HYDRAULIC MEASURES

FOR UNEXPECTED FLOOD CONTROL

(CASE STUDY: KESEM RIVER)

BY

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DEDICATION

*This study is dedicated to my mother **Belaynesh Melaku** and my teenage brother **Tsega Chane** with health.*

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ABSTRACT

Hydraulic Measures for Unexpected Flood Control

By: Melese Chanie

Any hydraulic structure constructed across a river is designed based on a prior estimation of design flood. This design flood estimation needs a hydrologic parameter estimation through the entire catchment area and along the river course. Such parameters have never been estimated accurately. Moreover, the design discharge estimated will be exceeded due to climate change, uncertainty of design flood estimation methods, hydrologic data constraint and the like. Thus, the design flood estimated for the design of a hydraulic structure across a river has a high probability of being exceeded. A measure that should contain any unexpected flood, a flood beyond the design flood, should be devised.

In this study, a hydraulic measure that utilizes river channel characters modification for containing the unexpected flood is practiced by taking 5.4km length of *Kesem River* which is found upstream of *Kesem Kebena Dam* as a case study. The study would improve the river flood storage character and reduce the unexpected flood that will come to the reservoir by changing the river channel character upstream before joining to the reservoir. In addition to this, there were also a number of channel character combination modifications to select the best combined river channel character improvement measures. Some of them were minimum slope and maximum roughness coefficient, average slope and maximum roughness coefficient, minimum slope and average roughness coefficient.

Based on the result of the study, the minimum slope and maximum roughness coefficient and average slope and maximum roughness coefficient combination modifications have good flood storage result among the channel character modification combinations and these two measures have relatively similar flood magnitude reductions. The maximum flood that could be reduced through the implementation of these combined measures for 10,000 return period design flood of $9237m^3/s$ was 0.38% and for the 100 years return period design flood of $3765m^3/s$ was 0.53%.

Therefore, for an effective and sustainable flood controlling measures for unexpected flood on a hydraulic structure, the need for reliable hydraulic measures are unquestionable.

Key Words: Hydraulic measures, distributed flow, saint venant equation, unexpected flood, Kesem River, reaches, nodes, roughness coefficient and slope, Kesem Kebena Dam.

ABBREVIATIONS

a.m.s.l	above mean sea level
E	East
FDPPA	Federal Disaster Prevention and Preparedness Commission
FEMA	Federal Emergency Management Agency
GIS	Geophysical Information System
MoWIR	Ministry of Water, Irrigation and Energy
n	Roughness coefficient
N	North
NYSDPC	New York State Disaster Preparedness Commission
OCHA	Office for the Coordination of Humanitarian Affairs
S	Slope of the river
UNDP	United Nation Development Program
USACR	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
WWDSE	Water Works Deign Supervision Enterprise

1. INTRODUCTION

1.1 Background

Floods are a sudden increase in the volume and/or velocity of a body of water, causing over flow or breaching of natural or manmade confines, which drowns or covers land areas that are usually dry [1]. Floods are known as the most frequent and destructive natural disasters in both developed and developing countries from the ancient up to now [1]. Being one of the largest and developing countries in East Africa, Ethiopia's topography characteristics has made the country pretty vulnerable to floods and resulting destruction and damage to: life, economic, and infrastructure system [1].

The maximum flood that any structure can safely pass is called the ‗design or expected flood' and is prioritized after making a cost-benefit analysis by exercising engineering judgment and consideration of hydrologic factors [2]. However, there might be a situation at which the amount of flood that estimated to be occurred becomes more than the expected flood throughout the life span of a hydraulic project due to climate change, uncertainty of design flood estimation methods, hydrologic data constraint and economic investment and this kind of flood is known as unexpected flood [3].

The flood i.e. either expected or unexpected flood, can basically be managed by two ways of hydraulic measures. These include structural and non-structural hydraulic measures [4]. Hydraulic measures are practically applicable flood controlling methods that are exercised in different flood plain project areas especially with places vulnerable to floods [2].

Now a day a number of irrigation, hydropower and water supply projects have been constructed throughout Ethiopia in a giant amount of budget both in federal and regional level. From those projects, most of them are constructed from earthen materials and they are vulnerable to floods. Moreover, these kinds of earthen structures are very critical in their full service delivery time [2]. Hence, the main and the first thing that should be carried out during the design of these hydraulic structures is that determining the probabilistic estimation of a flood having a specific magnitude that will be equaled or exceeded with a given frequency [2].

Among the origins for the occurrence of unexpected flood that mentioned before, climate change is a major development challenge to Ethiopia [5] and due to this the uncertainties in hydrologic design for hydraulic structures will increase. Then the hydrologists should take-into account the risks that will come because of this climate change when they design hydraulic structures which are vulnerable to floods. As the researcher has previously observed in *Kesem Kebena Dam and Irrigation Project,* there was a situation of Coffer dam failure due to unexpected flood. Hence, in the design of hydraulic structures specially which are vulnerable to floods hydrologic considerations alone will lead to uneconomic way and great uncertainties [4].

Then, hydraulic measures are the one options to reduce the failure of hydraulic structures due to unexpected floods during its life span. Therefore, these hydraulic measures have been used to reduce the occurrence of unexpected floods on hydraulic structures by taking measures during the flood event [2].

1.2 Relevance of the Study

This study was set out to show the unexpected flood controlling measures which will be helpful for the region that are aimed at reducing flood situations for structures in *Kesem River*. The result of this study can be used as an input for unexpected flood controlling considerations of various water development projects (irrigation, hydropower, water supply etc.) within the *Awash River* particularly for *Kesem River.* In addition to this, *Awash River* has a large irrigation potential and there is a need for flood controlling measures for the achievement of these planned irrigation projects in the area. For such important development activities to be realized, there is a need to have adequate flood controlling measures in the river. The result will help to control hydraulic structures from unexpected flood which are found in similar condition within the case study area.

1.3 Statement of the Problem

In the last decades, a number of hydraulic structures either concrete or earthen have been constructed in Ethiopia to be used for irrigation, water supply and hydropower purposes. It is known that most of them were designed under inadequate hydrological data condition. Thus their creek flows were not gauged. The reservoirs of these structures failed to deliver the design yields due to sediments, overtopping and failure-stability problems. The problem is by now even become worse due to unexpected flooding that arise from climate change in *Kesem River*. This is due to the absence of unexpected flood control measures upstream of the river. To solve this problem identifying the prioritized hyraulic measures from the preferred controlling measure is the best way.

The detail research questions are as follows:

1. How could control a hydraulic structure from unexpected flood?
2. What are the main causes of unexpected floods?
3. How could select the best among different hydraulic measures for unexpected flood control?
4. How much amount of floods percentage can be reduced using the prioritized hydraulic flood controlling measures?
5. Which model is preferable for routing the design flood throughout the prioritized river?

1.4 Objective of the Study

1.4.1 General Objective

The main objective of this study is finding the suitable prioritized hydraulic measure(s) for controlling unexpected flood of a hydraulic structure.

1.4.2 Specific Objectives

The specific objectives of this study are to:

- look for solutions that will help in reducing failures of hydraulic structures due to unexpected flood conditions.
- prioritize and propose hydraulic measures for controlling unexpected flood before, during and after construction of hydraulic structures
- determine the amount of flood percentage that can reduce by exercising the prioritized hydraulic measures.
- show hydraulic measures are the other solutions for controlling unexpected flood conditions and best economic design of hydraulic structures.

1.5 Scope of the Study

This research paper focuses on the prioritized hydraulic measure(s) for controlling unexpected flood for the case of *Kesem River* which is found upstream of *Kesem Kebena Dam*. Particularly the research would be conducted on some prioritized hydraulic measures because, it is not possible to deal with all measures for this research purpose. As it is mentioned before; the research site is *Kesem Kebena Dam of Kesem River* and the prioritized controlling measure would be applied 5.4km distance upstream of the point at which the reservoir back water at its full supply level.

1.6 Hypothesis

The consideration of structural and non structural hydraulic measures in the design of hydraulic structures will help to prevent the failures of these structures from unexpected flood. Therefore, the use of structural and non structural hydraulic measures will help to prevent the failures of hydraulic structures specially which are vulnerable to floods in addition to hydrological measures and design considerations alone.

1.7 Description of the Study Area

Ethiopia is located in the eastern part of Africa between 3º3′ and 18º12′N latitudes and 32º42′ and 48º12′E longitudes. The country has great geographical, topographical and climatological diversity: from high rugged mountains to deep gorges; from lowest altitude at about 120m below sea level to highest altitude of 4600m above sea level; from 2000mm high annual rainfall to 200mm of low annual rainfall. Besides, the *Great Rift Valley* divides the country in two parts forming the eastern and western high lands [6]. The country is endowed with large amount of water resource potential. It has 12 major drainage basins as shown in table 1.1 [6].

Table 1.1 : Major Drainage Basins of Ethiopia

No.	Basins	Locations	Area (km^2)	Area coverage (%)
1	Abay Basin	North West	192,953.00	17.11
1	Awash Basin	Central East	113,604.00	10.07
2	Aysha Basin	Extreme East	4,717.00	0.42
3	Baro Akobo Basin	West	73,958.00	6.56
5	Denakel Basin	North	66,489.00	5.90
6	Genale Dawa Basin	South	172,681.00	15.31
7	Mereb Basin	Extreme North	6,065.00	0.54
8	Ogaden Basin	East	82,157.00	7.29
9	Omo Gibe Basin	South West	74,912.00	6.64
10	Rift Valley Lakes	Central West	51,664.00	4.58
11	Tekeze Basin	North	81,034.00	7.19
12	Wabi Shebele Basin	South East	207,497.00	18.40
		Total	1,127,731.00	100.00

However, the research concentrates only on *Kesem River*, which is part of the *Awash Basin*, particularly on the upstream of *Kesem Kebena Dam*.

Figure 1:1 Location of Kesem River

The Kesem River is a tributary of the Awash River in Ethiopia. The Kesem is not a navigable stream, and flows with a great volume during the rainy season. It rises west of Kese Koremash, flowing east to the Awash, its course delineating a few kilometers of the northern boundary of the Awash National Park. The lower course defines the northern boundary of the Shewan district of Menjar. The *Kesem* catchment upstream of the dam site has different topographical, climatological and land use condition.

1.7.1 Topography

The *Kesem River* catchment to dam site covers about 3000km^2 and extends from an altitude of almost 3600m to 860m elevation. It rises on the high Ethiopian plateau and descends the western scrap of the *Great Rift Valley* to join the *Awash River*. The most prominent feature of the *Kesem Valley* is the steepness of slopes linking the plateau of the north, west and south extremities of the catchment with the gorges of the central area. The channels of the *Upper Kesem*, being narrow and highly sinuous, feature in fine sediments. They cascade into narrow, flat-floored trenches where they braid amongst the boulder and cobble bed materials. For a large part of the central *Kesem Catchment* the valley floor broadens, up to half a kilometer wide. Often, in the upper parts of this section, traditional irrigated agriculture interposes between the channels and side slopes. For the final section of its course, the character of the catchment changes once more as it becomes constrained in narrow gorges and canyons, interrupted at irregular intervals by wider reaches which have become depositional areas for course fluvial sediments.

1.7.2 Climate

The area experience a typically tropical semi-arid climate with rainfall normally in the range 350mm to 600mm. Temperature varies from mean minima of 15ºc and 21ºc to mean maxima of 23ºc and 38ºc in December and June respectively; frost is unknown. Mean relative humidity are lowest in July 36% and highest in August 58%. Mean daily sunshine reported on an annual basis is 8.5hr.

The overall pattern of rainfall approximately 60% of the annual total falling as the main rains between July and September. There is, however, another minor and reliable period of rainfall peaking sometimes during the period March to May, these short rains account for a further 25% of the annual total.

Rainfall in the basin increases three fold with the rise in altitude from the Awash basin into the highland plateau, though this increase is asymmetrical, the north of the basin being much wetter. To the south only the high plateau area has extensive agriculture which, looks like the other plateau, consists of a mosaic of cultivated plots. The lower parts of the basin are too dry to settled agriculture.

1.7.3 Land Use and Land Cover

The land use condition in *Awash* catchments upstream of *Kesem* includes mainly of cultivated agricultural land, grass land, forest land, rural and urban settlements. In the upper most part where there is high rainfall, land use is complete in May with barley and teff. On the lower most part, however, rainfall is too unreliable and the sparse dry acacia scrub gives way to wide stretches of bare ground. The most common soil types are clay, sand, clay-loam, silt-clay-loam, sand-clay, silt-clay [7]. Land use and soil type have a direct impact on the flood amount, speed and potential to create damage that is why the study gives attention for land use and land cover of the sub basin.

1.8 Outline of the Research

The thesis is organized into five chapters from introduction to the conclusion and recommendation.

The first and the second chapters deals with introduction, study of the problem, scope of the study, the objective of the research, the description of the study area; and the literature review and state of art related to hydraulic flood controlling measures for unexpected flood condition.

The third and fourth chapters illustrates the methodology and procedure to be applied in the research, from data collection to the result of the analysis; and the result of the two combined channel character improvement prioritized hydraulic measures; this part of the thesis presents the result of the analysis and evaluates the result with different physical realities respectively.

The last chapter of the paper concentrates on the conclusion and recommendation of the thesis which concludes the study and recommends the possible solutions.

2. LITERATURE REVIEW

2.1 Expected and Unexpected Floods

Floods are a sudden increase in the volume and/or velocity of a body of water that occur at irregular interval anywhere in drainage system of river and streams [1]. They are unexpected and one cannot say where and when floods will strike, the prediction is difficult for flood [4].

Whenever an important structure is to be constructed in the vicinity of a river, it must be properly planned and designed keeping in view the damage to which it is susceptible and the catastrophic which it is going to create in the event of its failure. Hence, while designing any important hydraulic structures, provision must be made for the design flood that is likely to occur during the life time of that particular structure [4].

The maximum flood that any structure can safely pass is called the ‗expected flood' and is prioritized after making a cost-benefit analysis and exercising engineering judgment and consideration of hydrologic factors [2].

In the design of hydraulic structures there might be a situation at which the amount of flood to be occurred becomes more than the expected flood through the life span of a hydraulic project due to climate change, uncertainty of design flood estimation methods, hydrologic data constraint and economic investment and this kind of flood is known as unexpected flood [2].

When the structure is designed for a flood less than the maximum probable, there exists a certain amount of flood risk to the structure since it is not economical to design for 100% flood protection [2]. The happening of unexpected flood is one reason for occurrence of disasters. As the disaster's data indicate, flood is coming one of the unexpected and critical issues and conditions. According to the previous study shows 234 biggest disasters of the last 50-55 years; 90% of them are constituted of storms and floods, amounting to about 1.45 million deaths [5].

The reasons for damages occur due to floods are poor design flood estimation and failures occur due to heavy flood i.e. flood exceeds more than the design flood, in which the mass of water spilling over the dam wall erodes the structure and causes failure.

2.2 Causes of Unexpected Flood

The causes of unexpected floods are numerous. Even if the causes are depending on the type of flood which it may cause to occur, the main emphasis here is what critically causes of unexpected flood. As *N.Douben* described unexpected flood may occur because of climate change, uncertainty of design flood estimation methods, hydrologic data constraint and economic investment. Such floods should be observed while design hydraulic structures particularly structures which made from earthen material [8].

2.2.1 Climate Change

As dictated by *N.Douben*, in the nearby future flood risks are almost certainly affected by the emerging change in climate, which has been a focus of public attention specially because of some spectacular windstorm and flood catastrophes that have occurred recently. In some regions of the world the effects must be considered grave [8].

The occurrence of flood disasters in different regions of Ethiopia comes from climate change [9]. As eye evidence shows the 2013 summer flood which occurred around *Kemise* caused for the death of 24 people, causes unexpected flood that comes due to climate change. On 5 August 2006, torrential rains caused the *Dachatu River* to burst its banks causes serious flash flooding in the region of *Dire Dawa* comes from climate change. In the same manner on 16 August 2006, severe flooding in *Kurez District*, *South Omo* many people were killed and displaced due to flooding that came because of climate change [9].

2.2.2 Uncertainty of Design Flood Estimation Methods

The estimation of design floods is necessary for the design and to quantify the risk of failure of hydraulic structures [10]. Traditionally, flood frequency analysis has been used to assess the design discharge for hydraulic structures. Unfortunately, this method involves uncertainties, be they of random or epistemic nature. Despite some success in measuring uncertainty, e.g. by means of numerical simulations, exhaustive methods for their evaluation are still an open challenge to the scientific community [11].

2.2.3 Hydrologic Data Constraint

Extreme flood events have been and continue to be one of the most important natural hazards responsible for deaths and economic losses. Extreme floods result in direct destructive effects during the time of the event, and they may also be followed by a related chain of indirect calamities such as famines and epidemics that produce additional damages and suffering. Extreme hydrological events that have occurred in the historical past may also occur in the future. Knowledge about magnitudes and recurrence frequencies of past extreme hydrological events in most regions are too short to adequately evaluate potential magnitudes and recurrence frequencies of extreme hydrological events [12].

2.2.4 Economic Investment

The investment costs of the different assets in flood mitigations should be considered while design hydraulic structures which are vulnerable to floods. Most of the time, the budget available for new investments in flood protection may be neglected due to budget constraints and it has a great consequence for the coming impact of flood due to climate change and uncertainties in hydrologic conditions. Furthermore, the perceptions of stake holders in a country, e.g., civilians, government, water boards, etc., concerning living with uncertainties with respect to floods are still very much targeted at full protection; hence, aiming at the highest returns. This means in practice that strengthening investments for flood controlling measures is still the most preferred option to reduce the flood hazard in flood plain projects [13].

2.3 Flood Types

Flash Floods : A flash flood is a very direct response to rainfall with a very high intensity or sudden massive melting of snow. The area covered by water in a flash flood is relatively small compared to other types of floods. The amount of water that covers the land is usually not very large, but is so concentrated on a small area that it can raise very high. Because of the sudden onset and the high travelling speed of the water, flash floods can be very dangerous. The water can transport large objects like rocks, trees and cars. When a dyke breaks along the sea or along a river, the water may flow in so suddenly and with such speed that you could compare it with a flash flood

Coastal Floods : A coastal flood is when the coast is flooded by the sea. The cause of such a surge is a severe storm. The storm wind pushes the water up and creates high waves. A storm is formed in al low pressure area. An interesting fact is that beneath a low pressure area the sea level is higher.This contributes to the high sea level, but the wind can have a larger effect. A flood starts when waves move inland on an undefended coast or overtop or breach the coastal defence works like dunes and dikes. The waves attack the shore time and again. When it is a sandy coast, each wave in a storm will take sand away. Eventually a dune may collapse that way. Very characteristic of a coastal flood is that the water level drops and rises with the tide. At high tide the water may flow in and at low tide it may recede again. When a sea defence is breached, low tide is the time to repair the breach. In the animation you see the build-up of force by the sea and how the sea floods the coast. Once it overtops and

Urban Floods : Urban flooding is specific in the fact that the cause is a lack of drainage in an urban area. As there is little open soil that can be used for water storage nearly all the precipitation needs to be transport to surface water or the sewage system. High intensity rainfall can cause flooding when the city sewage system and draining canals do not have the necessary capacity to drain away the amounts of rain that are falling. Water may even enter the sewage system in one place and then get deposited somewhere else in the city on the streets. Urban floods are a great disturbance of daily life in the city. Roads can be blocked, people can't go to work or to schools. The economic damages are high but the number of casualties is usually very limited, because of the nature of the flood. The water slowly raises on the city streets. When the city is on flat terrain the flow speed is low and you can still see people driving through it. The water rises relatively slow and the water level usually does not reach life endangering heights.

River floods : Rainfall over an extended period and an extended area can cause major rivers to overflow their banks. The water can cover enormous areas. Downstream areas may be affected, even when they didn't receive much rain themselves. With large rivers the process is relatively slow. The rain water enters the river in many ways. Some rain will fall into the river directly, but that alone doesn't make the river rise high. A lot of rain water will run off the surface when the soil is saturated or hard. It will flow to small rivers that flow to larger rivers and these rivers flow into even larger rivers. In this way all the rain that fell in a large area (catchment area) comes together in this one very large river. When there is a lot of rain over a long period, it takes time for all the rainwater to reach the river.

While the water level slowly rises, officials can decide to evacuate people before the river overflows. The area that is flooded can be huge. Villages surrounded by large stretches of water were cattle would normally graze. Whole communities can become isolated from the rest of the world as roads are blocked and communications are down.

When a dike or a dam breaks and a lot of water is released suddenly, the speed of the water at the breach can be compared with the speed of a flash flood. As a larger area gets covered the speed will be reduced. The water spreads out as much as possible flowing to the lower lying areas before slowly rising. A breach is very dangerous for the people living close to it. The strength of the water may carry cars, trees and even houses away and cause loss of live.

Pluvial Floods : Pluvial is a type of flooding that can happen in relatively flat areas. Rain water falling in an area is normally stored in the ground, in canals or lakes, or is drained away, or pumped out. When more rainwater enters a water system than can be stored, or can leave the system, flooding occurs. In this case, rain is the source of the flood: not water coming from a river, but water on its way to the river. That's why it is also called "pluvial flood". Puddles and ponds develop on the land, canals are filled to brim and spill over; gradually a layer of water covers the land. It is like urban flooding, but without the sewage systems and in more rural areas. Because of the gradual character people have time to go indoors or leave the area. The layer of water is no more than centimeters or perhaps decimeters high and causes no immediate threat to people's life's. Depending on the economic activity and size of the area that is covered it may cause immense economic damage.

2.4 Hydraulic Flood Controlling Measures

The flood i.e. either expected or unexpected flood, can be managed basically by two ways, which includes structural and non-structural hydraulic measures [4].

2.4.1 Structural Hydraulic Measures

Structural measures includes physical measures which are confining the flow between high banks, river channel character improvement, diversion of a portion of the flood through flood ways, construction of flood attenuation of dams and improve the storage characteristics of the reservoir.

2.4.2 Non Structural Hydraulic Measures

These includes the introduction of enforcement of sensible land use practice and soil conservation on flood plains, promulgation of dam safety regulations, adaptation of flood warning system, legislative and regulatory measures for controlling land occupies, community educations and geo physical information system (GIS) which provides for making warning plans.

2.5 Appropriateness of Flood Controlling Measures

As described by Kirit and Trivedi there are a lot of flood controlling measures either structural or non structural, and the specific necessity of these measures can be known by observing and assessing previously produced scientific papers.

2.5.1 Confining the Flow between High Banks

These structural hydraulic measures contolls downstream area from flood by constructing flood banks upstream of the prone area. The construction of flood banks is extensively followed, since it is an economical, direct and immediate method. The effects of these measures on flood flow increases the rate of flood flow, water elevation, carrying capacity of the channel, scouring action and decrease the surface slope of stream above the levied section [2].

2.5.2 River Channel Character Improvement

River channel character improvement includes sloping, roughing, cutting, straightening or deepening and improving river training works [2]. Specially, channel modifications for flood and erosion control include clearing and snagging, realignment, channel enlargement, stream bank protection, and channel lining. Such modifications are used only when necessary to re-establish the stream channel, provide proper sediment transport, and/or to provide sufficient flood control [14].

Most of the time channel modification is undesirable and not advisable, but sometimes necessary for gravel extraction works, construction of flood banks, and diversion of streams, or channeling for flood and drainage control, because channel modifications often result in degradation of in situ habitat and detrimental downstream impacts such as increased water velocity, decreased stability and increased erosion potential. Therefore, channel modifications careful timing of works, provision of alternative habitat and creative use of alternative materials are required to mitigate or avoid these adverse effects [15]. Channel improvement increases the discharging capacity of the stream thereby decreasing the height and duration of the flood.

2.5.3 Diversion of a Portion of the Flood through Flood Ways

This is simply diverting the excess flood through by pass structures. Most of the time flood ways are appropriate for diversion of flood which will attack a road [2].

Darrien Sai and *Ron* concluded that flood by pass structures are used for controlling flood for roads which become prone for flood plain. As they exercised for the mitigation measures like flooding of huge roads, flood by pass is the best option by increasing the road height at some level according to the expected depth of flood and with constructing appropriate flood pass structure. This will help for prevention from re-route the road and minimize the reconstruction cost [16].

2.5.4 Improve the Storage Character of the Reservoir

The improvement of the storage characteristics of the reservoir at which the reservoir water being stored is the other means of reservoir water enlargement next to the rise of dam height [17].

2.5.5 Providing a Temporary Storage of the Peak Floods

These are flood water retarding structures and constructed upstream of the reservoir area. The purpose of a flood control reservoir is to temporarily store a portion of the flood so that the flood peaks are flattened out [2]. The reservoir may be ideally situated immediately upstream of the area to be protected and the water discharged in the channel downstream at its safe capacity (known from its stage-discharge curve). All the inflow into the reservoir in excess of the safe channel capacity is stored until the inflow drops below the channel capacity and the stored water is released to recover the storage capacity for the next flood.

2.5.6 Adopting Soil Conservation Measures

This is simply the management of land in the catchment area. This measure is non structural measures. As the structural measures, they also greatly useful for reducing the amount of flood that will occur in unexpected manner. As the name indicates, conservation by itself mean that taking protection and mitigation measures; and proper use of soil materials to increase the storage characteristic of the catchment area. It involves a variety of measures including strip cropping, conservation tillage, green belts, and terracing and grassed water ways. These measures are used to reduce erosion on farm lands, particularly raw croplands, and to reduce sediment loadings to the stream channels [2].

2.6 Acquired Design Flood of Kesem Kebena Dam

According to the hydrologic design report of *Kesem Kebena Dam* by WWDSE hydrologic design report (2006) –many studies have been carried out by different agencies since early 1960s with respect to the development of *Awash* basin including the *Kesem Kebena River*. Many studies did not cover hydrology in detail, and the data position available to these studies was also limited. However, the study *‘Kesem Irrigation Project Feasibility Study’* by Sir.M.Mac Donald and Partners limited (August 1987) forms a very relevant document. Hence, it has been reviewed more closely, in general, for all aspects having bearing on hydrological study, and in particular, the hydrological study it”.

2.6.1 Catchment Details

As like the other catchments *Kesem River* has its own catchment characteristic. The total drainage area of *Kesem River* upstream of proposed *Kesem Kebena Dam* is 3,135km^2 and the main stream river length up to dam axis is 230km. Since the drainage area of the river is large the amount of runoff that will be collected in this drainage catchment to be expected is very intemperance [6]. The stream slope characteristics of *Kesem River* catchment varies from very gentle (0.6%) to cliff slope (2.3%). The river catchment has four major sub catchments and called as *‗Germama’*, *‗Inkoy’*, *‗Bariya Yemotebet’* and *‗Shenkora’*.

2.6.2 Analyzed Kesem Catchment Rainfall Data

As the hydrologic design report shows data on rainfall were collected for 14 rain gauge stations. The data of *Sheno*, *Shola Gebeya*, *Balchi*, *Chefa Donsa* and *Alaltu* were studied more intensively as they fall within the *Kesem Kebena Dam* catchment [6].

Thus, except July, August and September as shown in table 2.1 [6], rainfall in other months is highly variable, stressing the need to provide adequate storage with season to season carry over in the reservoir.

Table 2.1 : Monthly Mean and Standard Deviations of Kesem Dam Catchment Rainfall

Month	Monthly Mean Rainfall (mm)	Monthly Standard Deviation
January	12.1	18.4
February	28.2	32.7
March	47.2	33.0
April	5.7	31.3
May	45.8	34.9

June	63.1	31.4
July	242.5	8.1
August	261.4	61.2
September	99.3	30.4
October	25.1	31.0
November	9.9	18.5
December	5.7	8.1

2.6.3 Analyzed Kesem River Flow Data

The rating curve updated for good flow months from July to September are defined by the following set of relationship.

1. For years 1983 to 1988; $Q = 50.886(H - 0.1)^{1.8078}$
2. For years 1989 to 2003; $Q = 24.536(H - 0.2)^{2.6565}$

Where Q is the discharge in m^3/s; and H is observed gauge in meters.

The historically observed and forecast flow series was for 41 years length (1963- 2003) with 3.6% gaps. The gap filling was more encouraging by linear bivariate modeling with catchment rainfall, than rainfall- runoff correlation with *Awash* flows as observed at Awash station.

2.6.4 Probable Maximum Floods Study

The triangular unit hydrographs derived by USBR method for upland catchment, lowland catchment and for the whole catchment had the peaks of 81, 44 and 73 m^3/s. The respective time bases were 10, 21 and 24 hours. The 1 day probable maximum precipitation value estimated was 266mm. After clock hour correction to convert from 1 day to 24 hour rainfall by 1.15, the value was 306mm. Then after applying point to aerial rainfall correction for *Kesem* size catchment, this value got reduced to 230mm on applying a correction factor of 0.75. For hourly incremental rainfall, a uniform loss rate of 1.9mm was adopted.

Table 2.2 : Design Flood Magnitudes Corresponding to Various Return Period

Return period (years)	Design flood (*m^3/sec*)
2	1,041
5	1,622
10	2,060
20	2,525
50	3,200

100	3,765
200	4,385
500	5,300
1,000	6,072
2,000	6,921
5,000	8,177
10,000	9,237

Sources : Kesem Kebena Dam Hydrology Design Report

The convoluted design flood hygrograph derived for the situation of considering entire catchment as one unit, which is critical is given in figure 2.1 [6]. The peak flood base time of the design flood hydrograph is 9237.77m^3/sec and 47hours respectively. In addition the design flood for various return periods is found in table 2.2 [6].

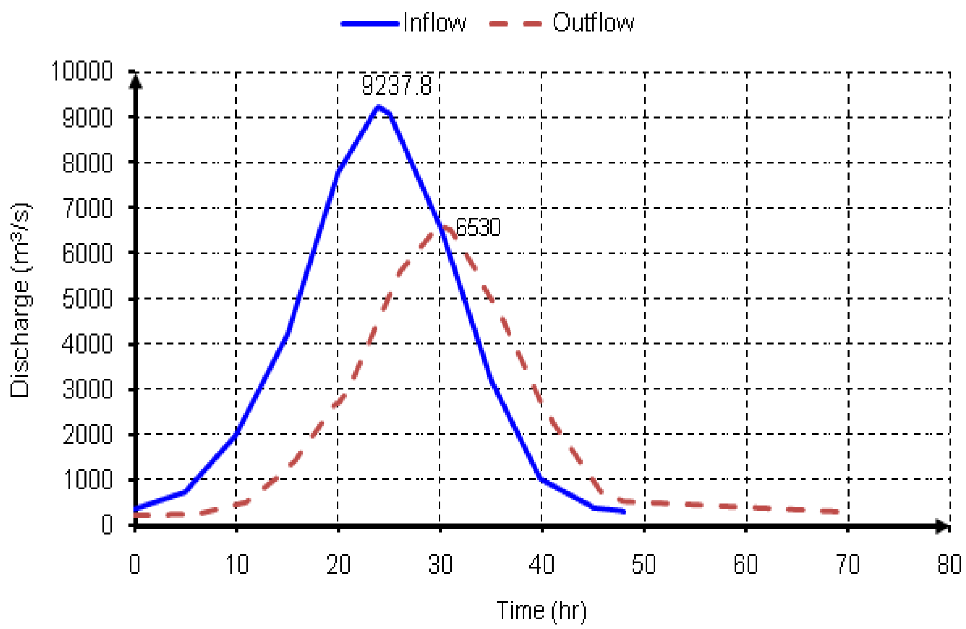


Figure 2:1 Routing Inflow and Outflow Hydrographs

2.7 River Flood Discharge Estimation Methods

The area velocity, slope area, salt concentration, moving boat and electromagnetic methods are commonly used for the measurements of discharge in a river. However the first two are mostly applicable and adaptable in different river hydraulics engineering sites and can help to measure easily [18].

2.7.1 Area Velocity Method

In this method, the discharge is determined from the area of cross-section and the mean velocity. The area of cross-section of the river is determined from the profile of the river bed obtained by the sounding. The river cross-section is divided in to a suitable number of vertical segments (or strips). The total discharge in the river is computed as the sum of the discharges in various segments. The discharge in each segment is equal to the area of the segment multiplied by the mean velocity of flow. This method is applicable during the flow time condition.

2.7.2 Area Slope Method

The area slope method can be improved to give good results by incorporating the principle of conservation of energy between the two points of the prioritized reach. This method is very vital if the concern is to estimate the initial discharge of Dry River using floating debris throughout the side of the river channel. Considering reference datum as the channel bed at two different points and Bernoulli‘s equation can be applied to calculate the head loss and the procedure application of this method is expressed in section 3.3.

2.8 River Roughness Coefficient and Slope Over View

Roughness coefficient and slope of the river are the two most preferable natural factors which govern the passage of a discharge throughout a river or a channel [19].

2.8.1 River Roughness Coefficient

Roughness coefficients represent the resistance to flood flows in channels and flood plains. The results of Manning‘s formula, an indirect computation of stream flow, have applications in flood-plain management, in flood insurance studies, and in the design of bridges and high-ways across flood plains. The roughness values for channels are determined by evaluating the effects of certain roughness factors in the channels. According to the united states geological survey water-supply paper 2339 guideline for selecting manning‘s roughness coefficients for natural channels and flood plains –the roughness value for a flood plain channels and rivers may vary from 0.011 to 0.07 [20].”

2.8.2 River Bed Slope

An understanding of how water flows is important for understanding how activities in the channel and watershed affect flow. The amount of water passing a point on the stream channel during a given time is a function of roughness coefficient and river bed slope of the flowing water [19]. Every channel has a diversified slope from extremely steep to very gentle slope.

2.9 Kinematic Wave Distributed Flood Routing

The flow of water through the soil and stream channels of a watershed is a distributed process because the flow rate, velocity, and depth vary in space throughout the watershed. Estimates of the flow rate or water level at important locations in the channel system can be obtained using a distributed flow routing model. This type of model is based on partial differential equations (the Saint-Venant equations for one-dimensional flow) that allow the flow rate and water level to be computed as functions of space and time, rather than of time alone as in the lumped models [21].

Distributed flow routing models can be used to describe the transformation of storm rainfall into runoff over a watershed to produce a flow hygrograph for the watershed outlet, and then to take this hygrograph as input at the upstream end of a river or pipe system and route it to the downstream end.

The solution of the kinematic wave equations specifies the distribution of the flow as a function of distance x along the channel and time t. The solution for Q(x,t) requires knowledge of the initial condition Q(x,0) or the value of the flow along the channel at the beginning of the calculations, and the boundary condition Q(0,t), the inflow hygrograph at the upstream end of the channel. The objective is to determine the outflow hygrograph at the downstream end of the channel, Q(L,t), as a function of the inflow hygrograph, any lateral flow occurring along the sides of the channel, and the dynamics of flow in the channel as expressed by the kinematic wave equations. The procedural application, methodology and application of this distributed flow routing is described in section 3.3.

3. PRIORITIZATION, METHODOLOGY AND ANALYSIS

3.1 Prioritized Hydraulic Flood Controlling Measures

As discussed in section 2.4 there are a lot of hydraulic flood controlling measures, but all measures are not necessarily significant for a specific site. Therefore, prioritizing the best measures for the specific site is very vital. The question of ‗when and where these measures are appropriate' can be answered by observing and assessing previously produced scientific papers which concerned the measures.

As H.M.Raghunath described in his book confining the flow between high banks flood controlling measure is useful for protecting area which is found on both sides of the flooding river. This will not have a prospect to decrease the amount of flood that will occur at the reservoir of the dam, relatively it will rapidly increase the flood discharge that will be added to the reservoir and quick the rise of flood elevation [2].

River channel character improvement hydraulic flood controlling measure helps for controlling unexpected flood before the happened flood take action on a structure. It controls flood by reducing the speed and increase the storage amount of water in a river through practicing them easily [2]. Since the measure can be exercised some distance far from upstream of the reservoir of a hydraulic structure, the flood magnitude reduces and stores throughout the river. Due to this reason, the flood can be detained before joining to the reservoir.

Diversion of a portion of the flood through flood ways hydraulic flood controlling measure is appropriate to keep structures by diverting some portion of the happened flood in other directions [2]. For the research case (*Kesem Kebena Dam* site), it has a similar observation use because the main concern here is protecting the structures specially the main dam, which is mostly constructed from earthen materials. Then, the measure will protect the structure from unexpected flood if some portion of the flood can be diverted or reduced. The provision of these bypass structures used for passing floods in the other side of reservoir area i.e. saddle point. Since, there are a number of saddle points through the rim of the reservoir in the case of the study area, it will be reasonable if there is a preparedness to divert some portion of flood through the other direction before it joins to the dam reservoir. Inaddition to this, in the case study area, there is neither population nor as such huge property in the downstream side of saddle point; it might be one means of flood controlling measures for the dam if flood bypass structure is constructed in the saddle point. As described in the hydrologic design report of the *Kesem Kebena Dam* and

Irrigation Project, there is no additional consideration of flood by pass structure except the main spill way [6]. Therefore, this flood controlling measure becomes a one option for the control of these hydraulic structures from unexpected flood. However the cost implication of this flood controlling measure is very expensive [22].

According to the U.S. Bureau of Reclamation study on improve the storage characteristics of the dam reservoir shows, excavation of some hill area at which the water will be slipped is one means to increase the amount of water to be stored in the reservoir. This measure also helps to reduce the flood height that occurrs for further over topping of structures. The measure is also economical when compared to the other measures, if the excavated material of the hill of the surface of the reservoir uses as a construction materials during the construction time [17]. According to this justification, this flood controlling measure has two uses i.e. it reduces the flood that will happen and increase the water yield which will be stored in the reservoir area.

As H.M.Raghunath described providing a temporary storage reservoir hydraulic flood controlling measure can be constructed on the upstream side of the point at which it is susceptible for flood. The measure is not a one time activity and it is appropriate for a particular work accomplishment like seasonal main dam construction which is found in the downstream side of the point of the temporary storage reservoir. Generally, the measure includes a number of activities and it needs a high investment and construction time [2].

Adopting soil conservation (land treatment) is the other hydraulic flood controlling measures and it takes place on the drainage area of the reservoir. When the upstream drainage areas are conserved, the amount of floods becomes retarded. Then, the attenuation rate increases i.e. the flood occurrence at one time becomes reduced by some percent due to the attenuation through the catchment area. Then, this will be also a good measure for controlling unexpected flood by making soil conservation of the drainage area before construction of the activities to be implemented [2].

Hence, to be more accurate and to have got a reasonable suggestion for the prioritization of the best hydraulic measures it is better to put criteria‘s and makes value for them. According to *Daniel B.Stephens* paper of prioritization and evaluation of flood controlling measures, the major points which should be observed while making flood controlling measures are economic point of view, simplicity of measures to construct as a flood controlling measure, suitability for unexpected flood reduction for the case of dam reservoir during its service life and the place where the measures are located with reference to the structure [23].

As explained before, each measure has its own suitability and draw backs. In addition to this, the above mentioned criteria's are also very significant to prioritize these measures. Hence, among the hydraulic flood controlling measures that discussed before; confining the flow between high banks, diversion of a portion of the flood through bypasses and providing a temporary storage of the peak floods requires a high amount of investment to implement them as the California Department of Water Resources, and California Natural Agency announced. The construction investment of the measures depends on the amount of flood which expected to be occurred. According to the departments, to construct a single well standard measure requires around 210 million birr [22]. It indicates that the cost of implementation of these measures is very expensive. Improve the storage character of the reservoir requires also an extensive amount of fund which is less than the already mentioned one and much higher than the channel character improvement as the two departments mentioned. In the case of channel character improvement and adopting soil conservation measures, they required less amount of fund to implement them as compared to the other flood controlling measures because they will be exercised in any kind of layman and with minimum amount of expenditure. Therefore in economic point of view river channel character improvement and soil conservation measures are the best measures among the mentioned hydraulic measures.

With respect to the flood reduction point of view, confining the flow between high banks has no any significance for the study area case and the other five hydraulic measures have their own contribution in flood reduction as explained earlier. However, their significance in reducing the occurred flood is not equally observed. Improve the storage characters of the dam reservoir has no any significance once the reservoir of the dam totally filled and the flood occurred because this type of measure could be exercised during the reservoir at its empty level. Therefore this measure is not significantly important for the case of flood protection during the service life of a hydraulic structure. Diversion of a portion of flood through flood ways hydraulic flood controlling measure is helpful for the case of areas which have seasonal unexpected flood occurrence. This type of measure is proposed from the flood experience which occurred in the previous seasons. In addition to this, the flood magnitude that will increase due to climate change and the like is not significantly large when compared to the design flood of the structure. This case has the same use for the case of *Kesem Kebena Dam* and *Irrigation Project*. Therefore thinking a head about climate changes and propose flood bypass structures is not economical as compared to the flood that will occur due to climate change. Providing a temporary storage reservoir hydraulic flood controlling measure is very significance for any type of flood magnitude. However, for lower flood magnitudes, it is not advisable when compared to the expenditure which the measure needs. Channel character improvement hydraulic flood controlling measure has its own contribution in flood reduction as like as the other measures. However, this measure helps for reduction of lower percentage of flood. The measure can exercised seasonally during the service life of hydraulic structures. Exercising soil conservation measure throughout the drainage area also helps for reducing some portion of the flood that will happened and added to the reservoir. Therefore, for lower flood percentage reduction, soil conservation and channel character hydraulic measures are the best options among the explained hydraulic flood controlling measures.

Among the mentioned measures, channel character improvement and soil conservation hydraulic measures are simple to construct because they need less time, construction and resource crews. The remaining measures i.e. confining the flow between high banks, providing a temporary storage reservoir, improve the storage characteristics of the dam reservoir and diversion of a flood through flood ways, however, needs a large construction crews, resources and times. Therefore as unexpected flood control particularly if the intention is to reduce a limited percentage of flood magnitude these laterally mentioned hydraulic measures are not significantly important.

Based on the reasons and clarification discussed above, the prioritized hydraulic measures for unexpected floods for the case study area are river channel character improvement and soil conservation measures. However, soil conservation measure was there in *Kesem Kebena Dam* upstream catchment but the flood came and occurred. From this what the researcher has understood was that even if the measure is already exercised, it wasn‘t critically significant. Therefore, the focus of the research is channel character improvement hydraulic measure which is the best prioritized flood controlling measures among the mentioned measures.

3.2 Data Used

The important primary and secondary data needed for this research work were collected from various sources. Most of them specially the primary data have been collected on the spot and these primary collected data are attached in Annex 1. For the collection of these primary data, this research made use of tough road, tape meter, GPS (Garmin model) which has 3m accuracy error, digital camera, rope and two layman. Important secondary data have been collected from different organizations and institutions. The data have been collected as soft copies, hard copies and maps, hydrological data and digitized map of the *Awash* basin were collected from the Ministry of Water and Energy, from the department of Hydrology and GIS. And data on the topographic map of the reservoir area were collected from the WWDSE. The researcher used some additional data for the verification of the collected primary data from Google earth through internet. In addition, some were modified and presented in the form of tables and figures for practical analysis.

3.3 Methodology, Procedures and Models

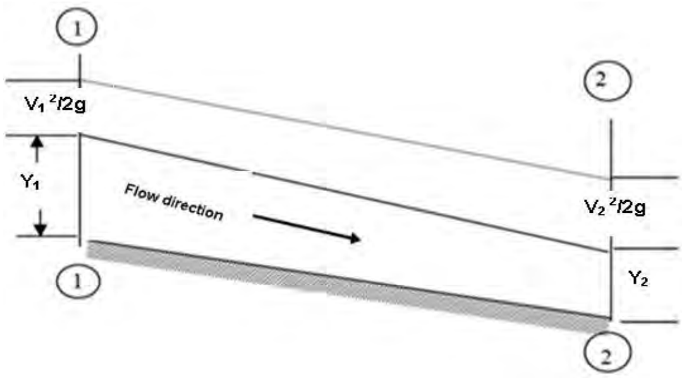
The methodology for controlling unexpected flood has been done based on the hydraulic flood controlling measures which were prioritized in section 3.1. According to this prioritization, river channel character improvement is the main research point and measure which should be conducted. This research did the analysis based on different ways of river roughness coefficient and slope combination for this channel character improvement flood controlling measure. At first, the research studied a channel character improvement by considering minimum roughness values with three different modified values of slope of the river i.e. minimum, average and maximum; next the average roughness coefficient of the river with these three different modified values of slope of the river for the prioritized flood measures which sited and studied; and lastly maximum roughness river values with the three different modified values of the river slopes as usual. The modification of the prioritized river system has taken place in the upstream river of *Kesem* which took more than 5km starting from the rim of the reservoir on the river side because it is difficult to deal by taking a long distance river length.

The research tried to do the amount of flood that could be reduced by exercising this combined flood controlling measures when the flood magnitude becomes more than the design flood. In addition to this flood percentage increment reduction, the study tried to compare and suggest the best flood reduction combinations between river roughness and slope modification.

Procedurally, the river channel character improvement would be conducted starting from prioritization of hydraulic measures as it is done in section 3.1.

In addition to this, important secondary data that are applicable for the research such as hydrological data, metrological data, topographical and digitized map of the dam reservoir area have been collected from different sources. As explained earlier in section 2.5 of the literature review, most of these important secondary data were found from WWDSE and the quality, continuity, consistency and independency of collected secondary data collected from different organizations have been checked. Also essential primary data have been collected on the river channel morphology on the site.

The amount of discharge for initial condition that should be passing at each cross section of the river which helps for distributed flow routing model would conducted using the area slope method in conjunction with the collected primary data. There are a number of methods available to estimate the initial discharge of a river (section 2.6). However, all of these methods are not appropriate for every type of river channels and situations. Hence, among these listed discharge estimation methods the slope area method is preferable for dry river discharge estimation. The way of determining this initial condition discharge at each cross section of the prioritized river using the slope area method by assuming uniform flow condition was did simply using the following procedures.



The discharge was routed starting from the point at which the rim of the reservoir found to the upstream of the river by dividing the river in to reaches. The cross sectional profile at (1) and (2), was found from the observed topographic survey of the river. Thus, the wetted cross sectional areas A_1 and A_2 and wetted perimeters P_1 and P_2 corresponding to the flood depths of the particular discharge was computed. The hydraulic radii R_1 and R_2 and the conveyances K_1 and K_2 (after selecting suitable roughness coefficient n_1 and n_2 for the section (1) and (2) respectively) were calculated. Also the average or equivalent conveyance K between Sections (1) and (2) was obtained by using equation (3.3.6). The discharge Q that passed through the cross sections was calculated using equation (3.3.4) by assuming suitable value of energy grade line. The velocity of water V_1 and V_2 at the two sections (1) and (2) were also estimated using the relations found in equation (3.3.8).

Then from equation (3.3.1) and (3.3.2), the value of H_1 and H_2 and the energy slope from equation (3.3.3) were estimated. From the calculation assumed value of S_f used in discharge calculation should be the same as the calculated value of Sf in equation (3.3.3). Most of the time the two values might differ. Thus, by taking the energy slope that calculated in equation (3.3.3) and repeat the iterations from the discharge estimation (3.3.4) till the energy slope at the end of the iteration becomes equal. Therefore, the discharge calculated at the end is the estimated flood discharge at initial condition that will be passed throughout the cross section of the river.

$$H_1 = \frac{V_1^2}{2g} + Y_1 \tag{3.3.1}$$

$$H_2 = \frac{V_2^2}{2g} + Y_2 \tag{3.3.2}$$

$$(\frac{H_1 - H_2}{l}) = S_f = (\frac{Q}{K})^2 \tag{3.3.3}$$

$$Q = A(\frac{1}{n})R^{2/3}S_f^{1/2} = KS_f^{1/2} \tag{3.3.4}$$

$$K = \frac{AR^{2/3}}{n} \tag{3.3.5}$$

$$K = \sqrt{K_1K_2} \tag{3.3.6}$$

$$K_1 = \frac{A_1R_1^{2/3}}{n_1}; K_2 = \frac{A_2R_2^{2/3}}{n_2} \tag{3.3.7}$$

$$Q = A_1V_1; Q = A_2V_2 \tag{3.3.8}$$

Where Q is the discharge in m^3/s; H is energy head in m; V is velocity of flow in m/s; I is river length between two reaches in m; n is the roughness coefficient; A is wetted area in m^2; S_f is energy slope; K is conveyance of the river; R is hydraulic radius.

Then, the design flood that passed through the river was computed using both the computed discharge at each cross section of the river and the inflow hydrograph at the entrance of the dam reservoir using distributed flow routing numerical solution by assuming kinematic wave flow condition.

For the determination of this design flood at each cross section of the river using distributed flow routing model, the river initial discharge should be computed first and the design flood at the inflow in to the river should be obtainable. However, for this research paper the inflow hygrograph to the dam reservoir i.e. the out flow hygrograph of the river has been already known, and the inflow hygrograph of the river was unknown. Hence, it is possible to compute the inflow hygrograph of the different section of the river node points using equation (3.3.9) and by back ward numerical solution trial and error methods [21].

$$Q_{i+1}^{j+1} = \frac{[\frac{\Delta t}{\Delta x} Q_i^{j+1} + \alpha\beta Q_{i+1}^{j} (\frac{Q_{i+1}^{j} + Q_i^{j+1}}{2})^{\beta - 1}]}{[\frac{\Delta t}{\Delta x} + \alpha\beta (\frac{Q_{i+1}^{j} + Q_i^{j+1}}{2})^{\beta - 1}]} \qquad (3.3.9)$$

Where Q^{j+1}_{i+1} the flood discharge at i+1 and j+1 space and time series respectively; Q^{j+1}_{i} the flood discharge at i and j+1 space and timeseries respectively; Q^{j}_{i+1} the flood discharge at i+1 and j space and time series respectively; Δt is the time interval between two time boundaries; Δx is the distance between two river nodes; β is the river *Boussinesq coefficient*; α is the area to discharge ratio coefficient.

As it has shown in equation (3.3.10) the value of Q^{j}_{i+1} was calculated from the known values of Q^{j+1}_{i+1} and Q^{j+1}_{i} by using trial and error iteration mode.

$$Q_{i+1}^{j} = \frac{[\frac{\Delta t}{\Delta x} Q_{i+1}^{j+1} + \alpha\beta Q_{i+1}^{j+1} (\frac{Q_{i+1}^{j} + Q_i^{j+1}}{2})^{\beta - 1} - \frac{\Delta t}{\Delta x} Q_i^{j+1}]}{[\alpha\beta (\frac{Q_{i+1}^{j} + Q_i^{j+1}}{2})^{\beta - 1}]} \qquad (3.3.10)$$

Then, after Q^{j}_{i+1} computation, the flood discharge at different cross section of the river was known. The percentage increment for this computation was exercised starting from 0.1%. And also in the analysis the extent of this flood controlling method application was evaluated after exercising different roughness coefficient and river bed slope combination. In addition to this, the study tried to compute the amount of flood at which it could be reduced in the combinations.

The model which helps for this study was distributed flow routing kinematic wave model using numerical solutions. The reason of prioritizing this model was because of the partial differential equations (the Saint Venant equations for one-dimensional flow) that allow the flow rate and water level to be computed as functions of space and time, rather than time alone as in the lumped models.

With the model, the study compared two different cases of river channel characteristic system. In the first case, the existing channel system studied and in the second case the modified channel system studied with respect to flood reduction and inundation. The analysis of the study has a number of combinations of maximum, average and minimum roughness coefficient and river slope modification.

3.4 Unexpected Floods Analysis

The analysis of unexpected flood was done according to the hydraulic flood controlling measures prioritized in section 3.1. Therefore, the analysis of the study focused only on the channel character improvement of the river alone.

3.4.1 River Reaches Description

For 5.4km length of Kesem River, where the data was collected and the study was undergone, the study has found around 30 reaches and 31 cross sectional nodes throughout the prioritized river length. When the data was collected, these reaches had their own criteria to sub divide as different reaches. According to *David L.Rosgen* the main points which should be observed while classifying river reaches were change in channel width (contraction and expansion) and water depth (reduce and increase), change in slope and curvature of an existing river morphology, existence of small tributaries even if their significance is assumed to be nothing in this study and physical channel roughness variation [24]. By using these criteria's, the study summarized and described all reaches as shown in table 3.1.

Table 3.1 : River Reaches Description

Reach Name	Notification	Entrance location	Exit location	Reach classification criteria's
Reach 01	Between Node 0 and Node 1	Node 1	Node 0	Entrance of the reservoir
Reach 02	Between Node 1 and Node 2	Node 2	Node 1	Existence of small tributaries, Expansion of channel width and
Reach 03	Between Node 2 and Node 3	Node 3	Node 2	Expansion of channel width and Increase in water depth
Reach 04	Between Node 3 and Node 4	Node 4	Node 3	Contraction of channel width and Increase in water depth
Reach 05	Between Node 4 and Node 5	Node 5	Node 4	Existence of small tributaries and Contraction of channel width
Reach 06	Between Node 5 and Node 6	Node 6	Node 5	Existence of small tributaries, Contraction of channel width and
Reach 07	Between Node 6 and Node 7	Node 7	Node 6	Contraction of channel width and Reduce in water depth
Reach 08	Between Node 7 and Node 8	Node 8	Node 7	Expansion of channel width and Reduce in water depth
Reach 09	Between Node 8 and Node 9	Node 9	Node 8	Expansion of channel width and Reduce in water depth
Reach 10	Between Node 9 and Node 10	Node 10	Node 9	Existence of small tributaries, Expansion of channel width and
Reach 11	Between Node 10 and Node 11	Node 11	Node 10	Contraction of channel width, Reduce in water depth and

Reach 12	Between Node 11 and Node 12	Node 12	Node 11	Existence of small tributaries and Contraction of channel width
Reach 13	Between Node 12 and Node 13	Node 13	Node 12	Expansion of channel width
Reach 14	Between Node 13 and Node 14	Node 14	Node 13	Existence of small tributaries, Expansion of channel width and
Reach 15	Between Node 14 and Node 15	Node 15	Node 14	Existence of small tributaries, Contraction of channel width and
Reach 16	Between Node 15 and Node 16	Node 16	Node 15	Expansion of channel width and Increase in water depth
Reach 17	Between Node 16 and Node 17	Node 17	Node 16	Expansion of channel width and Reduce in water depth
Reach 18	Between Node 17 and Node 18	Node 18	Node 17	Expansion of channel width and Reduce in water depth
Reach 19	Between Node 18 and Node 19	Node 19	Node 18	Expansion of channel width and Existence of small tributaries
Reach 20	Between Node 19 and Node 20	Node 20	Node 19	Contraction of channel width and Increase in water depth
Reach 21	Between Node 20 and Node 21	Node 21	Node 20	Existence of small tributaries and Contraction of channel width
Reach 22	Between Node 21 and Node 22	Node 22	Node 21	Contraction of channel width and Increase in water depth
Reach 23	Between Node 22 and Node 23	Node 23	Node 22	Contraction of channel width and Reduce in water depth
Reach 24	Between Node 23 and Node 24	Node 24	Node 23	Existence of small tributaries and Expansion of channel width
Reach 25	Between Node 24 and Node 25	Node 25	Node 24	Contraction of channel width, Reduce in water depth and
Reach 26	Between Node 25 and Node 26	Node 26	Node 25	Existence of small tributaries and Contraction of channel width
Reach 27	Between Node 26 and Node 27	Node 27	Node 26	Contraction of channel width and Increase in water depth
Reach 28	Between Node 27 and Node 28	Node 28	Node 27	Existence of curvature
Reach 29	Between Node 28 and Node 29	Node 29	Node 28	Reduce in water depth
Reach 30	Between Node 29 and Node 30	Node 30	Node 29	Reduce in water depth

The pattern of the river is classed as relatively straight, low sinuosity and meandering. The topographical morphology of the river looks like as shown in figure 3.1.

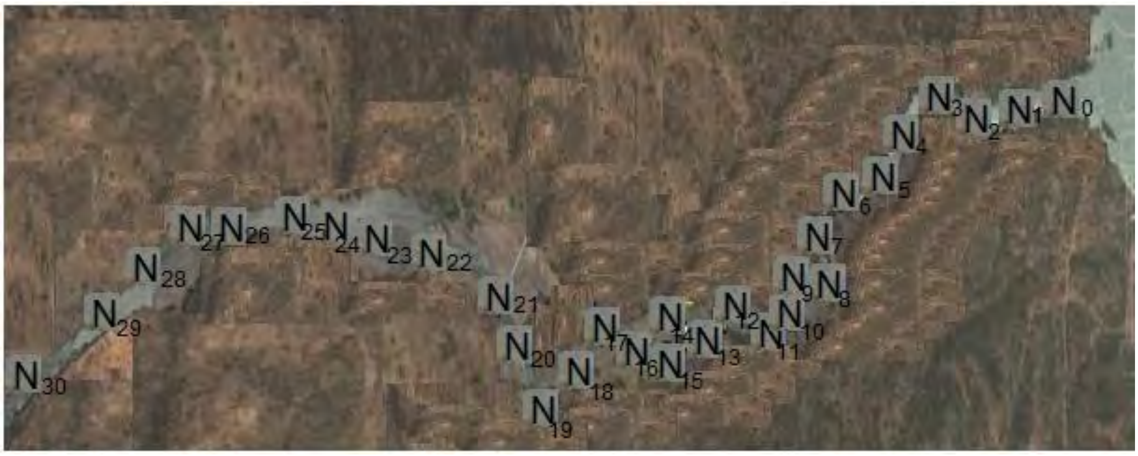


Figure 3:1 : Symbolized River Nodes and Schematization of Kesem River

3.4.2 River Cross Sections Schematization and Wetted Areas Computation

As shown in table 3.1, there are 30 reaches and 31 river cross sections (Nodes) for this channel character improvement work. Hence, to compute the river discharge first, the river cross section schematization and the wetted area of the river at different nodes were computed. The area was computed after the river cross section schematization has been done using excel spread sheet; and then by numbering the rectangles and multiply it by the area of one rectangle. At the end, the calculated area values of the river cross sections are found in Annex 3 with the computation of initial discharge.

The sample schematized area of the entrance to the dam reservoir and the entrance to the river in the upstream side are found in figure 3.2 and 3.3. The overall river node cross section schematization is found in Annex 2.

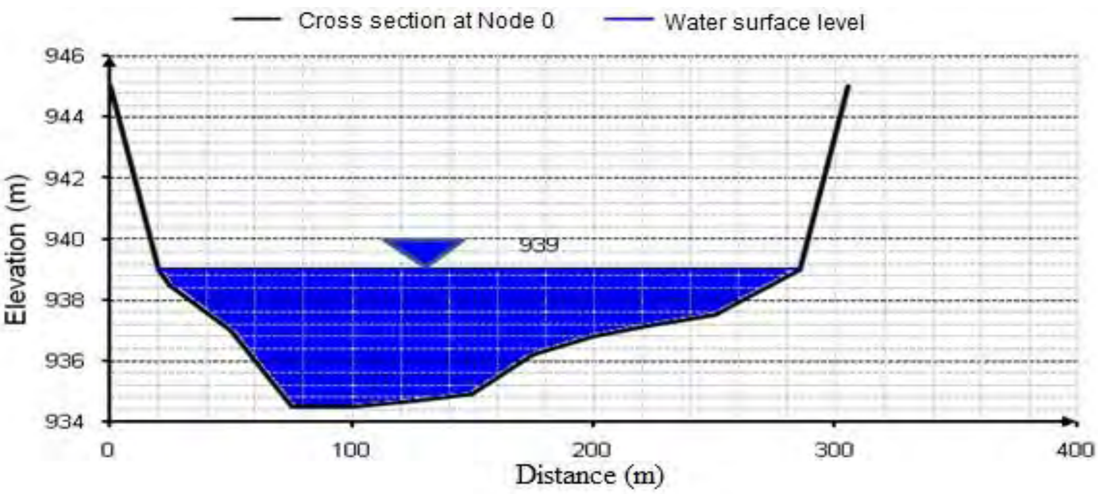


Figure 3:2 : River Cross Section at Node 0

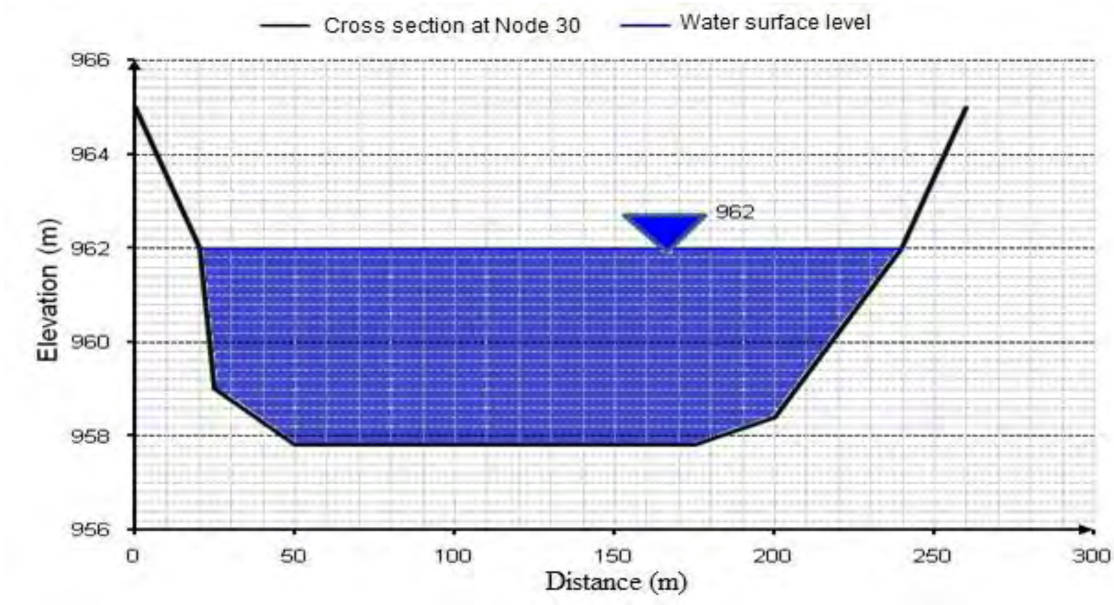


Figure 3:3 : River Cross Section at Node 30

3.4.3 Initial Discharge Computation of the River

By using the area slope method which procedurally expressed in section 3.3 and the primary data collected on the site, the initial discharge of the river could be computed after the computation of related terms like wetted area, flow depth and flow velocity. The result of the computed initial discharge and related term are found in Annex 3.

3.4.4 Design Flood Computation of the River

The amount of design flood for the period of flood time at different section of the river was found by using both the computed initial discharge of the river and the design flood inflow hydrograph at the entrance of dam reservoir.

Since the inflow hygrograph to the dam reservoir data was known from WWDSE hydrologic design report [6] and the initial discharge of the river was already computed as expressed and found in Annex 3. The design flood at different river cross section was computed easily using back ward differentiation distributing kinematic wave saint venant equation and grid point method. From the computed initial discharge, the amount of flood discharge of the inflow hygrograph which fitted with the value of the initial discharge at the entrance to the dam reservoir helps for the computation of design flood for the other cross section of the river nodes. The fitted discharge time value uses as initial time boundary condition for the computation whereas the inflow hydrograph values of the dam uses as the downstream boundary condition. In addition to this, for the estimation of this flood magnitude the entrance of the river uses as the upstream boundary condition. During initial discharge computation of the river, the value of discharge which fitted with the discharge in the inflow hydrograph to the reservoir values are at 14.02 and 34.15hr within the total base time of 48hrs. However, the flood magnitude computation of 34.15hr is very vital. Therefore, this time is the initial time boundary condition for the computation.

The grid point before and after the computation of the flood time condition discharge looks like in figures 3.4 and 3.5.

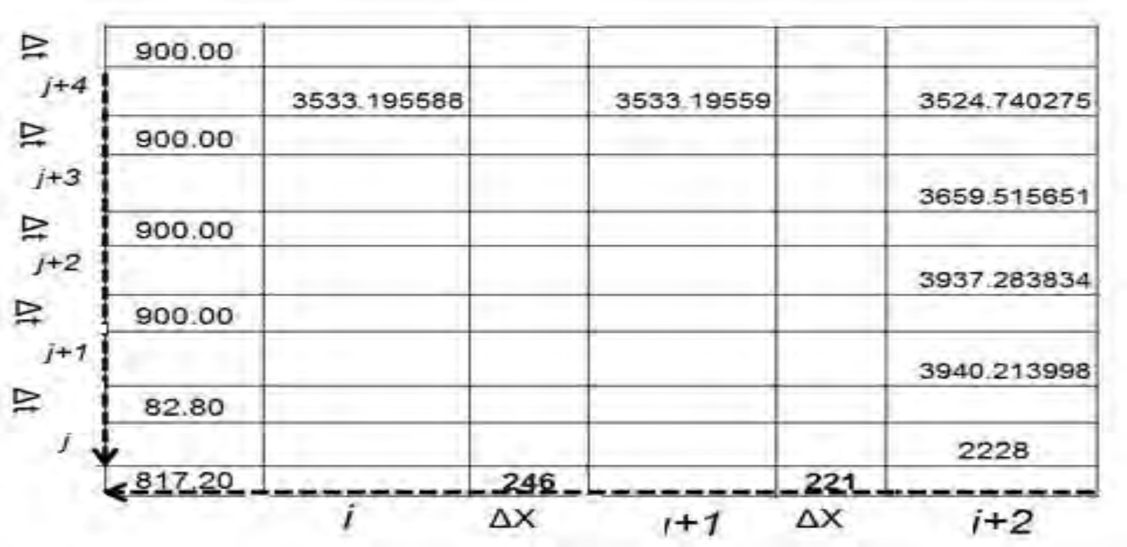


Figure 3:4 : Grid Point before the Computation of Flood Discharge

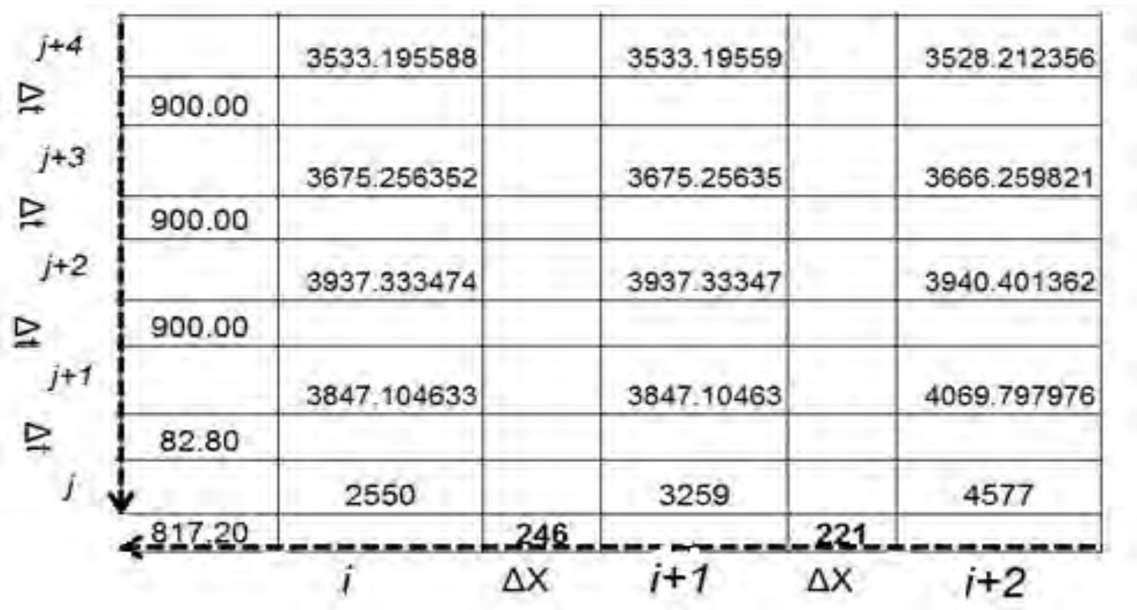


Figure 3:5 : Grid Point after the Computation of Flood Discharge

Then, the overall values of the computed discharge are found in Annex 4. The computed flood discharge at different cross sectional node of the river is helpful to draw the design flow hydrograph throughout the river. As shown in figure 3.6 and 3.7, the schematizations are found for the entrance to the dam reservoir and the entrance to the river. The other river node cross section estimated design flood hydrographs are found in annex 5.

The base time of the inflow hydrograph to the entrance of dam reservoir is 48 hours according to the WWDSE hydrologic design report [6]. When the study used for the computation of the flood discharge the value of delta x is simply the distance between the river nodes; and delta t = 15minutes. The river roughness coefficient and slope values for the study are found in the river data of annex 1. From the flood discharge computation, the maximum design flood that could pass during flood time through the sections at the prioritized river distances are computed and the peak flood discharge at different section of the river becomes as shown below;

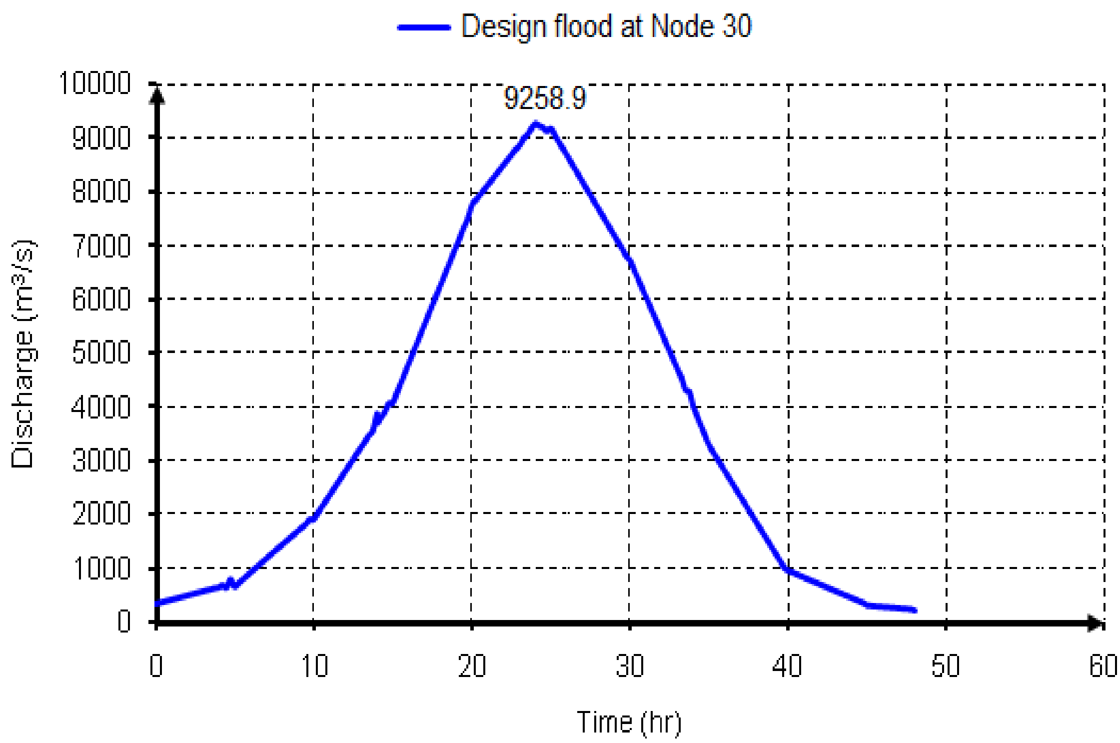


Figure 3:6 : Design Flood at Node 30 of the River

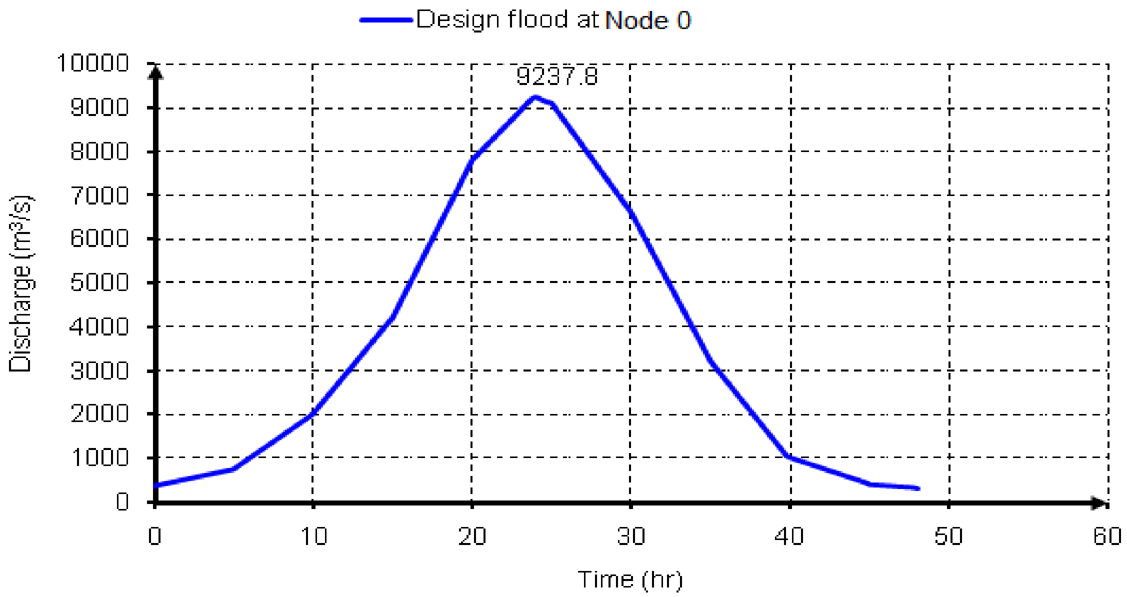


Figure 3:7 : Design Flood at Node 0 of the River

Table 3.2 : Design Flood at Different Nodes of the River

Node	30	29	28	27	26	25	24	23	22	21	20
Flood discharge (m3/s)	9259	9258	9257	9257	9256	9255	9254	9253	9253	9252	9251

Node	19	18	17	16	15	14	13	12	11	10	9
Flood discharge (m3/s)	9250	9250	9249	9248	9248	9247	9247	9246	9246	9245	9244

Node	8	7	6	5	4	3	2	1	0
Flood discharge (m^3/s)	9244	9244	9243	9242	9242	9241	9240	9239	9238

These flood magnitudes are the maximum values at which the river can carry at different cross sections and will pass through the design period of the dam reservoir.

3.4.5 Channel Character Improvement Combination Analysis

The unexpected flood occurs through the river due to different reasons which were explained in literature review section 2.2 and the maximum design flood which occurs and carried through the river was computed and found in section 3.4.4. Here the main concern is how much amount of flood can be reduced by exercising the channel character improvement works through the prioritized river length. In this study, using different slope and roughness coefficient modifications, peak flood at the entrance to the improved river length is computed by taking the inflow hydrograph of the dam (fig. 3.7). However, before the computation of this flood analysis, the occurrence time of this flood magnitude should be known. Then, to determine this occurrence time, the best means is making a trend line by relating design flood discharge with their base time. As the river inflow hydrograph to the dam reservoir indicates there is a time at which the flood magnitude increases from one value to the other. According to the time versus design flood relationship that is computed throughout the river, the trend line made an equation; $t = 2E\text{-}07*Q^2 - 0.001Q + 17.76$, where t is time in hr and Q is discharge in m^3/s. Then, when the increased unexpected flood values inserted in the above equation, it made the values of the time at which this flood happens. Based on this evaluation, the computed time for different discharge percentage increment can be found easily. Using the above trend line equation, 1% increased river entrance design flood amount will happen at 25.8hr of the base time. Here, during the wetted hydraulic radius computation, the new and the prior computed values has no a significance difference even if the values of the flood discharge, wetted area and perimeter were changed.

As a beginner researcher, it was so difficult to put the values of the river roughness coefficient of the existing natural river simply by eye observation. But as expressed in literature review section 2.7, there are a number of means to put these values with related to the site condition. For the computation, the river has its own natural roughness and slope values. Since these existing roughness coefficient values are shown in the table below [20].

Table 3.3 : Average Roughness Coefficient of the River

Partial River Length (m)	0 - 861	861 - 1582	1582 - 2010	2010 - 2394	2394 - 2516
Average n Values	0.02	0.03	0.025	0.02	0.025
Partial River Length (m)	2516 - 3003	3003 - 3924	3924 - 5372		
Average n Values	0.02	0.03	0.04		

The slope of *Kesem River* is very gentle and an average value of 1:200m. Therefore before doing the slope modification analysis there should be a check up of the suitability of the natural *Kesem River* for slope modification. As explained by H.M.Raghunath to exercise this river slope modification the slope of the river should be moderate and gentle. Moreover, the roughness of the river should be storable by itself. Hence, *Kesem River* characteristics are suitable for this case. In addition to this, the slope of the river has a great role for the modification of the river to store some amount of flood in the river during flood condition. The actual river slope is found in the table below and the study used it for further analysis as an input.

Table 3.4 : Average Slope of the River at Different Reaches

Reach Name	Reach 01	Reach 02	Reach 03	Reach 04	Reach 05	Reach 06
Ave. River Channel Slope Values	0.002	0.003	0.002	0.004	0.002	0.001
Reach Name	Reach 07	Reach 08	Reach 09	Reach 10	Reach 11	Reach 12
Ave. River Channel Slope Values	0.004	0.006	0.001	0.005	0.001	0.002
Reach Name	Reach 13	Reach 14	Reach 15	Reach 16	Reach 17	Reach 18
Ave. River Channel Slope Values	0.008	0.003	0.004	0.006	0.002	0.004
Reach Name	Reach 19	Reach 20	Reach 21	Reach 22	Reach 23	Reach 24
Ave. River Channel Slope Values	0.011	0.002	0.003	0.005	0.008	0.008
Reach Name	Reach 25	Reach 26	Reach 27	Reach 28	Reach 29	Reach 30
Ave. River Channel Slope Values	0.004	0.004	0.006	0.009	0.009	0.004

Here as, a researcher and a reader, there might be a question which related with the extent slope values at which applicable for the channel character improvement i.e. the maximum slope which should be exercised in this analysis. Hence as H.M.Raghunath pointed in his book, the maximum slope of the flood plain natural river should not be more than the maximum slope among the river slope values which are found throughout the natural river system. And river channel character improvement should be exercised when the average slope of the natural river should be less than 0.01 even if it depends in different factors [2].

3.4.5.1 Analysis Using Minimum Roughness Coefficient and Minimum River slope

According to G.J. Arcement, the minimum roughness coefficient mean that either the least value of the roughness coefficient among which found throughout the existing prioritized river or the minimum roughness coefficient that is recommended by different scholars [20]. However for channel modification the minimum roughness value of the river should be the minimum value from the already computed values throughout the existed river. The minimum value of the existed river prioritized because; first, when the value becomes lower and lower, the discharge that passes throughout of the river will increase and; second if we exercise a new roughness coefficient values, it needs another total river modification. According to this, the minimum roughness coefficient for the modification is the lowest value from the prioritized river system and it is 0.02.

Similarly, the minimum slope of the river is also the least slope among the slope which is found in the existing river system. Hence, this minimum slope is 0.001. Then the analysis would be done based on these two minimum roughness and slope values with the 1% design flood increment at the entrance of the upstream river i.e. the design flood at the entrance of the river and the entrance to the dam reservoir is 9259.2m^3/s and 9238m^3/s respectively. And the 1% increment design flood at the entrance to the river leads to the increase in some amount of the flood magnitude throughout the prioritized river system and the magnitude at the entrance to the dam reservoir becomes 9307m^3/s which means that there is an increment of 68m^3/s when compared to the design flood before 1% increment took place.

3.4.5.2 Analysis Using Average Roughness Coefficient and Minimum River Slope

Also the average roughness coefficient mean here is that the average value of the roughness coefficient among which found throughout the existing prioritized river system. According to this, the average roughness value of the existing river system is 0.029 which is found using the equation;

$$n_{ave} = \frac{sum(L_i n_i)}{sum(L_i)}$$

As explained before, the minimum slope of the river is 0.001. Then based on these two values, the analysis was did easily and when the design flood at the entrance to the river is increased by 1% the flood magnitude that exists at the entrance to the dam reservoir becomes 9307m^3/s which means that there is an increment of 68m^3/s when compared to the design flood that should exist at the entrance before the increment.

3.4.5.3 Analysis Using Maximum Roughness Coefficient and Minimum River Slope

The maximum roughness coefficient of the river is the maximum values which are recommended by different scholars for *Flood Plain Rivers*. Since *Kesem River* is a flood plain river and according to this the maximum recommended roughness coefficient values is 0.07. This value is the standard value of the maximum roughness coefficient at which the flood plain river should have according to G.J.Arcement [20].

As described before the minimum slope of the river is 0.001. Then, based on these two modifications the analysis was did easily and when the design flood at the entrance to the river increased by 1% the flood magnitude that exists at the entrance to the dam reservoir becomes 9307m^3/s which means that there is an increment of 68m^3/s when compared to the design flood that should exist at the entrance to the dam reservoir.

3.4.5.4 Analysis Using Minimum Roughness Coefficient and Average River slope

The minimum roughness coefficient is 0.002 and the average slope of the river is that the average value of the slope among which found throughout the existing prioritized river. According to this, the average slope value of the existing river system is 0.005 which is found using the an equation;

$$s_{ave} = \frac{sum(L_i s_i)}{sum(s_i)}$$

3.4.5.5 Analysis Using Average Roughness Coefficient and Average River Slope

The average roughness coefficient and average river slopes are 0.029 and 0.005 respectively. In the same manner of the other modifications, these combinations have been done with similarly procedure.

3.4.5.6 Analysis Using Maximum Roughness Coefficient and Average River Slope

As dictated before, the maximum roughness coefficient and average river slope are 0.07 and 0.005 respectively.

3.4.5.7 Analysis Using Minimum Roughness Coefficient and Maximum River Slope

The minimum roughness coefficient is 0.02. The maximum slope of the river is the maximum slope at which it is found throughout the river and helpful for this modification. The maximum river slope is 0.009.

3.4.5.8 Analysis Using Average Roughness Coefficient and Maximum River Slope

The average roughness coefficient and maximum river slope are 0.029 and 0.009 respectively.

3.4.5.9 Analysis Using Maximum Roughness Coefficient and Maximum River Slope

The maximum roughness coefficient and maximum river slope are 0.07 and 0.009 respectively.

4. RESULTS AND DISCUSSION

4.1 Channel Character Improvement Measure Results

As discussed briefly in analysis part of the previous chapter, there are a lot of combinations of channel character improvement work modifications and they have their own result after the combined modification has taken place and this result and its physical meanings are found here below.

4.1.1 Minimum n and Minimum River s Combination Result

The minimum roughness and minimum slope of the river exercised and modified throughout the existing river system has a result of the flood magnitude at the entrance to the dam reservoir becomes 9300m^3/s because of the 1% design flood increment at the entrance to the river. As described in section 3.4.5, the design flood which should be kept at the entrance to the dam reservoir should be 9238m^3/s which means there is more than 62m^3/s flood discharge increment. The flood discharge at the entrance to the dam reservoir due to the 1% flood discharge increment at the entrance to the upstream river has a result of 9307m^3/s before the implementation or modification of the these combined river channel character improvement and it has a 7m^3/s difference with the modified discharge result.

4.1.2 Average n and Minimum River s Combination Result

After the average roughness and minimum slope of the river exercised and modified through- out the existing river system the flood magnitude at the entrance to the dam reservoir be- comes 9291.7m^3/s, which has a 53m^3/s increased flood discharge difference when compared to the design flood that should exist at the entrance to the dam reservoir. Here, there is also the combined modification has a 15.3m^3/s flood reduction when compared with the flood discharge that comes due to 1% flood discharge increment at the entrance to the upstream river. Because the flood discharge at the entrance to the dam reservoir before the application of these combined modification i.e. using the natural river system has 9307m^3/s and after the application of the modified combination the discharge becomes 9291.7m^3/s.

4.1.3 Maximum n and Minimum River s Combination Result

When the maximum roughness and minimum slope of the river exercised and modified throughout, the existing river system the flood magnitude at the entrance to the dam reservoir becomes 9271.7m^3/s which has a 33.7m^3/s reduced flood discharge difference when compared to the design flood that should be kept at the entrance to the dam reservoir. In these combined modifications also there is a 35.3m^3/s flood reduction when compared to the flood magnitude that is exercised through the natural river system.

4.1.4 Minimum n and Average River s Combination Result

Then, based on these two combinations, the analysis can be done easily and when the design flood at the entrance to the river is increased by 1% the flood magnitude that will be exist at the entrance to the dam reservoir becomes 9341.3m^3/s which means that there is an increment of 103.3m^3/s when compared to the design flood that should be exist at the entrance to the dam reservoir. These river character improvement modifications also have a discharge difference result of 34.3m^3/s flood discharge magnitude at the entrance to the dam reservoir. As the figure shows these modifications relatively increase the flood amount that should be exist in the natural system at the specified point of the river.

4.1.5 Average n and Average River s Combination Result

Similarly, when the average roughness and average slope of the river exercised and modified throughout the existing river system, the flood magnitude at the entrance to the dam reservoir becomes 9338.8m^3/s which has a 31.8m^3/s increased flood discharge difference when compared to the design flood that should be kept at the entrance to the dam reservoir.

4.1.6 Maximum n and Average River s Combination Result

Hence the combination of these two modifications has a result of 9273.2m^3/s flood amount at the entrance to the dam reservoir. This means there is a 35.2m^3/s flood discharge reduction when compared to the design flood that should be found at the entrance to the dam reservoir. In similar fashion with the above alike mentioned flood reduction hydraulic measures these modifications have their own contribution in flood reduction situation. Hence these modifications have a 33.8m^3/s flood discharge reduction after the application of them when compared to the flood discharge of the natural system of the river.

4.1.7 Minimum n and Maximum River s Combination Result

The combination of these two modifications has a result of 9320.7m^3/s flood amount at the entrance to the dam reservoir. This means that simply there is 82.7m^3/s flood discharge increment at the design flood that should be found at the entrance to the dam reservoir. These modifications are the third type of modifications which are known by speedup or increased the flood discharge at the specified point when compared with the flood amount that should be found in the natural system of the river. Here, there is a 13.7m^3/s flood amount became more than that of the flood magnitude due to the natural river system.

4.1.8 Average n and Maximum River s Combination Result

Similarly, the combined effect of these two modifications has a result of 9314.5m^3/s flood amount at the entrance to the dam reservoir. This means that there is 76.5m^3/s discharge difference from the expected design flood that should be kept at the entrance to the dam reservoir. Even if the speeded up flood amount becomes small when compared to the other three measures; this combined modification measures have a 7.5m^3/s discharge increment as the desired point of the entrance to the dam reservoir.

4.1.9 Maximum n and Maximum River s Combination Result

At the last the combined effect of these two modifications has a result of 9296.7m^3/s flood amount at the entrance to the dam reservoir. As explained before the maximum design flood at the entrance to the dam reservoir is 9238m^3/s and it means that there is 58.7m^3/s flood discharge increment. This combined modified measure is the other measure which will be help full for the application of flood reduction measures as the analysis result shows and it has a 10.3m^3/s discharge reduction at the desired point of the river.

Table 4.1 : Channel Character Modifications Result

Channel Character Improvement Combinations	Min S and Min n	Min S and Ave n	Min S and Max n	Ave S and Min n	Ave S and Ave n	Ave S and Max n	Max S and Min n	Max S and Ave n	Max S and Max n
Unexpected Flood at Node 0 before Modification (m^3/s)	9307	9307	9307	9307	9307	9307	9307	9307	9307
Unexpected Flood at Node 0 After Modification (m^3/s)	9300	9291.7	9271.7	9341.3	9338.8	9273.2	9320.7	9314.5	9296.7
Reduced Flood (m^3/s)	7	15.3	35.3	-34.3	-31.8	33.8	-13.7	-7.5	10.3

4.2 Reduced Flood by the Combined Analysis and Discussion

The amount of flood that could be reduced due to the application of these channel character improvement combinations for the increment of 1% flood discharge amount at the entrance to the upstream river has the flood increment when compared with the expected design flood at the entrance to the dam reservoir and the flood magnitude that will be available because of the natural river system with different flood reduction river channel character combination modifications has shown in the table 4.1.

As the result of the analysis shown in table 4.1, there were found flood magnitude reduction and increments. In one side, there was a reduction in flood magnitude and in the other hand; there was flood increment when compared to the flood magnitude that should be secured in the natural river system at the entrance to the dam reservoir. Therefore, minimum slope and maximum roughness coefficient, average slope and maximum roughness coefficient, minimum slope and average roughness coefficient, maximum slope and maximum roughness coefficient and minimum slope and minimum roughness coefficient were grouped on one side; and the remaining i.e. average slope and minimum roughness coefficient, average slope and average roughness coefficient, maximum slope and minimum roughness coefficient and maximum slope and average roughness coefficient modifications were grouped on the other side.

According to the objective of the research, the second grouped river channel character modifications are not totally relevant because these combined modifications were increased the flood magnitude. Therefore, the first grouped measures have been the chosen combined modifications for further prioritization of best flood reduction modification analysis.

Based on the result that shown in table 4.1, the minimum slope and maximum roughness coefficient and average slope and maximum roughness coefficient combination modifications have a good channel storage improvement among the five combinations result and these two measures have relatively similar flood magnitude reductions. As expected, these river channel character improvement combined modification measures are the best combined measures among the nine combined measures that have been done in the analysis. In addition, the flood results after the modification of these measures are found in figure 4.1.

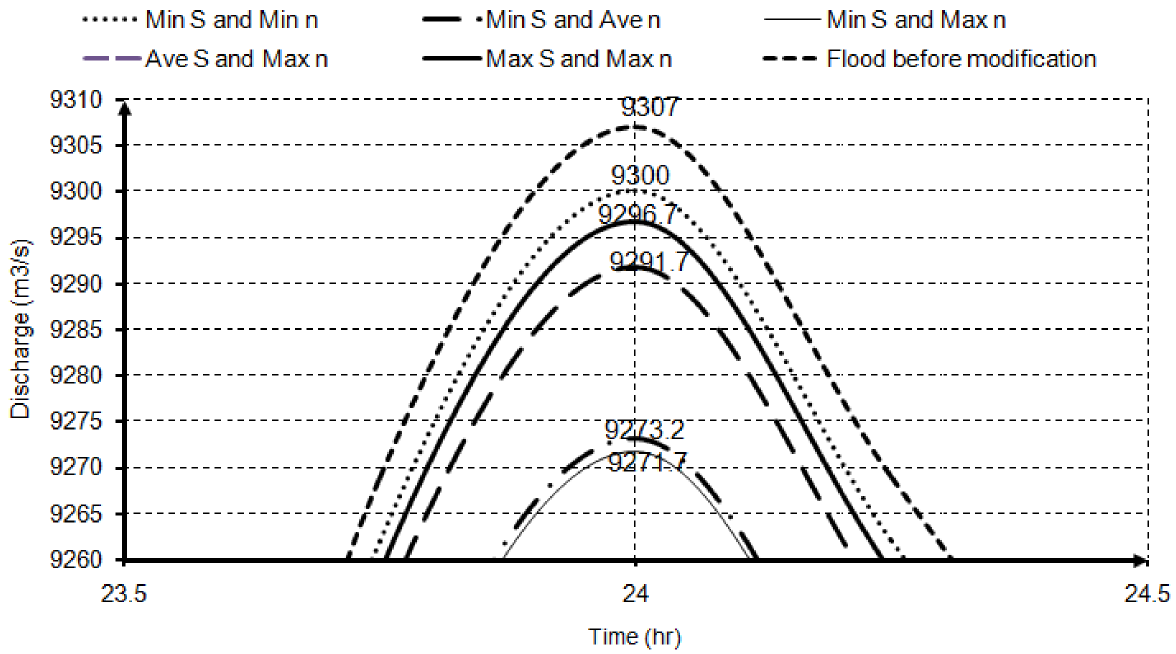


Figure 4:1 : Unexpected flood at Node 0 for Different Modification

However, as explained in the scope of the study before, the analysis has been done throughout the 5.4km prioritized natural river system and that is why the value of flood reduction magnitude shown becomes small. The analysis result also shows here above by exercising the river channel character improvement works it is possible to reduce the percentage of flood magnitude with relative to the design flood that should be kept at a desire point. The maximum percentage increment of the study was 1% design flood increment at the entrance to the upstream river. Since the result shows the extent at which the percentage reduction after the implementation of the combined river character improvement measures was below 1% for the design flood that should be maintained at the entrance to the reservoir. As the result pointed as in tabular form above the maximum percentage of flood reduction is 0.38%. This figure shows, if the flood design discharge at the entrance to the upstream river increased by 1% the percentage of flood magnitude that could be reduced at the entrance to the dam reservoir was 0.38% from the flood magnitude that occurred at the entrance to the dam reservoir after exercising the combined effect of minimum slope and maximum roughness coefficient.

As found in analysis section 3.4.5, there is a relationship which shows the time at which the flood will occur with respect to its magnitude. According to this justification, the 9307m^3/s flood at the entrance to the dam reservoir will occur at 25.8hr of the total 50.5hr base time.

Figure 3.7 shows the hydrograph of the design flood that exists at the entrance to the dam reservoir (Node 0) whereas fig. 4.2 and fig. 4.3 shows the flood that will occur before and after the channel character modification work has taken place respectively in the case of minimum s and maximum n.

Based on the flood amount reduction that will exist in the implementation of combined measures it is easy to calculate the extra amount of volume of water that will be added to the reservoir, if the measures would not be take place.

The excess flood hydrograph has an equation of $Q = -38.79t^2 + 1978t - 15913$ and this helps to estimate the total extra volume of water that would be added due to excess flood. The equation was developed by using the excess flood hydrograph design flood and th etime of occurrence of the flood. Therefore, this volume of water indicates how much amount of water could reduce or prevent from entrance to the dam reservoir due to flood by exercising the previously prioritized river channel character improvement modifications.

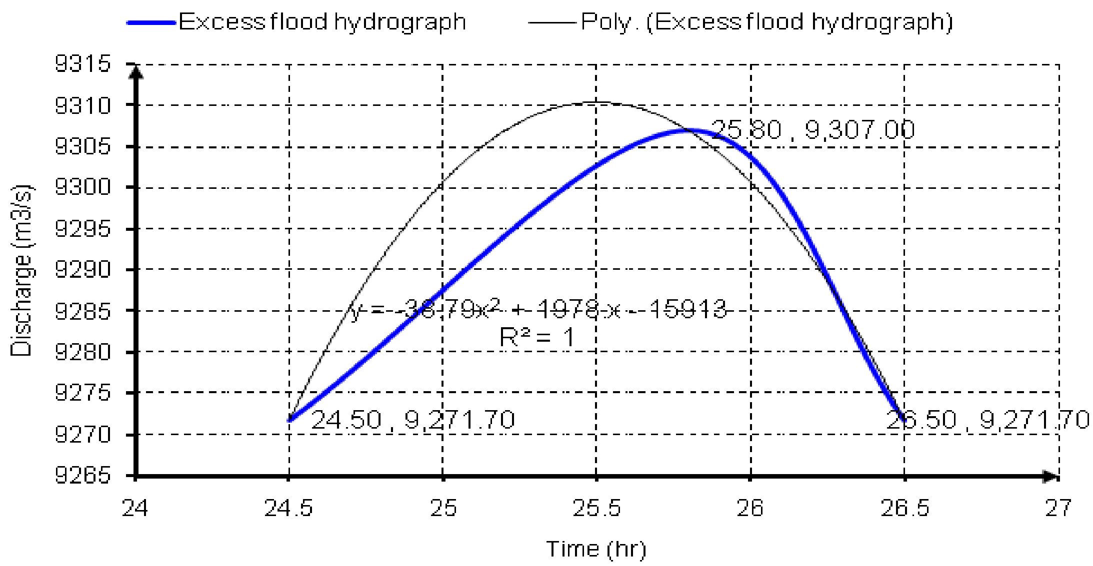


Figure 4:2 : Unexpected Flood Hydrograph and Trend Line

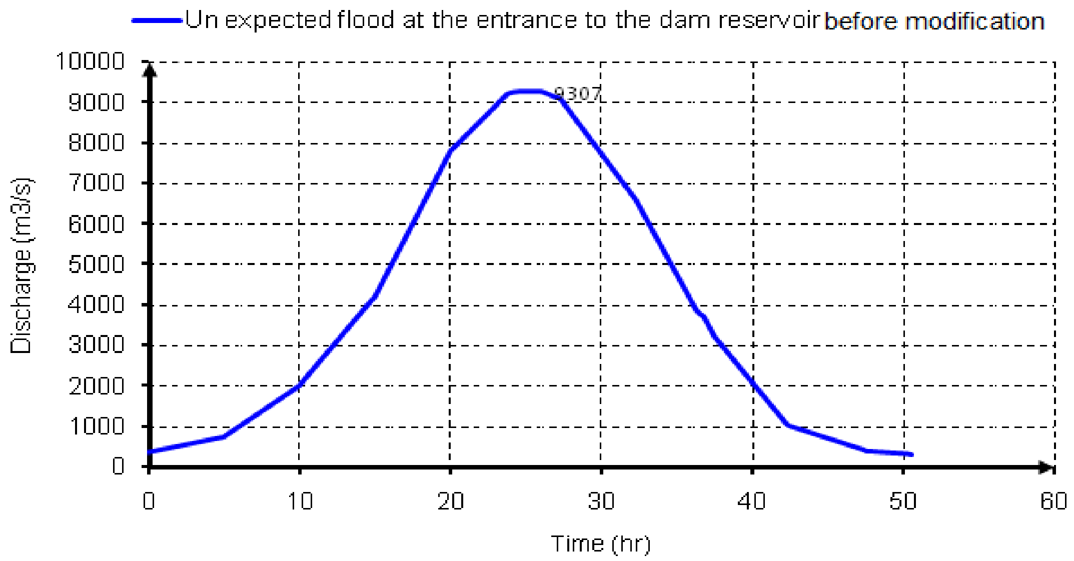


Figure 4:3 : Unexpected Flood at Node 0 before Min s and Max n Modification

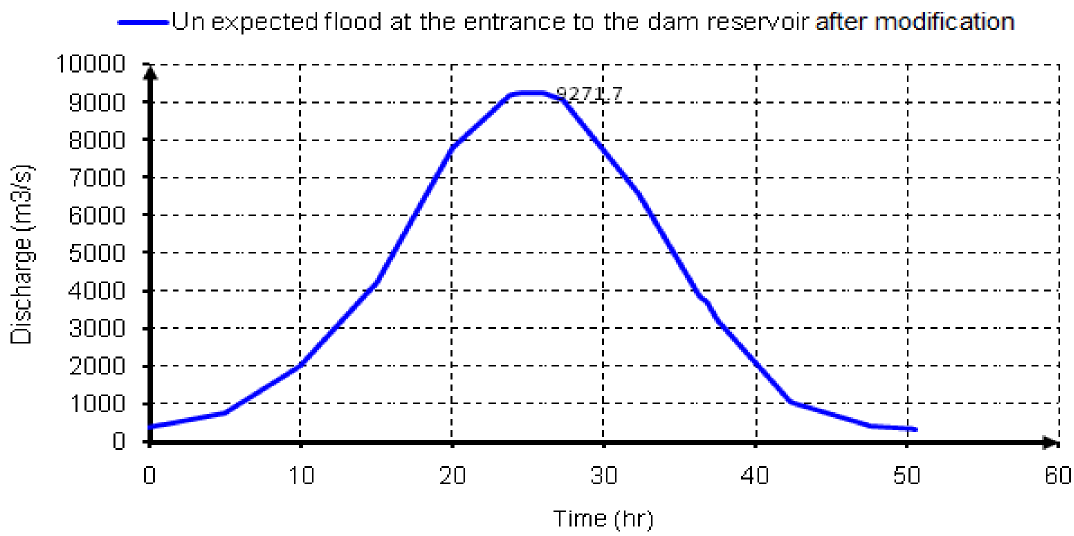


Figure 4:4 : Unexpected Flood at Node 0 after Min s and Max n Modification

Here the main point specially the hydrologist should be carried according to this research paper result shows that it might be the best way considering the hydraulic flood controlling measures for the reduction of flood risks that come due to climate change, hydrologic data constraint and the like during the estimation and fixing the flood design discharge of a hydraulic project.

4.3 Unexpected Flood Control for Lower Return Periods

The return period of *Kesem Kebena* Dam and Irrigation Project main dam design flood was 10,000 years. The corresponding design flood also 9237m^3/s for 10,000 years return period and 3765m^3/s for 100 years return period. The study tried to show the relevance of the measures in the case of lower return period design floods. Accordingly, in the case of 100 years return period for maximum roughness coefficient and minimum slope river combination modifications, there was a 20m^3/s discharge reduction when compared to the design flood that should be found at the entrance to the dam reservoir, which means there is a 0.53% flood discharge reduction. From this, what can be suggested is that the study was more relevant for design floods which have lower return periods.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The case study area was *Kesem River,* which is found upstream of *Kesem Kebena Dam. T*he main objectives of the study were to look for solutions which help in reducing failures of hydraulic structures due to unexpected flood conditions, to determine the amount of flood percentage that can reduce by exercising the prioritized hydraulic measures and to prioritize hydraulic measures for controlling of unexpected flood during the service life of a hydraulic structure.

In this study, prioritized flood controlling hydraulic measures were studied. The prioritized measures were river channel character improvement, soil conservation, improve the storage character of the reservoir, diversion of a portion of the flood through flood ways, providing a temporary storage of the peak floods and confining the flow between high banks. Among these measures river channel character improvement was the main research work and studied in detail.

From the computation made, the study shown hydraulic measures are one means of controlling unexpected flood. Moreover, combined river channel character improvement hydraulic measures are the best means of flood controlling and then these should be considered while designing and constructing hydraulic structures across a river for controlling unexpected flood.

The study tried to show the percentage of flood which can be reduced by exercising the best prioritized measure i.e. river channel character improvement.

In the design of hydraulic structures especially which are vulnerable to floods hydrologic considerations alone will lead to uneconomic way and great uncertainties. Therefore, the study also concluded that hydraulic measures are one means of resolving such kinds of problems.

Generally, the study looked for solutions that will help in reducing failures of hydraulic structures due to unexpected flood conditions, prioritized hydraulic measures for controlling of unexpected flood and shows hydraulic measures are the other solutions for unexpected flood conditions.

5.2 Recommendation

Finally, the study would like to recommend: Further research should be carried out by increasing the river length on the study area and for other catchments.

In addition to this, further research also has to be conducted for the prioritized hydraulic measures with in conjunction of detail cost estimation analysis because this study omits the consideration of cost analysis of the hydraulic measures.

The result of the study is very helpful for flood mitigation works. Therefore, stakeholders like ministry of water, irrigation and energy shoud refer and use this paper.

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ANNEX 1 : PRIMARY COLLECTED DATAS

No	River Stationing	Station	River Bank Elevation (m)	Water Surface Elevation (m)	Avergae Upstream Reach Length (m)	Avergae Manning's Value (n)	River Description	Channel Depth (m)
1	N_0	0	945.0		258	0.02	Clean, straight, full, no rifts	4.5
		20	939.0	939.0				
		25	938.5	939.0				
		50	937.0	939.0				
		75	934.5	939.0				
		100	934.5	939.0				
		125	934.7	939.0				
		150	934.9	939.0				
		175	936.2	939.0				
		200	936.8	939.0				
		225	937.2	939.0				
		250	937.5	939.0				
		285	939.0	939.0				
		305	945.0					
2	N_1	0	946.0		303	0.02	Clean, straight, full, no rifts	4.3
		26	939.4	939.4				
		30	938.0	939.4				
		50	936.5	939.4				
		75	935.6	939.4				
		100	935.2	939.4				
		125	935.9	939.4				
		150	935.9	939.4				
		175	935.1	939.4				
		200	935.9	939.4				
		225	936.3	939.4				
		250	937.0	939.4				
		275	938.0	939.4				
		300	938.5	939.4				
		327	939.4	939.4				
		350	945.5					
3	N_2	0	945.5		300	0.02	Clean, straight, full, no rifts	4.5
		20	940.2	940.2				
		25	939.2	940.2				
		50	939.0	940.2				
		75	938.5	940.2				
		100	937.0	940.2				
		125	935.8	940.2				
		150	935.7	940.2				
		175	935.9	940.2				
		200	935.9	940.2				
		225	935.9	940.2				
		250	935.9	940.2				
		275	935.9	940.2				
		300	936.8	940.2				
		325	939.0	940.2				
		333	940.2	940.2				
		350	945.0					

4	N_3	0	946.7		136	0.03	Clean, straight, full, no rifts and more stones	4.6
		18	940.7	940.7				
		20	939.7	940.7				
		50	936.7	940.7				
		75	936.1	940.7				
		100	936.6	940.7				
		125	936.5	940.7				
		150	936.5	940.7				
		175	936.5	940.7				
		200	939.5	940.7				
		230	940.7	940.7				
		249	946.5					
5	N_4	0	946.0		130	0.03	Clean, straight, full, no rifts and more stones	5.5
		15	941.2	941.2				
		25	938.8	941.2				
		50	936.7	941.2				
		75	936.2	941.2				
		100	935.7	941.2				
		125	935.7	941.2				
		150	936.7	941.2				
		175	939.8	941.2				
		195	941.2	941.2				
		210	946.0					
6	N_5	0	946.0		181.2	0.03	Clean, straight, full, no rifts and more stones	4.3
		20	941.0	941.5				
		25	939.0	941.5				
		50	937.0	941.5				
		75	936.9	941.5				
		100	937.2	941.5				
		125	936.9	941.5				
		150	936.9	941.5				
		175	936.9	941.5				
		200	937.0	941.5				
		225	939.0	941.5				
		249	941.2	941.5				
		270	946.0					
7	N_6	0	947.0		183.1	0.03	Clean, straight, full, no rifts and more stones	4.8
		18	941.7	941.7				
		25	938.0	941.7				
		50	937.0	941.7				
		75	936.9	941.7				
		100	936.9	941.7				
		125	936.9	941.7				
		150	938.0	941.7				
		175	939.0	941.7				
		210	941.7	941.7				
		230	947.0					

8	N_7	0	947.0		90.8	0.025	Clean, straight, full, no rifts and less stones	5.3
		20	942.5	942.5				
		30	941.0	942.5				
		50	939.0	942.5				
		75	937.5	942.5				
		100	937.2	942.5				
		125	937.3	942.5				
		150	937.2	942.5				
		175	937.4	942.5				
		200	938.2	942.5				
		238	942.5	942.5				
		255	947.0					
9	N_8	0	948.0		158.3	0.025	Clean, straight, full, no rifts and less stones	5.5
		25	943.0	943.0				
		50	939.0	943.0				
		75	937.6	943.0				
		100	937.5	943.0				
		125	937.6	943.0				
		150	937.6	943.0				
		175	938.0	943.0				
		200	939.0	943.0				
		225	941.0	943.0				
		250	943.0	943.0				
		270	948.0					
10	N_9	0	948.0		100	0.025	Clean, straight, full, no rifts and less stones	5.0
		18	943.2	943.2				
		25	940.3	943.2				
		50	939.2	943.2				
		75	938.2	943.2				
		100	938.2	943.2				
		125	938.2	943.2				
		150	938.2	943.2				
		175	938.7	943.2				
		200	941.3	943.2				
		243	942.8	943.2				
		260	948.0					
11	N_{10}	0	949.0		169.6	0.025	Clean, straight, full, no rifts and less stones	4.8
		15	943.7	943.7				
		25	940.8	943.7				
		50	939.4	943.7				
		75	938.9	943.7				
		100	938.9	943.7				
		125	938.9	943.7				
		150	938.9	943.7				
		175	939.9	943.7				
		200	942.0	943.7				
		218	943.7	943.7				
		235	949.0					

12	N_{11}	0	949.0		146.2	0.025	Clean, straight, full, no rifts and less stones	4.5
		17	943.9	943.9				
		25	940.8	943.9				
		50	939.6	943.9				
		75	939.4	943.9				
		100	939.4	943.9				
		125	939.4	943.9				
		150	939.4	943.9				
		175	940.7	943.9				
		207	943.9	943.9				
		220	949.0					
13	N_{12}	0	949.0		238	0.025	Clean, straight, full, no rifts and less stones	4.3
		15	944.0	944.2				
		25	942.0	944.2				
		50	941.0	944.2				
		75	939.9	944.2				
		100	939.9	944.2				
		125	939.9	944.2				
		150	940.0	944.2				
		175	940.2	944.2				
		200	942.0	944.2				
		232	944.2	944.2				
		250	949.0					
14	N_{13}	0	951.0		161.8	0.025	Clean, straight, full, no rifts and less stones	4.2
		20	946.0	946.0				
		25	944.5	946.0				
		50	943.4	946.0				
		75	941.9	946.0				
		100	941.8	946.0				
		125	941.8	946.0				
		150	942.0	946.0				
		175	943.0	946.0				
		200	944.5	946.0				
		224	946.0	946.0				
		240	951.0					
15	N_{14}	0	952.0		162	0.02	Clean, straight, full, no rifts	4.1
		15	946.4	946.4				
		25	943.2	946.4				
		50	942.8	946.4				
		75	942.3	946.4				
		100	942.3	946.4				
		125	942.3	946.4				
		150	942.3	946.4				
		175	942.3	946.4				
		200	942.3	946.4				
		225	942.4	946.4				
		250	943.4	946.4				
		285	946.4	946.4				
		300	952.0					

16	N_{15}	0	952.0		155.9	0.02	Clean, straight, full, no rifts	4.0
		18	947.0	947.0				
		25	945.0	947.0				
		50	943.5	947.0				
		75	943.2	947.0				
		100	943.0	947.0				
		125	943.0	947.0				
		150	943.0	947.0				
		175	943.0	947.0				
		200	943.2	947.0				
		225	943.8	947.0				
		268	947.0	947.0				
		285	952.0					
17	N_{16}	0	952.0		169.2	0.02	Clean, straight, full, no rifts	3.4
		15	948.0	948.0				
		25	947.1	948.0				
		50	946.0	948.0				
		75	945.0	948.0				
		100	944.6	948.0				
		125	944.6	948.0				
		150	944.6	948.0				
		175	944.6	948.0				
		200	944.6	948.0				
		225	944.6	948.0				
		250	944.6	948.0				
		275	944.6	948.0				
		300	944.6	948.0				
		325	944.6	948.0				
		350	944.6	948.0				
		375	945.0	948.0				
		400	945.6	948.0				
		435	948.0	948.0				
		450	952.0					
18	N_{17}	0	953.0		199.2	0.03	Clean, straight, full, no rifts and more stones	3.3
		17	948.3	948.3				
		25	947.0	948.3				
		50	946.5	948.3				
		75	946.0	948.3				
		100	945.4	948.3				
		125	945.0	948.3				
		150	945.0	948.3				
		175	945.0	948.3				
		200	945.0	948.3				
		225	945.0	948.3				
		250	945.0	948.3				
		275	945.0	948.3				
		300	945.0	948.3				
		325	945.0	948.3				
		350	945.0	948.3				
		375	945.4	948.3				
		400	945.4	948.3				
		425	947.5	948.3				
		450	948.0	948.3				
		470	948.3	948.3				
		485	953.0					

19	N_{18}	0	954.0		118	0.03	Clean, straight, full, no rifts and more stone	3.0
		19	949.0	949.0				
		25	948.0	949.0				
		50	947.0	949.0				
		75	946.5	949.0				
		100	946.4	949.0				
		125	946.1	949.0				
		150	946.0	949.0				
		175	946.0	949.0				
		200	946.0	949.0				
		225	946.0	949.0				
		250	946.0	949.0				
		275	946.0	949.0				
		300	946.0	949.0				
		325	946.0	949.0				
		350	946.0	949.0				
		375	946.0	949.0				
		400	946.4	949.0				
		425	948.0	949.0				
		467	949.0	949.0				
		480	954.0					
20	N_{19}	0	955.0		204	0.03	Clean, straight, full, no rifts and more stone	3.6
		15	950.3	950.3				
		25	948.8	950.3				
		50	948.2	950.3				
		75	948.0	950.3				
		100	947.8	950.3				
		125	947.5	950.3				
		150	947.2	950.3				
		175	947.0	950.3				
		200	946.7	950.3				
		225	946.7	950.3				
		250	946.7	950.3				
		275	946.7	950.3				
		300	946.7	950.3				
		325	947.0	950.3				
		350	947.7	950.3				
		375	947.8	950.3				
		400	948.8	950.3				
		425	949.8	950.3				
		450	950.3	950.3				
		467	955.0					

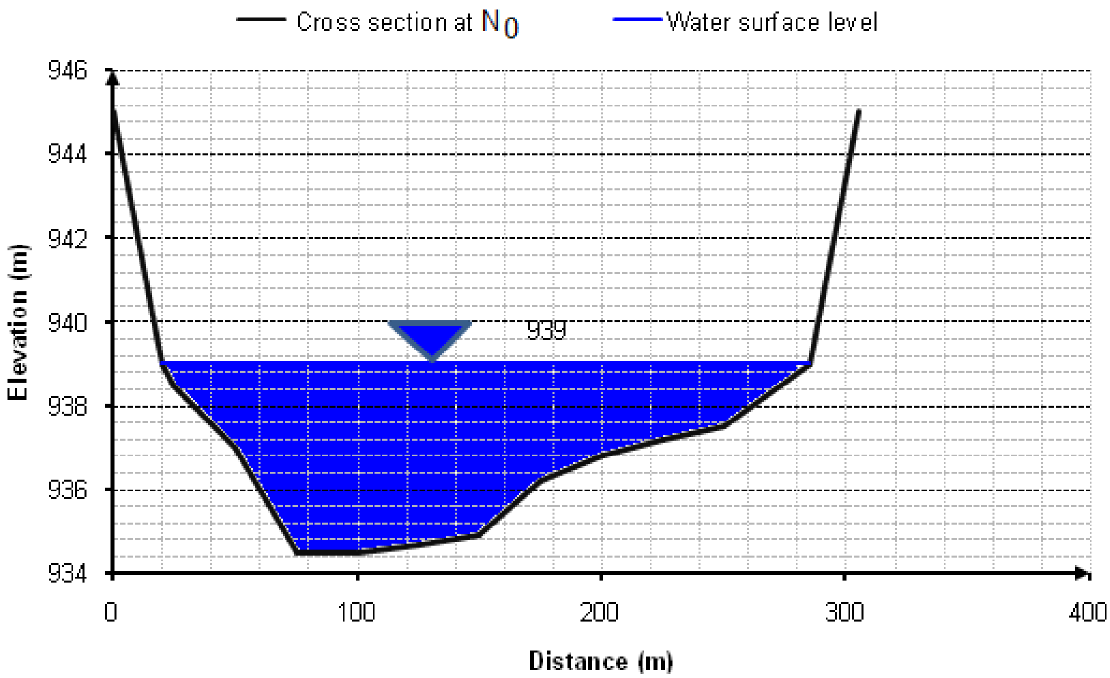
21	N_{20}	0	955.0		169	0.03	Clean, straight, full, no rifts and more stone	3.6
		14	950.5	950.5				
		25	947.5	950.5				
		50	947.4	950.5				
		75	947.4	950.5				
		100	946.9	950.5				
		125	946.9	950.5				
		150	946.9	950.5				
		175	946.9	950.5				
		200	946.9	950.5				
		225	946.9	950.5				
		250	946.9	950.5				
		275	946.9	950.5				
		300	946.9	950.5				
		325	947.4	950.5				
		350	947.4	950.5				
		375	947.5	950.5				
		410	950.5	950.5				
		425	955.0					
22	N_{21}	0	955.0		136	0.03	Clean, straight, full, no rifts and more stone	4.1
		14	951.0	951.0				
		25	949.0	951.0				
		50	947.9	951.0				
		75	947.9	951.0				
		100	947.4	951.0				
		125	946.9	951.0				
		150	946.9	951.0				
		175	946.9	951.0				
		200	946.9	951.0				
		225	946.9	951.0				
		250	946.9	951.0				
		275	946.9	951.0				
		300	946.9	951.0				
		325	947.5	951.0				
		350	949.0	951.0				
		375	950.0	951.0				
		390	951.0	951.0				

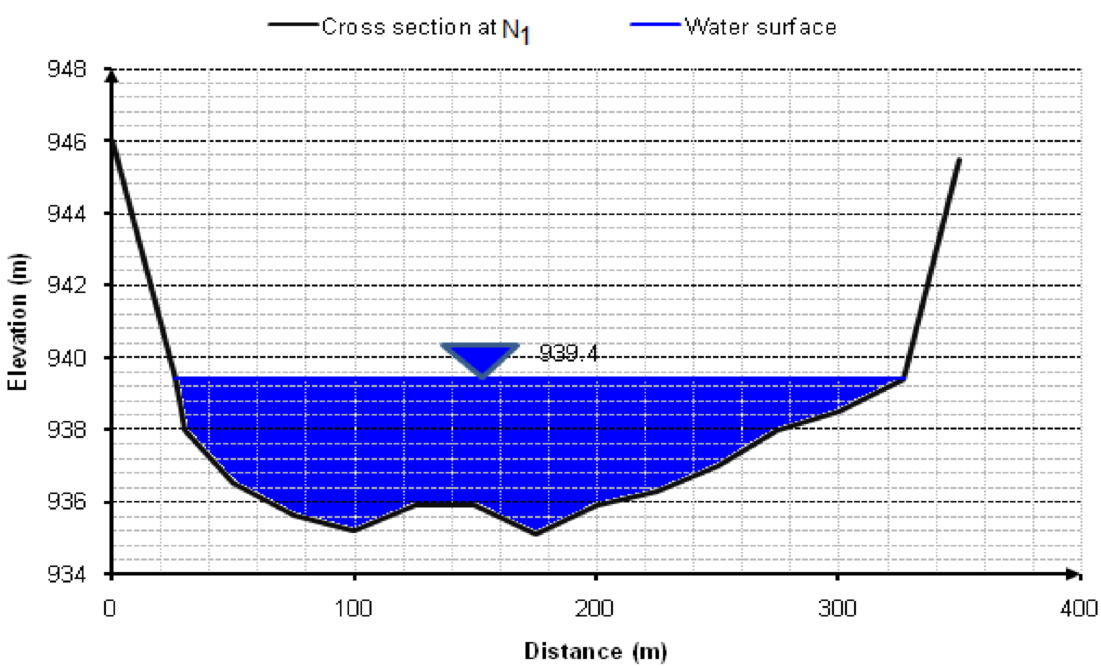
23	N_{22}	405	955.0		132	0.03	Clean, straight, full, no rifts and more stone	4.1
		0	956.0					
		15	952.0	952.0				
		25	951.5	952.0				
		50	950.0	952.0				
		75	948.5	952.0				
		100	947.9	952.0				
		125	947.9	952.0				
		150	947.9	952.0				
		175	947.9	952.0				
		200	947.9	952.0				
		225	947.9	952.0				
		250	947.9	952.0				
		275	948.9	952.0				
		300	949.9	952.0				
		325	950.2	952.0				
		350	951.2	952.0				
		370	952.0	952.0				
24	N_{23}	385	956.0		245	0.03	Clean, straight, full, no rifts and more stone	4.1
		0	957.0					
		13	953.0	953.0				
		25	951.0	953.0				
		50	948.9	953.0				
		75	948.9	953.0				
		100	948.9	953.0				
		125	948.9	953.0				
		150	948.9	953.0				
		175	948.9	953.0				
		200	948.9	953.0				
		225	948.9	953.0				
		250	948.9	953.0				
		275	948.9	953.0				
		300	949.4	953.0				
		325	950.5	953.0				
		350	952.0	953.0				
		375	952.5	953.0				
		395	953.0	953.0				
25	N_{24}	408	957.0		264	0.04	Mountain Streams, no vegetation in channel, banks usually steep, gravels, cobbles, and few boulders	3.6
		0	959.0					
		14	955.0	955.0				
		25	954.0	955.0				
		50	952.9	955.0				
		75	952.9	955.0				
		100	952.5	955.0				
		125	952.0	955.0				
		150	951.4	955.0				
		175	951.4	955.0				
		200	951.4	955.0				
		225	951.4	955.0				
		250	951.4	955.0				
		275	951.4	955.0				
		300	951.9	955.0				
		325	953.5	955.0				
		344	955.0	955.0				

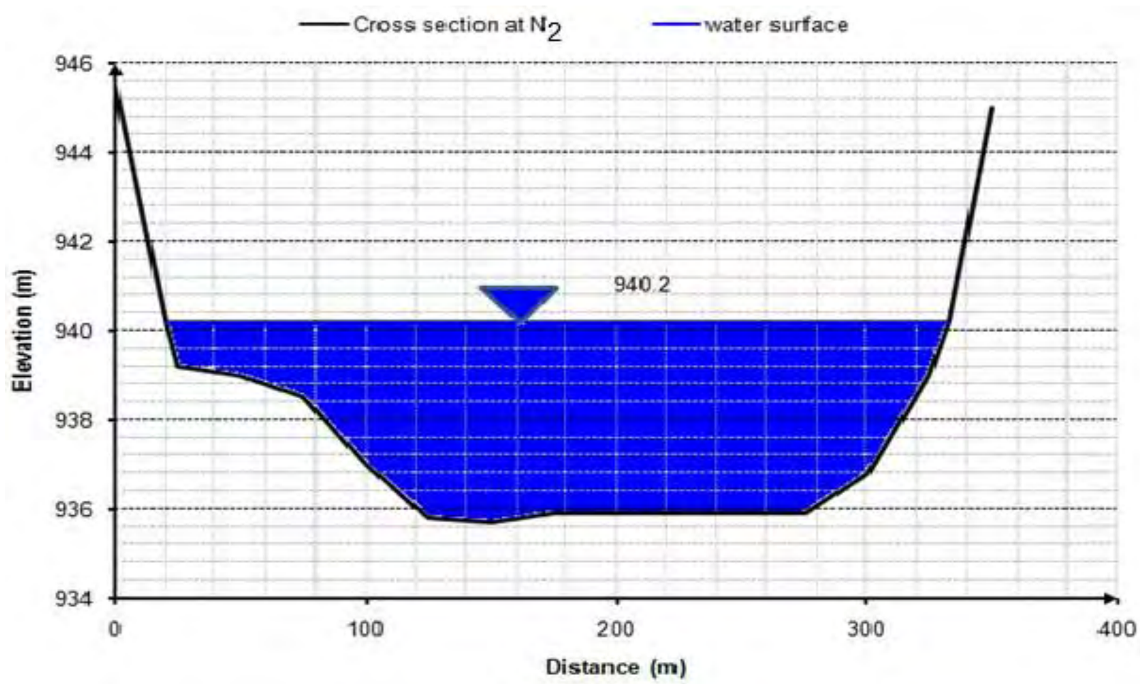
26	N_{25}	360	959.0		209	0.04	Mountain Streams, no vegetation in channel, banks usually steep, gravels, cobbles, and few boulders	3.1
		0	960.0					
		15	956.1	956.1				
		25	954.6	956.1				
		50	953.0	956.1				
		75	953.0	956.1				
		100	953.0	956.1				
		125	953.0	956.1				
		150	953.0	956.1				
		175	953.0	956.1				
		200	953.0	956.1				
		225	953.0	956.1				
		250	953.5	956.1				
		275	954.1	956.1				
		300	954.6	956.1				
		320	956.1	956.1				
27	N_{26}	335	960.0		90.8	0.04	Mountain Streams, no vegetation in channel, banks usually steep, gravels, cobbles, and few boulders	4.1
		0	961.0					
		14	957.0	957.0				
		25	954.0	957.0				
		50	953.0	957.0				
		75	952.9	957.0				
		100	952.9	957.0				
		125	952.9	957.0				
		150	952.9	957.0				
		175	952.9	957.0				
		200	952.9	957.0				
		225	952.9	957.0				
		250	953.9	957.0				
		285	957.0	957.0				
28	N_{27}	300	961.0		172	0.04	Mountain Streams, no vegetation in channel, banks usually steep, gravels, cobbles, and few boulders	4.1
		0	962.0					
		18	957.5	957.5				
		25	955.0	957.5				
		50	954.4	957.5				
		75	953.4	957.5				
		100	953.4	957.5				
		125	953.4	957.5				
		150	953.4	957.5				
		175	953.4	957.5				
		200	953.4	957.5				
		225	954.4	957.5				
		250	955.5	957.5				
		290	957.0	957.5				
29	N_{28}	305	962.0		221	0.04	Mountain Streams, no vegetation in channel, banks usually steep, gravels, cobbles, and few boulders	3.6
		0	963.0					
		14	959.0	959.0				
		25	956.4	959.0				
		50	955.4	959.0				
		75	955.4	959.0				
		100	955.4	959.0				
		125	955.4	959.0				
		150	955.4	959.0				
		175	955.4	959.0				
		200	955.4	959.0				
		225	955.4	959.0				
		250	956.4	959.0				
		279	959.0	959.0				

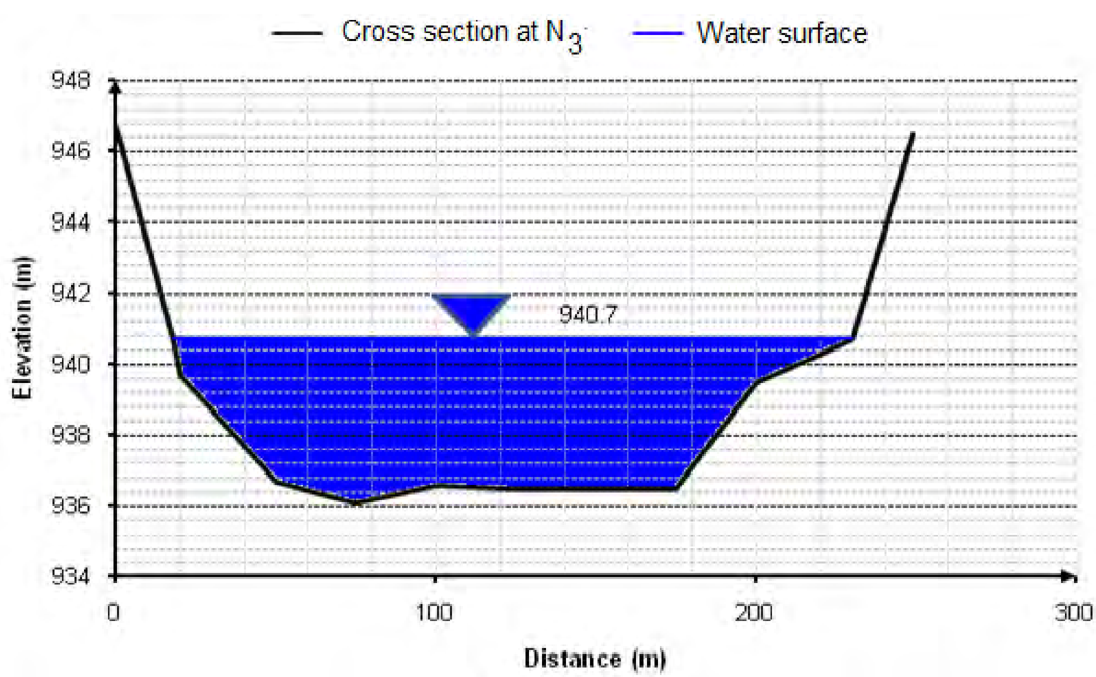
		295	963.0					
30	N_{29}	0	965.0		246	0.04	Mountain Streams, no vegetation in channel, banks usually steep, gravels, cobbles, and few boulders	3.4
		18	961.0	961.0				
		25	959.0	961.0				
		50	957.9	961.0				
		75	957.9	961.0				
		100	957.9	961.0				
		125	957.6	961.0				
		150	957.6	961.0				
		175	957.6	961.0				
		200	957.6	961.0				
		225	957.6	961.0				
		250	957.6	961.0				
		275	960.5	961.0				
		293	961.0	961.0				
31	N_{30}	310	965.0		Up stream end	0.04	Mountain Streams, no vegetation in channel, banks usually steep, gravels, cobbles, and few boulders	4.2
		0	965.0					
		20	962.0	962.0				
		25	959.0	962.0				
		50	957.8	962.0				
		75	957.8	962.0				
		100	957.8	962.0				
		125	957.8	962.0				
		150	957.8	962.0				
		175	957.8	962.0				
		200	958.4	962.0				
		240	962.0	962.0				
		260	965.0					

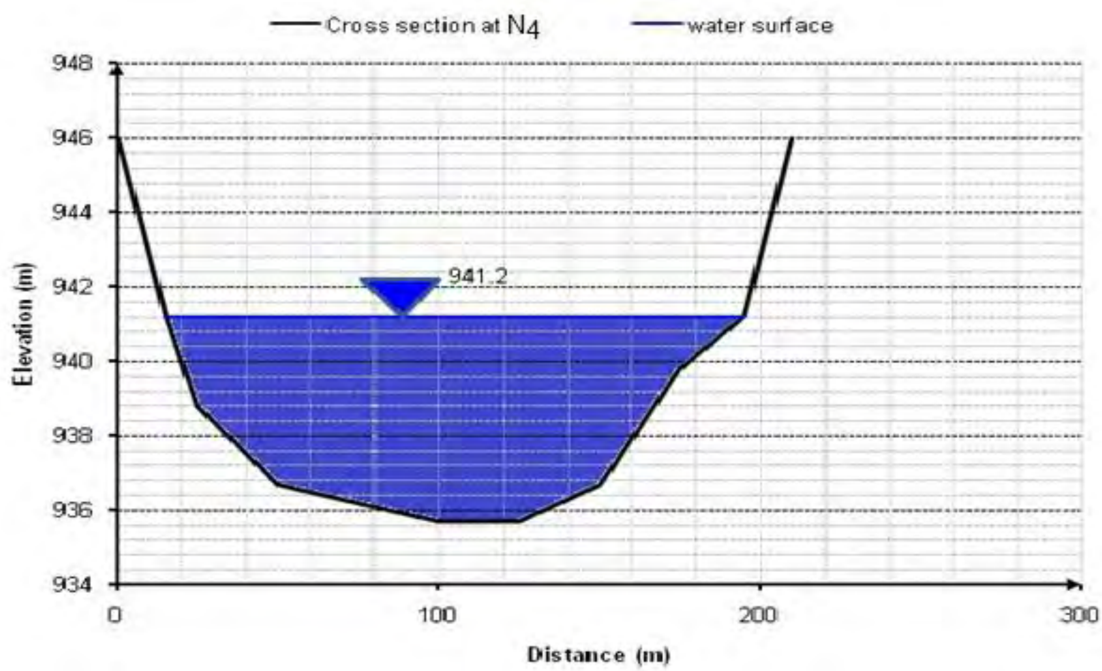
ANNEX 2 : RIVER NODE CROSS SECTION SCHEMATIZATION

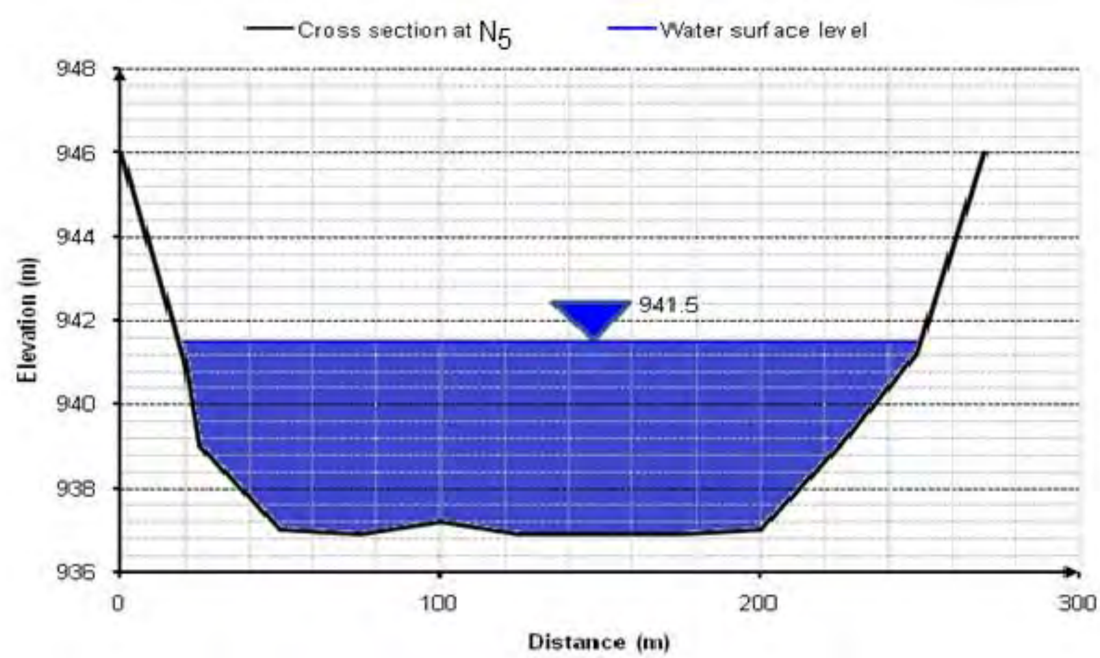


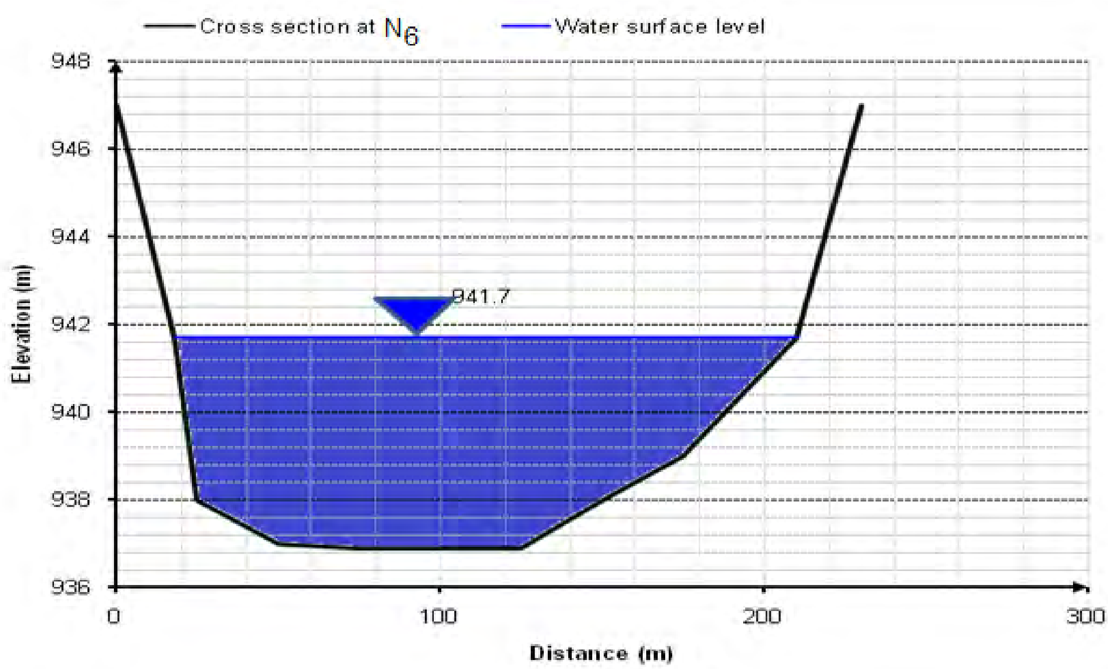


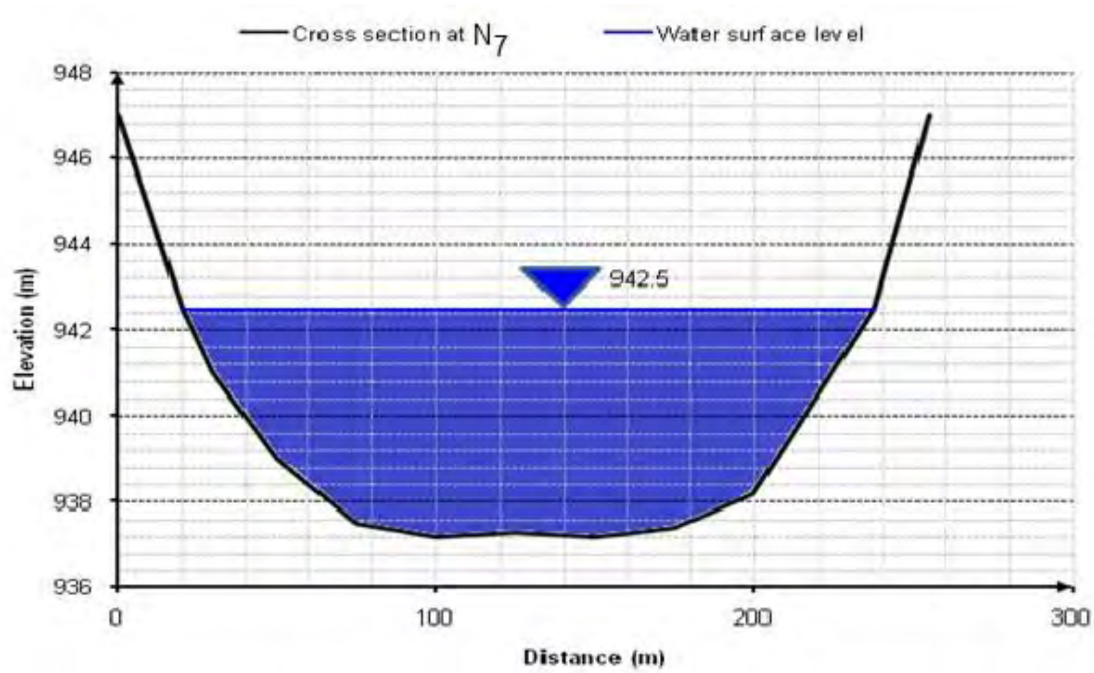

Cross section at N2
water surface
940.2
Elevation (m)
Distance (m)
946
944
942
940
938
936
934
0
100
200
300
400

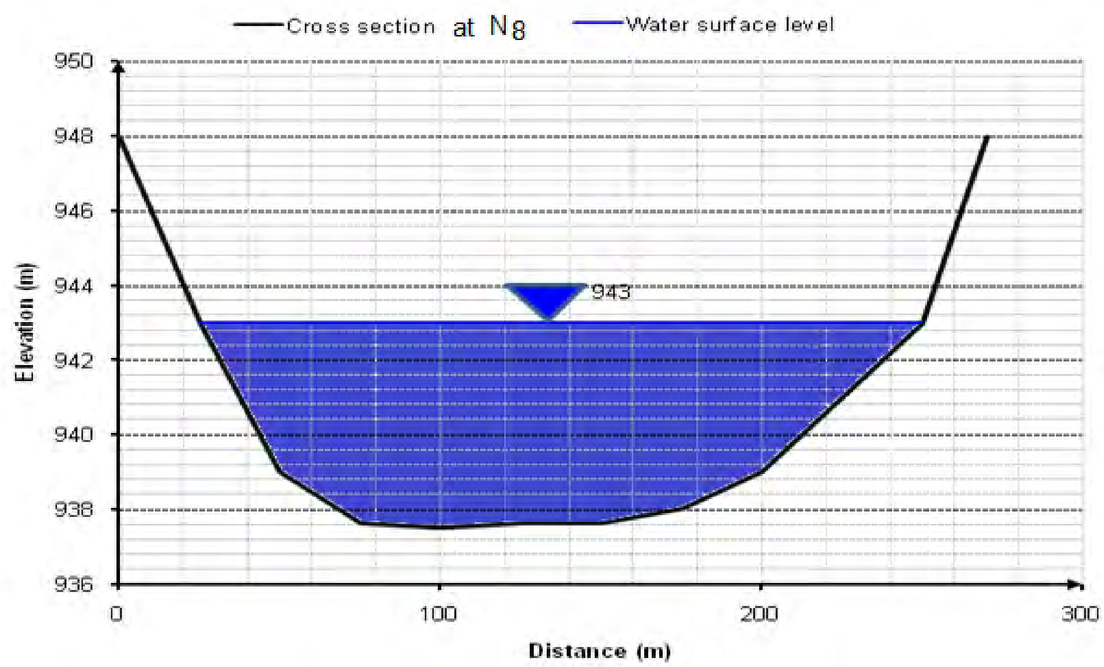

Cross section at N3
Water surface
940.7
Elevation (m)
Distance (m)
948
946
944
942
940
938
936
934
0
100
200
300

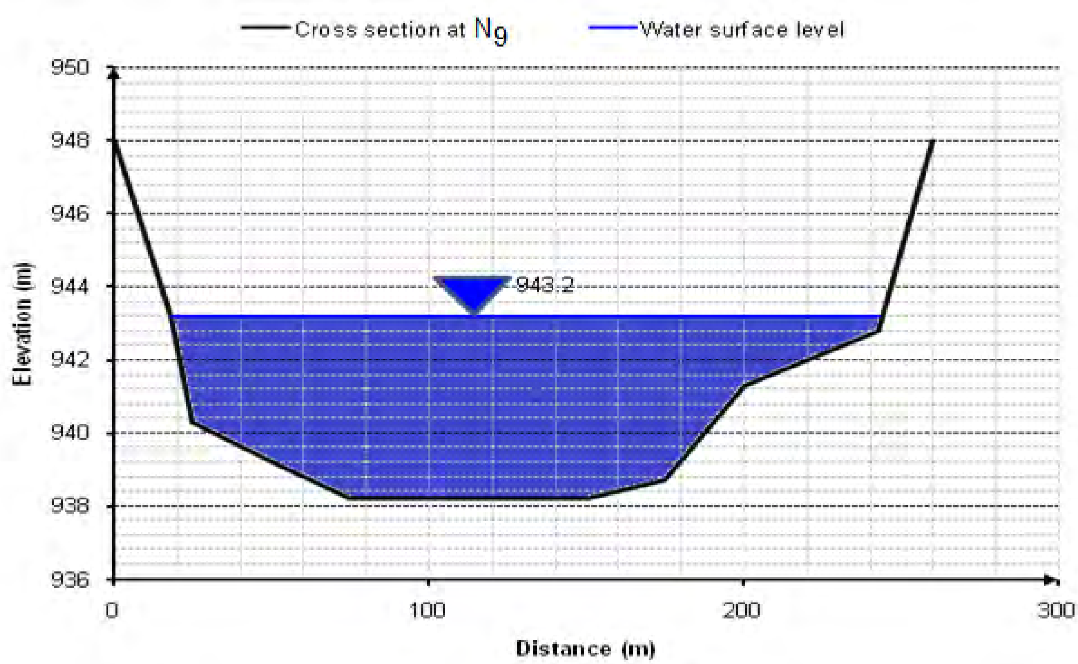

Cross section at N4
water surface
948
946
944
942
940
938
936
934
Elevation (m)
941.2
0
100
200
300
Distance (m)

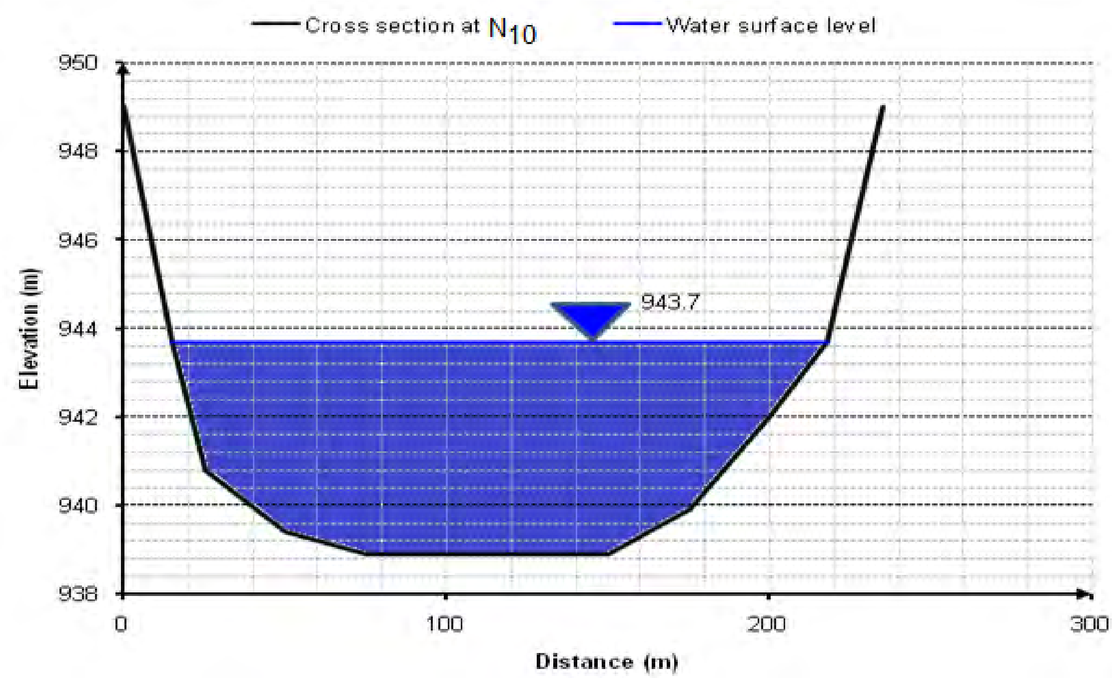

Cross section at N5
Water surface level
948
946
944
942
940
938
936
Elevation (m)
941.5
0
100
200
300
Distance (m)


Cross section at N_6
Water surface level
948
946
944
942
940
938
936
941.7
Elevation (m)
0
100
200
300
Distance (m)

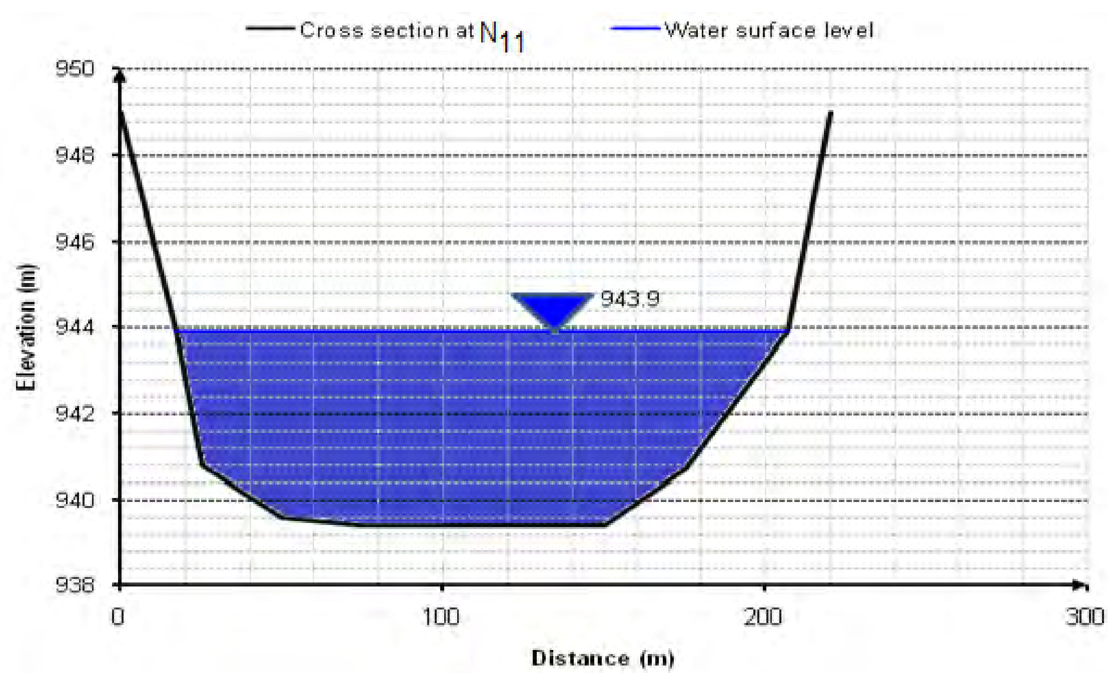

Cross section at N_7
Water surf ace lev el
948
946
944
942
940
938
936
942.5
Elevation (m)
0
100
200
300
Distance (m)


Cross section at N8
Water surface level
950
948
946
944
942
940
938
936
943
Elevation (m)
0
100
200
300
Distance (m)

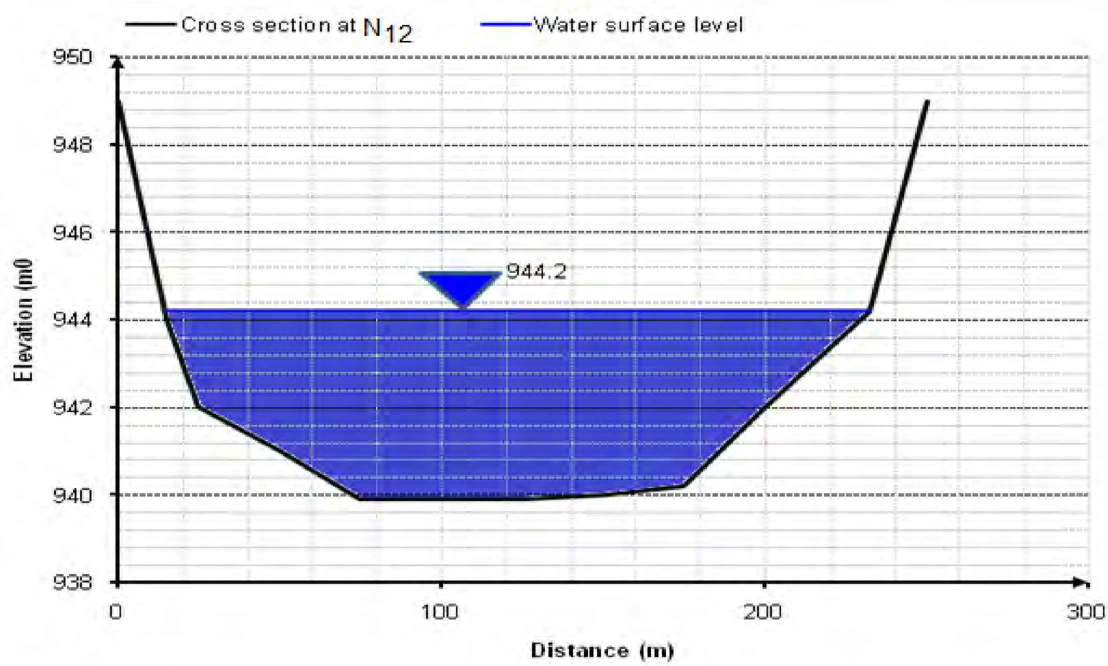

Cross section at N9
Water surface level
950
948
946
944
942
940
938
936
943.2
Elevation (m)
0
100
200
300
Distance (m)



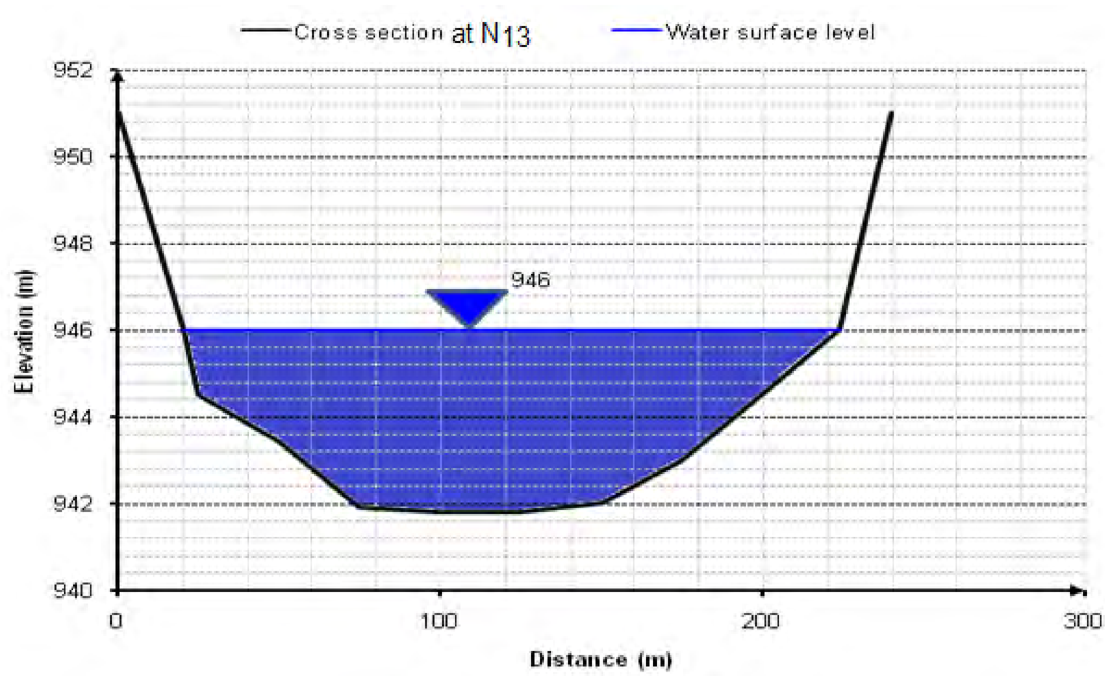
Cross section at N_{10}
Water surface level
943.7
Elevation (m)
Distance (m)
950
948
946
944
942
940
938
0
100
200
300



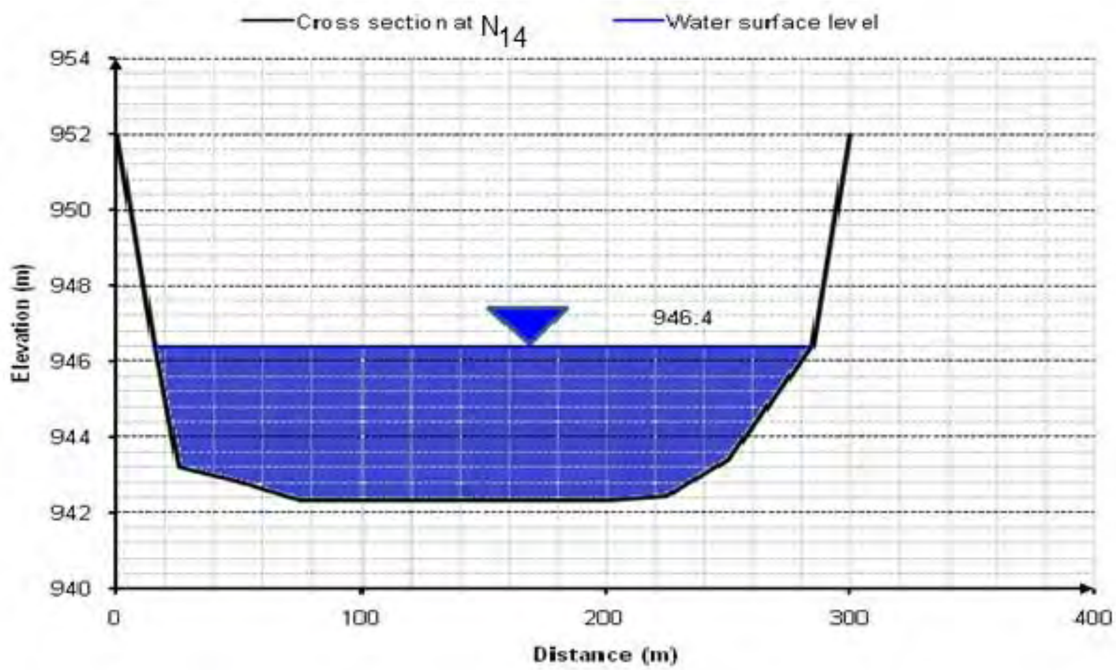
Cross section at N_{11}
Water surface level
943.9
Elevation (m)
Distance (m)
950
948
946
944
942
940
938
0
100
200
300

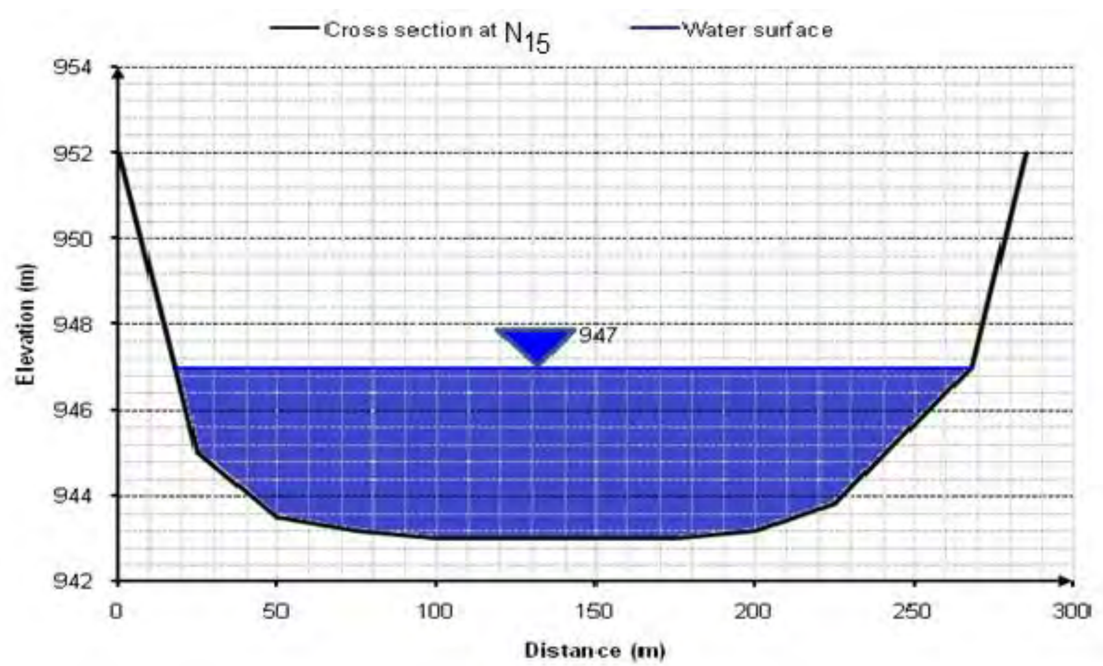


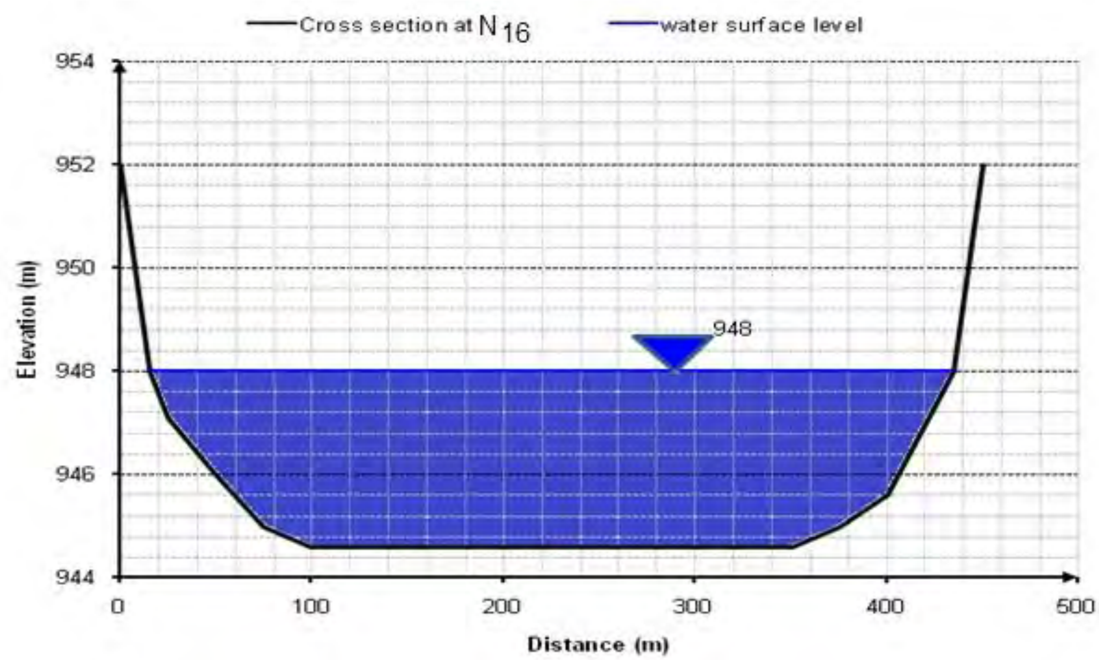
Cross section at N12
Water surface level
950
948
946
944
942
940
938
944.2
Elevation (m0
0
100
200
300
Distance (m)



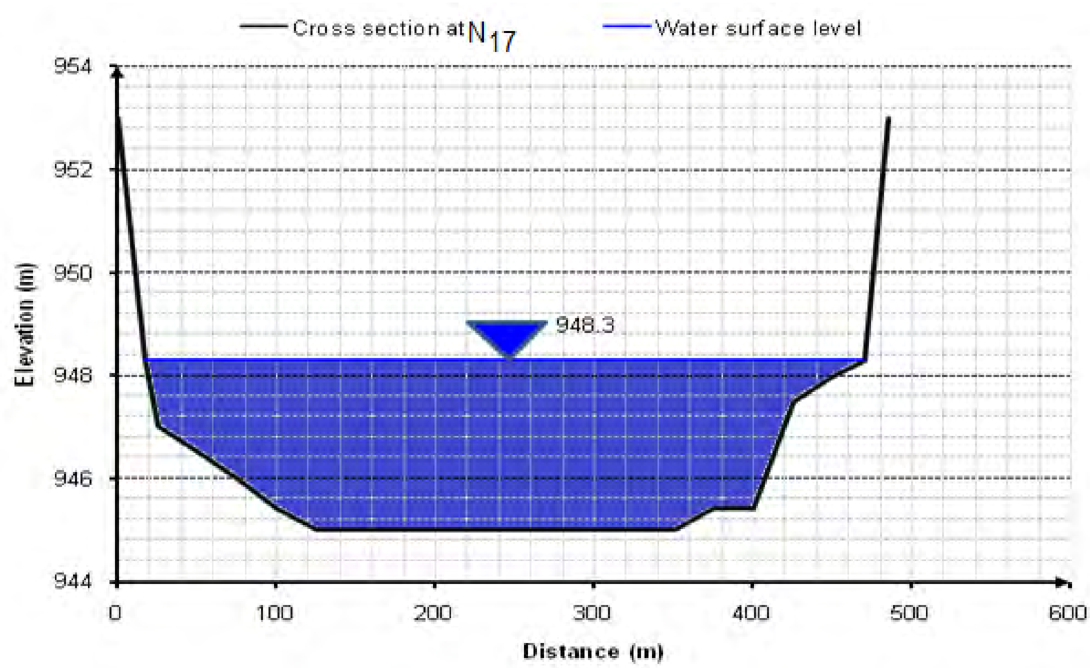
Cross section at N13
Water surface level
952
950
948
946
944
942
940
946
Elevation (m)
0
100
200
300
Distance (m)


Cross section at N_{14}
Water surface level
946.4
Elevation (m)
Distance (m)
954
952
950
948
946
944
942
940
0
100
200
300
400

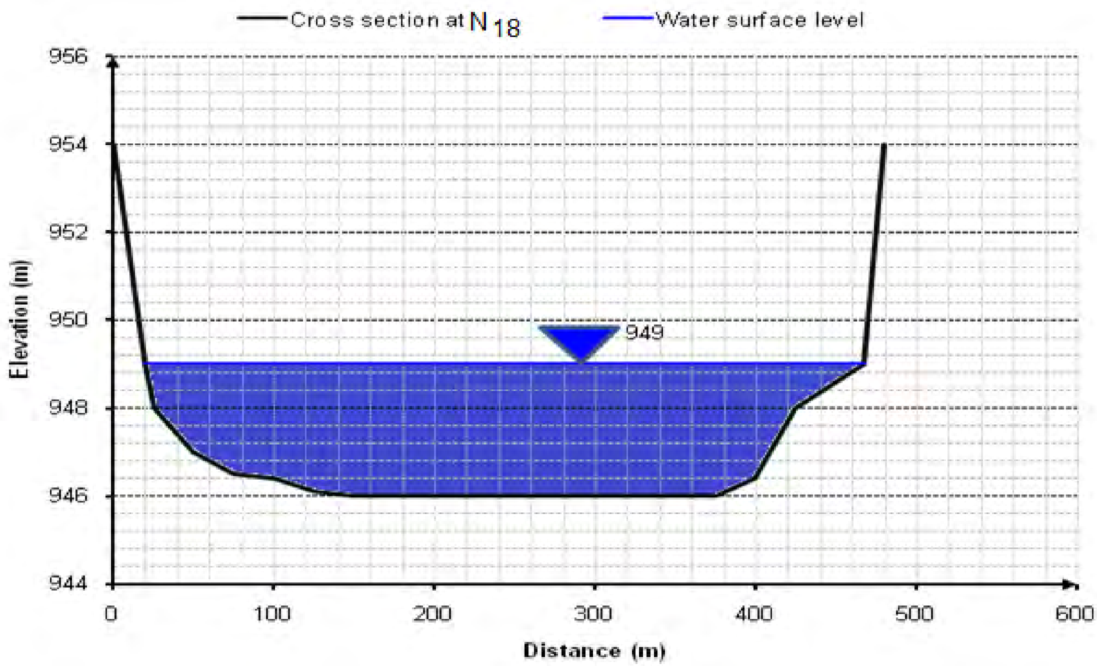

Cross section at N_{15}
Water surface
947
Elevation (m)
Distance (m)
954
952
950
948
946
944
942
0
50
100
150
200
250
300

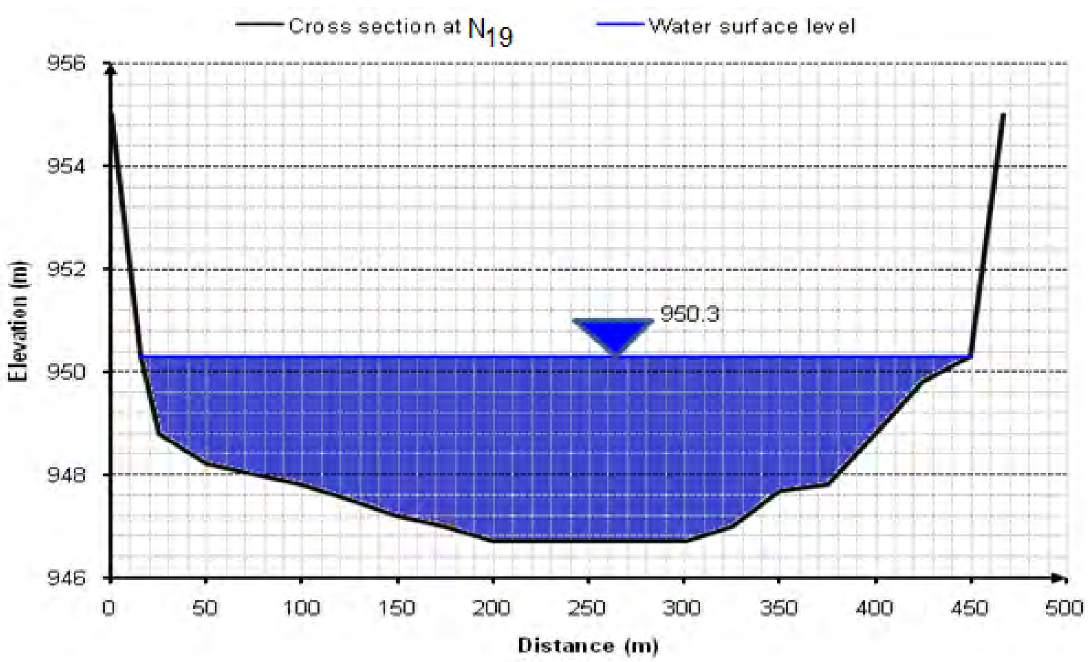


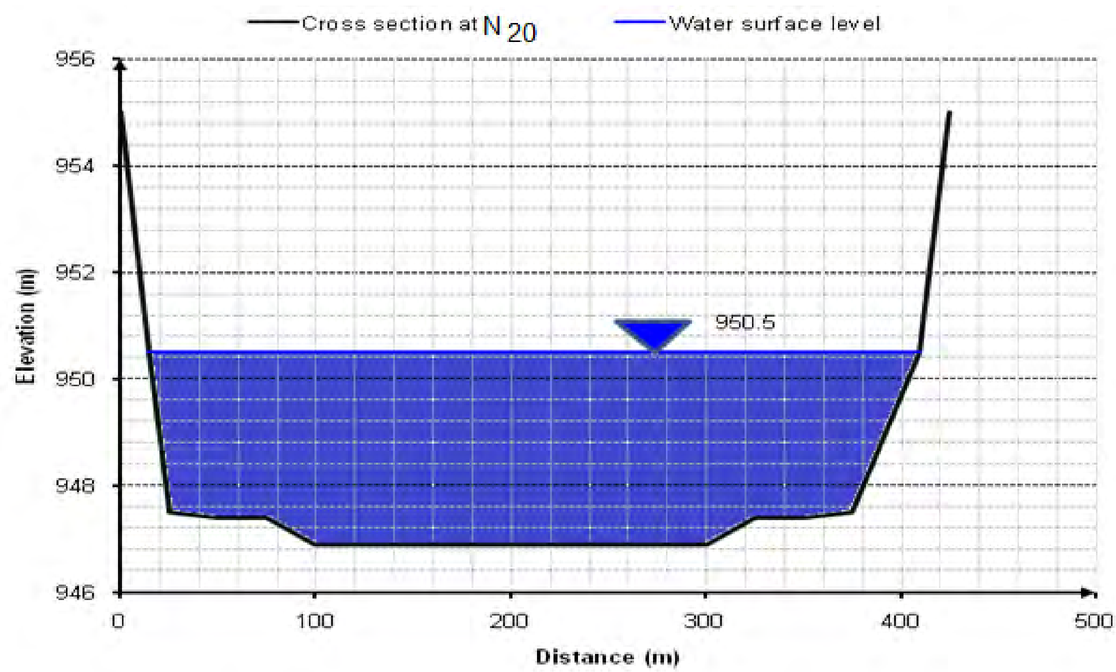
Cross section at N 16
water surface level
948
Elevation (m)
Distance (m)
954
952
950
948
946
944
0
100
200
300
400
500



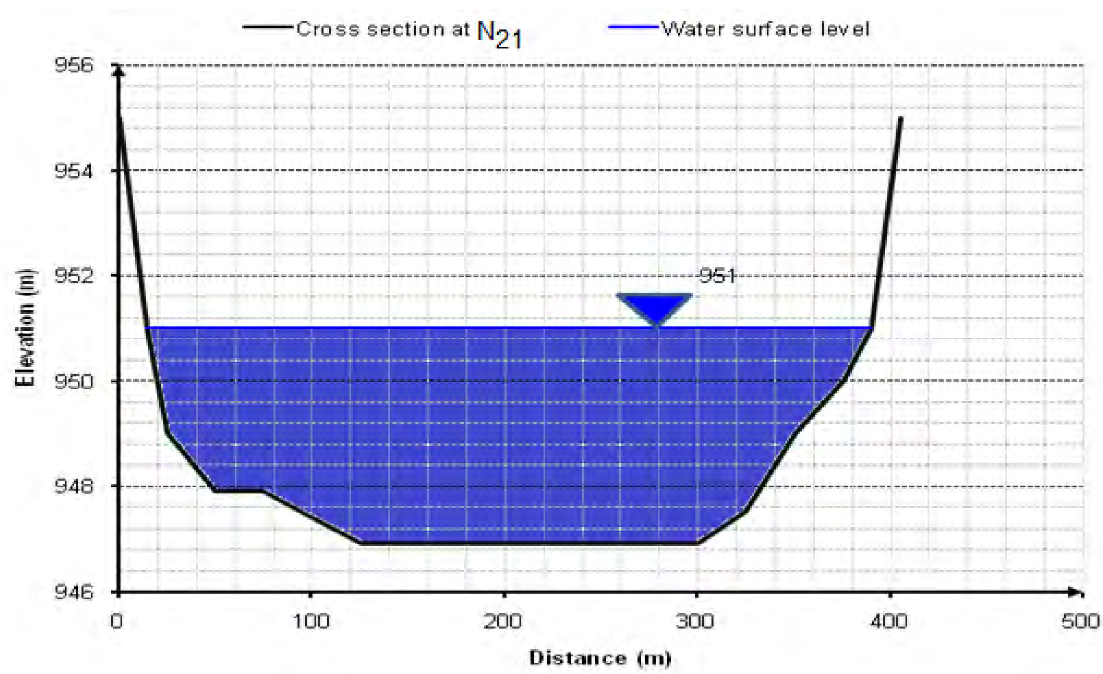
Cross section at N 17
Water surface level
948.3
Elevation (m)
Distance (m)
954
952
950
948
946
944
0
100
200
300
400
500
600


Cross section at N 18
Water surface level
949
Elevation (m)
Distance (m)
956
954
952
950
948
946
944
0
100
200
300
400
500
600

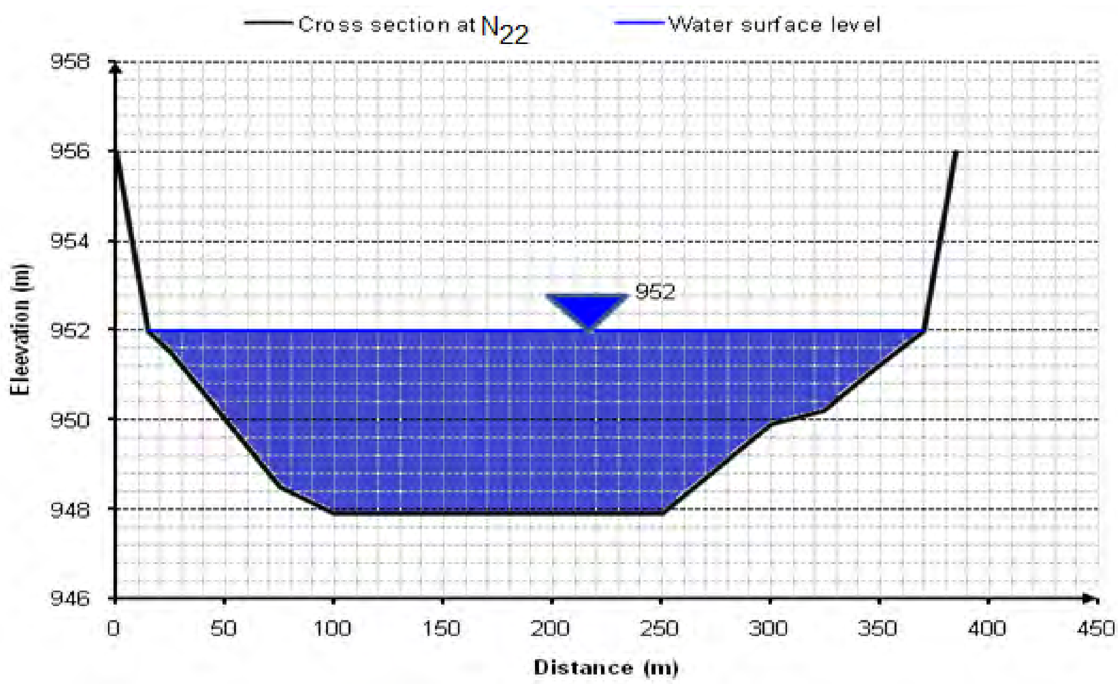

Cross section at N19
Water surface level
950.3
Elevation (m)
Distance (m)
956
954
952
950
948
946
0
50
100
150
200
250
300
350
400
450
500



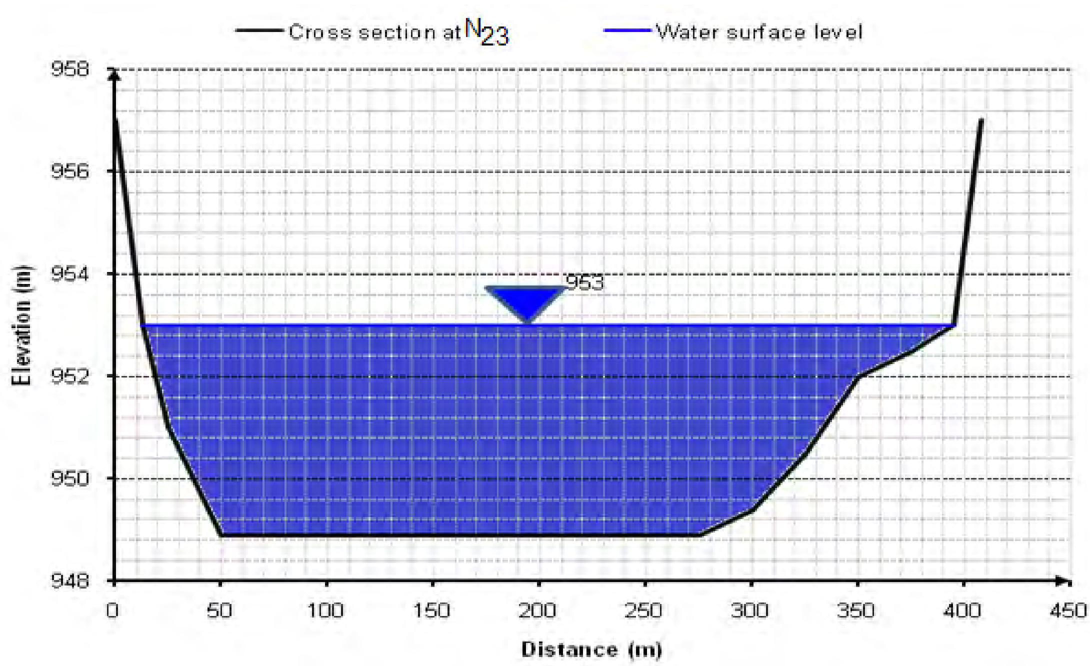
Cross section at N 20
Water surface level
956
954
952
950
948
946
950.5
Elevation (m)
0
100
200
300
400
500
Distance (m)



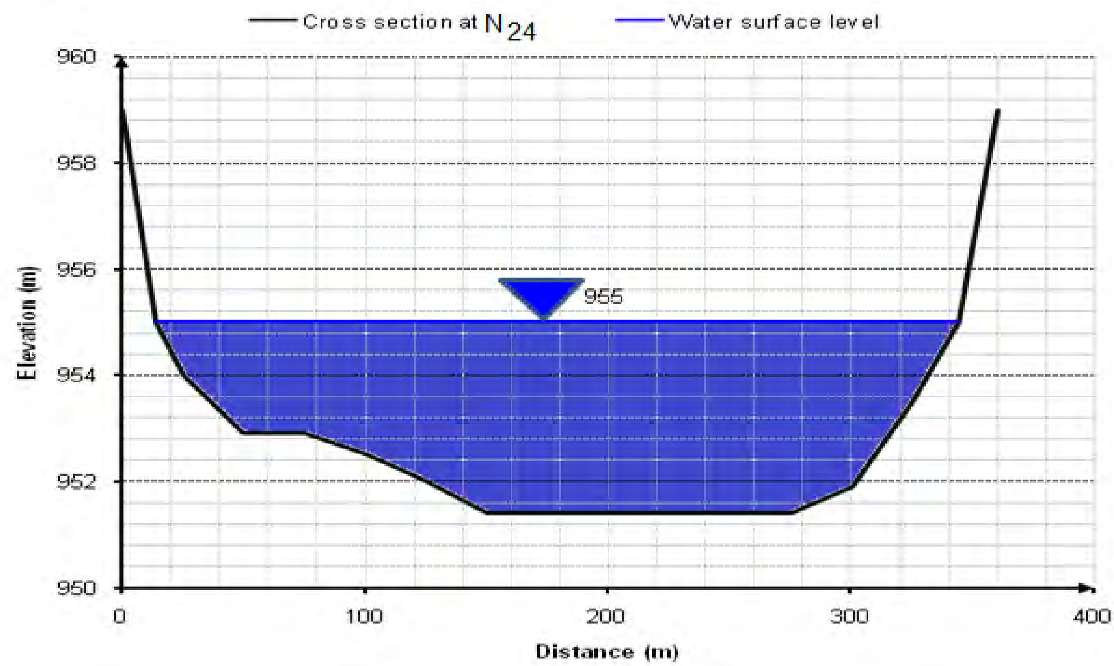
Cross section at N21
Water surface level
956
954
952
950
948
946
951
Elevation (m)
0
100
200
300
400
500
Distance (m)

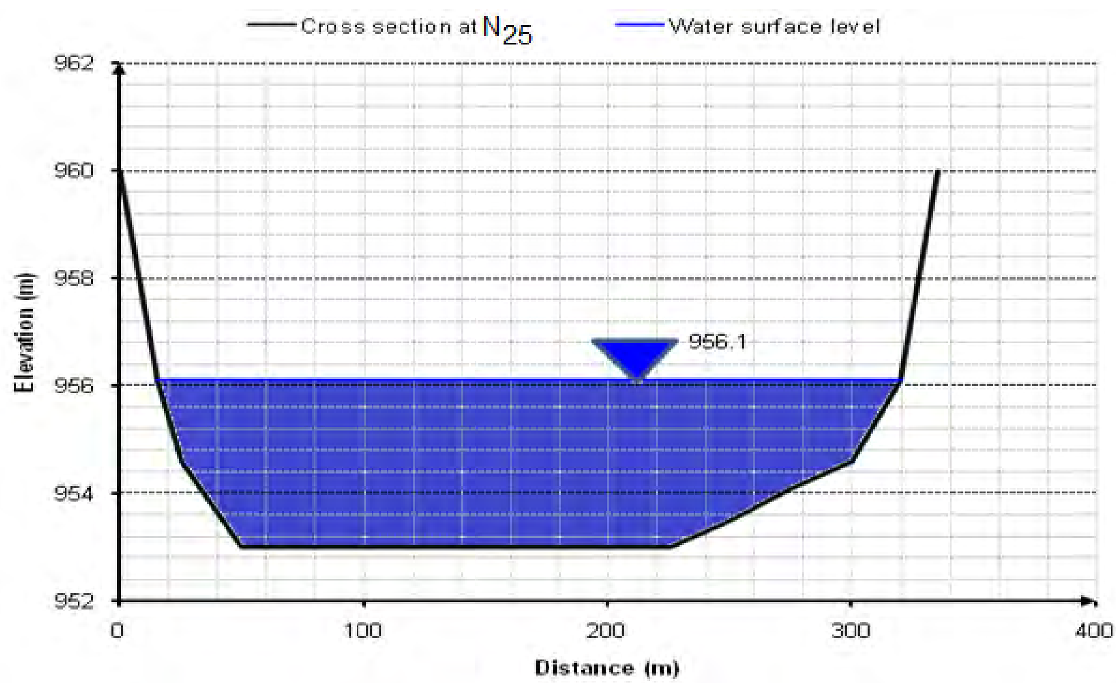


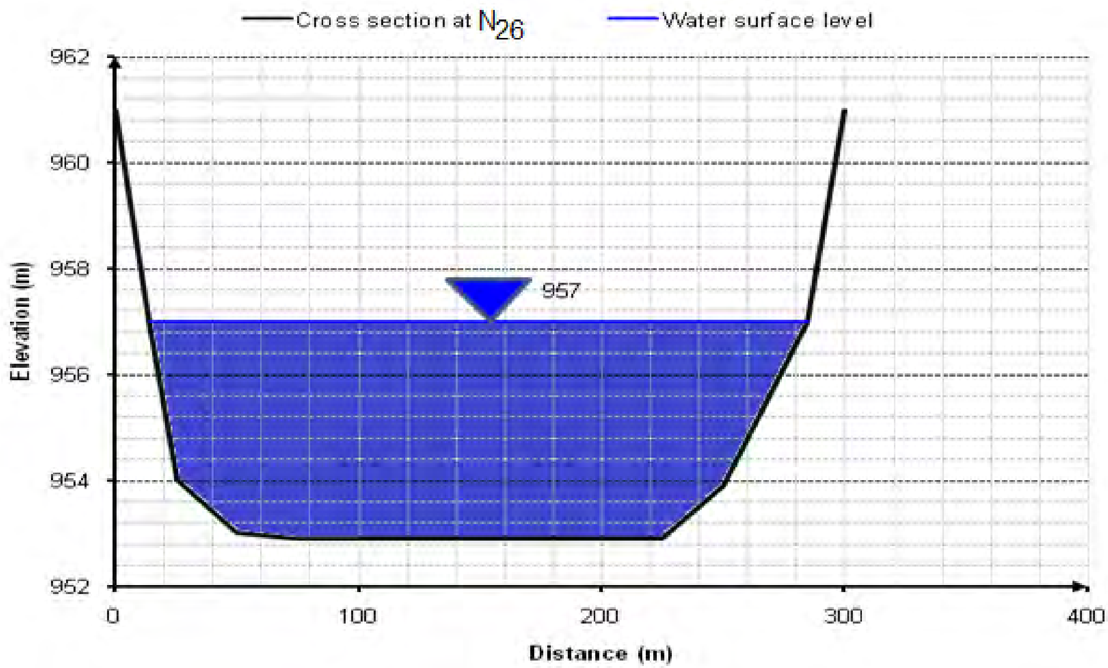
Cross section at N_{22}
Water surface level
952
958
956
954
952
950
948
946
Eleevation (m)
0
50
100
150
200
250
300
350
400
450
Distance (m)



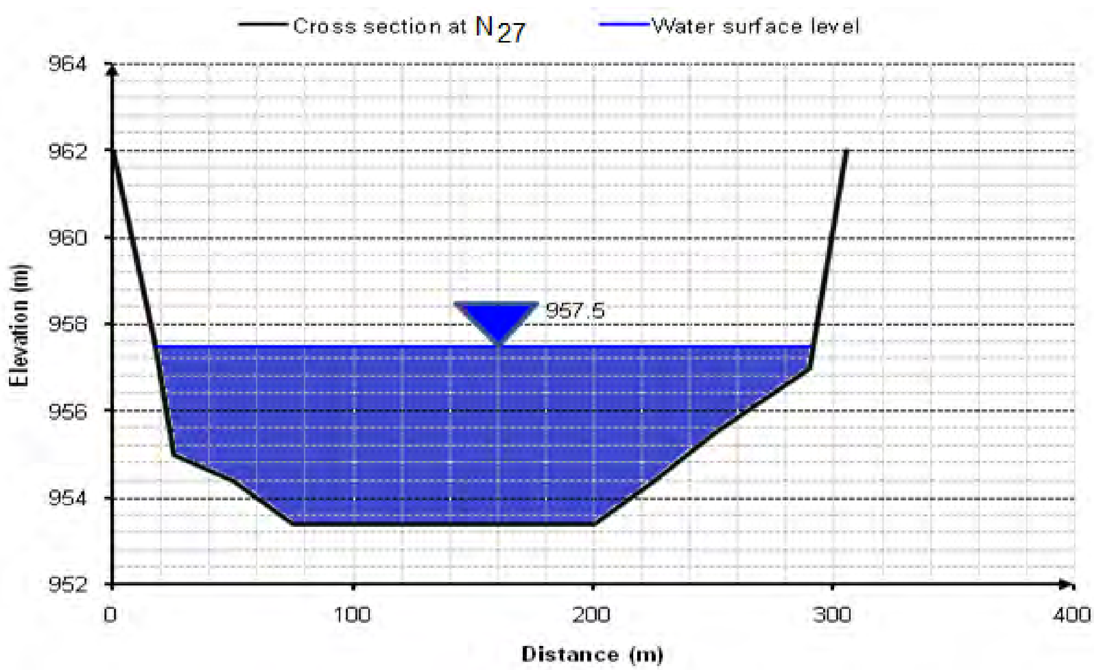
Cross section at N_{23}
Water surface level
953
958
956
954
952
950
948
Elevation (m)
0
50
100
150
200
250
300
350
400
450
Distance (m)


Cross section at N24
Water surface level
955
Elevation (m)
Distance (m)
960
958
956
954
952
950
0
100
200
300
400

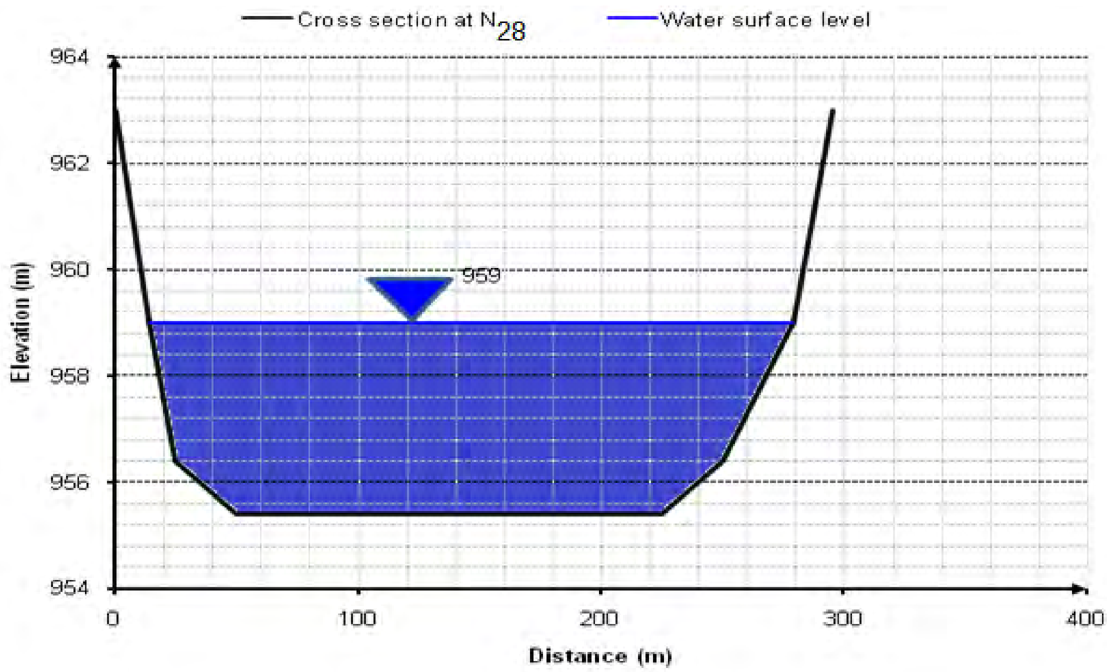

Cross section at N25
Water surface level
956.1
Elevation (m)
Distance (m)
962
960
958
956
954
952
0
100
200
300
400

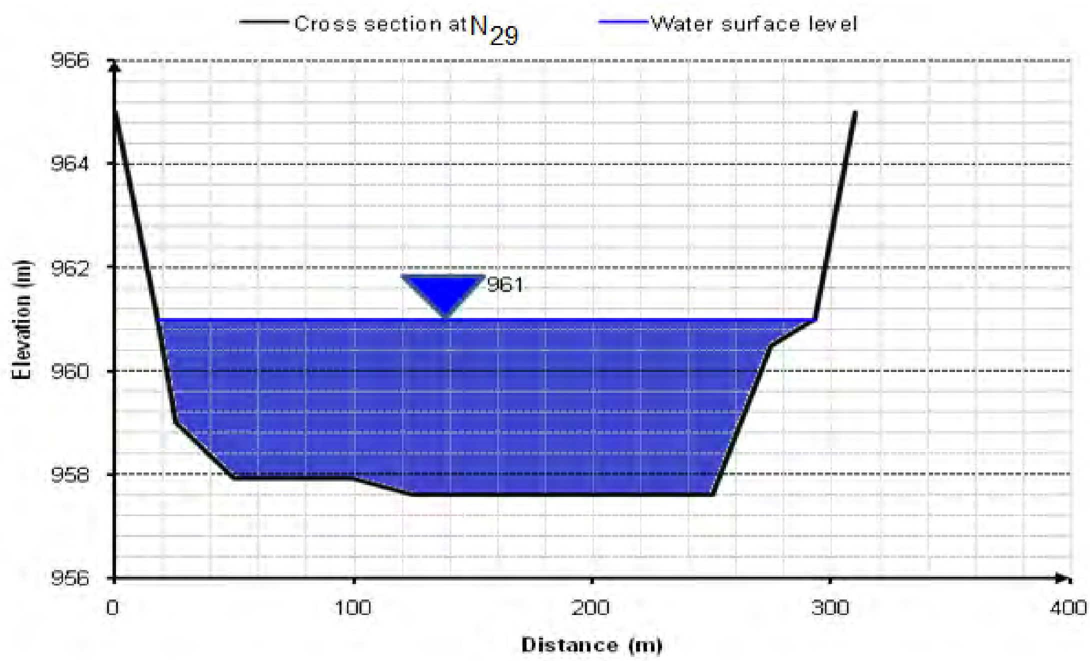


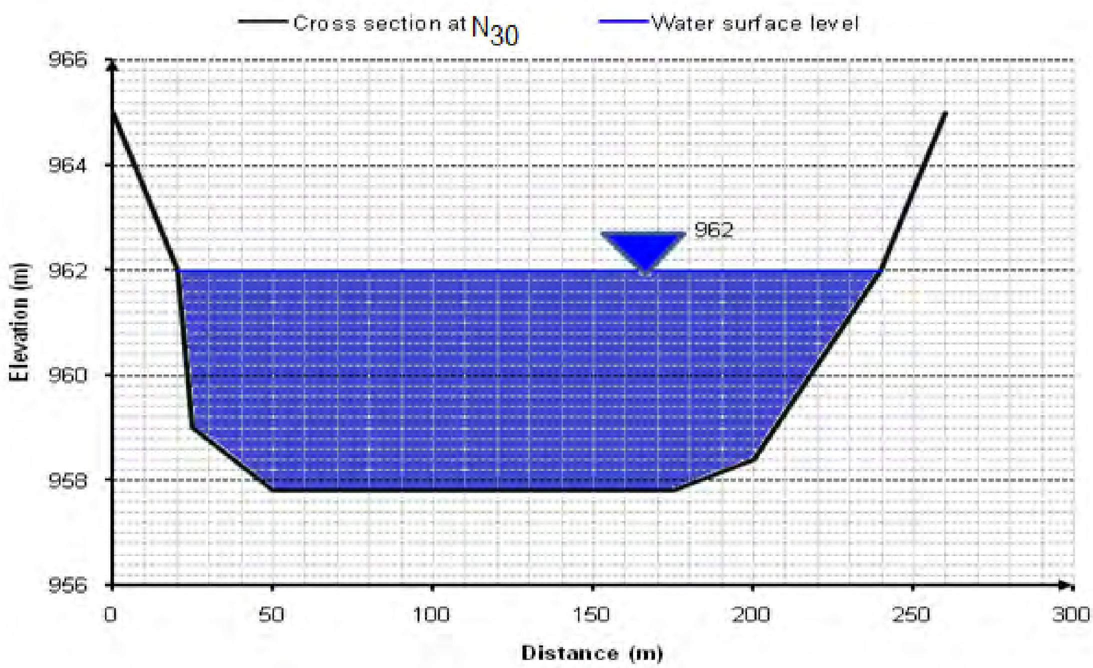
Cross section at N26
Water surface level
962
960
958
956
954
952
Elevation (m)
957
0
100
200
300
400
Distance (m)



Cross section at N 27
Water surface level
964
962
960
958
956
954
952
Elevation (m)
957.5
0
100
200
300
400
Distance (m)


Cross section at N_{28}
Water surface level
959
Elevation (m)
Distance (m)
964
962
960
958
956
954
0
100
200
300
400


Cross section at N_{29}
Water surface level
961
Elevation (m)
Distance (m)
966
964
962
960
958
956
0
100
200
300
400



Cross section at N_{30}
Water surface level
962
Elevation (m)
Distance (m)
966
964
962
960
958
956
0
50
100
150
200
250
300

ANNEX 3 : INITIAL DISCHARGE OF THE RIVER

Reach Name	Reach Node Notification	L	E	A	P	R	n	K	Ave. K	Ass. Sf	Q	V	H	Cal. Sf	Cal. Sf-Ass. Sf	b	a
1	N0		939.0	966	320.4	3.01	0.02	100802.2				3.91	939.8				
		258.0							101422.5	0.0014	3778.9			0.0014	1.83874E-14	0.6	6.92
	N1		939.4	993	337.0	2.95	0.02	102046.7				3.81	940.1				
2	N1		939.4	993	337.0	2.95	0.02	102046.7				5.26	940.8				
		303.0							102202.5	0.0026	5224.6			0.0026	-1E-06	0.6	5.84
	N2		940.2	996	338.0	2.95	0.02	102358.6				5.25	941.6				
3	N2		940.2	996	338.0	2.95	0.02	102358.6				4.71	941.3				
		300.0							77636.1	0.0037	4693.8			0.0037	3.55939E-14	0.6	5.29
	N3		940.7	806	248.4	3.24	0.03	58884.7				5.82	942.4				
4	N3		940.7	806	248.4	3.24	0.03	58884.7				4.50	941.7				
		136.0							62665.3	0.0033	3626.3			0.0033	1.33088E-14	0.6	6.12
	N4		941.2	824	217.8	3.78	0.03	66688.7				4.40	942.2				
5	N4		941.2	824	217.8	3.78	0.03	66688.7				3.67	941.9				
		130.0							65791.9	0.0021	3021.3			0.0021	-3.17055E-14	0.6	6.67
	N5		941.5	840	238.0	3.53	0.03	64907.2				3.60	942.2				

	N5		941.5	840	238.0	3.53	0.03	64907.2				3.79	942.2				
6		181.2							59285.1	0.0029	3181.9			0.0029	1E-06	0.6	6.30
	N6		941.7	700	198.0	3.54	0.03	54150.0				4.55	942.8				
	N6		941.7	700	198.0	3.54	0.03	54150.0				5.43	943.2				
7		183.1							53118.8	0.0051	3801.6			0.0051	1E-06	0.6	4.92
	N7		942.5	670	188.0	3.56	0.03	52107.3				5.67	944.1				
	N7		942.5	670	188.0	3.56	0.03	52107.3				4.67	943.6				
8		90.8							59453.7	0.0028	3131.8			0.0028	1E-06	0.6	5.79
	N8		943.0	760	228.0	3.33	0.025	67835.9				4.12	943.9				
	N8		943.0	760	228.0	3.33	0.025	67835.9				4.73	944.1				
9		158.3							59825.8	0.0036	3596.4			0.0036	2.61488E-14	0.6	5.18
	N9		943.2	660	233.6	2.83	0.025	52761.6				5.45	944.7				
	N9		943.2	660	233.6	2.83	0.025	52761.6				6.45	945.3				
10		100.0							53454.5	0.0063	4258.6			0.0063	-2.03674E-14	0.6	4.42
	N10		943.7	640	208.0	3.08	0.025	54156.6				6.65	946.0				
	N10		943.7	640	208.0	3.08	0.025	54156.6				3.19	944.2				
11		169.6							62511.8	0.0011	2043.4			0.0011	1E-06	0.6	7.20
	N11		943.9	652	198.0	3.29	0.02	72156.0				3.13	944.4				
	N11		943.9	652	198.0	3.29	0.02	72156.0				4.29	944.8				
12		146.2							71296.3	0.0015	2794.6			0.0015	1E-06	0.6	5.54
	N12		944.2	680	228.0	2.98	0.02	70446.9				4.11	945.1				

13	N12		944.2	680	228.0	2.98	0.02	70446.9				9.36	948.7				
		238.0							59679.8	0.0114	6363.1			0.0114	-3.9092E-14	0.6	3.21
	N13		946.0	620	213.0	2.91	0.025	50558.4				10.26	951.4				
14	N13		946.0	620	213.0	2.91	0.025	50558.4				3.32	946.6				
		121.8							59586.0	0.0012	2055.9			0.0012	1E-06	0.6	7.04
	N14		946.4	840	278.0	3.02	0.025	70225.6				2.45	946.7				
15	N14		946.4	840	278.0	3.02	0.02	87782.0				7.00	948.9				
		162.0							87978.2	0.0045	5879.2			0.0045	1E-06	0.6	4.61
	N15		947.0	820	260.0	3.15	0.02	88174.7				7.17	949.6				
16	N15		947.0	820	260.0	3.15	0.02	88174.7				5.67	948.6				
		155.9							89642.6	0.0027	4652.2			0.0027	1E-06	0.6	5.22
	N16		948.0	1020	427.0	2.39	0.02	91135.0				4.56	949.1				
17	N16		948.0	1020	427.0	2.39	0.02	91135.0				2.95	948.4				
		169.2							74579.3	0.0016	3007.8			0.0016	1E-06	0.6	7.40
	N17		948.3	1050	456.0	2.30	0.03	61031.1				2.86	948.7				
18	N17		948.3	1050	456.0	2.30	0.03	61031.1				3.44	948.9				
		199.2							63923.8	0.0032	3613.9			0.0032	1E-06	0.6	7.92
	N18		949.0	1110	456.0	2.43	0.03	66953.6				3.26	949.5				
19	N18		949.0	1110	456.0	2.43	0.03	66953.6				7.21	951.6				
		118.0							60727.4	0.0174	8003.6			0.0174	-2.61596E-15	0.6	4.76

	N19		950.3	980	447.6	2.19	0.03	55080.2				8.17	953.7				
20	N19		950.3	980	447.6	2.19	0.03	55080.2				2.22	950.6				
		105.0							70099.4	0.0010	2174.1			0.0010	1E-06	0.6	11.27
	N20		950.5	1260	407.0	3.10	0.03	89214.1				1.73	950.7				
21	N20		950.5	1260	407.0	3.10	0.03	89214.1				3.90	951.3				
		169.0							92606.7	0.0028	4914.5			0.0028	-4.77209E-14	0.6	7.86
	N21		951.0	1280	378.5	3.38	0.03	96128.3				3.84	951.8				
22	N21		951.0	1280	378.5	3.38	0.03	96128.3				6.70	953.3				
		198.0							81764.7	0.0110	8575.2			0.0110	1E-06	0.6	5.07
	N22		952.0	1040	366.0	2.84	0.03	69547.3				8.25	955.5				
23	N22		952.0	1040	366.0	2.84	0.03	69547.3				5.21	953.4				
		132.0							76845.8	0.0050	5416.8			0.0050	4.07209E-14	0.6	6.35
	N23		953.0	1200	388.0	3.09	0.03	84910.2				4.51	954.0				
24	N23		953.0	1200	388.0	3.09	0.03	84910.2				5.85	954.7				
		245.0							68474.9	0.0105	7025.2			0.0105	3.34784E-14	0.6	5.19
	N24		955.0	1040	336.0	3.10	0.04	55220.8				6.76	957.3				
25	N24		955.0	1040	336.0	3.10	0.04	55220.8				3.23	955.5				
		264.0							43243.4	0.0060	3355.6			0.0060	6.55725E-15	0.6	6.88
	N25		956.1	750	309.0	2.43	0.04	33863.9				4.47	957.1				
26	N25		956.1	750	309.0	2.43	0.04	33863.9				3.02	956.6				

		209.0							33003.2	0.0047	2265.2			0.0047	1E-06	0.6	7.17
	N26		957.0	690	271.0	2.55	0.04	32164.4				3.28	957.5				
	N26		957.0	690	271.0	2.55	0.04	32164.4				3.23	957.5				
27		90.8							39058.2	0.0033	2227.6			0.0033	1.50882E-14	0.6	7.60
	N27		957.5	880	278.0	3.17	0.04	47429.4				2.53	957.8				
	N27		957.5	880	278.0	3.17	0.04	47429.4				5.20	958.9				
28		172.0							39578.1	0.0134	4577.0			0.0134	-1.23027E-14	0.6	5.02
	N28		959.0	700	270.0	2.59	0.04	33026.4				6.54	961.2				
	N28		959.0	700	270.0	2.59	0.04	33026.4				4.65	960.1				
29		221.0							36790.6	0.0078	3256.1			0.0078	-1.23269E-14	0.6	5.83
	N29		961.0	805	277.0	2.91	0.04	40983.9				4.04	961.8				
	N29		961.0	805	277.0	2.91	0.04	40983.9				3.17	961.5				
30		246.0							32562.7	0.0061	2550.0			0.0061	-4.86174E-14	0.6	6.34
	N30		962.0	570	233.0	2.45	0.04	25871.9				4.47	963.0				

Where:

L = length between the reaches, E = Node elevation above mean sea level, A = Cross sectional area of the node, P = wetted perimeter of the node, R = hydraulic radiuds, n = roughness coefficient of the reach, K = conveyance coefficient, Q = computed discharge, V = velocity, H = hydraulic head, Sf = reach slope, a = area to discharge ratio coefficient and, β = Boussinesq coefficient

ANNEX 4 COMPUTED DESIGN FLOOD OF THE RIVER

A. From Node 30 – Node 16

No	hr	Node 30	Node 29	Node 28	Node 27	Node 26	Node 25	Node 24	Node 23	Node 22	Node 21	Node 20	Node 19	Node 18	Node 17	Node 16
1	0.00	319.4	321.4	323.1	324.2	325.1	327.0	329.4	331.0	332.0	333.3	335.0	336.5	337.2	339.2	340.7
2	0.25	339.3	341.3	342.9	344.0	344.9	346.8	349.0	350.6	351.7	352.9	354.5	356.0	356.7	358.6	360.1
3	0.50	359.2	361.1	362.7	363.8	364.6	366.4	368.7	370.2	371.2	372.4	374.0	375.5	376.1	378.0	379.5
4	0.75	379.0	380.9	382.4	383.5	384.3	386.1	388.2	389.8	390.8	391.9	393.5	394.9	395.6	397.4	398.9
5	1.00	398.7	400.6	402.1	403.1	403.9	405.7	407.8	409.3	410.2	411.4	413.0	414.3	415.0	416.8	418.2
6	1.25	418.4	420.2	421.7	422.7	423.5	425.2	427.3	428.7	429.7	430.8	432.4	433.7	434.3	436.1	437.5
7	1.50	438.1	439.8	441.3	442.3	443.0	444.7	446.8	448.2	449.1	450.3	451.7	453.1	453.7	455.4	456.8
8	1.75	457.7	459.4	460.8	461.8	462.6	464.2	466.2	467.6	468.5	469.6	471.1	472.4	473.0	474.7	476.1
9	2.00	477.3	479.0	480.4	481.3	482.0	483.7	485.6	487.0	487.9	489.0	490.4	491.7	492.3	494.0	495.3
10	2.25	496.8	498.5	499.8	500.8	501.5	503.1	505.0	506.4	507.3	508.4	509.8	511.0	511.6	513.3	514.6
11	2.50	516.3	518.0	519.3	520.2	520.9	522.5	524.4	525.8	526.6	527.7	529.1	530.3	530.9	532.5	533.8
12	2.75	535.8	537.4	538.7	539.6	540.3	541.9	543.8	545.1	546.0	547.0	548.4	549.6	550.2	551.8	553.0
13	3.00	555.3	556.8	558.2	559.0	559.7	561.3	563.1	564.4	565.3	566.3	567.6	568.8	569.4	571.0	572.3
14	3.25	574.7	576.3	577.6	578.4	579.1	580.6	582.5	583.7	584.6	585.6	586.9	588.1	588.7	590.2	591.5
15	3.50	593.9	595.5	596.8	597.7	598.4	599.9	601.7	603.0	603.8	604.8	606.2	607.3	607.9	609.4	610.6
16	3.75	614.8	616.0	617.0	617.7	618.2	619.6	621.2	622.4	623.2	624.2	625.4	626.6	627.1	628.6	629.8
17	4.00	627.0	630.1	632.4	633.8	634.9	637.0	639.3	640.8	641.8	642.9	644.3	645.6	646.2	647.7	649.0
18	4.25	672.8	669.7	667.7	666.7	666.0	665.1	664.8	664.8	664.9	665.2	665.7	666.4	666.7	667.8	668.7
19	4.50	619.2	629.8	637.7	642.6	646.2	653.3	660.5	665.0	667.8	670.8	674.4	677.2	678.5	681.7	683.9
20	4.75	780.6	771.1	763.9	759.4	756.0	749.3	742.4	738.1	735.4	732.6	729.3	726.7	725.5	722.9	721.1
21	5.00	638.9	644.0	648.2	651.0	653.2	658.0	663.9	667.9	670.6	673.8	678.0	681.7	683.4	688.3	692.2
22	5.25	705.6	710.5	714.5	717.1	719.3	723.9	729.5	733.4	736.0	739.0	743.1	746.7	748.4	753.1	756.8
23	5.50	771.9	776.5	780.4	783.0	785.0	789.5	794.9	798.6	801.1	804.1	808.0	811.4	813.1	817.6	821.2
24	5.75	837.8	842.3	846.0	848.5	850.4	854.8	860.0	863.6	866.0	868.9	872.7	876.0	877.6	882.0	885.5
25	6.00	903.3	907.7	911.3	913.7	915.6	919.8	924.9	928.4	930.7	933.5	937.2	940.4	942.0	946.3	949.7

26	6.25	968.7	972.9	976.4	978.8	980.6	984.7	989.6	993.0	995.3	998.0	1001.6	1004.7	1006.2	1010.4	1013.7
27	6.50	1033.8	1037.9	1041.3	1043.6	1045.4	1049.4	1054.2	1057.5	1059.7	1062.4	1065.8	1068.9	1070.4	1074.4	1077.7
28	6.75	1098.8	1102.8	1106.1	1108.3	1110.1	1114.0	1118.6	1121.9	1124.0	1126.6	1130.0	1133.0	1134.4	1138.4	1141.6
29	7.00	1163.6	1167.5	1170.7	1172.9	1174.6	1178.4	1183.0	1186.1	1188.2	1190.8	1194.1	1197.0	1198.4	1202.3	1205.4
30	7.25	1228.3	1232.1	1235.2	1237.4	1239.1	1242.7	1247.2	1250.3	1252.4	1254.8	1258.1	1261.0	1262.3	1266.1	1269.2
31	7.50	1292.8	1296.6	1299.6	1301.7	1303.4	1307.0	1311.4	1314.4	1316.4	1318.8	1322.0	1324.8	1326.2	1329.9	1332.9
32	7.75	1357.3	1360.9	1364.0	1366.0	1367.6	1371.2	1375.4	1378.4	1380.4	1382.8	1385.9	1388.7	1390.0	1393.6	1396.5
33	8.00	1421.6	1425.2	1428.2	1430.2	1431.8	1435.3	1439.5	1442.4	1444.3	1446.6	1449.7	1452.4	1453.7	1457.3	1460.2
34	8.25	1485.9	1489.4	1492.3	1494.3	1495.9	1499.3	1503.4	1506.3	1508.2	1510.5	1513.5	1516.2	1517.4	1521.0	1523.8
35	8.50	1550.1	1553.6	1556.4	1558.3	1559.9	1563.2	1567.3	1570.1	1572.0	1574.3	1577.2	1579.8	1581.1	1584.6	1587.3
36	8.75	1614.2	1617.6	1620.4	1622.3	1623.8	1627.1	1631.1	1633.9	1635.8	1638.0	1640.9	1643.5	1644.7	1648.1	1650.8
37	9.00	1678.4	1681.8	1684.6	1686.4	1687.9	1691.1	1695.0	1697.8	1699.6	1701.7	1704.6	1707.1	1708.3	1711.7	1714.4
38	9.25	1742.4	1745.5	1748.2	1750.0	1751.4	1754.6	1758.5	1761.2	1763.0	1765.1	1768.0	1770.5	1771.7	1775.1	1777.7
39	9.50	1802.6	1806.8	1810.2	1812.4	1814.1	1817.8	1822.1	1825.0	1826.9	1829.2	1832.1	1834.6	1835.8	1839.1	1841.7
40	9.75	1889.0	1889.5	1890.1	1890.5	1890.9	1892.0	1893.7	1895.0	1895.9	1897.0	1898.7	1900.3	1901.1	1903.4	1905.3
41	10.00	1893.5	1899.1	1903.8	1906.9	1909.3	1914.8	1921.3	1925.8	1928.9	1932.5	1937.2	1941.4	1943.5	1949.0	1953.5
42	10.25	2006.1	2011.5	2016.1	2019.1	2021.5	2026.8	2033.2	2037.6	2040.6	2044.1	2048.8	2052.9	2054.9	2060.3	2064.6
43	10.50	2118.4	2123.8	2128.2	2131.2	2133.5	2138.7	2145.0	2149.3	2152.2	2155.6	2160.2	2164.2	2166.2	2171.5	2175.7
44	10.75	2230.6	2235.9	2240.2	2243.1	2245.4	2250.5	2256.6	2260.9	2263.7	2267.1	2271.5	2275.5	2277.4	2282.6	2286.8
45	11.00	2342.7	2347.8	2352.1	2354.9	2357.2	2362.1	2368.1	2372.3	2375.1	2378.4	2382.8	2386.7	2388.5	2393.6	2397.7
46	11.25	2454.6	2459.6	2463.8	2466.6	2468.8	2473.7	2479.6	2483.7	2486.4	2489.6	2493.9	2497.8	2499.6	2504.6	2508.6
47	11.50	2566.4	2571.3	2575.4	2578.2	2580.4	2585.1	2590.9	2595.0	2597.6	2600.8	2605.0	2608.8	2610.6	2615.5	2619.5
48	11.75	2678.1	2682.9	2687.0	2689.7	2691.8	2696.5	2702.2	2706.2	2708.8	2711.9	2716.1	2719.8	2721.5	2726.4	2730.3
49	12.00	2789.7	2794.5	2798.4	2801.1	2803.2	2807.8	2813.4	2817.3	2819.9	2823.0	2827.1	2830.7	2832.4	2837.2	2841.0
50	12.25	2901.2	2905.9	2909.8	2912.4	2914.5	2919.0	2924.5	2928.4	2930.9	2934.0	2938.0	2941.5	2943.3	2948.0	2951.7
51	12.50	3012.6	3017.3	3021.1	3023.7	3025.7	3030.2	3035.6	3039.4	3041.9	3044.9	3048.9	3052.4	3054.1	3058.7	3062.4
52	12.75	3124.0	3128.6	3132.3	3134.9	3136.9	3141.3	3146.6	3150.4	3152.8	3155.8	3159.7	3163.2	3164.8	3169.4	3173.0
53	13.00	3235.3	3239.8	3243.5	3246.0	3248.0	3252.4	3257.6	3261.3	3263.7	3266.6	3270.5	3273.9	3275.5	3280.1	3283.7
54	13.25	3346.4	3350.8	3354.5	3357.0	3359.0	3363.3	3368.5	3372.2	3374.6	3377.5	3381.3	3384.6	3386.2	3390.7	3394.2
55	13.50	3459.5	3463.3	3466.6	3468.8	3470.7	3474.7	3479.7	3483.2	3485.6	3488.4	3492.1	3495.4	3496.9	3501.3	3504.8

56	13.75	3551.1	3560.7	3567.5	3571.7	3574.8	3580.8	3587.4	3591.7	3594.5	3597.6	3601.7	3605.3	3606.9	3611.5	3615.1
57	14.00	3857.4	3809.3	3780.6	3765.3	3755.3	3741.0	3731.1	3726.8	3725.0	3723.8	3723.7	3724.4	3724.8	3727.1	3729.3
58	14.02	3689.3	3693.7	3697.3	3699.7	3701.7	3705.9	3710.9	3714.4	3716.8	3719.6	3723.2	3726.5	3728.1	3732.4	3735.8
59	14.25	3793.3	3797.1	3800.3	3802.4	3804.2	3808.0	3812.7	3816.0	3818.2	3820.8	3824.3	3827.5	3829.0	3833.1	3836.5
60	14.50	3890.6	3896.4	3901.1	3904.1	3906.5	3911.7	3917.7	3921.9	3924.6	3927.7	3931.9	3935.5	3937.2	3941.8	3945.5
61	14.75	4049.4	4050.1	4050.7	4051.2	4051.7	4052.9	4054.6	4055.9	4056.8	4058.0	4059.7	4061.3	4062.1	4064.5	4066.5
62	15.00	4060.3	4067.0	4072.5	4076.3	4079.3	4085.8	4093.6	4099.1	4102.7	4107.1	4112.8	4117.9	4120.4	4127.1	4132.5
63	15.25	4242.7	4249.3	4254.7	4258.4	4261.3	4267.7	4275.4	4280.8	4284.4	4288.7	4294.3	4299.3	4301.7	4308.3	4313.6
64	15.50	4424.9	4431.4	4436.7	4440.3	4443.2	4449.5	4457.1	4462.4	4465.9	4470.1	4475.7	4480.6	4482.9	4489.5	4494.7
65	15.75	4607.0	4613.4	4618.7	4622.2	4625.0	4631.2	4638.7	4643.9	4647.4	4651.5	4657.0	4661.8	4664.1	4670.6	4675.7
66	16.00	4789.0	4795.3	4800.5	4804.0	4806.8	4812.9	4820.2	4825.4	4828.8	4832.8	4838.2	4843.0	4845.3	4851.6	4856.6
67	16.25	4970.9	4977.1	4982.2	4985.7	4988.4	4994.4	5001.6	5006.7	5010.1	5014.1	5019.4	5024.1	5026.3	5032.6	5037.5
68	16.50	5152.7	5158.8	5163.9	5167.2	5170.0	5175.9	5183.0	5188.0	5191.3	5195.3	5200.5	5205.1	5207.3	5213.5	5218.4
69	16.75	5334.4	5340.5	5345.4	5348.8	5351.4	5357.3	5364.3	5369.2	5372.5	5376.4	5381.6	5386.1	5388.3	5394.4	5399.2
70	17.00	5516.1	5522.0	5526.9	5530.2	5532.9	5538.6	5545.6	5550.4	5553.6	5557.5	5562.6	5567.1	5569.2	5575.2	5580.0
71	17.25	5697.6	5703.5	5708.3	5711.6	5714.2	5719.9	5726.7	5731.5	5734.7	5738.5	5743.5	5748.0	5750.1	5756.0	5760.7
72	17.50	5879.1	5884.9	5889.7	5892.9	5895.5	5901.1	5907.9	5912.6	5915.8	5919.5	5924.5	5928.9	5931.0	5936.8	5941.4
73	17.75	6060.6	6066.3	6071.0	6074.2	6076.7	6082.3	6089.0	6093.6	6096.7	6100.5	6105.4	6109.7	6111.8	6117.5	6122.1
74	18.00	6242.0	6247.6	6252.3	6255.4	6257.9	6263.4	6270.0	6274.6	6277.7	6281.4	6286.2	6290.5	6292.6	6298.3	6302.8
75	18.25	6423.3	6428.9	6433.5	6436.6	6439.1	6444.5	6451.0	6455.6	6458.6	6462.2	6467.0	6471.3	6473.3	6478.9	6483.4
76	18.50	6604.6	6610.1	6614.6	6617.7	6620.2	6625.5	6632.0	6636.5	6639.5	6643.1	6647.8	6652.0	6654.0	6659.6	6664.0
77	18.75	6785.8	6791.2	6795.8	6798.8	6801.2	6806.5	6812.9	6817.4	6820.3	6823.9	6828.6	6832.7	6834.7	6840.2	6844.6
78	19.00	6967.0	6972.4	6976.9	6979.9	6982.3	6987.5	6993.8	6998.2	7001.2	7004.7	7009.3	7013.4	7015.4	7020.8	7025.2
79	19.25	7147.6	7153.0	7157.5	7160.5	7162.9	7168.2	7174.5	7178.9	7181.9	7185.3	7189.9	7194.0	7196.0	7201.4	7205.7
80	19.50	7333.0	7337.7	7341.7	7344.3	7346.5	7351.2	7357.0	7361.1	7363.8	7367.1	7371.5	7375.4	7377.2	7382.4	7386.6
81	19.75	7491.7	7498.9	7504.7	7508.6	7511.7	7518.3	7526.1	7531.5	7535.1	7539.3	7544.8	7549.6	7551.9	7558.1	7563.0
82	20.00	7743.9	7746.5	7748.7	7750.2	7751.4	7754.0	7757.2	7759.3	7760.8	7762.5	7764.8	7766.9	7767.9	7770.6	7772.7
83	20.25	7837.1	7839.8	7842.0	7843.5	7844.6	7847.2	7850.4	7852.5	7854.0	7855.7	7858.0	7860.0	7861.0	7863.7	7865.9
84	20.50	7930.4	7933.0	7935.2	7936.7	7937.9	7940.4	7943.6	7945.7	7947.2	7948.9	7951.2	7953.2	7954.2	7956.8	7959.0
85	20.75	8023.6	8026.3	8028.5	8029.9	8031.1	8033.7	8036.8	8038.9	8040.4	8042.1	8044.3	8046.3	8047.3	8050.0	8052.1

86	21.00	8116.9	8119.5	8121.7	8123.1	8124.3	8126.9	8129.9	8132.1	8133.5	8135.2	8137.5	8139.5	8140.5	8143.1	8145.2
87	21.25	8210.1	8212.8	8214.9	8216.4	8217.5	8220.1	8223.1	8225.3	8226.7	8228.4	8230.6	8232.6	8233.6	8236.2	8238.3
88	21.50	8303.4	8306.0	8308.1	8309.6	8310.7	8313.3	8316.3	8318.5	8319.9	8321.6	8323.8	8325.8	8326.7	8329.4	8331.5
89	21.75	8396.6	8399.2	8401.4	8402.8	8404.0	8406.5	8409.5	8411.6	8413.0	8414.7	8417.0	8418.9	8419.9	8422.5	8424.6
90	22.00	8489.9	8492.4	8494.6	8496.0	8497.2	8499.7	8502.7	8504.8	8506.2	8507.9	8510.1	8512.1	8513.0	8515.6	8517.7
91	22.25	8583.2	8585.7	8587.9	8589.3	8590.4	8592.9	8595.9	8598.0	8599.4	8601.1	8603.3	8605.2	8606.1	8608.7	8610.8
92	22.50	8675.6	8678.3	8680.5	8682.0	8683.1	8685.7	8688.8	8690.9	8692.3	8694.0	8696.3	8698.2	8699.2	8701.8	8703.9
93	22.75	8773.5	8775.6	8777.3	8778.5	8779.5	8781.6	8784.2	8786.1	8787.3	8788.8	8790.8	8792.6	8793.4	8795.8	8797.7
94	23.00	8848.8	8852.3	8855.1	8857.0	8858.6	8861.9	8865.8	8868.5	8870.3	8872.5	8875.3	8877.8	8878.9	8882.2	8884.8
95	23.25	8979.0	8981.0	8982.7	8983.8	8984.7	8986.7	8989.2	8990.9	8992.1	8993.5	8995.4	8997.0	8997.8	9000.0	9001.8
96	23.50	9051.9	9055.0	9057.4	9059.1	9060.4	9063.3	9066.8	9069.2	9070.8	9072.7	9075.1	9077.3	9078.3	9081.2	9083.4
97	23.75	9164.8	9167.2	9169.2	9170.5	9171.5	9173.6	9176.1	9177.7	9178.8	9180.1	9181.7	9183.1	9183.7	9185.4	9186.8
98	24.00	9259.2	9258.1	9257.3	9256.7	9256.3	9255.3	9254.1	9253.2	9252.7	9252.0	9251.1	9250.4	9250.0	9249.0	9248.1
99	24.25	9220.4	9219.6	9218.8	9218.3	9218.0	9217.1	9216.0	9215.2	9214.7	9214.1	9213.2	9212.5	9212.1	9211.1	9210.3
100	24.50	9189.6	9187.8	9186.3	9185.4	9184.7	9183.1	9181.3	9180.1	9179.3	9178.4	9177.2	9176.2	9175.7	9174.5	9173.5
101	24.75	9119.7	9120.9	9121.9	9122.5	9122.9	9123.8	9124.8	9125.3	9125.7	9126.1	9126.5	9126.8	9126.9	9127.2	9127.4
102	25.00	9170.9	9167.5	9164.8	9162.9	9161.4	9158.1	9154.2	9151.4	9149.6	9147.4	9144.5	9141.9	9140.7	9137.3	9134.5
103	25.25	9046.3	9042.9	9040.1	9038.2	9036.7	9033.5	9029.5	9026.7	9024.9	9022.7	9019.7	9017.2	9015.9	9012.5	9009.7
104	25.50	8921.7	8918.3	8915.5	8913.6	8912.1	8908.8	8904.8	8902.0	8900.1	8897.9	8895.0	8892.4	8891.1	8887.7	8884.9
105	25.75	8797.1	8793.7	8790.9	8789.0	8787.4	8784.1	8780.1	8777.3	8775.4	8773.2	8770.3	8767.6	8766.4	8762.9	8760.1
106	26.00	8672.5	8669.1	8666.2	8664.3	8662.8	8659.5	8655.4	8652.6	8650.7	8648.5	8645.5	8642.9	8641.6	8638.1	8635.3
107	26.25	8547.9	8544.5	8541.6	8539.7	8538.2	8534.8	8530.7	8527.9	8526.0	8523.8	8520.8	8518.1	8516.9	8513.3	8510.5
108	26.50	8423.4	8419.9	8417.0	8415.1	8413.5	8410.2	8406.1	8403.2	8401.3	8399.1	8396.1	8393.4	8392.1	8388.6	8385.8
109	26.75	8298.8	8295.3	8292.4	8290.5	8288.9	8285.5	8281.4	8278.5	8276.6	8274.3	8271.3	8268.6	8267.4	8263.8	8261.0
110	27.00	8174.3	8170.7	8167.8	8165.9	8164.3	8160.9	8156.8	8153.9	8151.9	8149.7	8146.6	8143.9	8142.6	8139.0	8136.2
111	27.25	8049.7	8046.2	8043.3	8041.3	8039.7	8036.3	8032.1	8029.2	8027.3	8025.0	8021.9	8019.2	8017.9	8014.3	8011.4
112	27.50	7925.2	7921.6	7918.7	7916.7	7915.1	7911.7	7907.5	7904.5	7902.6	7900.3	7897.2	7894.5	7893.2	7889.5	7886.7
113	27.75	7800.7	7797.1	7794.1	7792.1	7790.5	7787.1	7782.8	7779.9	7777.9	7775.6	7772.5	7769.8	7768.4	7764.8	7761.9
114	28.00	7676.2	7672.6	7669.6	7667.6	7666.0	7662.5	7658.2	7655.3	7653.3	7650.9	7647.8	7645.1	7643.7	7640.1	7637.1
115	28.25	7551.7	7548.0	7545.0	7543.0	7541.4	7537.9	7533.6	7530.6	7528.6	7526.3	7523.1	7520.4	7519.0	7515.3	7512.4

116	28.50	7427.2	7423.5	7420.5	7418.5	7416.9	7413.3	7409.0	7406.0	7404.0	7401.6	7398.5	7395.7	7394.3	7390.6	7387.6
117	28.75	7302.7	7299.0	7296.0	7294.0	7292.3	7288.7	7284.4	7281.4	7279.4	7277.0	7273.8	7271.0	7269.6	7265.9	7262.9
118	29.00	7178.3	7174.6	7171.5	7169.5	7167.8	7164.2	7159.8	7156.8	7154.8	7152.3	7149.1	7146.3	7144.9	7141.2	7138.2
119	29.25	7053.5	7049.8	7046.8	7044.7	7043.1	7039.5	7035.1	7032.1	7030.1	7027.7	7024.4	7021.6	7020.2	7016.4	7013.4
120	29.50	6931.7	6927.6	6924.3	6922.0	6920.2	6916.3	6911.6	6908.4	6906.2	6903.7	6900.3	6897.4	6895.9	6892.0	6888.9
121	29.75	6793.9	6791.3	6789.0	6787.5	6786.3	6783.5	6780.1	6777.6	6776.0	6774.0	6771.3	6768.9	6767.7	6764.4	6761.7
122	30.00	6709.5	6704.3	6700.1	6697.2	6694.9	6689.9	6683.8	6679.5	6676.7	6673.3	6668.8	6664.8	6662.9	6657.7	6653.5
123	30.25	6540.6	6535.4	6531.1	6528.2	6525.9	6520.8	6514.6	6510.3	6507.5	6504.1	6499.5	6495.5	6493.6	6488.3	6484.0
124	30.50	6371.8	6366.6	6362.2	6359.3	6356.9	6351.8	6345.6	6341.2	6338.3	6334.9	6330.3	6326.2	6324.3	6318.9	6314.6
125	30.75	6203.1	6197.7	6193.3	6190.3	6188.0	6182.8	6176.5	6172.1	6169.2	6165.7	6161.1	6157.0	6155.0	6149.6	6145.2
126	31.00	6034.3	6028.9	6024.5	6021.5	6019.1	6013.8	6007.5	6003.0	6000.1	5996.5	5991.9	5987.7	5985.7	5980.2	5975.8
127	31.25	5865.6	5860.2	5855.7	5852.7	5850.2	5844.9	5838.5	5834.0	5831.0	5827.4	5822.7	5818.5	5816.5	5810.9	5806.5
128	31.50	5697.0	5691.5	5686.9	5683.9	5681.4	5676.1	5669.6	5665.0	5662.0	5658.4	5653.6	5649.3	5647.3	5641.7	5637.2
129	31.75	5528.5	5522.9	5518.3	5515.2	5512.7	5507.2	5500.7	5496.1	5493.0	5489.3	5484.5	5480.2	5478.2	5472.4	5467.9
130	32.00	5360.0	5354.3	5349.6	5346.5	5344.0	5338.5	5331.8	5327.2	5324.1	5320.4	5315.5	5311.1	5309.0	5303.2	5298.6
131	32.25	5191.5	5185.8	5181.1	5177.9	5175.3	5169.8	5163.0	5158.3	5155.2	5151.4	5146.5	5142.1	5139.9	5134.1	5129.4
132	32.50	5023.2	5017.4	5012.6	5009.3	5006.8	5001.1	4994.3	4989.5	4986.3	4982.5	4977.5	4973.0	4970.9	4965.0	4960.2
133	32.75	4855.0	4849.1	4844.2	4841.0	4838.3	4832.6	4825.6	4820.8	4817.6	4813.7	4808.6	4804.1	4801.9	4795.9	4791.1
134	33.00	4685.4	4679.7	4675.0	4671.8	4669.2	4663.6	4656.7	4651.9	4648.6	4644.8	4639.6	4635.1	4632.9	4626.8	4622.0
135	33.25	4527.4	4519.7	4513.5	4509.4	4506.2	4499.4	4491.4	4485.8	4482.2	4477.9	4472.3	4467.4	4465.0	4458.5	4453.4
136	33.50	4301.6	4304.2	4305.4	4305.8	4305.8	4304.6	4301.8	4299.4	4297.6	4295.3	4291.8	4288.6	4287.0	4282.3	4278.4
137	33.75	4265.0	4263.0	4260.0	4257.0	4248.0	4241.0	4237.3	4218.1	4208.5	4198.3	4182.4	4173.5	4169.2	4155.7	4146.5
138	34.00	3984.3	3984.4	3976.4	3976.4	3968.4	3968.5	3960.6	3960.7	3952.7	3952.8	3944.9	3945.0	3937.1	3937.2	3929.4
139	34.15	3877.4	3877.6	3869.9	3870.1	3862.4	3862.6	3854.9	3855.1	3847.5	3847.7	3840.1	3840.3	3832.7	3832.9	3825.4
140	34.25	3804.4	3804.6	3797.1	3797.4	3789.9	3790.2	3782.8	3783.0	3775.6	3775.9	3768.5	3768.8	3761.4	3761.7	3754.4
141	34.50	3624.4	3624.9	3617.9	3618.3	3611.4	3611.9	3604.9	3605.4	3598.5	3599.0	3592.1	3592.5	3585.7	3586.2	3579.4
142	34.75	3444.5	3445.1	3438.7	3439.3	3432.9	3433.5	3427.1	3427.8	3421.4	3422.0	3415.7	3416.3	3410.0	3410.6	3404.4
143	35.00	3264.5	3265.3	3259.4	3260.2	3254.4	3255.2	3249.3	3250.1	3244.3	3245.1	3239.3	3240.1	3234.3	3235.1	3229.4
144	35.25	3144.9	3145.8	3140.3	3141.2	3135.7	3136.6	3131.1	3132.1	3126.6	3127.5	3122.1	3123.0	3117.6	3118.5	3113.1
145	35.50	3025.3	3026.3	3021.1	3022.2	3017.0	3018.1	3013.0	3014.0	3008.9	3009.9	3004.8	3005.8	3000.8	3001.8	2996.7

146	35.75	2905.7	2906.8	2902.0	2903.2	2898.4	2899.5	2894.8	2895.9	2891.2	2892.3	2887.6	2888.7	2884.0	2885.1	2880.4
147	36.00	2786.0	2787.3	2782.9	2784.2	2779.7	2781.0	2776.6	2777.8	2773.4	2774.7	2770.3	2771.6	2767.2	2768.5	2764.1
148	36.25	2666.4	2667.8	2663.7	2665.1	2661.1	2662.4	2658.4	2659.8	2655.7	2657.1	2653.1	2654.4	2650.4	2651.8	2647.8
149	36.50	2546.8	2548.3	2544.6	2546.1	2542.4	2543.9	2540.2	2541.7	2538.0	2539.5	2535.8	2537.3	2533.6	2535.1	2531.5
150	36.75	2427.2	2428.8	2425.5	2427.1	2423.7	2425.4	2422.0	2423.6	2420.3	2421.9	2418.6	2420.2	2416.9	2418.5	2415.2
151	37.00	2307.6	2309.3	2306.3	2308.1	2305.1	2306.8	2303.8	2305.5	2302.6	2304.3	2301.3	2303.0	2300.1	2301.8	2298.8
152	37.25	2188.0	2189.9	2187.2	2189.1	2186.4	2188.3	2185.6	2187.5	2184.8	2186.7	2184.1	2185.9	2183.3	2185.1	2182.5
153	37.50	2068.4	2070.4	2068.0	2070.0	2067.7	2069.7	2067.4	2069.4	2067.1	2069.1	2066.8	2068.8	2066.5	2068.5	2066.2
154	37.75	1948.7	1950.9	1948.9	1951.0	1949.1	1951.2	1949.2	1951.3	1949.4	1951.5	1949.6	1951.6	1949.7	1951.8	1949.9
155	38.00	1829.1	1831.4	1829.8	1832.0	1830.4	1832.6	1831.0	1833.3	1831.7	1833.9	1832.3	1834.5	1832.9	1835.1	1833.6
156	38.25	1709.5	1711.9	1710.6	1713.0	1711.7	1714.1	1712.9	1715.2	1714.0	1716.3	1715.1	1717.4	1716.2	1718.5	1717.2
157	38.50	1589.9	1592.4	1591.5	1594.0	1593.1	1595.5	1594.7	1597.1	1596.2	1598.7	1597.8	1600.2	1599.4	1601.8	1600.9
158	38.75	1470.3	1472.9	1472.4	1474.9	1474.4	1477.0	1476.5	1479.0	1478.5	1481.1	1480.6	1483.1	1482.6	1485.1	1484.6
159	39.00	1350.7	1353.4	1353.2	1355.9	1355.8	1358.4	1358.3	1361.0	1360.8	1363.5	1363.3	1366.0	1365.8	1368.5	1368.3
160	39.25	1231.1	1233.9	1234.1	1236.9	1237.1	1239.9	1240.1	1242.9	1243.1	1245.9	1246.1	1248.8	1249.0	1251.8	1252.0
161	39.50	1111.4	1114.4	1114.9	1117.9	1118.4	1121.4	1121.9	1124.8	1125.4	1128.3	1128.8	1131.7	1132.2	1135.1	1135.7
162	39.75	991.8	994.9	995.8	998.9	999.8	1002.8	1003.7	1006.7	1007.6	1010.7	1011.6	1014.6	1015.5	1018.5	1019.3
163	40.00	940.0	943.1	944.1	947.3	948.3	951.4	952.5	955.5	956.6	959.7	960.7	963.8	964.8	967.9	968.9
164	40.25	908.2	911.4	912.5	915.7	916.8	919.9	921.1	924.2	925.3	928.4	929.6	932.7	933.8	936.9	938.0
165	40.50	876.4	879.6	880.9	884.1	885.3	888.5	889.7	892.9	894.1	897.2	898.5	901.6	902.8	905.9	907.1
166	40.75	844.7	847.9	849.2	852.5	853.8	857.0	858.3	861.5	862.8	866.0	867.3	870.5	871.8	874.9	876.3
167	41.00	812.9	816.2	817.6	820.9	822.3	825.5	826.9	830.2	831.6	834.8	836.2	839.4	840.8	844.0	845.4
168	41.25	781.2	784.5	786.0	789.3	790.8	794.0	795.6	798.8	800.3	803.6	805.1	808.3	809.8	813.0	814.5
169	41.50	749.4	752.7	754.4	757.7	759.3	762.6	764.2	767.5	769.1	772.3	773.9	777.2	778.8	782.0	783.6
170	41.75	717.7	721.0	722.7	726.1	727.8	731.1	732.8	736.1	737.8	741.1	742.8	746.1	747.8	751.1	752.7
171	42.00	685.9	689.3	691.1	694.5	696.3	699.6	701.4	704.8	706.6	709.9	711.7	715.0	716.8	720.1	721.8
172	42.25	654.1	657.6	659.5	662.9	664.8	668.2	670.1	673.4	675.3	678.7	680.6	683.9	685.8	689.1	691.0
173	42.50	622.4	625.8	627.8	631.3	633.3	636.7	638.7	642.1	644.1	647.5	649.4	652.8	654.8	658.1	660.1
174	42.75	590.6	594.1	596.2	599.7	601.8	605.2	607.3	610.7	612.8	616.2	618.3	621.7	623.8	627.2	629.2
175	43.00	558.9	562.4	564.6	568.1	570.3	573.7	575.9	579.4	581.6	585.0	587.2	590.6	592.8	596.2	598.3

176	43.25	527.1	530.7	533.0	536.5	538.8	542.3	544.5	548.0	550.3	553.8	556.0	559.5	561.8	565.2	567.4
177	43.50	495.4	498.9	501.3	504.9	507.3	510.8	513.2	516.7	519.0	522.6	524.9	528.4	530.7	534.2	536.6
178	43.75	463.6	467.2	469.7	473.3	475.8	479.3	481.8	485.3	487.8	491.3	493.8	497.3	499.7	503.3	505.7
179	44.00	431.9	435.5	438.1	441.7	444.2	447.9	450.4	454.0	456.5	460.1	462.7	466.2	468.7	472.3	474.8
180	44.25	400.1	403.8	406.4	410.1	412.7	416.4	419.0	422.7	425.3	428.9	431.5	435.1	437.7	441.3	443.9
181	44.50	368.3	372.0	374.8	378.5	381.2	384.9	387.7	391.3	394.0	397.7	400.4	404.0	406.7	410.3	413.0
182	44.75	336.6	340.3	343.2	346.9	349.7	353.4	356.3	360.0	362.8	366.5	369.3	372.9	375.7	379.4	382.2
183	45.00	291.1	294.8	297.8	301.6	304.6	308.3	311.3	315.0	318.0	321.7	324.7	328.4	331.3	335.0	337.9
184	45.25	284.7	288.5	291.5	295.3	298.3	302.0	305.0	308.8	311.7	315.5	318.4	322.1	325.1	328.8	331.7
185	45.50	278.4	282.2	285.2	289.0	292.0	295.7	298.7	302.5	305.5	309.2	312.2	315.9	318.9	322.6	325.5
186	45.75	272.0	275.8	278.9	282.6	285.7	289.4	292.5	296.2	299.2	303.0	306.0	309.7	312.7	316.4	319.4
187	46.00	265.7	269.5	272.5	276.3	279.4	283.2	286.2	290.0	293.0	296.7	299.7	303.5	306.5	310.2	313.2
188	46.25	259.3	263.1	266.2	270.0	273.1	276.9	279.9	283.7	286.7	290.5	293.5	297.3	300.3	304.0	307.0
189	46.50	253.0	256.8	259.9	263.7	266.8	270.6	273.6	277.4	280.5	284.2	287.3	291.0	294.1	297.8	300.8
190	46.75	246.6	250.4	253.6	257.4	260.5	264.3	267.4	271.1	274.2	278.0	281.1	284.8	287.9	291.6	294.7
191	47.00	240.3	244.1	247.2	251.0	254.2	258.0	261.1	264.9	268.0	271.7	274.8	278.6	281.7	285.4	288.5
192	47.25	233.9	237.7	240.9	244.7	247.9	251.7	254.8	258.6	261.7	265.5	268.6	272.4	275.5	279.2	282.3
193	47.50	227.6	231.4	234.6	238.4	241.6	245.4	248.5	252.3	255.5	259.3	262.4	266.2	269.3	273.0	276.1
194	47.75	221.2	225.1	228.3	232.1	235.3	239.1	242.3	246.1	249.2	253.0	256.2	259.9	263.1	266.8	270.0
195	48.00	194.7	198.6	201.9	205.8	209.0	212.9	216.1	219.9	223.2	227.0	230.2	234.0	237.2	241.0	244.2

B. From Node 15 – Node 0 of the River

No	hr	Node 15	Node 14	Node 13	Node 12	Node 11	Node 10	Node 09	Node 08	Node 07	Node 06	Node 05	Node 04	Node 03	Node 02	Node 01	Node 0
1	0.00	341.7	342.7	343.7	344.6	345.6	347.1	347.7	348.7	349.3	350.4	351.8	352.8	353.8	355.8	357.9	360.0
2	0.25	361.1	362.0	363.0	364.0	364.9	366.4	366.9	367.9	368.5	369.6	371.0	372.0	373.0	374.8	376.9	379.0
3	0.50	380.5	381.4	382.4	383.3	384.2	385.6	386.2	387.1	387.7	388.8	390.1	391.1	392.1	393.9	396.0	398.0
4	0.75	399.8	400.7	401.7	402.5	403.5	404.9	405.4	406.3	406.9	408.0	409.3	410.2	411.2	413.0	415.0	417.0
5	1.00	419.1	420.0	420.9	421.8	422.7	424.1	424.6	425.5	426.1	427.1	428.4	429.4	430.3	432.1	434.0	436.0

6	1.25	438.4	439.2	440.2	441.0	441.9	443.3	443.8	444.7	445.3	446.3	447.5	448.5	449.4	451.1	453.1	455.0
7	1.50	457.7	458.5	459.4	460.3	461.2	462.5	463.0	463.9	464.4	465.4	466.6	467.6	468.5	470.2	472.1	474.0
8	1.75	477.0	477.8	478.7	479.5	480.4	481.7	482.1	483.0	483.6	484.5	485.8	486.7	487.6	489.3	491.1	493.0
9	2.00	496.2	497.0	497.9	498.7	499.6	500.8	501.3	502.2	502.7	503.7	504.9	505.8	506.7	508.3	510.1	512.0
10	2.25	515.4	516.2	517.1	517.9	518.7	520.0	520.5	521.3	521.9	522.8	524.0	524.9	525.7	527.4	529.2	531.0
11	2.50	534.7	535.4	536.3	537.1	537.9	539.2	539.6	540.5	541.0	541.9	543.1	544.0	544.8	546.4	548.2	550.0
12	2.75	553.9	554.6	555.5	556.3	557.1	558.3	558.8	559.6	560.1	561.0	562.2	563.0	563.9	565.5	567.2	569.0
13	3.00	573.1	573.8	574.7	575.4	576.2	577.5	577.9	578.7	579.2	580.1	581.3	582.1	582.9	584.5	586.2	588.0
14	3.25	592.3	593.0	593.8	594.6	595.4	596.6	597.0	597.8	598.3	599.2	600.3	601.2	602.0	603.5	605.3	607.0
15	3.50	611.4	612.2	613.0	613.7	614.5	615.7	616.1	616.9	617.4	618.3	619.4	620.3	621.1	622.6	624.3	626.0
16	3.75	630.6	631.3	632.2	632.9	633.7	634.8	635.3	636.0	636.6	637.4	638.5	639.3	640.1	641.6	643.3	645.0
17	4.00	649.7	650.5	651.3	652.0	652.8	654.0	654.4	655.2	655.6	656.5	657.6	658.4	659.2	660.7	662.3	664.0
18	4.25	669.4	670.0	670.7	671.3	672.0	673.1	673.5	674.3	674.8	675.6	676.6	677.5	678.2	679.7	681.3	683.0
19	4.50	685.3	686.5	687.7	688.8	689.9	691.4	691.9	692.9	693.5	694.4	695.6	696.5	697.3	698.7	700.4	702.0
20	4.75	720.1	719.3	718.6	718.0	717.5	716.9	716.8	716.6	716.5	716.5	716.7	716.9	717.2	718.1	719.4	721.0
21	5.00	694.7	697.0	699.6	702.0	704.4	708.2	709.5	712.0	713.6	716.3	719.7	722.3	724.8	729.5	734.7	740.0
22	5.25	759.2	761.4	764.0	766.2	768.6	772.2	773.5	775.9	777.4	780.0	783.3	785.9	788.3	792.8	797.9	803.0
23	5.50	823.6	825.7	828.1	830.3	832.6	836.1	837.4	839.7	841.2	843.7	846.9	849.4	851.7	856.1	861.1	866.0
24	5.75	887.8	889.8	892.2	894.3	896.6	899.9	901.2	903.4	904.9	907.3	910.5	912.8	915.1	919.4	924.2	929.0
25	6.00	951.9	953.9	956.2	958.2	960.4	963.7	964.9	967.1	968.5	970.9	973.9	976.2	978.4	982.6	987.3	992.0
26	6.25	1015.9	1017.8	1020.1	1022.1	1024.2	1027.4	1028.5	1030.7	1032.1	1034.4	1037.4	1039.6	1041.8	1045.9	1050.4	1055.0
27	6.50	1079.8	1081.7	1083.9	1085.8	1087.9	1091.0	1092.1	1094.2	1095.6	1097.9	1100.8	1103.0	1105.1	1109.1	1113.5	1118.0
28	6.75	1143.6	1145.5	1147.6	1149.5	1151.6	1154.6	1155.7	1157.8	1159.1	1161.3	1164.1	1166.3	1168.3	1172.3	1176.6	1181.0
29	7.00	1207.4	1209.2	1211.3	1213.2	1215.2	1218.2	1219.2	1221.2	1222.5	1224.7	1227.5	1229.6	1231.6	1235.4	1239.7	1244.0
30	7.25	1271.1	1272.9	1275.0	1276.8	1278.7	1281.7	1282.7	1284.7	1285.9	1288.1	1290.8	1292.9	1294.8	1298.6	1302.8	1307.0
31	7.50	1334.8	1336.6	1338.6	1340.4	1342.3	1345.1	1346.2	1348.1	1349.3	1351.4	1354.1	1356.1	1358.1	1361.8	1365.9	1370.0
32	7.75	1398.4	1400.2	1402.1	1403.9	1405.8	1408.6	1409.6	1411.5	1412.7	1414.8	1417.4	1419.4	1421.3	1424.9	1428.9	1433.0
33	8.00	1462.0	1463.7	1465.7	1467.4	1469.2	1472.0	1473.0	1474.9	1476.0	1478.1	1480.6	1482.6	1484.5	1488.0	1492.0	1496.0
34	8.25	1525.6	1527.3	1529.2	1530.9	1532.7	1535.4	1536.4	1538.2	1539.4	1541.4	1543.9	1545.8	1547.7	1551.2	1555.1	1559.0
35	8.50	1589.1	1590.8	1592.6	1594.3	1596.1	1598.8	1599.7	1601.5	1602.7	1604.6	1607.1	1609.0	1610.8	1614.3	1618.1	1622.0

36	8.75	1652.6	1654.2	1656.1	1657.7	1659.5	1662.1	1663.1	1664.8	1666.0	1667.9	1670.4	1672.2	1674.0	1677.4	1681.2	1685.0
37	9.00	1716.1	1717.7	1719.5	1721.1	1722.8	1725.4	1726.4	1728.1	1729.2	1731.1	1733.6	1735.4	1737.2	1740.5	1744.2	1748.0
38	9.25	1779.4	1781.0	1782.8	1784.4	1786.1	1788.7	1789.6	1791.4	1792.5	1794.4	1796.8	1798.6	1800.3	1803.6	1807.3	1811.0
39	9.50	1843.4	1845.0	1846.7	1848.3	1849.9	1852.4	1853.3	1854.9	1856.0	1857.8	1860.1	1861.9	1863.5	1866.7	1870.3	1874.0
40	9.75	1906.6	1907.9	1909.3	1910.6	1912.1	1914.4	1915.2	1916.8	1917.8	1919.6	1921.9	1923.7	1925.5	1928.9	1932.9	1937.0
41	10.00	1956.3	1959.0	1962.0	1964.7	1967.5	1971.8	1973.4	1976.2	1978.1	1981.2	1985.2	1988.2	1991.1	1996.7	2002.8	2009.0
42	10.25	2067.5	2070.0	2073.0	2075.6	2078.4	2082.6	2084.1	2086.9	2088.7	2091.8	2095.7	2098.7	2101.5	2106.9	2112.9	2119.0
43	10.50	2178.5	2181.0	2183.9	2186.5	2189.2	2193.3	2194.8	2197.6	2199.3	2202.3	2206.2	2209.1	2211.9	2217.2	2223.1	2229.0
44	10.75	2289.5	2291.9	2294.8	2297.3	2300.0	2304.0	2305.4	2308.2	2309.9	2312.8	2316.6	2319.5	2322.2	2327.4	2333.2	2339.0
45	11.00	2400.4	2402.8	2405.6	2408.0	2410.7	2414.6	2416.1	2418.7	2420.4	2423.3	2427.0	2429.8	2432.5	2437.6	2443.3	2449.0
46	11.25	2511.2	2513.6	2516.3	2518.8	2521.3	2525.2	2526.6	2529.2	2530.9	2533.8	2537.4	2540.1	2542.8	2547.8	2553.4	2559.0
47	11.50	2622.0	2624.4	2627.0	2629.4	2632.0	2635.8	2637.2	2639.7	2641.4	2644.2	2647.7	2650.4	2653.0	2658.0	2663.5	2669.0
48	11.75	2732.8	2735.1	2737.7	2740.1	2742.6	2746.3	2747.7	2750.2	2751.8	2754.6	2758.1	2760.7	2763.3	2768.1	2773.6	2779.0
49	12.00	2843.5	2845.8	2848.3	2850.7	2853.1	2856.8	2858.1	2860.6	2862.2	2864.9	2868.4	2871.0	2873.5	2878.3	2883.6	2889.0
50	12.25	2954.2	2956.4	2958.9	2961.2	2963.6	2967.3	2968.6	2971.1	2972.6	2975.3	2978.7	2981.3	2983.8	2988.5	2993.7	2999.0
51	12.50	3064.8	3067.0	3069.5	3071.8	3074.1	3077.7	3079.0	3081.5	3083.0	3085.6	3089.0	3091.5	3094.0	3098.6	3103.8	3109.0
52	12.75	3175.4	3177.6	3180.1	3182.3	3184.6	3188.2	3189.4	3191.8	3193.4	3196.0	3199.3	3201.8	3204.2	3208.8	3213.9	3219.0
53	13.00	3286.0	3288.1	3290.6	3292.8	3295.1	3298.6	3299.8	3302.2	3303.7	3306.3	3309.5	3312.0	3314.4	3318.9	3323.9	3329.0
54	13.25	3396.6	3398.7	3401.1	3403.2	3405.5	3409.0	3410.2	3412.5	3414.0	3416.6	3419.8	3422.2	3424.6	3429.0	3434.0	3439.0
55	13.50	3507.1	3509.2	3511.6	3513.7	3515.9	3519.3	3520.6	3522.9	3524.3	3526.8	3530.0	3532.4	3534.7	3539.1	3544.1	3549.0
56	13.75	3617.4	3619.5	3621.9	3624.0	3626.3	3629.6	3630.9	3633.1	3634.6	3637.1	3640.2	3642.6	3644.9	3649.3	3654.1	3659.0
57	14.00	3730.9	3732.4	3734.3	3736.0	3737.9	3740.9	3742.0	3744.1	3745.4	3747.8	3750.7	3753.0	3755.2	3759.5	3764.2	3769.0
58	14.02	3738.0	3740.1	3742.4	3744.5	3746.7	3750.0	3751.2	3753.5	3754.9	3757.3	3760.4	3762.8	3765.1	3769.4	3774.2	3779.0
59	14.25	3838.6	3840.6	3842.9	3845.0	3847.1	3850.4	3851.6	3853.8	3855.2	3857.6	3860.7	3863.0	3865.2	3869.5	3874.2	3879.0
60	14.50	3947.9	3950.0	3952.4	3954.6	3956.9	3960.3	3961.5	3963.8	3965.2	3967.7	3970.7	3973.1	3975.3	3979.6	3984.3	3989.0
61	14.75	4067.8	4069.0	4070.5	4071.9	4073.3	4075.6	4076.5	4078.1	4079.1	4081.0	4083.4	4085.2	4087.0	4090.6	4094.7	4099.0
62	15.00	4135.9	4139.1	4142.8	4146.0	4149.5	4154.7	4156.6	4160.1	4162.3	4166.1	4171.0	4174.7	4178.2	4185.0	4192.4	4200.0
63	15.25	4317.0	4320.2	4323.7	4326.9	4330.3	4335.5	4337.3	4340.7	4343.0	4346.7	4351.5	4355.1	4358.6	4365.2	4372.6	4380.0
64	15.50	4498.0	4501.1	4504.6	4507.8	4511.1	4516.2	4518.0	4521.4	4523.5	4527.2	4531.9	4535.5	4538.9	4545.4	4552.7	4560.0
65	15.75	4679.0	4682.0	4685.5	4688.6	4691.9	4696.8	4698.6	4702.0	4704.1	4707.7	4712.4	4715.9	4719.2	4725.7	4732.8	4740.0

66	16.00	4859.9	4862.9	4866.3	4869.3	4872.6	4877.5	4879.2	4882.5	4884.6	4888.2	4892.8	4896.2	4899.5	4905.9	4912.9	4920.0
67	16.25	5040.7	5043.7	5047.0	5050.1	5053.2	5058.1	5059.8	5063.0	5065.1	5068.7	5073.1	5076.6	5079.8	5086.1	5093.0	5100.0
68	16.50	5221.5	5224.4	5227.8	5230.7	5233.9	5238.6	5240.3	5243.5	5245.6	5249.1	5253.5	5256.9	5260.1	5266.2	5273.1	5280.0
69	16.75	5402.3	5405.2	5408.5	5411.4	5414.5	5419.2	5420.9	5424.0	5426.0	5429.5	5433.9	5437.2	5440.4	5446.4	5453.2	5460.0
70	17.00	5583.1	5585.9	5589.1	5592.0	5595.1	5599.7	5601.4	5604.5	5606.5	5609.9	5614.2	5617.5	5620.6	5626.6	5633.3	5640.0
71	17.25	5763.8	5766.6	5769.8	5772.6	5775.6	5780.2	5781.9	5784.9	5786.9	5790.2	5794.5	5797.7	5800.9	5806.8	5813.4	5820.0
72	17.50	5944.4	5947.2	5950.4	5953.2	5956.2	5960.7	5962.3	5965.4	5967.3	5970.6	5974.8	5978.0	5981.1	5986.9	5993.4	6000.0
73	17.75	6125.1	6127.8	6130.9	6133.7	6136.7	6141.1	6142.8	6145.8	6147.7	6150.9	6155.1	6158.3	6161.3	6167.1	6173.5	6180.0
74	18.00	6305.7	6308.4	6311.5	6314.3	6317.2	6321.6	6323.2	6326.1	6328.0	6331.3	6335.4	6338.5	6341.5	6347.2	6353.6	6360.0
75	18.25	6486.3	6489.0	6492.0	6494.8	6497.7	6502.0	6503.6	6506.5	6508.4	6511.6	6515.7	6518.8	6521.7	6527.4	6533.7	6540.0
76	18.50	6666.9	6669.5	6672.6	6675.2	6678.1	6682.4	6684.0	6686.9	6688.7	6691.9	6695.9	6699.0	6701.9	6707.5	6713.7	6720.0
77	18.75	6847.5	6850.1	6853.1	6855.7	6858.5	6862.8	6864.3	6867.2	6869.1	6872.2	6876.2	6879.2	6882.1	6887.6	6893.8	6900.0
78	19.00	7028.0	7030.6	7033.5	7036.2	7039.0	7043.2	7044.7	7047.6	7049.4	7052.5	7056.4	7059.4	7062.3	7067.8	7073.9	7080.0
79	19.25	7208.5	7211.1	7214.0	7216.6	7219.4	7223.6	7225.1	7227.9	7229.7	7232.7	7236.6	7239.6	7242.5	7247.9	7253.9	7260.0
80	19.50	7389.3	7391.8	7394.6	7397.2	7399.9	7404.0	7405.5	7408.2	7410.0	7413.0	7416.9	7419.8	7422.6	7428.0	7434.0	7440.0
81	19.75	7566.1	7569.0	7572.2	7575.1	7578.2	7582.7	7584.3	7587.3	7589.2	7592.5	7596.5	7599.6	7602.5	7608.0	7614.0	7620.0
82	20.00	7774.1	7775.4	7776.9	7778.2	7779.6	7781.7	7782.4	7783.8	7784.8	7786.3	7788.3	7789.7	7791.2	7793.9	7796.9	7800.0
83	20.25	7867.2	7868.5	7870.0	7871.3	7872.7	7874.8	7875.5	7876.9	7877.8	7879.4	7881.3	7882.8	7884.2	7886.9	7890.0	7893.0
84	20.50	7960.4	7961.6	7963.1	7964.4	7965.8	7967.8	7968.6	7970.0	7970.9	7972.4	7974.4	7975.8	7977.3	7980.0	7983.0	7986.0
85	20.75	8053.5	8054.7	8056.2	8057.5	8058.9	8060.9	8061.7	8063.1	8064.0	8065.5	8067.4	8068.9	8070.3	8073.0	8076.0	8079.0
86	21.00	8146.6	8147.9	8149.3	8150.6	8152.0	8154.0	8154.8	8156.1	8157.0	8158.5	8160.5	8161.9	8163.3	8166.0	8169.0	8172.0
87	21.25	8239.7	8241.0	8242.4	8243.7	8245.0	8247.1	8247.8	8249.2	8250.1	8251.6	8253.5	8255.0	8256.4	8259.0	8262.0	8265.0
88	21.50	8332.8	8334.1	8335.5	8336.8	8338.1	8340.2	8340.9	8342.3	8343.2	8344.7	8346.6	8348.0	8349.4	8352.1	8355.0	8358.0
89	21.75	8425.9	8427.2	8428.6	8429.9	8431.2	8433.3	8434.0	8435.4	8436.2	8437.7	8439.6	8441.1	8442.5	8445.1	8448.0	8451.0
90	22.00	8519.0	8520.3	8521.7	8523.0	8524.3	8526.3	8527.1	8528.4	8529.3	8530.8	8532.7	8534.1	8535.5	8538.1	8541.0	8544.0
91	22.25	8612.2	8613.4	8614.8	8616.1	8617.4	8619.4	8620.1	8621.5	8622.4	8623.8	8625.7	8627.2	8628.5	8631.1	8634.1	8637.0
92	22.50	8705.2	8706.4	8707.9	8709.1	8710.5	8712.5	8713.2	8714.5	8715.4	8716.9	8718.8	8720.2	8721.6	8724.2	8727.1	8730.0
93	22.75	8799.0	8800.1	8801.5	8802.6	8803.9	8805.8	8806.5	8807.8	8808.7	8810.1	8811.9	8813.3	8814.6	8817.2	8820.1	8823.0
94	23.00	8886.4	8887.9	8889.7	8891.2	8892.8	8895.3	8896.1	8897.8	8898.8	8900.6	8902.8	8904.5	8906.1	8909.2	8912.6	8916.0
95	23.25	9003.0	9004.0	9005.3	9006.4	9007.5	9009.3	9010.0	9011.2	9011.9	9013.2	9014.9	9016.2	9017.4	9019.7	9022.4	9025.0

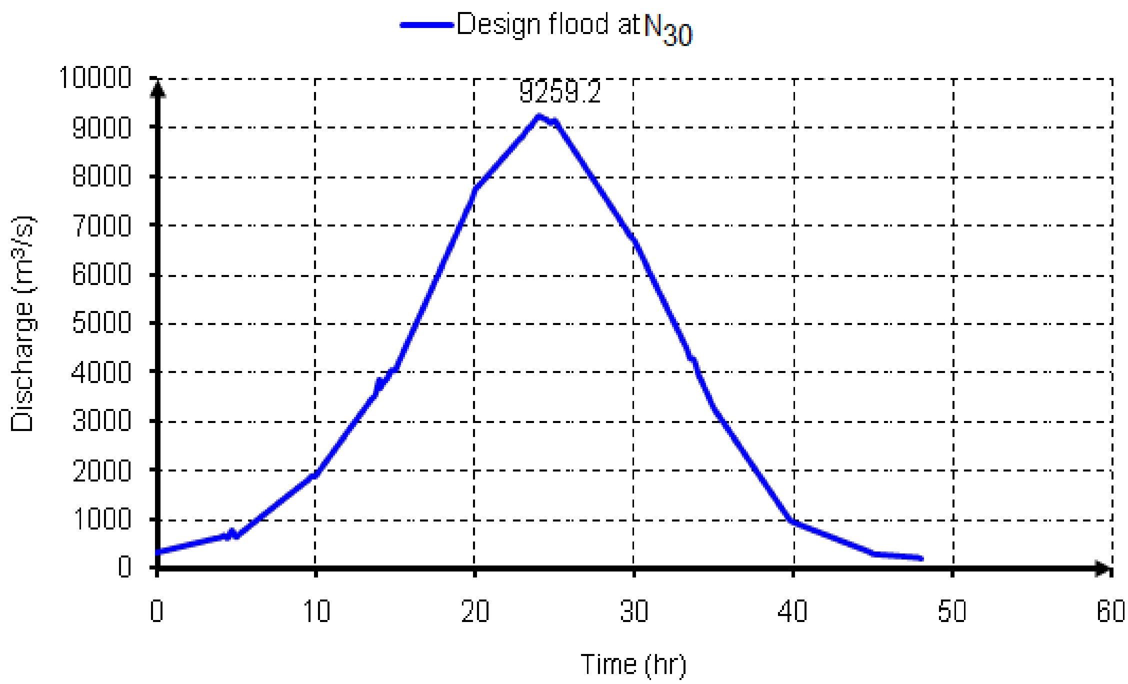
96	23.50	9084.9	9086.2	9087.7	9089.1	9090.5	9092.6	9093.3	9094.7	9095.6	9097.1	9099.0	9100.5	9101.8	9104.4	9107.2	9110.0
97	23.75	9187.6	9188.4	9189.2	9190.0	9190.7	9191.8	9192.2	9193.0	9193.4	9194.2	9195.1	9195.8	9196.4	9197.6	9198.8	9200.0
98	24.00	9247.6	9247.1	9246.6	9246.1	9245.5	9244.7	9244.5	9243.9	9243.6	9243.0	9242.2	9241.7	9241.1	9240.1	9238.9	9237.8
99	24.25	9209.8	9209.3	9208.8	9208.3	9207.8	9207.0	9206.7	9206.1	9205.8	9205.2	9204.5	9203.9	9203.4	9202.3	9201.2	9200.0
100	24.50	9172.8	9172.2	9171.6	9171.0	9170.4	9169.5	9169.2	9168.6	9168.2	9167.6	9166.8	9166.2	9165.6	9164.6	9163.4	9162.2
101	24.75	9127.4	9127.5	9127.5	9127.5	9127.5	9127.4	9127.4	9127.3	9127.2	9127.0	9126.8	9126.6	9126.4	9125.9	9125.2	9124.5
102	25.00	9132.8	9131.2	9129.3	9127.7	9125.9	9123.2	9122.3	9120.5	9119.3	9117.4	9114.9	9113.0	9111.2	9107.7	9103.9	9100.0
103	25.25	9008.0	9006.3	9004.5	9002.8	9001.0	8998.4	8997.4	8995.6	8994.4	8992.5	8990.0	8988.1	8986.3	8982.8	8978.9	8975.0
104	25.50	8883.2	8881.5	8879.6	8878.0	8876.2	8873.5	8872.5	8870.7	8869.6	8867.6	8865.1	8863.2	8861.3	8857.8	8853.9	8850.0
105	25.75	8758.3	8756.7	8754.8	8753.1	8751.3	8748.6	8747.7	8745.8	8744.7	8742.7	8740.2	8738.2	8736.4	8732.9	8729.0	8725.0
106	26.00	8633.5	8631.9	8630.0	8628.3	8626.5	8623.8	8622.8	8621.0	8619.8	8617.8	8615.2	8613.3	8611.5	8607.9	8604.0	8600.0
107	26.25	8508.7	8507.1	8505.2	8503.5	8501.6	8498.9	8497.9	8496.1	8494.9	8492.9	8490.3	8488.4	8486.5	8483.0	8479.0	8475.0
108	26.50	8383.9	8382.3	8380.3	8378.6	8376.8	8374.1	8373.1	8371.2	8370.0	8368.0	8365.4	8363.5	8361.6	8358.0	8354.0	8350.0
109	26.75	8259.1	8257.5	8255.5	8253.8	8252.0	8249.2	8248.2	8246.3	8245.1	8243.1	8240.5	8238.6	8236.7	8233.1	8229.1	8225.0
110	27.00	8134.4	8132.7	8130.7	8129.0	8127.1	8124.3	8123.3	8121.5	8120.3	8118.2	8115.6	8113.6	8111.7	8108.1	8104.1	8100.0
111	27.25	8009.6	8007.9	8005.9	8004.2	8002.3	7999.5	7998.5	7996.6	7995.4	7993.3	7990.7	7988.7	7986.8	7983.2	7979.1	7975.0
112	27.50	7884.8	7883.1	7881.1	7879.3	7877.5	7874.7	7873.6	7871.7	7870.5	7868.5	7865.8	7863.8	7861.9	7858.2	7854.1	7850.0
113	27.75	7760.0	7758.3	7756.3	7754.5	7752.6	7749.8	7748.8	7746.9	7745.7	7743.6	7740.9	7738.9	7737.0	7733.3	7729.2	7725.0
114	28.00	7635.2	7633.5	7631.5	7629.7	7627.8	7625.0	7623.9	7622.0	7620.8	7618.7	7616.0	7614.0	7612.0	7608.3	7604.2	7600.0
115	28.25	7510.5	7508.7	7506.7	7504.9	7503.0	7500.1	7499.1	7497.2	7495.9	7493.8	7491.1	7489.1	7487.1	7483.4	7479.2	7475.0
116	28.50	7385.7	7383.9	7381.9	7380.1	7378.2	7375.3	7374.3	7372.3	7371.1	7368.9	7366.2	7364.2	7362.2	7358.4	7354.2	7350.0
117	28.75	7261.0	7259.2	7257.1	7255.3	7253.4	7250.5	7249.4	7247.5	7246.2	7244.1	7241.4	7239.3	7237.3	7233.5	7229.3	7225.0
118	29.00	7136.2	7134.4	7132.4	7130.5	7128.6	7125.7	7124.6	7122.6	7121.4	7119.2	7116.5	7114.4	7112.4	7108.6	7104.3	7100.0
119	29.25	7011.5	7009.7	7007.6	7005.8	7003.8	7000.9	6999.8	6997.8	6996.5	6994.3	6991.6	6989.5	6987.5	6983.6	6979.3	6975.0
120	29.50	6886.9	6885.1	6883.0	6881.1	6879.1	6876.1	6875.0	6873.0	6871.7	6869.5	6866.7	6864.6	6862.6	6858.7	6854.4	6850.0
121	29.75	6760.0	6758.4	6756.5	6754.8	6753.0	6750.3	6749.3	6747.4	6746.2	6744.2	6741.5	6739.5	6737.5	6733.7	6729.4	6725.0
122	30.00	6650.7	6648.2	6645.4	6642.8	6640.1	6636.0	6634.5	6631.7	6630.0	6626.9	6623.1	6620.2	6617.4	6612.0	6606.0	6600.0
123	30.25	6481.3	6478.7	6475.8	6473.3	6470.5	6466.4	6464.9	6462.1	6460.3	6457.2	6453.3	6450.4	6447.5	6442.1	6436.1	6430.0
124	30.50	6311.8	6309.3	6306.3	6303.7	6300.9	6296.8	6295.2	6292.4	6290.6	6287.5	6283.6	6280.6	6277.7	6272.3	6266.2	6260.0
125	30.75	6142.4	6139.8	6136.9	6134.2	6131.4	6127.2	6125.6	6122.8	6120.9	6117.8	6113.8	6110.8	6107.9	6102.4	6096.2	6090.0

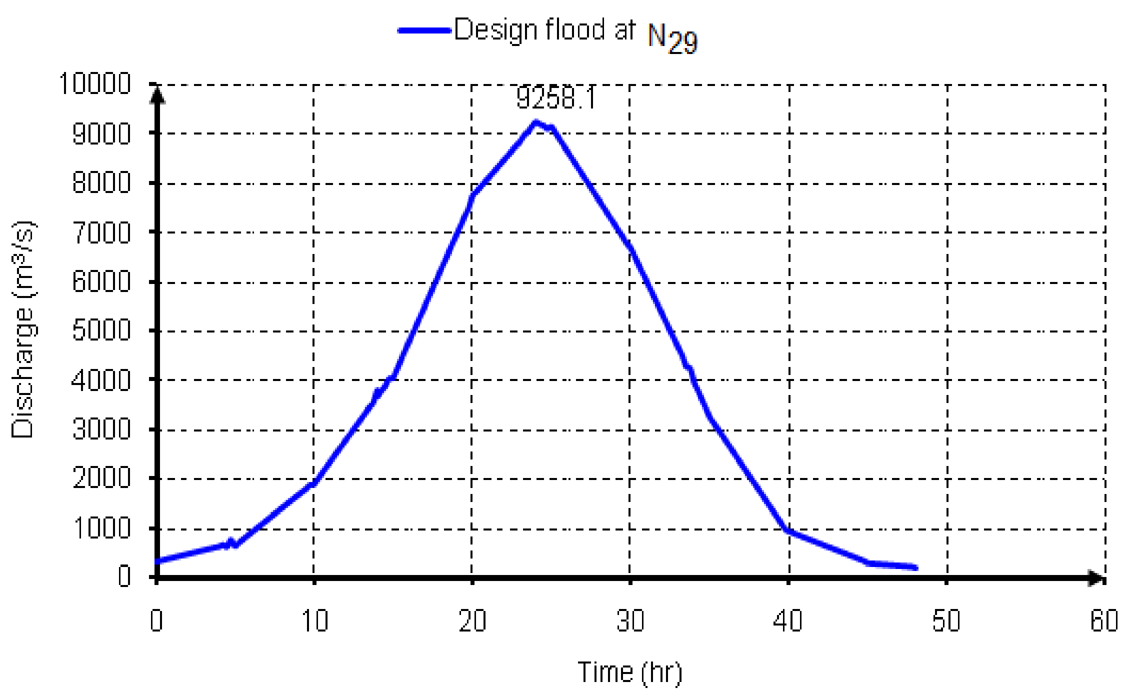
126	31.00	5973.0	5970.4	5967.4	5964.7	5961.9	5957.6	5956.0	5953.1	5951.3	5948.1	5944.1	5941.1	5938.1	5932.5	5926.3	5920.0
127	31.25	5803.6	5801.0	5797.9	5795.2	5792.4	5788.0	5786.5	5783.5	5781.7	5778.5	5774.4	5771.3	5768.4	5762.7	5756.4	5750.0
128	31.50	5634.3	5631.6	5628.5	5625.8	5622.9	5618.5	5616.9	5613.9	5612.1	5608.8	5604.7	5601.6	5598.6	5592.8	5586.5	5580.0
129	31.75	5465.0	5462.2	5459.1	5456.4	5453.4	5449.0	5447.4	5444.4	5442.5	5439.2	5435.0	5431.9	5428.8	5423.0	5416.5	5410.0
130	32.00	5295.7	5292.9	5289.8	5287.0	5284.0	5279.5	5277.9	5274.8	5272.9	5269.6	5265.3	5262.1	5259.1	5253.2	5246.6	5240.0
131	32.25	5126.4	5123.6	5120.4	5117.6	5114.6	5110.0	5108.4	5105.3	5103.3	5100.0	5095.7	5092.4	5089.3	5083.4	5076.7	5070.0
132	32.50	4957.2	4954.4	4951.1	4948.2	4945.2	4940.6	4938.9	4935.8	4933.8	4930.4	4926.0	4922.7	4919.6	4913.5	4906.8	4900.0
133	32.75	4788.0	4785.1	4781.9	4778.9	4775.8	4771.1	4769.4	4766.3	4764.3	4760.8	4756.4	4753.1	4749.9	4743.7	4736.9	4730.0
134	33.00	4618.8	4615.9	4612.6	4609.7	4606.5	4601.7	4600.0	4596.8	4594.8	4591.3	4586.8	4583.4	4580.2	4573.9	4567.0	4560.0
135	33.25	4450.1	4447.1	4443.7	4440.6	4437.3	4432.5	4430.7	4427.4	4425.3	4421.8	4417.2	4413.8	4410.5	4404.2	4397.1	4390.0
136	33.50	4275.8	4273.4	4270.7	4268.2	4265.5	4261.3	4259.8	4256.9	4255.0	4251.7	4247.4	4244.1	4240.8	4234.4	4227.2	4220.0
137	33.75	4141.8	4138.5	4133.4	4130.1	4126.0	4117.0	4113.9	4108.1	4104.2	4097.7	4088.9	4081.8	4075.0	4064.6	4057.4	4050.0
138	34.00	3929.4	3921.6	3921.7	3913.9	3914.0	3906.3	3906.4	3898.6	3898.7	3891.0	3891.1	3883.5	3883.5	3875.9	3876.0	3880.0
139	34.15	3825.6	3818.1	3818.3	3810.8	3811.0	3803.5	3803.7	3796.3	3796.5	3789.1	3789.3	3782.0	3782.1	3774.8	3775.0	3779.0
140	34.25	3754.6	3747.3	3747.6	3740.3	3740.6	3733.4	3733.6	3726.4	3726.7	3719.5	3719.8	3712.6	3712.9	3705.7	3706.0	3710.0
141	34.50	3579.8	3573.0	3573.5	3566.7	3567.2	3560.5	3560.9	3554.2	3554.6	3548.0	3548.4	3541.8	3542.2	3535.6	3536.0	3540.0
142	34.75	3405.0	3398.7	3399.4	3393.1	3393.7	3387.5	3388.1	3382.0	3382.6	3376.4	3377.0	3370.9	3371.5	3365.4	3366.0	3370.0
143	35.00	3230.2	3224.4	3225.2	3219.5	3220.3	3214.6	3215.4	3209.8	3210.5	3204.9	3205.7	3200.1	3200.8	3195.2	3196.0	3200.0
144	35.25	3114.0	3108.6	3109.5	3104.1	3105.0	3099.7	3100.6	3095.3	3096.2	3090.9	3091.8	3086.5	3087.4	3082.1	3083.0	3087.0
145	35.50	2997.8	2992.7	2993.8	2988.7	2989.8	2984.8	2985.8	2980.8	2981.8	2976.9	2977.9	2972.9	2973.9	2969.0	2970.0	2974.0
146	35.75	2881.6	2876.9	2878.0	2873.4	2874.5	2869.8	2871.0	2866.3	2867.4	2862.8	2863.9	2859.4	2860.5	2855.9	2857.0	2861.0
147	36.00	2765.4	2761.0	2762.3	2758.0	2759.2	2754.9	2756.1	2751.9	2753.1	2748.8	2750.0	2745.8	2747.0	2742.8	2744.0	2748.0
148	36.25	2649.2	2645.2	2646.5	2642.6	2643.9	2640.0	2641.3	2637.4	2638.7	2634.8	2636.1	2632.2	2633.6	2629.7	2631.0	2635.0
149	36.50	2533.0	2529.3	2530.8	2527.2	2528.6	2525.0	2526.5	2522.9	2524.4	2520.8	2522.2	2518.7	2520.1	2516.6	2518.0	2522.0
150	36.75	2416.8	2413.5	2415.1	2411.8	2413.4	2410.1	2411.7	2408.4	2410.0	2406.8	2408.3	2405.1	2406.7	2403.4	2405.0	2409.0
151	37.00	2300.6	2297.6	2299.3	2296.4	2298.1	2295.2	2296.9	2294.0	2295.6	2292.7	2294.4	2291.5	2293.2	2290.3	2292.0	2296.0
152	37.25	2184.3	2181.8	2183.6	2181.0	2182.8	2180.2	2182.0	2179.5	2181.3	2178.7	2180.5	2178.0	2179.8	2177.2	2179.0	2183.0
153	37.50	2068.1	2065.9	2067.8	2065.6	2067.5	2065.3	2067.2	2065.0	2066.9	2064.7	2066.6	2064.4	2066.3	2064.1	2066.0	2070.0
154	37.75	1951.9	1950.0	1952.1	1950.2	1952.3	1950.4	1952.4	1950.5	1952.6	1950.7	1952.7	1950.8	1952.9	1951.0	1953.0	1957.0
155	38.00	1835.7	1834.2	1836.4	1834.8	1837.0	1835.4	1837.6	1836.0	1838.2	1836.7	1838.8	1837.3	1839.4	1837.9	1840.0	1844.0

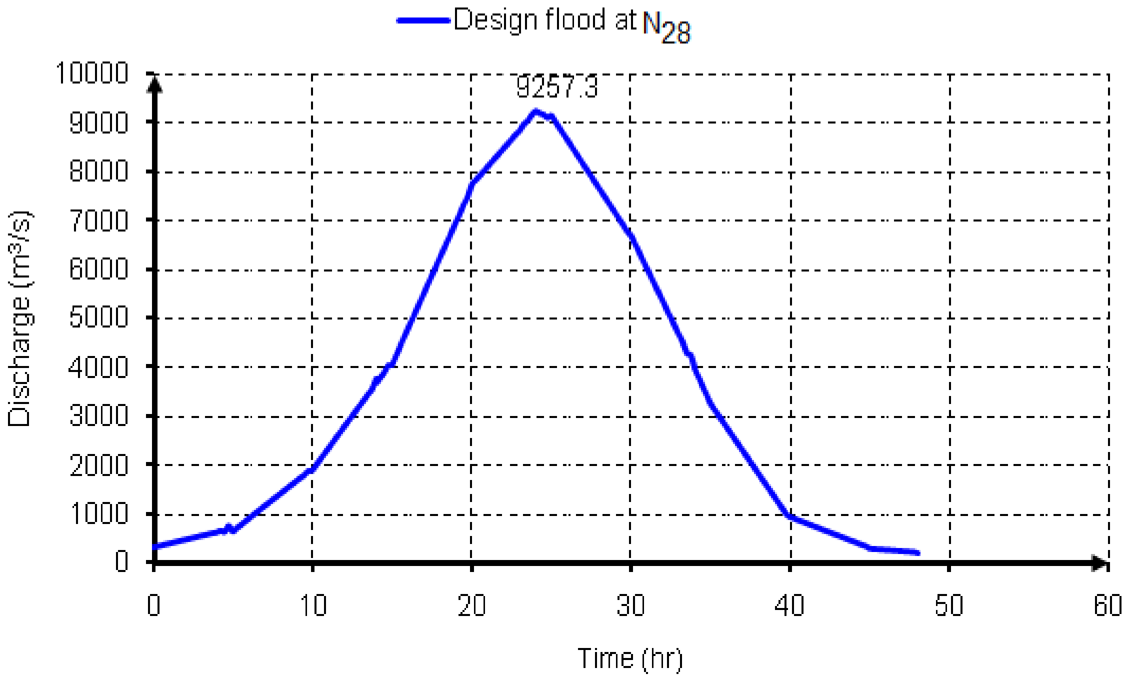
156	38.25	1719.5	1718.3	1720.6	1719.4	1721.7	1720.5	1722.8	1721.6	1723.8	1722.6	1724.9	1723.7	1725.9	1724.8	1727.0	1731.0
157	38.50	1603.3	1602.5	1604.9	1604.0	1606.4	1605.6	1607.9	1607.1	1609.5	1608.6	1611.0	1610.1	1612.5	1611.7	1614.0	1618.0
158	38.75	1487.1	1486.6	1489.1	1488.6	1491.1	1490.6	1493.1	1492.6	1495.1	1494.6	1497.1	1496.6	1499.0	1498.5	1501.0	1505.0
159	39.00	1370.9	1370.8	1373.4	1373.2	1375.9	1375.7	1378.3	1378.1	1380.7	1380.6	1383.2	1383.0	1385.6	1385.4	1388.0	1392.0
160	39.25	1254.7	1254.9	1257.7	1257.8	1260.6	1260.8	1263.5	1263.7	1266.4	1266.6	1269.3	1269.4	1272.1	1272.3	1275.0	1279.0
161	39.50	1138.5	1139.1	1141.9	1142.5	1145.3	1145.8	1148.7	1149.2	1152.0	1152.5	1155.4	1155.9	1158.7	1159.2	1162.0	1166.0
162	39.75	1022.3	1023.2	1026.2	1027.1	1030.0	1030.9	1033.9	1034.7	1037.7	1038.5	1041.5	1042.3	1045.2	1046.1	1049.0	1053.0
163	40.00	971.9	973.0	976.0	977.0	980.0	981.1	984.1	985.1	988.1	989.1	992.1	993.1	996.0	997.0	1000.0	1004.0
164	40.25	941.1	942.2	945.3	946.4	949.4	950.5	953.6	954.7	957.7	958.8	961.8	962.9	965.9	967.0	970.0	974.0
165	40.50	910.2	911.5	914.5	915.7	918.8	920.0	923.1	924.3	927.3	928.5	931.6	932.8	935.8	937.0	940.0	944.0
166	40.75	879.4	880.7	883.8	885.1	888.2	889.5	892.6	893.9	897.0	898.3	901.3	902.6	905.7	907.0	910.0	914.0
167	41.00	848.5	849.9	853.1	854.5	857.6	859.0	862.1	863.5	866.6	868.0	871.1	872.5	875.6	876.9	880.0	884.0
168	41.25	817.7	819.2	822.4	823.8	827.0	828.5	831.6	833.1	836.3	837.7	840.9	842.3	845.4	846.9	850.0	854.0
169	41.50	786.8	788.4	791.6	793.2	796.4	798.0	801.2	802.7	805.9	807.5	810.6	812.2	815.3	816.9	820.0	824.0
170	41.75	756.0	757.7	760.9	762.6	765.8	767.5	770.7	772.3	775.5	777.2	780.4	782.0	785.2	786.8	790.0	794.0
171	42.00	725.1	726.9	730.2	731.9	735.2	736.9	740.2	741.9	745.2	746.9	750.1	751.9	755.1	756.8	760.0	764.0
172	42.25	694.3	696.1	699.5	701.3	704.6	706.4	709.7	711.6	714.8	716.6	719.9	721.7	725.0	726.8	730.0	734.0
173	42.50	663.4	665.4	668.7	670.7	674.0	675.9	679.2	681.2	684.5	686.4	689.7	691.6	694.8	696.7	700.0	704.0
174	42.75	632.6	634.6	638.0	640.0	643.4	645.4	648.7	650.8	654.1	656.1	659.4	661.4	664.7	666.7	670.0	674.0
175	43.00	601.7	603.9	607.3	609.4	612.8	614.9	618.3	620.4	623.7	625.8	629.2	631.3	634.6	636.7	640.0	644.0
176	43.25	570.9	573.1	576.5	578.8	582.2	584.4	587.8	590.0	593.4	595.6	598.9	601.1	604.5	606.7	610.0	614.0
177	43.50	540.0	542.4	545.8	548.1	551.6	553.9	557.3	559.6	563.0	565.3	568.7	571.0	574.4	576.6	580.0	584.0
178	43.75	509.2	511.6	515.1	517.5	521.0	523.4	526.8	529.2	532.6	535.0	538.5	540.8	544.2	546.6	550.0	554.0
179	44.00	478.3	480.8	484.4	486.9	490.4	492.8	496.3	498.8	502.3	504.7	508.2	510.7	514.1	516.6	520.0	524.0
180	44.25	447.5	450.1	453.6	456.2	459.8	462.3	465.9	468.4	471.9	474.5	478.0	480.5	484.0	486.5	490.0	494.0
181	44.50	416.6	419.3	422.9	425.6	429.2	431.8	435.4	438.0	441.6	444.2	447.7	450.4	453.9	456.5	460.0	464.0
182	44.75	385.8	388.6	392.2	394.9	398.5	401.3	404.9	407.6	411.2	413.9	417.5	420.2	423.8	426.5	430.0	434.0
183	45.00	341.6	344.5	348.1	351.0	354.7	357.6	361.2	364.1	367.7	370.5	374.1	377.0	380.6	383.4	387.0	391.0
184	45.25	335.4	338.3	342.0	344.9	348.6	351.5	355.1	358.0	361.6	364.5	368.1	371.0	374.6	377.4	381.0	385.0
185	45.50	329.2	332.2	335.8	338.8	342.4	345.4	349.0	351.9	355.5	358.4	362.1	364.9	368.5	371.4	375.0	379.0

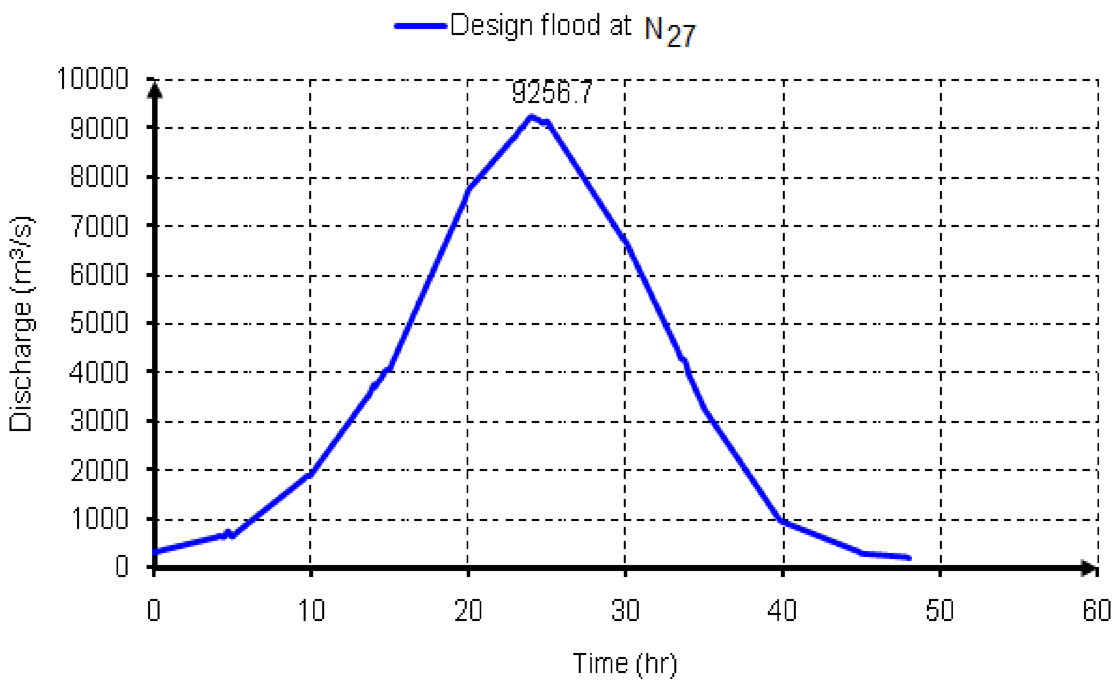
186	45.75	323.1	326.0	329.7	332.7	336.3	339.3	342.9	345.8	349.5	352.4	356.0	358.9	362.5	365.4	369.0	373.0
187	46.00	316.9	319.9	323.6	326.5	330.2	333.2	336.8	339.8	343.4	346.3	350.0	352.9	356.5	359.4	363.0	367.0
188	46.25	310.7	313.7	317.4	320.4	324.1	327.1	330.7	333.7	337.3	340.3	343.9	346.9	350.5	353.4	357.0	361.0
189	46.50	304.5	307.6	311.3	314.3	318.0	321.0	324.6	327.6	331.3	334.2	337.9	340.8	344.4	347.4	351.0	355.0
190	46.75	298.4	301.4	305.1	308.1	311.8	314.8	318.5	321.5	325.2	328.2	331.8	334.8	338.4	341.4	345.0	349.0
191	47.00	292.2	295.3	299.0	302.0	305.7	308.7	312.4	315.4	319.1	322.1	325.8	328.8	332.4	335.4	339.0	343.0
192	47.25	286.0	289.1	292.8	295.9	299.6	302.6	306.3	309.4	313.0	316.1	319.7	322.7	326.4	329.4	333.0	337.0
193	47.50	279.9	283.0	286.7	289.8	293.5	296.5	300.2	303.3	307.0	310.0	313.7	316.7	320.3	323.4	327.0	331.0
194	47.75	273.7	276.8	280.5	283.6	287.3	290.4	294.1	297.2	300.9	304.0	307.6	310.7	314.3	317.4	321.0	325.0
195	48.00	248.0	251.2	254.9	258.1	261.8	265.0	268.7	271.9	275.6	278.7	282.4	285.5	289.2	292.3	296.0	300.0

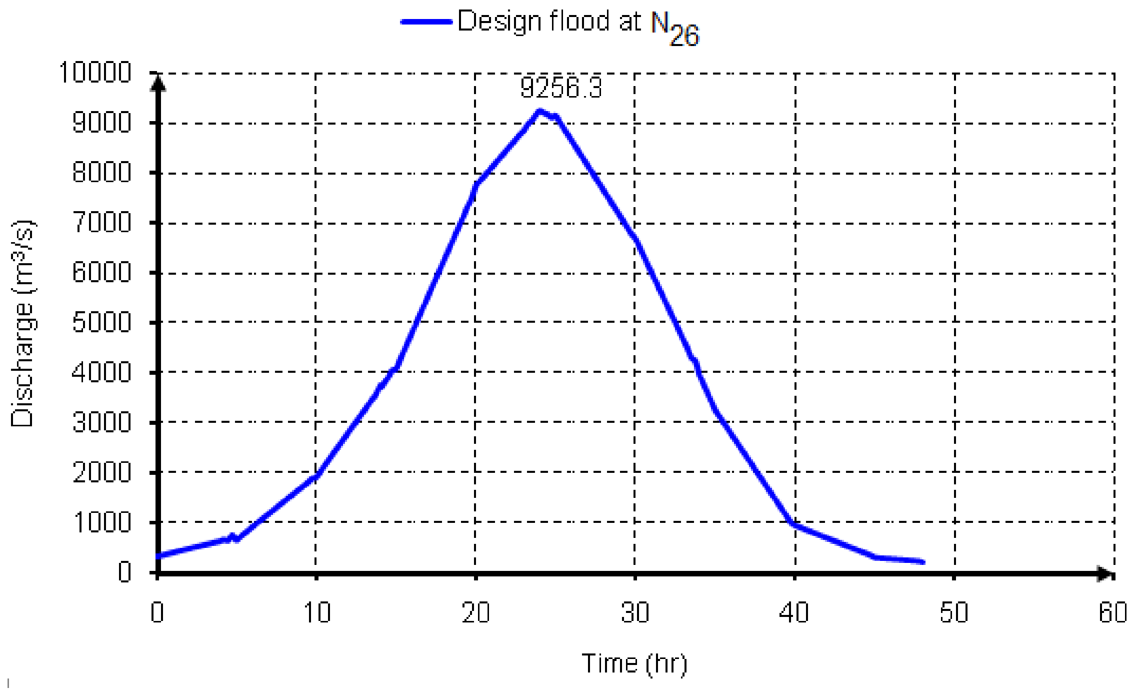
ANNEX 5 : RIVER DESIGN FLOOD HYDROGRAPHS



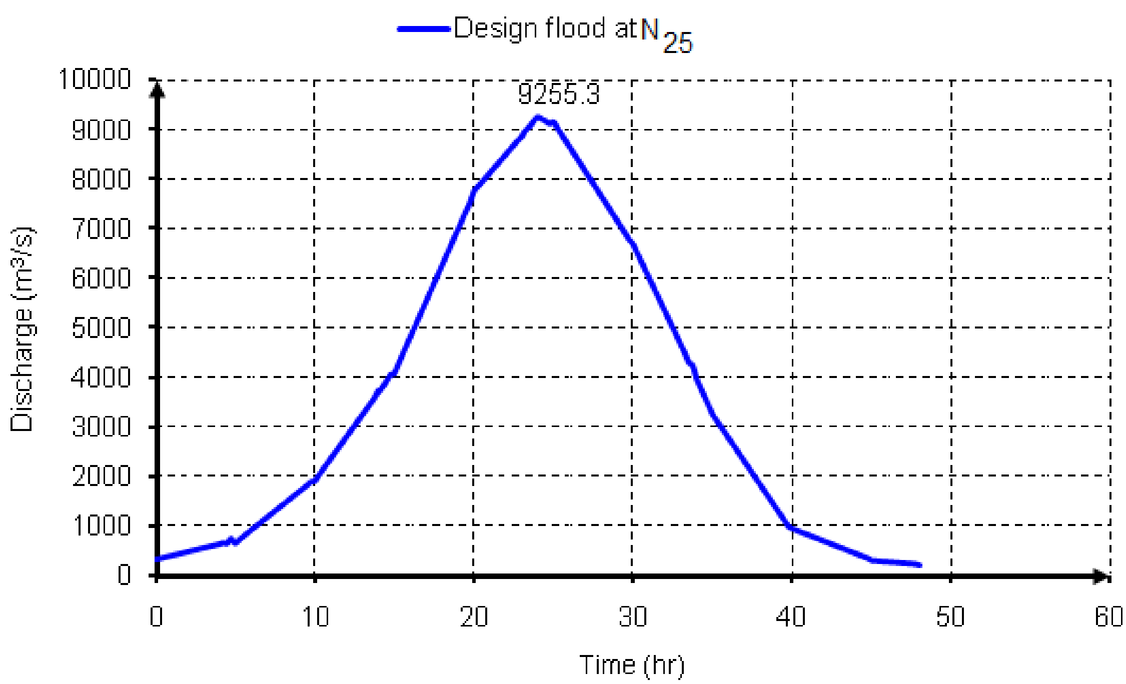



Design flood at N_{28}
9257.3
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Discharge (m³/s)
0
10
20
30
40
50
60
Time (hr)

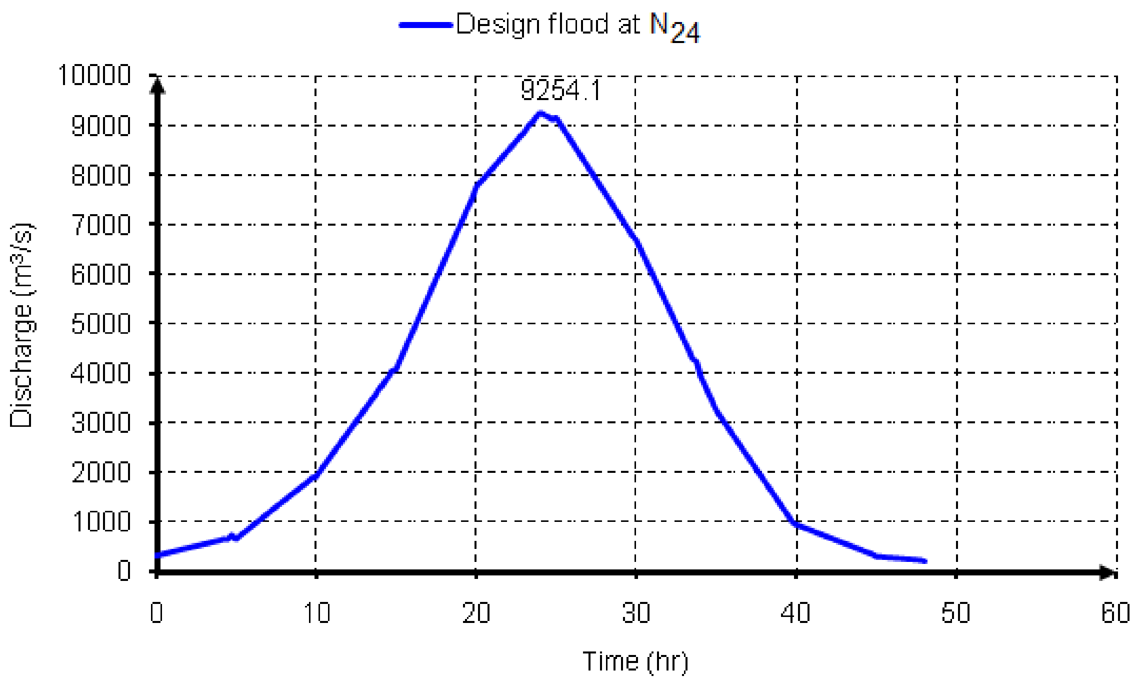

Design flood at N_{27}
9256.7
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Discharge (m³/s)
0
10
20
30
40
50
60
Time (hr)



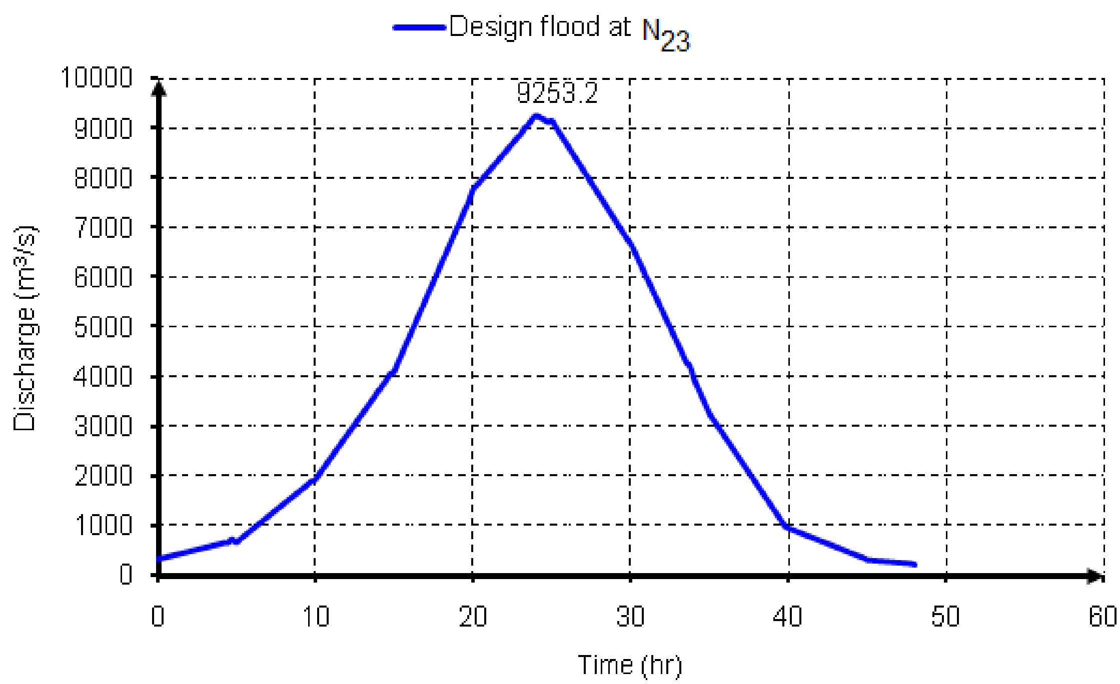
Design flood at N_{26}
9256.3
Discharge (m³/s)
Time (hr)



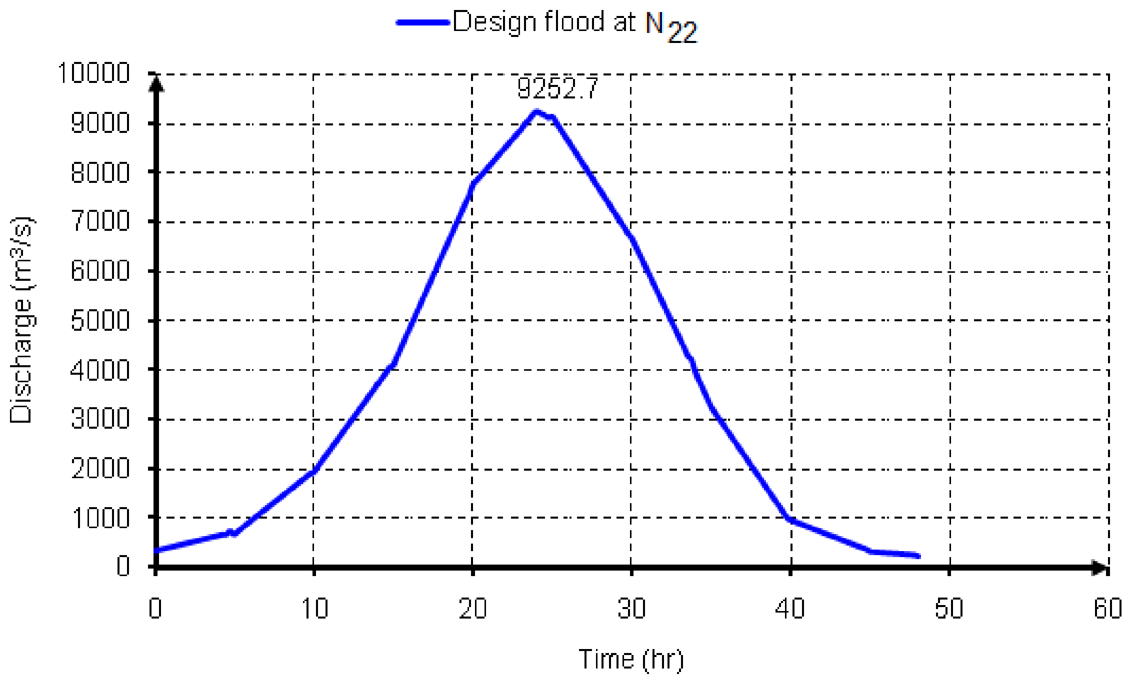
Design flood at N_{25}
9255.3
Discharge (m³/s)
Time (hr)

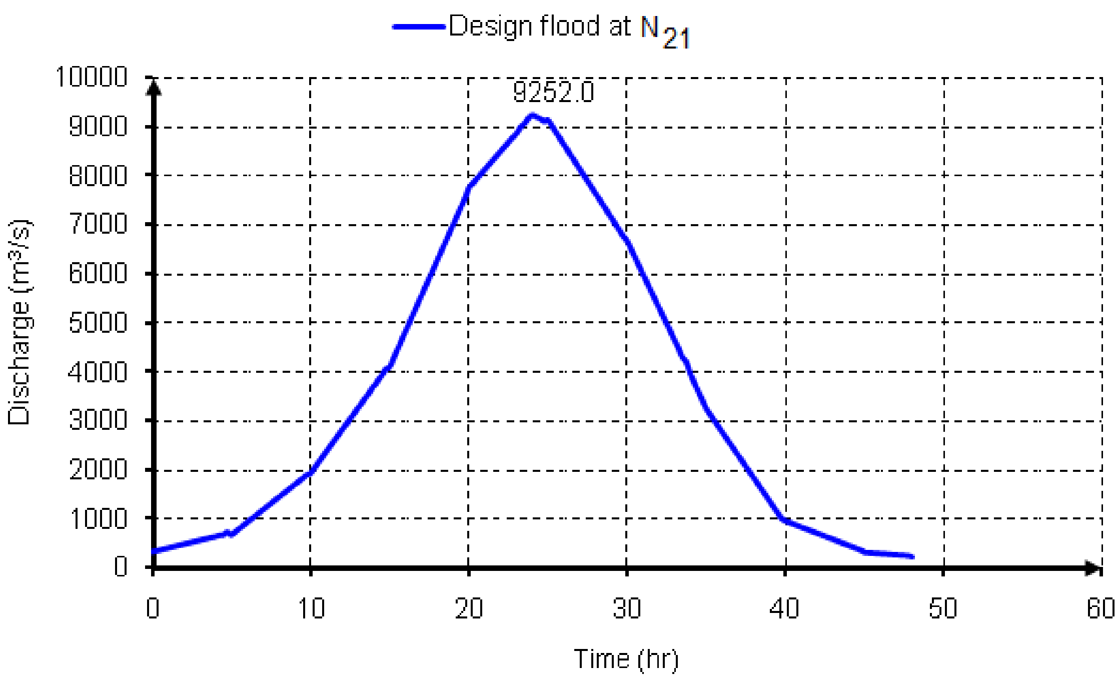


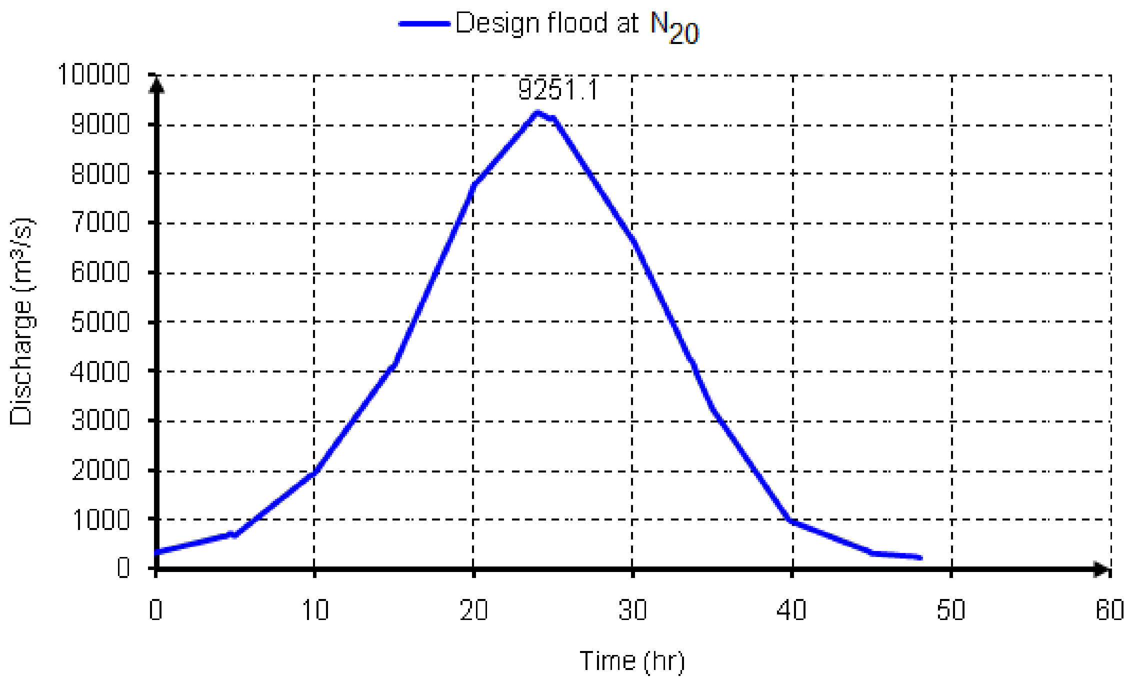
Design flood at N24
9254.1
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Discharge (m3/s)
0
10
20
30
40
50
60
Time (hr)



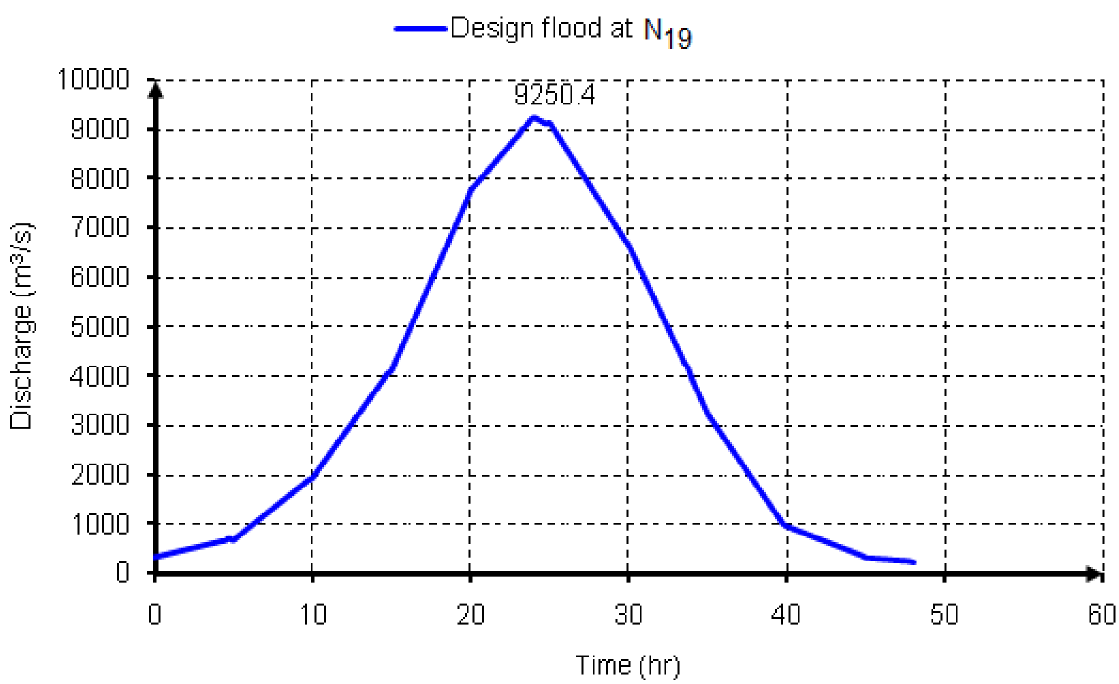
Design flood at N23
9253.2
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Discharge (m3/s)
0
10
20
30
40
50
60
Time (hr)


Design flood at N22
9252.7
Discharge (m³/s)
Time (hr)

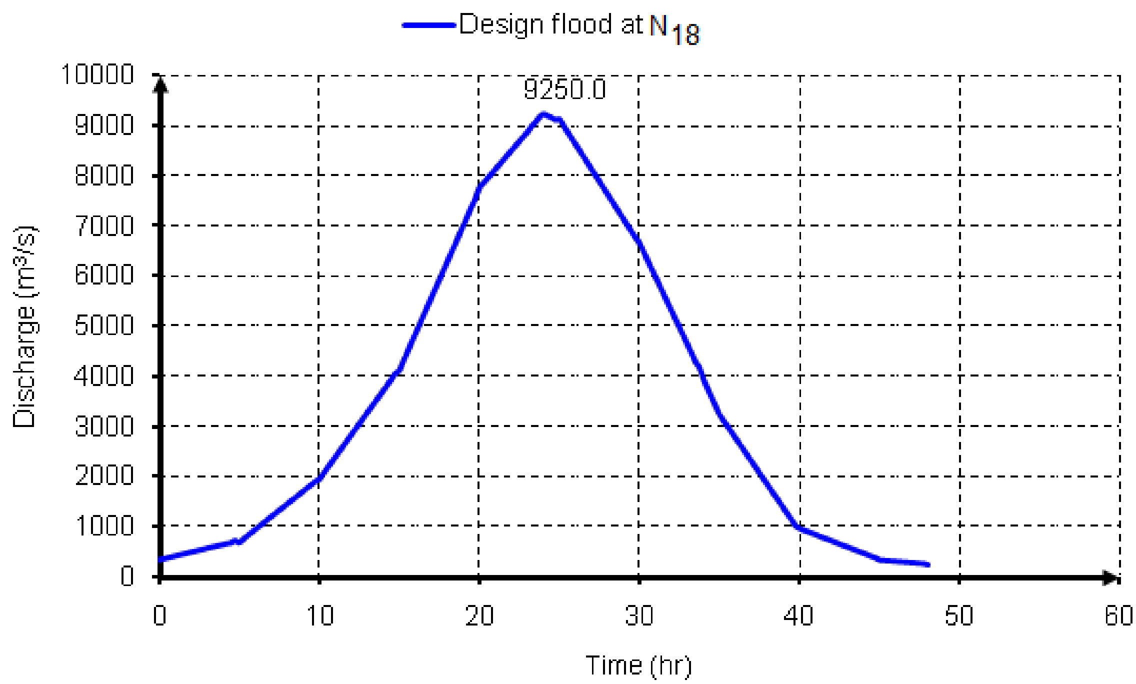

Design flood at N21
9252.0
Discharge (m³/s)
Time (hr)

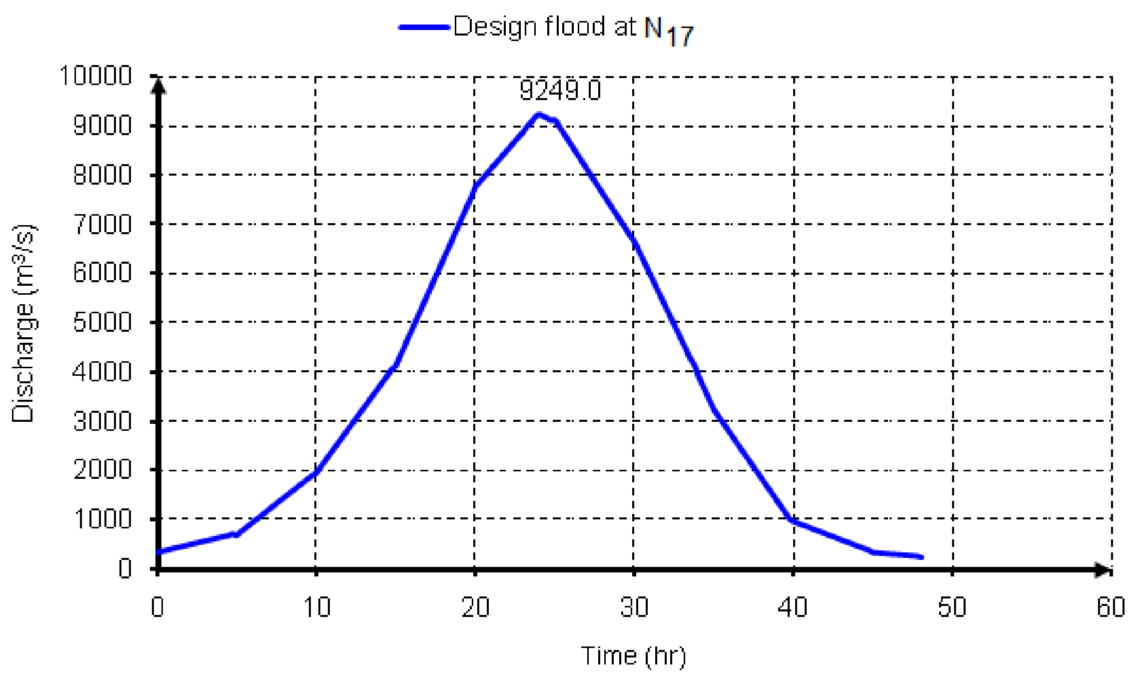


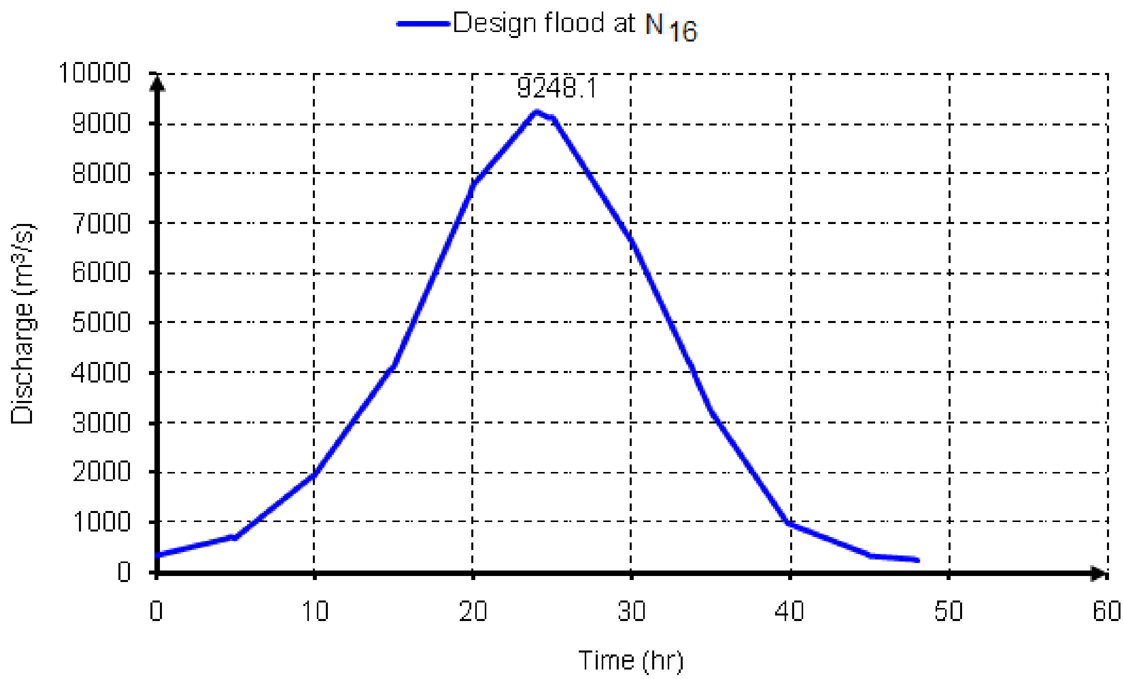
Design flood at N20
9251.1
Discharge (m³/s)
Time (hr)

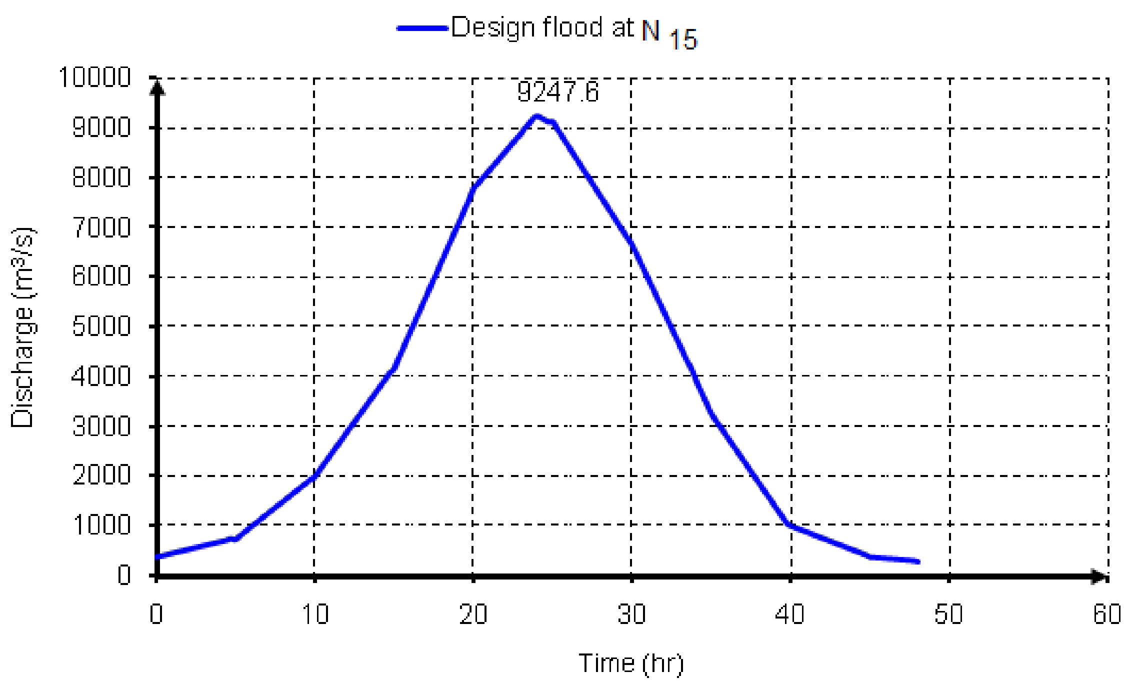


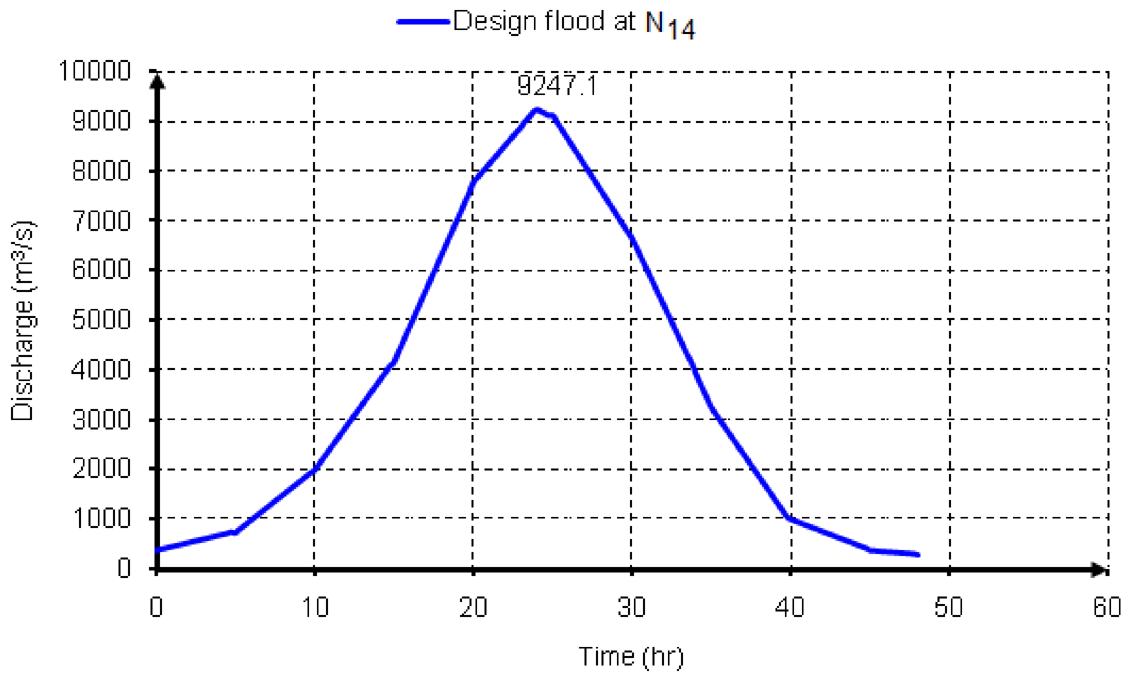
Design flood at N19
9250.4
Discharge (m³/s)
Time (hr)


Design flood at N18
9250.0
Discharge (m3/s)
Time (hr)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60

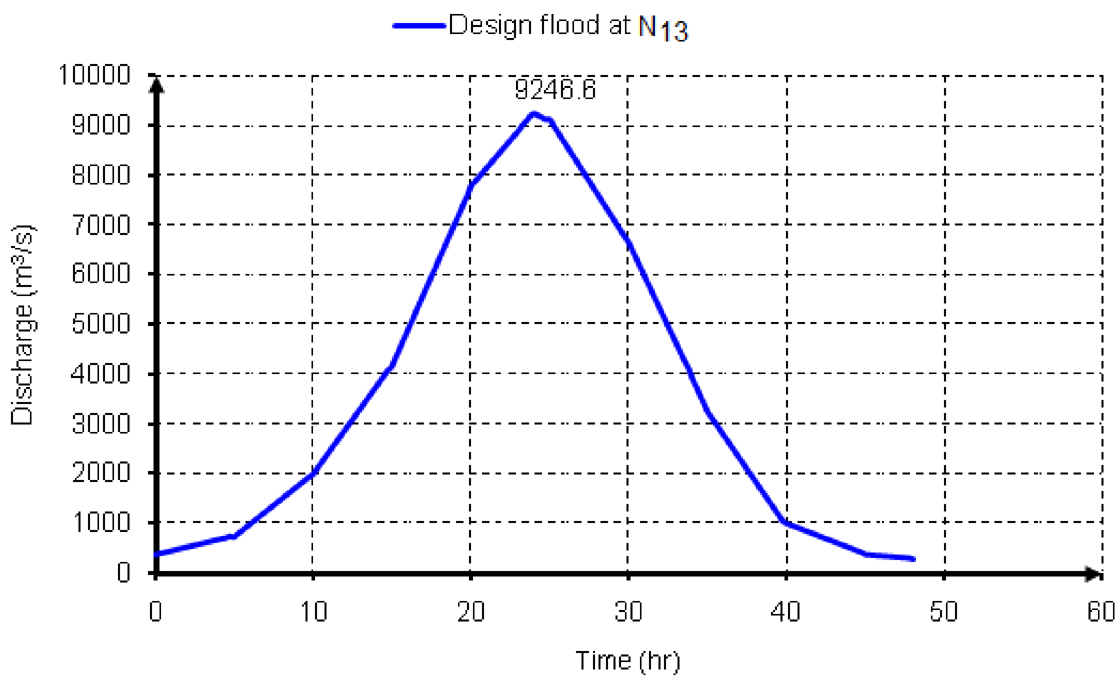

Design flood at N17
9249.0
Discharge (m3/s)
Time (hr)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60


Design flood at N 16
9248.1
Discharge (m³/s)
Time (hr)
0
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
10
20
30
40
50
60

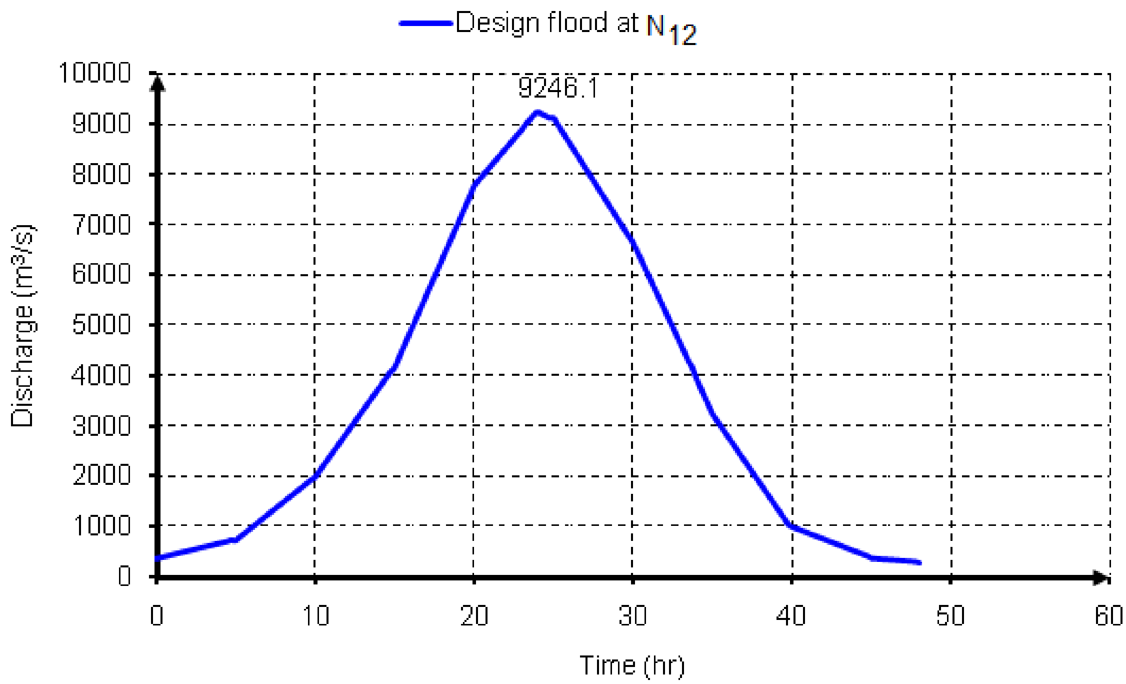

Design flood at N 15
9247.6
Discharge (m³/s)
Time (hr)
0
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
10
20
30
40
50
60



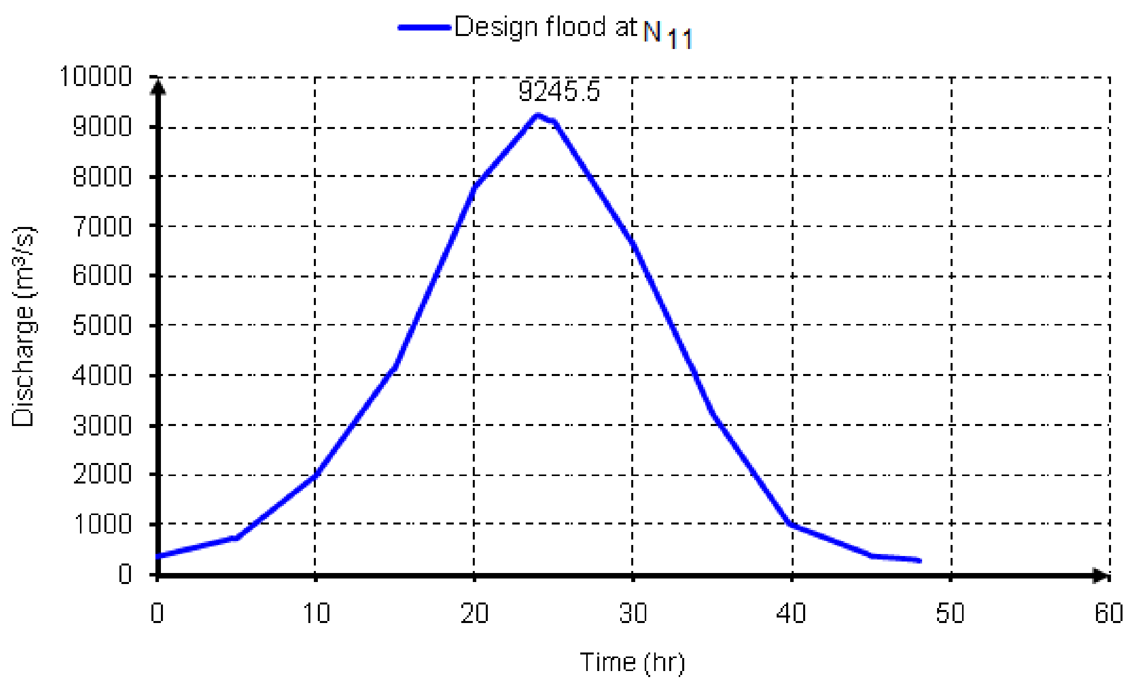
Design flood at N14
9247.1
Discharge (m³/s)
Time (hr)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60



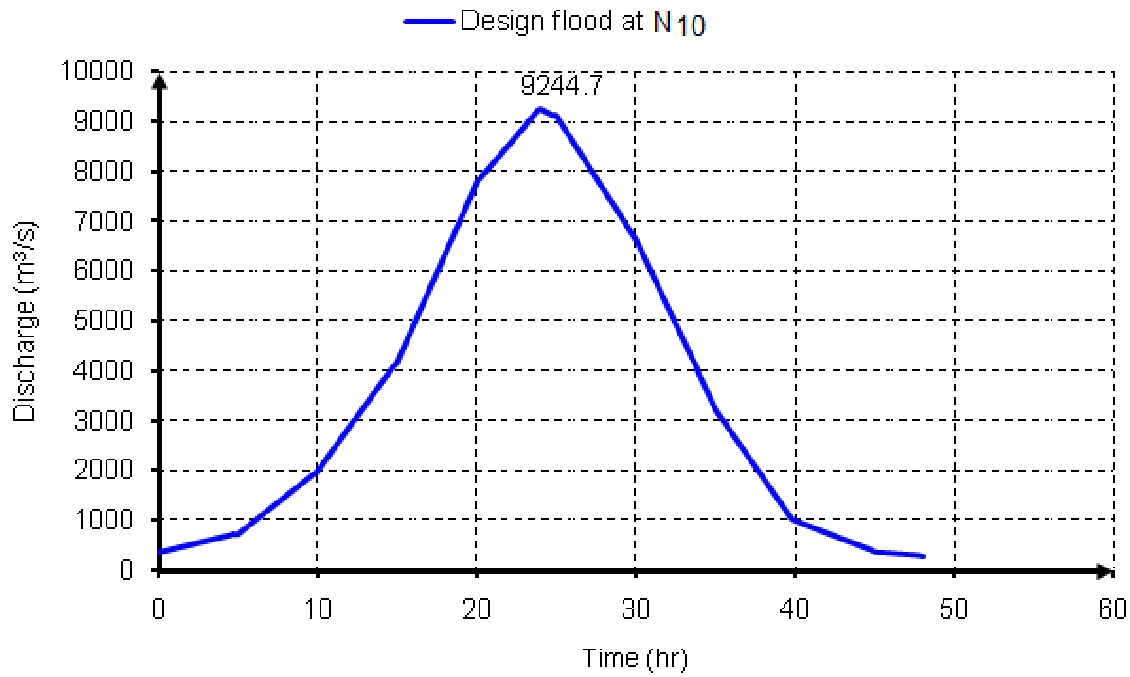
Design flood at N13
9246.6
Discharge (m³/s)
Time (hr)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60

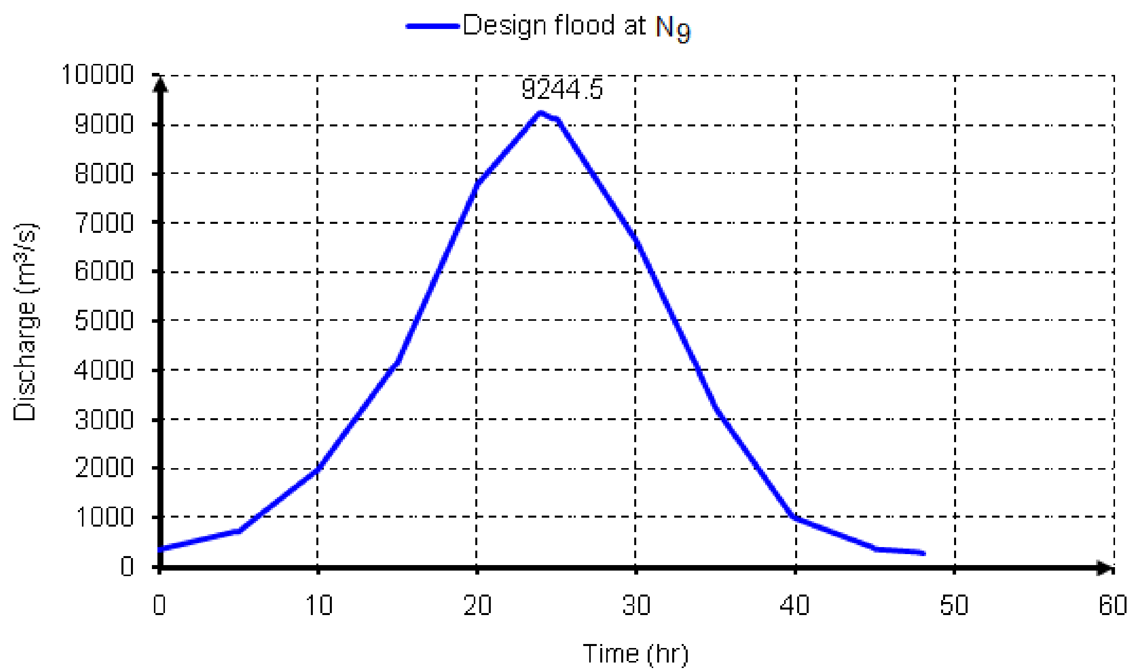


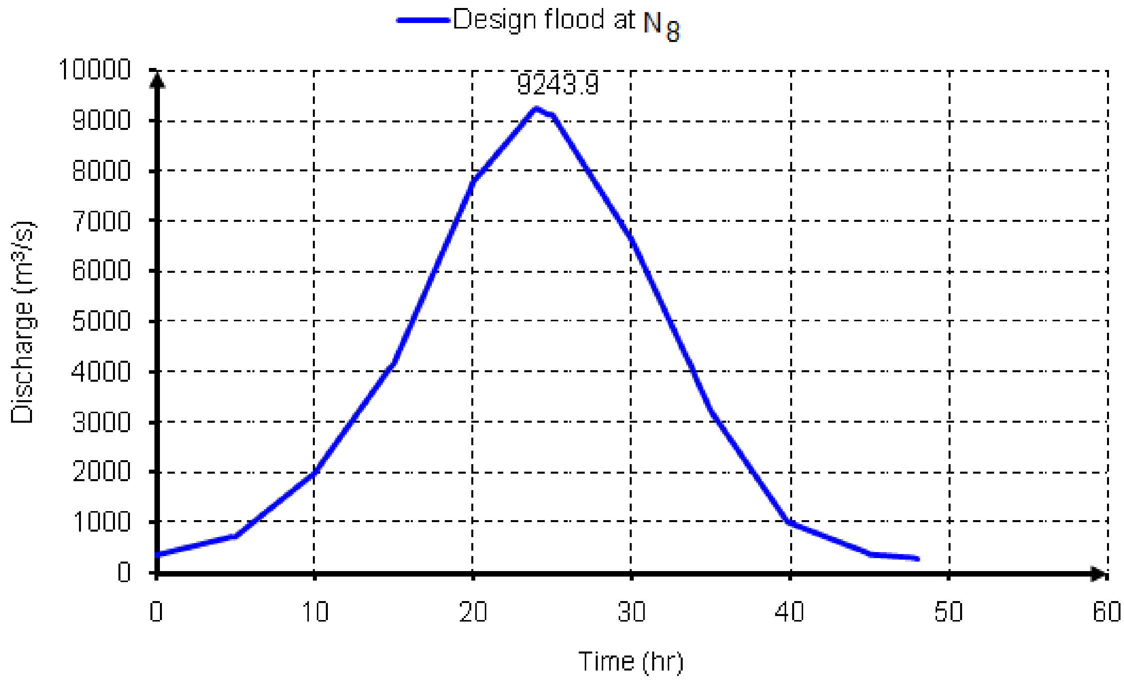
Design flood at N_{12}
9246.1
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Discharge (m³/s)
0
10
20
30
40
50
60
Time (hr)



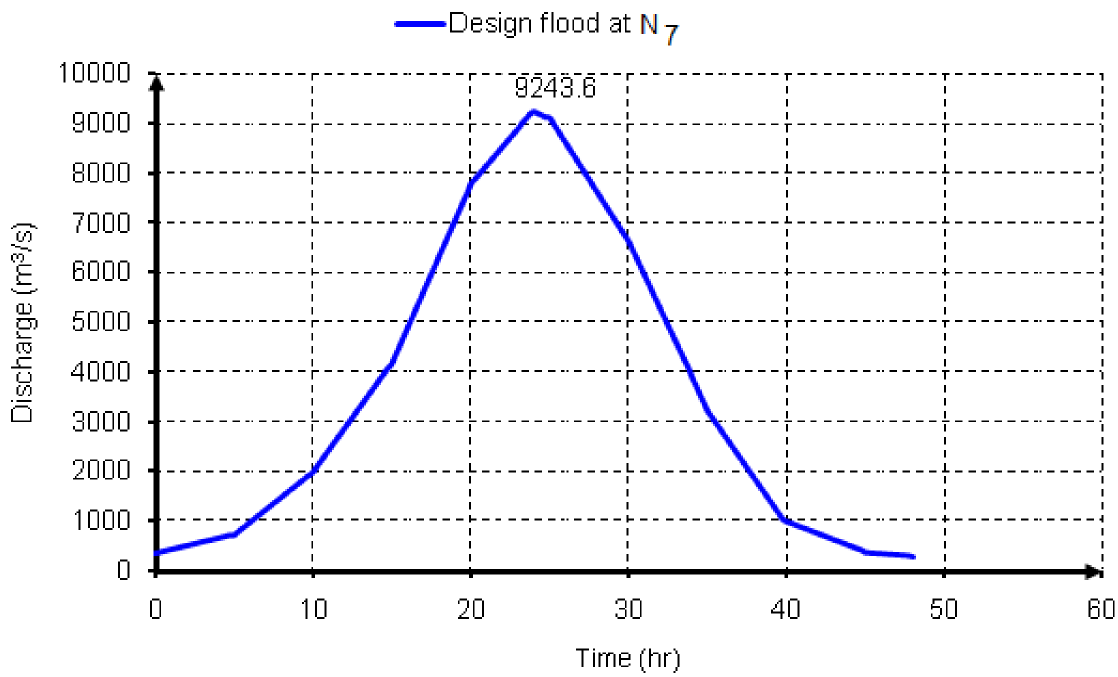
Design flood at N_{11}
9245.5
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Discharge (m³/s)
0
10
20
30
40
50
60
Time (hr)


Design flood at N10
9244.7
Discharge (m3/s)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60
Time (hr)

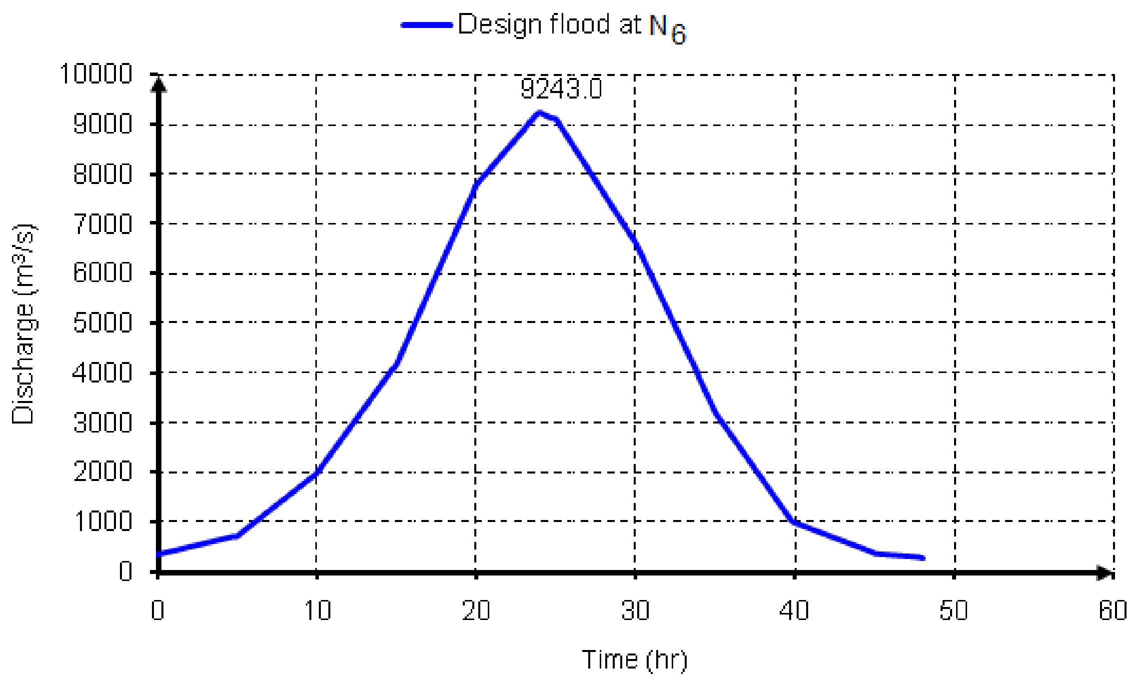

Design flood at N9
9244.5
Discharge (m3/s)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60
Time (hr)



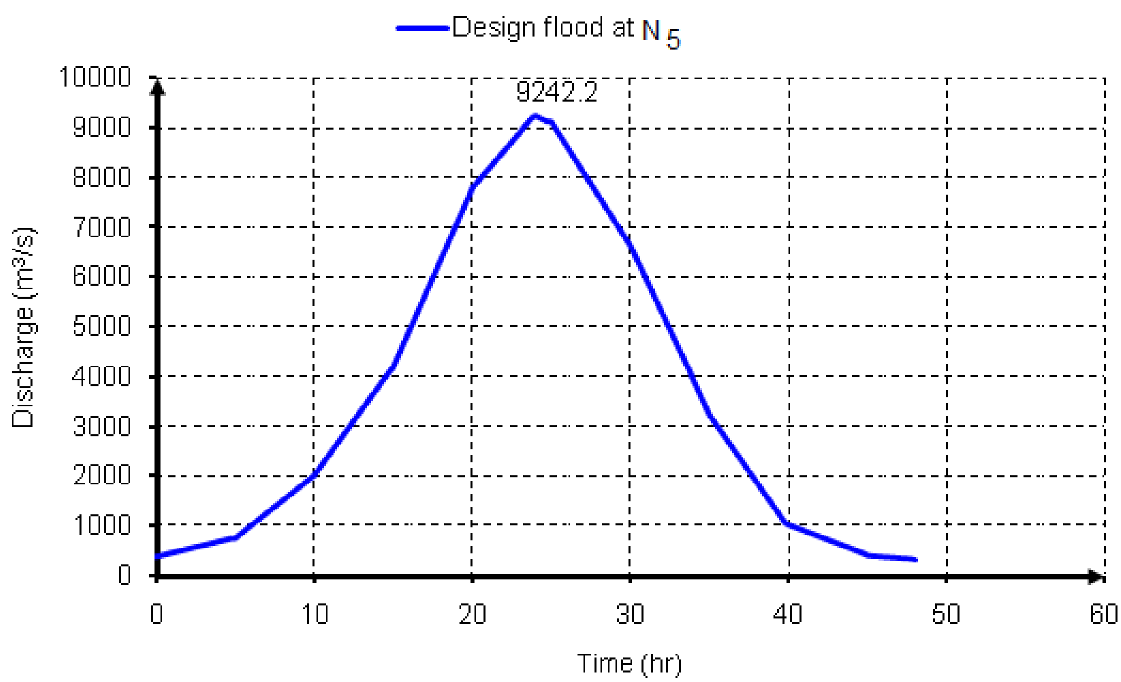
Design flood at N 8
9243.9
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Discharge (m³/s)
0
10
20
30
40
50
60
Time (hr)



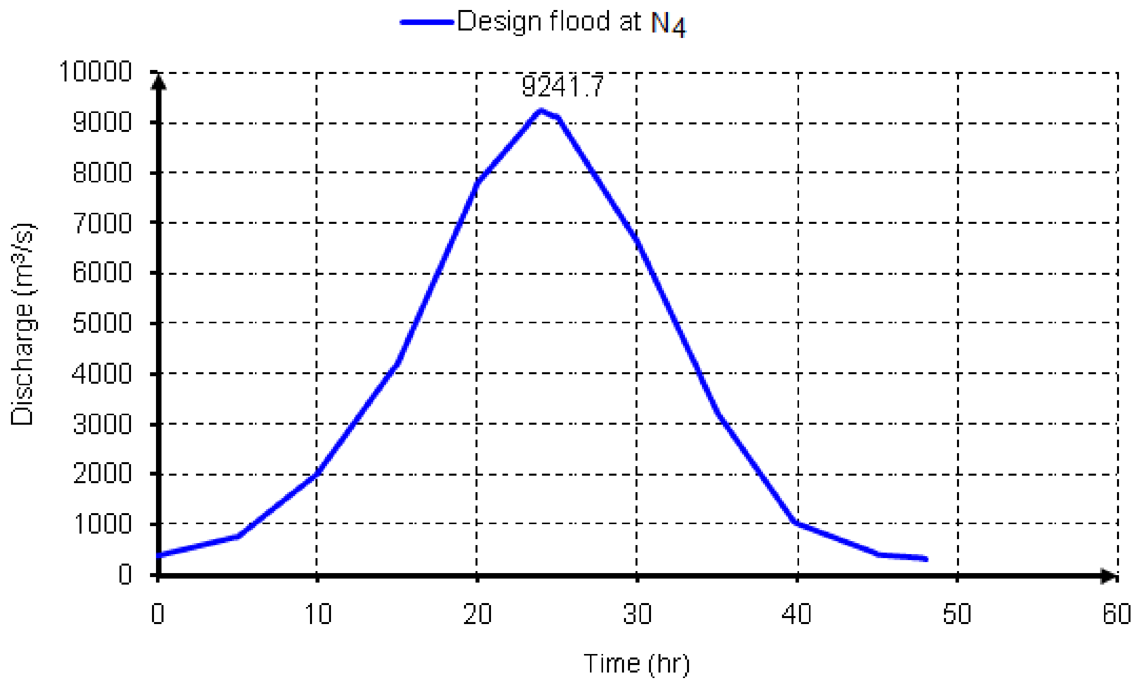
Design flood at N 7
9243.6
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Discharge (m³/s)
0
10
20
30
40
50
60
Time (hr)

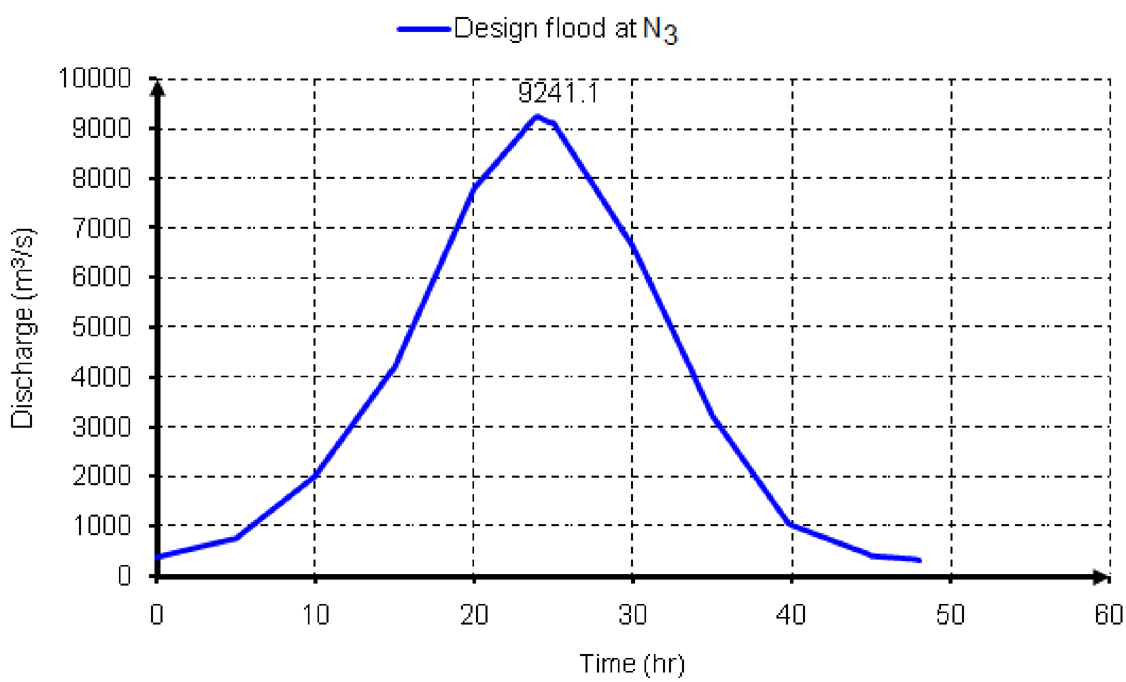


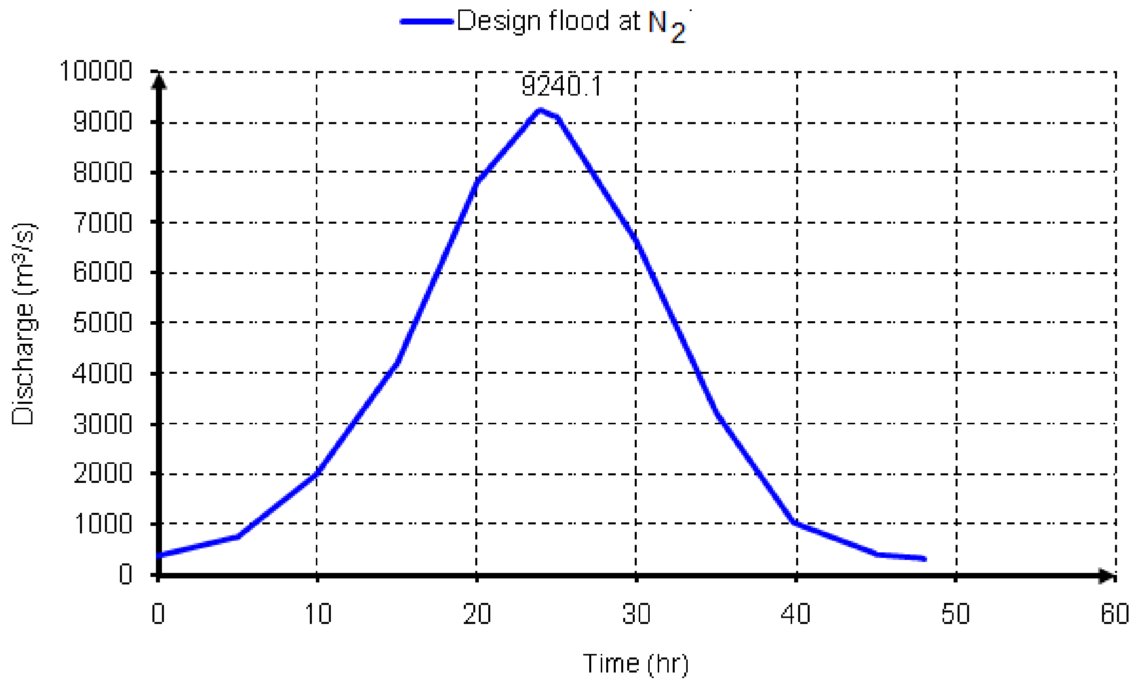
Design flood at N6
9243.0
Discharge (m³/s)
Time (hr)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60

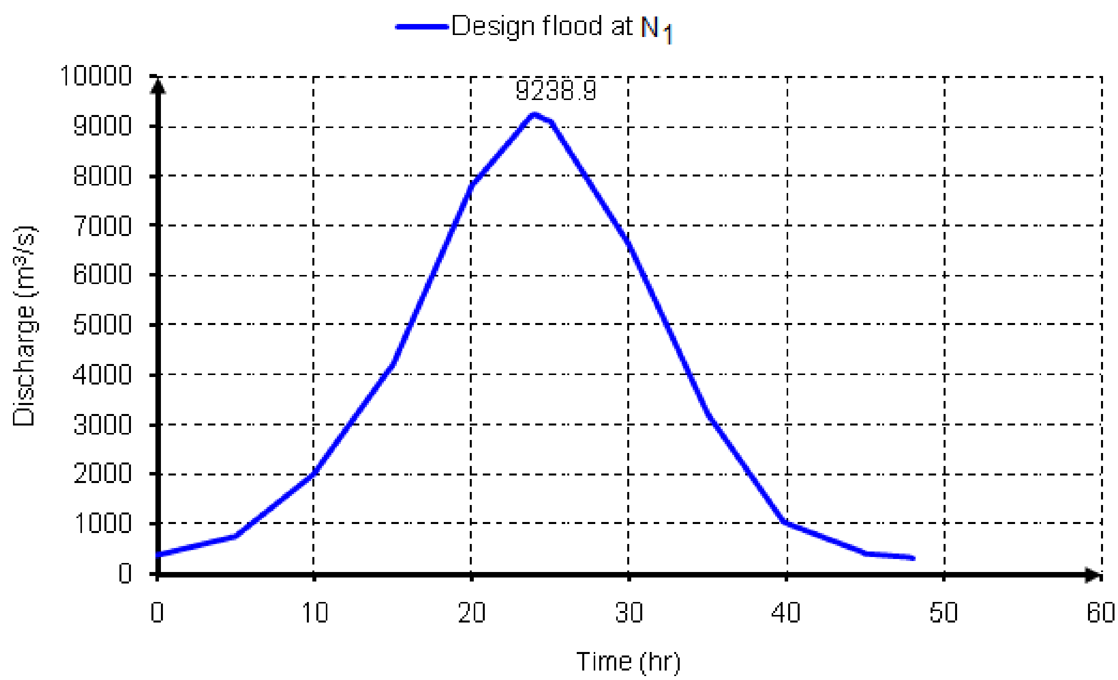


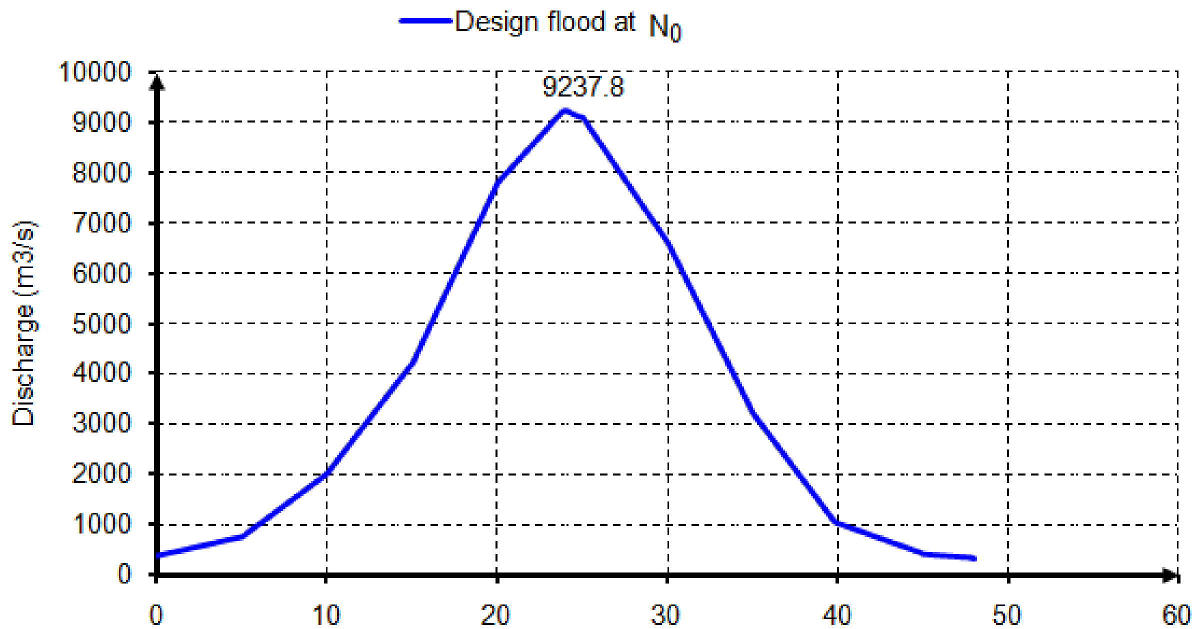
Design flood at N 5
9242.2
Discharge (m³/s)
Time (hr)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60


Design flood at N_4
9241.7
Discharge (m³/s)
Time (hr)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
10
20
30
40
50
60


Design flood at N_3
9241.1
Discharge (m³/s)
Time (hr)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
10
20
30
40
50
60


Design flood at N_2
9240.1
Discharge (m³/s)
Time (hr)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
0
10
20
30
40
50
60


Design flood at N_1
9238.9
Discharge (m³/s)
Time (hr)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
0
10
20
30
40
50
60


Design flood at N_0
9237.8
Discharge (m3/s)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60

DECLARATION

I, hereby declare that this thesis is my original work and has not been presented for a degree in any other university, and that all sources of materials have been duly acknowledged.

Name: MELESE CHANIE

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This thesis has been submitted for the examination with my approval as a University advisor.

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