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SIMULATION AND MODELING OF WATER QUANTITY OF HADITHA DAM UPSTREAM AND DOWNSTREAM

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Master's Thesis

Supervisor

Asst. Prof. Dr. Mohsen SEYEDİ

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The thesis titled “SIMULATION AND MODELING OF WATER QUANTITY OF HADITHA DAM UPSTREAM AND DOWNSTREAM” prepared by RAAD ALDULAIMI and submitted on 19/12/2022 has been **accepted unanimously** for the degree of Master of Science in Civil Engineering

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Raad Falih Hasan

Signature

DEDICATION

To my mother's soul...

To my wife...

the companion of the struggle and the difficult circumstances who did not spare time or effort to help me.

ABSTRACT

SIMULATION AND MODELING OF WATER QUANTITY OF HADITHA DAM UPSTREAM AND DOWNSTREAM

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The situation of the variation of water quantities behind and after the dams is effective matter for the management team to consider when controlling the dam. The continuous inflow toward the catchment area leads to high accumulation in the storage area. The study deal with the analysis of Haditha Dam in the way of examining the available surface area as well as the volume for the catchment area for identifying the capacity of these zones to keep the water without the risk of flooding. The study used the water balanced equation by determining the monthly increment in the water storage. These increment was used to get the desired outflow that can be adopted for better operation of the dam. High amounts of outflow determined in the beginning of the operation year. These amount can lead to rapid raising of the water level toward more high elevation and can leading to the overtopping to be happened. The times per month for reaching up level of dam crest (154 m) were determined. The January month had the most critical short time by 10.7 hours. The variation of the surface area and the available volumes with respect to the elevations were evaluated in graph and tables. The study then based on these results to calculate the outflow that can be adopted per each month with respect to the elevation from the normal water elevation (147 m) to the upper elevation before the problem of overtopping (154 m). the study explained these data in graphs for each month. The January month showed more critical and huger amount of flow to be spent out toward the downstream area for keeping the dam without risk conditions. The study included graphs and tables for better defining the results along the analysis and calculation steps. The simulation of the flood was made using HEC RAS software. The flood wave distance with time from initial overtopping state were obtained from the simulation and explained in figures. The wave move to about 15.4 km after 40 hours of flood to be occur.

Keywords: Water Quantity, Haditha Dam, Simulation, Water Flood, Overtopping

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ABBREVIATIONS

CP	:	Critical Period
PMF	:	Probable Maximum Flood
EL	:	Elevation

LIST OF SYMBOLS

V_t	:	Resultant of storage volume of resevior at time t
V_{t-1}	:	Storage volume of resevior before change
Q_C	:	Inflow toward the storage area
Q_{in}	:	Lateral inflow from other ubstreams toward the storage area
Q_{out}	:	Outflow from the storage area
U_{RL}	:	Water withdrawl at time t
P	:	Amount of participation
E	:	Amount of evaporation
A	:	Area of reservoir
V_t	:	Resultant of storage volume of resevior
V_{t-1}	:	Storage volume of reservoir before change
Q_C	:	Inflow toward the storage area
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1. INTRODUCTION

1.1 INTRODUCTION

The dam is a large barrier that is built to retain large amounts of water, as well as to control the flow of water. It keeps the quantities of water from the upper side of the dam structure in the form of a water tank. It also considered as an industrially constructed project to impound the surface water that is derived from large pools of water. Dams may also be used to store groundwater, as they are constructed below the surface of the earth. These reservoirs are used to provide water when needed, and the main function of the dam is to resist the dangers of floods [1] [2]. Dams are often built for multiple purposes, including irrigation, as well as hydroelectric power generation, in addition to their main function to control flood risks. Continuous change in the river system could be occurred as a result of sediment accumulation due to the establishment of dams, as well as a change in water flows [3]. The differences that occur in the hydrological cycle lead to the construction of dams, this matter become necessary to help conserve the surplus water in times of floods and to provide it during the drought period when the water level decreases. The purpose of constructing dams is including the environmental benefits resulting from the release of water that is stored by the dam in a manner similar to the natural flow of river water [4]. Thus, it is necessary to study the impact of vibrational effects due to the powerhouse operation on the dam body, taking into consideration the dam type, the powerhouse type and the turbine type. Studies focusing on the modeling of dynamic behaviors and the hydraulic performance of embankment dams are essential to improving dam safety. When the flow of water is in large quantities, the dams store these quantities, and when the natural water flows are not sufficient to meet the required need for water uses, this water is released from the reservoirs toward the downstream areas. Dams are important for agricultural and industrial purposes, providing drinking and recreational water, and many other benefits [5]. The flood problem is so important negative limit that the designer and auditor must keep the dam from. The case of overflows that caused by the excessive water storage which raises the water level more than the existing height of the barrier leading to bad impact for the downstream zones and weakening of the dam structure [6]. Iraq Includes different sources that provides water quantities for different uses. Euphrates and Tigress Rivers are the main water pathways that the Iraqi hydrological infrastructures deepened on. Different dams were constructed on the rivers streams for controlling the capacity of reservoir and the releasing of water [7]. Haditha Dam is considered one of the most important dams erected on the Euphrates River in Iraq, where it is used for irrigation and for water storage purposes and to reduce the risk of floods [8]. It is necessary to study the impact of vibrational effects due to the powerhouse operation on the dam body, taking into consideration the dam type, the powerhouse type and the turbine type. Studies focusing on the modeling of dynamic behaviors and the hydraulic performance of embankment dams are essential to improving dam safety.

1.2 PROBLEM STATEMENT

Haditha dam constructed on the upstream zone on Euphrates River to serve the areas from the western of Iraq. The climate in Iraq is fluctuating according to the seasons from the so hot and droughty weather to coldly and rainy one. Analysis the state of water behind the dam and the quantity of released water including of the parameters that impact the quantity of water like inflow rate and climate conditions can support and improve the conserving of the water sources and the storage quantity and eliminate the chance of flooding.

1.3 CONTRIBUTION

The control of the dam’s operation is considered one of the most important measures that reduce the special losses in the available water storage and provide protection for the downstream lands from the dangers of the dam’s failure. The study included analytical steps placed in order of priorities to achieve the best results. A simulation of the hydrological behavior of a modern dam was adopted, including Dam breach modeling using HEC RAS software based on the required data related to the location of the dam on the Euphrates River. The results obtained are used to model the dam's operation, water storage and flow.

1.4 AIM AND OBJECTIVE

Using the HEC RAS software to collect the data needed to simulate the hydrological condition of a Haditha dam upstream and downstream including simulation and analysis of the dam break state with the overflow condition, and then use the data to derive the governing equations that can be used for better process control. The following steps were made for achieving the scope of the study:

a) Providing of necessary data from the related offices and scientific references that include elevations and topography of lands, discharges before and after dam, cross sections of downstream water path, precipitation intensity, evaporation rate, and any other geometrical and hydrological parameters.

b) Converting the results into matrices and adopt them in the simulation process inside HEC RAS software.

c) Using HEC RAS software in dam break modeling for evaluating the influence of flood case on the downstream area including identifying of peak outflow rate with time and the impact of top flow over dam.

d) Using of statistical formulas for describing the correlation of parameters impact on dam performance.

e) Deriving of governing model that can control the hydrological behavior of the dam for optimum conditions.

2. LITERATURE REVIEW

2.1 OVERVIEW

Dams are considered important units in hydrological system in a country or zone. It contribute to large area land to be irrigated with amounts of surface water and also the downstream regions can become urbanized more because reducing of the risk of flooding and increment availability of generating electricity [9]. The site of the Mosul Dam was selected as the most suitable location to serve the three irrigation projects. It also offered the largest reservoir volume from topographic considerations. The geological conditions of the site did not seem to have received enough considerations The important of dams in Iraq can be considered noticeably in the way of storage water and regulate the overall streamlines of the rivers and the providing water quantities that link the region of water resources with downstream zone in which water can be used for different purpose like irrigation [10]. Figure (1) explained the distribution of water resources in upstream to downstream regions.

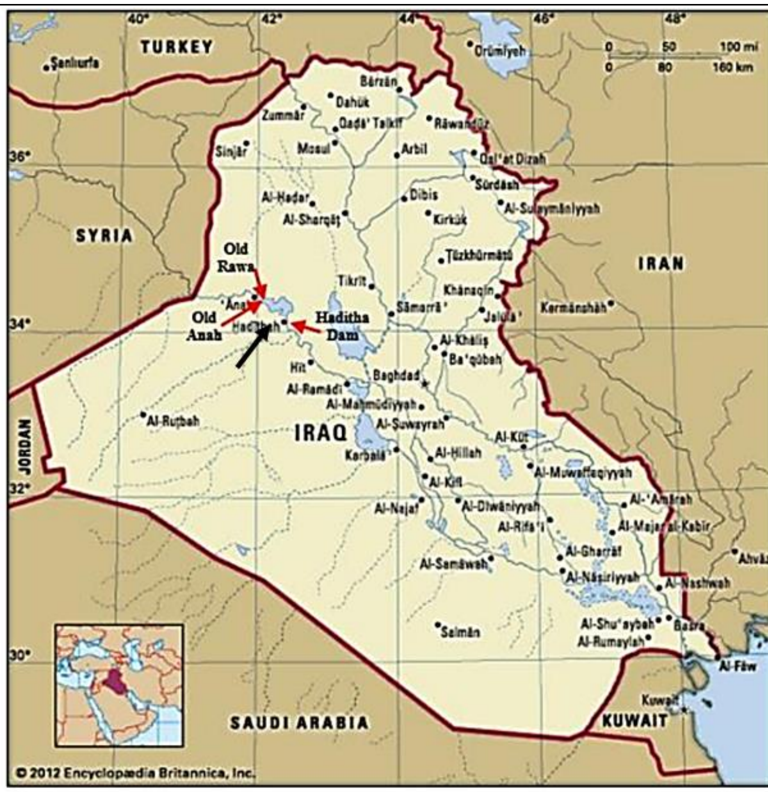

Figure 2.1: Water resources distribution in Iraq [56]

2.2 PROPERTIES OF THE DAM REGIN

The construction of Mosul Dam was started on the 25th January 1981 and completed on 24th July 1986. Studies and investigation works were carried out by different consultants who had selected different sites and prepared different designs from 1951 until 1978. The present selected Mosul Dam site was the subject of the last investigation campaign, and the contract for preparing the planning report, the final design and tender document were awarded late in 1978 and these works were completed in 1980 only to start construction immediately afterwards. The important stage in the assigning of the reservoir is to choose the site that is suitable because it has importance in many branches as well as from an aesthetic point of view, as the area surrounding the reservoir is considered recreational, so that when choosing a bad site, it causes many harmful effects [12]. There are many techniques and technology that are used to choose the site, and there are also traditional methods that consume time and are very expensive. As for the present time, the progress that is taking place in technology in which space technologies are used. It can use the maximum number of resources and be at the optimal cost. Satellites are used in terms of remote sensing, which provides a complete view of the earth, and this imaging technology is used to update maps within a time frame, which provides information on the use of land cover [13]. The factors affecting the determination and selection of the location of the reservoir include topography of the land, drainage and rainfall network, geology (mineral), soil, as well as land cover use (forest and agriculture), development plan and road network. Many environmental factors are also considered [14]. The design of the spillway must be sufficient to release the floodwaters more than the reservoir capacity. The appropriate design of spillway prevents the potential risk of failure and dam overtopping. A spillway is very important to the safety of dams. It is more humane and better to locate a reservoir near the strategic points that covered the demand, in addition to reducing the dumping of areas of historical value or resettling all settlements. These factors and criteria are used to determine the location of the reservoir [15]. Many of the restriction criteria indicate that reservoir sites should not be located near densely populated areas, and should contain many areas where water resources are concentrated In Haditha Dam, the case was completely different. No clays were available available at the site or at any reasonable distance from it. Sandy gravel materials were available in large quantities at the river channel and the banks of the river but at some distance at the upstream. Dolomitic limestone was available from the Euphrates Formation but the quality was questionable and could not be used for upstream rip-rap, although it was sufficient for use in the protection of the downstream slope of the dam[16].Agricultural and civil activities are affected by the sudden flood. This negative impact of these floods continues for a very long time after the flood. In addition to these unexpected floods, some morphological features that accompany a particular area may worsen the condition associated with the flash flood, and may cause a major disaster [17].To reduce the risk of this negative impact, as there are many projects that are proposed by the competent authorities, such as drainage systems for rainwater, as well as dams and some tracking channels. As for the old dams that were built, they served only one purpose [18].

2.3 SIGNIFICANCE OF RESERVOIR

Dams are the structures that responsible for restricting the flow of water in a river. Both rivers and streams represent a group of bodies of surface water that are flowing and are driven by the property of gravity that works to drain the water. Once of stop and slow the movement of surface water flow, this leads to the water gathering in the form of a lake or reservoir behind the dam [19]. Reservoirs and dams exist in nature, where many man-controlled structures have been designed. Geological events such as landslides or some types of volcanic eruptions or the effect of the upward force of the earth, which forms mountains. These collapses caused the construction of rocky dams, and lakes are prevented from these dams [2]. A reservoir is a huge structure that holds large amounts of water. The dam is a barrier to surface water that is derived from large and small watersheds and is constructed artificially. Some types of dams are used to store groundwater, as they are built underground. Mainly the reservoir represents the mass of water that is stored in the side of the upper dam. Reservoirs provide water for many uses in human activities, as they do not control the quantities of floods only Mosul and Haditha Dams are the two largest dams of Iraq. They were construct in localities having completely different materials for use in the core and rip-rap. While clay for the core was abundant in Mosul Dam site it was completely missing in the other dam site. Where solid and sound limestone for the rip-rap was available in large quantities in Mosul dam only dolomitic limestone of inferior quality was there in Haditha Dam site [20].

2.4 ADVANTAGEES OF RESERVOIR

The operation of the water storage procedure depends on the specific purposes of it that are compatible with its operation. The functional requirements and multiple purposes of the reservoirs uses are as follows:

2.4.1 Irrigation

Irrigation requirements are seasonal and vary in nature and this difference depends largely on the cropping patterns present in the command area. The irrigation water quantities that required can be considered consumptive and there is no small part of this water that is saved which is considered a return flow that can be utilized to save water. These requirements are directly related to the amount of rain that falls in the water storage area [21]. Water requirements are different, with maximum being during the summer and winter months. The minimum of these demands is during the monsoon period. The annual demand rate is constant in the absence of a high variation in the types of crops from one year to another and there is no increase in demand in the water collecting area. The quantity of water that available in the storage place protects the crops and provides safety in the dry season, so it is necessary saving a large amount of water that is stored in tanks where this storage is compatible with the requirements [22].

2.4.2 Municipal Water Supply

The water requirements for municipal purposes are not subject to change throughout the year, especially when compared to the requirements of hydropower and irrigation. The rapid expansion and growth leads to an increase in the demand for water requirements from year to year. Summer is one of the seasons in which the peak demand for water requirements occurs. When designing, expectations are made for industrial and population growth to determine the target value, and to achieve a high level of reliability, the supply system is designed to achieve these purposes [5] .

2.4.3 Flood Control

For the purpose of calming the flows, reservoirs can be play important action in preventing flood. Special reservoirs are designed to control the dangers of flooding. A specific part of the flows that enter the reservoir is stored for the purpose of releasing the balanced water, as in this way the moderation of the flood is achieved. The attenuation that results from the flood or the degree of moderation depends on the empty area of the reservoir in which the flood enters. There must be an empty space in the storage land for the purpose of achieving this purpose, as the safe capacity of the storage area at the downstream channel is higher than the storage releases [23].

2.4.4 Hydroelectric Generation

There is a seasonal difference in the requirements for hydropower, and there may be a daily difference, but to a lesser degree. In addition, there is a difference in hours as well. The fluctuations depend largely on the type of electrical loading for industrial, agricultural and municipal requirements. In other word, many of the hydroelectric requirements are at their maximum value, especially during the summer as it is in the municipal areas that the peak demand is during the day in the morning and evening time. The water passes through the turbines, where the water is reused for many consumer uses and is downstream. The amount of power generated depends on the effective head and the volume of water [24].

2.4.5 Recreation Region

There are many benefits to the storage formation as it is used for various purposes such as fishing, swimming, boating, and others. In a few cases, the storage land is operated to be used for recreational purposes, where the benefits of recreation are transverse in relation to other uses of the tank, when the tank is full, especially during the recreational season when the best support for recreational activities is provided. Rapid and large fluctuations in the water level of the reservoir cause damage to recreational views, since near the edge of the reservoir there can be many marshlands [25].

2.4.6 Navigation

Usually the objective of the process of designing storage tanks is to make the extension of the river emanating from the water storage area can be used for navigation. It is suitable for this purpose for achieving of a sufficient depth of the extension of the river channel that is used for the purpose of navigation. There is a seasonal variation that can be observed through the water requirements. When the channel contains a sufficient depth of flow. Water is widely available, especially during the monsoon period, when there is often no demand for water. The greatest demands on water are often in the dry season, and for the purpose of achieving the required depth, the need for large releases of water increases. The demand during any period also depends on the size, movement and type of waterways that are navigable [26].

2.5 CLIMATE INFLUENCE ON WATER STORAGE

The effects of climate change are likely to affect all storage options. An example of this is the longer periods of drought, as well as the decrease in precipitation and the measures used to maintain the soil water level, and this causes an increase in the moisture content of the soil, which affects the crops. If the leakage rate decreases, then the recharge of groundwater can be reduced due to rising sea levels. This leads to the exposure of the aquifers, which are close to the coast, to the intrusion of a high percentage of salt water, and this is considered a great danger. [27]. Climate change also affects some of the external factors that result from different types of storage. For example, storage zone that involves usually considerable amount of water create fertile grounds for the breeding of insects such as mosquitoes, which may cause many dangerous diseases transmitted by water. That rising temperatures exacerbate the situation, especially with climate change, and the damages caused by environmental effects, which arise threaten the value and quality of water in river downstream the dam. These factors must be determined when planning, designing and operating the place and behavior of reservoirs [28].

2.5.1 Impact of Weather Fluctuation

The increase in surface temperature, the severity of droughts and heat waves, as well as the change in the intensity of precipitation and snowmelt at a large level, as well as reducing the amount of snow cover, in addition to changes in surface run-off and soil moisture are among the most important hydrological changes that are associated with global climate change [29].

The increase in the additional warming causes a high potential for the most severe and irreversible changes in most components of the biosphere and the climate system. The increase in the intensity and frequency of seasonal droughts is expected in autumn and summer. Many regions with melt water from snow cover are expected to have a significant increase in the ratio of winter to annual flows, and cause the ratio of low flows to decrease. The increase in the frequency and intensity of the presence of extreme weather phenomena, in turn, leads to a significant change in the patterns of sewage flow, which has a significant impact on many hydrological effects and processes that are downstream of the existing water infrastructure and may cause the presence of floods whose quantity exceeds the limits of the design of dams [30].

Many traditional water management practices are based on past hydrological expertise and persistence that provide support for infrastructure and planning operations. In addition, even with levels of climate variability, water management professionals struggle, as major droughts and flood disasters are widespread all over the world [31].

The geographical location of Iraq is between longitude (38.43 degrees - 48.32 degrees east) and latitude (29.05 degrees - 37.24 degrees north). In general, Iraq's climate is considered to be semi-tropical and continental, as well as semi-arid. For the mountainous regions, the climate is Mediterranean. It is characterized by short cold winters and very hot summers. It is also characterized by the widening of the daily annual temperatures, and the reason for this is due to the lack of water bodies, which reduce the summer heat and the cold winter [32].

2.5.2 Impact of Precipitation

Runoff is one of the parts of precipitation that flows into oceans and rivers, such as underground or surface flow. There are two different mechanisms used to create runoff: over-infiltration and over-saturation. Excess saturation is created when the soil is completely saturated as the additional rain cannot seep into the soil, while excess infiltration occurs when the rate of water infiltration is less than the intensity of rainfall, as the surface runoff flows over the land in different locations. Runoff is an important factor that can describe the response of a water basin, whether on an annual or event basis [33].The annual runoff factor represents the total amount of surface runoff over the total amount of precipitation in a period of one year, while the event-based runoff factor represents the ratio of the total flow to the total amount of precipitation. The event flow can be used instead of using the total amount of annual flow, for the total flow in which the flow state that is before the event is combined with the response of one event [34].

In general, Iraq's climate is considered to be subtropical, continental, and semi-arid, while the northern regions and northeastern mountainous regions are within the classification of the Mediterranean climate. The periods of winter rainfall are from October to May. The annual average of rainfall is estimated at 216 mm, where this rain covers almost 60% of the southern Iraq [35] [36].

2.5.3 Impact of Evaporation

Since the amount of water that is lost due to storage evaporation depends on multiple factors, including the factor of the storage method of water and the volume of storage as well as the evaporative demand that is in the atmosphere. [37]. Many attempts had been adopted that are used to reduce losses that occur due to evaporation by changing the method of water storage there can be management to reduce water loss from storage dams by increasing the depth of these reservoirs, as well as using another method to use a good quality lining and it is installed to prevent leakage. Several windbreaks can also be used under certain conditions, but these are likely to have very little effect for the purpose of reducing evaporation, because solar radiation rather than wind is the main driver of evaporation [38]. In semi-arid hydrology, losses due to evaporation are very important because they have a significant impact on the storage capacity of surface reservoirs, so the capacity used to calculate evaporation is very important in these areas. The special evaporation calculation in the storage formation layout can lead to changes in the critical period sequence (CP, where the storage zone is empty and without spillage) as well as changes in failure periods, especially when the tank has no capacity to converge [39].

2.6 FLOOD MECHANISM

Flooding of rivers can have economic, social and environmental consequences. However, the limited understanding of the many regional variations of flooding leads to many poorly understood flood trends as well as uncertain predictions of future flooding. Knowing the process provides a very useful context for the mechanisms that are of most importance when studying non-response of floods. Focusing on the assessments of floods over large areas on recurring events such as the presence of annual peaks is important procedure. Many flood changes that are severe but only rare and for a small number of sites with continuous monitoring records are rarely studied [40]. Understanding these changes of severe floods, which are rare, is of particular importance, as these events are often very damaging. Using much conjunctional and regional flood information, it has been found during recent decades that there is a strong contract. Some fluctuations occur and an overall increase in the size and frequency of severe floods occurs across many continents [41].

In summary Flood occurs as the accumulation of water that floods in the lands in large quantities like flowing water, which can be routing to storage zone in addition to a result of heavy rainfall and result from increasing quantities in the volume of water forming a watercourse, such as a lake or river or a reservoir, after its quantity exceeds the limits of normal water. Most of it is harmful, and causes the destruction of homes.

2.6.1 Overtopping Flow

An overflow occurs when a dam's structure has increased water retention capacity as the water flow passes over the structure. The potential sites for overflow are retention basins, dams, etc. The level of corrosion protection required can be assessed, and the drainage design must be checked. Using the historical record, this can be accepted, or the maximum probable flood (PMF) or the use of isometric maps, or any other public methods [42].

The final determination of the design discharge is made through distinguished engineering practice, as well as the use of multiple methods for that. The amount of excess volume V can be defined as the excess quantities of water that are above the level of the top of the dam, and it is measured in cubic meters per meter width per wave. The average over-discharge does not give any indication of the number of waves that exceed the amount of water exceeded by the individual waves. Fewer ultra-high waves cause more erosion than ultra-high waves of small sizes, but with large exceeded sizes [43]. The distinction can be made between the two cases, especially to describe the water load when using excess volumes. Overrun is the cause of many dam failures, especially in the past. Overflow mainly not been completely avoided in the future due to the unpredictability of the amounts of water levels being designed and the costs of high dams which are uneconomic. It is also required to determine the relevant layer thicknesses and overflow velocities which are responsible for the erosion that occurs at the top of the dam as well as the infiltration of the ground side of the dam [44].

2.7 EFFECT OF DAM ON WATER RESOURCES

Many dams have been built for the purpose of storing water or for the purpose of producing electricity and the main purpose is to control the risks posed by floods, as well as some other uses. The many long-term consequences of dams and groundwater recharge include providing water for many local municipal purposes. Dams retain water And that at the lowest point for the purpose of saving water, which irrigates many cultivated areas, especially in seasons when there is drought. The dams reduce the use of groundwater quantities; Thus, it leads to an increase in water, especially on the lower side [45].

The operation of the reservoir mainly affects the characteristics of the surface flow, as well as its relationship to the presence of surface water and also the effect of groundwater in it, where the change in the relations of drainage and recharge occurs. These effects lead to the occurrence of many changes that occur in the level of the water plate, especially as it works to change the amount of water that is within the human uses. It is expected that the direct impact of all dams will be on the quantities of groundwater between the upstream and downstream. In addition, in many normal cases, the rise of groundwater occurs at the surfaces of the reservoir [11].

2.8 SUMMARY OF THE PRESENT WORK

The study included in the research had spent used the related information of Haditha dam involving the topography and contour lines distribution of the site behind the dam which act as reservoir and the data of climate characteristics in Iraq relating to the study area including the rain intensity and the temperature values along the year and information about the inflow and outflow of the dam based on the water body in Euphrates river for analysis the action of the dam among all surrounding the hydrological factors. Simulating of the dam upstream and downstream had been build using HEC RAS program for better results. The chance of flood as the case of overflow had been determined in the study. The study derived an equation depending on the factors, parameters, and results. The equation governing the activity of the dam with respect the resultant of the available water quantities.

2.9 LITERATURE SURVEY

The study had assessed the effect of the early, normal, and maximum water level of reservoir in dam for the purpose of hydrological risk and safety analysis. Case study of dam placed on Tagus River was adopted in the study. Location of dam is in Western Spain. The outline that applied was included the influence of many physical parameters like the quantity of water, inflow, and outflow. The study depended on the method of Volumetric Evaluation in analysis procedure [46].

That had investigated a method of real-time for flood controlling. The study aimed to model the state of dams that contains gate-controlled. Optimization procedure of the model was used based on mixing of programing of integer linear and Bayesian Networks. The study tried to examine the relationship between reservoir storage, inflow, and outflows. The case study used was Talave reservoir that located in Spain [47].

The study had simulated the case of hydrological failure for the dam of Foster Joseph Sayers using HEC RAS software. The dam located in Pennsylvania. The study involved many parameters like the geometrical state of study area, elevation of storage water, and outflow magnitude in different time steps. Influence of parameters on the downstream areas at different locations using the software was examined [48].

The study had used HEC-RAS software for simulating dam failure. The study applied on Kalyani dam that constructed across the river of Swarnamukhi in India. Unsteady flow was adopted for predication the characteristics of the wave that generated after the dam in failure state. The study involved the influence of water levels and discharges per specific time steps. The study aimed to describe the impact of flood on the downstream area [49].

The study had established profile of dam breach that described the performance of Temenggor Dam in Malaysia including the predicting of breach outflow in hydrograph. The study involved using of regression equations as a way for satisfying results for the breach state. Simulating was performed depended on the evaluated breach parameters like the discharges, water storage quantity, and levels in the case of overtopping failure. (HEC-RAS) software was used for simulations process. The study had been adopted toward preventing the impact of dam failure on the related areas [50].

The study had studied and analyzed the conditions of weather such as air temperatures, evaporation, and precipitation on the water balance of Przebędowo reservoir located in Poland. The study involved the examining of fluctuations in water that influence the levels in specific time steps during the seasons. The study explained in graphs the influence of increment and decreasing of the intensities of precipitation and evaporation in hot and cold months on the water level of the reservoir

Extreme weather events, particularly droughts, frequently contribute to disturbances in the natural water balance . As it was reported by Wibig , the present-day climate warming, in Poland manifested in an increase of temperature in the second half of the 20th century by almost 1°C, has led to a growing risk of water deficits. Climate warming results in an increased potential evaporation, which at practically unchanged precipitation totals causes a reduction of the climatic water balance. in central and eastern Poland in the months of the vegetation season the frequency of negative climatic water balances is 2-fold greater than the incidence of positive balances. The negative values of this index have been recorded most frequently in the spring months, while the positive balances have been most common in September. For this reason it continues to be of paramount importance to conduct research on water balances both for entire catchments and reservoirs located in such catchments. However, it needs to be stressed here that at the end of the 20th century very few studies concerned water balances of lakes in Poland; as indicated by Choiński due to problems in preparing water balances for lake waters such case studies were conducted for only several dozen of lakes in Poland [51].

The study had collected data of the mean of annual flow that gathered from Karkheh River where the study aimed to analysis the behavior of inflow and water storage in an upstream area of Karkheh dam. The study depended on statistical analysis using Regressive Integrated Moving Average. Mean inflow toward the reservoir of Karkheh dam was determined. The study explained in diagrams the fluctuation of inflow behind the dam along the year [52].

The study had used the method of hydrological sensitivity to evaluate the variation in discharge in the upper basin of Hwacheon dam. The study included the influence of inflow and rainfall data on the reservoir activity. The method of hydrological sensitivity that implemented in this study was based on Budyko-based function. Dividing of time series and examined the change in points for average inflow and rainfall along total length of time was the outline of applied the sensitive method in this study. The results had been explained in diagrams and could be used for gaining better hydrological benefits of Hwacheon dam

Water resource planning in a trans-boundary river basin is complex because of different institutional and scientific concerns and it may become increasingly difficult as a consequence of water scarcity caused by climate change. The analysis of discharge variations in a trans-boundary river basin is very important because the results can be key to resolve complex problems including decreased hydropower generation, degraded water quality, and deficient water supplies. Despite its importance, there are relatively few studies dealing with hydrological variation in a trans-boundary river basin. Therefore, this study used the hydrological sensitivity method to identify the discharge variation in the Hwacheon dam upper basin, a representative trans-boundary river basin between South Korea and North Korea. This particular basin was selected because the inflow into the Hwacheon dam in South Korea has decreased significantly after the construction of the Imnam dam in North Korea in 2000. The hydrological sensitivity method is a simple approach to analyze variations in discharge. After collecting 51 years (1967–2017) of rainfall and inflow data, a change point that represents an abrupt change in the time series was detected by using moving average, double-mass curve analysis, Pettitt's test, and Bayesian change-point analysis. The change point detected by these methods was 1999. The hydrological sensitivity method using five Budyko-based functions was applied to a time series divided into before and after the detected change point [53].

The study had analysis in hydrological way the influence of breach of Haditha Dam in the case of collapsing on the downstream areas. The study analyzed the hydrograph shape using the procedure of level pool in reservoir routing for evaluating the outflow caused by the storage water in dam reservoir. The breach size was calculated along specific periods of time by considering a linear increment of depth and width from the first values toward the final height of predicting quantity of water stream [54].

The study investigated the fluctuant accumulation of water quantity related to Haditha Dam reservoir by monitoring the levels in the area of surface water of Lake. The study evaluated the required levels over a series of time by using techniques of Satellite imagery and GIS to reach the scope of the study. Both minimum and maximum water storage were determined for analyzing the performance of reservoir with respect to the inflow of river and resultant of water quantity stored [55].

3. METHODOLOGY

3.1 GENERAL INFORMATION OF HADITHA DAM

After the constructing of Habbaniyah reservoir project thinking starts to place a dam on the upper river to serve the around areas as well as control the inflow water and enhance the irrigation and other water consumption branches; The reservoir Haditha of Dam completely cover the areas related to (Anah) and (Rawa) in western Iraq. The Dam body located on the river of Euphrates in border of Al-Haditha city. The dam restricts the water flow behind it in Lake of Qadisiyah [9]. The specific site of the Haditha Dam is located in a narrow part of the Euphrates River, and the dam is located some kilometers from the source of the city. This choice was determined based on the geological and topographic conditions, as well as the method of formation of karst rocks found in the dam's supports, where there are appropriate conditions for the completion of works as well as local building materials [11]. The total length of the dam is approximately 9,064 km. The height of the dam is 57 meters, which is calculated from the deepest point, found in the river channel, which is dictated by hydrological and topographical factors. [8]. The Haditha Dam photographic and satellite image were showed in figure (3.1):

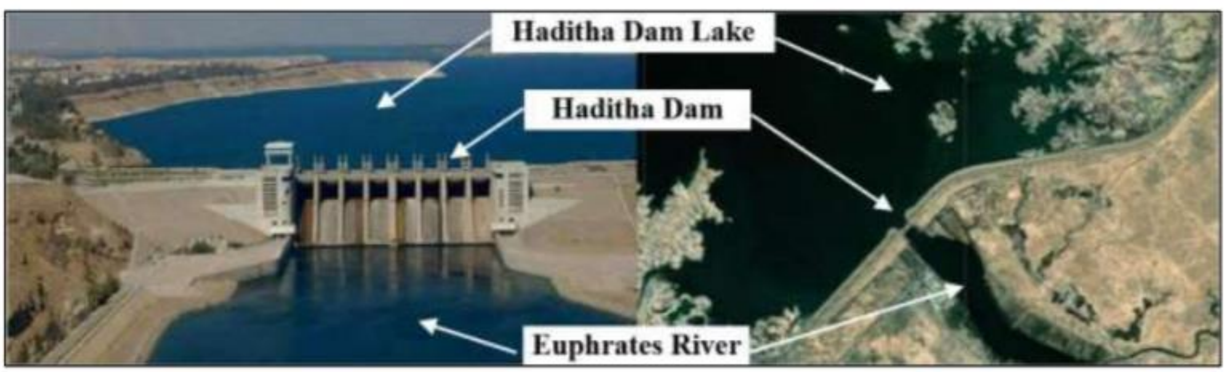

Figure 3.1: Haditha Dam photographic and satellite image [55].

3.2 UPSTREAM ANALYSIS

The Euphrates Rivers are the major sources of water in Iraq. Huge quantity of water from the river per year is gained at the city Hit in which the city lies 200 km downstream from the Iraqi-Syrian border. The river discharge is the main source that contribute Haditha reservoir. Figure (3.2) explained the formation of the reservoir and water collection behind Haditha dam.

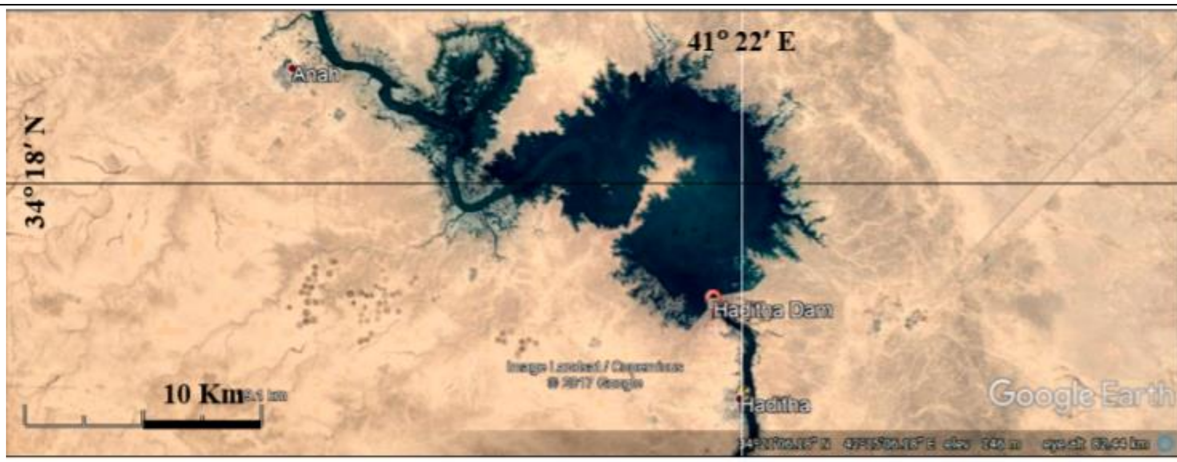

Figure 3.2: Formation of Haditha dam reservoir [56]

For analysis the region of Haditha Lake, the area was divided into grid in which the properties of the area relating to the topography was controlled and analyzed and considering the input quantity of water as boundary conditions. These amounts of water reflected the Euphrates River flow rate and the rainfall rate as input data, while the output was considered by the rate of evaporation and the quantity of effluent discharge from the dam, the figure that related to dam reservoir as explained in figure (3.2) were adapted by using AUTOCAD program for assigning the proper network. For these network, each intersection point between two perpendicular lines used as nodes lies on the region of the reservoir from the inlet of flow that indicated by the approach of Euphrates River. The region also included the water catchment area and the dam frame that showed as well. The dam in which restricted the large distributed water that cover the catchment area to a narrow path relatively in the way the outflow of the dam toward the downstream portion of the Euphrates River.

The area that represented applying of the grid on Haditha Dam region was showed in figure (3.3):

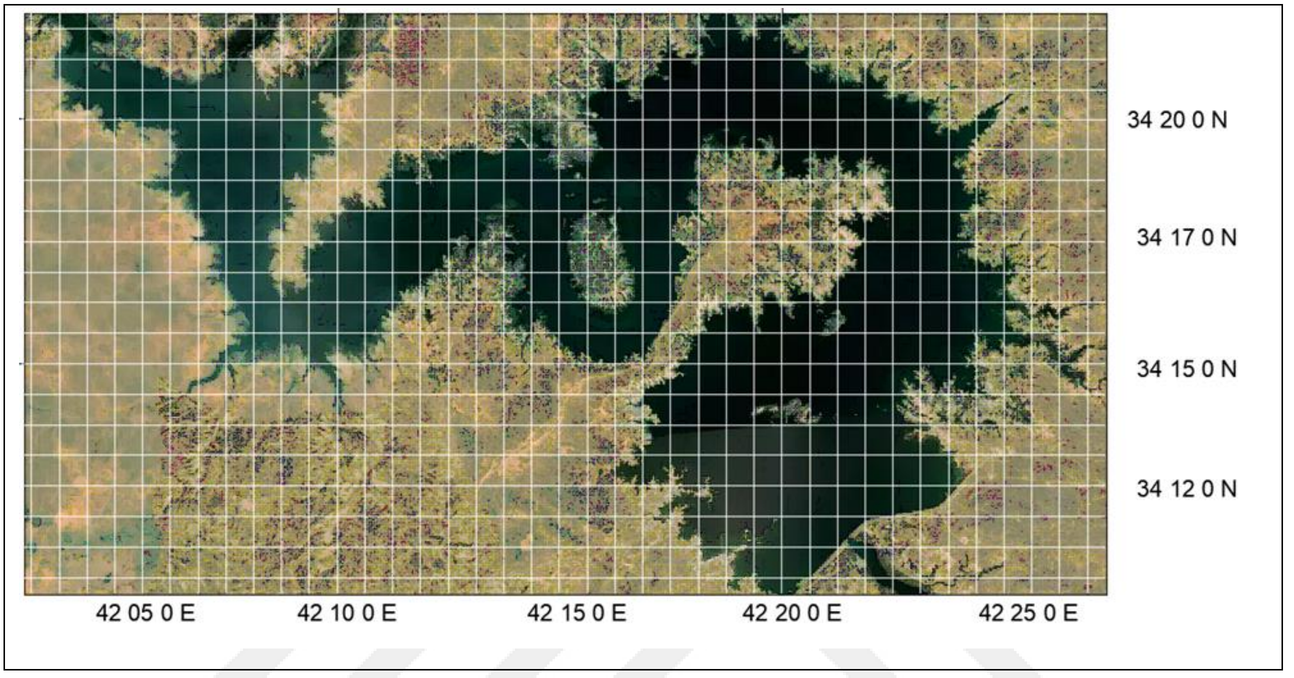

Figure 3.3: Grid analysis of the case study area[56]

3.3 DOWNSTREAM ANALYSIS

The region after the dam involved the banking of the Euphrates River regularity in which its path move forward along hundreds of kilometers. The quantity of water along the path of the river after the dam is controlled mainly by the amount of discharge in which the dam operated with. These data should be satisfying the allowable requirement of water in west, middle, and south of Iraq for different purpose including irrigation, water treatment plants, and other using. Figure (3.5) showed the regularity of the river path after the dam.

The grid in figure (3.3) was then adapted by the topography data that obtained from the Iraqi Ministry of Water Resources, these data were used to assign the difference in elevation in with the catchment area can function the water storage according the input quantity of water relating to the inlet flow rate and rate of participation. The result of elevation data were explained in figure (3.4).

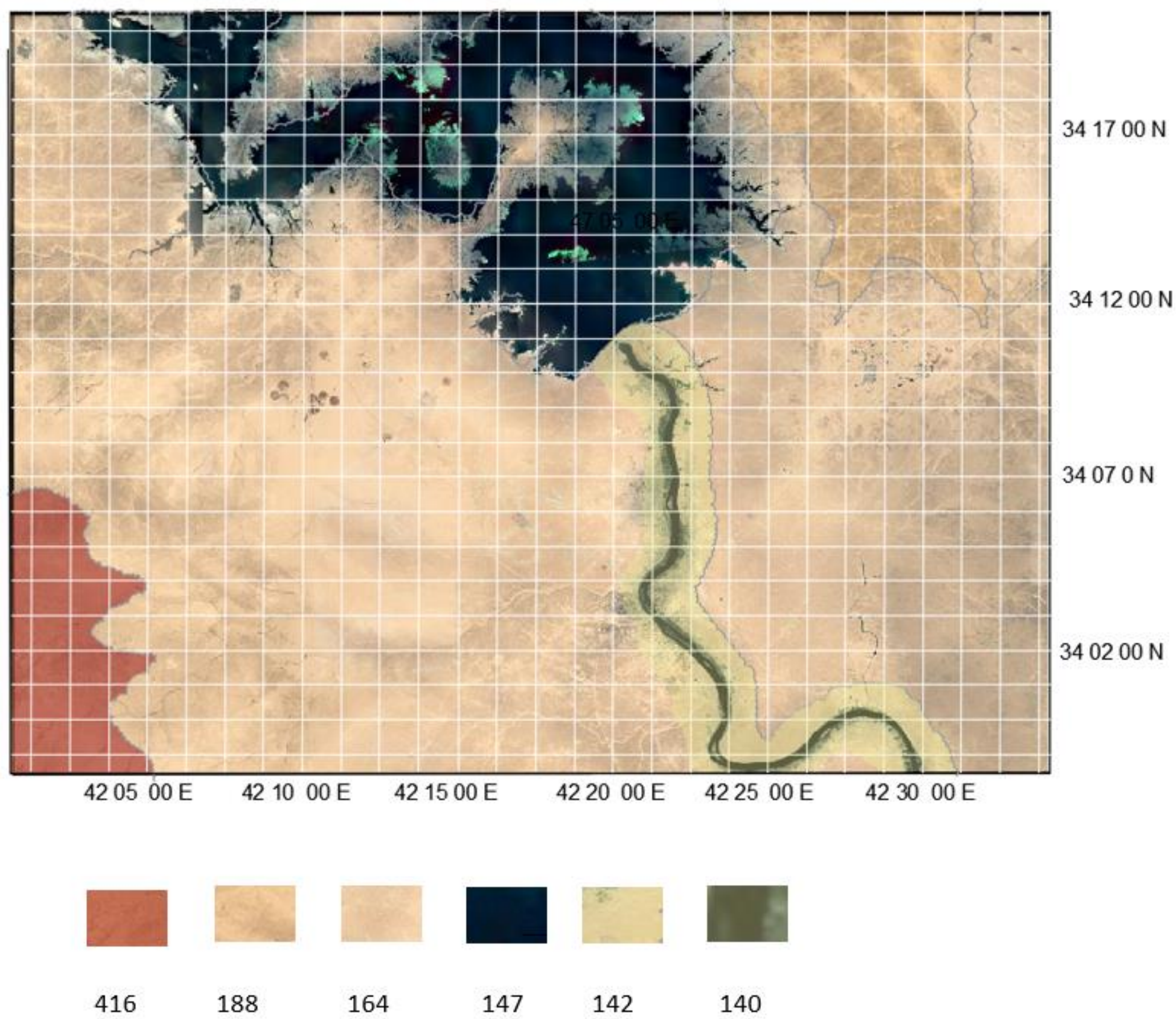

Figure 3.4: Elevation data of Haditha Dam region[56]

The data that obtained from the grid and elevation of Haditha Dam reservoir were arranged

In useful matrix in which was adopted for analysis the hydrological action for the upstream behind the dam and the flowrate downstream the dam.

The methodology included the analysis of the volumetric rate of water the been occupied by the catchment area as this state influence the discharge to the downstream area and how the dam can satisfy the water demand for irrigation and other purposes. For placing the first step toward that analyzing procedure, the equation of water balance was adopted to arrange the influence of the hydrological action that gained by the movement and routing of the water body, the equation of mass balance relating to the storage area and downstream region is as following [57]:

$$V_t = V_{t-1} + Q_C + Q_{in} - Q_{out} - U + (P - E) * A \tag{3.1}$$

Where:

V_t : the resultant of storage volume of resevior (m^3) at time t

V_{t-1} : the storage volume of resevior before change (m^3)

Q_C : the inflow toward the storage area (m^3)

Q_{in}: the lateral inflow from other ubstreams toward the storage area (m^3)

Q_{out} : the outflow from the storage area (m^3)

U_{RL} : Water withdrawl (m^3) at time t

P: Amount of participation (mm)

E: Amount of evaporation (mm)

A : $Area\ of$ reservoir (m^2)

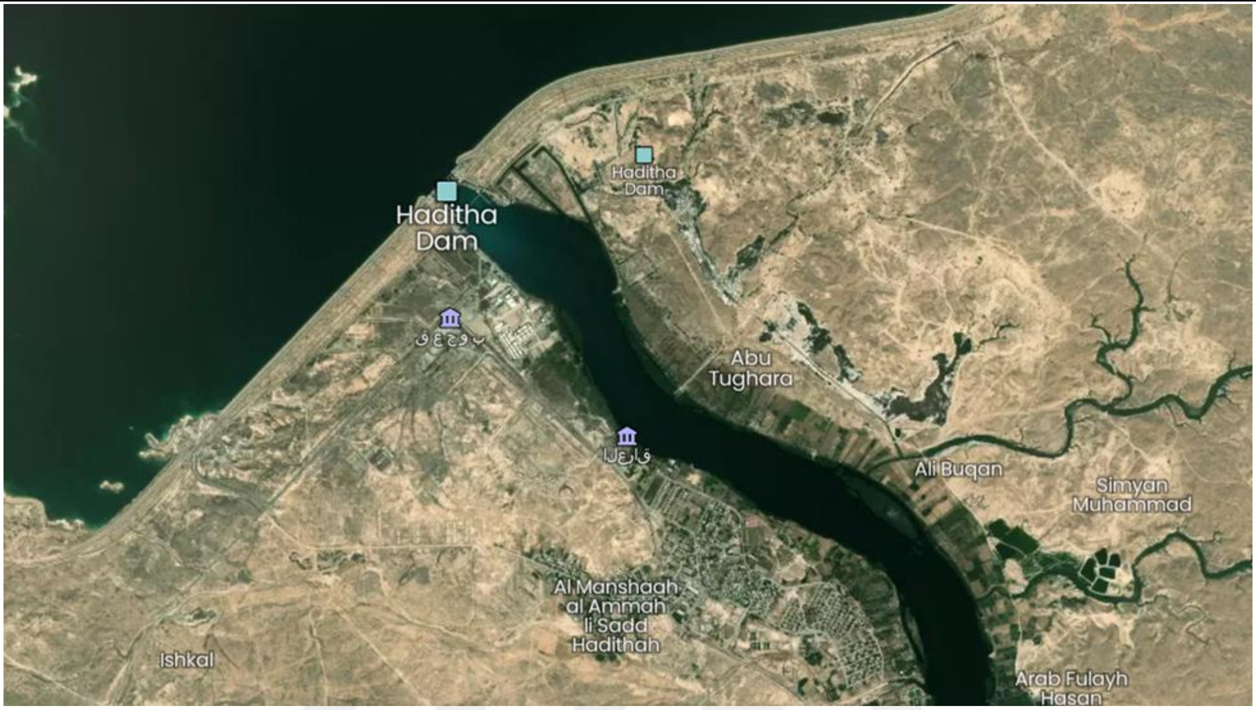

Figure 3.5: Euphrates River in downstream region [57]

3.4 HEC RAS WORK

For analysis the regions behind and after the Haditha Dam, HECRAS software were used. The behavior of topography was used in the program to simulate the state water catchment area and the 2D flow area after the dam in which for examining the case of failure by overtopping that could be occur when troubles happened to the regular flowrate of the dam.

The first step of using the program was by the evaluating the necessary data that reflect the elevation of the dam and the amount of inflow rate which influence the water storage capacity.

Figure (3.6) explained the initial work by assigning the map inside the program

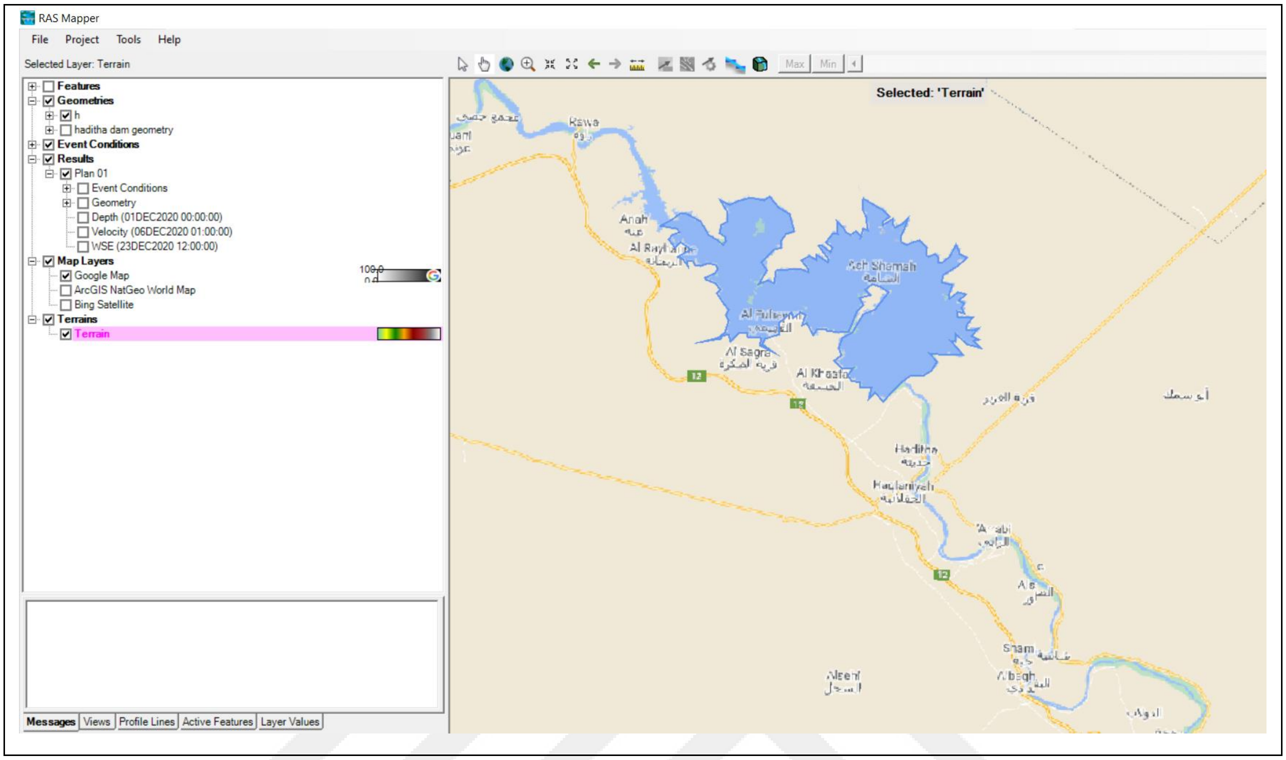

Figure 3.6: Assigning of Haditha Dam map inside the program

The previous step was so important step in the program as it gave the initial platform for the program to recognize in more preciously the lands that the dam placed in. the following step was by assigning of the catchment area as shown in figure (3.7):

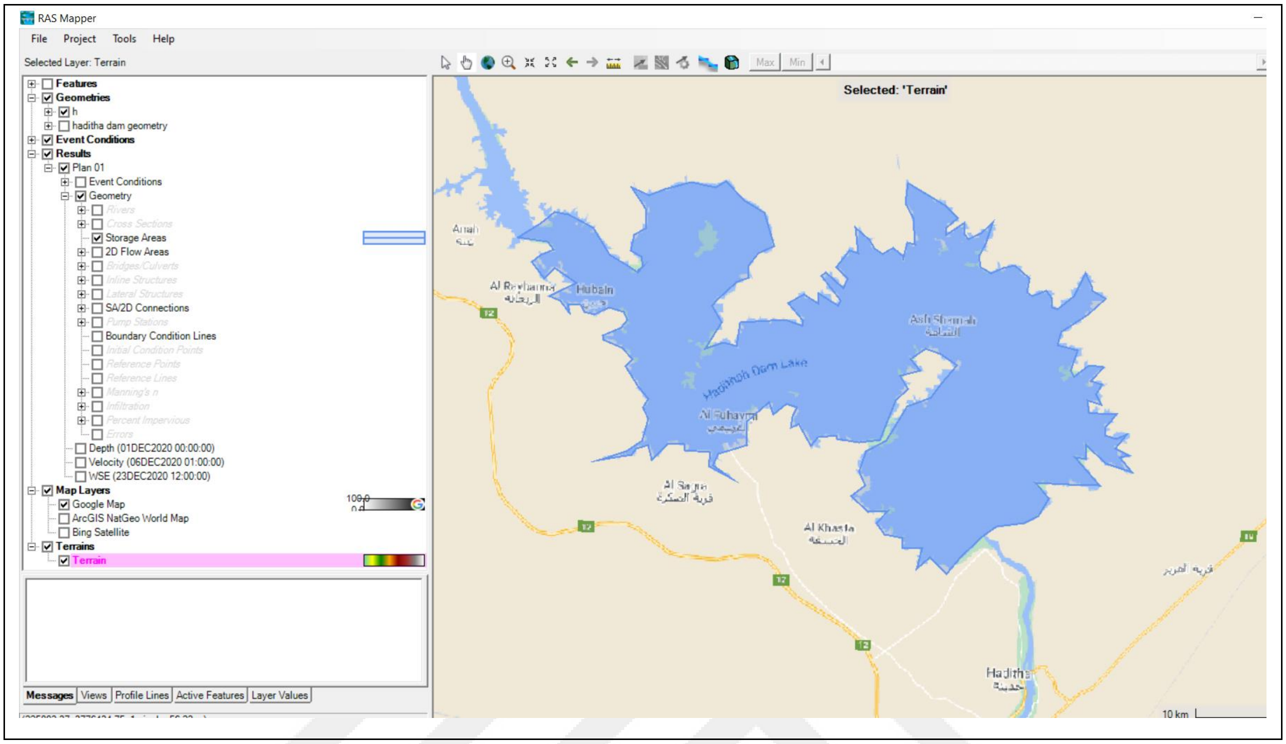

Figure 3.7: Assigning of Haditha Dam catchment area

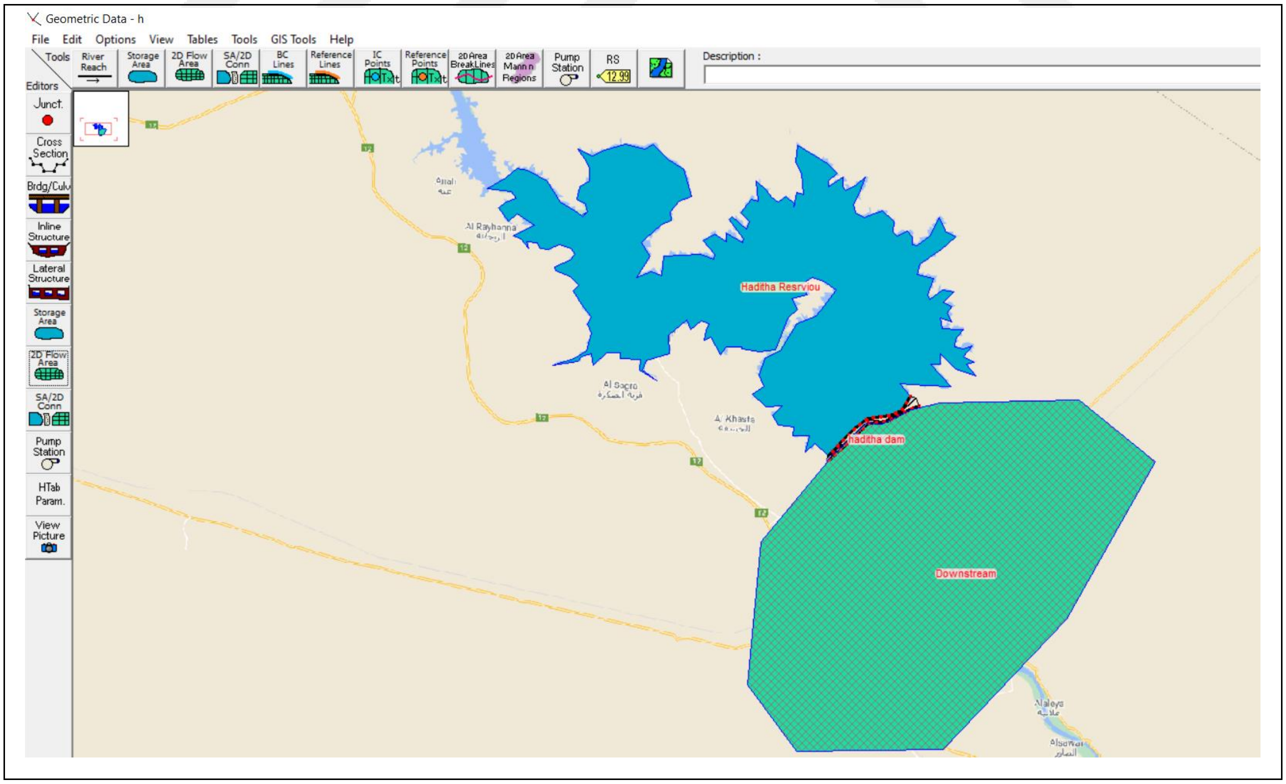

Figure 3.8: Determination of the 2D downstream area in the program

After that, the construction part of the dam and the 2D flow area in the downstream region where placed in the program according to the map. The area region after the dam covered about 25 km downstream along the Euphrates River. Figure (3.8) showed the simulating of Haditha dam body and the downstream area over the map.

The required data that used in the HEC RAS program was summarized in table (3.1), table (3.2), table (3.3), and table (3.4):

Table 3.1: Haditha Dam initial data [20]

Haditha Dam	
Elevation of dam crest (m)	154
Length of dam (m)	9000
Height of dam (m)	57

Table 3.2: Volume of storage –elevation data of Haditha Dam reservoir

Reservoir volume	
Elevation (m)	Volume of storage (*10^3 m^3)
147	827000
150	966000
152	2008000
154	3131000

The inflow of the storage area that obtained in the study was the monthly inflow with the length of 4 year from 2018 to 2021. The magnitudes of flowrate in the mentioned period was illustrated in table (3.3).

Table 3.3: The Inflow of the storage area of Haditha Dam

Inflow (m^3/s)				
Year / Month	2018	2019	2020	2021
10	322	313	314	295
11	432	423	413	403
12	506	495	484	483
1	688	684	680	676
2	675	668	660	662
3	500	490	480	470
4	319	302	297	286
5	439	437	435	439
6	385	384	383	381
7	500	503	506	508
8	672	681	691	690
9	476	472	479	481

The monthly average amount of Precipitation was demonstrated in table (3.4) (Iraqi meteorological organization and seismology).

Table 3.4: Average amount of precipitation and Evaporation on Haditha dam area

Month	Precipitation Intensity (mm)	Evaporation (mm)
10	10	83.3
11	17.2	24.5
12	17.6	8.1
1	19.7	6
2	22.5	10.6
3	17.7	36.3
4	13.6	83.6
5	5.8	159.7
6	0	230.6
7	0	286.9
8	0	244.3
9	0.7	147.2

The data in the previous tables were used as input data for achieving better simulation of the overtopping case as the breach could occur for the dam. The increment of the Euphrates River depth in the region after the dam as well as the chance of immersing more land along the flood action.

4. RESULTS AND DISCUSSION

4.1 WATER BALANCE EVALUATION

The equation of water balance based mainly on the inflow toward the reservoir area. The intensity of precipitation and also the potential evaporation can play other role in the water quantity in the catchment area. By taking the initial storage volume before change equal to 827000000 m^3, and the initial surface area equal to 500 km2 ,the annually predicted quantity of water was evaluated as following (table 4.1).

Figure 4.1 showed the monthly precipitation on the study area the explained the variation in the monthly rainfall intensity while figure 4.2 showed the monthly evaporation rate in mm that can contribute to the losing of considering quantity of water from the storage zone.

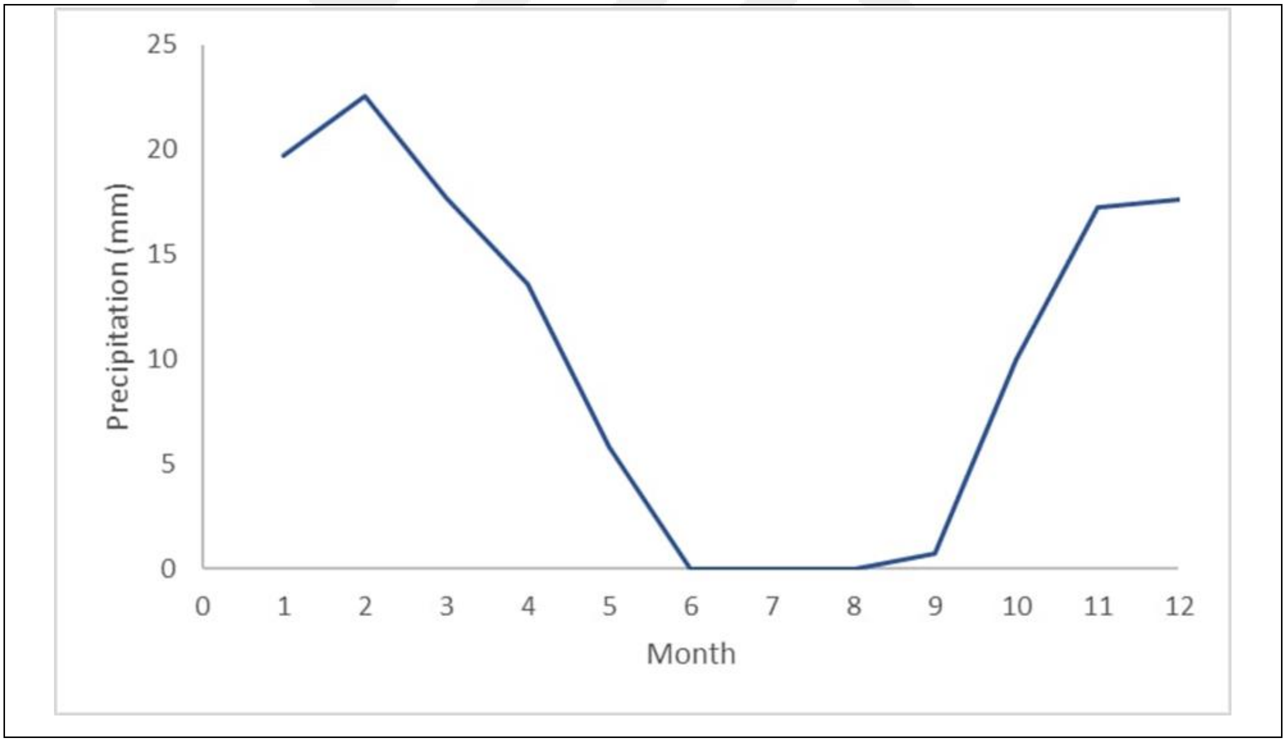

Figure 4.1: Monthly Precipitation (mm)

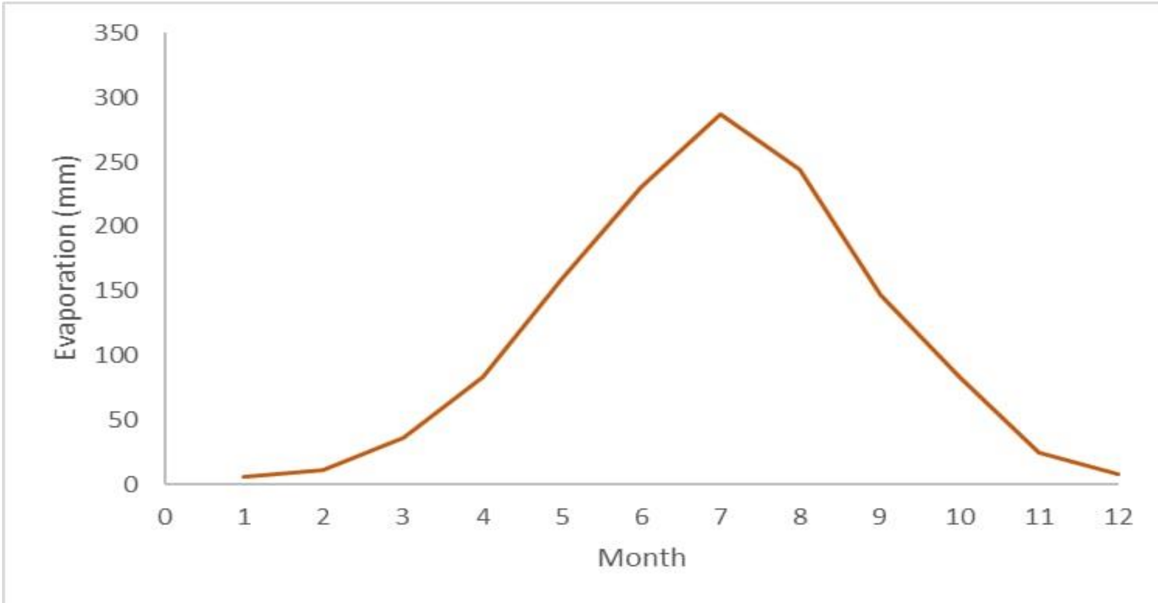

Figure 4.2: Monthly Evaporation (mm)

Table 4.1: Monthly predicted quantity of water

Month	Qc (m^3/sec)	P (mm)	E (mm)	Change in Vt (m^3)
10	295	10	83.3	727990000
11	403	17.2	24.5	1040926000
12	483	17.6	8.1	1256686000
1	676	19.7	6	1759042000
2	662	22.5	10.6	1721854000
3	470	17.7	36.3	1208940000
4	286	13.6	83.6	706312000
5	439	5.8	159.7	1060938000
6	381	0	230.6	872252000
7	508	0	286.9	1173286000
8	690	0	244.3	1666330000
9	481	0.7	147.2	1173502000

In the previous table, the amount of change in water quantity was calculated by using the water balance equation. The magnitude of the change depended on the positive quantity of water that come from the rate of inflow toward the catchment area and depended also on the monthly amounts of rainfall and evaporation as a losses in water quantity. The resultant of Vt was used to identify the amount of the Haditha Dam outflow for best management condition.

The amounts of outflow as calculated from the results of table 4.1 were included in table 4.2 and sketched in figure 4.1:

Table 4.2: The Monthly outflow for Haditha Dam

Month	Outflow m3/sec
10	280.9
11	401.6
12	484.8
1	678.6
2	664.3
3	466.4
4	272.5
5	409.3
6	336.5
7	452.7
8	642.9
9	452.7

The monthly outflow rate was explained in figure 4.3

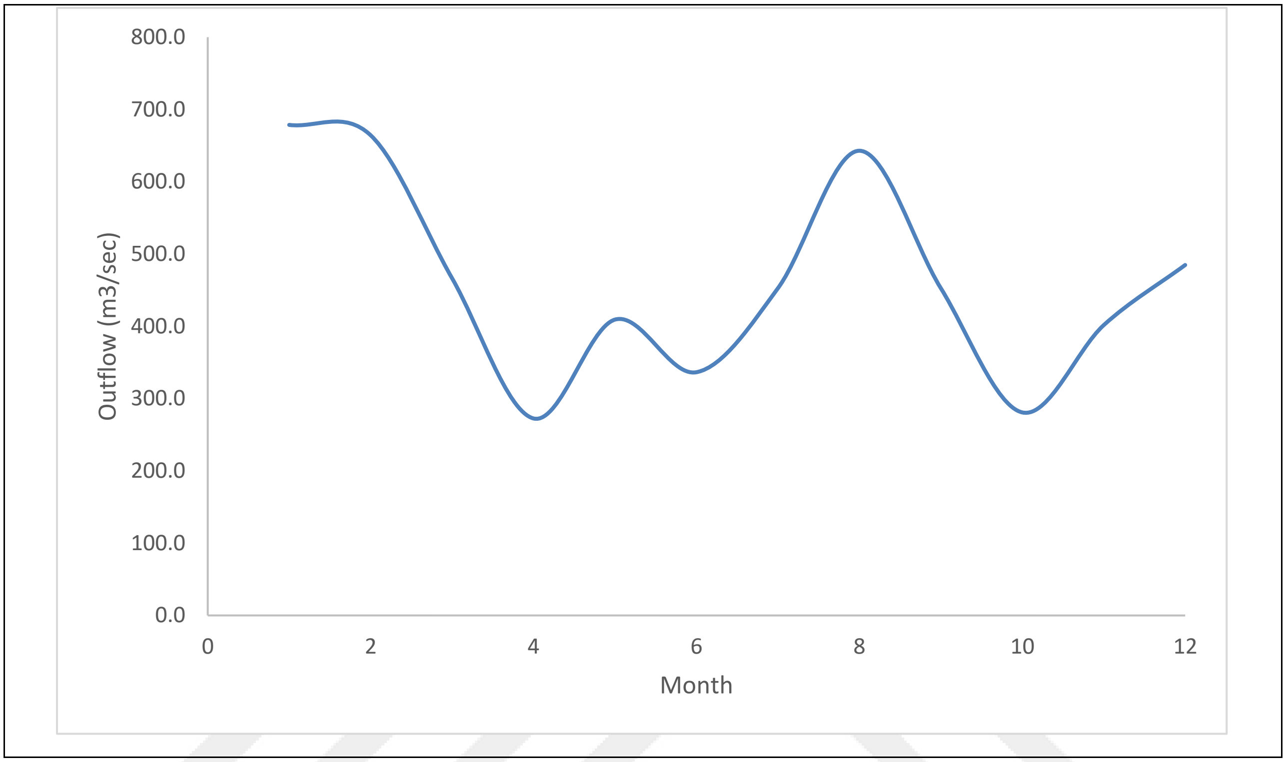

Figure 4.3: Variation of monthly outflow

The monthly outflow rates in table 4.2 reflected the balance of water quantities, so that, the increasing in these amounts can lead to decreasing the storage quantity in the reservoir while the decreasing of these amounts can lead raising of the water depth behind the dam. Figure 4.2 explained the volume according to the elevation rising behind the dam.

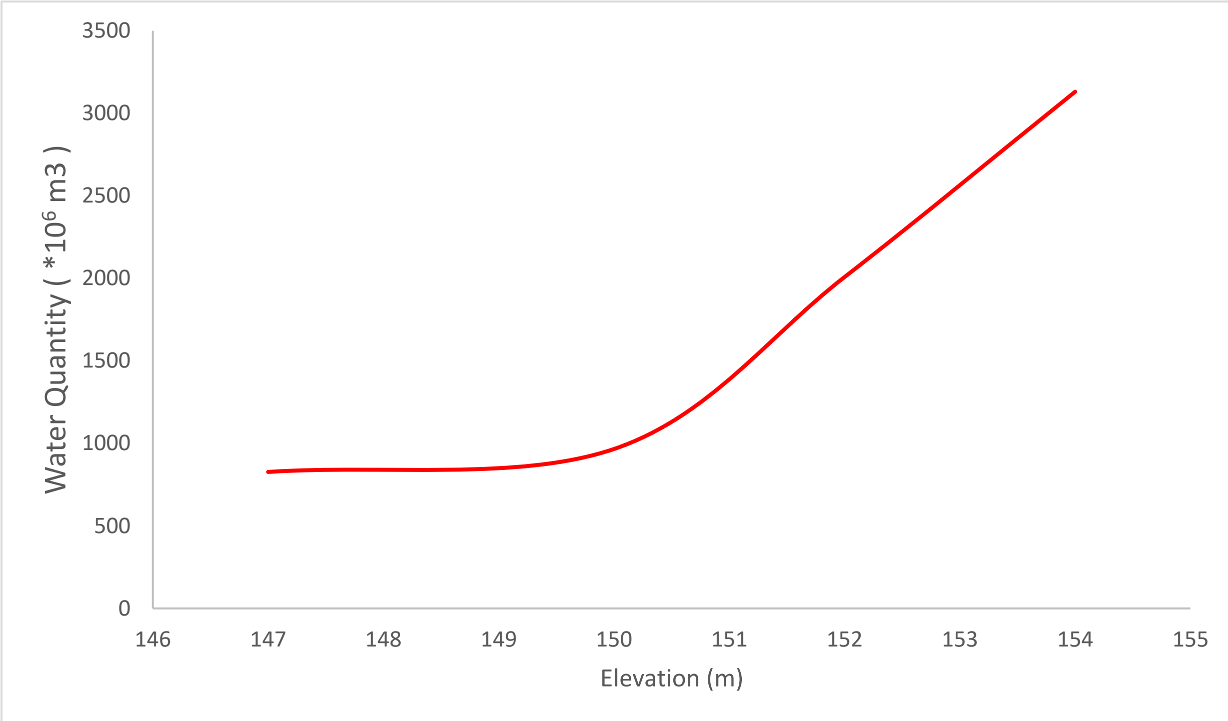

Figure 4.4: Relationship between volume of water and the elevation

For assigning a mathematical link between the elevation of water and the surface area of water, correlation statistical analysis was done and explained in figures 4.5 and 4.6. The link that obtained from the figures was used in the calculation of the coverage area by the raising of water. The increment of the volume happens as the elevation of water cover more lands behind the dam. Each level has its storage capacity, so that, the depth of water behind the dam raise with various speed. The minimum elevation of water surface for best condition assigned as 147 m. The average area relating to the elevation were included in table 4.3:

The data of surface area of the reservoir in the study area were showed in figures 4.5 and 4.6 as following:

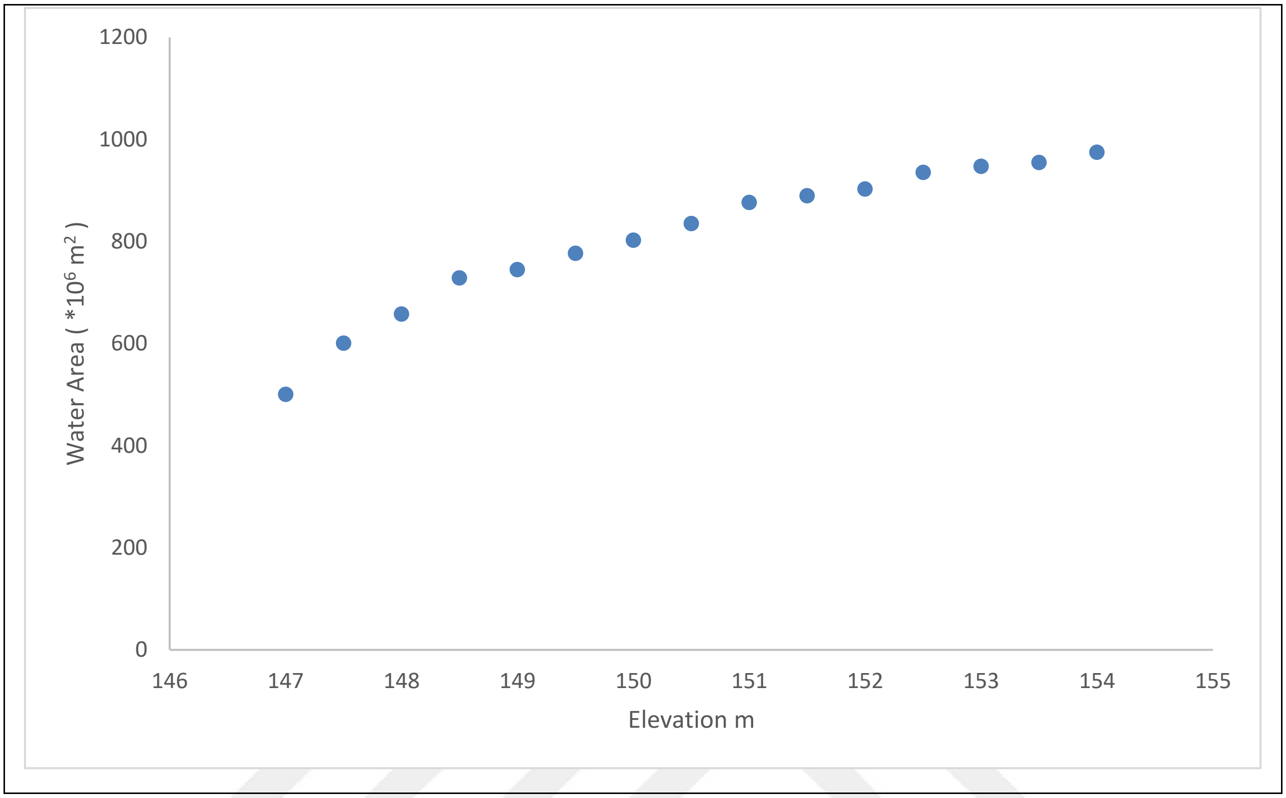

Figure 4.5: Scatter relationship between surface area of water and the elevation

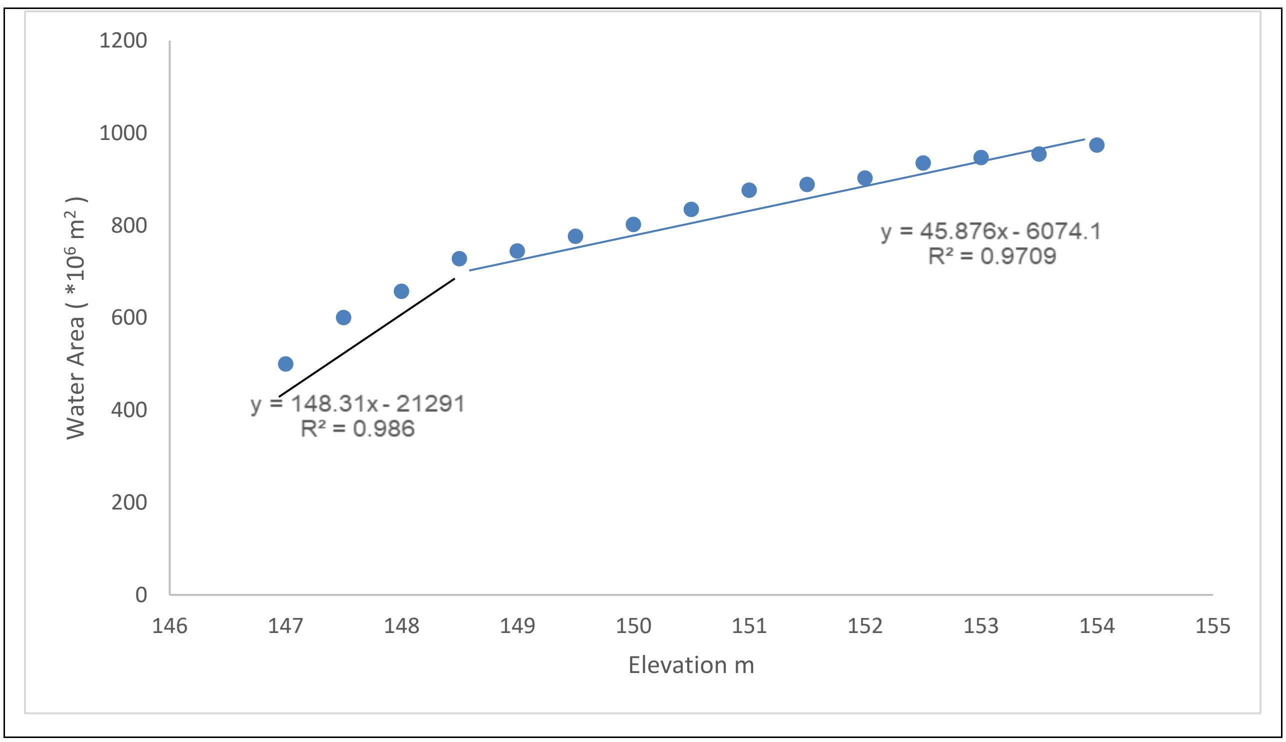

Figure 4.6: Correlation between surface area of water and the elevation

Table 4.3: The Calculated area with respect to water elevation

Elevation	Area (m2)
147.5	584725000
148	658880000
148.5	733035000
149	761424000
149.5	784362000
150	807300000
150.5	830238000
151	853176000
151.5	876114000
152	899052000
152.5	921990000
153	944928000
153.5	967866000
154	990804000

For identifying the coverage area caused by the case of decreasing the outflow toward the downstream area, the water balanced quantity of water was satisfied with the increasing of area according to the elevation change.

4.2 HEC RAS SIMULATION

The situation of dam breach as simulation by HEC RAS software were implemented with the geometrical and physical conditions. The results of the flood wave after 0,10, 20, 30, and 40 hours were explained in figures 4.7, 4.8, 4.9, 4.10, and 4.11 .

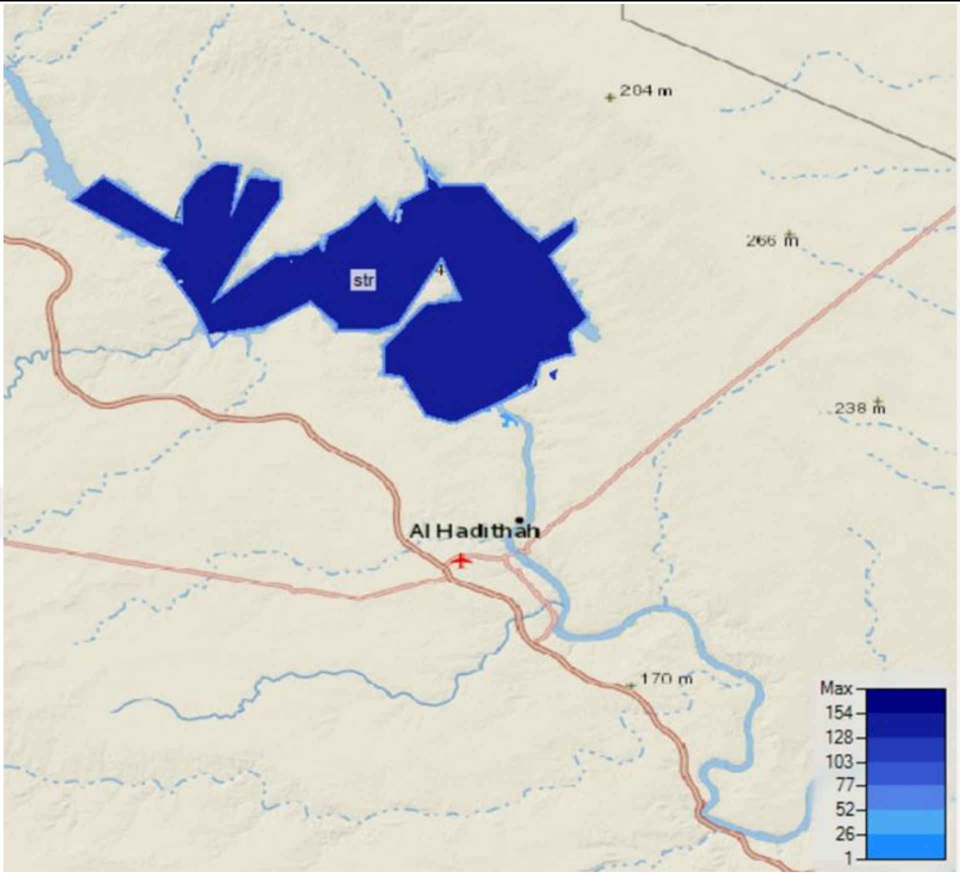

Figure 4.7: Flood wave after dam breach (time = 0 hours)

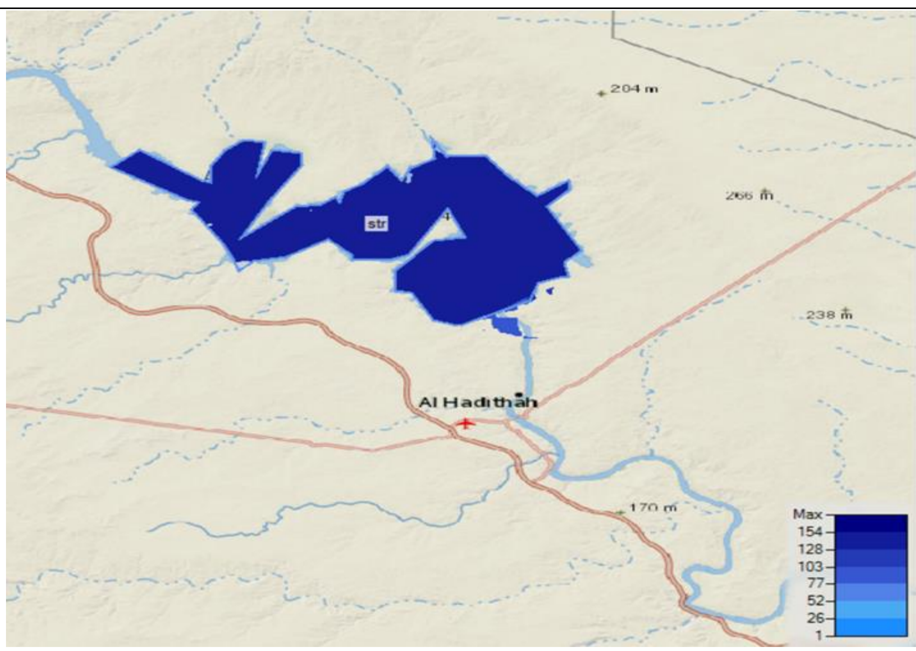

Figure 4.8: Flood wave after dam breach (time = 10 hours)

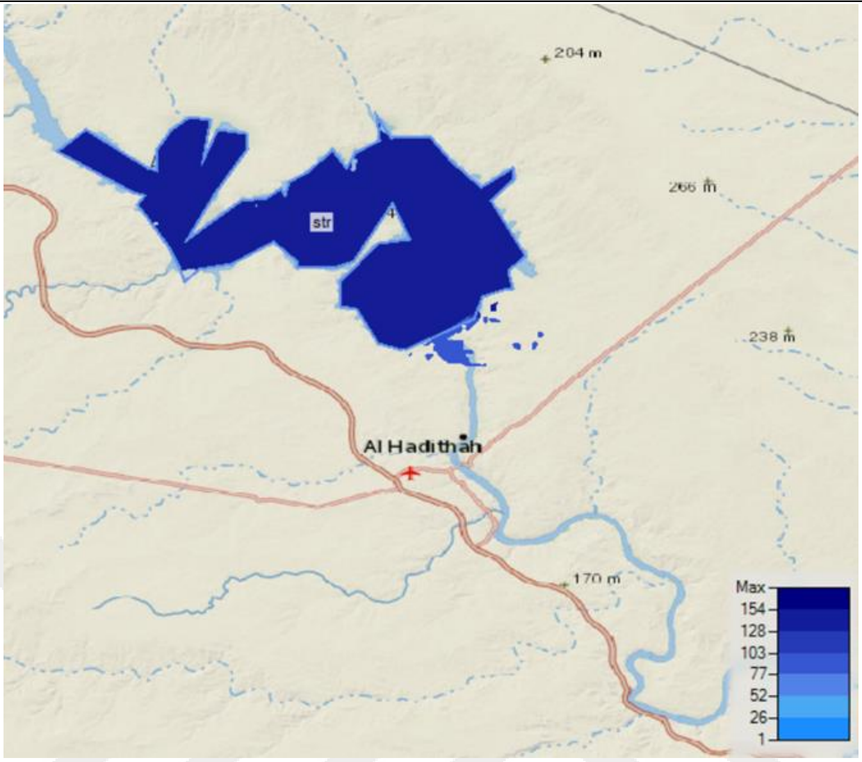

Figure 4.9: Flood wave after dam breach (time = 20 hours)

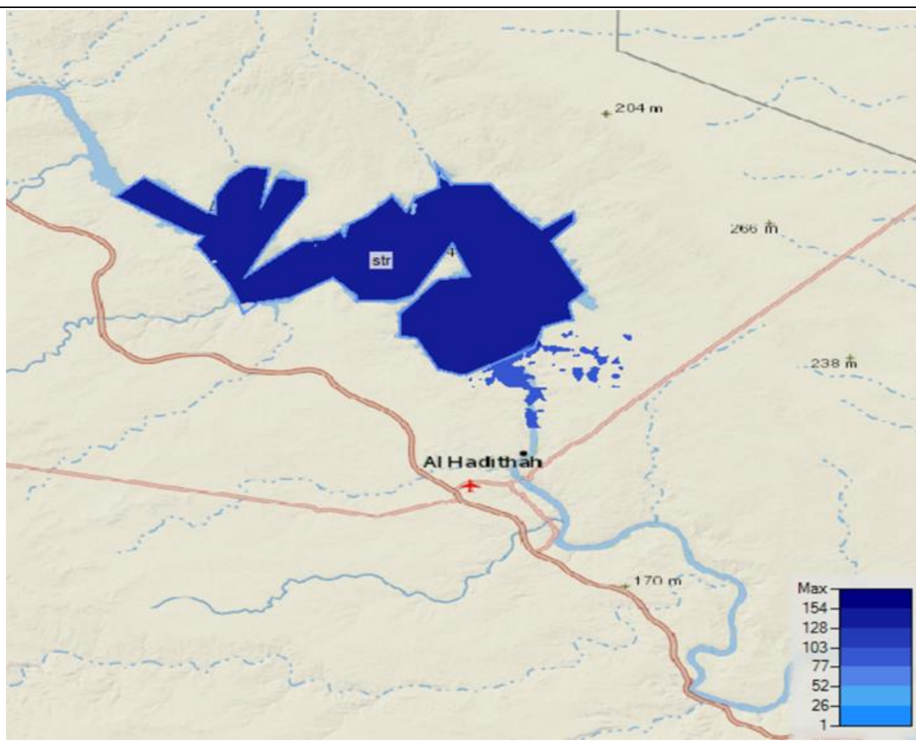

Figure 4.10: Flood wave after dam breach (time = 30 hours)

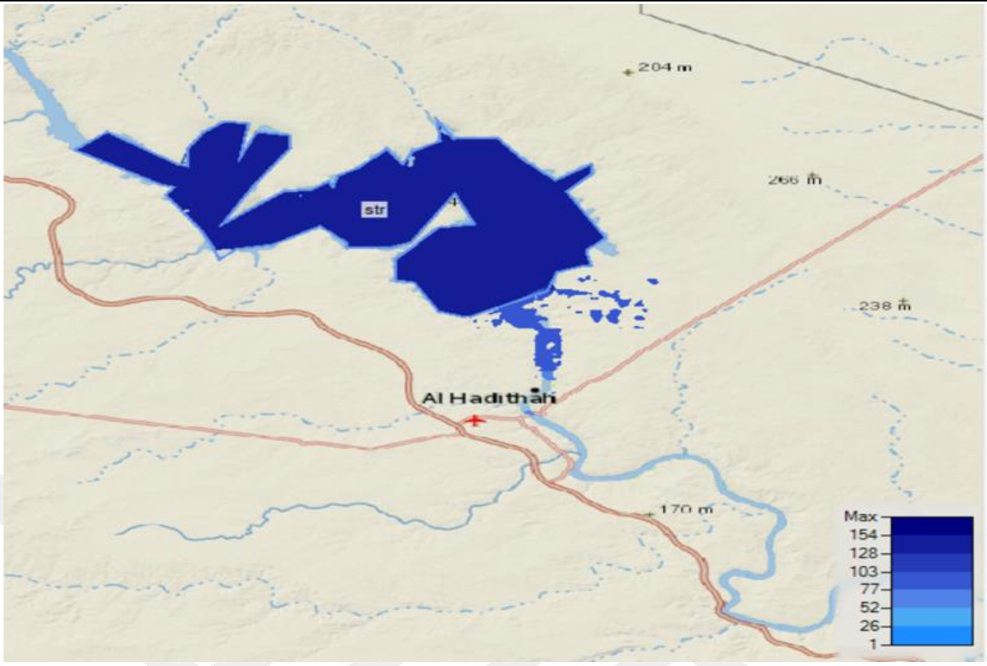

Figure 4.11: Flood wave after dam breach (time = 40 hours)

As found in HEC RAS simulation, The spatial increment of the wavelength move distances of 3.8, 5.1, 11.3 and 15.4 km after 10, 20, 30, and 40 hours of initial dam overtopping case.

4.3 MODEL EVALUATING

The applicable model that can be used in the management of the water capacity of Haditha dam can be based on the water quantity balance equation.

By assuming the variables as x1,x2,x3,….and so on, the equation can be written as the following:

$$x1 - x2 + (x3 - x4)\ A = x5 \qquad (4.1)$$

where:

x1 = inflow rate (cubic meter per second)

x2 = outflow rate (cubic meter per second)

x3 and x4 referred to the rainfall intensity and the evaporation (in mm) respectively

x5 = the current storage rate

A = area of reservoir

EL = Elevation (a. s. l.) (above sea level)

The equation that represented the surface area of water in storage zone between two elevations is:

A= 148.3 El – 21291   for elevation from 147 to 150

A= 45.876 EL – 6074.1   for 150 < El <154

As result for the modeling, the value of best outflow rate that used for the downstream can be considered when the water elevation reaches any elevation above the normal elevation. By adopting EL1= 147 m as normal elevation, the data that been calculated from the equations above were included tables 4.4, 4.5 and 4.6and also the figures:

Table 4.4: Maximum Predicted monthly outflow (January to April) with respect to current elevation

Elevations (m)	January (m3/sec)	February (m3/sec)	March (m3/sec)	April (m3/sec)
147.5	678.7	664.3	466.4	272.4
148	679.0	664.6	466.0	270.9
148.5	679.2	664.8	465.6	269.5
149	679.5	665.1	465.2	268.0
149.5	679.8	665.3	464.8	266.6
150	680.1	665.5	464.5	265.1
150.5	680.3	665.7	464.2	264.1
151	680.4	665.8	464.1	263.6
151.5	680.5	665.9	463.9	263.2
152	680.5	665.9	463.8	262.8
152.5	680.6	666.0	463.7	262.4
153	680.7	666.1	463.6	262.0
153.5	680.8	666.2	463.5	261.5
154	680.9	666.2	463.4	261.1

Table 4.5: Predicted monthly outflow (May to August) with**(m3/sec)** respect to current elevation

Elevations (m)	May (m3/sec)	June (m3/sec)	July (m3/sec)	August (m3/sec)
147.5	409.0	336.1	452.2	642.4
148	405.9	331.3	446.2	637.4
148.5	402.7	326.6	440.3	632.3
149	399.5	321.8	434.3	627.3
149.5	396.3	317.0	428.4	622.2
150	393.1	312.2	422.5	617.2
150.5	390.8	308.8	418.1	613.5
151	389.9	307.4	416.4	612.0
151.5	388.9	306.0	414.7	610.5
152	388.0	304.6	412.9	609.0
152.5	387.1	303.2	411.2	607.6
153	386.1	301.8	409.5	606.1
153.5	385.2	300.4	407.7	604.6
154	384.3	299.0	406.0	603.1

Table 4.6: Predicted monthly outflow (September to December) with respect to current elevation

Elevations (m)	September (m3/sec)	October (m3/sec)	November (m3/sec)	December(m3/sec)
147.5	452.5	280.7	401.6	484.8
148	449.5	279.2	401.4	485.0
148.5	446.4	277.7	401.3	485.2
149	443.4	276.2	401.1	485.4
149.5	440.4	274.7	401.0	485.6
150	437.3	273.1	400.8	485.8
150.5	435.1	272.0	400.7	486.0
151	434.2	271.6	400.7	486.0
151.5	433.3	271.2	400.6	486.1
152	432.5	270.7	400.6	486.1
152.5	431.6	270.3	400.5	486.2
153	430.7	269.8	400.5	486.3
153.5	429.8	269.4	400.4	486.3
154	428.9	268.9	400.4	486.4

According to the data in tables 4.4, 4.5, and 4.6, the figures from 4.12 to 4.23 showed the predicted outflow that must obtained from the dam to control the increment of the storage according to the continues inflow from the feeding river and the resultant of the rainfall intensity and the evaporation rate that based on the period time in the year and weather conditions

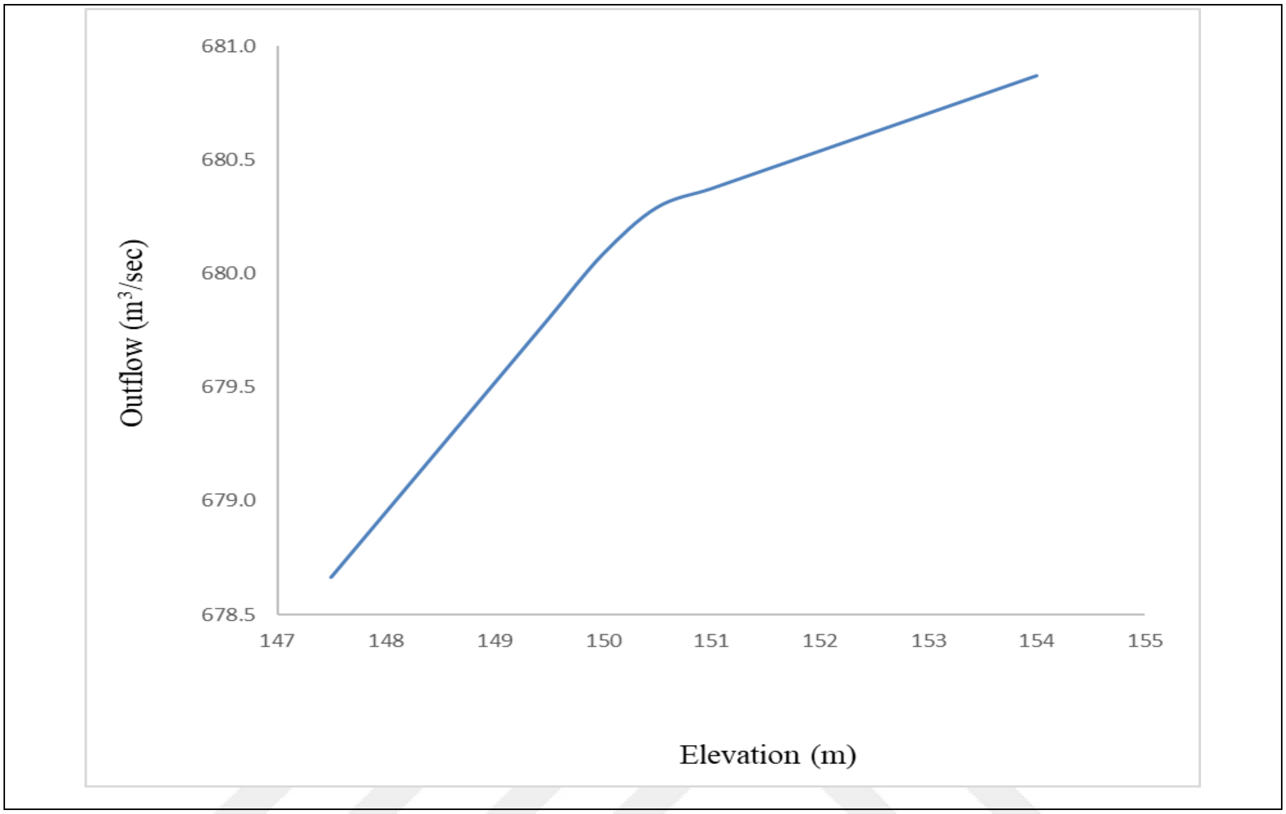

Figure 4.12: Outflow with reservoir water elevation (January)

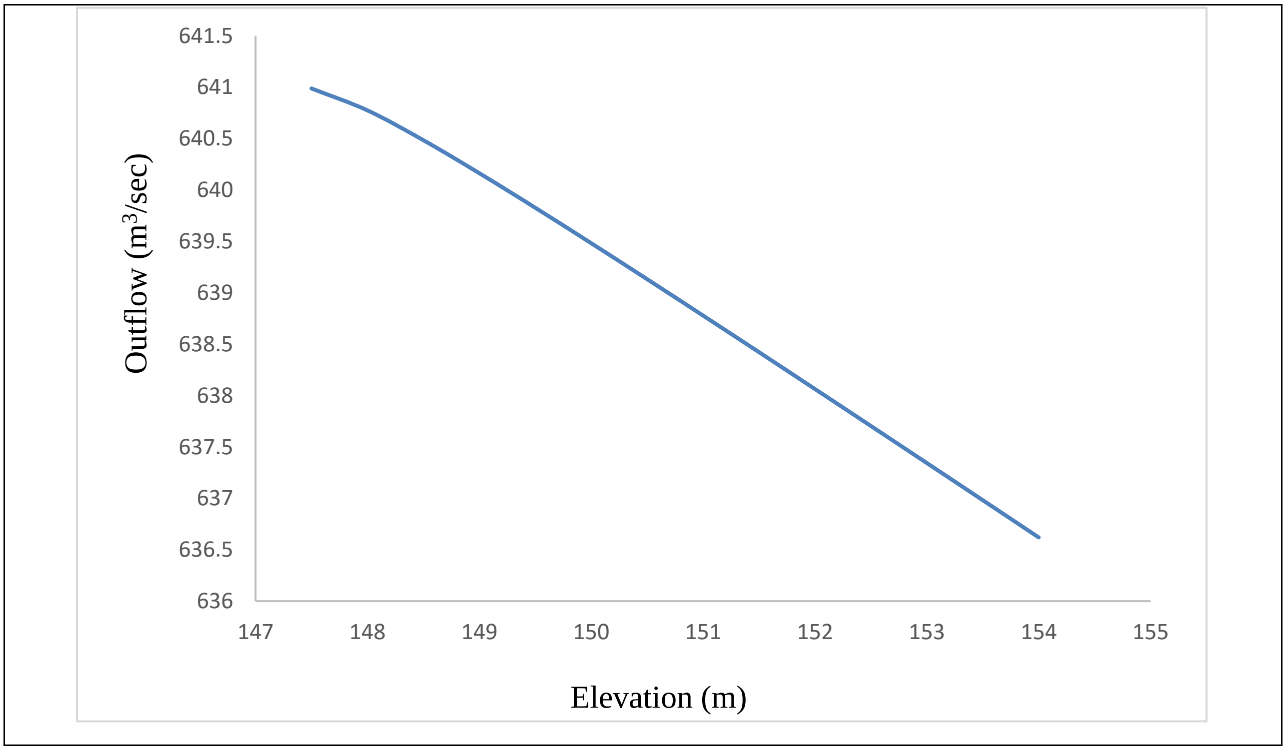

Figure 4.13: Outflow with reservoir water elevation (February)

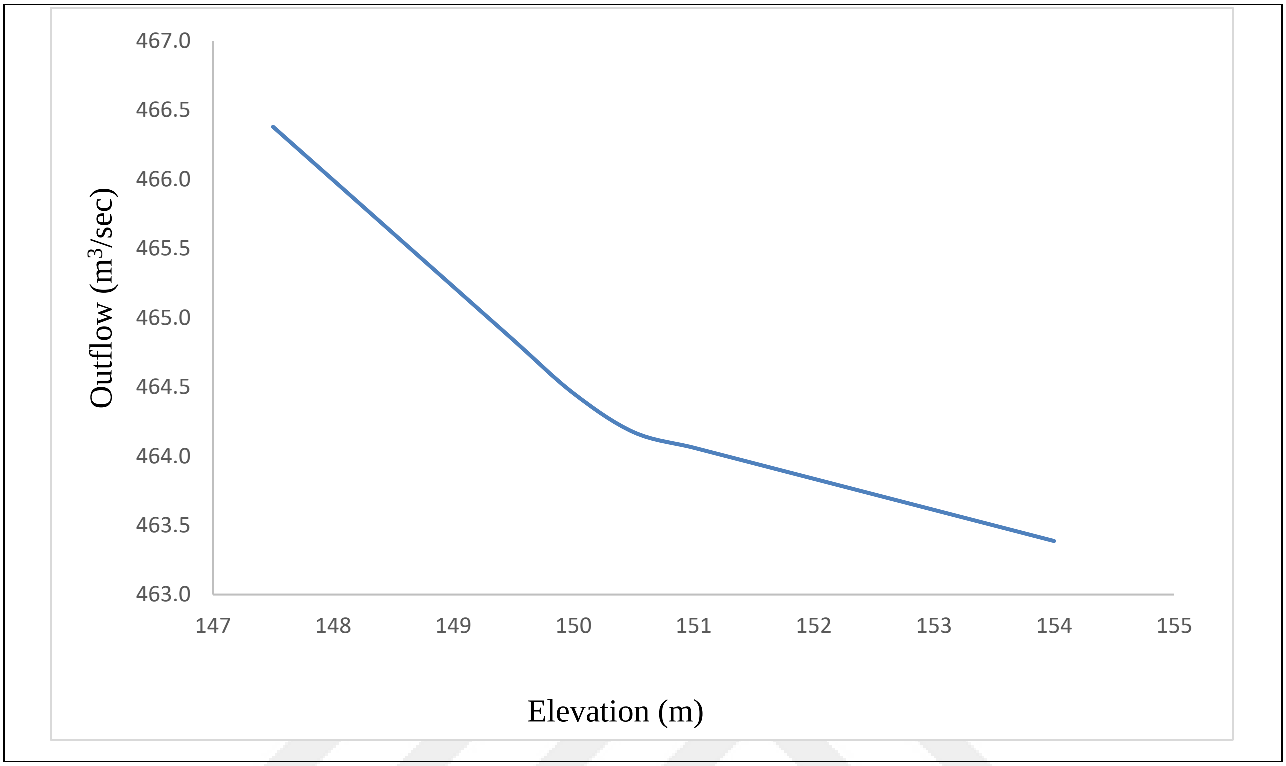

Figure 4.14: Outflow with reservoir water elevation (March)

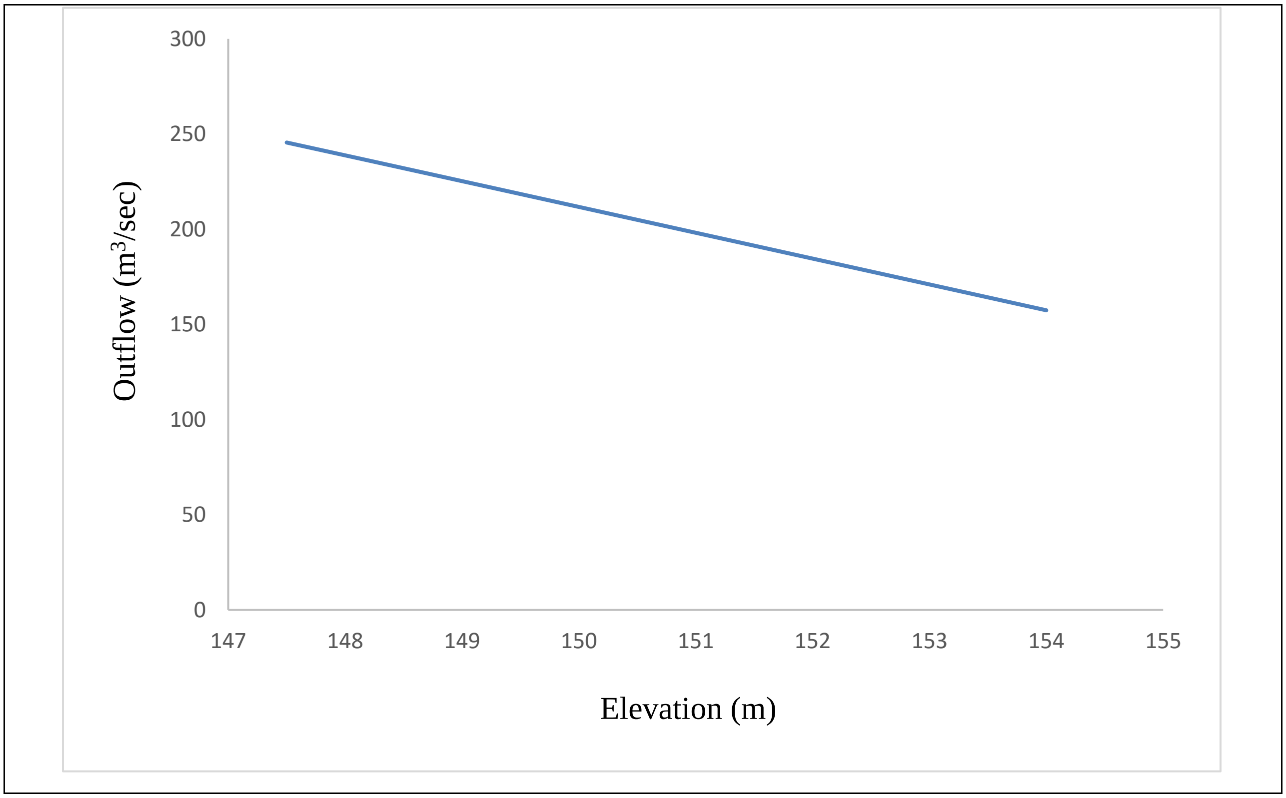

Figure 4.15: Outflow with reservoir water elevation (April)

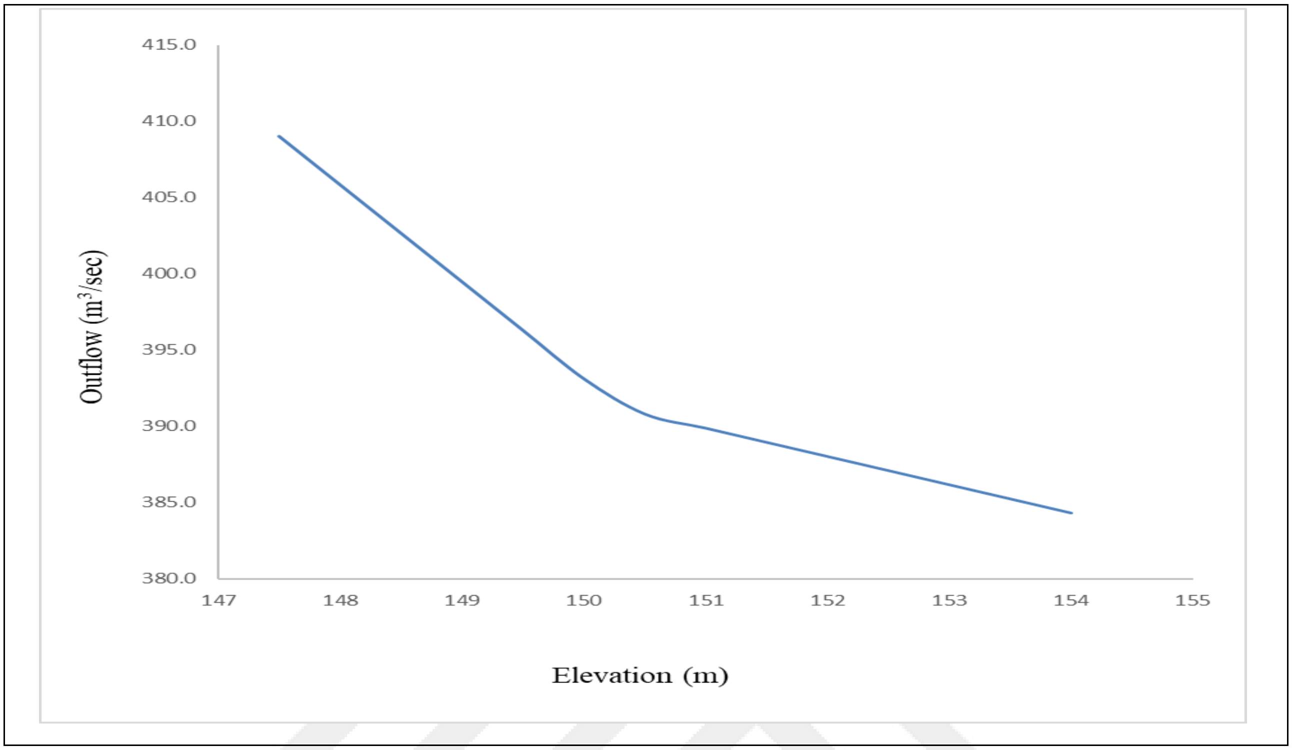

Figure 4.16: Outflow with reservoir water elevation (May)

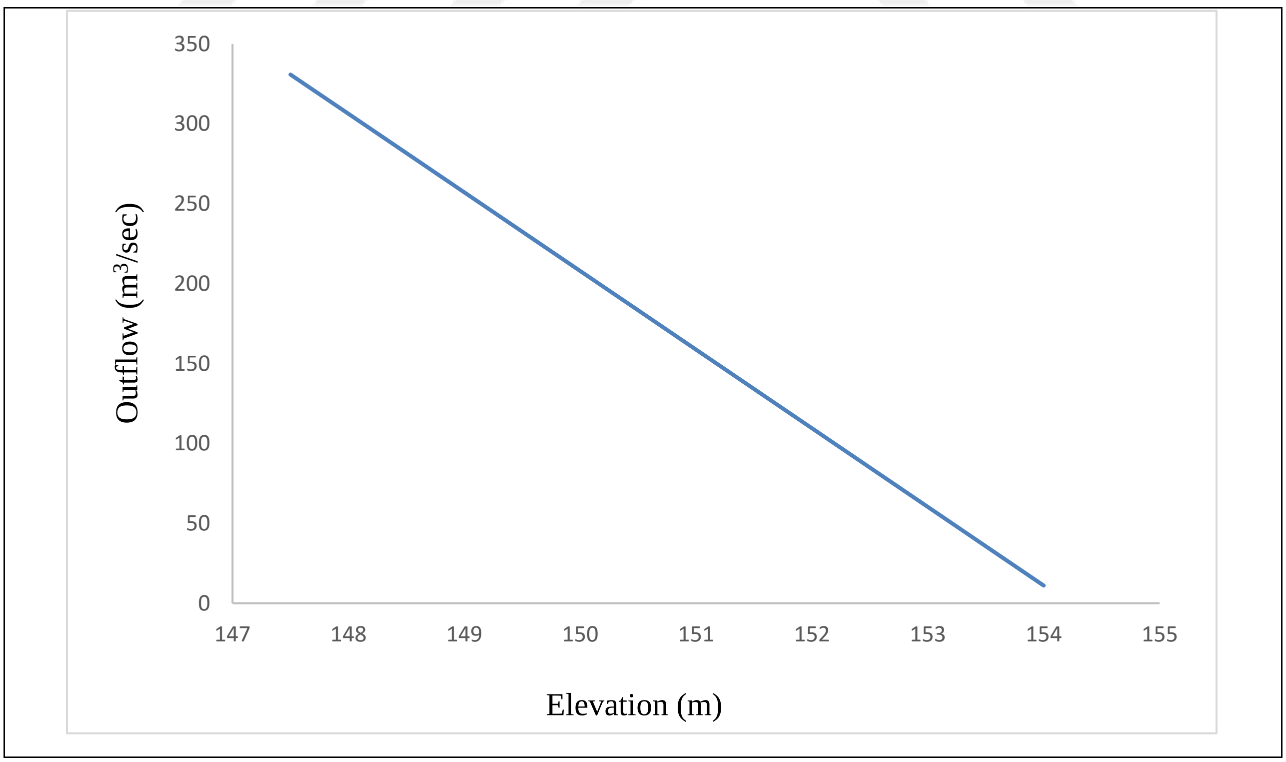

Figure 4.17: Outflow with reservoir water elevation (June)

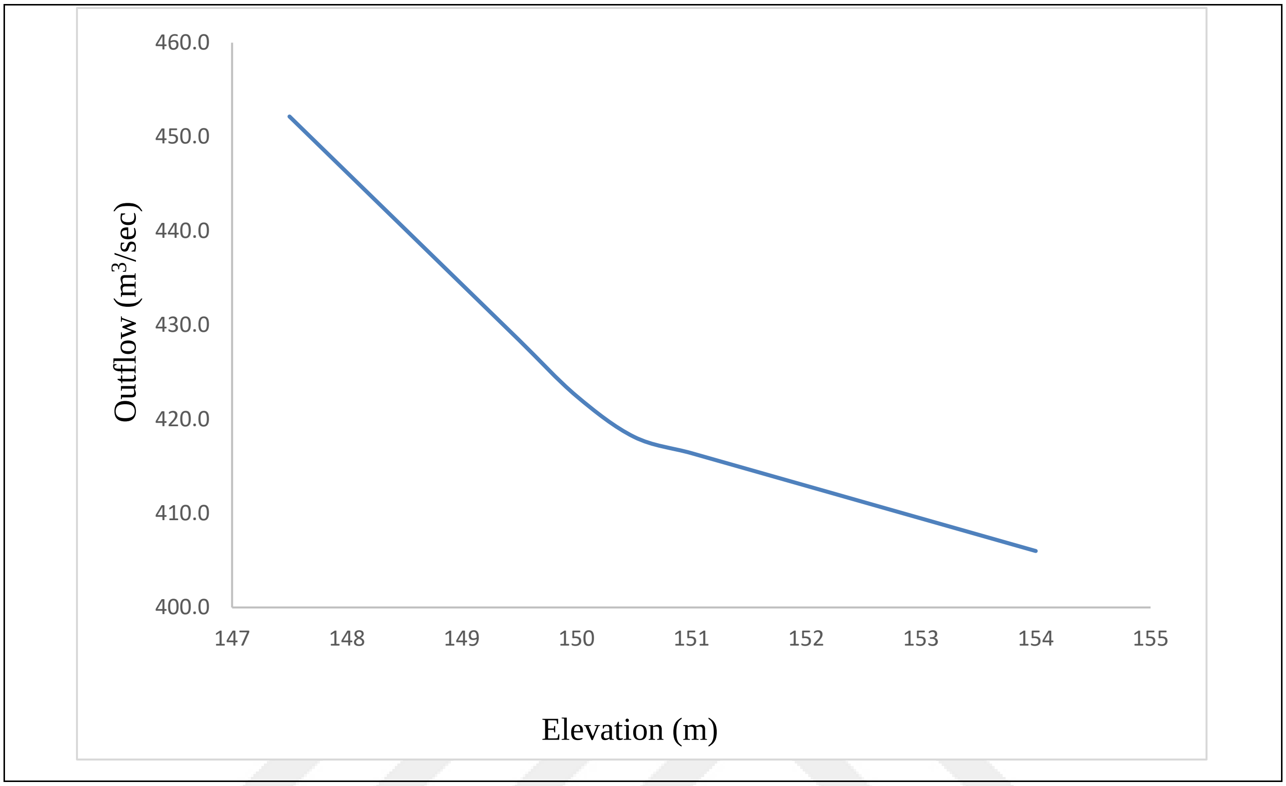

Figure 4.18: Outflow with reservoir water elevation (July)

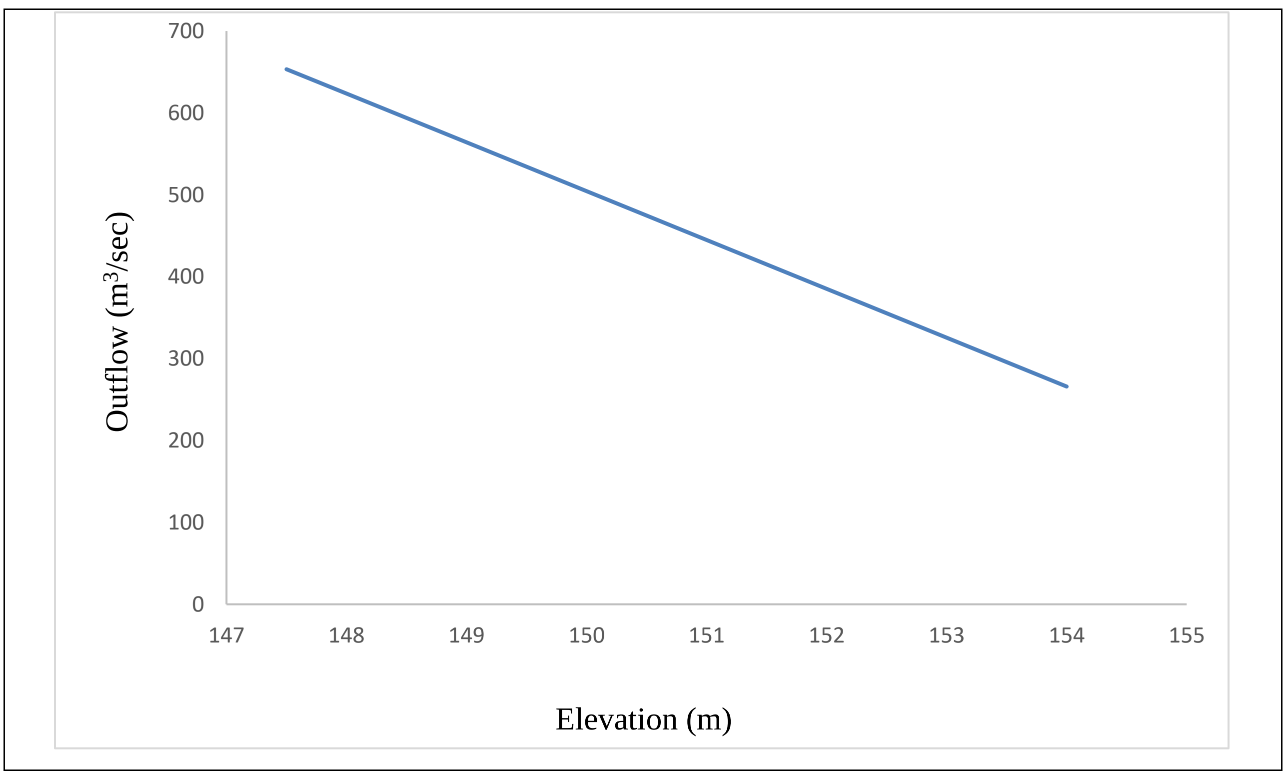

Figure 4.19: Outflow with reservoir water elevation (August)

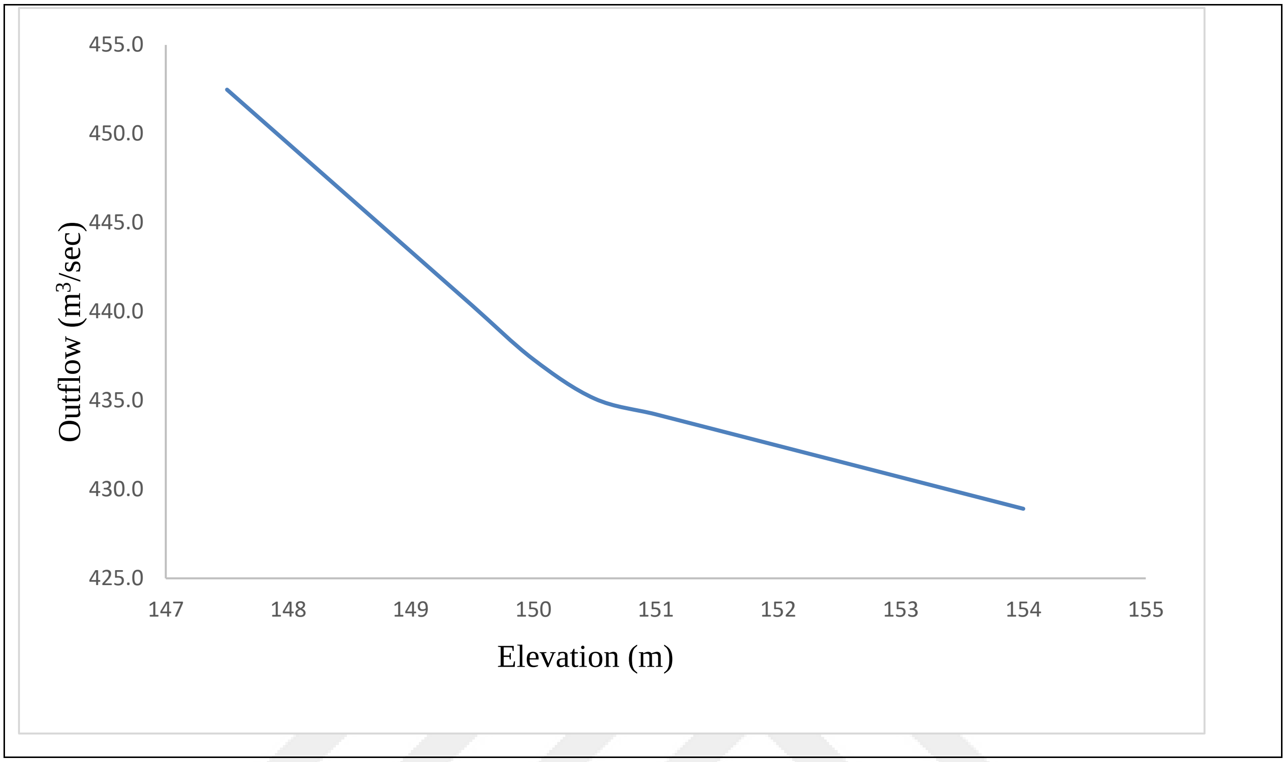

Figure 4.20: Outflow with reservoir water elevation (September)

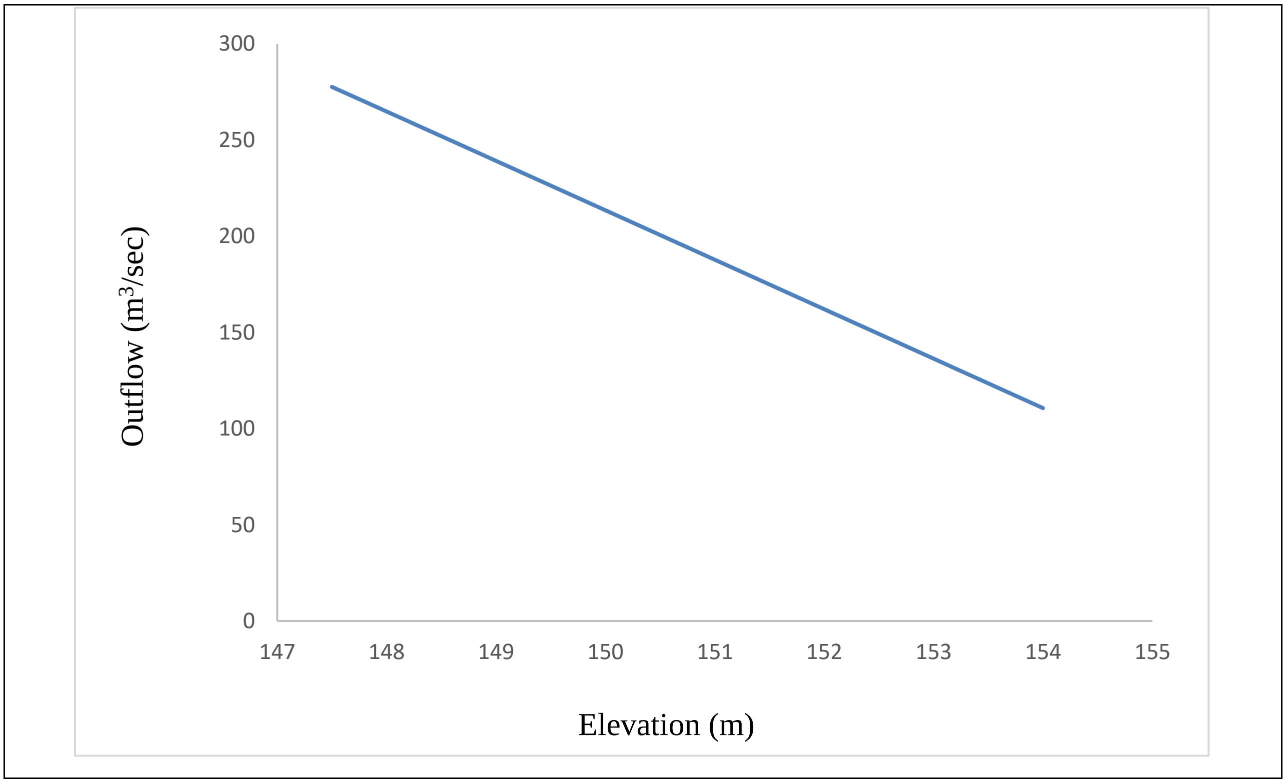

Figure 4.21: Outflow with reservoir water elevation (October)

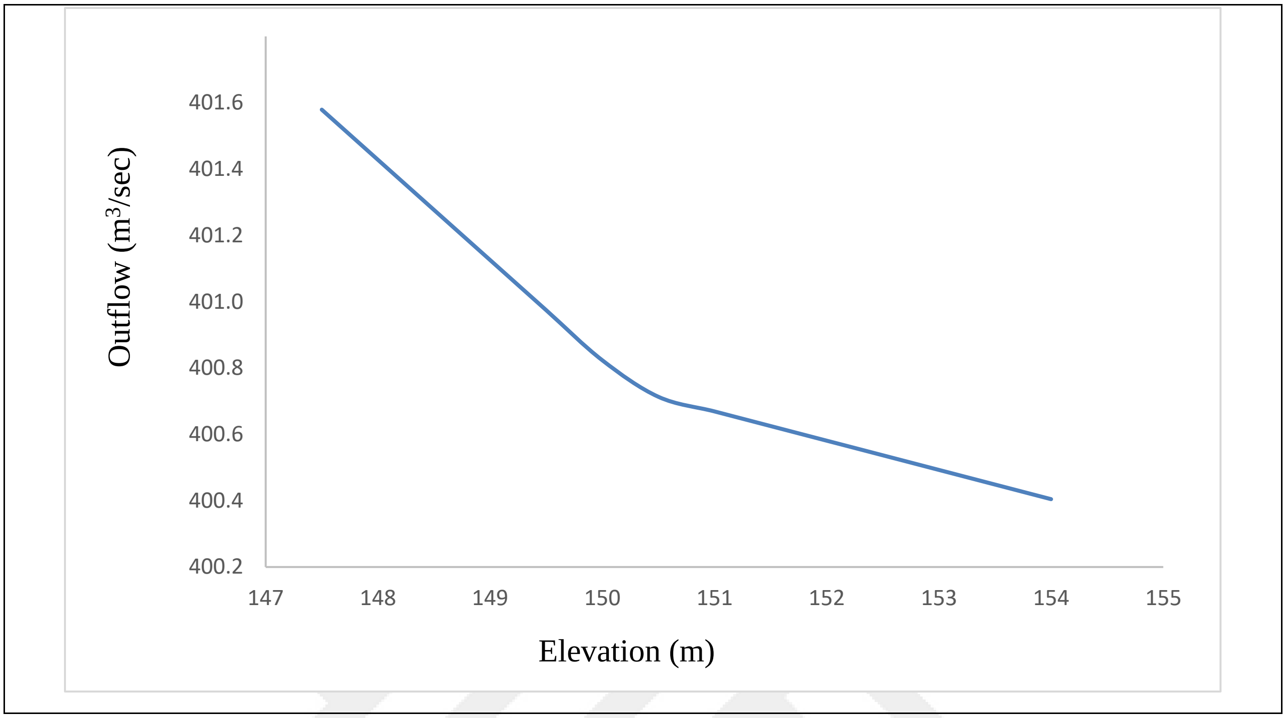

Figure 4.22: Outflow with reservoir water elevation (November)

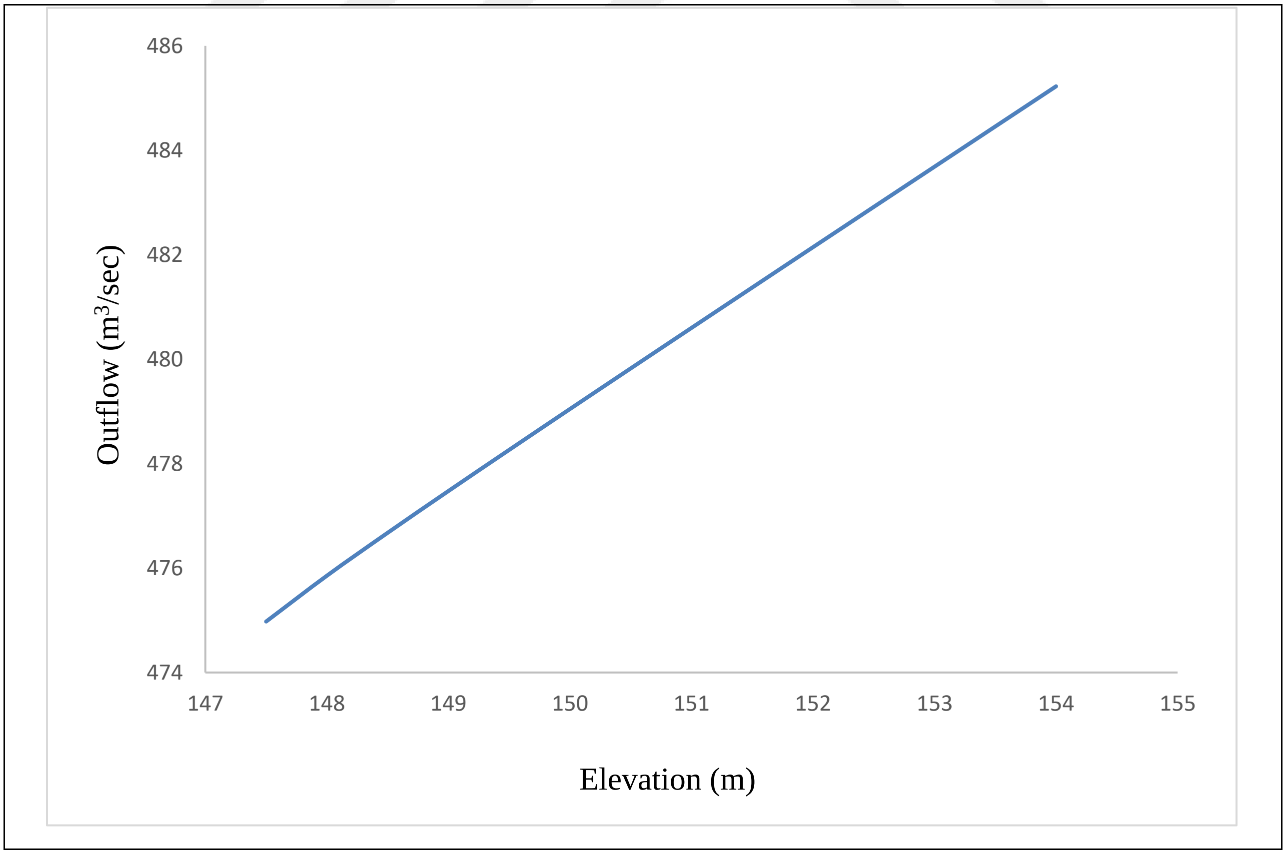

Figure 4.23: Outflow with reservoir water elevation (December)

5. CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

The conditions that relating for better controlling of Haditha Dam by analysis the upstream and downstream regions were investigated. The data that obtained were arranged and processed in the way of reaching the outline of the research pathway. The data include the topographic behavior of the upstream and downstream areas and also the amounts of monthly inflow toward the catchment area behind Haditha Dam. Both of the effect of rainfall and evaporation along the year were included in the study. the change in the amounts of water storage was evaluated along the year. The highest change in the reservoir quantity of water was detected in the beginning and in the second part of the operation year. The data then moved toward the analysis of the outflow that can been adopted for better controlling the operation of the dam without any chance of flood. The normal water elevation in the catchment area was considered as 147 m.s.l. The study examined the increment in available volume of the catchment area with respect to the contour lines behind the dam. The calculation of the volume and the surface area were implemented from the elevation of 147 m to the elevation of the dam crest (154 m). Regression correlation was built inside the study for calculating the available surface area with respect to the elevations (147 to 154) m. By using the water balance equation with the calculated and gathered data, the time needed for water to reach specific elevation was evaluated. The January month gave the shorter time of 10.7 hr for the water level to be raise up from the elevation of 147 m to the elevation of 154 m. these values of times were considered by the study as important tool for dealing with the matter of avoiding the risk of the flood that cause by overtopping. The flood simulation was built by using HEC RAS software in which the wave length of flood was appeared with about 15.4 km after 40 hours from overtopping to be occurred. The final results of the study were the graphs for monthly controlling the outflow after the dam with respect to the current water level. The water level by this graphs can obtained as important parameters to get the desired outflow after the dam without more raising of water level. The January month showed the more critical situation in which high amounts of outflow must be move out for preserving the catchment area with sufficient water and for conserving the downstream area from flood risk

5.2 FUTURE WORK

a) The studying of the flood conditions of other dams like Mosul dam in north of Iraq can be important topic for future work. The dam failure and its risk is main subject to be analyzed for keeping human life and the hydrological sources in safe side.

b) The future work can also cover the subjects of the effective flow of Tigris and Euphrates Rivers in the way of better using these amount of water for different sector like agriculture and industry. The amounts of water storage in Iraq ad how these important infrastructure can be conserved is significance topic to be deal with for assigning better controlling of these amounts in the way of enhancing the public economy. The matter of water pollutions and how the dams can be used as effective procedure to eliminate the contaminant loading especially in the water storage area as these zones can give important positive action in the ecological system.

c) The upcoming study can move more than that by analysis in statistical techniques the time needed for water level to up more height according to the monthly conditions. These types of studies can be adopted in the operating of the dam for better elimination of flood status.

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