

RESERVOIR OPERATION STRATEGY TO ENHANCE DOWNSTREAM WATER QUALITY; NEW APPLICATION OF CE-QUAL-W2

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ABSTRACT

In this research, various reservoir operation strategies in selective withdraw framework and with different satisfaction reliabilities are defined in Karkheh Reservoir. The “what-if” scenarios in Karkheh Reservoir, as the largest and multi purposes hydraulic project in Iran are evaluated using CE-QUAL-W2 model. The 2D hydrodynamic and water quality simulation model is modified to blend water from multiple vertical outlets and calculate the performance criteria to choose appropriate reservoir operation in the selective longitudinal and/or vertical withdraw scheme. CE-QUAL-W2 model is applied to evaluate Karkheh Reservoir responses to various boundary conditions and to explore the potential for changing reservoir operations in order to enhance downstream water quality to benefit declining Karkheh ecosystem. Total Dissolved Solid (TDS), NO₃, PO₄, and dissolved oxygen (DO) are the main indicators considered to evaluate the performance of different reservoir operational strategies in Karkheh Reservoir. Various reservoir operational strategy in selective withdraw scheme are contrasting and comparing based on aggregate index of water quality indicators (TDS, NO₃, PO₄, and DO). Application the simulation methodology demonstrated the utility of this approach, which works well and provides proper results.

1 INTRODUCTION

Water pollution is one of the serious threats to human health and environment. The various waste due to human related activities introduced into rivers, lakes, reservoirs, groundwater aquifers, and coastal sources and cause water pollution. The contaminated water is unsuitable for different uses such as drinking, agricultural, industrial, terrestrial and aquatic ecosystems (Ganoulis, 2009).

In the artificial water resources systems such as reservoirs, design and operation of engineering structure have more effects on the quality of water resources and aquatic ecosystem. During recent decades, more attentions have been paid to environmental impacts in addition to economics and safety issues in reservoir planning and operation.

In this regards, the water quality and environmental issues have been considered as one of the main technical aspects of water resources systems.

Large dams have major effects on the natural characteristics of water resources. In addition to hydrological changes, physical, chemical, and biological characteristic of water body would be influenced (Friedl and Wuest, 2002) by water impoundments. In the other words, the long residence time of reservoir water containing nutrients and other pollution constituents is problematic because most constituents can persist much longer time under regulated water flow condition compared with natural river condition (Chung and Gu, 2009). The reservoir water quality affects environmental interest such as wildlife and aquatic ecosystem, and can impact and/or impair water uses. Reservoir managers and the operators have come to the realization which operational modification of reservoirs should be considered to improve the environmental issues (Ganoulis, 2009).

Water circulation currents affect the fate and transport of pollution in the water body. The pollutions are subject to advection, turbulent dispersion, diffusion, different type of decays (physical, chemical, and biological), and etc. Traditionally, allocation appropriate amount of water to a given demand is defined as water resources management process. But nowadays, water allocation should be assigned in a way to satisfy the both water quality and quantity.

Water quality in reservoirs is influenced by natural hydrological and/or meteorological events and human interference. Pretreatment or control the pollution inflow to reservoir, in-pool management, and management reservoir outflows are some human planning to manage water quality in reservoirs (Dortch, 1997). The first and second management alternatives are beyond the scope of this research. Among the three management alternatives, reservoir operation strategy is the most common applicable techniques employed in reservoir water quality managements. Reservoir operation strategy in selective scheme consists of timing, amount, and depth of reservoir discharges which affects the temporal and spatial trend of pollutions in reservoir and downstream water. During recent decades, there would be some research on reservoir water quality management based on reservoir operational strategy technique.

Dai and Labadie (2001) integrated MODSIM and QUAL2E model to incorporate water quality standard constraints in water allocation in the river basin network. The proposed methodology applied to the lower Arkansas River basin in Colorado which successfully models the complex legal and administrative issues including the many water exchange mechanisms governing use of off stream reservoirs in the basin. The proposed water quality and quantity model determines the solutions satisfying water right priorities, while attempting to maintain minimum water quality requirements. Campbell et al. (2001) implemented computer models of water quantity (MODSIM) and quality (HEC-5Q) to evaluate alternative water management scenarios in the main stem Klamath River from Keno, Oregon, to Seiad Valley, California. The water quality and quality models were used to evaluate various system operations to explore the potential reservoir operational strategy enhancing downstream water quality to improve fish habitants. In 2007, MERES as a water quality simulation model implemented by Stamou et al. to determine the minimum water level (MWL) in Plastiras reservoir in Greece as a multi-purpose reservoir. The reservoir operational strategy is defined corresponding to various values of MWL. Ensuring a very good water quality, providing a given annual water supply with acceptable reliability, and a very good

quality of landscape with an acceptable area of dead zones were the main criteria of selected MWL. Olsson et al. (2010) implemented a water quality simulation model and water balance criteria to evaluate the effectiveness of proposed reservoir operation strategy compared with conventional operation strategy in Kaparas reservoir, which is located in the lower Amu Darya River, on the border of Turkmenistan and Uzbekistan. The water quality simulation model provides effective tools addressing the complex water quality process even more under stressed conditions.

Various descriptors can be applied to characterize water quality issues in water body. Temperature and dissolved oxygen (DO) can be introduced as the primary issues for most reservoirs since temperature affects physical and chemical reaction rates, biotic growth rates, and fishery habitat (warm, cool, or cold-water), and aquatic life is depend on oxygen availability. Nutrient enrichment accelerates the algae productivity causes oxygen depletion, taste, and odor problems. Total dissolved solids (TDS), as a major character of drinking water supply and other uses, and total suspended solids (TSS), as an important transport mechanism for nutrients and contaminants in reservoirs, are some water quality indicators describe the system characterize (Dortch (1997)). Describing the system performance with several water quality constituents complicates the decision making process. Therefore a water quality index (WQI) should be defined to summarize existing water quality data, to communicate information on the quality of the affected environment, and to evaluate system vulnerability to the pollution (Canter (1997)).

This paper discusses the Karkheh Reservoir responses to the series of alternative reservoir operation scenarios defined by the user to investigate the potential for enhancing the downstream water quality in Karkheh Reservoir. Particularly, the various reservoir operation strategies are evaluated by 2D hydrodynamic and water quality simulation model to determine whether changes in Karkheh Reservoir operation could alleviate the water quality of released water. The reservoir operation strategies included changes in the timing, quantity, and location of withdrawals of water in Karkheh Reservoir.

2 RESERVOIR OPERATION

Reservoir operation is a more common technique to enhance downstream and in reservoir water quality. The amounts, timing, and location of withdrawal ultimately determine the vertical and longitudinal distribution of temperature, dissolved oxygen, and nutrients. Changing the reservoir operational strategy modify the hydraulic residence time whereas the impure inflow water can be released or retained to allow sedimentation and/or nutrient enrichment (Dortch, 1997). Modification the reservoir operating rule curve for water quality enhancement should incorporate other reservoir purposes. Sometimes, the amount, location, and timing of water release cause conflict consequence in reservoir objectives. For example, many tall hydropower reservoir operation managers prefer to release water from only upper outlet to maximize power generation (such as Karkheh Reservoir). But epilimnetic withdrawal increases stratification stability resulting in less transfer of DO from the epilimnion to the hypolimnion. Hypolimnetic DO depletion accompanied by sediment nutrient release results the undesirable outcomes in reservoir (Dortch, 1997).

Whereas reservoir operation is employed to control downstream and in reservoir

water quality, selective withdraw scheme in reservoir operation has profound impact on water quality. In fact, reservoir operational strategy based on selective withdraw scheme is an important phenomena in the transport and fate of temperature and constituents in reservoirs. The selective withdrawal scheme pulls out water from stratified layers in reservoir trough selected depth. In fact, this strategy would be applicable in reservoirs with multi vertical and/or longitudinal outlets. The withdraw location (level and/or longitudinal position) affect reservoir and downstream water quality.

The fate and transport of constituents would be complicated in the stratified and changeable circulation patterns reservoirs. Therefore, a numerical simulation model is required to model the distribution of constituents in reservoirs both temporally and spatially. The mathematical water quality simulation models predicts the physical, chemical, and biological processes governing water quality in water bodies such as reservoirs, lakes, and rivers.

3 MODELING

Water quality simulation models are such as effective tools to predict the fate and transport of pollutions in reservoirs under various management decisions. The effect of input contamination flow rates and reservoir operational strategy based on selective scheme may be assessed by mathematical and numerical water quality simulation model prior to implementation. Access to the calibrated and validated water quality simulation model in the reservoirs with the main technical and/or political objectives is preferable to analyze various “what-if” scenarios in decision making process. As an example, satisfying the downstream water quality targets is determined by comparing and contrasting several reservoir operation strategies based on selective withdraw framework with the aid of water quality simulation model. Temperature, DO, TDS, NO_3 , and PO_4 are the most common water quality parameters considered as a quality targets. Considering several water quality constituents increases the conflicts and decision making complexities.

CE-QUAL-W2 is a longitudinal-vertical hydrodynamic and transport model programmed to simulate long-term, time-varying water quality responses of lakes, reservoirs, and estuaries. The vertical and longitudinal temperature and water quality gradients reproduce in CE-QUAL-W2 accurately even during multi decades. The simulation algorithms of temperature and twenty two water quality constituents are included in CE-QUAL-W2 programming codes. Other parameters and formulations are easily accommodated in the modular code by the advanced water quality modelers.

Laterally averaged equations of momentum, continuity, and transport are included in CE-QUAL-W2 model which incorporate the vertically varying, longitudinal momentum balance, vertical momentum in the form of the hydrostatic approximation, local continuity, vertical integration of the continuity equation based on a free surface condition as one of its boundaries, and longitudinal and vertical transport of any number of constituents (Cole and Wells, 2008). CE-QUAL-W2 is an efficient tool to simulate the fate and transport process of pollutions in reservoirs according to various reservoir discharges from multiple outlets.

In this study, a new subroutine is programmed to CE-QUAL-W2 version 3.5 to blend water from multiple vertical outlets to estimate water quality constituents released downstream, calculate WQI based on some water quality indicators (DO, TDS, PO_4 ,

and NO_3), and determine the statistical functions of reservoir responses to the several operational strategies in selective withdraw schemes. The minimum and maximum values of WQI and the statistical functions calculated based on daily water quality released downstream provide the favorable criteria to evaluate the performance of reservoir operation strategies. These criteria may provide valuable information for managers in decision making process before implementing the defined scenario. Based on the results, the proper reservoir operation strategy in selective withdraw scheme (vertical and longitudinal withdraw), enhancing downstream water quality parameters, is chosen as the proper alternative.

The model user provides the type and location of all available outlets (vertical and longitudinal outlets), the time series of the reservoir discharges, the withdrawal percentage of each outlet, the satisfaction reliabilities, and the stress related water quality parameters. The model and its new subroutine then assigns various amount and location of withdraw in reservoir to provide the time series of system responses. Then the minimum and maximum values of WQI and other statistical functions based on Karkheh Reservoir responses are calculated in new routine.

4 STUDY AREA AND TEST CASE

In the semi arid south west of Iran the Karkheh Reservoir as vital water resources supplies the hydropower, municipal, industrial, agricultural, and environmental demands of millions of users. Karkheh Reservoir was constructed by Iran Water and Power Company (IWPC) in 1998. The reservoir is the largest artificial lake in Iran and can store up to 5000 MCM of water. With $5 \times 10^9 \text{ m}^3$ capacity, 64 km length, and 162 Km^2 surface areas in normal water level (220 masl.), the Karkheh Reservoir is located on $32^\circ 50'$ and $48^\circ 15'$ latitude and longitude, respectively. Its average and maximum depth are 61.8 and 117 meters, respectively (Afshar and Saadatpour, 2009). Because of environmental concern in downstream reach of the Karkheh River, more attentions should be paid to the released water quality enhancement. The hydroelectric plant being constructed at the Karkheh dam will be capable of generating 934 GWh of electricity per year.

Karkheh Dam has four outlets located in longitudinal and vertical positions in the impoundment. Dasht Abbas tunnel as a longitudinal withdraw located in the length 45 Km on elevation 176.5 masl. along the Karkheh Reservoir. The remains three outlets located in the length 60 Km as the reservoir intake; the bottom outlet is used for sediment flushing and the middle outlet (outlet 1) and upper outlet (outlet 2) can be used for the selective withdraw. The upper outlet is used for supplying the demand of hydropower plant, municipal, and agricultural. The middle outlet is used to supply only municipal and agricultural demands. The Dasht Abbas tunnel transferred the required water for agricultural demands to Dasht Abbas, Fakeh, and Mousian plains.

The geographic location of the Karkheh river basin in Iran and the study area of Karkheh Reservoir and its relative stations are shown in Figures 1 (a) and (b).

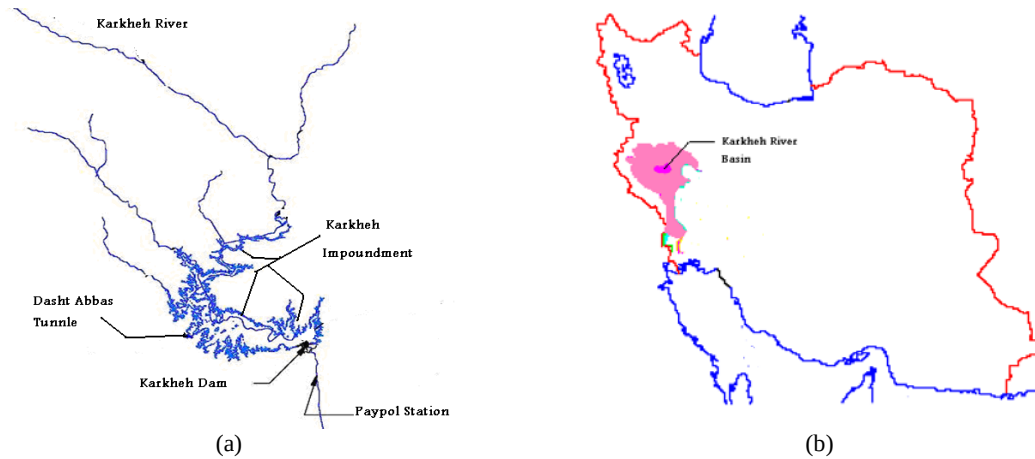


Figure 1: (a) The Study Area of Karkheh Reservoir and its longitudinal Outlet Positions; (b) The Geographic location of Karkheh Basin in Iran

The construction of Karkheh Reservoir imposed environmental changes on downstream waterway and invaluable ecosystem. The potential downstream impacts of Karkheh Reservoir can affect both the quality and quantity of a water resource. The changes in downstream hydrology may affect the ecological values of aquatic ecosystems. Water quality has both aesthetic (taste, appearance, and odor) and health related (chemical and physical contaminants) components. The changes in water quality parameters include nutrients, salinity, and DO. It should be recognized that the downstream ecosystems of Karkheh Reservoir require given regular seasonal flow cycles with suitable quality to maintain aquatic biota and ecosystem processes. Unfortunately, changing the hydrological regime and water quality pattern of Karkheh River due to Karkheh impoundment and especially the development of agricultural activities in downstream regions, application of fertilizers and pesticides in farms threats and diminishes the downstream water quality.

Until now, the water resources managers have preferred to withdraw water from upper outlet to supply hydroelectric plant demands to generate more hydropower energy. To achieve this goal and access to large water volumes, they desire to supply the agricultural demand of Dasht Abbas, Fakeh, and Mousian plains through Garmsir project and restrict Dasht Abbas tunnel water withdrawal. Therefore, developing a reservoir operation based on selective withdraw scheme would be an efficient technique to mitigate downstream water quality deterioration.

5 MODEL APPLICATION

The enhanced programming is applied to Karkheh Reservoir in east western region of Iran. The proposed tool in this research, as a predictive tool for water quality in reservoir, evaluate various “what-if” scenarios of Karkheh Reservoir operation strategy based on selective withdraw framework.

Karkheh Reservoir as a multi-purpose hydraulic project is used for flood control,

hydropower generation, downstream environmental demand, and as a source of agricultural, municipal, and industrial water for the nearby population. The Karkheh Dam has a spillway to accommodate the release of high flows, it is used infrequently. The conventional developed reservoir operation strategy has paid far greater attention to cost and benefit than to issues of environmental impact. The main objective of the conventional reservoir operation strategy was to satisfy the demand with complete reliability, given the possibilities and limitations of the water supply. The balance between supply and demand was taken into consideration water quantity aspect only. To generate more hydropower energy, most releases in Karkheh Reservoir are made through the upper outlet located on level 174 masl. Karkheh Reservoir is deep enough which experience thermal stratification in the end of spring to the middle of fall. In this research, the calibrated and validated model of water quality simulation tool, CE-QUAL-W2, which was made by Afshar and Saadatpour (2009) is applied to address the water quality questions and issues in Karkheh Reservoir. 2D hydrodynamic and water quality simulation model, CE-QUAL-W2, provides rational physical transport mechanism in longitudinal and vertical axis in reservoirs. Also, the selective withdrawal algorithms such as those in semi analytical- empirical models, SELECT (Davis et al., 1987), are implemented within CE-QUAL-W2 to compute the withdrawal zone which is used as a downstream boundary condition.

Water quantity and quality aspects are much inter-related and should be considered within integrated framework. Consideration the water quality is related to the integrity of ecosystems and is a way to protect the environment. In Karkheh River basin, the downstream water quality interest is increasingly important due to invaluable environmental ecosystem, human health related problems, and limited source of safe waters. Therefore, the water quality issue in Karkheh Reservoir considered as reservoir operation purpose. In fact, the modifying the reservoir operational strategy is a planning management strategy which mitigate downstream water quality deterioration. To achieve this goal, the managers should explore the reservoir operational strategy based on selective withdraw framework to results in lower water quality deterioration in downstream.

The simulation methodology in this study may be used to determine whether downstream water quality indicators can be improved under various operational scenarios, and assess the effectiveness of different combinations of outlets. In Karkheh Reservoir, water quality parameters such as TDS, DO, PO_4 , and NO_3 are important indicators should be considered. In fact, the suitability of given released water depend on these water quality variables. To introduce the water quality, an overall index is required. In this research, the aggregated index introduced by Swamee and Tyagi (2000) is used to describe the system responses.

The defined operation strategy scenarios were run with the CE-QUAL-W2 model. The defined scenarios are based on single and/or combination of multiple longitudinal and vertical outlets. The relative success of each scenario was evaluated based on its minimum water quality index. The time series of DO concentration in release water based on various reservoir operational strategies are shown in Figure 2.

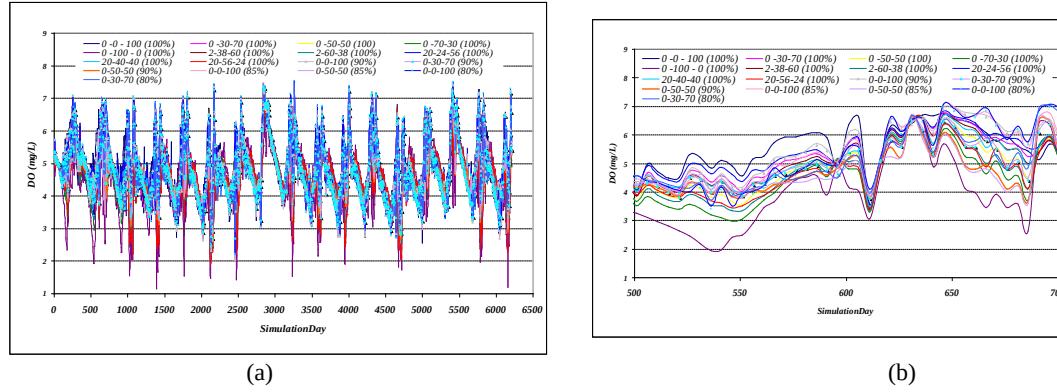


Figure 2: Time Series of Dissolved Oxygen Concentration Release Downstream Under Various Operational Strategies; (a) Long Time Period, (b) During Short Time Period

Each of the reservoir operational alternatives was evaluated by CE-QUAL-W2 model to determine the respective effect on downstream water quality attributes important to the restoration of downstream ecosystem in Karkheh River during long term period. The exceedence probability of DO concentration is shown in Figure 3. Other water quality attribute (NO_3 , PO_4 , and TDS) are assessed under various reservoir operational strategy, too.

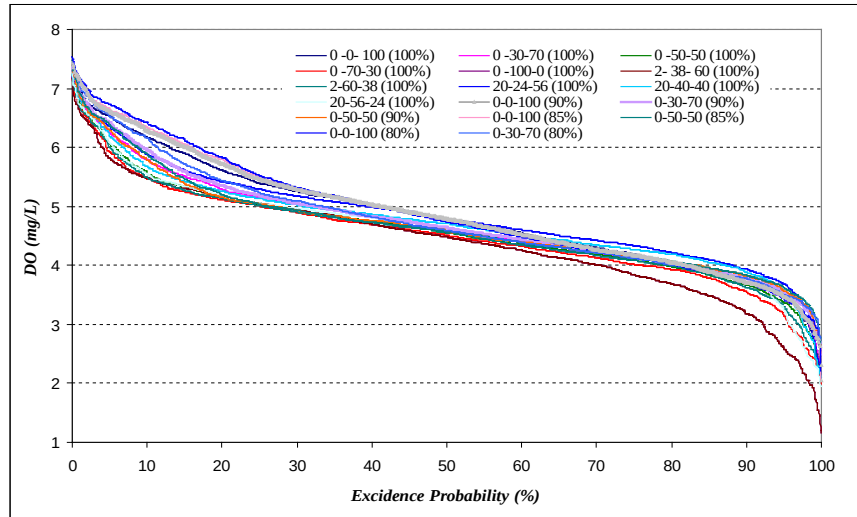


Figure 3: The Diagram of Exceedence Probability of DO Concentration Under Various Reservoir Operational Strategy

The objectives for these alternatives emphasized increasing or decreasing the availability of water supply, changing the location of water withdraw, and changing the

reservoir storage to provide for a more favorable water quality in downstream. Water quality variations were expected as a result of changes in the quantity, timing, mass storage, and withdraw location within the reservoir. The maximum, minimum, average, and standard deviation of water quality indicators as the stress related qualities are shown in Table I. As mentioned earlier, to evaluate the performance of various reservoir operation strategies, WQI is defined to aggregate the effect of several water quality parameters. The minimum and maximum values of WQI are shown in Table I.

Table I: The Statistical Function of Water Quality Attribute in Karkheh Reservoir Operational Strategy Based on Selective Withdraw Framework

No	L - M - U (SL) ⁺ (Min WQI; MaxWQI)		TDS	PO4	NO3	DO	No	L - M - U (SL) ⁺ (Min WQI; MaxWQI)		TDS	PO4	NO3	DO
1	* Percentage (100%) (0.2935;0.8824)	Max	580.28	0.221	1.82	7.27	10	20-56-24 (100%) (0.2283;0.8216)	Max	738.21	0.251	1.88	7.28
		Min	5.00	0.007	0.53	2.06			Min	5.00	0.009	0.47	1.95
		Ave.	280.07	0.027	0.80	4.84			Ave.	279.22	0.033	0.78	4.63
		Stdev.	78.68	0.024	0.19	0.93			Stdev.	87.29	0.033	0.21	0.82
2	0 -30 -70 (100%) (0.2629;0.8575)	Max	645.09	0.227	1.83	7.20	11	0 -0 -100 (90%) (0.3122;0.8789)	Max	549.35	0.205	1.74	7.43
		Min	5.00	0.009	0.51	2.19			Min	5.00	0.007	0.53	2.04
		Ave.	279.34	0.030	0.79	4.68			Ave.	279.46	0.026	0.78	4.87
		Stdev.	82.45	0.027	0.19	0.83			Stdev.	79.05	0.022	0.18	0.96
3	0 -50 - 50 (100%) (0.2449;0.8353)	Max	690.26	0.236	1.84	7.28	12	0 -30 -70 (90%) (0.2935;0.8562)	Max	582.49	0.210	1.75	7.36
		Min	5.00	0.009	0.50	2.13			Min	5.00	0.008	0.51	2.49
		Ave.	278.86	0.032	0.78	4.59			Ave.	279.04	0.029	0.77	4.74
		Stdev.	84.73	0.030	0.20	0.80			Stdev.	82.67	0.025	0.18	0.84
4	0 -70 - 30 (100%) (0.2289;0.8156)	Max	736.17	0.249	1.86	7.30	13	0 -50 - 50 (90%) (0.2794;0.8347)	Max	610.87	0.219	1.76	7.46
		Min	5.00	0.009	0.48	1.99			Min	5.00	0.008	0.49	2.52
		Ave.	278.52	0.033	0.78	4.52			Ave.	278.65	0.031	0.76	4.67
		Stdev.	86.56	0.032	0.21	0.82			Stdev.	84.71	0.027	0.19	0.78
5	0 -100-0 (100%) (0.2072;0.8125)	Max	809.61	0.269	2.00	7.18	14	0 -0 - 100 (85%) (0.3143;0.8748)	Max	545.90	0.201	1.72	7.46
		Min	5.00	0.009	0.46	1.17			Min	5.00	0.007	0.53	2.06
		Ave.	278.29	0.035	0.77	4.41			Ave.	279.28	0.025	0.77	4.88
		Stdev.	89.15	0.035	0.22	0.96			Stdev.	79.48	0.021	0.17	0.98
6	2-38-60 (100%) (0.2548;0.8471)	Max	664.50	0.231	1.84	7.23	15	0 -50 - 50 (85%) (0.2816;0.8361)	Max	606.53	0.211	1.74	7.48
		Min	5.00	0.009	0.51	2.19			Min	5.00	0.007	0.49	2.62
		Ave.	279.03	0.031	0.79	4.66			Ave.	278.64	0.030	0.76	4.69
		Stdev.	83.47	0.028	0.20	0.81			Stdev.	85.09	0.026	0.19	0.80
7	2-60-38 (100%) (0.2354;0.8249)	Max	716.98	0.243	1.85	7.31	16	0 -0- 100 (80%) (0.3169;0.872)	Max	541.86	0.195	1.69	7.53
		Min	5.00	0.009	0.49	2.10			Min	5.00	0.007	0.53	2.22
		Ave.	278.65	0.033	0.78	4.56			Ave.	279.42	0.025	0.77	4.89
		Stdev.	85.85	0.031	0.20	0.80			Stdev.	80.04	0.021	0.17	1.00
8	20-24-56 (100%) (0.2634;0.8611)	Max	643.75	0.228	1.84	7.18	17	0 -30- 70 (80%) (0.2977;0.8539)	Max	575.11	0.210	1.72	7.46
		Min	5.00	0.008	0.51	2.08			Min	5.00	0.007	0.50	2.73
		Ave.	278.21	0.030	0.79	4.84			Ave.	279.37	0.028	0.76	4.76
		Stdev.	81.60	0.027	0.19	0.80			Stdev.	83.73	0.023	0.18	0.89
9	20-40-40 (100%) (0.2451;0.8385)	Max	689.69	0.238	1.86	7.23	withdraw from Longitudinal, Middle, and Upper Outlets (Water Supply Satisfaction Level)						
		Min	5.00	0.009	0.49	2.09							
		Ave.	278.84	0.031	0.78	4.73							
		Stdev.	84.62	0.030	0.20	0.78							

The time series of water quality attribute derived based on alternative water management scenarios are evaluated by WQI introduced by Swamee and Tyagi (2000). The minimum WQI during long time simulation period is used to evaluate the performance of defined reservoir operation strategy affecting downstream water quality. The WQI is implemented to assess various reservoir operation strategies to determine how much changes in Karkheh Reservoir system operation could alleviate some of the water quality related stresses experienced by Karkheh ecosystem. The time series of

WQI calculated based on Karkheh Reservoir system responses under various operational strategies and the diagram of exceedence probability are shown in Figures 4 and 5.

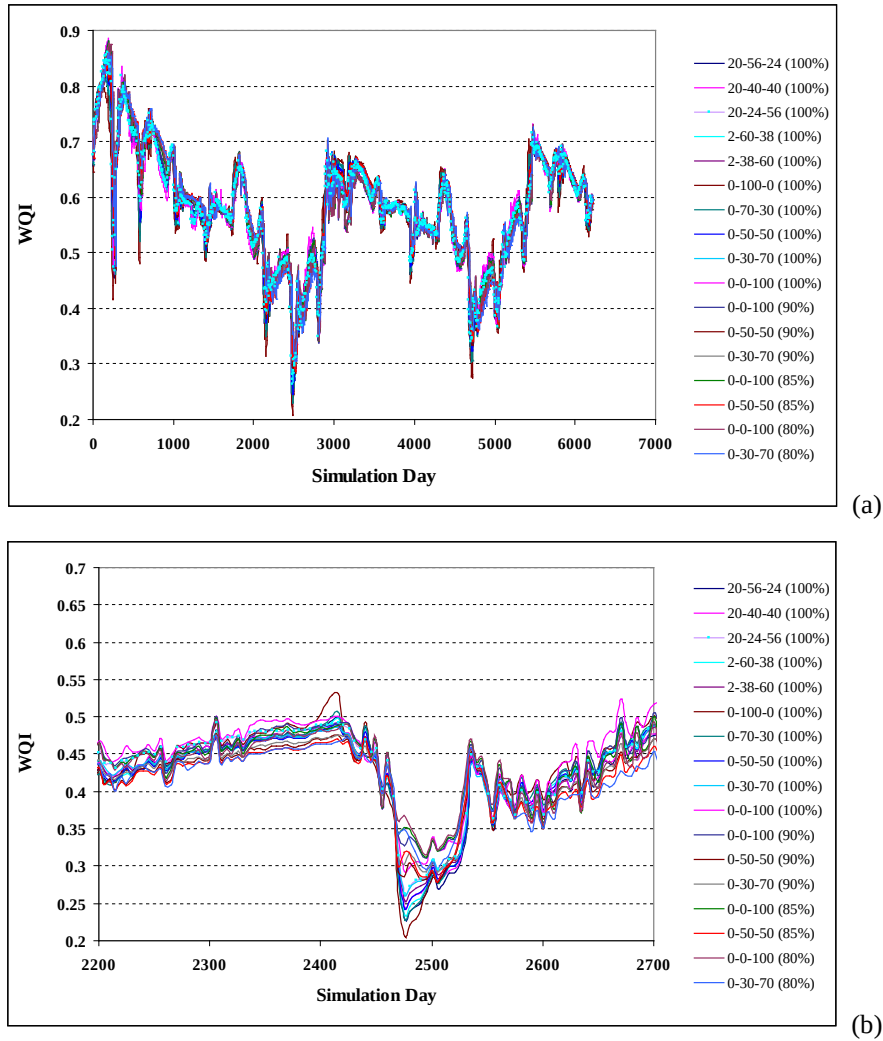


Figure 4: Time Series of WQI under Various Operational Strategies in Karkheh Reservoir; (a) Long Time; (b) Short Time

As it can be seen in the figures, the modifications of the reservoir operations can maintain the traditional municipal and agricultural supply in favorable satisfaction level while improving downstream water quality. But the various alternative reservoir operational strategies may decrease the power generation. Water resources management could consider other objectives to choose the suitable reservoir operation strategy. Based on the proposed methodology in this study scenario no. 16 is appropriate

alternative which decrease downstream water quality deterioration. In the selected scenario, the generated hydropower energy is 80% conventional hydropower energy. Therefore water resources management requires trade-offs of water quality index with other objectives in the multi purposes reservoir such as Karkheh.

6 CONCLUSION

Supplying safe and clean water is vital and important to protect human health and ecosystems. To achieve this goal implementation the appropriate reservoir operation strategy is a technique which could alleviate downstream water quality.

In this research, various reservoir operation strategies are evaluated by 2D hydrodynamic and water quality simulation model. CE-QUAL-W2 (Ver 3.5) coding is modified to blend water from various vertical outlets to determine reservoir responses to different reservoir operation strategy. The proposed methodology applied in Karkheh Reservoir in Iran as the largest and multi purposes hydraulic project. There are three selective outlets in Karkheh Reservoir which two vertical outlets located in length 64 Km and the longitudinal one located in Km 45 along the reservoir. Various alternatives of reservoir operational strategies in selective withdraw schemes and with different satisfaction reliability are evaluated to determine whether changing the reservoir operation could enhance released water quality to alleviate downstream ecosystem. TDS, DO, PO₄, and NO₃ were the important water quality indicators considered to assess system responses. To describe system responses consisting of different water quality constituent, a WQI is defined to aggregate the water quality indicators. The evaluation of various reservoir operation strategy show the inter relation of water quality and quantity and the importance of paying attentions to both quantity and quality. Also considering the trade-off between water quality objective with other quantity objectives is better perceived.

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