Government which will be responsible for similar effluent re-use schemes elsewhere in Cyprus including Limassol and Ayia Napa.

CONCLUSION

The irrigation re-use facilities of the Larnaca Sewerage and Drainage Project show how sewage effluent can be turned from a pollution hazard to a beneficial asset at an economically justifiable cost and at a lower capital cost than the marine disposal alternative.

Experience elsewhere, particularly in the Gulf States, has shown that irrigation of amenity areas can be very successful and contribute to an enhanced environment to the benefit of all.

Close monitoring of the operation of the whole of the system (sewers, treatment plant and irrigation facilities) will be essential to ensure success of the system, with particular regard to prevention of saline intrusion and maintenance of health standards.

Acknowledgement

The authors would like to express their thanks to Mr R A Angier, Irrigation Consultant to Howard Humphreys, who was responsible for the field investigations and feasibility analysis of the irrigation scheme, and to the Larnaca Sewerage and Drainage Board for their permission to publish this paper.