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Development of an Operational Strategy for Controlling the Water Quality in the Jordan Valley

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DEVELOPMENT OF AN OPERATIONAL STRATEGY FOR CONTROLLING THE WATER QUALITY IN THE JORDAN VALLEY

By Azm S. Al-Homoud
Professor of Civil Engineering, School of Engineering
American University of Sharjah, P. O. Box 26666
Sharjah, United Arab Emirates, E-mail: ahomoud@aus.ac.ae

ABSTRACT

The Karameh Dam Project will comprise the construction of an earthfill embankment dam to form a storage reservoir in the Wadi Mallaha. This wadi is a tributary of the Jordan River and is situated near the town of Karameh in the Jordan Valley. The reservoir is to be connected with the King Abdullah Canal (KAC) by means of a twin pipeline system which will be used to fill the reservoir during the winter months and which will allow pumping from the reservoir back into the canal during the summer. The reservoir will impound a gross storage volume of about 55 MCM with a surface area of approximately 5 km^2 at full storage level. The primary objective of the storage of surplus winter flows is to allow further development of irrigation in the Southern Zone of the Jordan Valley.

A detailed study of water quality has been undertaken to assess the suitability of water stored in the reservoir for irrigation purposes. The study included qualitative and quantitative measurements of flows in the KAC, the Zarqa River, the Wadi Mallaha and its tributaries and in the reservoir basin. This paper summarizes the analytical testing programme and evaluations undertaken during the study period. It summarizes the likely future water quality in the Jordan Valley during the proposed reservoir service life. An operational strategy for controlling the water quality in the reservoir and ensuring delivery of appropriate water to the irrigated land of the Southern Zone is described.

The study was commissioned to determine a likely operating regime necessary for the Karameh Reservoir in order to supply water of suitable quality for irrigating crops in the southern Zone. This paper summarizes Reservoir Water Quality Studies and collates the data gathering.

The principal source of water for the Karameh reservoir is excess winter flows in the King Abdullah Canal (KAC) However, it was recognized that the highly saline inflows to the reservoir from Wadi Mallaha catchment itself could have an effect on the overall quality of water in the reservoir.

Within the reservoir, water quality will be reflected by the chemical and physical combination of the inflowing waters. In order to identify both water quality and relative flow rates of the primary sources of water into Karameh Reservoir, a water quality sampling programme was developed which included establishing a number of sampling and flow measuring stations. These were specifically chosen to represent all potential sources of inflow to the reservoir, and comprise the King Abdullah Canal (KAC), the Zarqa River, the Wadi Mallaha and artesian flows in the reservoir basin. Flow measuring stations were located on the Wadi Mallaha and its tributaries and were designed to record any uncontrolled base flows into the reservoir basin. Some data records supplied by the JVA from 1959 onwards were used to try to establish long term trends in water quality and thus were related to the recent data collected over a one year period.

An operational strategy has been recommended to limit a salt build up in the impounded water body. When the electrical conductivity of water reaches a value of 4000 μS/cm it will be flushed to the Jordan River. This threshold value of 40O μS/cm is considered to be the concentration which would maximize the returns of the required cropping patterns, yet still utilize the available water in the most effective manner. It should be noted that the strategy is based on the theoretical modeling of mixing of the waters entering the reservoir. The factors which will determine actual quality are very complex and inter-related and cannot be fully modeled. Such factors include chemical reaction, temperature, release rates, nutrient loading and eutrophication. The actual operating regime must be developed with monitoring and experience of the reservoir during and after first impoundment. It is anticipated that the operating strategy may need modification to suit the quality of the water entering the reservoir.

Thermal stratification of the reservoir is likely to occur in the early summer when air temperatures increase and periods of calm weather prevail. Towards the end of October the thermocline will break down and the autumn turnover will occur, causing mixing within the water body.

Due to the concentrations of nutrients in the source waters it is anticipated that algae will develop in the upper parts of the water column particularly during periods of calm weather. High chlorophyll concentrations in the top meter of the reservoir could be common and it would be necessary for the water to be drawn off below the layer enriched with algae. Species of blue-green algae are likely to develop near the surface and these can produce toxins which at high concentrations can be harmful, or in extremes, lethal for livestock.

A destratification system in the reservoir will thus be necessary to eliminate the anoxic hypolimnion and reduce the total algal biomass. The construction of a drop structure at the KAC turnout will further assist in oxygenating the water as it enters the canal.

The study has shown that although the quality of water provided from the Karameh reservoir under the recommended operating conditions is poor relative to the water currently available from the KAC, it is nevertheless considered to be satisfactory for the development recommended. A water management operating strategy has to be developed during the early years of operation taking account the quality of the water entering Karameh, cropping patterns, irrigation methods and water quality management practices. The farmers will also need to ensure that the appropriate agricultural practices are adopted if the anticipated yields are to be realized.

The various primary source waters have been characterized in terms of determinands which contribute to reservoir water quality and which are of greatest relevance to the irrigated crops, particularly their yield. These characteristic determinands have been introduced to a numerical mixing model of the Jordan Valley Water Resource System to simulate the interactions of the various source waters, and to permit qualitative and quantitative predictions of the water which will be available for irrigation purposes.

In addition, the results from the Reservoir Water Quality Studies have been examined with historical data to assess the nature and seasonal variations in the source waters and the potential for, and/or extent of, stratification within the entrained water body. Based on this assessment, recommendations for the operation of the reservoir have been made.

The Karameh Reservoir will retain water from a number of sources which vary in chemical composition. The Reservoir Water Quality Studies have been undertaken to quantify the existing chemistries and flows of the various water sources which will be the input of the reservoir. The factors which determine the actual quality of a water body are however chemically very complex and interrelated and cannot be fully modeled.

As the Karameh Reservoir will receive water from a variety of sources and its chemical composition and behavior when mixed will reflect the make-up and relative contributions of these sources, the principal source will be surplus winter flows from the Yarmouk and Zarqa river transferred along the KAC.

The quality and quantity of some of the principal water sources, the Yarmouk and northern wadis as Ear south as Zarqa, have been deteriorating over the last 30 years or so. This deterioration is due to urbanization, industrialization and increasing abstraction of aquifer water. Direct inflows to the reservoir from irrigation returns and artesian sources are already highly saline but are unlikely to deteriorate further.

During the very early life of the reservoir it is anticipated that salts from soils in the reservoir basin will be washed out more rapidly than in later years. The concentration of salts within the impounded water body in the first years is therefore likely to be much higher than predicted using the numerical model.

The quantity of water entering the reservoir from Irrigation returns and artesian sources will be about 150 Us if no diversion of these waters takes place. Of this, approximately 15 to 25 Us will be from artesian water if the reservoir were empty. When the reservoir is full the artesian pressure will be balanced by the reservoir head and such inflows will effectively ease until drawdown occurs. It is estimated that these water could contribute 75% or more of the total salts in the reservoir body.

The quantity of artesian waters entering the reservoir basin reflects the current Hydrogeological regime. This situation may be markedly affected by future seismic activity leading to a change in flow pattern and a possible increase in artesian inflows.

It is considered that to optimize the use of this water resource an operational strategy is adopted whereby all the water is flushed from the reservoir when its electrical conductivity exceeds 4000 µS/cm. The operational strategy can be modified as monitoring data is input to the mixing model. Revised operational strategies can be devised to suit the existing water quality and any changes in demand at the field edge.

The reservoir water body will stratify each summer but be mixed in the cooler winter months. The mean thermocline depth will be some 10 m or so below the reservoir surface when at full storage level. During calm periods a second thermocline may develop close to the reservoir surface.

The reservoir will contain high nutrient levels and algae will develop m the stratified reservoir. Oxygen demand caused by algae will lead to the development of oxygen deficient water entrapped beneath the thermocline. In these reducing conditions chemical changes will occur in the water and sediments and the quality will be reduced. Should considerable reduction occur in the hypolimnion then water discoloration and release of gas are likely to occur. Additionally the oxygen demand at the turnout into the KAC will be large and gas release and the development of certain anaerobic bacteria may occur. Precipitation of ferrous compounds may also occur in the irrigation system which may cause operation problems.

To avoid the build up of algae in the water body it will be necessary to artificially destratify and aerate the reservoir. Destratification will have the multiple benefits of reducing the total algal biomass, selecting against blue-green algae and eliminating the anoxic hypolimnion. This will have a substantial and beneficial impact upon the overall water quality, with well mixed conditions and relatively low concentrations of algae.

The construction of a drop structure at the KAC turnout will further assist in oxygenating the water as it enters the canal and reduce the risk of gas release, bacterial development and blockages within irrigation pipework.

A range of measures have been investigated to control the quality of the water in the proposed Karameh reservoir in order that a satisfactory standard of water may be delivered to the irrigated lands. These measures are part of an overall water quality management strategy, incorporating a comprehensive monitoring programme to begin during the construction phase are essential for the successful operation of the system. The strategy must be developed and refined as experience of operations is gained in the early years of service.

It is strongly recommended that a comprehensive water quality monitoring programme is developed during the construction period and first few years of operation. This will permit the development of and appropriate operation strategies. Monitoring should include sampling of source waters as well as mixed waters in the reservoir itself. Temperature and salinity gradients, oxygen demand, nutrient bevels and the concentration of a number of key determinands should be regularly measured throughout the entire water column at a number of locations in the reservoir.

It is recommended that electrical conductivity is adopted as the primary indicator of wafer quality in the reservoir and is monitored continuously. Operation strategies may, therefore, be expediently controlled using regular determinations of electrical conductivity.

Based on the findings of the study it is considered that the most effective and economic means of controlling reservoir salinity is to evacuate all water from the reservoir when its salinity exceeds 4000 μS/cm.

Water quality in the reservoir is improved if the ratio of saline wadi water in the reservoir to fresher KAC water is kept as low as possible. It is therefore recommended that measures are taken to divert as great a proportion as possible of the wadi flows which permanently enter the basin above FSL. It is also recommended that studies are carried out to examine ways of transferring larger volume of floodwaters into the reservoir, either by increasing the flow carrying capacity of the KAC downstream of Abu Ezzeghan, or perhaps by diverting water from the Zarqa or Jordan rivers into the reservoir.

The reservoir is part filled and emptied during the construction period (when the embankment is constructed to a sufficient height) in order that salts on the base and sides of the basin are dissolved and flushed away. As the water quality during the early filling will be poor, it is recommended that provision be made for complete flushing of the first year's water and reduced reservoir yield for a number of years thereafter. In parallel with this filling, sampling should take place to determine the insitu release of salts from the soils to the water.

It is recommended that a destratification system, such as a bubblier system be installed to promote vertical mixing of the impounded water and thus destratify the water column.

To ensure that anaerobic water does not enter the KAC in significant quantities it is recommended that a drop structure, or other form of reaerating structure, be incorporated into the turnout. All waters pumped from the reservoir would thus benefit from aeration at this location.

To minimize the risk of humans or livestock drinking water that could contain toxins from blue-green algae, a security fence should be placed around the reservoir at full storage level. A programme of water quality testing similar to the testing carried out for this study, should be continued throughout the period of construction to provide further confidence to establish trends and seasonal variations to the water quality database. This will enable better dentition of data used in the mixing models and hence the most appropriate operation strategy for operation of the reservoir.

It is recommended that the surplus flow in the KAC is used during the period of construction of the Karameh dam to leach the salts from the soils of the Southern Zone. These soils are currently relatively saline and it is thought that a period of prolonged inundation would lower the salt levels in preparation for the use of irrigated water from the Karameh reservoir.

It is recommended that the agricultural extension services be alerted to the general deterioration of the water resource with time and in particular the quality of water that will be available from the Karameh reservoir. A strategy for informing farmers of its use combined with a general improvement in agricultural practices can then be in place prior to arrival of the first water. In particular, salt sensitive crops such as citrus and banana should not be irrigated from the KAC and the irrigation system for existing plantations should be isolated from the KAC. Investigations should also be put in hand into the possibility of early planting of dates using alternative water supplies to shorten the period prior to commercial production. Records of crop yields following the use of Karameh water should be maintained. Any modification in market requirements and hence the quality of the irrigation source water can then be considered to establish the most appropriate operating strategies for Karameh.