Biological Forum – An International Journal **7**(1): 693-706(2015)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Modeling of Vargar Dam Reservoir Operation by Using System Dynamic

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(Received 07 January, 2015, Accepted 14 March, 2015)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Population growth and accordingly increasing rise of requirements and demands in societies for access to water supply with appropriate quality, remarkable increase of additional water supply costs, necessity of controlling water resources from contamination and irregular utilization of surface and underground waters and the necessity of protection from them, have made water supply management encounter with serious challenges from different perspectives. In this research, a model was developed with system dynamics method using Vensim software from Wergar river basin in Abdanan, one of the Ilam province towns in west of Iran. The modeling of Wergar reservoir dam utilization and study of conditions before and after dam building was performed in this model using weather reports and also the hydrology of the Wergar river basin watershed. In this research by examining conditions before and after dam building, it was found that by building dam on this river in the suggested construction place, the rate of agricultural and environmental need has increased 80 percent. Considering the obtained results from dam building managing the water supply of this region seems a necessary subject. That by doing so, a substantial step will be taken to reduce agricultural problems of this region.

Key words: Drainage basin, System dynamics model, Vargar Dam, Vensim

INTRODUCTION

One of the ways to overcome the problem of shortage of water resources and contribute to the sustainable development of water resource systems is the assessment of management policies and help in decision-making at the macro level. One of the important issues in water resource management is the evaluation and decision-making based on the total system rather than restricting a single reservoir approach which requires having an integrated vision of the mentioned system. In recent decades using various methods of analysis in the field of system simulation and in optimization has become an efficient tool in resource management which has an important role in overcoming the challenges in this field.

Irregular population development, agricultural development and rapid growth in industry increase water demand every day. A part of requirements is provided by the surface water supplies' control through dam construction. Limited controllable waters and continuously increasing needs demands better planning in order to water management and proper utilization of the limited resources. If these available resources are properly utilized, it is possible to provide for the current and even future needs.

In the optimization methods the effect of different policies on the performance of water supply system is measurable through the objective functions and solution set points; while in the simulation method the results of various policies must be interpreted in a way that they provide the selection of the better policy.

Different purposes in the analysis of reservoir systems lead to various models of these systems. The main purpose of these models is to regulate and evaluation of various plans in order to respond the needs associated with water. The conventional models in systems engineering that are used in the reservoirs are the optimization simulation models and a combination of optimization and simulation. The optimization models are based on making an objective function minimum or maximum which consists of decision variables considering the constraints. In other words, these models are automatically after the optimum decision variables that provide for all constraints. The purpose of the simulation models is to improve the plans and operation policies.

These models predict the system behavior based on the value of the variables specified by the user. The reliability of the simulation methods is in their ability to solve models of analysis of water resources system that have non-linear relations and constraints, whereas the optimization methods are less capable of conducting them.

System analysis has an important role in water resources management and simulation is an essential decision-making tool in the process of reservoir management. However, there is a need for tools that can describe complicated systems based on the realities and help the user to participate in model development to increase the confidence in modeling.

Models with dynamic characteristic are among the numerous models of water management. In these models the understanding of the problems and changes are in the form of loops and feedback. By means of this method the unpredicted uncertain outcomes of the decisions become clear. The purpose of this method is to simulate the behavior of systems in current and future conditions to accelerate and facilitate the learning process. The system dynamics is easier and more effective compared to other system analysis methods and does not need complicated mathematical descriptions in system description. This method was originally developed by Forrester to provide a better understanding of strategy problems in Complex system dynamics.

System dynamics approach is a method for analysis, problem solving and system simulation. This technique is a method for the analysis of complex systems and problems with the help of computer simulations which was developed by Forrester in 1960s in the MIT College.

System dynamics is a formulated method for analyzing the components of a system that has a cause and effect relationships, logical and mathematical foundation and feedback loops.

Keyes and Palmer used the system dynamics approach in the stimulation of the drought studies.

Fletcher used the system dynamics approach as a decision making analysis method in water management.

Simonovich and Fahmy used the above method for evaluating long-term water resources and the analysis of the policies in the Lake Nile basin in Egypt.

Royston used the system dynamics approach in providing water demand and operation of multipurpose reservoir. Ahmad and Simonovich using the method analyzed the operation of Shellmouth reservoir in the Lake Assiniboin for a year of high water and some occurred floods. In this research the effects of flood management in the reservoirs with gated overflow and gate-less overflow were compared and the model behavior is sensitively analyzed for the initial condition of the reservoir level.

Teegavarapu and Simonovich in order to model the operation of the multi reservoir system to produce electricity used system dynamics and in order to analyze the performance of the system used the reliability and vulnerability indices.

Simonovich and Lee (2003) after developing a simulation model based on system dynamics for a complicated flood control system used reliability in evaluating the performance of system components under applying various scenarios.

Van Derzag (2005) explored the concept of water integrated management and using this concept he has provided a solution for the allocation of optimal water in a part of south Africa and has defined the water integrated management as a new method to manage the resources and attain the development goals, mutual respect, understanding and cooperation between the water users in the South Africa.

Kronaveter and Shamir (2009) have presented an appropriate model regarding the cooperation and negotiation in the allocated water reservoirs. In this model a negotiation backup system is used to help both negotiators in allocating water reservoirs. Through analyzing the benefits of this system, they have introduced it as a solution to find a solution in decision space.

Mimi and Sawalhi (2003) through using an optimization method based on simple additive method through considering various criteria provided optimal water reservoir allocation of the River Jordan among the parties. In this paper the application of The International laws in solving the dispute over the Jordan River led to some inconsistencies among the countries of negotiation and they have presented the multivariate decision making method as a solution to allocate the Jordan River water among the parties.

Jalali and Afshar (2004) presented a model based on System dynamics to operate the hydroelectric dams.

Sadeqi (2004) presented a model based on System dynamics to operate the reservoirs in order to control flood.

Hosseini and Baqeri (2012) analyzed the System dynamics of Dasht e Mashhad water resources to examine the strategies of sustainable development. This research is conducted to describe the implementation of Integrated Water Resources Assessment, evaluation of Dashte Mashhad water reservoirs and the actions and policies in the process of economic development programs.

Abrishamchi *et al* (2012) evaluated the water resources development projects in multi reservoir system under the Dare Rud basin using the functional indices. In this study the system dynamics approach was devised to simulate the water resources under the Dare Rud basin of the Aras River. The comparison results of the indices with various definitions indicated that although using the estimators based on maximum amount was recommended in the previous studies but the estimators based on the average have more useful information due to considering system condition in various conditions.

Sheikh Khozani et al (2010) modeled the utilization of multipurpose reservoirs using system dynamics approach. The purpose of the above modeling was to determine the effect of various policies of utilization on the reservoir behavior and the providing moderate needs in future (2031). Based on the obtained results it was revealed that the implementation of appropriate policies not only it is possible to provide for the current needs but also consider the future needs.

Safari and Zarghami (2013) studied the optimal allocation of surface water resources of the Urmia basin to the interested provinces based on distance based decision making methods. In this study a multivariate decision making mode was performed based on distance by methods of simple additive method, compromise programming and TOPSIS method of water allocation the water of Urmia Lake is shared among the beneficiaries considering social, economic and the environmental criteria and the optimal share of each province of the surface water was determined and the capability of these methods was compared.

Identify problems in mentioned area by using a careful study and reviewing last studies in that area is the important part of this research or study. By identifying the area's problems we define and explain the system dynamics method and by using this method and available data relationships between variables will be defined and by the validation of the model, the accuracy of model structure will be measured and assessed. Purpose of this study is optimum utilization of water resources and soil of mentioned area by control and regulation of the river Vargar and using regulated water to provide reliable water for agriculture villages Vargar, good water and house and Garden keeping requirements for minimum environmental requirements of downstream.

MATERIALS AND METHODS

A. Study area

The study area is for construction of adamon the river Vargarin the Abdanan one of the cities of the province of Ilam in west of Iran. The study area is located in coordinate between 47 degrees and 15 minutes to about 47 degrees and2minutes east and 32 degrees and 54minutes to 33degrees, 4 minutes north latitude. The area of its basinis18,370 hectares and located in ABDANAN hydrologic units. This unit confined from the north to valley city unit, from the west to Kabir Mountain border and from south to the Dehloran. And most important river is Doyrij that its branches stem from Kabir mountain's heights. The Abdanan situation in Ilam and districts in abdan an showed in figure 1 and 2 separately. The extent of the study areais3000 hectares, that the villages Vargar, Abkhosh, Saraybagh, and Hezarani are the centers of population.

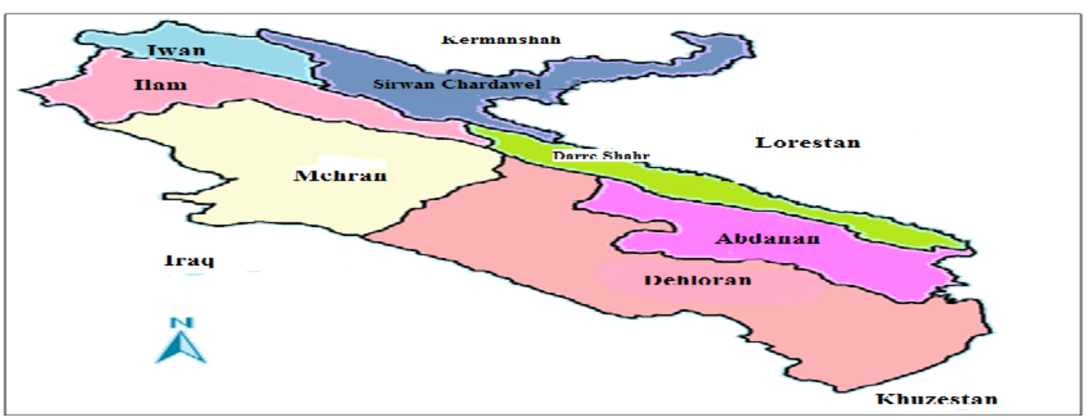

Fig. 1. The location of the Abdanan in ilam province.

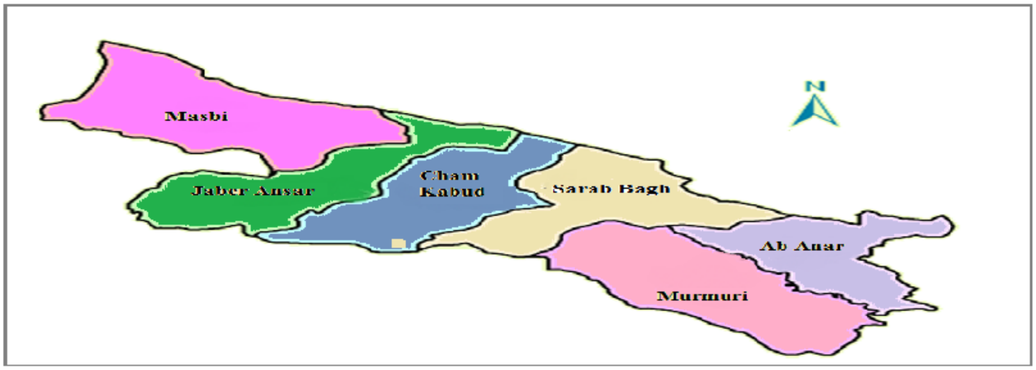

Fig. 2. The location of the villages in Abdanan Township.

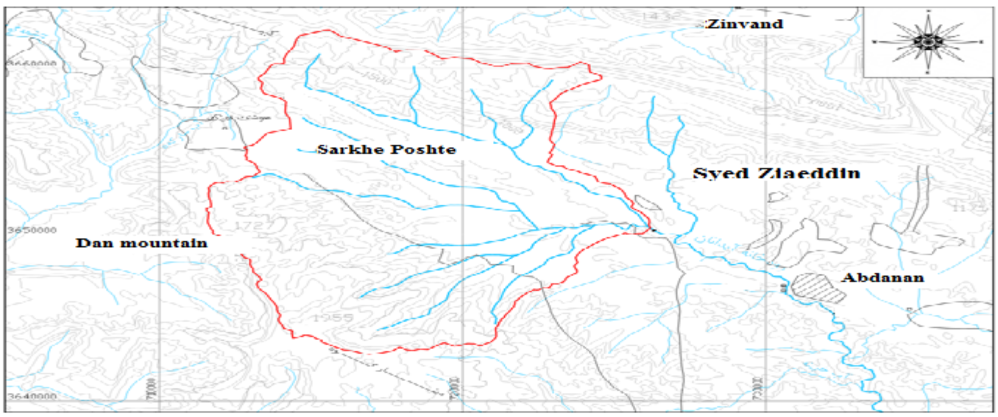

Fig. 3. The location of drainage Basin of Abadan River in the proposed site.

By using the ration of areas method and registered data in gauging station in Duyrej, time series of Vargar River in the proposed dam site at the period (92-1349) has been calculated. The mean and average flow entering water in the dam Vargar is 0.88cubic meters per second. In Fig. 4 the average monthly changes and coefficient of variation of inlet flow to Vargar dam has been shown that it's most flows happens in Aban, Azar and Farvardin. Also in figure 5 Flow duration curve of the river at the dam Vargar defined. As you can see, the base flow of the river is very low and the average flow of the river only occurs in about29% of cases. Fig. 4 shows Changes in annual stream flow with a5-year moving average discharge or flow. This series including respectively the courses, wet, dry, wet and dry.

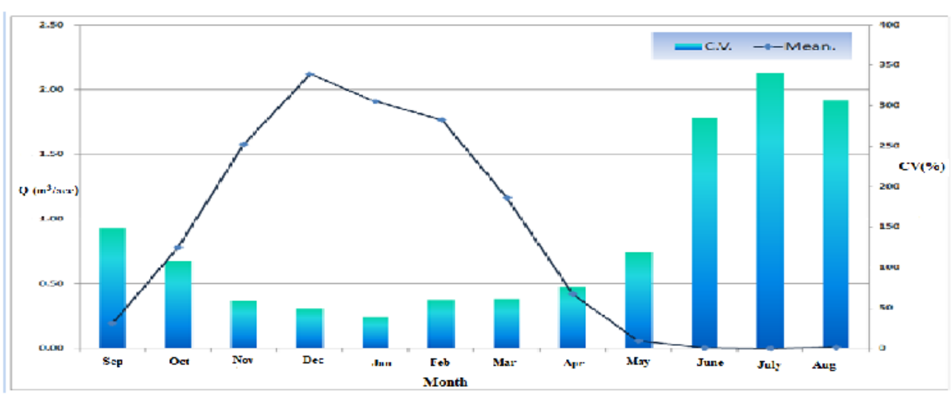

Fig. 4. Monthly Changes and coefficient change discharge of the river at the dam site Vargar.

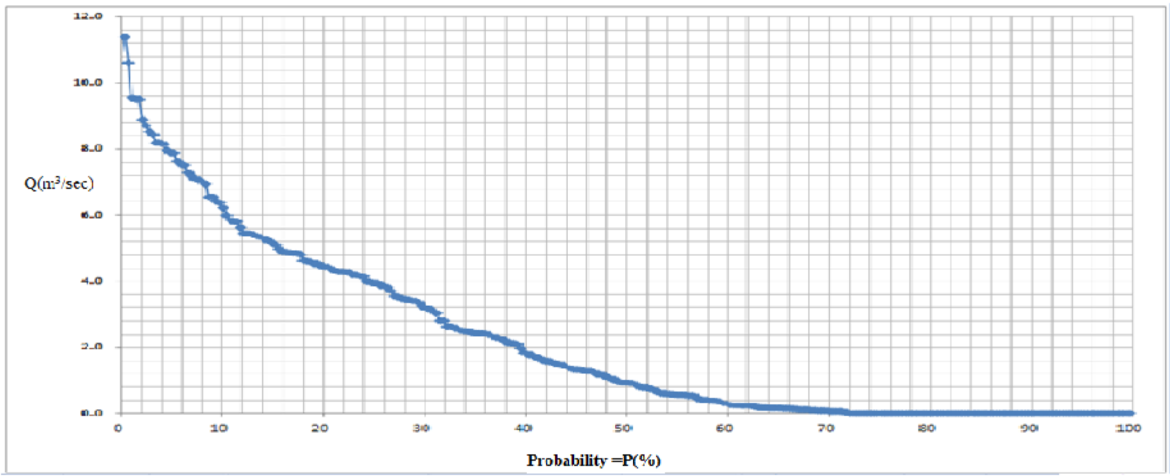

Fig. 5. Monthly discharge duration curve of the river discharge at the dam site Verger.

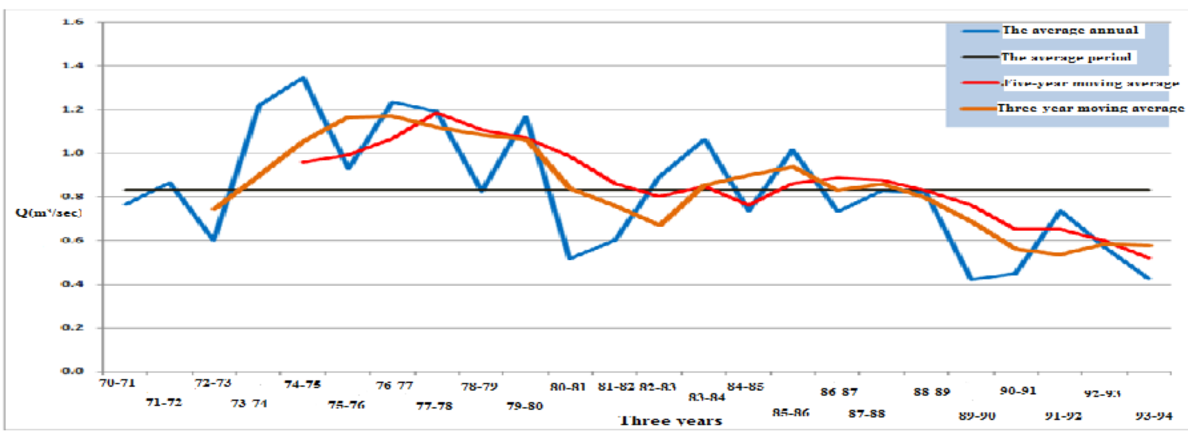

Fig. 6. Annual changes of river brought with 3 and 5 years moving average at the dam site Vargar.

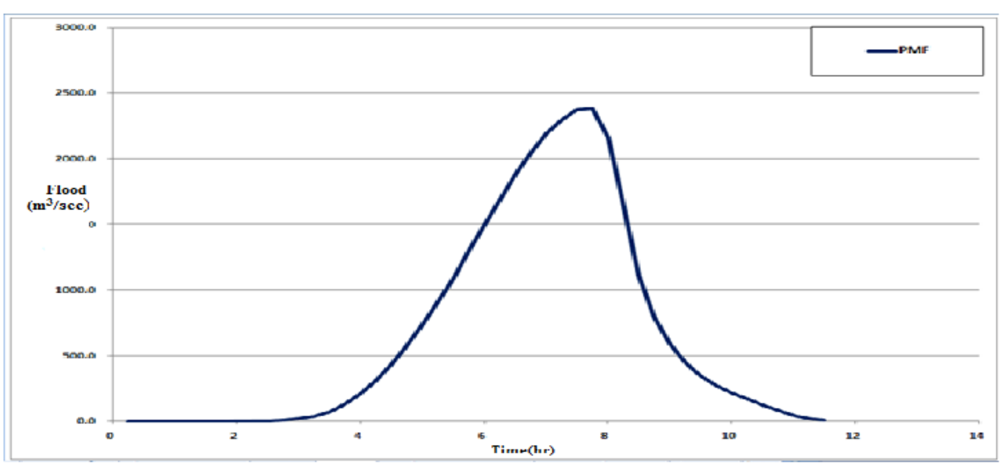

Fig. 7. Probable maximum flood hydrograph at the proposed dam site Vargar-Abdanan.

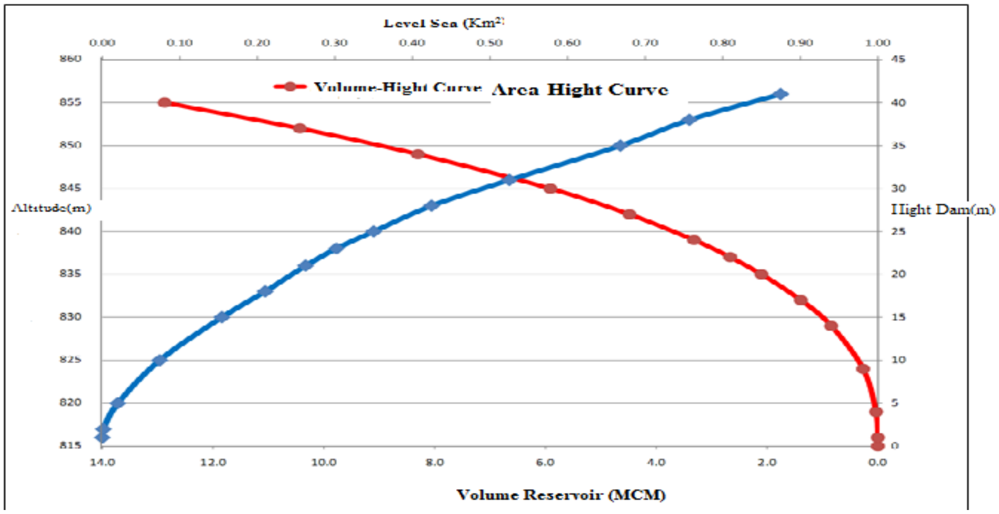

Fig. 8. Volume-surface-height curve of the proposed dam site Vargar.

System dynamics formulated method for analyzing the components of a system. This technique was developed in the world of industry and commerce but nowadays it has been entered in many scientific fields.

System dynamics has many advantages. Due to analytical and critical approach to the modeling process, this process provides a better understanding of the system. The system dynamics model provides the possibility of entering qualitative and quantitative variables in the system simultaneously.

The tools being used in better understanding of system dynamics model are the causal diagram and flow diagram.

The causal diagram is a diagram that represents the causal relationships between the system variables. By this tool the mental models of individuals is easily understood. The causal relationship is presented in through a curve with an arrow to indicate the operation. In order to build a model and collect data various research methods are applicable.

System Dynamics is a management tool for decision making about the dynamic systems that allow simulation and understanding complex systems using mathematical models, In other words, a method for understanding the dynamic continuous behavior of systems. System Dynamics is based on two main principals: The first principal is the attention to the time factor in which the system behavior is evaluated over time. The second principal is the attention to the feedback in each system.

The potential of using the system dynamics in water resources was first introduced by Lee in the 90s. He stressed that Hydrological modeling is performed in two stages: conceptualization and programming that these two stages are presented in System dynamics. System dynamics in water resources management is used in water resources, ecological and environmental modeling and basin modeling.

In system dynamics the variables are divided into two major groups of state and rate variables. State variable is the main component of the system which is the main objective is the simulation, cognition and behavior changes in this variable over the time. What causes changes in the state variable is the rate variables associated with it. In addition to these two variables some covariates are used to apply the mathematical relationship between the components of the system. In this simulation method changes and the variable behavior of the stave variable is performed using the numerical solution of differential equations governing the relationships between the components.

B. Determining the out flow from the reservoir

This is the most fundamental part of modeling. At this stage in defining the output relations of the reservoir the decision-making in rules plays an essential role. Fig. 4-3 shows portion of the input-output model for the structure of the tank and it goes. As is evident in Fig., storage capacity of the reservoir had been shown by a remember variable (state) and each input variables such as evaporation, release and over flow had been shown by a Variable flow determining the flow over flow will define due to squeeze the maximum height (maximum volume) and the input and output streams and storage volume that, total current and flow release and storage losses will be deducted from total in flow and storage volume. The remaining volume compared with the maximum amount and its extra and add will be going out as an over flow from the tank.

For simulation of dam action we used model based on reservoir water balance and the following equation:

That in it:

St+1: tank Volume at the end of exploitation period *t* based on millions of cubic meters.

St: tank volume at the beginning of exploitation period *t* based on millions of cubic meters.

It: The volume of in flow to the reservoir at the beginning of exploitation period *t* based on millions of cubic meters.

ET: evaporation volume from the lake during the operation per million cubic meters.

RT: The total volume of the dam out flows in each exploitation period *t* to preparing needs in terms of millions of cubic meters.

Spilt: The overflow in each exploitation period *t* in million cubic meters.

Loss: Losses due to seepage and evaporation.

Amounts of water over flow and the water shortage in the operation of the dam estimated by the following equations:

That in it:

-The maximum volume of the reservoir (MCM)

- Overflow water (MCM)

- The minimum tank size or volume of intake level (MCM)

- The volume of water shortage (MCM)

DISCUSSION AND CONCLUSIONS

With having an initial normal level, and by the incoming water volume per month and add it to the volume of the tank after deducting average evaporation in the month, model will prepare the needs with priority and at the end of each month, will announce the amount of overflow from the reservoir or the lack of any requirement to provide. At the end of the simulate reservoir Vargar the basic information presented in the previous sections are used. Simulation, summary results of the provision and operation of the repository is shown.

The simulation results of water resources in the selected option. In the selected options, due to the topography and the valley model floor elevation of dam is 816 meters above sea and the barrier or dam height at normal level is 28 meters and located in the elevation above sea level 844, and also the dam will be 250 meters wide in this area. The maximum volume of tank after sediment distribution is 77.2 million cubic meters and it's useful volume is 27.2 million cubic meters. According to the simulation of the operation of the dam Vargar in this scenario, in 24-year period (1391-1367). The results are provided in table.

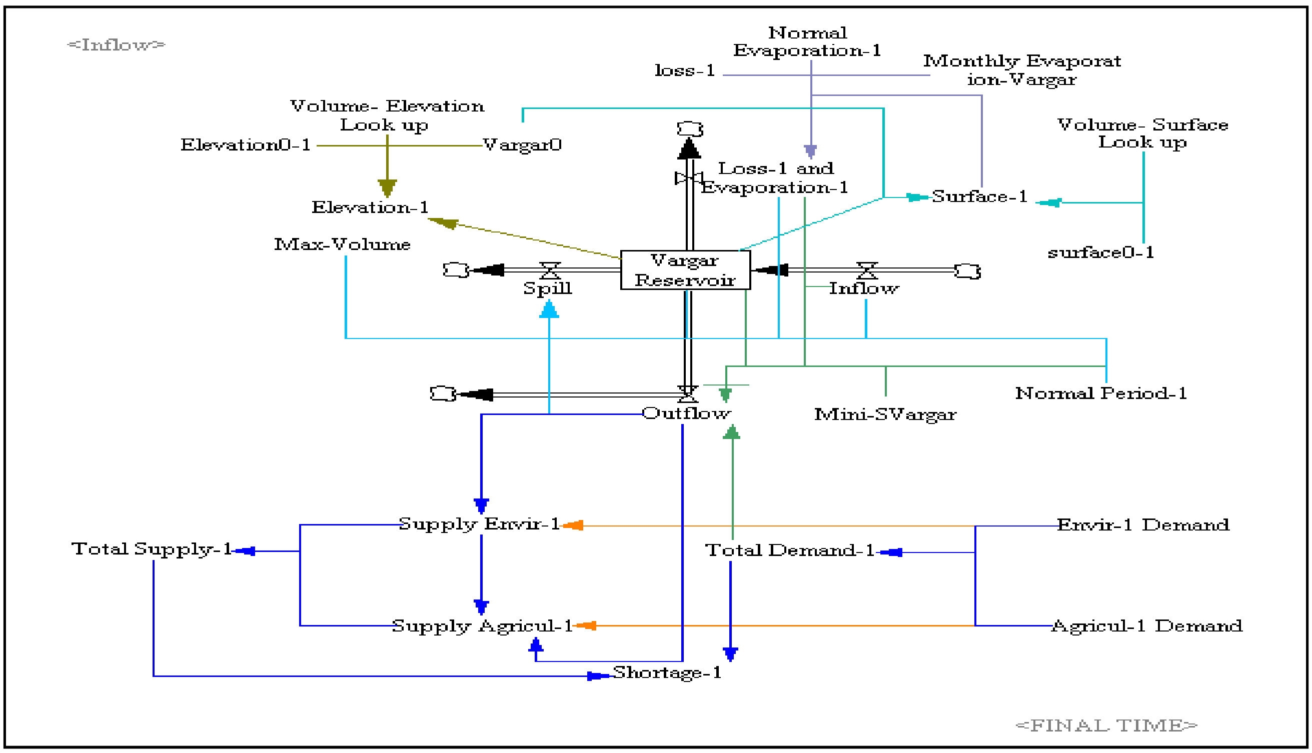

Fig. 9. The main part of the model to determine the output volume of the reservoir.

Table 1: Summary results of reservoir simulation.

Storage Dam Specification	Unit	Value
Normal water Level	m	844
Normal Storage Before Sedimentation	MCM	4/98
Normal Storage After Sedimentation	MCM	2/77
Normal Reservoir Area Before Sedimentation	ha	48/58
Normal Reservoir Area After Sedimentation	ha	37/58
Conservation Storage	MCM	2/27
Minimum Operation Level	masl	827
Dead Storage	MCM	0/50
River Bed Level	m	816
Annual Dam Inflow	MCM	18/58
25 Years Sedimentation	MCM	2/33
Agriculture Demand	MCM	3/63
Environmental Demand	MCM	1/80
Regulation Volume	MCM	4/76
Agriculture Satisfied	%	85/5
Environmental Satisfied	%	81/7
Spill Volume	MCM	20/42

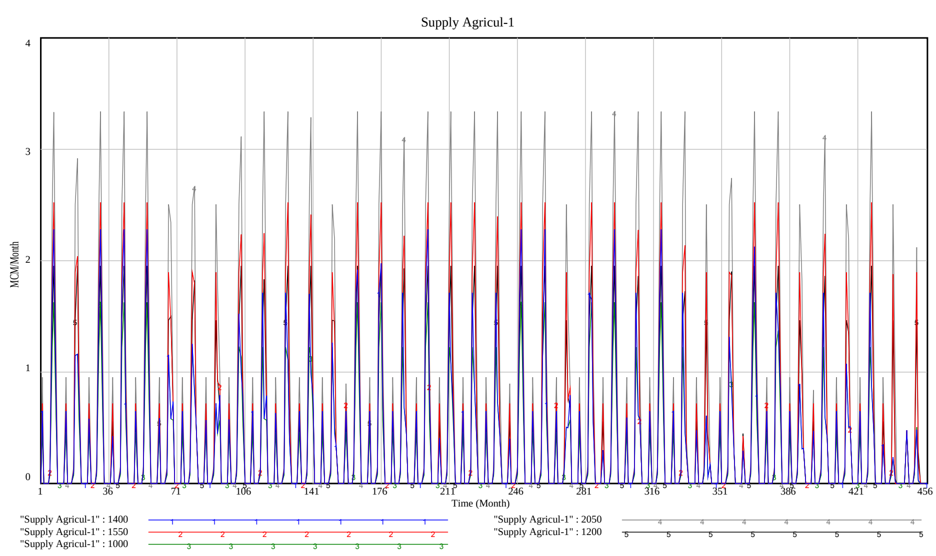

Fig. 10. Long series of agricultural of water supply volume-percentage.

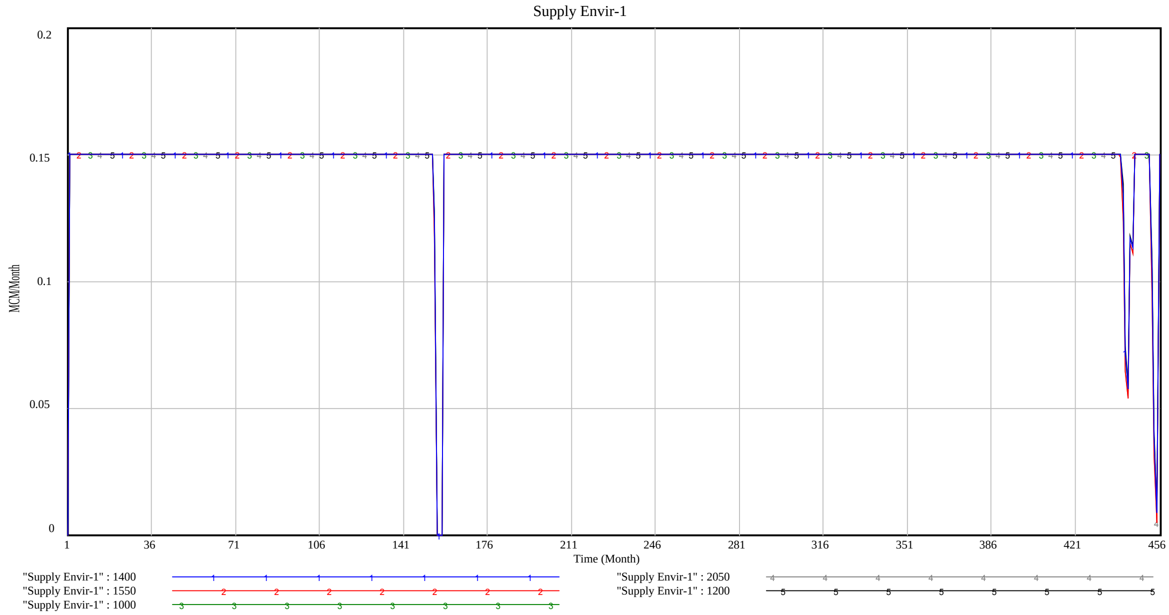

Fig. 11. Long series of environmental of water supply volume-percentage.

As the above tables show by constructing the proposed dam on their ver Vargar agricultural and environmental needs of the area, from about 4% to 5/85 and 7/81 for agricultural and environmental needs increased with the knowledge and according to the climatic conditions of Iran, especially in the mentioned area, river water management and efficient use of water resources of the vital needs for decreasing farmers problems use to prepare water for them.

In addition, the predicted pattern of changes in water supply systems, affected by the actions of exploitation policies, could assist beneficiaries for optimal use of available water resources.

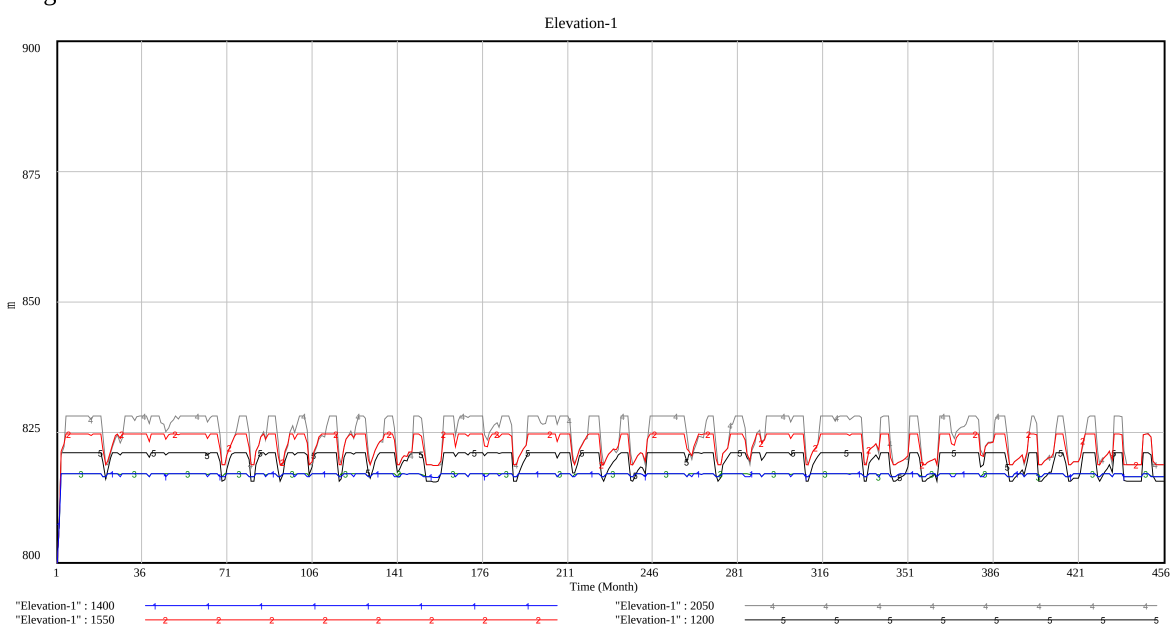

Fig. 12. Long series of Vargar dam level reservoir changes (Masl).

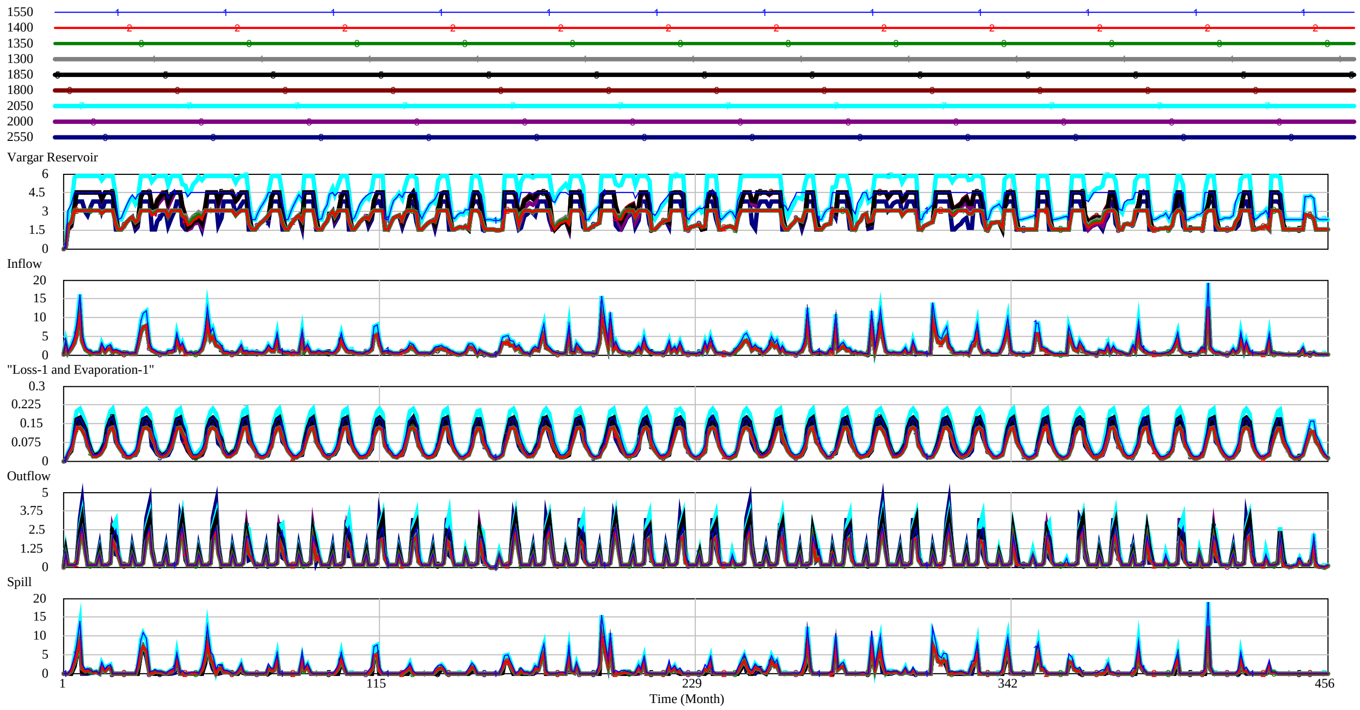

Fig. 13. Long series of Vargar dam volume reservoir changes (Mcm).

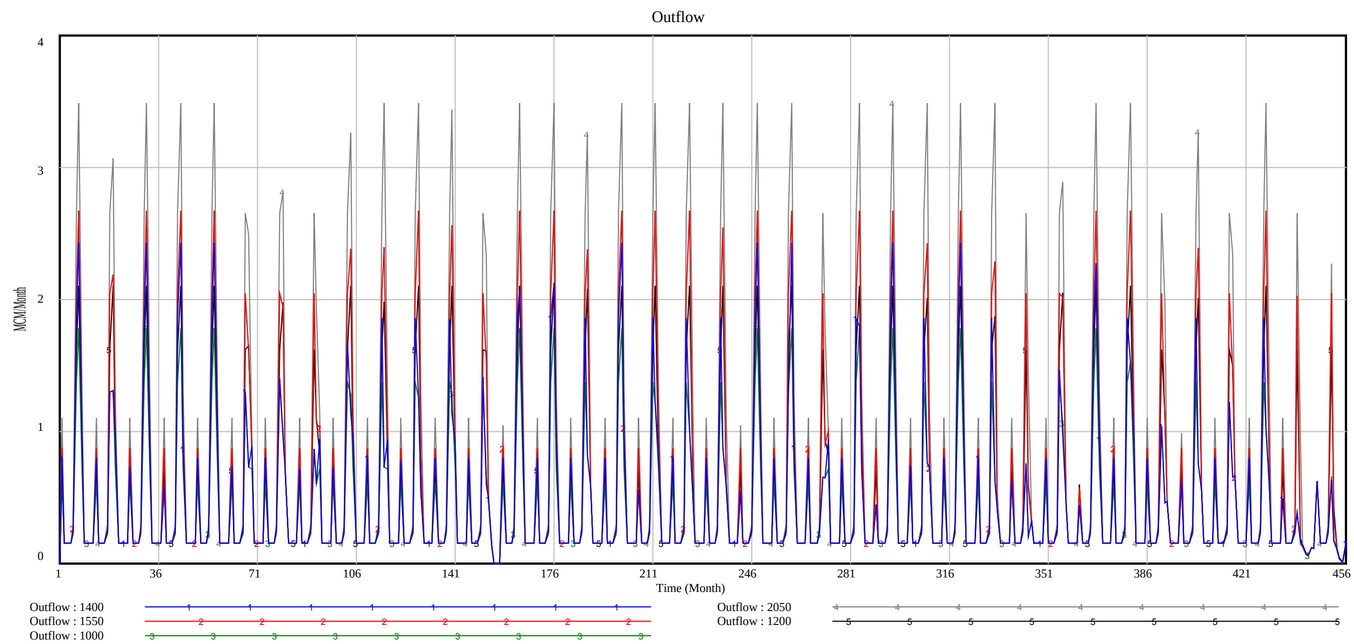

Fig. 14. Long series of total of water output from the reservoir dam (Mcm).

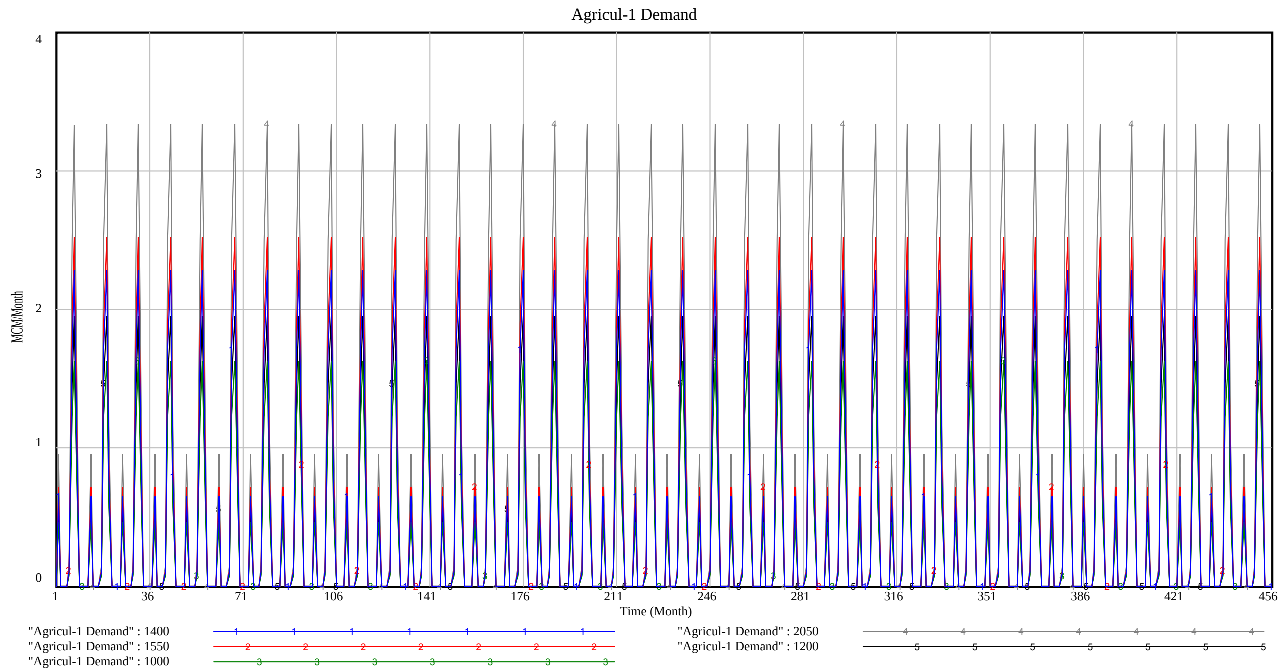

Fig. 15. Long series of agricultural regulation water of Vargar dam (Mcm).

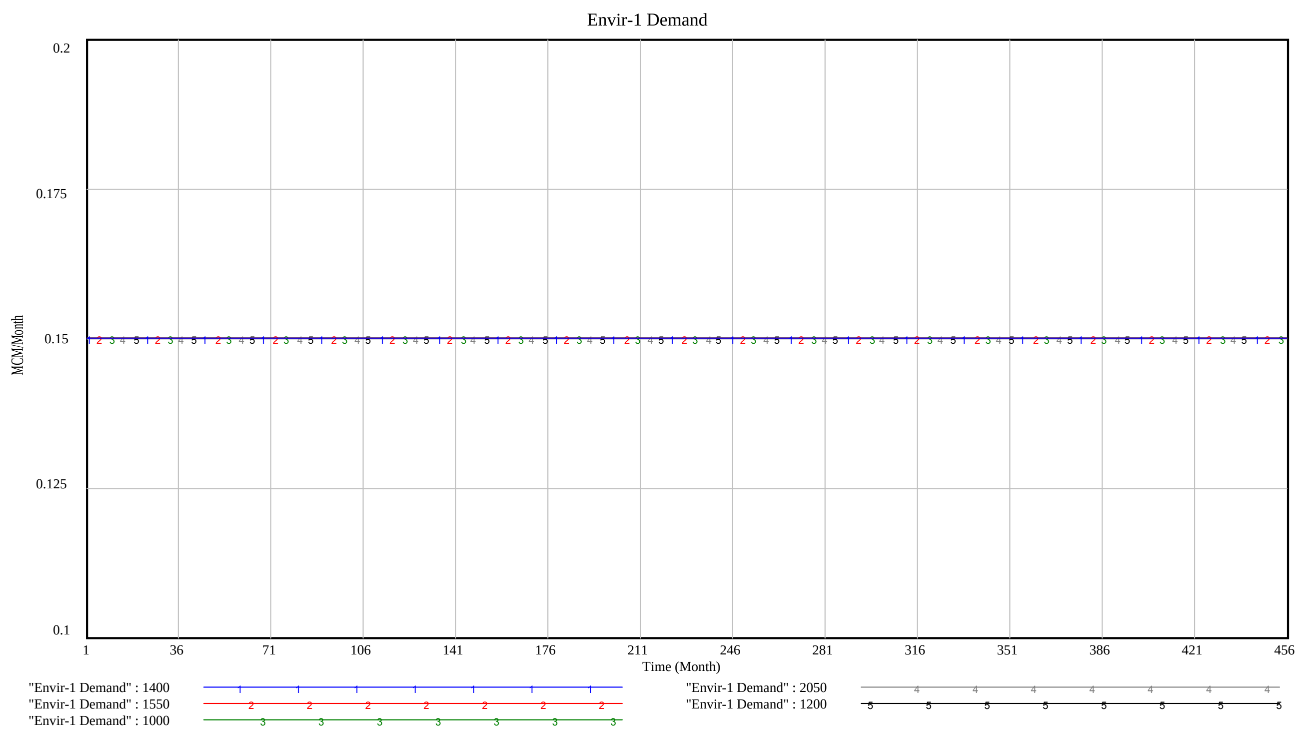

Fig. 16. Long series of environmental regulation water of Vargar dam (Mcm).

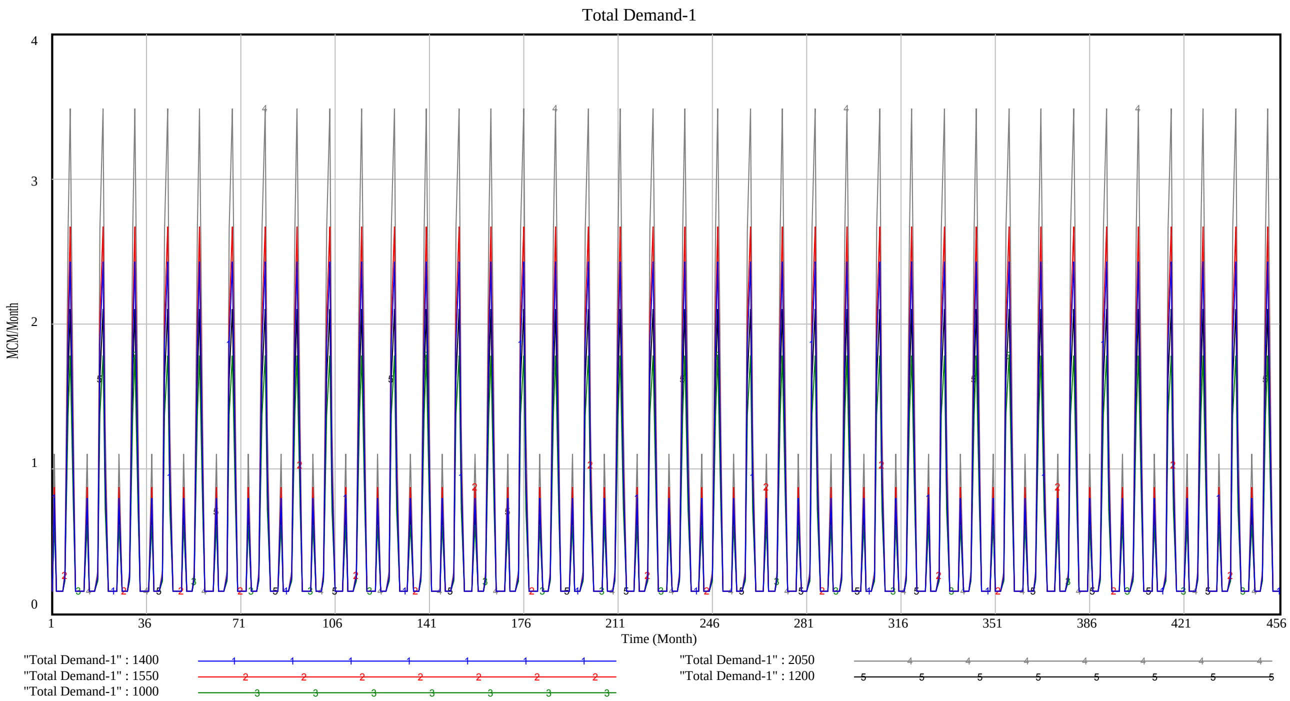

Fig. 17. Long series of total of regulation water of Vargar dam. (Mcm).

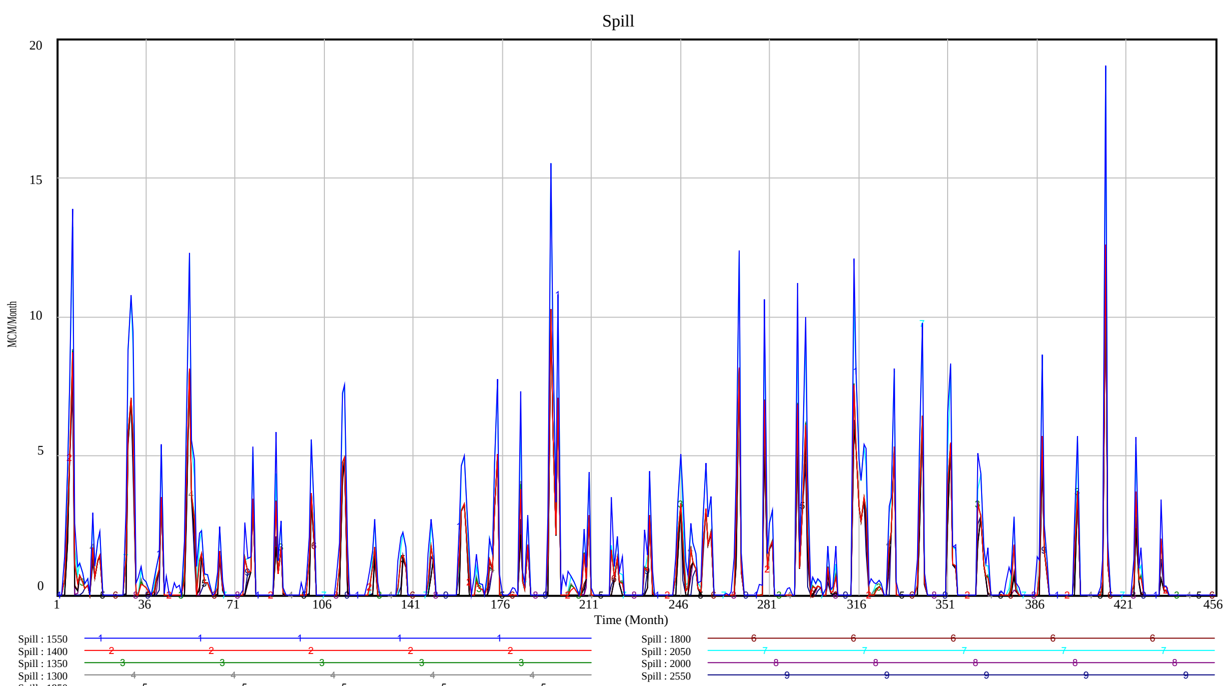

Fig. 18. Long series of net outflow from theVargar dam.(Mcm).

According to the results of following research, constructing dam to manage the water resources of the area seems to be essential. That if this case happens an essential step towards reducing agricultural problems will be done.

Finally, due to all the factors considered in this study and sensitivity to supply water rights and area needs the following is suggested:

(i) Identify and study more closely of the current and future uses of the study area.

(ii) Comprehensive study of water in the catchment area of Vargar River.

(iii) Reviewing different cenarios of development and utilization of water resources.

(iv) Prioritize the provision and development of water resources.

(v) Reviewing effects of climate change and uncertainty in the discharge or flow entering the dam.

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