Genetic Algorithm Model to Optimize Water Resources Allocation in Gaza Strip

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Abstract— Groundwater aquifer is considered the main and only water supply source for all kind of human usage in Gaza Strip (domestic, agricultural and industrial). This source is severely deteriorated in both quality and quantity for many reasons, including low rainfall, dramatic increase in the urban areas and population, pollution from overland activities, and seawater intrusion. In 2011, the Palestinian Water Authority has instituted a plan for integrated management of Gaza water resources that considers introducing of new external water resources to the system such as seawater desalination and treatment and reuse of wastewater. In this work, a genatic algorithm model was developed to seek the optimal combination of the management scenarioios of Palestinian water authority plan. The optimization code is designed and run using MATLAB R2011b. The objective function maximized the benefits and minimizes the cost related to the use of different sources of water. The decision variables represents water allocation over different users sectors. The benefits from utilizing water for municipal and industrial purposes are based on the marginal value of water which is derived from the economic equilibrium point between supply and demand curves. The benefits from irrigation water are affected by the relationship between crop yield and salinity. The constraints in the optimization model are allowed to iterate between two bounds (upper bound and lower bound) until the optimal value for each variable is found. The results show that there is a significant improvement in aquifer's water levels in the majority area of the Gaza Strip for the planning years 2015, 2025, and 2035 providing that the planned phased desalination and wastewater treatment schemes are implemented in the specifies time horizon. The results show that the resulted quality of available water for agriculture use in term of total weighted average of electrical conductivity is 962 µS/cm in the year 2015, and 876 µS/cm in the year 2025, and 842 µS/cm in the planning year 2035. The results also show that the resulted quality of available water for municipal and industrial use in term of total weighted average of electrical conductivity is 867 µS/cm in the year 2015, and 685 µS/cm in the year 2025, and 631 µS/cm in the planning year 2035.

Index Terms— Gaza Strip, Optimization, Genetic algorithms, water resources allocation, marginal value of water

I INTRODUCTION

A Water Resources Optimization

The availability of freshwater is imperative to economic and social development. Therefore, sources of freshwater should be managed in a sustainable manner. Sustainable water resource systems include three integrated processes, namely the natural environment, the socio-economic environment and the management system. The purpose of the integrated system is not only to use natural resources without degrading the quality of the water or land, but also to ensure that present and future water demands are met irrespective of the changes in circumstances [1].

The optimization model consists of an objective function or a quantity that is maximized or minimized, and a set of additional constraints or conditional statements that must be satisfied. In Recent years, optimization has been widely used in groundwater planning and management models. In the past decade, nonlinear programming techniques have been applied to groundwater management models since these often give rise to highly non-convex and non-linear programming problems [2].

Most of optimization problems related to the interaction of groundwater resources and socioeconomic activities are nonlinear. The non-linearity comes from the complexity groundwater system. In addition cost functions tend to change no-linearly with economy of scale [3]. Genetic algorithms (GA) have been used extensively for solving complex and highly non-linear optimization problems. Genetic algorithms are based on a random search scheme based inspired by biological evolution. GA is an optimization technique based on the process of biological evolution [4]. The concept of GA is based on the initial selection of a relatively small population. Each individual in the population represents a possible solution in the parameter space. The fitness of each individual is determined by the value of the objective function calculated, based on that set of parameters. The natural evolutional processes of reproduction, crossover, mutation, and selection, are applied using probability rules to evolve the new and better generations. The evolution based search algorithms claim to find much better near-optimal solution than any other optimization method [5].

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B About the Study Area

Groundwater aquifer is considered the main and only water supply source for all kind of human usage in Gaza Strip (domestic, agricultural and industrial). This source is severely deteriorated in both quality and quantity for many reasons, including low rainfall, dramatic increase in the urban areas and population, pollution from overland activities, and seawater intrusion. In 2011, the Palestinian Water Authority has instituted a plan for integrated management of Gaza water resources that considers introducing of new external water resources to the system such as seawater desalination and treatment and reuse of wastewater. In this work, a genatic algorithm model was developed to seek the optimal combination of the management scenarioios of Palestinian water authority plan [6].

II METHODOLOGY

The optimization code is designed and run using MATLAB R2011b. The code initializes a random sample of individuals with different parameters to be optimized using the genetic algorithm approach.

A Objective Function

The objective of the management model is to maximize the total benefits from the use of water sources for different purposes with minimum cost. The objective function can be expressed as:

$$Max\ Z = \sum_{\substack{i=1 \\ J=1}}^{\substack{i=n \\ j=n}} Q_{i,j} * \left(B_j - C_i\right) \qquad (1)$$

Where;

I: indicates a particular source of water from n sources,

J: denotes the sector where the water is utilized, and

Q i,j: represent the quantity of water extracted from source (i) and utilized in sector (j), which is represented by the following equation:

$$Qi,j = Q\,11 + Q\,21 + Q\,31 + Q\,41 + Q\,51 + Q\,12 + Q\,52 + Q\,62 + Q\,7$$

Where;

$Q_{11:}$ the quantity of water supplied from groundwater wells to the municipal and industrial users.

$Q_{21:}$ the quantity of water supplied from brackish groundwater desalination to the municipal and industrial users.

$Q_{31:}$ the quantity of water supplied from seawater desalination to the municipal and industrial users.

$Q_{41:}$ the quantity of water supplied from imported water from Mekorot Company (Israel) to the municipal and industrial users.

$Q_{51:}$ the quantity of water supplied from imported water from Egypt to the municipal and industrial users.

$Q_{12:}$ the quantity of water supplied from groundwater wells to the agriculture sector.

$Q_{52:}$ the quantity of water supplied from imported water from Egypt to the agriculture sector.

$Q_{62:}$ the quantity of water supplied from reclaimed water to the agriculture sector, and

$Q_{7:}$ the quantity of harvested water from storm water and used to replenish the groundwater aquifer.

$B_{j:}$ the estimated benefits resulting from utilizing one cubic meter of water for municipal and industrial sector and/or for agricultural sector ($B_{M\&I}$ or B_{Ag}).

$C_{i:}$ the estimated cost to supply a unit volume of water from different sources including physical losses.

B Estimation of Benefits from Municipal and Industrial Sectors (BM&I)

The benefit from utilizing water for municipal and industrial purposes (BM&I) is based on the marginal value of water (optimal value of water) which is based on the economic equilibrium point between supply and demand curves This point corresponds to the marginal value of unit volume of good quality water which is 1.03 $/m^3. The lower value water corresponds to the present quality situation [7]. Based on that, the benefit of water supply is given by the relation:

$$B_{M\&I} = 1.51 - 0.48\, EC_{M\&I} \qquad (2)$$

Where;

$B_{M\&I}$: economic value of unit water for municipal and industrial purposes, and

$EC_{M\&I}$: Electrical Conductivity of blended water (mS/cm) from different sources which given by the following mass balance relation:

$$EC_{M\&I} = \frac{\sum_{M\&I} Q_i * EC_i}{\sum_{M\&I} Q_i} \qquad (3)$$

Where;

ECi = electrical conductivity of each source used for municipal and industrial purposes.

$\sum_{M\&I} Q_i$ = sum of the quantities of water from different sources used for municipal and industrial purposes.

C Estimation of Benefits from Agricultural Sector (BAg)

The benefits from irrigation water (BAg) are affected by the relationship between crop yield and salinity. A series of this type of relationships were developed for different categories of crops as shown in Figure 1. The different categories are also illustrated in Table 1[8].

For Gaza Strip case and for the purpose of simplification of the optimization model, medium curve (average crop) ,between the four curves shown in Figure 1, is selected to represent Gaza Strip agricultural sector. The reason for this is that no accurate data is available about the crop distribution particularly for future prediction. In addition to that, we are concerned about the macro-scale picture of problem.

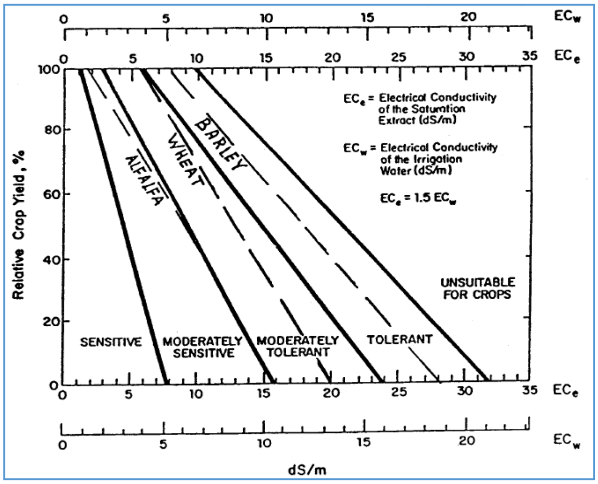

Figure 1: Relative CropYyield vs. Salinity [8]

TABLE 1
Crops Categories and their Tolerance to Salinity [8]

Tolerance to Salinity	Crop
Tolerant	Barley, Sugar Beet
Moderately Tolerant	Wheat, Wheat Grass, Zucchini, Beet (red), Orange
Moderately Sensitive	Tomato, Cucumber, Alfalfa, Clover, Corn, Potato
Sensitive	Onion, Carrot, Bean, Apple, Cherry, Strawberry,

D Limits and Constraints

Most of the constraints in GA model are allowed to iterate between two bounds (upper bound and lower bound) until the optimal value for each variable is found. Quality variables and resource variables constraints can be expressed by the following inequalities:

$$EC_{i,min} \leq EC_i \leq EC_{i,max}$$

$$Q_{ij,min} \leq Q_{ij} \leq Q_{ij,max}$$

These values are either based on the nature or environment carrying capacity such as sustainable abstraction quantities from the groundwater aquifer or they are based on local polices for allocating the resources for different sectors. Table 2, below shows the upper and lower bounds of the different variables used in the GA model.

TABLE 2
GA Model input variables and limits

Variable (GA Model)	Variable (text)	Unit	Year 2015		Year 2025		Year 2035	
			Min	Max	Min	Max	Min	Max
X1	Q11	m^3	60*1	67*1	40*1	48*1	40*1	48*10
X2	Q21	m^3	0	5*10	0	5*10	0	5*106
X3	Q31	m^3	0	13*1	0	72*1	0	130*1
X4	Q41	m^3	5*10	15*1	5*10	21*1	5*10	21*10
X5	Q51	m3	0	5*10	0	10*1	0	10*10
X6	Q12	m^3	60*1	70*1	40*1	50*1	40*1	50*10
X7	Q52	m^3	0	5*10	0	10*1	0	10*10
X8	Q62	m^3	0	10*1	0	20*1	0	40*10
X9	EC1	µS/c	1000	1670	1000	1040	1000	1040
X10	EC2	µS/c	500	1000	500	1000	500	1000
X11	EC3	µS/c	500	700	500	700	500	700
X12	EC4	µS/c	700	1040	700	1040	700	1040
X13	EC5	µS/c	500	700	500	700	500	700
X14	Q7	m^3	0	20*1	0	30*1	0	40*10
Calcu-	ECT1	µS/c	N/A	1500	N/A	1500	N/A	1500
Calcu-	ECT2	µS/c	N/A	1650	N/A	1650	N/A	1650

E Other Constraints

The sustainable abstraction from the groundwater aquifer is estimated at 110 x 106 cubic meter per year [10]. This value changes based on the applied strategies for inflows and outflows to the aquifer and the availability of other resources and are modeled by the following equation:

$$Q_{11} + Q_{12} + 1.5Q_{21} \leq Q_7 + 110 * 10^6 \qquad (4)$$

Q7 is the quantity of water added from harvesting and infiltration so it will increase the upper bound of the aquifer capacity.

Based on Metcalf and Eddy (2003) [10] the integrated aquifer management plan assumed that at least 25% of irrigation demand should come from the aquifer and the rest can be supplied from treated effluent. This argument can be modeled in the following constraint:-

$$Q_{62} \leq 0.75\,(Q_{12} + Q_{52} + Q_{62}) \qquad (5)$$

F Total Water Demand Constraints

Table 3 bellow summarizes the total water demand of water for both domestic & industrial and agriculture. These constraints are for the years 2015, 2025 and 2035 [6, 9].

TABLE 3
GA Model Input Variables and Limits

Constrains	Total Water Demand		
	Year 2015	Year 2025	Year 2035
$Q_{11} + Q_{21} + Q_{31} + Q_{41} + Q_{51}$	94 MCM	140 MCM	198 MCM
$Q_{12} + Q_{52} + Q_{62} \geq$	77 MCM	69 MCM	61 MCM

G Cost Variables

The under mentioned variables are the cost variables for the model [6]:

C11: the unit cost for quantity of water supplied from groundwater wells to the municipal and industrial users. ($ 0.30 /M^3),

C21: the unit cost for the quantity of water supplied from brackish groundwater desalination to the municipal and industrial users. ($ 0.75/M^3),
C31: the unit cost for the quantity of water supplied from seawater desalination to the municipal and industrial users. ($ 0.90/M^3),
C41: the unit cost for the quantity of water supplied from imported water from Mekorot company (Israel) to the municipal and industrial users. ($ 0.85/M^3),
C51: the unit cost for the quantity of water supplied from imported water from Egypt to the municipal and industrial users. ($ 0.80/M^3),
C12: the unit cost for the quantity of water supplied from groundwater wells to the agriculture sector. ($ 0.20/M^3),
C52: the unit cost for the quantity of water supplied from imported water from Egypt to the agriculture sector. ($ 0.80/M^3),
C62: the unit cost for additional treatment for the quantity of water supplied from reclaimed water to the agriculture sector. ($ 0.35/M^3), and
C7: the unit cost for additional treatment for the quantity of water harvested and infiltrated into the aquifer groundwater ($ 0.35/M^3).

III Results and Discussion

A Genetic Algorithm Model Results for Short Term Management for Year 2015

According to the Palestinian Central Bureau of Statistics (PCBS) [10], the growth population rate of 3.5% was assumed to estimate the future municipal well abstractions. Based on that the projected population of Gaza strip by year of 2015 will stand at 1.8 million inhabitants distributed over the five governorates. The estimated quantities of water for domestic demand were calculated considering the recommendations of GETAP 2011[6] by considering a benchmark water consumption of 135 liters per capita/day for the whole of Gaza Strip towards the end of the short-term intervention period.
Table 4 summarizes the distribution of projected population of Gaza Strip as well as the demanded quantities of water for domestic and agriculture use. As the result of the instability of the political situation and the absence of the industrial infrastructure, the consumption for industrial demand will consider being 2MCM/year [11]. Considering the required quantities for both domestic and agriculture use with all constrains and limits the GA model solved the case for optimal quantities by maximizing the total benefits and minimizing the cost. The optimal quantities after comparing 100 generations are summarized in Table 5.

TABLE 4
Projected Population and Domestic & Agriculture Water Demand in year 2015

Governorate	Year	Population	Consumption (L/Capita/ Day)	Domestic Water Demand per Governorate (m^3/year)	Agriculture Water Demand For All Governorates (m^3/year)
North	2015	501,979	135	17,535,100	77,000,000
Gaza		922,078	135	32,209,983	
Middle		381,779	135	13,336,278	
Khan		503,341	135	17,582,699	
Rafah		322,037	135	11,249,383	
Total		2,631,214	135	91,913,443	77,000,000

TABLE 5
Optimal Water Quantities for Short Term Management in Year 2015

Description	Source	Variable	Unit	Quantity
Domestic and Industrial Demand	Groundwater wells	Q11	M^3	$65*10^6$
	Desalinated water from brackish wells	Q21	M^3	$1.08*10^6$
	Desalinated Sea Water.	Q31	M^3	$13*10^6$
	imported water from Mekorot Company	Q41	M^3	$9.90*10^6$
	Imported water from Egypt.	Q51	M^3	$4.90*10^6$
Total			**M^3**	**$93.88*10^6$**
Agriculture Demand	Groundwater wells	Q12	M^3	$63*10^6$
	Imported water from Egypt	Q52	M^3	$4.96*10^6$
	Reclaimed water	Q62	M^3	$9.28*10^6$
Total			**M^3**	**$77.24*10^6$**
Harvested Water	Harvested water from storm water	Q7	M^3	$19.87*10^6$
Electrical Conductivities of water from different sources	Water from aquifer	Ec1	μS/cm	1000
	Desalinated water from brackish wells	Ec2	μS/cm	500
	Desalinated seawater.	Ec3	μS/cm	500
	Imported water from Mekorot Company.	Ec4	μS/cm	700
	electrical conductivity of water imported from Egypt	Ec5	μS/cm	500
Final Quality of water In terms of Electrical Conductivity	Calculated average electrical conductivity for domestic water	ECT1	μS/cm	867
	Average electrical conductivity for irrigation water	ECT2	μS/cm	962

Best Function Value	**$ 77 *10^6$**

The results show that there is a significant improvement in aquifer's water levels in the majority area of the Gaza Strip especially in the middle area. The levels will gradually to increase to reach 4 meters below MSL in north area and 11 meters below MSL in south area. As for quality, the results show that the total average of electrical conductivity for the domestic and agriculture uses for water are 867 µS/cm and 962 µS/cm respectively. This means that the total dissolved solids (TDS) for domestic use is around 500 mg/liter and 580 mg/liter for agriculture use. Figure 2 shows the the results of the simulations for the water levels in the aquifer using SEAWAT model when adopting the optimized scenario for short term planning in year 2015.

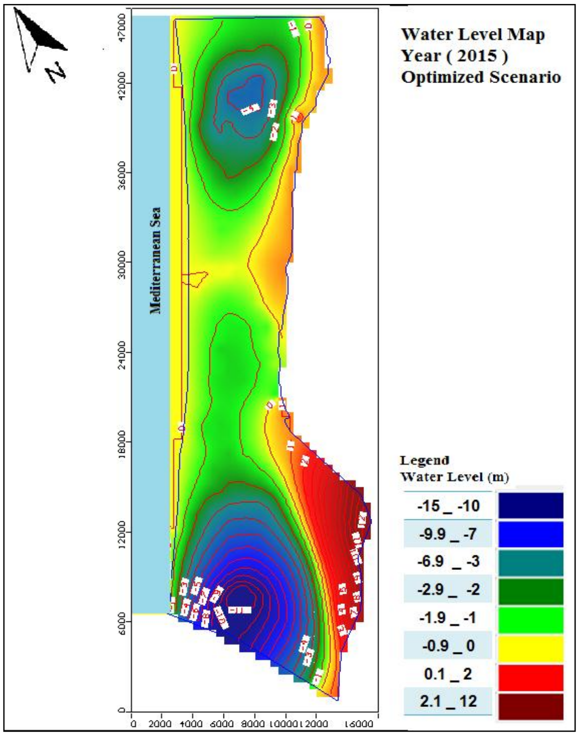

Figure 2: Predicted Water Level for Optimized Scenario (year 2015)

B Genetic Algorithm Model results for Medium Term Management for Year 2025

The estimated quantities of water for domestic demand were calculated considering the recommendations of GETAP 2011[6] by considering a benchmark water consumption of 150 liters per capita/day for the whole of the Gaza Strip towards the end of the medium-term intervention period. Table 6 summarizes the distribution of projected population of the Gaza Strip as well as the demanded quantities of water for domestic and agriculture use. As the result of the instability of the political situation and the absence of the industrial infrastructure, the consumption for industrial demand will consider to be 2MCM/year [11]. Considering the required quantities for both domestic and agriculture use with all constrains and limits, the GA model solved the case for optimal quantities by maximizing the total benefits and minimizing the cost. The optimal quantities after comparing 100 generations are summarized in Table 7 of Genetic Algorithm model interface for year 2025.

TABLE 6

Projected Population and Domestic & Agriculture Water Demand in year 2025

Governorate	Year	Population	Consumption (L/Capita/ Day)	Domestic Water Demand per Governorate (m^3/year)	Agriculture Water Demand For All Governorates (m^3/year)
North	2015	501,979	150	27,483,350	69,000,000
Gaza		916,655	150	50,186,861	
Middle		373,197	150	20,432,535	
Khan		456,331	150	24,984,122	
Rafah		322,035	150	17,631,416	
Total		2,570,197	150	140,718,284	69,000,000

TABLE 7

Optimal Water Quantities for Medium Term Management in Year 2025

Description	Source	Variable	Unit	Quantity
Domestic and Industrial Demand	Groundwater wells	Q11	M^3	$48*10^6$
	Desalinated water from brackish wells	Q21	M^3	$5*10^6$
	Desalinated Sea Water.	Q31	M^3	$67*10^6$
	imported water from Mekorot Company	Q41	M^3	$10*10^6$
	Imported water from Egypt.	Q51	M^3	$10*10^6$
Total			**M^3**	**$140*10^6$**
Agriculture Demand	Groundwater wells	Q12	M^3	$49*10^6$
	Imported water from Egypt	Q52	M^3	$9.7*10^6$
	Reclaimed water	Q62	M^3	$20*10^6$
Total			**M^3**	**$78.7*10^6$**
Harvested Water	Harvested water from storm water	Q7	M^3	$18*10^6$
Electrical Conductivities of water from different sources	Water from aquifer	Ec1	µS/cm	1000
	Desalinated water from brackish wells	Ec2	µS/cm	500
	Desalinated seawater.	Ec3	µS/cm	500
	Imported water from Mekorot Company.	Ec4	µS/cm	700
	electrical conductivity of water imported from Egypt	Ec5	µS/cm	500
Final Quality of water In	Calculated average electrical conductivity for domestic water	ECT1	µS/cm	685

terms of Electrical Conductivity	Average electrical conductivity for irrigation water	ECT2	µS/cm	876
Best Function Value			**$ 79 *10^6^**	

The results show that there is a significant improvement also in aquifer's water levels in the majority area of the Gaza Strip especially in the middle area. The levels will gradually to increase to reach 4 meters below MSL in north area and 8 meters below MSL in south area. As for quality, the results show that the total average of electrical conductivity for the domestic and agriculture uses are water is 685µS/cm and 876 µS/cm respectively. This means that the TDS for domestic use is around 400 mg/liter and 530 mg/liter for agriculture use. Figure 3 shows the water levels of aquifer throughout the Gaza Strip by adopting the optimized scenario for medium term planning in year 2025. Figure 3 shows the the results of the simulations for the water levels in the aquifer using SEAWAT model when adopting the optimized scenario for short term planning in year 2025. Figure 3 clearly dominstrate the imporovement in the water level in the aquifer compared to the year 2015.

C Genetic Algorithm Model results for Short Term Management for year 2035

The estimated quantities of water for domestic demand were calculated considering the recommendations of GETAP 2011[6] by considering a benchmark water consumption of 150 liters per capita/day for the whole of the Gaza Strip towards the end of the long-term intervention period. Table 8 summarizes the distribution of projected population of the Gaza Strip as well as the demanded quantities of water for domestic and agriculture use. As the result of the instability of the political situation and the absence of the industrial infrastructure, the consumption for industrial demand will consider to be 2MCM/year [11].

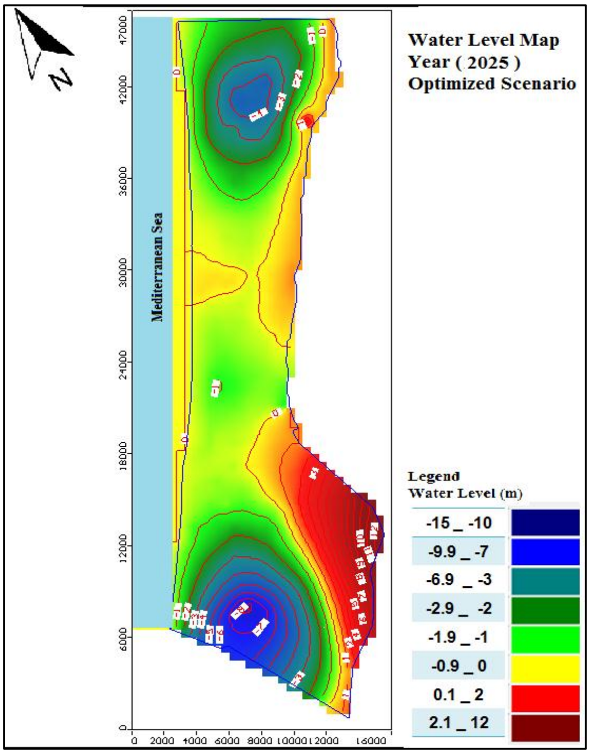

Figure 3: Predicted Water Level for Optimized Scenario (year 2025)

Considering the required quantities for both domestic and agriculture use with all constrains and limits, the GA model solved the case for optimal quantities by maximizing the total benefits and minimizing the cost. The optimal quantities after comparing 100 generations are summarized in Table 9 of Genetic Algorithm model interface for year 2035.

TABLE 8

Projected Population and Domestic & Agriculture Water Demand in year 2035

Governorate	Year	Population	Consumption (L/Capita/ Day)	Domestic Water Demand per Governorate (m³/year)	Agriculture Water Demand For All Governorates (m³/year)
North	2015	708,091	150	38,767,982	61,000,000
Gaza		1,293,033	150	70,793,556	
Middle		526,431	150	28,822,097	
Khan		643,701	150	35,242,630	
Rafah		454,262	150	24,870,844	
Total		3,625,518	150	198,497,110	61,000,000

TABLE 9

Optimal Water Quantities for Short Term Management in Year 2035

Description	Source	Variable	Unit	Quantity
Domestic and	Groundwater wells	Q11	M^3	$48*10^6$

Industrial Demand	Desalinated water from brackish wells	Q21	M^3	$5*10^6$
	Desalinated Sea Water.	Q31	M^3	$125*10^6$
	imported water from Mekorot Company	Q41	M^3	$10*10^6$
	Imported water from Egypt.	Q51	M^3	$10*10^6$
Total			**M^3**	**$198*10^6$**
Agriculture Demand	Groundwater wells	Q12	M^3	$50*10^6$
	Imported water from Egypt	Q52	M^3	$10*10^6$
	Reclaimed water	Q62	M^3	$30*10^6$
Total			**M^3**	**$80*10^6$**
Harvested Water	Harvested water from storm water	Q7	M^3	$18*10^6$
Electrical Conductivities of water from different sources	Water from aquifer	Ec1	µS/cm	1000
	Desalinated water from brackish wells	Ec2	µS/cm	500
	Desalinated seawater.	Ec3	µS/cm	500
	Imported water from Mekorot Company.	Ec4	µS/cm	700
	electrical conductivity of water imported from Egypt	Ec5	µS/cm	500
Final Quality of water In terms of Electrical Conductivity	Calculated average electrical conductivity for domestic water	ECT1	µS/cm	631
	Average electrical conductivity for irrigation water	ECT2	µS/cm	842
Best Function Value			**$ 86 *10^6**	

The results show that there is a significant improvement in water levels in aquifer in the majority area especially in the middle area. The levels reach to a significant of 13 meters above MSL in the eastern area and show a significant increase also in both north with 3 meters below MSL and in south area with 4 meters below MSL. As for quality, the results show that the total average of electrical conductivity for the domestic and agriculture uses are water is 631 µS/cm and 842 µS/cm respectively . This means that the TDS for domestic use is around 380 mg/liter and 500 mg/liter for agriculture use. Figure 4 shows the water levels of aquifer throughout Gaza Strip by adopting the optimized scenario for long term planning in year 2035.
Figure 4 shows the the results of the simulations for the water levels in the aquifer using SEAWAT model when adopting the optimized scenario for short term planning in year 2025. Figure 4 show more imporovement in the water level in the aquifer compared to the year 2015, and year 2025.

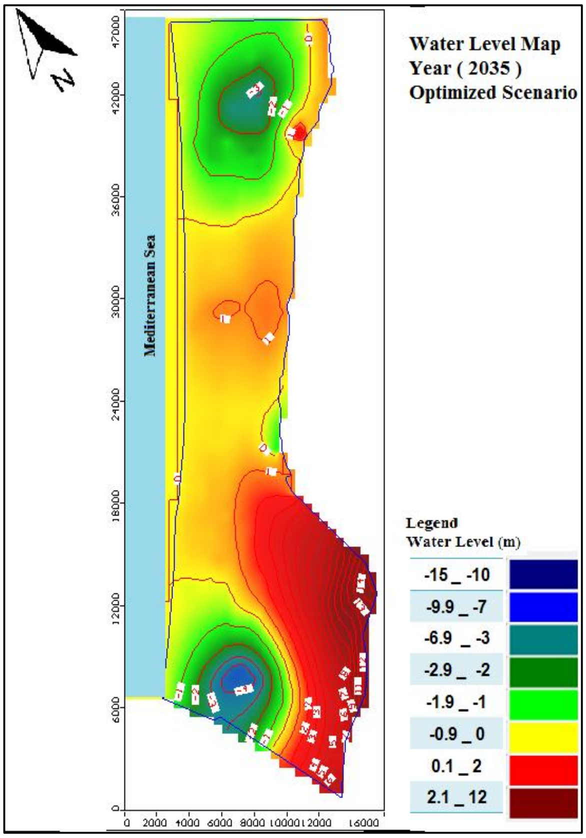

Figure 4: Predicted Water Level for Optimized Scenario (year 2035)

IV CONCLUSIONS

A Optimal solution for short term planning in Year 2015

The optimal quantities for domestic and industrial demands are 65*106 M^3 from Groundwater, 1.08*106 M^3 from desalinated brackish wells, 13*106 M^3 from desalinated from sea water, $9.90*10^6$ M^3 imported water from Mekorot company and $4.90*10^6$ M^3 from imported water from Egypt.
The optimal quantities for agriculture demand are $63*10^6$ M^3 from Groundwater, 4.96 $*10^6$ M^3 of imported water from Egypt and 9.28 $*10^6$ M^3 from reclaimed water .
The results of the model show that a quantity of 19.87 $*10^6$ M^3 of harvested water should have injected to aquifer to add additional quantities and to improve the ground water quality .
The results show that the final quality of available water for agriculture use in term of total weighted average of electrical conductivity is 962 µS/cm which is equal to 577 mg/l and 230 mg/l for TDS and CL- respectively.

B Optimal solution for medium Short term planning in Year 2025

The optimal quantities for domestic and industrial demands are $48*10^6$ M^3 from Groundwater, $5*10^6$ M^3 from desalinated brackish wells,67*10^6 M^3 from desalinated from sea water, 10*10^6 M^3 imported water from Mekorot company and 10*10^6 M^3 from imported water from Egypt.

The optimal quantities for agriculture demand are 49*106 M^3 from Groundwater, 9.7 *106 M^3 from imported water from Egypt and 20 *10^6 M^3 from reclaimed water.

The results of the model show that a quantity of 18 *10^6 M^3 of harvested water should have injected to aquifer to add additional quantities and to improve the ground water quality .

The results show that the final quality of available water for agriculture use in term of total weighted average of electrical conductivity is 876 µS/cm which is equal to 526 mg/l and 210 mg/l for TDS and CL respectively.

C Optimal solution for long term planning in Year 2035

The optimal quantities for domestic and industrial demands are 48*10^6 M^3 from Groundwater, 5*10^6 M^3 from desalinated brackish wells, 125*10^6 M^3 from desalinated from sea water, 10*10^6 M^3 imported water from Mekorot company and 10*10^6 M^3 from imported water from Egypt.

The optimal quantities for agriculture demand are 50*10^6 M^3 from Groundwater, 10*10^6 M^3 imported water from Egypt and 30 *10^6 M^3 from reclaimed water .

The results of the model show that a quantity of 18 *10^6 M^3 of harvested water should have injected to aquifer to add additional quantities and to improve the ground water quality.

The results show that the final quality of available water for agriculture use in term of total weighted average of electrical conductivity is 842 µS/cm which is equal to 505 mg/l and 202 mg/l for TDS and CL- respectively.

References

[1] Qahnam K. Aspects of Hydrogeology, Modeling, and Management of Seawater Intrusion for Gaza Aquifer – Ppalestine. Ph.D. Dissertation, Department of Civil Engineering, University of Mohammad al Khamis. Morroco, (2004).

[2] Willis, R. and Yeh W. W-G, Groundwater Systems Planning and Management. Prentice-Hall, Inc, New Jersey, (1987).

[3] Ghabayen S, McKee M, Kemblowski MA, Bayesian Belief Network Model for Multi-Objective Optimization of the Gaza Water Resources System. AWRA Annual Conference, San Diego, California,
(2003).

[4] Holland, J., Adaptation in Natural and artificial Systems, Univ. of Mich. Press, Ann Arbor, (1975).

[5] Ouazar, D., and Cheng A. H. D., Application of genetic algorithms in water resources, in Groundwater Pollution Control. Edited by K. L. Katsifarakis, chap. 7, pp. 293-316, WIT Press., Boston, (1999).

[6] The Gaza Emergency Technical Assistance Programme on Water Supply to the Gaza Strip (GETAB), Component 1- The Comparative Study of Options for an Additional Supply of Water for the Gaza Strip (CSO-G), (2011).

[7] Ghabayen S., Probabilistic Expert System for Analysis and Optimization of Large Scale Water Resources Systems. Ph.D. Dissertation, Utah State University, Utah, USA, (2004).

[8] Hill R. and Koeing R., Water Salinity and Crop Yield. Report #Ag 425.3. Utah State University Cooperative Extension, (1999).

[9] Metcalf and Eddy, Integrated Aquifer Management Plan: Model Final Report. Coastal Aquifer Management Program, (2003).

[10] Palestinian Central Bureau of Statistics (PCBS), " Population and Housing and Establishment Census ". Census Final Results in Gaza Strip, Palestinian National Authority. (2007)

[11] Palestinian Water Authority (PWA). (2012). Water Supply Annual Report 2010.