SPC

Progress in Chemical and Biochemical Research

Journal homepage: www.pcbiochemres.com

Original Research Article

Estimation of Sustainable Utilization Model of Common Groundwater Aquifers: A Case Study of Urban and Operators-Game Theory

Sanaz Nozariamini[1*], Sara Miryousefi Ata[2]

[1]*Transportation Engineer DOT California, Alumni California Polytechnic University Pomona, USA*
[2]*PhD candidate at Louisiana State University, USA*

ARTICLE INFO

Article history

Submitted: 2020-08-03
Revised: 2020-08-10
Accepted: 2020-08-16
Available online: 2020-09-13
Manuscript ID: PCBR-2008-1118
DOI: 10.22034/pcbr.2020.114030

KEYWORDS

Agriculture,
Static Game Model,
Sustainable Equilibrium,
Water

ABSTRACT

The growth and expansion of the population on the one hand and the supply of water to provide food to the growing population on the other hand in recent decades has caused serious differences among the users of water resources. Due to the limited resources, the need for sustainable use of these resources is evident. In systems consisting of several independent decision makers, game theory is a powerful tool for users to achieve a stable equilibrium point. The purpose of this study is to present a dynamic model in order to resolve the differences between the operators of the common greenhouse and achieve a stable balance. In this article, based on the way of cooperation and degree of interaction of water users, their behavior is modeled in the form of three scenarios as model of static games without cooperation, model of dynamic games without cooperation and finally, model with full cooperation. In order to compare the results obtained from application of the above scenarios, the exploitation of a common groundwater aquifer has been studied between urban and agricultural exploiters. The results show that the revenues from the model with full cooperation are more than the models without cooperation.

GRAPHICAL ABSTRACT

* Corresponding author: Nozariamini, Sanaz
✉ E-mail: sanaz.nozariamini@gmail.com

INTRODUCTION

The growth and expansion of the population on the one hand and the supply of water to provide food to the growing population on the other hand in recent decades has caused serious differences among users of water resources. Due to the limited resources, the need for sustainable use of these resources is evident [1-3]. In systems that consist of several independent decision makers, game theory is a powerful tool in achieving a stable equilibrium point for users. The purpose of this study is to present a dynamic model in order to resolve differences between users of the common greenhouse and achieve a stable balance [4-7]. In order to compare the results obtained from the application of three common scenarios as model of static games without cooperation, model of dynamic games without cooperation and finally, model with full cooperation, the exploitation of a common groundwater aquifer which is located between two urban and agricultural operators in the hypothetical region, has been studied. The results show that the revenues from the model with full cooperation are more than the models without cooperation. The depletion and destruction of common natural resources among several exploiters has become a pervasive rule in the quantitative and qualitative state of exploitation of natural resources, while Hardin referred to it as the "tragedy of commonalities." Explaining the growing trend of degradation of shared natural resources, he referred to the issue of "the benefit of one exploiter against the loss of all [8-11]." In other words, a user's disobedience to the rules will only lead to his or her own short-term gain, while the loss of his or her wrong decision will affect all users. In the event that players do not comply with the rules and restrictions of the game, appropriate penalties are not imposed or players can not consider their long-term interests, a tragedy of commonalities awaits players. In the field of exploitation of natural resources in general and exploitation of groundwater resources in particular, there are several evidences that have proved the possibility of such conditions [12-16].

Researchers have long been interested in providing models that are consistent with decision-making environments in order to resolve differences between users and achieve a stable balance. Although there is much research in the history of game theory formation, game theory discussions generally begin. Can be attributed to Van Newman and Morgenstern after the publication of The Theory of Games in Economic Behavior in 1944. Various researchers have played a valuable role in the development of game theory. The use of game theory in the field of exploitation of common natural resources in order to resolve differences between exploiters gradually came to the attention of researchers; for example, Fisher and Mirman in exploiting common water resources for fishing using non-cooperative games, Burton et al. in the field of air pollution control and Mazandarani Zadeh and Ghaheri (2007) using games without cooperation, Coppola and Zidarovsky in the field of collaborative exploitation of the common groundwater aquifer, and Coppola and Szidarovszky, 2004 and Ganji et al. studied the collaborative operation of dam reservoirs. Burness and Brill (2001) explained the effect of annual inflation coefficient, the effect of increasing demand, the use of new pumping equipment with greater efficiency during the years of operation and the use of appropriate hydraulic models, etc. on the results of dispute resolution models. Taking into account the above factors, the advantage of using cooperative models over non-cooperative models became clear. Coppola and Szidarovszky (2004) examined the resolution of disputes between the Water Supply Authority and the Health Authority [17-20]. The issue examines determination of groundwater aquifer exploitation policies to supply the city with drinking water, while part of the aquifer is contaminated with some kind of pollutant. Increasing the pumping flow causes more hydraulic slope and increases the risk of pollution, and on the other hand, reducing the pumping rate will cause dissatisfaction of residents. In order to calculate the changes in the aquifer level due to the decisions of the players, first using the results of the Modflow hydraulic model, a neural network model has been taught and then in order to reduce the computation time, the trained neural network model has been used instead of the Modflow hydraulic model [21-23]. Luisiga et al. examined the cooperative and non-cooperative behavior of two groundwater users from the perspective of game theory. The two operators of the joint greenhouse are pumping water. The two can either work together to determine their share of the total pumping rate or operate without cooperation [24]. The results of the model implementation, in the coastal aqueduct of Santa Barbara in the United States, in two-player mode, indicate a great advantage of cooperative behavior over non-cooperative behavior. Nakao and his colleagues outlined the benefits of working with two longtime rivals to exploit the joint US-Mexico border watershed [25].

Practical purposes

In most previous researches, in order to reduce the volume of calculations, instead of using hydraulic relations in estimating the amount of drop in the aquifer level, approximate relations have been used. While the use of hydraulic relations, which have the ability to accurately calculate the amount of groundwater drop, will lead to more reliable results. In this research, Chah-Tis equation will be used to predict the amount of aquifer drop. Also, in most of the above studies, players' decisions are modeled as a continuous variable, while in real issues such as the issue of pumping groundwater discharge, as a player decision variable, it is a discrete variable. In the present study, the use of discrete decision variables has been considered. Game theory or competition strategy is a mathematical theory that deals with competitive situations. This theory is useful when two or more decision makers with conflicting goals are trying to make a decision. In such a situation, the decision of one decision maker influences the decision of the other. Game theory does not describe how the game is performed, but only describes the method and principles of selecting players' movements [26-29].

Net Strategy (set of choices before each player): If we represent the number of player's net strategies i with mi and their set with Mi, then we can display the set of members Mi with mi prime number; in other words

$$Mi = \{1,2, \dots . mi\} \tag{1}$$

Mixed strategy (probabilistic combination of a set of choices in front of players): If we display the set of probabilities defined on a point k with xk:

$$X_k = \{(X_1, X_2, \dots \dots ., X_k | \forall X_i \gg 0 \text{ and } \textstyle\sum_{i=1}^{K} x_i = 1) \tag{2}$$

The set of probabilities defined on mi for player i is equal to Xmi. Therefore, the set of strategies of player i mixed with Si can be represented as Si = Xmi. In the game theory literature, Si is also called the i-player decision space. Strategic form of the game: Game G is displayed in the strategic form in the following three forms:

$$G = (N, (M_i)_{i\in N}, (u_i)_{i\in N}) \tag{3}$$

So that N = [1] is a set of players and M1, M2, ..., Mn is a set of players' strategies ui (m1, m2, ..., mn) → R is the consequence of player i When the strategy of the other players is m1, m2, ..., mn so that mj ∈M j for j = 1,2, ..., n. Therefore, the outcome of player i depends not only on his chosen strategy, but also on the strategy of other competitors. The outcome matrix of player i is a matrix whose elements express the outcome of player i against each pair of decisions he and his competitors make [30]. If the number of players in a game is equal to 2, it is called a "two-player game". Two-player game can be represented as BG = (SI, SII, A, B) that SII and SI, which is a set of mixed strategies of players II and I, respectively, and B and A are the outcome matrix of players II and I, respectively and each game BG = (SI, SII, A, B) has at least one equilibrium point.The answer to the BG game is obtained by solving the quadratic planning problem as follows:

The necessary and sufficient condition for (x *, y *) to be the answer of the game BG = (SI, SII, A, B) is that this vector be the answer of the following quadratic planning problem:

$$\max X^T (A+B) y - \propto - \beta \qquad (4)$$

$$* = x^{*^T} A y^*, \quad \beta^* = x^{*^T} B y^* \quad and \quad x^{*^T}(A+B)y^* - \alpha^* - \beta^* = 0 \quad \text{St:}$$

$$ay \ll \propto e, \quad B^T x \ll \beta e, \ x \in S^m, y \in S^n, \quad \alpha, \beta \in R$$

If (x *, y *, α *, β *) is the answer of the above second degree programming, the following can be concluded:

(4) And y^* are called the equilibrium strategy of players I and II, respectively. Thus, the strategic balance of the game is a vector in which each player uses the best answer against the game of other rivals. In this case, no player tends to change strategy and the vector (x *, y *) will be the stable equilibrium point of the BG game.

Analyzed area

Meteorology

Meteorological parameters including temperature, relative humidity, wind, rainfall and evaporation are very important and effective factors on the hydrological cycle and directly or indirectly affect the amount and intensity of surface currents, erosion and sedimentation of catchments and groundwater reserves. The study of these parameters plays an important role in recognizing hydrological phenomena for the useful use of limited water resources.

Table 1: Details of meteorological stations under study

No.	Station code	Station type	geographical characteristics			Date of establishment
			length	Width	Height	
1	43-201	Evaporation	611468	611468	2192	1365
2	43-082	Evaporation	3354519	618577	1690	1345
3	*	Synoptic	345116	658815	2020	1365
4	43-068	Rain gauge	3363110	662410	2275	1365
5	43-055	Rain gauge	3419127	596721	2342	1367
6	43-054	Rain gauge	3399082	592050	2117	1367
7	26-030	Save	3372127	671977	2549	1354

Table 2: Average monthly temperature of the studied stations during the statistical period

Sea height	October	November	December	January	February	March	April	May	June	July	Aguste	September	Yearly
2192	16.2	10.1	4.8	0.9	0.7	5.3	9.8	15.6	21	24.9	24.8	21.7	13
2020	16.5	10.8	5.6	3.3	3.7	7.5	12	17.3	22.2	25.6	24.9	13.6	13.6
16.90	17.9	12.1	6.8	4.2	4.6	8.7	12.4	18.1	23.6	27	26.4	23	15.4

Temperature

Temperature is one of the meteorological parameters that is measured and presented in synoptic and climatological stations under the supervision of the Meteorological Organization and evaporator stations affiliated to the Ministry of Energy. In order to study the temperature in the area using the information of the stations located in the study area and adjacent to it, the temperature gradient per month was drawn for the stations used and then the same temperature map was drawn. The average monthly temperature of these stations during the statistical period is presented in **Table.2**. The relationship of temperature gradient in the study area is as follows:

$$T = -0.005(H) + 24.83 \quad (5)$$

In this relation, T is the temperature in terms of degrees Celsius and H is the altitude in terms of sea level. Using the temperature distribution in the identifying station and considering the isothermal map, the average monthly and annual temperature in the plains and altitudes of the study area of the region has been calculated and presented in **Table.3**. Therefore, the average temperature in the plain is 11.5 and at altitudes of 10.1 degrees Celsius.

Rain

Rainfall is one of the most important meteorological parameters and is measured in stations under the supervision of the Meteorological Organization and the Ministry of Energy. Evaporation station of the region with 25 years of statistical history (66-65-90-89), has been selected as a representative of the heights and plains of the study area. In order to investigate the precipitation in the study area, the stations inside and outside the study area have been used. Rainfall gradient was calculated and then using topographic map and area, rain was drawn. To prepare the precipitation gradient, all three parameters of altitude, longitude and latitude have been considered in the calculations according to **Table.4** due to more precision.

$$P = -0.011117X - 0.0137Y + 0.52061H + 52683.338 \quad r=0.92 \quad (6)$$

In this regard, P is the average annual rainfall in millimeters, H is the height in meters, X and Y is the longitude in terms of UTM. According to the rain map, the average annual rainfall in the plain is 445.9 mm and at altitudes of 505.6 mm. According to the distribution of rainfall in the representative station of the region, the average monthly rainfall in the area and the heights of this area are determined and presented in **Table.3**.

Table 3. Monthly meteorological statistics of the study area of the region by plains and altitudes

Parameter	Heights & plains	October	November	December	January	February	March	April	May	June	July	Aguste	September	Yearly
Temperature (°C)	Plains	14.2	8.1	3.2	0	0	3.9	8.3	14.2	19.3	23.0	22.7	19.3	11.5
	Heights	12.7	6.5	1.7	0	0	1.9	6.3	12.4	17.6	21.3	21.1	17.5	10.1
Rainfall (mm)	Station	3.33	27.17	91.74	103.1	94.58	86.18	61.57	19.38	0.97	0.83	0.06	0	488.91
	Plains	3.0	24.8	83.7	94.1	86.3	78.6	56.2	17.7	0.9	0.8	0	0	445.9
	Height	3.4	28.1	94.9	106.6	97.8	89.1	63.7	20	1	1	0	0	505.6
Evaporation (mm)	Plains	192	105.2	59.9	57.3	46.6	99.9	151	217.3	309.7	344.9	348.4	290.5	2222.7
	Height	176	96.4	54.9	52.5	42.7	91.5	138.5	199.2	283.8	316.1	319.4	266.3	2037.3

Table 4. Parameters required to calculate annual rainfall and evaporation gradients

Location	Rain	Evaporation	Height	X	Y
Evaporation	489.1	2145.4	2200	612538	3398792
Evaporation	442	2476.8	2200	612638	3398792
Synoptic	133.4	2531.9	2020	658815	345116
Rian	388.3	*	2275	662410	3363110
Rian	387.1	*	2342	596721	3419127
Save	350	*	2549	671977	3372127

Evaporation

The main part of evaporation is related to atmospheric precipitation in the catchment area and part is related to evaporation and transpiration of plants and part is related to evaporation from wet soil surface, ice and snow surfaces, surface currents, Lake Surface and ponds and reservoirs of regions and etc. Evaporation parameter is measured at synoptic and evaporative stations. In this study area, there are only rainfall stations, so the evaporation stations in the region have been selected as a representative of the evaporation of the plains and heights. Using the evaporation information of the stations inside and outside this study area of the map, the evaporation has been determined according to the map. The average monthly evaporation of these stations during the statistical period is presented in **Table.5**. The relation of the evaporation gradient for the study area is as follows:

$$E = 0.004698 \times 0.000922Y - 0.67566H - 2380.7 \qquad r = 0.92 \tag{6}$$

This relationship is arranged by E average annual evaporation in millimeters, H in height in meters, X and Y in latitude and longitude in UTM. Using the monthly evaporation distribution in Abadeh and Kaftar introducing stations, the monthly evaporation values of the plains and altitudes are calculated and presented in **Table.3**. Based on this, the average annual evaporation from the basin in the plain is estimated to be 2222.7 mm and the altitudes to be 2037.3 mm.

Table 5. Average monthly evaporation of the studied stations during the available statistical period

Sea height	October	November	December	January	February	March	April	May	June	July	Aguste	September	Mean value
2192	185.3	101.5	57.8	55.3	45	96.4	145.8	209.8	298.9	332.9	336.3	280.4	2145.4
2350	200.4	118.9	70.2	46.3	49.5	90.7	145.4	223.9	316.4	363.5	357.2	294.2	2276.6
2020	247.9	125.1	16.8	6.3	6.8	37.4	173.6	302.8	398.5	443.5	419.9	353.6	2531.9
1690	232.1	167.5	91.2	62.1	70.3	121.8	179.6	244.4	323.4	349.9	338.2	296.3	2476.8

Evaporation from the free surface of water

In order to estimate evaporation from the free surface of water, various methods such as water balance method, evaporation pan method and experimental equations have been proposed. This parameter has been determined using the following equation in the study area.

$$E_{SW} = K * E_{pan} \tag{7}$$

In this regard, E_{SW} evaporation from the free surface of water in millimeters, E_{pan} evaporation from the pan and K is a constant coefficient that varies between 0.58 and 0.78 for a standard class A (American) evaporator. Considering the pan coefficient of 0.73 and its application in the annual evaporation of the plain at the rate of 2222.5 mm, the amount of evaporation from the free water surface is equal to 1642.4 mm and the annual evaporation from the heights of 2037.3 mm and the amount of evaporation from the free surface of water is equal to 1487.3 mm.

Potential evapotranspiration

Potential evapotranspiration is another important meteorological parameter. This parameter is the amount of evapotranspiration that is done in a certain period of time from surface of water and soil with full coverage of the reference plant such as grass. Accurate calculation of potential evapotranspiration is performed using a lysimeter. Since the use of this device is not widely practiced, the experimental equations of evapotranspiration are mainly used. Many of these methods require multiple parameters that limit their use. One of the methods for determining the evapotranspiration potential is the Torrent White method, which can be determined using temperature. This method has modifications to the lighting hours per month and the monthly temperature is less than or equal to zero and the temperature is more than 26.5 ˚C. In order to calculate the actual evapotranspiration, monthly temperature and rainfall parameters are required, separately for plains and altitudes. For this purpose, using the monthly distribution information of these two parameters according to **Table.3**, the monthly temperature and rainfall in the study area have been calculated separately for plains and altitudes. Using the monthly temperature parameter, first the monthly index, then the annual temperature and the coefficient in the White Torrent formula are calculated, then the potential evapotranspiration rate is calculated separately for the plains and altitudes by the White Torrent method. **Table.6** and **7** show how to calculate the actual evapotranspiration by the Torrent White method in the highlands and plains.

Table 6: Calculations of potential evapotranspiration by Torrent White Dasht method

Parameter	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**Aguste**	**September**	**Yearly**
Temperature	14.2	8.1	3.2	0	0	3.9	8.3	14.2	19.3	23	22.7	19.3	11.5
im value	4.8	2.1	0.5	0	0	0.7	2.1	4.8	7.7	10	9.8	7.7	50.3
Nm value	0.9	0.9	0.8	0.9	0.9	1	1.1	1.2	1.2	1.2	1.1	1.1	----
Potential sweating	54.4	26.5	7.2	0	0	11.6	33.4	72.5	107	134.4	121	98.4	667

Table.7. Calculations of potential evapotranspiration by Torrent White method at high altitudes

Parameter	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**Aguste**	**September**	**Yearly**
Temperature	12.7	6.5	1.7	0	0	1.9	6.3	12.4	17.6	21.3	21.1	17.5	10.1
im value	4.1	1.5	2	0	0	0.2	1.4	3.9	6.7	8.9	8.8	6.6	42.4
Nm value	0.9	0.9	0.8	0.9	1	1.1	1.2	1.2	1.2	1.2	1.1	1.1	--
Potential sweating	53.6	24	4.3	0	0	6.1	28.3	69.5	105.7	132	120.4	96.2	64.08

Surface water

One of the main components of water balance equations is surface runoff. Determination of surface runoff is done daily and instantaneously using runoff measurements at hydrometric stations or through regional or experimental relationships. Analysis of surface water statistics and information is of great importance. Runoff coefficient of catchments, basin and flood flows, inlet and outlet surface water volume from the study areas determined during these calculations, are used as primary information in the study of water balance of the studied catchment and are of great importance.

Table 7: Average monthly flow and basic flow in hydrometric station

Month	October	November	December	January	February	March	April	May	June	July	Aguste	September	Yearly
Total flow rate (m^3/s)	2.9	3.29	6.62	10.2	13.4	13.6	11.5	6.62	3.34	2.8	2.75	2.56	6.64
Ref. flow rate (m^3/s)	2.9	3.08	3.24	3.60	4.12	4.38	4.43	3.63	3.04	2.8	2.75	2.56	3.38
Runoff flow rate (m^3/s)	0	0.21	3.38	6.63	9.28	9.22	7.10	2.99	0.3	0	0	0	3.26
Volume of ref. flow rate (m^3)	7.5	7.98	8.40	9.33	10.6	11.3	11.4	9.41	7.88	7.3	7.14	6.65	105.2
Volume of runoff flow rate	0	0	8.77	17.1	24	23.9	18.4	7.74	0.77	0	0	0	100.8

To calculate the amount of runoff produced at the heights of the study area, the average flow statistics of the hydrometric station located at the outlet of the basin and on the Gavgdare River during the statistical period (1365-66) has been used. According to the discharge of the station, the base discharge is extracted and separated in **Table.8**. After separating the base flow from the total flow, the runoff is calculated at 3.26 m^3/s. The value of Justin coefficient from the above relations is calculated to be 0.237. **Table.9** therefore, according to the total area of the study area of 1590.5 km^3 and the average rainfall of 475.7 mm, the total volume of rainfall is 756.7 million cubic meters per year. On the other hand, the annual runoff volume is 100.71 million cubic meters, which is 13.31% of the rainfall coefficient of the study area. Also, according to the Justin coefficient, the amount of runoff at altitudes of 52.79 million cubic meters per year is equivalent to 14.5% of the rainfall at high altitudes. The difference between the amounts of runoff in the study area from the runoff of heights equivalent to the discharge produced in the plain is 47.92 million cubic meters per year, equivalent to 12.35 percent.

Table 8. Calculation of Justin coefficient in the reference station

Runoff percent	Rain volume (million m^3)	Runoff yearly (million m^3)	Runoff height (cm)	Temperature (˚C)	Slope	K coefficient	Rainfall (cm)	Area (km^3)
13.31	756.7	100.71	6.33	10.8	0.04	0.237	47.58	1590.5

Table 9. Calculation of runoff coefficient in the study area of the region by plains and elevations

Runoff percent	Rainfall vol. (million m^3)	Runoff yearly (million m^3)	Runoff height (cm)	Temperature (˚C)	Slope	K coefficient	Rainfall (cm)	Area (km^3)	No.
13.31	756.7	100.71	--	---	--	--	47.575	1590.5	All understudy region
14.5	364.1	52.79	7.33	10.1	0.04	0.237	50.56	720.1	Height
12.35	388.1	47.92	--	--	--	--	44.59	870.4	Plains

DISCUSSION

According to the map, the groundwater level is for the flow of groundwater from the southeast to the northwest of the plain. Alignment curves are drawn at a distance of 10 meters. The level curve of 2270 meters is visible on the southeast side of the plain and the level curve of 2110 meters is visible on the northwest side of the plain. In the northwestern and southeastern parts of the plain, the entrance level curves show from the heights to the alluvium, and also in the northwestern part of the plain, the exit level curves from the alluvium to the heights can be seen. Hydrodynamic coefficients have been used to update the atlas of water resources of the lake catchment area. In groundwater maps, the slope of the plain follows the trend of level maps. According to the above map, the groundwater inlet is in the northwestern part of the plain. In the northwestern part, the outlet is seen, which is due to the discharge of groundwater to the heights. Groundwater drop maps show areas with severe drop in the plain that the water level changes in September and April 77-76 to September and April to 91-90. The maximum drop is in the southeastern part towards the center of the plain. Exploitation wells have been drilled in the whole study area, and the decrease due to irregular extraction is evident throughout the plain.

Table 10. Characteristics of minimum and maximum drop in plain observation wells

No.	X	Y	September 2011	April 2011	Minimum drop	Maximum drop
1	623388	3393544	4.63	3.71	-0.66	-0.42
2	619369	3395437	35.05	31.31	-2.37	-0.95
3	614114	3397092	47.58	44.80	-2	1.26
4	627502	3391702	19.15	16.34	-0.07	-0.47
5	609873	3399283	34.07	33.9	-0.11	2.99
6	606452	3397273	24.55	19.06	-2.47	1.97
7	607967	3393023	24.94	24.26	0.52	-0.4
8	625735	3388352	6.38	1.40	-0.24	-2.67
9	607589	3398929	10.55	4.81	-1.02	0.08
10	61384	3395497	37.73	34.82	-0.48	-1.29
11	609739	3394696	6.15	1.76	0.19	-0.47

CONCLUSION

Based on the latest statistics and hydrographic information of the alluvial aquifer unit and the rainfall diagram of the evaporating station, information about the water level has been available from October 1996 about 2163.53 to October 2012 about 2159.3 meters, with a water drop of 4.23 meters during this period. Considering the area of Thyssen network and taking into account the storage coefficient of 5% and water level drop of 4.23 meters, the reservoir volume changes equal to 143.77 million m^3, which during the statistical period of 76-75 to 91-90 for 16 years shows 8.66 million cubic meters per year of reservoir deficit.

$$V = A * S * H = 655 * 0.05 * 4.23 = 138.53\ (mcm)\Delta$$

$V\Delta$= *reserviour volume changes*, A = *Thyssen network area*, S = *storage coefficient*, H = *water level drop* & (mcm) = *million cubic meters per year*

According to the statistics of the year 1988-89 and the protection statistics of the regional water organization, there were a total of 1572 water sources in this study area. From all these sources, there are 1518 wells, 5 springs in Sakht formation and 1 spring in alluvium, 30 aqueducts in alluvium and 18 motor pumps. In total, the total annual discharge from the study area is estimated at 252.39 (194.4 wells, 4.23 aqueducts, 51.04 springs and motor pump 2.71) million cubic meters. It is necessary to explain that the total water discharged from the water resources of this area in the plain (consumed for 7 months) and for agricultural use (250.14 million cubic meters) and drinking (2.19 million cubic meters) and industry (0.07 million cubic meters). One of the basic pillars of water resources management in the current situation is the optimal use of available resources. In order to consider various dimensions and complexities of water resources systems, managers and planners today have resorted to using optimization models as an efficient tool to achieve optimal decisions. A variety of evolutionary, deterministic and non-deterministic, static and dynamic, linear and nonlinear optimization models are used in various aspects of water resources management. The development of human knowledge and creation of new tools and their combination with existing optimization models have provided new opportunities for better decision makers in the development and planning of water resources. Creating tools and the need for access to modern technology such as the World Wide Web and GIS Information value of new data and information due to behavioral changes in watersheds and the importance of rapid use of this information for analysis, design and information in emergencies and public education and consumption water conservation has created new coordinates in water resources management. Today, with the rapid development of information technology, a new space has been provided for development of new tools for the analysis, planning and management of water resources systems. With access to the Internet, an infinite space of information and science is provided to the user, which can be used to reach the most effective decisions. Useful tools that have been significantly expanded are remote sensing and GIS. Using remote sensing, quantitative and qualitative variables can be identified and effective parameters about them can be measured and relationships between them can be interpreted. For example, using sensor information on airplanes and satellites, valuable information such as soil moisture, snow cover and flood spread can be obtained, which are of great importance in water resources management. There are always problems in the decision-making process of water resources management due to the existence of different sectors that consume and produce wastewater, because different sectors have different goals, views and priorities, and final decision should be in such a way that all these differences has been. Among the most important differences in water resources, we can mention the quantity and quality of water allocated to different sections, the quantity and quality of wastewater and effluents, which will suffer damage if the system is not managed properly. Limited resources and increasing water needs, which is due to population growth and development of cities and new community management policies, cause problems in water allocation. By knowing more and more the reasons for differences and modeling those using different methods and including them in the optimization models, one can be very sure that the results of the developed model are feasible and practical.

Acknowledgements

The study presented in this paper is part of a research of Sanaz Nozariamini (Transportation Engineer DOT California, Alumni California Polytechnic University Pomona).

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HOW TO CITE THIS ARTICLE

Sanaz Nozariamini, Sara Miryousefi Ata, Estimation of Sustainable Utilization Model of Common Groundwater Aquifers: a Case Study of Urban and Operators-Game Theory, Prog. Chem. Biochem. Res. 2020, 3(4) (2020) 390-401

DOI: 10.22034/pcbr.2020.114030

URL: http://www.pcbiochemres.com/article_114030.html