The Water Resources of Lima, Peru

M. C. D. La Touche, MA, FICE *(Member)**

Abstract

Lima, the capital city of Peru, depends for its water supply on the resources of the River Rimac and the alluvial aquifer above which the city is situated. This paper describes the limitations of the present supply and possible new sources which could be developed to augment the water supply in future.

Key words: **Lima; resource development; water resources; yields.**

Introduction

The population of Lima has increased from 0.6 million in 1940 to 1.8 million in 1961 and almost 7.0 million today, and is expected to exceed 12 million within the next thirty years.

The city is situated at the foot of the Andes mountains in the desert strip which adjoins the Pacific coast of Peru and northern Chile. Despite being located within the tropics, the city has a temperate climate with a mean annual temperature of 18°C due to the cold Humboldt current which runs up the coast of South America from the Antarctic. Rainfall in the city is negligible.

Since the founding of the city in 1535, Lima has obtained its water supply from the River Rimac (Fig. 1). Water is drawn both directly by draw-off from the river and indirectly from the alluvial aquifer which underlies the lower reaches of the river and over which the city has been built. The organization which is responsible for water supply and sewage disposal in the city is the Servicio de Agua Potable y Alcantarillado de Lima (SEDAPAL).

Surface-water Resources

The River Rimac rises in the high Andes mountains about 100 km to the east of Lima (Fig. 1). Rainfall in the mountains is seasonal; at the continental divide, it varies from an average of about 6 mm in June to 170 mm in February, with an annual mean of about 1000 mm. The estimated open-water evaporation in the mountains (based on the Penman equation) is about 1100 mm/annum.

During the period 1968–92, the average annual rate of flow in the River Rimac at Chosica (about 40 km upstream from Lima where the river emerges from the mountains) has been about 31 m^3/s, varying from an average minimum of about 18 m^3/s during the dry season to an average maximum of about 60 m^3/s in March during the wet season (Fig. 2). The average river flow also varies considerably from year to year (Fig. 3). Dry-season flows in the river can also be substantially reduced in years when rainfall in the mountains is below average.

Lima's water supply is taken from the river through an intake operated by SEDAPAL at La Atarjea just upstream from the city and 28 km downstream of Chosica. Water from the river is also used to irrigate fields on the alluvial fan between Chosica and the city boundary, and parks within the city.

The actual average minimum flow in the river at Chosica exceeds the natural catchment flow of about 9 m^3/s, due to regulation provided by a number of small reservoirs (total capacity 76 million m^3) which have been constructed in the headwaters of tributaries to the River Rimac by the electricity supply company for the purpose of maintaining the output at five hydro-electric power stations in the catchment. Since 1969, the flow in the river has been augmented by a diversion across the continental divide, averaging 3.6 m^3/s. The diversion is regulated by storage in Lake Marcapomacocha and other nearby small lakes, amounting to 86 million m^3.

Yuracmayo is a recently completed conventional reservoir which has added 43 million m^3 to the storage available in the Rimac catchment and is estimated to increase the minimum flow at the La Atarjea water-supply intake in drought years by about 2.5 m^3/s.

During recent years the spread of the city over previously agricultural land has reduced the agricultural diversions from the river downstream of Chosica, augmenting the minimum flow at the La Atarjea water-supply intake.

The quality of the water in the river is affected by three problems. First is the high content of some heavy metals due to mining operations upstream; fortunately, these can be settled out at the water-treatment works. Secondly, contamination occurs from sewage discharges to the river, although sewage-treatment plants exist at Chosica and Chiclacayo, and others are planned. The third problem is due to very high sediment loads of up to 35 000 mg/l which can occur at times of high flow, and which result from landslides into the river in the steep canyons upstream. The material is washed downstream, resulting in high levels of suspended solids which may persist for several hours.

The River Chillon (average flow of 6.8 m^3/s), to the north of the city, has been used for irrigation only. In the low-flow season there is generally no discharge to the sea. The River Lunin (average flow 4.0 m^3/s), to the south of the city, is used for irrigation and local supplies, and dries up during the low-flow season.

*Consultant, Binnie Black & Veatch, Redhill, Surrey, UK.

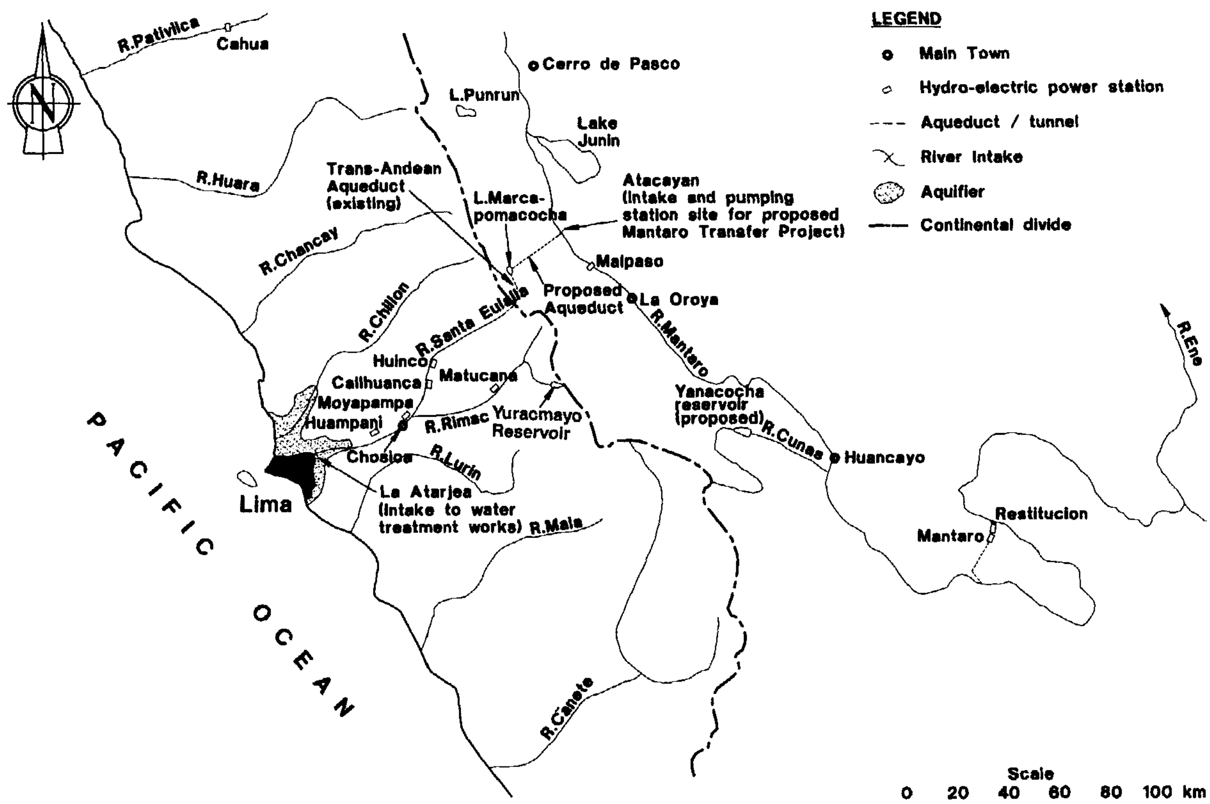

Fig. 1. Water resources for Lima

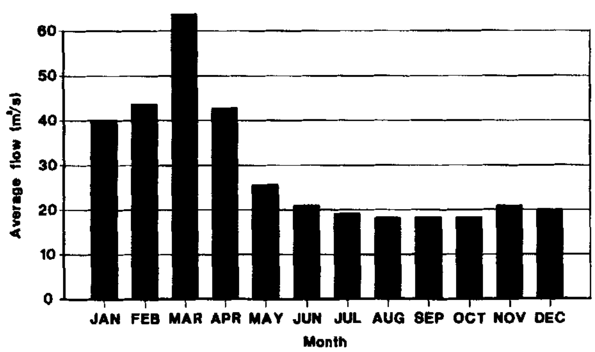

Fig. 2. Average monthly flows in River Rimac at Chosica

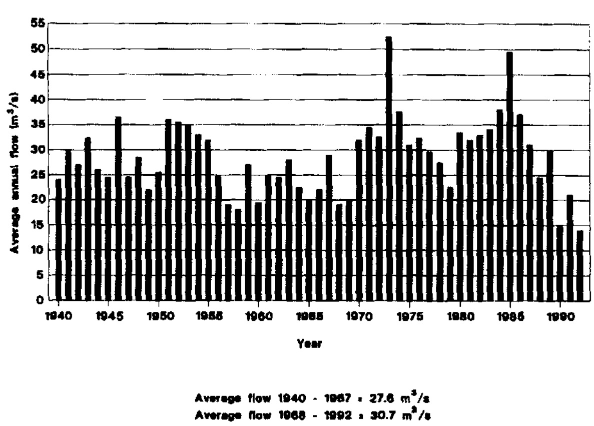

Fig. 3. Average annual flow in River Rimac at Chosica

Groundwater

Lima is situated on an alluvial fan crossed by the Rivers Rimac and Chillon in their lower reaches before they discharge to the Pacific Ocean. The estimated average abstraction from the aquifer in 1993 was 9.9 m^3/s, of which 7.3 m^3/s was from wells operated by SEDAPAL, the remainder from privately-owned wells to supply factories. However, during the years 1969–1992, groundwater levels were reduced by 15–30 m. The characteristics and future potential of the aquifer are described elsewhere[(1)].

Resource Management

The estimated demand for water in the SEDAPAL supply area has increased as the city has expanded, from an average of 13 m^3/s in 1970 to about 22 m^3/s today, and is forecast to reach 37 m^3/s by the year 2020.

Leakage from the distribution system is estimated to be about 34% of the supply – the remainder being mainly losses and wastage on consumers' premises. Action has been proposed to reduce percentage losses, and these are allowed for in estimates of future demand. Reductions in leakage from the distribution pipe network will not, however, add significantly to the resources available to meet the demand, since leakage is a component of aquifer recharge. To avoid depleting the aquifer at an even greater rate than is occurring at present, it will therefore be necessary to reduce abstractions by the same amount as leakage is reduced. The main benefit from leakage control will be reduced pumping costs.

In order to make better use of available sources, proposals have been made for the conjunctive use of surface water and groundwater. The capacity of the water-treatment plant will be increased so that in the high-flow season more water can be drawn from the river and fed into supply, while pumping from groundwater is correspondingly reduced. The capacity of the La Atarjea plant has already been increased to 20 m^3/s (in comparison to a normal river flow of about 15 m^3/s at the La Atarjea intake in the low-flow season) and a further increase to 25 m^3/s is contemplated. With conjunctive use, the aquifer acts as a balancing reservoir to compensate for the variation in surface-water flows.

Potential Sources

Although the new reservoir at Yuracmayo, together with conjunctive use and demand management, will help towards matching supply and demand, new sources are likely to be needed to meet the future estimated demand. Flow in rivers to the north and south of Lima is mostly committed to irrigation. However, some surplus is available which could be exploited for the benefit of the city. Proposals have been put forward to develop the resources of the River Chillon conjunctively with artificial recharge to give a yield of about 2 m^3/s. To the north of the River Chillon, the principal rivers are the Chancay and Huara with average flows of 15 and 28 m^3/s respectively. Yields of up to 11 m^3/s have been estimated for projected schemes using the resources of these rivers together with a trans-Andean diversion from Lake Punrun. To the south of the River Lurin the main rivers are the Mala (average flow 16 m^3/s) and the Cañete (average flow 52 m^3/s), but only about 11 m^3/s could be made available for Lima.

Water is already transferred across the continental divide from Lake Marcapomacocha, and many options exist for increasing the transfer. These include extending the catchwaters or pumping water from the River Mantaro which flows about 30 km to the east of the continental divide but at a lower level than the existing trans-Andean aqueduct.

Detailed designs and tender documents for a scheme to pump an average of 16 m^3/s from the River Mantaro to Marcapomacocha were completed in 1985. At the proposed intake point, the River Mantaro has an average flow of about 70 m^3/s. There are three hydroelectric power stations downstream and the river is regulated by releases from Lake Junin about 40 km upstream from the proposed intake. Lake Junin is a natural lake, but its level is regulated by a small weir across its outlet.

Flow in the River Mantaro suffers heavily from pollution, particularly heavy metals, due to upstream discharges of acidic minewaters, spillages from tailings lagoons, and effluent discharges from ore-processing plants at Cerro de Pasco. Action, already planned, to improve the quality of the water in the river would need to be implemented before it can be used as a source of potable water supply.

The Mantaro project did not proceed, due to lack of funds. Since then, studies have been undertaken to try to identify cheaper alternatives, particularly developments which would spread the required capital investment over an extended period. Possibilities exist for alternative trans-Andean aqueducts to the Rivers Chillon and Huara, as well as other routes delivering to the River Rimac.

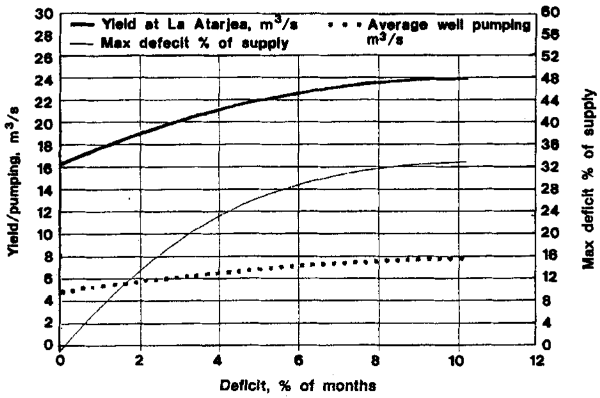

Fig. 4. River Rimac: water-supply yield at La Atarjea

Yield Estimates

In the 1980s, simulation computer models were developed to estimate the yields of the main surface-water schemes being considered. Groundwater potential was also assessed using a finite-difference model of the Lima aquifer[1]. More recently, a model of the Rimac catchment was prepared to estimate the combined yield of surface-water and groundwater sources following the commissioning of Yuracmayo reservoir and other proposed projects. The model was run using monthly river-flow data for the period 1968–93, and thus included the effect of the severe droughts in 1990 and 1992. The model output showed the number of failures (if any) to meet the demand and the severity of the corresponding deficits, as well as the average rate of pumping from groundwater. Fig. 4 shows how the yield of the combined surface-water and groundwater resources will vary – depending upon the criterion adopted for the acceptable frequency of deficits after the Yuracmayo reservoir is brought into use. The graph also shows the corresponding maximum probable deficit and the average rate of pumping from groundwater.

Conclusions

The object of this paper has been to summarize the yields and characteristics of the sources which are used to meet the demand for water in Lima, and to indicate the potential of those which might be developed in the future. Whether, and to what extent, new sources are developed will depend upon (i) the growth in the population of the city, (ii) the effectiveness of demand management measures, and (iii) the standard of supply acceptable to consumers; and will be influenced by economic, environmental and political considerations.

Acknowledgements

The author wishes to thank colleagues at Binnie Black & Veatch for their help and advice during the preparation of the paper.

Reference

(1) Watkins, M. D., Evans, D. A. and Lloyd, J. W. Continual assessment of the groundwater resources of Lima. *J. Ch. Instn. Wat. & Envir. Mangt.*, 1997, **11**, (6), 440