IIOAB JOURNAL
ISSN: 0976-3104

RESEARCH

UNDERGROUND DAM MODELING USING SWAT SOFTWARE

Hamed Nayebi[1], Mohammad Shirvani[2]*, Mahdi Kamfiroozi[2]

[1] *Dept. of Water Engineering, Faculty of Technology and Engineering, Bandar Abbas Branch, Islamic Azad University, Bandar Abbas, IRAN*

[2] *Sama Technical and Vocational Training College, Islamic Azad University, Bandar Abbas Branch, Bandar Abbas, IRAN*

ABSTRACT

An effective approach for supplying water for various sectors especially in arid and semi-arid regions and fighting drought stress is to enhance underground water reserves. In this research, required properties for locating underground dams and water balance in Daragah watershed in Hormozgan province are investigated. These properties include the main features required for initial location of underground dams considered in all studies dealing with underground dam construction; however, for the first time, subsurface flow is calculated by SWAT hydrological model. Therefore, three criteria and ten indices (subsurface flow volume, surface flow volume, drainage density, alluvium depth, axis length, fulcrum lithology, permeability, slope, reservoir volume, and upstream catchment area) were adopted for prioritization. The determined regions evaluated based on three criteria as hydrology, reservoir and dam axis and prioritized according to the indices. Thus, locating the suitable place for construction of dam using SWAT model and the discussed indices is a scientific methodology for this task. This approach significantly saves time and cost and is able not only to determine the suitable locations, but also to determine the best region for construction of underground dam.

KEY WORDS
SWAT Model, Underground Dam, Subsurface Flow, Daragah Watershed, Location.

Published: 10 Sept 2016

***Corresponding Author**
Email:
m.shirvani@iauba.ac.ir

INTRODUCTION

Water shortage has been a major challenge in arid regions including a large part of Iran country. In these regions, it is extremely difficult to improve available water supply. Therefore, the main way to combat water deficit in these regions is to accurately protect and use the available water by a correct management. An effective way for accurate use of water in arid regions is to collect the water existing in these regions [1]. Use of groundwater has long has spread in Iran, which does not have an abundance of surface water resources. From the distant past to the present, sensitive exploitation of groundwater resources for reasons of social, technical and economic is considered more than other water sources. On the one hand, they are very good quality compared to surface water, existing endowments tanks under the ground, and etc., and has caused a lot of interest in water supply in the country. The use of underground water, although it is extracted, it is usually more expensive than water withdrawals from rivers, which for the following reasons is the most interest:

- They are usually free of pathogens and thus don't require purification.
- They have constant chemical composition.
- Underground waters are often colorless and lack darkening materials.
- Underground waters are not affected by short term droughts [2].

The main problem in the development and creation of underground dams is the complexity of determining appropriate areas for dam construction. This problem stems from the fact that involved norms and many factors including physical, social and economic criteria in their proper location [3]. In this study, is consider simulated Daragah watershed water balance using the SWAT hydrological model and identify appropriate locations, in terms of surface and underground water flows and using the layers that is obtained SWAT model, as well as other layers of information to be taken to determine suitable locations for underground dam construction [4].

Research hypotheses

It is possible to anticipate the behaviors of artificial groundwater aquifers using underground dam modeling.

MATERIALS AND METHODS

In general, the present study is carried out in five steps as follows:
1. Identification and selection of the regions with high potential for construction of underground dam.
2. Identification of suitable points within these regions.
3. Determination and preparation of parameters required for prioritization.
4. Running SWAT model and simulation of runoff and subsurface flow.
5. Decision making.

At the first step, regions with high potential for construction of underground dam were evaluated. For this purpose, we used of extracted data from the base map, findings in this field, as well as expert opinions. This potential area is including alluvial bed rivers that are having maximum slopes of 5%, and there is no agricultural, industrial and residential land therein. In addition to the above conditions, this alluvial bed should not be based on linear structures, such as faults. To expedite decision making and also avoidance of to gather additional information to requirements about the studied issue, at first, we need to delete inappropriate places taking into consideration a number of criteria and key factors. According to surveys and studies that have been conducted in other countries by researchers and experts about underground dams, suitable slope of waterways, to be able to create a suitable underground water tank with underground dam construction, where should not be more than 5%.

Regions Prioritization Criteria

The first step in evaluation of regions with high potential for construction of underground dams is to determine criteria and sub-criteria playing role in location of dams. To achieve the expected objectives, a model composed of three levels of goal, criteria, indices and items (classes) was developed. Level one is the target of research, which is the identification of suitable areas for the implementation of underground dam. At the second level, there are criteria for decision making or the parameters affecting this value including hydrological factors, factors related to dam construction site of related to the dam reservoir. On the third level there are sub-criteria. Sub-criteria or indicators of hydrology include subsurface flow, runoff volume and drainage density [5].

SWAT Model

SWAT is a model with physical basis as it simulates the process of the original system at large scale based on basic equations of physics. Most of the relations in this model have physical basis showing the need for a large number of variables for accurate running of the model. This model is in the semi-distributed models group, because in it, is spatial information for similar units together with hydrological data and considers the scope and drainage for the same units, which is described each network by its own parameters, initial conditions and inputs of rainfall. As a result, it is possible to predict the location of hydrological processes and erosion anywhere in the watershed. Furthermore, this model has been continuous, because is having components that defines evaporation and perspiration and water movement in soils between rainstorms and therefore, is able to balance water and energy among rainstorms [6].

Preparation of Input Data

Basic maps include digital elevation model (DEM), land use map and soil map. Before running the model, input data including climatic and hydrological data, digital elevation model, soil map, land use map, stream network map and sub-basin boundaries were prepared. In addition to the cases mentioned, it is necessary that at least one station selected in the catchment areas studied as meteorological reference stations, and 14 statistical characteristics of long-term meteorological information to be provided on a monthly basis in the Wgn file to model. The model can be used these data to simulate failures meteorological data. These data are shown in Table: 1.

Table 1: The necessary data model for meteorological reference stations

Row	Parameter name	Parameter characteristic
1	Mean daily maximum temperatures per month	TMPMX
2	Mean daily minimum temperature per month	TMPMN
3	Standard deviation of daily maximum temperatures per month	TMPSTDMX
4	Standard deviation of daily minimum temperature per month	TMPSTDMN
5	Mean total rainfall per month	PCPMM
6	Standard deviation of daily precipitation per month	PCPSTD
7	Coefficient of skewness of daily rainfall per month	PCPSKW
8	Probability of rainy day after a dry day in the month	PR-W1
9	Probability of rainy day after a rainy day in the month	PR-W2
10	Mean rainy days in the month	PCPD
11	The maximum half-hour rainfall in total of collecting statistics	RAINHHMX
12	Mean solar radiation per month	SOLARAV
13	Mean daily dew point temperature in the month	DEWPT
14	Mean daily wind speed in the month	WNDAV

RESULTS

The Results of the SWOT Model

In SWAT model, sub-watersheds' maps are produced based on streams status of the watershed. Daragah watershed is divided in to 57 parts. Based on the results, the studied basin cover an area of 278512ha, 57 sub-watersheds and 286 hydrological reaction units (HRU) with the largest sub-watershed has 24599ha area and 5 HRUs (Table2).

IIOAB JOURNAL
ISSN: 0976-3104

Table 2: Profile of below catchment of inside basins provided by SWAT model

	Min height	Max height	Sub-basin	Min height	Max height
1	1676	2114	**29**	1478	2478
2	1595	1986	**30**	1475	2458
3	1595	2325	**31**	1487	1799
4	1594	1601	**32**	1475	1933
5	1676	2264	**33**	1448	2493
6	1584	2224	**34**	1448	1893
7	1583	1679	**35**	1514	1948
8	1579	1858	**36**	1514	1981
9	1580	2073	**37**	1541	2532
10	1594	2519	**38**	1432	1762
11	1562	2063	**39**	1433	2077
12	1602	2665	**40**	1339	1725
13	1603	2220	**41**	1290	2380
14	1528	2313	**42**	1338	1933
15	1527	1845	**43**	1296	1811
16	1563	2305	**44**	1289	1374
17	1475	2114	**45**	1294	2213
18	1476	2388	**46**	1541	2426
19	1430	1897	**47**	1233	1978
20	1430	2361	**48**	1232	1654
21	1659	2223	**49**	1222	2193
22	1660	2853	**50**	1222	1342
23	1522	2719	**51**	1637	2761
24	1522	2051	**52**	1324	2192
25	1359	1749	**53**	1324	2352
26	1359	1945	**54**	1637	2718
27	1496	2719	**55**	1085	2303
28	1496	2493	**56**	1084	2555

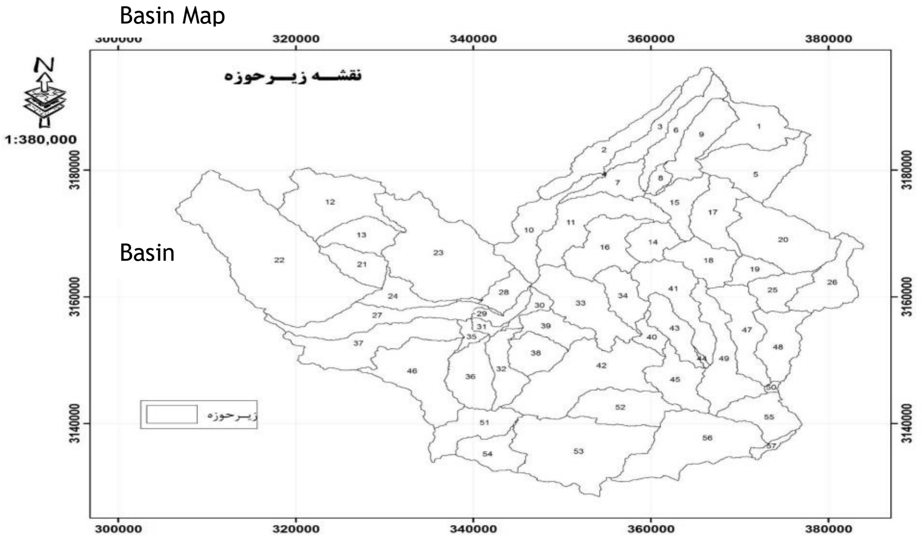

Fig. 1: Map of catchment of Daragah watershed mapped using the SWAT model

Calibration and Verification of Model's Prediction

The trend and period of calibration and verification of SWAT model for determining the prediction was performed for 30% of the remaining data to make prediction after ensuring its capability. Simulated average value of 50 river flow cycles was produced. Thus, after verification with respect to predictions was acting on the basis of the following forms to find the optimal value of the predictable cycle as advanced to acceptable and closer results, which then, they are compared with observational data [7]. The period of warming model was diagnosed with an important factor, while the forecast model.

Determine the Priority Axes

After accounting items related to each of the main criteria, indices of decuple, priority axes for each of the major and minor criteria were calculated separately in each of the branches of the decision-making and

IIOAB JOURNAL ISSN: 0976-3104

finally, after mixing and collecting them, it was shown as a final number, which should be given the lower number, the desired axis is more value and a higher priority for underground dam construction.

Table 3: Prioritize the sub-criteria of the Hydrology main criteria

Axis Code	Volume of subsurface flow	Runoff volume	Drainage density
A 1	1	1	13
A 2	3	6	10
A 3	2	2	11
A 4	12	12	1
A 5	4	3	7
A 6	8	8	14
A 7	6	7	12
A 8	10	9	6
A 9	5	5	9
A 10	9	11	15
A 11	7	4	8
A 12	13	13	4
A 13	14	14	3
A 14	15	15	2
A 15	11	10	5

Table 4: Prioritize the sub-criteria of the dam construction main criteria

Axis Code	Depth of alluvium	Axis length	Abutments Lithology
A 1	9	8	1
A 2	5	9	2
A 3	6	10	5
A 4	7	13	5
A 5	10	7	4
A 6	12	3	1
A 7	2	6	1
A 8	3	5	1
A 9	13	12	3
A 10	4	14	2
A 11	15	4	5
A 12	11	2	3
A 13	8	11	3
A 14	14	15	2
A 15	1	1	1

Table 5: Prioritize the sub-criteria of the tank main criteria

Axis Code	Permeability	Slope	Tank capacity	Upstream basin area
A 1	2	14	12	12
A 2	8	3	4	10
A 3	4	9	10	9
A 4	7	8	5	13
A 5	6	1	3	5
A 6	1	6	9	11
A 7	11	15	14	8
A 8	10	10	13	1
A 9	9	4	2	4
A 10	13	12	8	14
A 11	15	7	7	3
A 12	14	2	11	6

A 13	3	11	6	15
A 14	5	5	1	7
A 15	12	13	15	2

As can be seen, axes A5, A15 and A5 were identified as the best places for construction of underground dams in Daragah watershed based on hydrological, dam construction and reservoir criteria; respectively. By combining all the findings, A5 is selected as the best axis. Final prioritization map of the studied axes is depicted in fig. 2.

Table 6: Prioritize the sub-criteria of the tank main criteria

Axis Code	Hydrology	Dam construction	Dam tank	Total
A 1	2	4	10	6
A 2	3	3	4	2
A 3	2	6	6	4
A 4	4	9	7	11
A 5	1	6	1	1
A 6	6	3	5	6
A 7	4	2	13	10
A 8	4	2	8	4
A 9	3	10	3	3
A 10	9	5	12	13
A 11	3	8	6	7
A 12	6	3	7	8
A 13	7	7	9	12
A 14	8	11	2	9
A 15	5	1	11	5

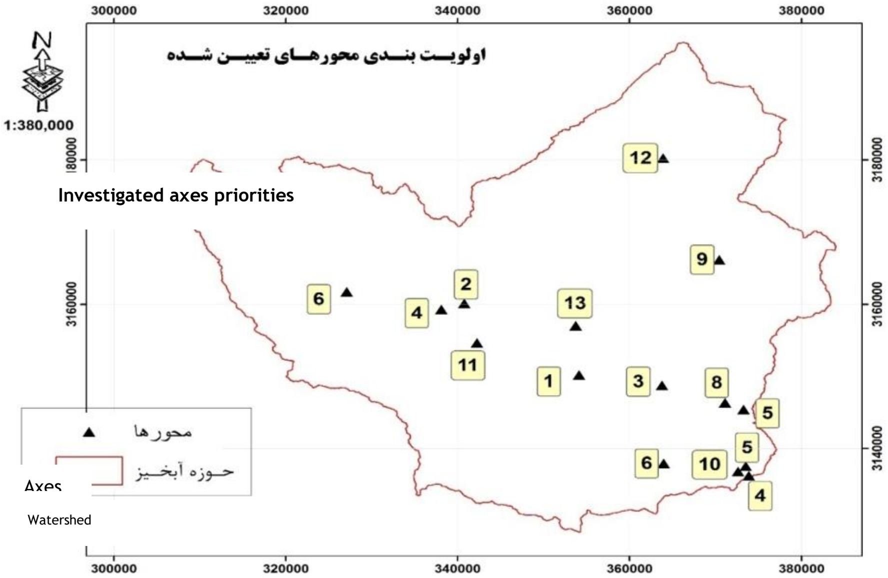

Fig. 2: The final map of investigated axes priorities for underground dam construction

CONCLUSION

The findings result from the first run of SWAT model and evaluation of simulation accuracy indices show that this model, in the first run and using default values of the parameters, was not able to accurately model the peak discharge time regarding coincidence with rainy months and real peak discharges. Obtain low values of evaluation indexes and unacceptable estimate compared to the actual values is not acceptable accuracy for runoff flow simulation of Daragah river watershed, and calibration of this model can help to improve results and increase accurately simulate it. So, after this step was done to verify the calibration of the model in order to improve the accuracy of runoff flow simulation in the Daragah watershed. Because achieving high levels of evaluation criteria, very good modeling, the time of occurrence of peak flows and based peak, and despite more estimates of peak discharges is desirable the modeling results. In general, the results obtained are indicative of the ability and acceptable accuracy of SWAT model in the simulation monthly runoff flow rate of Daragah watershed. The findings of this study

IIOAB JOURNAL ISSN: 0976-3104

confirm the study's results of Goudarzi & et al (2009), Omani & et al (2006), Rostamian & et al (2008), Changbin & et al (2010), Shimelis & et al (2010), Tibebe & Bewket (2010), Xu & et al (2009), that in general, they have declared satisfactory the ability of SWAT model in simulation of river flow in the studied area.

CONFLICT OF INTEREST

There is no conflict of interest.

ACKNOWLEDGEMENTS

None.

FINANCIAL DISCLOSURE

None.

REFERENCES

[1] Akbari H. [2010] Daily river flow simulation of Chehelchai of Golestan province using the SWAT model. Master's thesis Watershed Group. Gorgan University of Agricultural Sciences and Natural Resources. 120 p.

[2] Pour Abdollah, M Tajrishi M. [2006] Erosion basin modeling using the RUSLE and SWAT models (Case Study: Amameh sub-basin), the Seventh International Congress on Civil Engineering.

[3] Heydari H, Shahriari Sohrab. [2011] Locating underground dam of Garmab river basin (Golestan research station). Geographical Research Journal, Issue 100: 131-148.

[4] Rostam Afshar N. [1996] Water Resources Engineering, Printing and Publishing Organization of Ministry of Culture and Islamic Guidance, p. 296.

[5] Kil SL, Eun-Sung C. [2006] Hydrological effects of climate change, groundwater withdrawal, and land use in a small Korean watershed. Hydrol. Process 21: 3046–3056 [2007].

[6] Vanrompay L. [2003] Report on The Technical Evaluation & Impact Assessment of Subsurface Dams (SSDs), TLDP technical report, pp. 14.

[7] Wipplinger O. [1961] 'The storage of water in sand, South-West Africa Administration. Water Affairs Branch, 1958. PP 107.