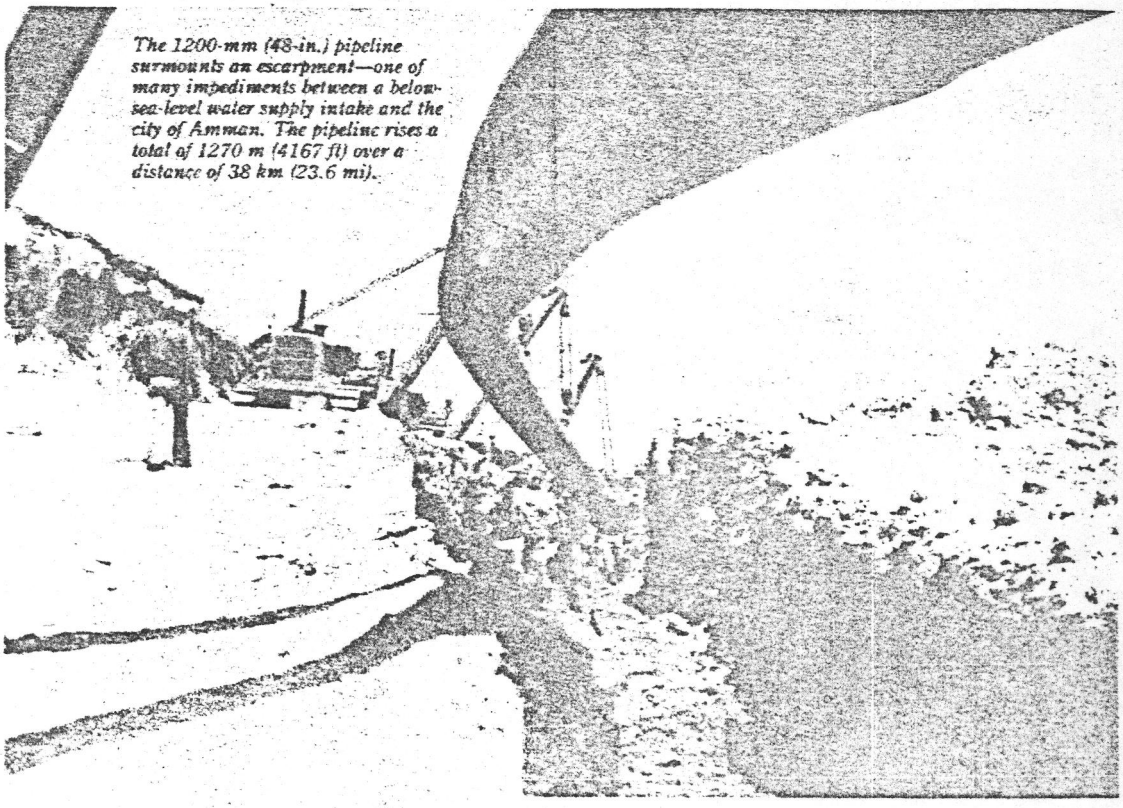


The 1200-mm (48-in.) pipeline surmounts an escarpment—one of many impediments between a below-sea-level water supply intake and the city of Amman. The pipeline rises a total of 1270 m (4167 ft) over a distance of 38 km (23.6 mi).

Jordan Meets Water Supply Challenges

L. Lynn Pruitt and Robert L. Thoem

A new water system for the Amman, Jordan, metropolitan area will be completed in early 1985. The surface water supply is taken from a canal at an elevation of 230 m below sea level and pumped in a series of steps to a treatment plant near the city at an elevation of 1040 m above sea level. The 121-ML (32-mgd) initial capacity of the system will approximately double the supply currently available for the city's nearly 1 million inhabitants.

A critical water shortage in Jordan's most populous cities, towns, and villages will be alleviated in early 1985 upon completion of a regional water supply network. The system will divert raw water from the East Ghor Main Canal, an irrigation canal in the Jordan River Valley, and deliver treated water through 38 km (23.6 mi) of pipeline to the Amman metropolitan area (Figure 1).

Jordan has a varied but generally arid climate. In the past, it has relied on groundwater sources for potable water supply. However, rapid economic development and population growth are outpacing the capacity of groundwater resources. The city of Amman, with a population of nearly 1 million, has experienced severe water shortages. Some parts of the city receive water service only once or twice a week. Nearly all buildings have roof storage tanks to provide water whenever the distribution system does not meet the demand.

Project description

The new system has an initial treated water design capacity of 45×10^6 m³/year or 85 m³/min (22 500 gpm or 32 mgd). This is approximately double the current curtailed water consumption; however, the demand for water is expected to increase significantly with availability of an adequate supply.

Water will be diverted from the Jordan Valley irrigation canal to an intake pump station, which discharges the water to storage tanks that provide presettling of the raw water (Figure 2). Four booster pump stations then lift the raw water to the treatment plant site. Another pump station provides the final lift to the

Journal of the American Water Works Association, Vol 76, no. 6
1984

terminal reservoir located on high ground just outside Amman. Water then flows by gravity to an existing reservoir in Amman. Water service for segment 2 of the project will be distributed from the terminal reservoir to other locations in Amman and to nearby communities. Design of segment 2 facilities has been completed, and construction will soon be under way.

Water in the canal is drawn from 230 m (755 ft) below sea level and pumped to the terminal reservoir, which is 1040 m (3412 ft) above sea level, a total lift of 1270 m (4167 ft).

The intake structure and the pump station are located on the floor of the Jordan Valley. Pump stations 1 through 4 are closely spaced up the steep Jordan Valley terrain to lift the water 1130 m (3706 ft) within an 11-km (7-mi) horizontal distance. The treatment plant is located at the top of the escarpment, followed by the fifth pump station and the new and existing reservoirs.

Unusual features

Several unusual features are associated with this project:

- A rugged, steep terrain makes construction difficult;
- Severe seismic conditions are equal to or greater than those found in the State of California;
- Soil conditions range from expansive clays to rock;
- A large-diameter, high-pressure pipeline crosses major faults;
- Pump stations require extremely high heads at moderate-sized flows;
- A major electrical transmission and distribution system was designed to serve the significant new power load; and
- A complete telemetry network was installed for system monitoring and control.

Intake pump station

At the intake, water is diverted from the East Ghor Main Canal through a bar screen to the intake pump station and then to traveling water screens. Four vertical pumps are provided, each with a capacity of 22 m³/min (5800 gpm) at an 18-m (60-ft) head. Vertical pumps were selected to reduce construction costs and to minimize space requirements in an agricultural area where land is extremely valuable.

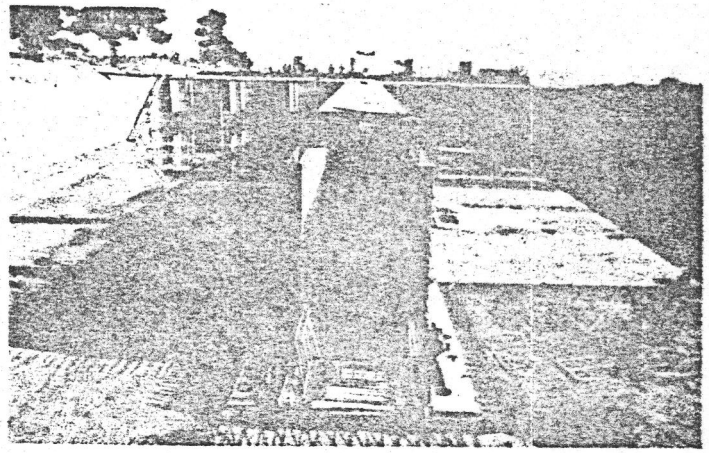
Pump stations 1 through 5

For the five high-lift pump stations, essentially the same layout was utilized to minimize design, construction, and operation and maintenance costs. To simplify operation and maintenance, pump stations 1 through 4 were located physically and hydraulically so that identical pumps and motors could be used at each station.

The pumps at each station lift water from a storage tank to a similar tank at the next station. Each storage tank is located approximately 20 m (65 ft) above the pump station to meet pump net-positive suction head requirements. Independent pumping was selected in lieu of direct in-line pumping to permit simpler system start-up and control.

Four horizontal centrifugal, single-stage pumps are provided at each station. Single-stage, rather than multistage, units were chosen to minimize maintenance. Units at stations 1 through 4 have a capacity of 22 m³/min (5800 gpm) each at a head of 285 m (935 ft). Each

The interior of the settling basin at the Amman treatment plant is shown during construction.



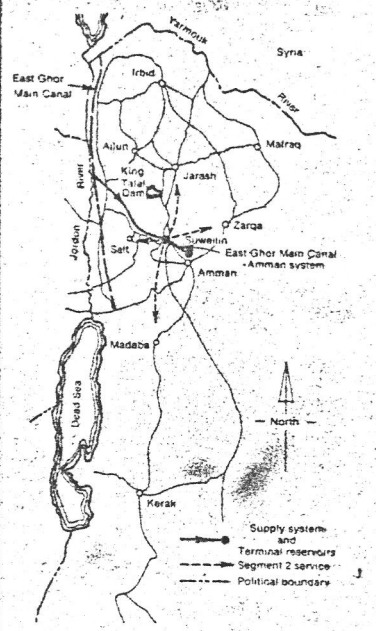


Figure 1. The Jordan Valley water system layout

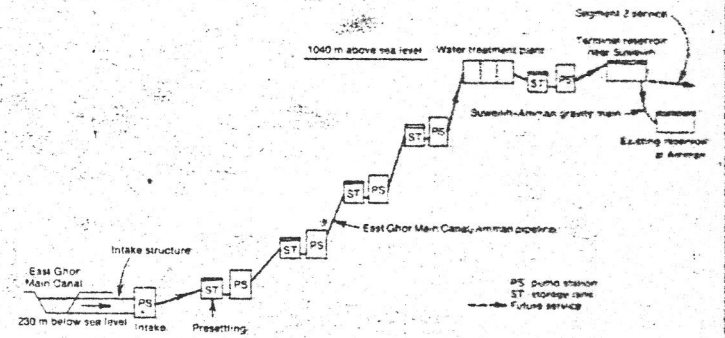
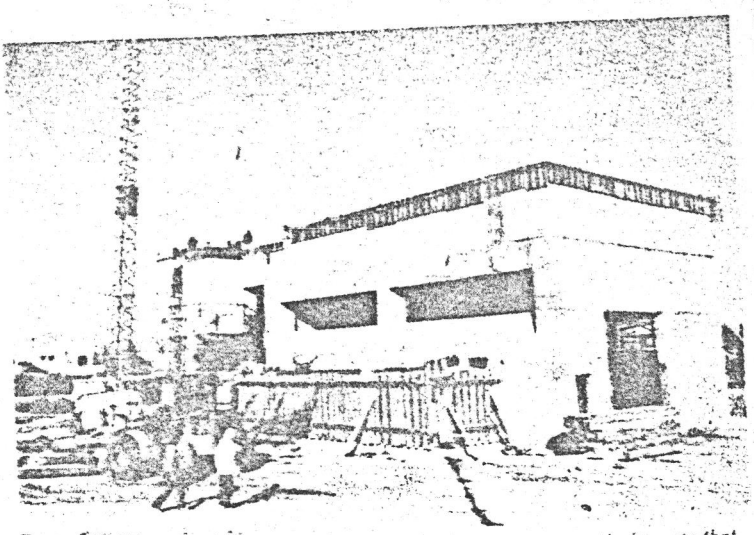


Figure 2. Schematic of the first segment of the Jordan Valley water supply system



The intake pump station under construction will house the four vertical pumps that were chosen to reduce construction costs and to minimize space requirements, since arable land in Jordan is extremely valuable.

pump at station 3 is slightly smaller, with a capacity of 21 m³/min (5650 gpm) at 198-m (650-ft) head. Because of the high cost of electrical power in Jordan (US $0.06/kW-h when this project was designed in 1979), a minimum pump efficiency of 84 percent was specified, with a penalty clause for those not meeting this level of efficiency.

Pipeline

The pipeline from the intake pump station to the terminal reservoir is 29 km (18 mi) of 1200-mm- (48-in.-) diameter steel line. A 9-km- (5.6-mi-) long, 1000-mm (39-in.) steel line is used between the two reservoirs in the Amman area. Because of the high power cost, head loss throughout the hydraulic system was kept low. Life-cycle cost evaluations were used to select pipe diameters.

The pipeline is divided into three pressure classes, with design pressures ranging from 1723 to 3861 kPa (250 to 560 psi). High pressures and potential seismic forces resulted in selection of steel pipe for the entire project. The pipe is butt-welded, coated, and lined and has a 1-m (3.3-ft) minimum cover. Cathodic protection is provided.

Special trench configurations and bedding and backfill compaction are provided at fault crossings to allow for pipe movement during an earthquake.

All large-diameter pipe will be field bent, using techniques from the oil and gas pipeline industry, to meet the numerous vertical and horizontal curves required by the rough topography.

Treatment plant

The location initially proposed for the water treatment plant was in the Jordan Valley near the intake structure. This would have allowed the pumping of treated water throughout the pipeline, minimizing deposition of solids in pump storage tanks and increasing potable water service off the transmission line. However, during the geotechnical and seismicity studies, it was determined that subsurface conditions at this location were unstable, so the water treatment plant was relocated to the top of the escarpment and out of the Jordan Valley. The 45 × 10³ m³/year (32-mgd) treatment facility is designed to provide water that meets the World Health Organization guidelines of acceptability under varying raw water conditions.

Treatment facilities consist of a raw water regulating basin, flocculation and settling basins, dual media filters, clear well, sludge drying beds, wash-water recovery basin, and chemical and control buildings. All flow through the plant is by gravity. The raw water and clear well basins allow for some emergency storage in case of pump station, treatment plant equipment, or power failure.

Terminal reservoir

The terminal reservoir has a capacity of approximately 247 000 m³ (65 mil gal), providing about two days of storage at the design flow rate. The large capacity provides for power or equipment failures of longer duration and periodic shutdowns for maintenance purposes. This approach was selected in lieu of providing major standby equipment and electrical generating capabilities throughout the system.

The concrete reservoir is divided into three major basins with separate inlets and outlets. Its unusual shape is dictated by available land, topography, and subsurface soil conditions.

Controls

The master control center for the entire project is located at the treatment plant; however, each pumping station will also have its own local control panel. A monitoring panel will also be located in the operating agency's management office in Amman. Voice communications between all operating facilities will be possible. As much automatic control as practical is provided but not to the point of excluding operator decisions and overrides.

Construction costs

Engineering studies for this project started in July 1979, and the design was completed 10 months later in May 1980. Project reviews and arrangements for financing from several funding sources required more than a year, with bids being received in late 1981. Contract agreements were finalized in May 1982 with Korean, Lebanese, British, and Hungarian construction firms. The project was separated into five contracts, and the total cost is approximately US $107 million (after currency conversions). The pipeline contract constitutes 40 percent of the total cost, pump stations 23 percent, treatment plant 20 percent, terminal reservoir 16 percent, and electric transmission 1 percent. Construction is currently scheduled to be completed in early 1985.

A life-cycle cost analysis indicates this project will supply potable water to the Amman region at a unit cost of approximately US $0.80/m³ (US $3.03/1000 gal). Although this is a higher unit cost than that for existing groundwater sources, it is about one fourth the cost of water that is routinely delivered by truck in Amman.

This water supply project is being administered by the Jordon Valley Authority and represents a significant undertaking for the Kingdom of Jordan.

About the authors:
L. Lynn Pruitt, a hydraulic engineer who is design manager for Stanley Consultants, Inc., Stanley Building, Muscatine, IA 52761, has worked on several water supply projects in Jordan in addition to the Amman project. Since 1978, he has visited the country eight times. Robert L. Thoem is a senior project manager with Engineering-Science, Inc., 57 Executive Park South, Atlanta, GA 30329.