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Water Management in Kuwait for Facing Future Challenges

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Abstract. The main challenge facing the water resources system in Kuwait is the limited availability of water supply resources. In order to meet the needs for increasing demand for fresh water, the production capacity increased by more than 400 times during the past six decades. Saving water and electricity are the basis for the development now taking place in Kuwait. The average consumption of water per capita jumped from 22 cubic meters in 1960 to reach 164 cubic meters in 2014 where this consumption is considered as one of the highest consumptions all over the world.

The objectives of this research are to study the current and future water budget up to Year 2030 based on different scenarios (depending on population growth) and to propose some measures to reduce demand-based on controlling both the population growth and water price.

This research implemented the water evolution and planning (WEAP) Model. The findings indicated that the continuation of current policies will result in water shortage in 2030 which equal 277 MCM/year in case of the continuation of the current policies. The un-met demand would be completely covered for all sectors in 2030 after implementing some measures. On the other hand, the water supply decreased by 120.63 MCM/year as result of the new policy. The new policy permitted 150 L/capita/day for free and then set a price of 1$ per additional consumed cubic meter for Ambitious and Economic Scenario.

Keywords: Un-met Demand; Water Management; WEAP; Future Scenarios; Population growth; Water Price.

1. INTRODUCTION

Kuwait's desert climate which is described as hyper-arid i.e. hot and dry climates is not favorable to the existence of any river systems in the country. There are no permanent rivers or lakes, but small wadis were developed in the shallow depressions in the desert terrain. During the rainy season, surface runoff sometimes occurs in the large wadi depressions. Flash floods are reported to last from only few hours up to several days and only a small percentage of the precipitation infiltrates into the groundwater supply due to the extremely high evaporation losses and high deficit in soil mixture.

The average water consumption per capita jumped from 22 cubic meters in the year of 1960 to 42 cubic meters in the year of 1980; 134.6 cubic meters in 1992; 180.32 cubic meters in 2000 and finally 163.11 cubic meters in 2014. This consumption is considered as one of the highest water consumptions in the world [1].

Since Kuwait is one of those countries, which suffer from the scarcity of fresh water therefore water desalination is considered as the main resources of water to meet various demands such as domestic and industry. In the near future, the Kuwait's Government spends US 4$ billion per year to meet the demands for the water sector [2].

Studies and analyzes of the water resources status in Kuwait concluded that utilization of the groundwater resources should be based on sustainability[3] .But, unfortunately, the current practices are far exceeding the mining aquifer system capabilities. The current practice for minimizing the production from the fresh groundwater lenses should continue. Also, attempting to manage the recharge of the runoff water for feeding the lenses should be considered. The reuse of waste water is a promising source for water, which may be progressively used to replace the brackish groundwater in landscape and agricultural farms irrigation.

[4] This research indicated the Water Saving Practices in Kuwait achieved improvements in the urban migration andin the standard of living. It is also indicated that the absence of conservation programs in the Arabian Gulf Countries in general and in Kuwait particularly, have resulted in excessive domestic water consumption. Current programs, in these countries, are focusing, mainly, on the development of water resources rather than management of them, in order to meet the rising water demand.

[5] Studied the water management in Kuwait to face the future challenges that face Kuwait due to shortage in water resources. Using the WEAP Model, the study assessed three scenarios of water resources situation in the year 2025. The current un-met demand of water was 15.1 BCM/yr, which was found only in the agricultural sector and was compensated by drainage water reuse and the un-official withdrawal of deep ground water. Water shortage in year 2025 is expected to be 26 BCM/yr.

The objectives of this research are to:

- Studying the current and future water budget up to the year of 2030 according to different scenarios (based on population growth).
- Suggesting some measures to reduce demand based on controlling both population growth and water prices.

2. Methodology

2.1 Model Descriptions

This research implemented uses the Water Evolution and Planning (WEAP) Model which was applied in water resources assessments and development programs in many of countries (i.e. United States, Egypt and Israel) [4]. The (WEAP) Model is a microcomputer tool used for integrated water resources planning asit provides a comprehensive, flexible and user-friendly framework for policy analysis. WEAP places the demand side of the equation (water use patterns, re-use, equipment efficiencies, allocation and prices) on an equal footing with the supply side (stream flow, reservoirs, groundwater, and water transfers). It simulates water demand, flows, supply, storage, pollution generation, treatment and discharge and evaluates a full range of water development and management options, taking account of the multiple and competing uses of water systems. The (WEAP) system is represented by a network of nodes and links whereeach node and link requires data that depends on what that node or link represents [6].

The basic equation of WEAP Model uses the water balance equation with its general form: Input (I) – Output (O) = Change in storage (ΔS), where inputs are runoff, precipitation and ground water influent; and the outputs are evaporation, domestic use, irrigation use, industrial use, and losses. Each component is estimated as follows:

- 'Precipitation' is collected from rainfall gauges.
- 'Runoff' is estimated by the duration of precipitation s/hr or min/hr.
- 'Groundwater influent' depends on the permissible and available volumes of each basin or area.
- 'Irrigation Use' is calculated from the consumption use rate, distribution losses, field application losses and conveyance losses.
- Evaporation is measured from water level changes in the evaporation pans.

The WEAP structure consists of five main views, as follows:

- The Schematic View contains GIS-based tools, in which objects of both demand and supply can be created and positioned as nodes within the system.
- The Data View uses mathematical expressions to create variables and relationships, assumptions and projections.
- The Results View detailed and flexible display of all model outputs, in charts and tables, and on the schematic.
- The Scenario Explorer highlights key data and results in the system for quick viewing.
- The Notes View provides a place to document any data and assumptions. For every demand node, the level of priority is set for allocation of constrained resources among multiple demand sites where WEAP attempts to supply all demand sites with highest demand priority, then moves to lower priority sites until all of the demand is met or all of the resources are used, whichever happens first.

2.2 Designing Future Scenarios

There are several scenarios which encompass the current scenario in addition to three future scenarios for the year of 2030 depending on population growth and an additional scenario based on water pricing. The use of current scenario for the year 2015 was for calibration process. The future scenarios were as follows:

(1) Year 2030 Normal Scenario: It expected demand developments with the same current policies and without alternative measures due to average yearly increase in population with (2.97 %).

(2) Year 2030 Pessimist Scenario: It identified the extra withdrawal volume to cover the un-met demands due to average yearly increasing in population with (5.66 %).

(3) Year 2030 Ambitious Scenario that explored the impacts of new alternative measures on future water resources system in Kuwait due to minimum yearly increase in population at (1.46 %).

2.3 Model Calibration

The first step of model application is to calibrate the model for water demand in Kuwait for the year 2015 (Baseline).

The current situation in Kuwait was simulated by (WEAP) model based on the input data Figs (1 to 4) where this was viewed as a calibration step of the model to the water resources system in Kuwait. The total demand of all sectors during the calibration process was 937.01 MCM/yr. The calibration process incorporated the assembled field measurements in 2015 where the actual total demand is 946.68 MCM/yr.

The Mean Percentage Relative Error (MPRE) (%) for the current simulation was calculated as follows:

$$\text{MPRE} = \frac{\sum\left[\left(\frac{\text{Numerical result} - \text{Field measurement}}{\text{Field measurement}}\right)\times 100\right]}{\text{Number of results}}$$

MPR Model values for all three sectors are 1.023 % for the total demand. This indicated that the model underestimated the field measurements of the total demand by 1.023 %. Thus, it was clear that WEAP model can perform well in simulating future demands.

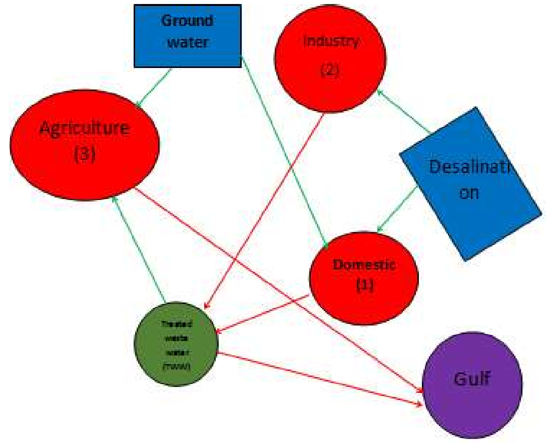

Fig. (1) Schematization of Nodes and Links in the current scenario for Kuwait in the year of 2015

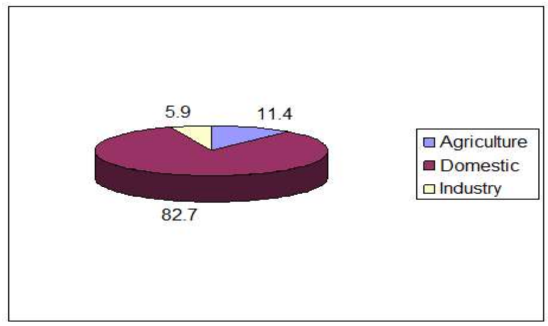

Fig. (2) Water Demand for Kuwait (not including loss and reuse) in the year of 2015

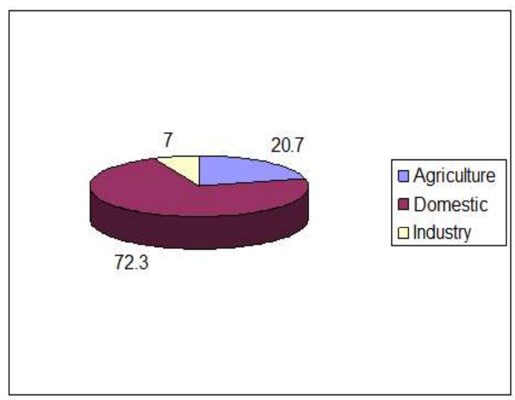

Fig. (3) Water Supply Requirement for Kuwait (including loss and reuse) in the year of 2015

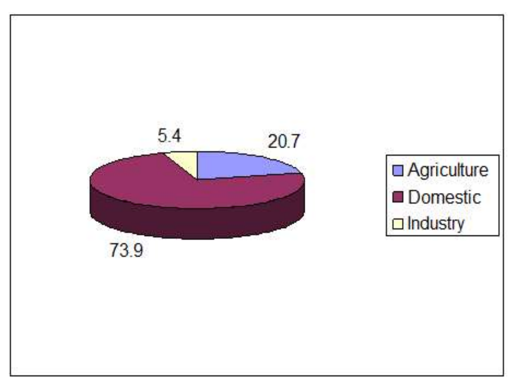

Fig. (4) Water Supply Delivered for Kuwait (including loss and reuse) in the year of 2015

3. Results and Analysis

3.1 Normal Scenario for 2030

For year 2030, the Normal Scenario depends on the average yearly increase in population i.e. (2.97%) and the number of population will increase from 4239006 Capita in 2015 to 5963219 capita in 2030. Also, population will increase by 1724213 capita after 15 years.

3.1.1 Model Results for 2030 Normal Scenario

The model will run for two cases:

The first case (with the population increase) is accompanied by same water supply for the year 2015.

The second case (with the population increase) is accompanied by an increase in water supply.

For the first case, the number of population will increase from 4239006 capita in 2015 to 5963219 capita in 2030, but in this case, the water supply is fixed as that in the year 2015. Fig. (5) shows that during the 2030, the coverage in domestic sector ranges between 74.35 to 83.76 % with yearly average 79.51 % due to the gap between water demand and water supply in domestic sector.

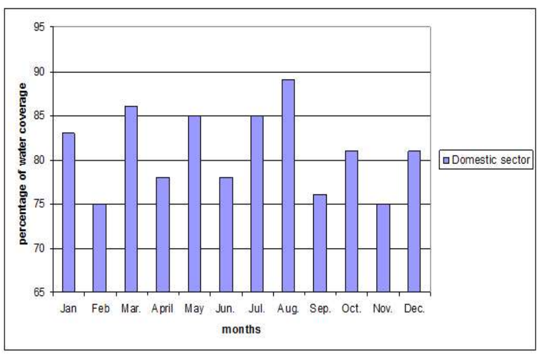

Fig. (5) Monthly water coverage in Kuwait in 2030 for normal scenario

It is also clear from Fig. (6), that the un-met demand for all sectors is 277 MCM/year and according to the priority scale the domestic take number 1, industry number 2 and agriculture number 3. The un-met demand in domestic sector is 196.19 MCM/year compared to 73.51 MCM/year in industry sector and hence this means that the industry sector will be fully un-covered and the domestic sector will be un-covered by 20.49%. The agriculture sector will not suffer from any water shortage because its water supply depends on brackish and wastewater treatment.

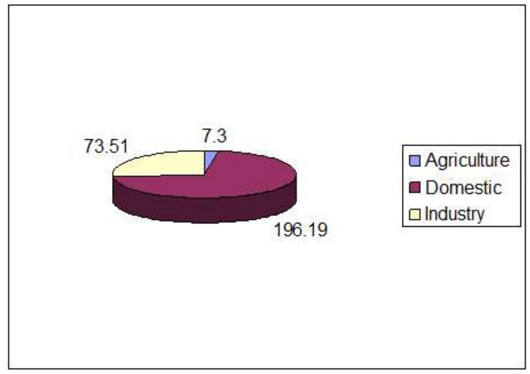

Fig. (6) The Un-metdemand in Kuwait in 2030 for normal scenario with 2015 water supplying

But for the second case, Fig. (7) shows that the total water demand for all sectors in 2030 is 1148. 14 MCM/year where but it is 870.48 MCM/year in 2015. The water demand will increase by 277 MCM/year i.e. almost 31% after 15 years.

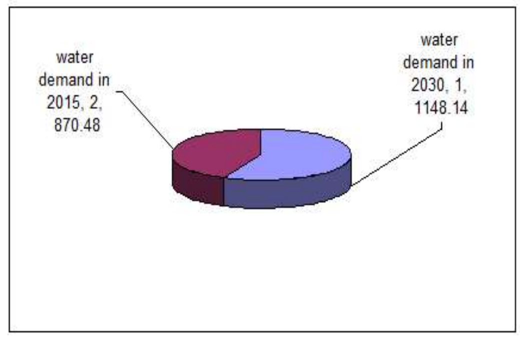

Fig. (7) Water demand in Kuwait (not including loss and reuse) in 2030 Normal Scenario

Fig. (8) shows, that the total water supply for all sectors in 2030 is 1224.33 MCM/year and but it is 946.68 MCM/year in 2015. The water supply will increase by 277 MCM/year almost 31% after 15 years.

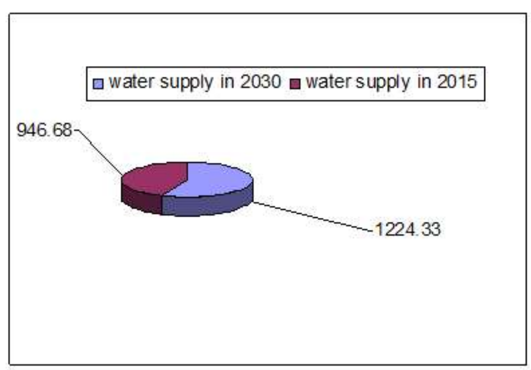

Fig. (8) Water supply requirement in Kuwait (including loss and reuse) in Year 2030 Normal Scenario.

3.2 Pessimist Scenario for 2030

Normal Scenario for 2030 depends on average yearly increase in population i.e. (5.66 %) where the population will increase from 4239006 Capita in 2015 to 8126050 capita in 2030 which in turn means that population will increase by 3887044 capita after 15 years.

3.2.1 Model Results for 2030 Pessimist Scenario

The model will also, be run for two cases. The first case deals with the population increases (but with the same water supply for 2015) but the Second case with the population increases and developing water supply.

The first case, due to the gap between water demand and water supply in the domestic sector, the average monthly coverage in the domestic sector during the year 2030 for Pessimist Scenario range is between 54.56%and 61.46 % with yearly average is 58.39 %.

The un-met demand for all sectors is 623 MCM/year and according to the priority scale the domestic take number 1, industry number 2 and agriculture number 3. The un-met demand in the domestic sector is 549.47 MCM/year and is 73.51 MCM/year in the industry sector. So, this means that the industry sector will be fully un-covered and the domestic sector will be un-covered by only 41.61% but the agriculture sector will not suffer from any shortage because its water supply depends on the treatment of brackish and wastewater.

On the other hand, for the second Case, In year 2030, the water demand for all sectors for Pessimist Scenario is 1500 MCM/year where this value was 870.48 MCM/year in 2015. The water demand will increase by 629.52 MCM/year i.e. almost 72.32 % after 15 years.

In year 2030, the water supply for all sectors for Pessimist Scenario is 1570 MCM/year where this value was 946.68 MCM/year in 2015. The water supply will increase by 623.32 MCM/year i.e. almost 65.84 % after 15 years. In year 2030, Water coverage for all sectors for Pessimist Scenario due to increase the water supply by 623.32 MCM/year after 15 years from 2015 to 2030 for Pessimist Scenario.

The estimated cost to produce water is about 3$/m^3$ and it is sold to the citizen at 10% of its actual cost. So, the Kuwait's government needs to spend about 1875 Million USD/year only to produce this additional amount of water to fully cover the demand in the domestic sector. Also, the Kuwait's government needs to build a new desalination plant or increase the capacity of the old plants.

3.2.2 Model Results for Year 2030 Ambitious Scenario

Also, the model for year 2030 will run for the same mentioned two cases. For the first one, the population will increase from 4239006 Capita in 2015 to 4994483 capita in year 2030 where population will increase by 755477 capita but in this case the amount of water supply is fixed as that of the year 2015. During the year 2030, the average monthly coverage in domestic sector for Ambitious Scenario rangesbetween 88.77% to 100 % with yearly average coverage of 94.31 % due to the gap between water demand and water supply in the domestic sector. The un-met demand for all sectors is 121.66 MCM/year and according to the priority scale, the domestic take number 1 and industry number 2 and agriculture number 3. The un-met demand in domestic sector is 48.15 MCM/year and 73.51 MCM/year in industry sector. So, this means that the industry sector will be fully un-covered and the domestic sector is un-covered by 96.6 %. The agriculture sector will not suffer from any water shortage because its water supply depends on both brackish and brackish.

But for the second case, In year 2030, the water demand of all sectors for Ambitious Scenario is 992.14 MCM/year where this value was 870.48 MCM/year in 2015. The water demand will increase by 121.66 MCM/year almost 72.32 % after 15 years. In year 2030, the water supply of all sectors for Ambitious Scenario is 1068.33 MCM/year where this value was 946.68 MCM/year in 2015. The water supply will increase by 121.66 MCM/year almost 65.84 % after 15 years. In year 2030, full water coverage of all sectors for Ambitious Scenario due to increasing the water supply by 121.66 MCM/year after 15 years from 2015 to 2030 for Pessimist Scenario.

3.3 Measures for Water Demand in Year 2030

It is clear from the previous study that desalination is considered as the main source of water supply in Kuwait. The Distilled water (freshwater) is mainly used in domestic appliances whichcovers over 89% from the total production. Industry uses only 11 % from fresh water. In the year 2015, the consumption was 441 L/capita/day, i.e. 161 m^3/year/capita which, equivalent to 97 Imperial Gallon/capita/day. The quantity of water over the allowance should be priced [7] so as to limit over-consumption [7]. This kind of pricing schedule would be efficient in significantly reducing demand for water. This study shows that a price of water of 1$/m^3$, after a 150 L/capita/day allowance, would reduce the demand from 20 to 40 percent.

In this study, the taken measures will reduce the total water demand in domestic sector by 30 % due to the price of water of 1$/m^3$, after a 150 L/capita/day allowance. So, total monthly gross production of fresh water will be reduced by 26.69 %

In 2030, the water demand for all sectors for Ambitious and Economic Scenario is 749.86 MCM/year where this value was 870.48 MCM/year in 2015. The water demand will decrease by 120.14 MCM/year almost 13.85 % after 15 years.

Conclusions

The researcher chose to implement the Water Evolution and Planning (WEAP) Model. Several scenarios were proposed wherethese scenarios encompass the current scenario in addition to three future scenarios for year 2030 depending on population growth and an additional scenario based on water pricing. The findings indicated that in case of continuation of current policies the water shortage in year 2030 would be 277 MCM/year. In year 2030, the un-met demand for all sectors will be 623 MCM/year in the Pessimist scenario. In case of the Ambitious Scenario, due to controlling the population increase the un-met demand in year 2030 for all sectors will be 121.66 MCM/year. In this study, the measures will reduce the total demand for water in domestic sector by 30 % due to price of water of 1$/m^3$, after a 150 L/capita/day allowance. Therefore, total monthly gross production of fresh water will be reduced by 26.69 %. In year 2030, the water demand from all sectors for Ambitious and Economic Scenariowill be 749.86 MCM/year where this value was 870.48 MCM/year in year 2015. The water demand will decrease by 120.14 MCM/year almost 13.85 % after 15 years.

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