# A STUDY ON FLOOD MANAGEMENT PRACTICES FOR GÜZELYURT

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

ERDAL ŞAHİN

IN PARTIAL FULLFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
CIVIL ENGINEERING

AUGUST 2012

Approval of the thesis:

**A STUDY ON FLOOD MANAGEMENT PRACTICES FOR GÜZELYURT**

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## ABSTRACT

**A STUDY ON FLOOD MANAGEMENT PRACTICES FOR GÜZELYURT**

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August 2012, 141 Pages

This study deals with the investigation of characteristics of a flash flood and development of design of flood mitigation facilities occurred in Güzelyurt in North Cyprus on 18th of January, 2010 and development of design of flood mitigation facilities. Hydrologic and hydraulic modeling of this flood event has been utilized to develop solutions for preventing the region from the flood. Topographical maps and soil properties are used in hydrological modeling. The data are inserted into a geographical information system program (ARC-GIS) where basin properties are obtained. Since there is no any stream flow gauging station along the creeks in the study area, the synthetic unit hydrograph is developed by using Soil Conversation Service Method to obtain design flood hydrographs. In hydraulic modeling, the cross-section data of Fabrika Creek and Bostancı Creek are taken by using global navigation satellite system (GNSS) device and total station. These data are entered into the HEC-RAS program. Flood inundation maps are generated for both creeks. After hydrological and hydraulic modeling, two solutions are proposed. The first one is to build a detention basin for storing water and a lateral channel for diverting extra flow from Bostancı Creek to Fabrika Creek. The second solution is to build a lateral channel from Bostancı Creek to Güzelyurt Dam for diverting all water during a flood event. Based on hydrologic, hydraulic, and cost analysis, the first solution is accepted to be the feasible solution. In addition, flow carrying capacities of the creeks are improved.

Keywords: Hydrological-hydraulic modeling, flood inundation map, detention basin, diversion channel, Güzelyurt- Bostancı

# ÖZ

## GÜZELYURT TAŞKIN YÖNETİM SİSTEMİ ÜZERİNE BİR ÇALIŞMA

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Ağustos 2012, 141 sayfa

Bu çalışma, 18 Ocak 2010 tarihinde Kuzey Kıbrıs'ın Güzelyurt bölgesinde meydana gelen ani taşkın özelliklerini araştırmak ve taşkına karşı gerekli koruyucu projeleri geliştirmeye dayanmaktadır. Bu çalışmada meydana gelen taşkının hidrolojik ve hidrolik modellemesi yapılarak taşkın korumaya yönelik çözümler üretilmiş ve hangi çözümün daha uygun olduğu araştırılmıştır. Hidrolik modellemede bazı topografik haritalar incelenmiş ve toprak haritalardan toprak yapısıyla ilgili bilgiler alınmıştır. Bu bilgiler havza oluşturulmak için kullanılan coğrafi bilgi sistemi (ARC-GIS) programına girilerek çalışılan havzaların sınırları belirlenmiştir. Çalışma alanındaki dereler üzerinde herhangi bir akım gözlem istasyonu olmamasından dolayı ABD Toprak Muhafaza Servisi yöntemi kullanılarak sentetik birim hidrografı çıkarılmış ve tasarım taşkın hidrografları elde edilmiştir. Hidrolik modellemede, derelerin en-kesit detayları küresel navigasyon uydu sistemi (GNSS) ve total station kullanılarak alınmıştır. Bu veriler HEC-RAS programına girilmiştir. Hidrolik modelleme sonucunda çalışma alanının taşkın haritaları çıkarılmıştır. Taşkın etkilerini azaltmaya yönelik başlıca iki tane çözüm önerisi sunulmuştur. Bu önerilerden bir tanesi Bostancı Deresi üzerine bir sel kapanı yaparak Bostancı Deresinin fazla sularını bir çevirme kanalıyla Fabrika deresine iletmektir. İkinci çözüm olarak Bostancı Deresinden Güzelyurt Barajına bir çevirme kanalı yapılarak taşkın anında gelen tüm suyun Güzelyurt Barajına verilmesidir. Hidrolojik, hidrolik ve maliyet analizlerine dayanarak birinci seçeneğin daha uygun olduğu kabul edilmiştir. Ayrıca Bostancı Deresinin akım geçirme kapasitesini artırıcı önlemler geliştirilmiştir.

Anahtar Kelimeler: Hidrolojik-hidrolik modelleme, taşkın haritası, sel kapanı, çevirme kanalı, Güzelyurt- Bostancı.

*To my family and those who struggle to get education*

# ACKNOWLEDGEMENTS

First and foremost, the author would like to express his thankfulness to his supervisor Prof. Dr. A. Melih YANMAZ and co-supervisor Assist. Prof. Dr. Bertuğ AKINTUĞ for their supervision, contribution patience and encouragement throughout this study. This study would have not been possible without their support.

Sincere thanks are extended to Serdar Sürer, M.Sc. and Assoc. Prof. Dr. Zuhal Akyürek for worthful contributions and sharing their knowledge. It is with pleasure to thank the mayor and governor of Güzelyurt for providing technical assistance.

The author also wishes to thank his friends Bekir Çaygeç, Kalender Akgül, Nazım Onur Çolak, Uğur Tunca, Metin Baturhan Duygu, Sercan Erdem Balabanlı, Emir Demirtaş, İsmail Barış Cengiz, Yaşar Bulut Koray, Sezai Mert Diner, Münevver Çelik, Arda Buğra Özer, Irmak Kibele Kırlı, Ekin Özbey for motivation and support. They make his life meaningful.

Sincere gratitude is expressed to Mesut Yüksel Şahin. No one walks alone on the journey of life and he always walks beside the author.

Finally, the author is grateful to all of his family members especially his father İbrahim Şahin, his mother Nuriye Şahin, his sisters Eda Şahin and Esra Şahin for their endless love, help, encouragement, and inspiration to complete this study.

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## LIST OF SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| A | : Basin area |
| b | : Width of the channel |
| $C_e$ | : Cost of embankment |
| $C_{ex}$ | : Cost of excavation |
| $C_{Exp}$ | : Expropriated price |
| $C_{lc}$ | : Cost of lined channel |
| CN | : Curve number |
| $C_s$ | : Cost of spillway |
| CSU | : Colorado State University |
| $C_{uex}$ | : Unit price of excavation |
| $C_{uexp}$ | : Unit price of expropriation |
| $C_{ul}$ | : Unit price of lined channel |
| D | : Diameter of pipe |
| $d_A$ | : Annual average precipitation depth |
| $d_{max}$ | : Annual maximum precipitation depth |

$D_{50}$ : Median Sediment Size

DEM : Digital Elevation Model

DR : Direct Runoff

$D_{r50}$ : Median riprap size

$D_{95}$ : Size of grain for which 95% is finer

$d_s$ : Depth of scour

f : Friction factor

$F_r$ : Froude number

GIS : Geographical Information System

GNSS : Global Navigation Satellite System

$h_c$ : Embankment crest elevation

$h_f$ : Major loss

$h_{lb}$ : Minor losses with respect to pipe shape

$h_{le}$ : Minor losses at pipe entrance

$h_{lex}$ : Minor loss of pipe exit

$h_m$ : Maximum reservoir elevation

$I_p$ : Peak discharge

$K_1$ : Correction factor for pier nose shape

$K_2$ : Correction factor for flow angle of attack

$K_3$ : Bed condition correction factor

$K_4$ : Correction factor for armoring by $D_{95}$ grain size

$K_{lb}$ : Loss coefficient for pipe component

$K_{le}$ : Loss coefficient for pipe entrance

$K_{lex}$ : Loss coefficient for pipe exit

L : Length of pipe

$L_c$ : Total length of channel

$L_m$ : The main stream length

m : Coefficient due to sinuosity

$n_1$ : Roughness coefficient due to cross sectional variance

$n_2$ : Roughness coefficient due to channel geometry

$n_3$ : Roughness coefficient according to undulations at river bed

$n_4$ : Roughness coefficient due to vegetation

$n_b$ : Roughness coefficient due to bed material

S : Potential max retention

SCS : Soil Conservation Service

$S_h$ : The bed slope of the main stream

$S_s$ : Specific gravity of riprap

$S_t$ : Storage

$S_0$ : Bed slope

t : Time

$t_b$ : Base time

$t_c$ : Thickness of riprap layer

$t_l$ : Basin lag

$t_p$ : Time to peak

$t_r$ : Duration of rainfall excess

$T_r$ : Return Period

$t_p$ : Peak time

UH : Unit Hydrograph

$V_0$ : Local maximum velocity at original cross section

W : Weight of riprap

Q : Discharge

$Q_p$ : Peak discharge

$y_1$ : Flow depth just upstream of pier

$y^*$ : Total height of channel which includes free board

# CHAPTER I

# INTRODUCTION

## 1.1 Statement of the Problem

Climate has been changing rapidly leading to extreme meteorological and hydrological events in recent years. In other words, temperature, precipitation and wind patterns are constantly evolving. Observed weather conditions are not only extremely high but also extremely low all around the world when compared to historical data. In recent years, short and sudden rainfall events, which cause flooding, have been becoming more frequent. This kind of a flood is called flash flood, which is one of the most important natural hazards in the world. It can cause loss of lives and damage to all types of facilities. “A flash flood is in short, a sudden local flood of great volume and short duration which follows within a few (usually less than six) hours of heavy or excessive rainfall, or due to dam or levee failure or the sudden release of water impounded by an ice log jam” (GFMM, 2007). A flash flood can be caused by very intense rain falling on saturated or impermeable surface resulting in high-volume surface runoff. Water level rises suddenly in rivers during the flash flood and velocity of water is very high. Flood water brings uproot trees and boulders. It destroys bridges and buildings along its path. According to GFMM (2007), there are number of examples for flash flood damage around the Central and Eastern Europe. For example, in the summer of 1997, heavy rainfall which continued in a short time generated extensive floods in Slovakia. The damage costs amounted to nearly 50 million US dollars. In these floods, 366 cities and municipalities were affected, 8255 houses were flooded and 70 of them were completely destroyed. The second example is from Romania where 1734 localities were affected from flash flood which occurred in 2005. The cost of the flood damage was approximately 1.4 billion € (GFMM, 2007). Another example is from Turkey. According to State Water Works (SWW) (2008), a total of 606 people are dead because of floods occurred in the last 35 years. Table 1.1 shows the damages of biggest floods occurred between 1970 and 1997 in Turkey. Most of these floods took place in Eastern Black Sea Basin. The total area of this basin is 24077 $km^2$ and average precipitation depth is around 1250 mm. In this basin, totally 50 big floods have happened between 1955 and 2005. These floods caused 258 deaths and 800 million TL damages. The biggest flood occurred on 20$^{th}$ June 1990 in this basin. This flood was caused by overflowing of ten different streams and approximately 74.3 $km^2$ area was affected. The cost of the flood damage was approximately 550 million TL and 57 people died because of this flood (Yüksek et al., 2008).

Table 1.1 Biggest floods between 1970 and 1997 in Turkey (SWW, 2008)

| Date | Place | Number of Loss of life | Flooded Area ($10^3$ Hectar) | Total Cost $10^6$ US Dolar |
|---|---|---|---|---|
| August, 1979 | Yeşilırmak | 61 | 2 | 9 |
| March, 1980 | Seyhan, Adana | 1 | 47 | 1 |
| January, 1982 | Gaziantep | - | - | 154 |
| June, 1990 | Northern Black Sea | 56 | 7 | 19 |
| July, 1995 | Senirkent, Isparta | 74 | - | - |
| November, 1995 | İzmir | 61 | - | 1070 |
| November, 1995 | Aksu, Antalya | 4 | 201 | 1 |

In 2007-2008, the driest winter season on record was observed in Cyprus. However, in 2009-2010, there were heavy rainfalls which led to flooding during the winter season. On

January 18, 2010, a 16 hour-long non-stop heavy rainfall in Güzelyurt region of North Cyprus, caused a flash flood. The village of Bostancı and the town of Güzelyurt were affected badly by this flooding. According to district governorship, damage cost is approximately 5 million Turkish Liras. The details of damage are shown in Table 1.2. In addition to this, total amount of household items which are distributed to flood victims are 1.5 million TL and the total damage cost of animal producers is 300,000 TL.

Table 1.2 The cost of Güzelyurt-Bostancı Flood damage on 18$^{th}$ January 2010

| **Damaged item** | **Number of Damaged properties** | **Invoice Amount (TL)** | **Amount Paid (TL)** |
|---|---|---|---|
| Vehicles | 194 | 468,917.58 | 215,372.41 |
| Houses | 256 | 406,498.50 | 372,838.5 |
| Work Places | 119 | 1,406,469.98 | 579,047.97 |
| Industrial Places | 16 | 268,106.80 | 160,864.08 |
| Total | 585 | 2,549,992.86 | 1,328,122.96 |

## 1.2 Objective of the study

The main objective of the study is to develop suitable and economic solutions for flood protection for Güzelyurt region, North Cyprus. Within the scope of this thesis, various relevant hydrologic and geomorphologic parameters are gathered together for determining the flood hydrographs. Moreover water surface profile computations are carried out to determine the extent of flooded regions. Flow carrying capacity of the river including a number of bridges and culverts is examined. Besides that, hydraulic modeling is utilized to determine capacities of creeks for different flow rates. Scouring depths at bridges are estimated and applicable armoring type scour countermeasures are designed. Solutions to protect Güzelyurt region from future flooding events are discussed. The first solution proposed involves building a detention basin on Bostancı Creek and a diversion channel between this basin and Fabrika Creek. The second solution is building a diversion channel between Bostancı Creek and Güzelyurt Dam. Finally, some recommendations for preventing floods are presented.

The organization of the thesis is as follow;

- Chapter 1 presents the introduction, objectives of the study and scope of the thesis.
- Chapter 2 gives information about recent studies about flood management.
- Chapter 3 includes description of the Güzelyurt – Bostancı region.
- Chapter 4 mainly deals with hydrologic calculations which are rainfall frequency analysis, generating flood hyetograph, and obtaining flood hydrograph.
- Chapter 5 explains hydraulic analyses which include water surface profile computation, determination of the Manning roughness coefficient, HEC-RAS modeling, creating flood map, scour computations, design and placement of riprap.
- Chapter 6 discusses the possible remedial measures, such as design of flood detention basin, diversion channel and their total costs.
- Chapter 7 includes the conclusions derived from this study.

# CHAPTER II

# LITERATURE REVIEW

In recent years, floods have been occurring more frequently around the world because of extreme hydrological and meteorological events. These floods destroy residential areas and cause heavy financial damages. Most important of all, floods can cause loss of life. Therefore, there are many studies about flood management around the world. Decision support system for flood management in the Red River basin can be given as an example (Siminovic, 1998). Red River flood damaged residents in both US and Canada. Red River basin covers 116,500 $km^2$ areas for which nearly 103,600 $km^2$ of land is in the United States and the remaining 13,000 $km^2$ is in Canada. In this report, flood management process is divided into three major stages: (a) planning; (b) flood emergency management; and (c) post flood recovery. Planning stage means that, different alternative measures are analyzed and compared for possible application for decreasing flood damages in the region. During flood emergency management, current flood situation is evaluated and daily operation of flood control is done. The important aspect of evaluating flood situation is identification of potential events which could affect the current flood situation, such as wind set up and heavy rainfall. In the post flood recovery, all environmental impacts are examined and solutions are generated. According to solutions, diversion structures to divert flow during the peak flow from protection region and channel modification to increase the hydraulic capacity or ability of the river to transmit flow are suggested (Siminovic, 1998).

Correia et al, (1997) developed hydrologic and hydraulic flood modeling. The area of the study is Livramento catchment (24 $km^2$), in Setubal located 35 km south of Lisbon in Portugal. In hydrologic modeling, they used XSRAIN model. This model is used for generating flood hydrograph for a given rainfall event. The input data of this program are watershed boundary, watershed area, average watershed slope, and Curve Number (CN). After finishing hydrological model, peak discharge is obtained and it is used in hydraulic model. In hydraulic modeling, HEC-RAS program is used.

Another example is about determining flood map by using HEC-HMS and the HEC-RAS programs for İzmir Bostanlı basin. The total basin area is 29.6 $km^2$ and the total length of the creek is 14.28 km (Gül and Gül, 2010). HEC-HMS is used for developing hydrologic model and HEC-RAS is used in hydraulic modeling.

Various flood mitigation facilities were constructed and some flood management strategies were established in Turkey following the severe floods, some of which are 25-26 August, 1982 (Ankara), 18-20 June, 1990 (Trabzon), 16-17 May, 1991 (Eastern Anatolia), 4$^{th}$ November, 1995 (İzmir), 21$^{th}$ May, 1998 (Western Black Sea), 28th May, 1998 (Hatay), 2$^{th}$ November, 2006 (Batman), and 9$^{th}$ October, 2011 (Antalya). The reasons of flood events and the corresponding proposed remedial measures are similar in Turkey. That is why only the characteristics of one of the floods are described herein. İluh River caused a severe flood in 2$^{th}$ November 2006 in Batman, which is located in Southeastern Anatolia Region. In this flood, 10 people died and the total damages of flood costs are in the order of millions of TL. The reasons of flood were investigated by surveying the flooded area, and analyzing the meteorological and soil data. According to the results of this study, natural factors, such as low absorption capacity of the soil, caused this flood as well as human-induced factors. The capacity of İluh River decreases drastically because of buildings of various types in the main channel and floodplains. Furthermore, the capacities of appurtenant structures on the river are also low. These adverse effects pronounced damages of flood. As remedial measures, cleaning of river bed, demolishing of all types of facilities on the waterway, and increasing the flow carrying capacities of the hydraulic structures are recommended (Sunkar and Tonbul, 2008).

The last example is about the great flood of 1993 in Mississippi River Basin. This flood is the costliest flood in the USA history. Therefore, it is called the great flood. The Mississippi River is the seventh largest river with respect to its discharge (580 $km^3$/year). In the summer season of 1993, the upper part of this basin, which is called Midwestern USA experienced unexpected heavy precipitation (200-350% above the normal values). The damages of the Mississippi flood are numerous and various. More than 3000 $km^3$ water overflowed onto the floodplains and approximately 440,000 $km^2$ land areas were flooded. More than 100,000 houses were damaged and 250,000 people suffered for potable water as many as 19 days. In this event, 52 people died, 1000 hydraulic structures, such as bridges and levees were damaged, and $3.2*10^6$ ha of farmland was flooded. Some locations on the Mississippi River flooded for almost 200 days. The total damage cost of this flood is approximately between 12 and 16 billion $ (Horowitz, 2006). The management of the Mississippi has been carried out by the USACE. The management and rehabilitation consist of river channelization including straightening, widening, and deepening; building hydraulic structures, such as levees, and dams for controlling water (Raffensperger, 1997)

# CHAPTER III

# DESCRIPTION OF STUDY AREA

## 3.1 Overview of the Güzelyurt-Bostancı Case Study

On 18th of January, 2010, continuous rainfall was observed in Güzelyurt region of Northern Cyprus. The amount of daily total rainfall was the highest in the recorded history (1978-2009). The highest total daily rainfall was 75 mm in Zümrütköy up to 2010, but on the flood day, the daily rainfall was recorded as 160 mm. The observed amount of rainfall of all regions and the amount of rainfall on January 18, 2010 can be seen in Table 3.1 in which $d_A$ and $d_{max}$ denote the annual average and maximum precipitation depth, respectively. Locations of Güzelyurt and neighboring villages are shown in Figure 3.1.

After this very heavy rainfall, a flash flood, that has never been observed in the recorded history, occurred. This flood caused considerable damage in Güzelyurt and its close proximity. Figure 3.2 and Figure 3.3 show the level of damage of this flood in Güzelyurt. This flood was caused by excessive amount of rainfall in a short period of time on saturated soil having a very small absorption capacity. Typically, six hours of heavy rain is sufficient to cause flash flood on saturated soil (Chow et al., 1988).

In line with the thesis objective, hydrologic and hydraulic modeling is conducted to obtain the flood inundation map. As a result of hydrologic modeling, the flood hydrographs can be obtained. Moreover, the results of hydrologic modeling can be used in the hydraulic modeling for the analysis of hydraulic structures, such as levees and diversion channels. They may also be used in the flood management programs for a better control of the river environment. Therefore, hydrologic modeling is essential for the establishment of flood mitigation systems. With the help of Arc-GIS (ESRI, 2008), the boundary of the basin is obtained using the relevant information of a previous study conducted for modeling of Bostancı-Güzelyurt flood and determination of flood risk areas in Güzelyurt Region (Akıntuğ et al., 2011). Furthermore, hydraulic modeling is performed by using HEC-RAS program (USACE, 2010). These computations are also used for checking the adequacy of creeks and appurtenant structures like bridges and culverts. Finally, solutions for protection from flood are proposed.

Table 3.1 Precipitation data for Meteorological stations located in Güzelyurt region

| **Station** | **Water year** | **$d_A$ (mm)** | **$d_{max}$ (mm)** | **18 January 2010 $d_A$ (mm)** |
|---|---|---|---|---|
| Çamlıbel | 1978-2009 | 432 | 108 (05-12-2001) | 169 |
| Kozanköy | 1985-2009 | 497 | 150 (05-12-2001) | 182 |
| Kalkanlı | 2001-2009 | 320 | 74 (10-12-2002) | 114 |
| Güzelyurt | 1978-2009 | 281 | 87 (19-08-2001) | 101 |
| Bostancı | 2000-2009 | 378 | 127 (19-08-2001) | 150 |
| Zümrütköy | 1978-2009 | 272 | 75 (01-11-1986) | 160 |

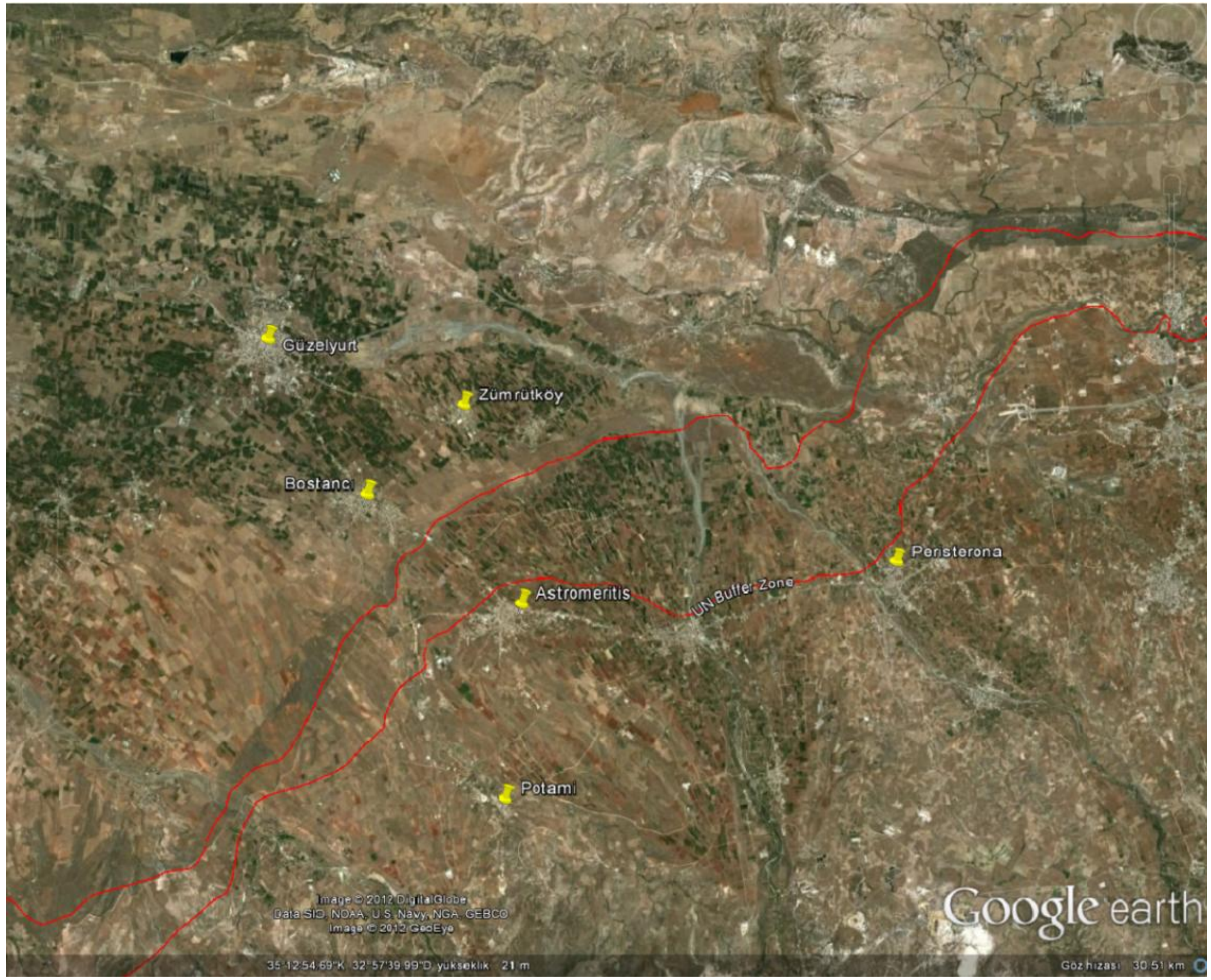


Figure 3.1 Location of Meteorological stations around the study area (Google Earth, 2011)


Figure 3.2 A view from Bostancı after flood (Akıntuğ et al., 2011)

Figure 3.3 A typical flood damage in Bostancı (Akıntuğ et al., 2011)

### 3.2 Description of the Flood Site

Cyprus with a total area of 9251 km$^2$ is the third largest island after Sicily (25710 km$^2$) and Sardinia (24090 km$^2$) in the Mediterranean Sea (Koday, 2000). The map of Cyprus and the location of Güzelyurt can be seen in Figure 3.4. The study area is located in Bostancı which is a village in Güzelyurt region. There are a number of basins in Güzelyurt region but only two of them that were severely exposed to flood are studied in this thesis. These basins are next to each other. Figure 3.5 shows the locations of Bostancı and Fabrika Creek basins. There are orange gardens, wheat and barley fields, and urban areas in the Bostancı Creek basin. Fabrika Creek basin has some differences when compared to the Bostancı Creek Basin. The upstream part of this basin is mountainous area, whereas the downstream of the basin consists of orange gardens, wheat and barley fields. Moreover, there are a few buildings in this basin. Bostancı Creek is composed of five branches. These branches are combined at the entrance of Bostancı village. The Fabrika Creek starts from Potami Mountain in Southern Cyprus. The significant parts of these basins are located in Southern Cyprus (See Figure 3.5).


Figure 3.4 Location of Güzelyurt in Cyprus (Google Earth, 2011)


Figure 3.5 Locations of Bostancı Creek and Fabrika Creek (Google Earth, 2011

### 3.3 Determination of the Basin Characteristics

There are no stream gauging stations in the aforementioned basins. That is why a synthetic unit hydrograph needs to be developed. In order to obtain such a hydrograph, the basin geometry and geomorphologic characteristics should be determined first. For this purpose, the software Arc-Hydro; which is an application of Arc-GIS software program, is used. Arc-GIS is a complete software program that is used for designing and managing solutions through the application of geographic knowledge (ESRI, 2008). For the creation of the digital elevation model (DEM) of the region, 1/25000 scaled contour map sheets were obtained from the Mapping Office of Northern Cyprus Government. Using contour maps, the digital elevation model of the basins is created. Arc- Hydro D8 algorithm is operated for forming the basins of both creeks. The main and side branches of the river are generated with this algorithm. To catch a good agreement between the map and the findings of the Arc-Hydro, some adjustments are made in Arc-Hydro medium. Basins of both creeks, generated by ArcGIS software program depicted on Google Earth map, are seen in Figures 3.6. After generating the boundaries of the basins, the basin properties are determined. The length of the main branch and the area of the Fabrika Creek basin are obtained as 17.34 km and 30 $km^2$, respectively. The Bostancı Creek basin area and the length of the main branch were obtained as 33.5 $km^2$ and 13.9 km, respectively (Akıntuğ et al., 2011). The downstream reaches of these basins have almost zero slopes where the river cross-sections cover very wide surface width. With highly pervious soil characteristics, flow disappears and feeds the groundwater. That is why the outlets of these basins do not reach directly to the Mediterranean Sea on the surface.

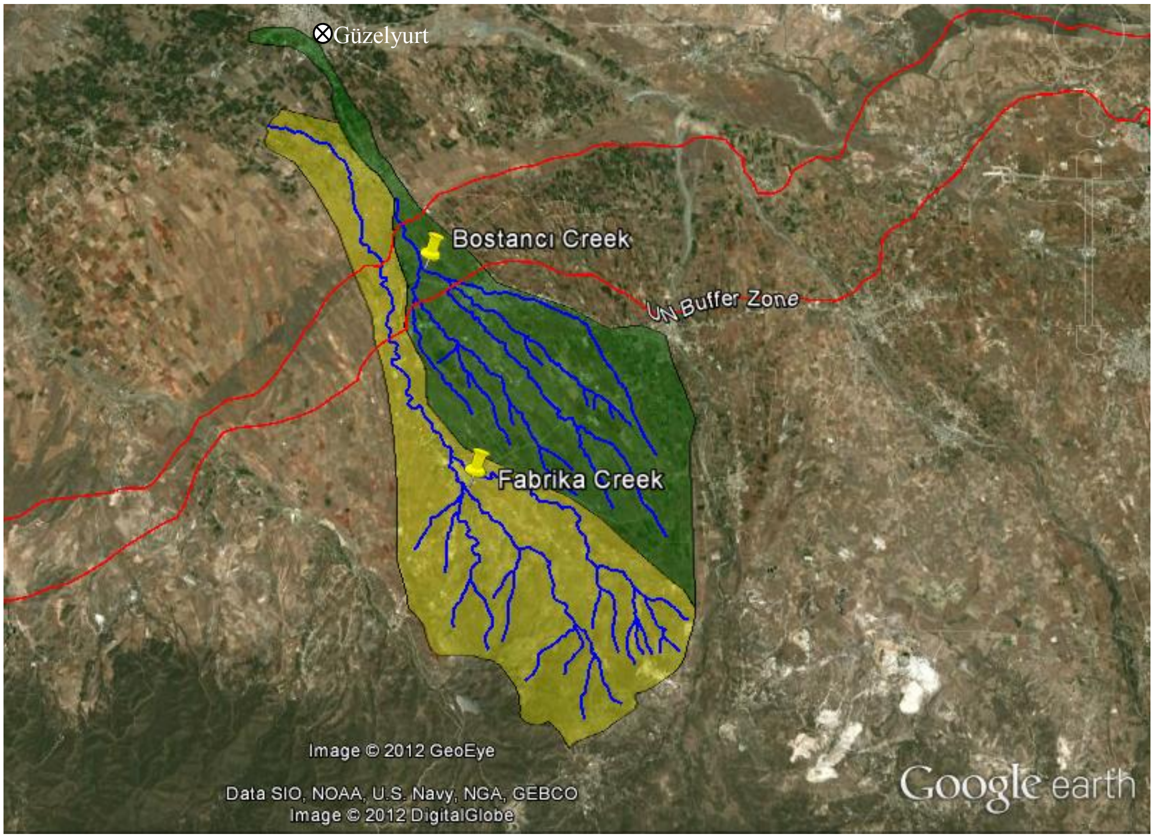


Figure 3.6 Fabrika Creek and Bostancı Creek Basin (Google Earth, 2011)

### 3.4 Field Measurements

Cross-sections of the Bostancı Creek and Fabrika Creek are measured using the field measurement devices, such as the Global Navigation Satellite System (GNSS) and total stations. GNSS field measurement devices and total stations are all-purpose devices that are used for surveying and geodesy (Heister, 2008). Elevation and coordinates are taken from these measurements which are subject to error up to 3 cm in the horizontal direction and 2 cm in the vertical direction. The total study reach is divided into 38 cross-sections for the Bostancı Creek and 37 cross-sections for the Fabrika Creek (Figures 3.7 and 3.8, respectively). Bostancı Creek disappears when it approaches to orange gardens located between Güzelyurt and Bostancı and it is formed again at the end of orange garden.

Bostancı Creek has seven bridges and seven culverts i.e. three of circular and four of rectangular section. Besides that, there are a bridge and a box culvert on Fabrika Creek. The bridges of Bostancı Creek are shown in Figures 3.9 through 3.15. The bridge and culvert of Fabrika creek are shown in Figures 3.16 and 3.17.

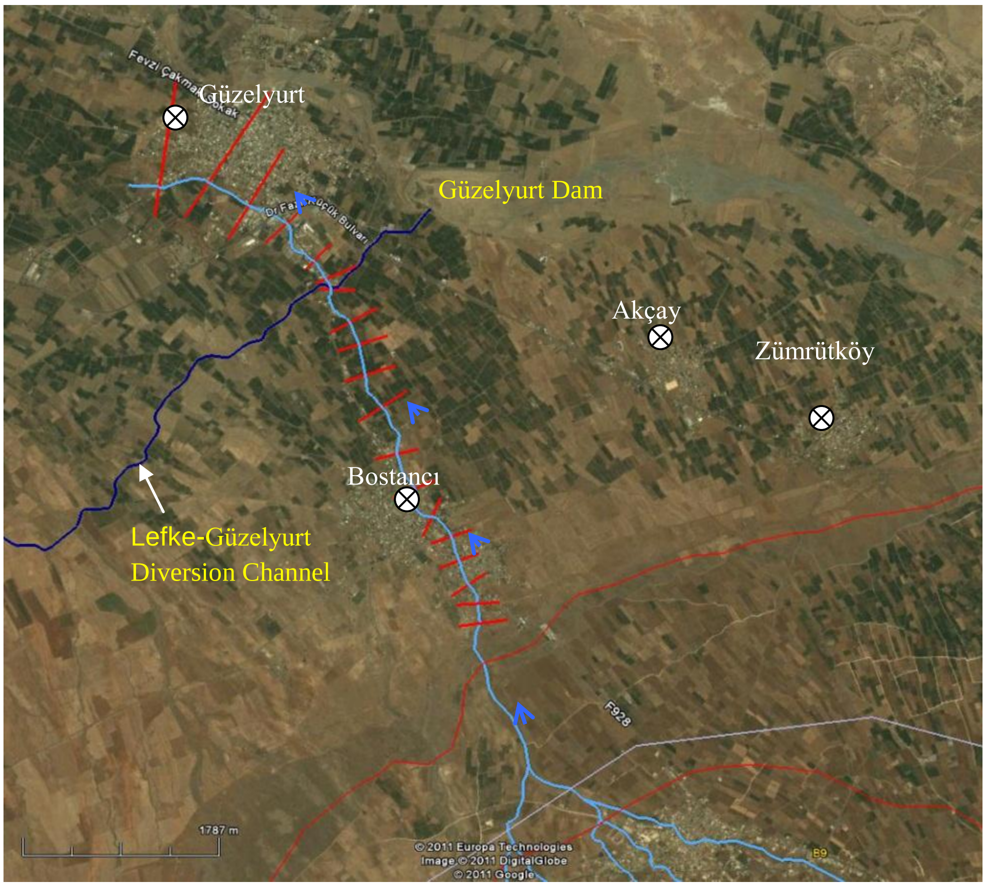


Figure 3.7 Cross section location on Bostancı Creek (Akıntuğ et al., 2011)


Figure 3.8 Cross-section location on Fabrika Creek (Google Earth, 2011)


Figure 3.9 The first bridge on Bostancı Creek


Figure 3.10 The second bridge on Bostancı Creek


Figure 3.11 The third bridge on Bostancı Creek


Figure 3.12 The fourth bridge on Bostancı Creek


Figure 3.13 The fifth bridge on Bostancı Creek


Figure 3.14 The sixth bridge on Bostancı Creek

Figure 3.15 The seventh bridge on Bostancı Creek

Figure 3.16 The culvert on Fabrika Creek

Figure 3.17 The bridge on Fabrika Creek

Hydraulic analyses will be carried out using the characteristic information of these appurtenances.

# CHAPTER IV

# HYDROLOGIC ANALYSIS

Many problems in hydraulic engineering can be solved by considering peak design discharge. Bridges, storm drain inlets, and culverts can be given as examples of hydraulic structures in urban and suburban developments that are designed using peak discharge (McCuen, 1998). However, hydrographs need to be determined for the design of flood storage facilities since they provide the necessary flood volume to be handled. In hydrological modeling part, firstly the rainfall frequency analysis is carried out. As there are no stream-gauging stations in the study area, synthetic unit hydrograph method is used for determining flood hydrograph for the basins concerned. Basin properties are required for generating synthetic unit hydrograph. Basin boundaries and properties are found by using the ARC-GIS software program (See Chapter 3). Finally, maximum inflow is calculated for the Fabrika Creek basin. Maximum inflow for Bostancı Creek is taken from an earlier study (Akıntuğ et al., 2011).

## 4.1 Rainfall Frequency Analysis.

Hydraulic systems are sometimes impacted by extreme hydrological events, such as the Güzelyurt- Bostancı flood. The magnitude of an extreme event is inversely proportional to its frequency of occurrence. Very extreme events may occur less frequently than moderate events. Frequency of occurrence of magnitude of extreme events is based on the objective of frequency analysis of hydrologic data and frequency of occurrence is calculated by using probability distributions.

In order to determine the return period of flood in the Bostancı Creek, the flow data from recent years are needed. Due to the absence of a stream gaging station on this creek, the flood hydrograph cannot be derived using rainfall-runoff relationship of the basins. For this reason, synthetic hydrograph method is employed by using the rainfall data and the basin characteristics. The major parts of the Bostancı Creek and Fabrika Creek basins are in Southern Cyprus such that the related meteorological stations are not accessible. Therefore, Zümrütköy meteorological station, which is located close to the basins with sufficient historical data, is used for the rainfall frequency analysis (See Figure 3.1) Zümrütköy station has daily data for the time period of 1978-2010. Maximum daily rainfall data per year are chosen for the frequency analysis. Figure 4.1 shows that, 160 mm rainfall is the heaviest rainfall on the record data from 1978 to 2010. The rainfall depth values corresponding to 50, 100, 200, and 500 years of return period are obtained through a frequency analysis using HEC-SSP (USACE, 2009) program. The details of computations can be found in Akıntuğ et al. (2011). Table 4.1 shows the results of the frequency analysis for Zümrütköy station in which $T_r$ is the return period (Akıntuğ et al., 2011). In the frequency analysis, normal, log-normal, Pearson Type 3, and Log-Pearson Type 3 distributions have been tested under 95% confidence level using Chi-Square test. Log-Pearson Type 3 distribution is then selected as the best distribution (See Akıntuğ et al., 2011).

Table 4.1 The results of frequency analysis for the Zümrütköy Meteorological Station (Akıntuğ et al., 2011)

| $T_r$ (year) | Zümrütköy rainfall depth (mm) |
|---|---|
| 50 | 117 |
| 100 | 150 |
| 200 | 191 |
| 500 | 261 |

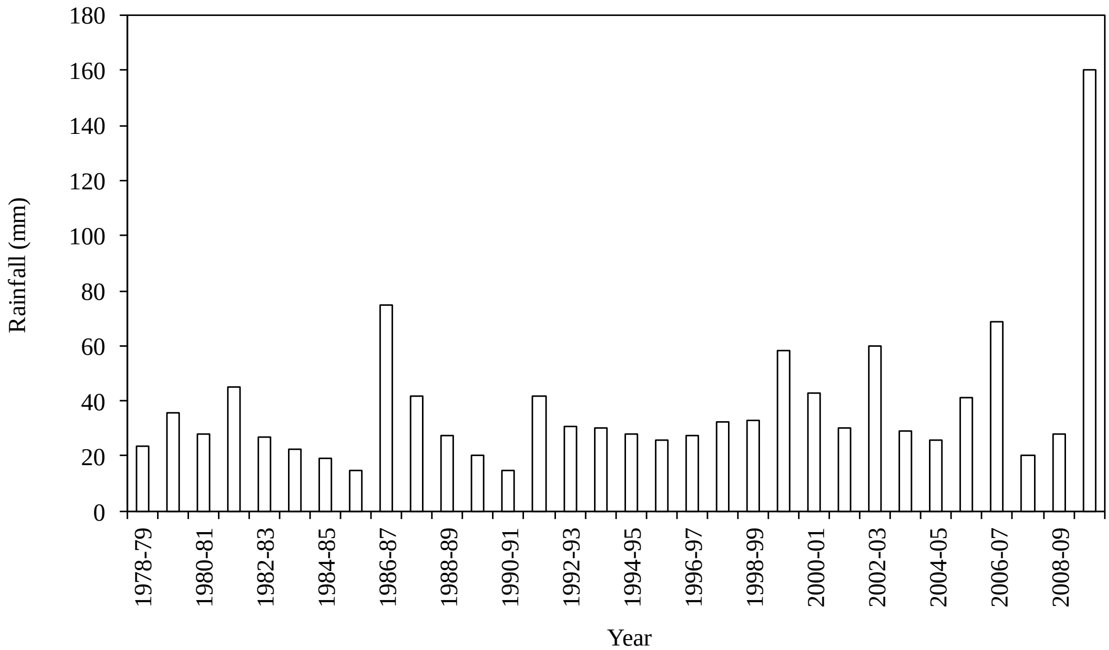


Figure 4.1 The maximum annual daily rainfall values for the Zümrütköy station (Akıntuğ et al., 2011)

### 4.2 Rainfall Pattern in Güzelyurt Region

In order to create a synthetic flood hydrograph, the representative hyetograph of rainfall of the basin is required. This could be possible using the hourly rainfall data of meteorological station(s) in and around the region. Since only the Güzelyurt station has a recording gage and the study area is small enough, it is assumed that Güzelyurt station data can be used as representative information of the basin. The hourly rainfall data of Güzelyurt station between 2000 to 2010 in winter season (December, January, February) are used to obtain the percent distribution of daily rainfall. Only the rainfall depth values greater than 10 mm were taken into consideration. After analyzing these precipitations, 59 rainfall storms were found to be greater than 10 mm in 24 hour periods. The average rainfall duration of 59 storms is 18 hours and the average amount of rainfall depth is calculated as 19 mm. However, during the flood day, 100.7 mm precipitation is observed at Güzelyurt station. This flood is assumed to be the design event in this study. In order to obtain the design hyetograph, it is assumed that the hyetograph consists of four equal parts having a six hour period. Using the available data, the rainfall pattern of Güzelyurt region is obtained as shown in Figure 4.2. The distribution of rainfall for a period of 6 hours, in consecutive order, are 41%, 33%, 18%, and 8%.

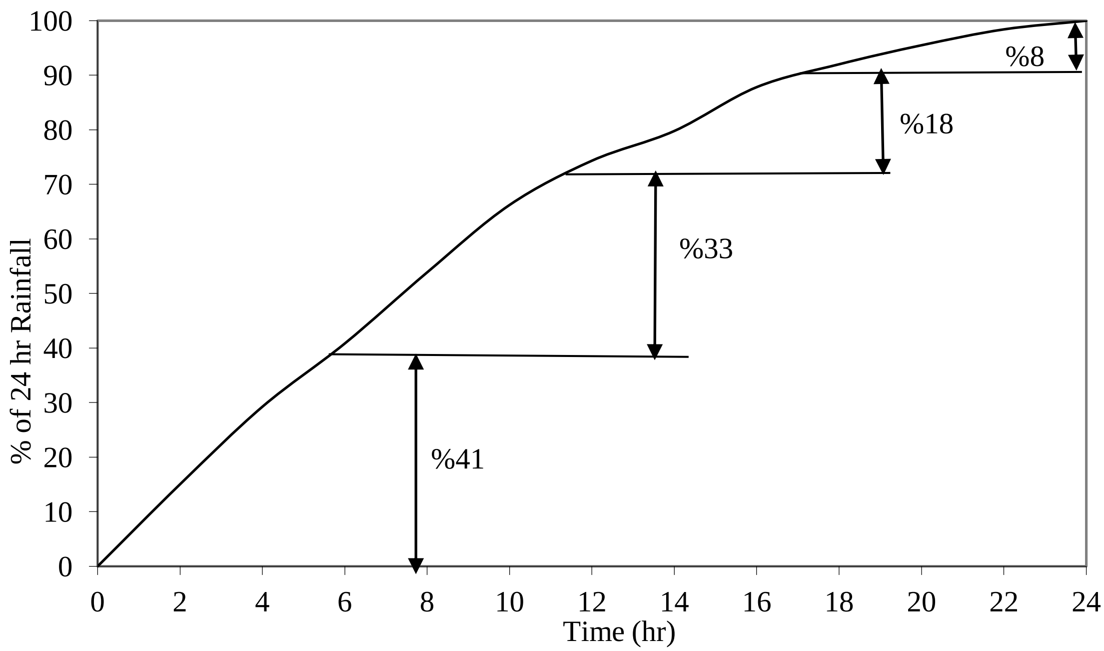


Figure 4.2 Percentage distribution of daily rainfall of Güzelyurt station (Akıntuğ et al., 2011)

### 4.3 Generating Flood Hyetograph

Güzelyurt station is the closest station to the flood region. When hourly rainfall values of this station are examined, rainfall was observed to begin at 9 o'clock on 18 January 2010 and it continued 15 hours (Table 4.2). A total of 100.7 mm rainfall was measured at that day.The rainfall intensity–time graph (hyetograph) is obtained for 6 hours rainfall data which are taken from Güzelyurt station on 18 January 2010. As it can be seen from Table 4.3, rainfall intensity reached the highest value (14.5 mm/hour) 8 hours after the beginning of rainfall (17:00 and 19:00). Using the rainfall data of Güzelyurt station for the aforementioned storm, the hyetograph is obtained (Figure 4.3)

Table 4.2 Hourly and total rainfall values of Güzelyurt station on 18 January 2010

| | **Time (hour)** | **Time (hour)** | **Rainfall (mm)** | **Total Rainfall (mm)** |
|---|---|---|---|---|
| | | 0 | 0.0 | 0.0 |
| **18 January 2010** | 09:00-10:00 | 1 | 3.8 | 3.8 |
| | 10:00-11:00 | 2 | 1.9 | 5.7 |
| | 11:00-12:00 | 3 | 1.6 | 7.3 |
| | 12:00-13:00 | 4 | 3.0 | 10.3 |
| | 13:00-14:00 | 5 | 4.2 | 14.5 |
| | 14:00-15:00 | 6 | 8.0 | 22.5 |
| | 15:00-16:00 | 7 | 8.4 | 30.9 |
| | 16:00-17:00 | 8 | 14.8 | 45.7 |
| | 17:00-18:00 | 9 | 12.3 | 58.0 |
| | 18:00-19:00 | 0 | 16.7 | 74.7 |
| | 19:00-20:00 | 11 | 16.0 | 90.7 |
| | 20:00-21:00 | 12 | 4.0 | 94.7 |
| | 21:00-22:00 | 13 | 1.5 | 96.2 |
| | 22:00-23:00 | 14 | 2.8 | 99.0 |
| | 23:00-24:00 | 15 | 1.7 | 100.7 |
| **19 January 2010** | 00:00-01:00 | 16 | 0.0 | 100.7 |
| | 01:00-02:00 | 17 | 0.0 | 100.7 |
| | 02:00-03:00 | 18 | 0.0 | 100.7 |

Table 4.3 Depth and intensity of rainfall on the 18th January 2010 at Güzelyurt station

| **Time (hr)** | **Rainfall Depth (mm)** | **Intensity (mm/hr)** |
|---|---|---|
| 0-2 | 5.7 | 2.85 |
| 2-4 | 4.6 | 2.30 |
| 4-6 | 12.2 | 6.10 |
| 6-8 | 23.2 | 11.60 |
| 8-10 | 29.0 | 14.50 |
| 10-12 | 20.0 | 10.00 |
| 12-14 | 4.3 | 2.15 |
| 14-16 | 1.7 | 0.85 |

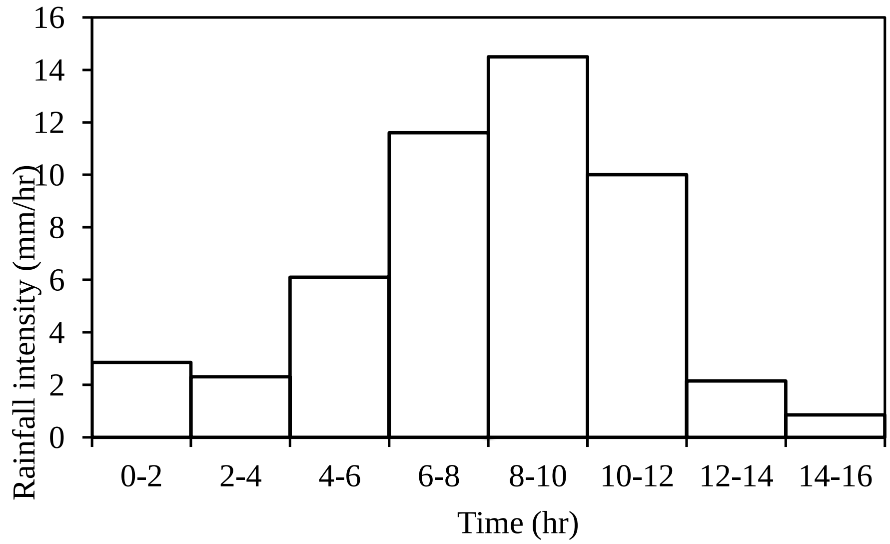


Figure 4.3 Hyetograph of the storm observed at Güzelyurt station on 18 January 2010

However, in the aforementioned flood date (January 2010), 150 mm rainfall was measured in Bostancı and 160 mm rainfall was observed in Zümrütköy. The meteorological station of Zümrütköy is non-recording. Therefore, it is assumed that, the 160 mm rainfall was distributed following the same rainfall distribution pattern as the Güzelyurt station. Table 4.4 shows the estimated percentage and the rainfall depth in Zümrütköy. Figure 4.4 shows the modified hyetograph of Güzelyurt station with respect to Zümrütköy observation on 18 January 2010 i.e. based on 160 mm rainfall depth. This hyetograph is accepted as the design hyetograph.

Table 4.4 Distribution of rainfall depth based on 160 mm rainfall

| **Time (hr)** | **%(Percentage)** | **Depth (cm)** | **Intensity (mm/hr)** |
|---|---|---|---|
| 0-2 | 5.66 | 0.91 | 4.56 |
| 2-4 | 4.57 | 0.73 | 3.68 |
| 4-6 | 12.12 | 1.94 | 9.76 |
| 6-8 | 23.04 | 3.69 | 18.56 |
| 8-10 | 28.80 | 4.61 | 23.2 |
| 10-12 | 19.86 | 3.18 | 16 |
| 12-14 | 4.27 | 0.68 | 3.44 |
| 14-16 | 1.69 | 0.27 | 1.36 |
| | Total: %100 | Total: 16 cm | |

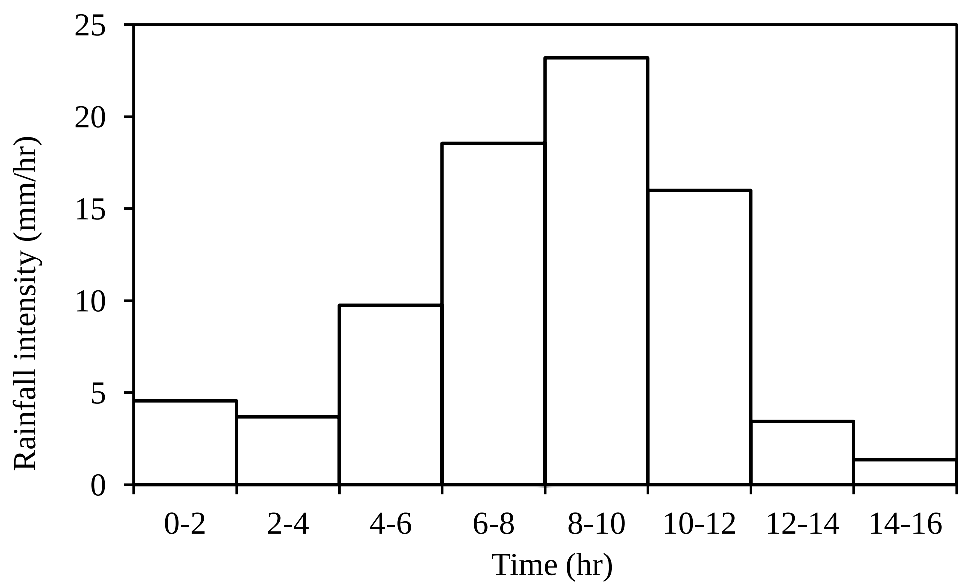


Figure 4.4 Modified hyetograph of Güzelyurt station for 18 January 2010 based on 160 mm rainfall (Akıntuğ et al., 2011)

### 4.4 Obtaining Unit Hydrograph

Unit hydrograph for Fabrika Creek basin is generated by the synthetic unit hydrograph method, which is developed by Soil Conservation Service, USA (USDA, 1972). Peak discharge and time to peak can be calculated from the equations below;

$$Q_p = \frac{2.08A}{t_p} \qquad (4.1)$$

in which;

$$t_p = \frac{t_r}{2} + t_1 \qquad (4.2)$$

$$t_b = 2.67t_p \qquad (4.3)$$

$$t_1 = \frac{L^{0.8}(S+1)^{0.7}}{1900S_h^{0.5}} \qquad (4.4)$$

$$S = \frac{1000}{CN} - 10 \qquad (4.5)$$

where, A is the basin area ($km^2$), $t_p$ is the time to peak (hr), $Q_p$ is the peak discharge ($m^3/s$), $t_r$ is the duration of excess rainfall (hr), $t_l$ is the basin lags (hr), $t_b$ is the base time (hr), L is the main stream length (ft), S is the potential maximum retention (inch), and $S_h$ is the bed slope of the main stream. Besides that, CN is the curve number and it is taken from a table which is related to soil group, surface cover, and antecedent moisture condition (USDA, 1972). Soils of Güzelyurt-Bostancı region can be accepted as having moderately high runoff potential (Group C). Hydrologic soil group condition of Güzelyurt-Bostancı basin is antecedent moisture condition. After surveying the soil map of Cyprus (Figure 4.5) and the field map which is obtained from Google Earth, the weighted CN value is obtained as 77.34. For calculating the slope of Fabrika Creek, twenty points are specified from the Fabrika creek.  The average slope of this creek is found as 0.015. All of other required parameters are obtained by using the ArcGIS software program. The required parameters for Bostancı Creek have already been computed by Akıntuğ et al. (2011). Table 4.5 shows parameters needed to calculate the synthetic unit hydrographs of the basins.


Figure 4.5 General soil map of Cyprus (Akıntuğ et al., 2011)

Table 4.5 Parameters for obtaining the six-hour unit hydrograph for the creeks

| **Parameter** | **Bostancı Creek Basin** | **Fabrika Creek Basin** |
|---|---|---|
| CN | 76.48 | 77.34 |
| L (ft) | 45931 | 57806 |
| S (inch) | 3.08 | 2.93 |
| $S_h$ (%) | 1.4 | 1.5 |
| $t_L$ (hr) | 6.38 | 7.23 |
| $t_p$ (hr) | 9.38 | 10.23 |
| A ($km^2$) | 33.50 | 30.00 |
| $Q_p$ ($m^3$/s) | 7.43 | 6.1 |
| $t_r$ (hr) | 6 | 6 |

After calculating peak discharge and time to peak values, the unit hydrograph is created. The similar computations have already been performed by Akıntuğ et al (2011) for Bostancı Creek basin. Figures 4.6 and 4.7 show the unit hydrographs for six hours ($UH_6$) for both creeks.

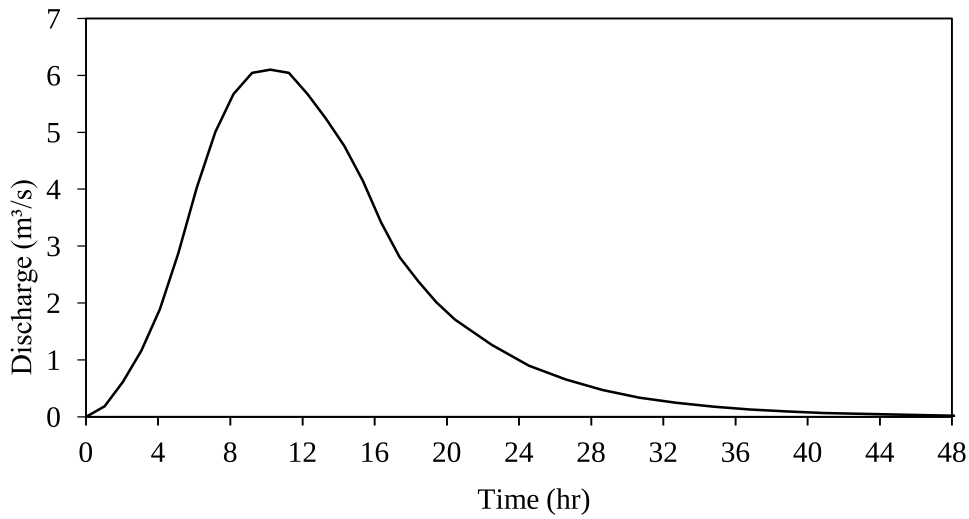


Figure 4.6 $UH_6$ of Fabrika Creek

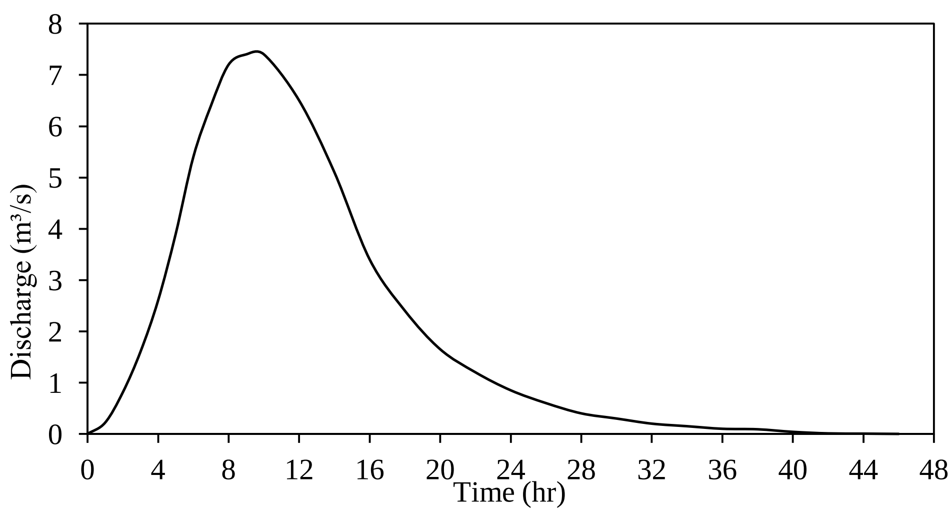


Figure 4.7 $UH_6$ of Bostancı Creek (Akıntuğ et al., 2011)

Since the time step of storm hyetograph (Figure 4.4) is two hours, the $UH_2$ is required to calculate the flood hydrograph. S-curve method is used for obtaining $UH_2$ from $UH_6$ (Chow et al., 1988). After calculating $S_6$ which is shown in Figure 4.8, $UH_2$ is then obtained (Figure 4.10) for Fabrika Creek. $S_6$ and $UH_2$ for Bostancı Creek are taken from Akıntuğ et. al., (2011) (See Figures 4.9 and 4.11).

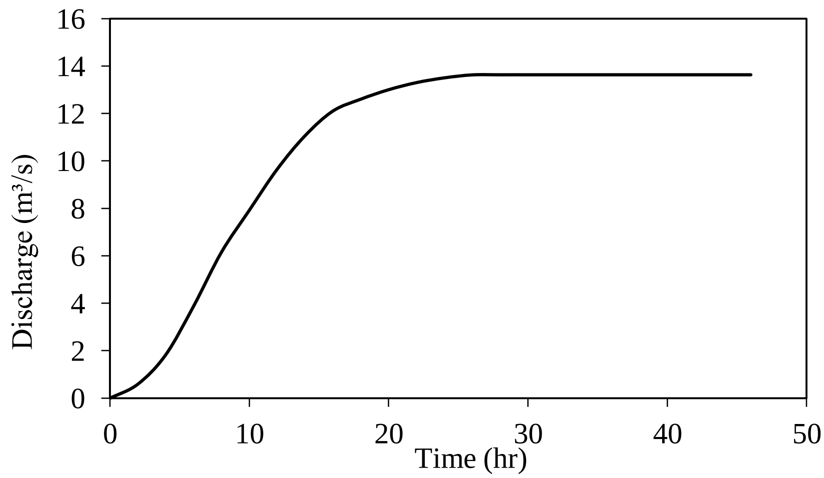


Figure 4.8 $S_6$ curve of Fabrika Creek basin

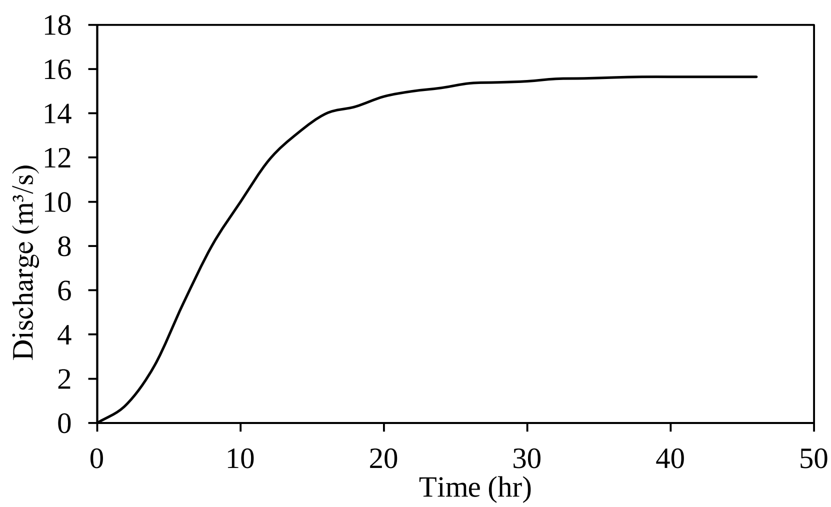


Figure 4.9 $S_6$ curve of Bostancı Creek basin (Akıntuğ et al., 2011)

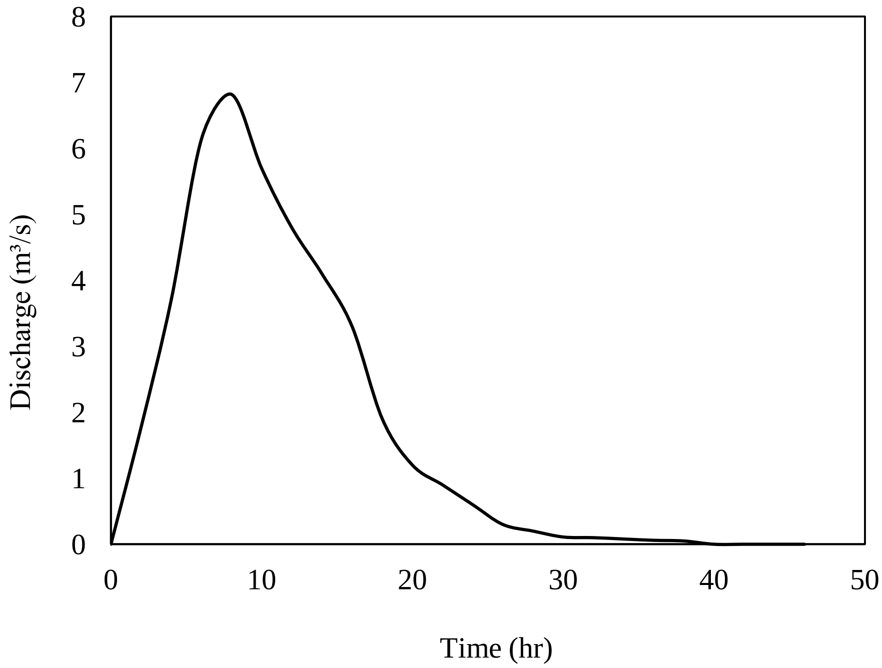


Figure 4.10 $UH_2$ of Fabrika Creek basin

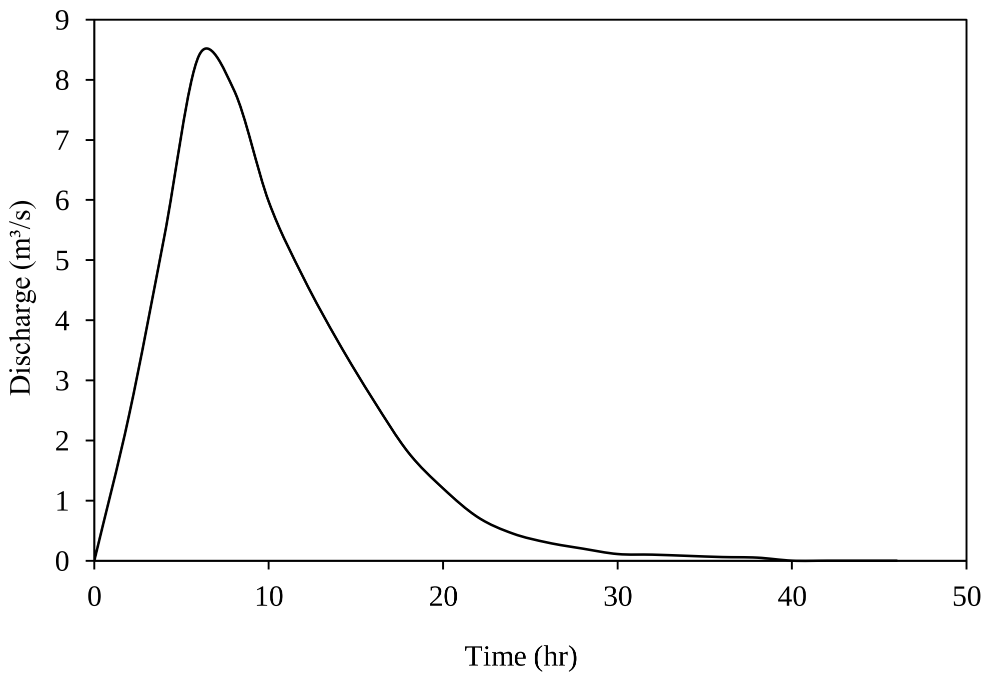


Figure 4.11 $UH_2$ of Bostancı Creek basin (Akıntuğ et al., 2011)

After obtaining $UH_2$, direct runoff can be easily calculated using the convolution (lagging) principle. The ordinates of the direct runoff hydrograph (DR) is computed from

$$DR = 0.91UH_2 + (2\text{ hr lag})\ 0.73UH_2 + (4\text{ hr lag})\ 1.94UH_2 + (6\text{ hr lag})\ 3.69UH_2 + (8\text{ hr lag})\ 4.61\ UH_2 + (10\text{ hr lag})\ 3.18UH_2 + (12\text{ hr lag})\ 0.68UH_2 + (14\text{ hr lag})\ 0.27UH_2 \quad (4.6)$$

As it seen in Figure 4.12, the peak discharge of the design flood hydrograph is 90.3 $m^3/s$ for Fabrika Creek. According to the similar computations which have been performed by Akıntuğ et al., (2011), the peak discharge of the design flood hydrograph is 104.6 $m^3/s$ for Bostancı Creek (See Figure 4.13). As it was previously stated the Fabrika Creek hydrograph is developed to represent January 2010 flood (design flood). Besides that, the hydrographs are generated for different return periods i.e 50, 100, 200, and 500 years for the Bostancı Creek (Akıntuğ et al., 2011). As it can be seen from Figure 4.13, the return period of the design flood hydrograph is approximately 300 years, which is conservative.

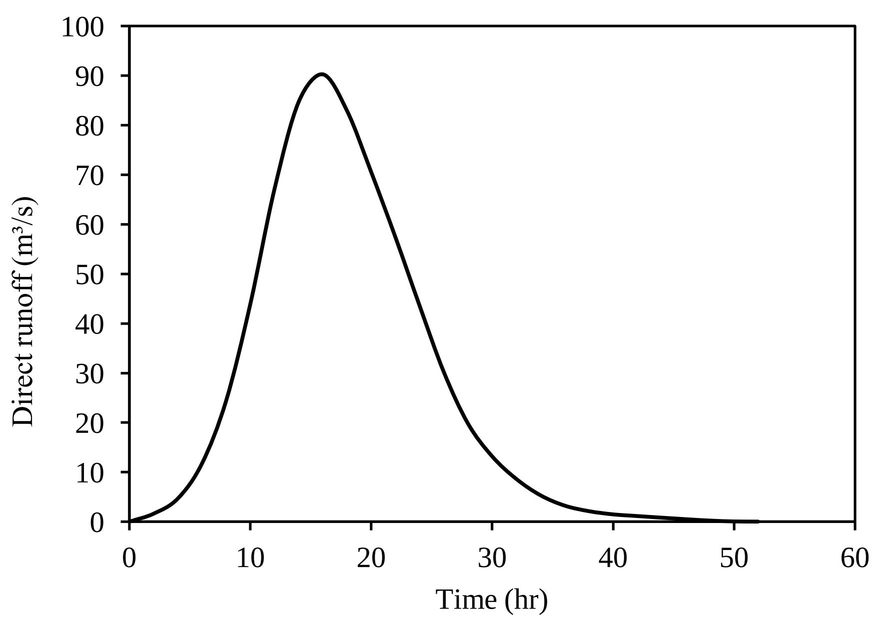


Figure 4.12 Design flood hydrograph of Fabrika Creek basin

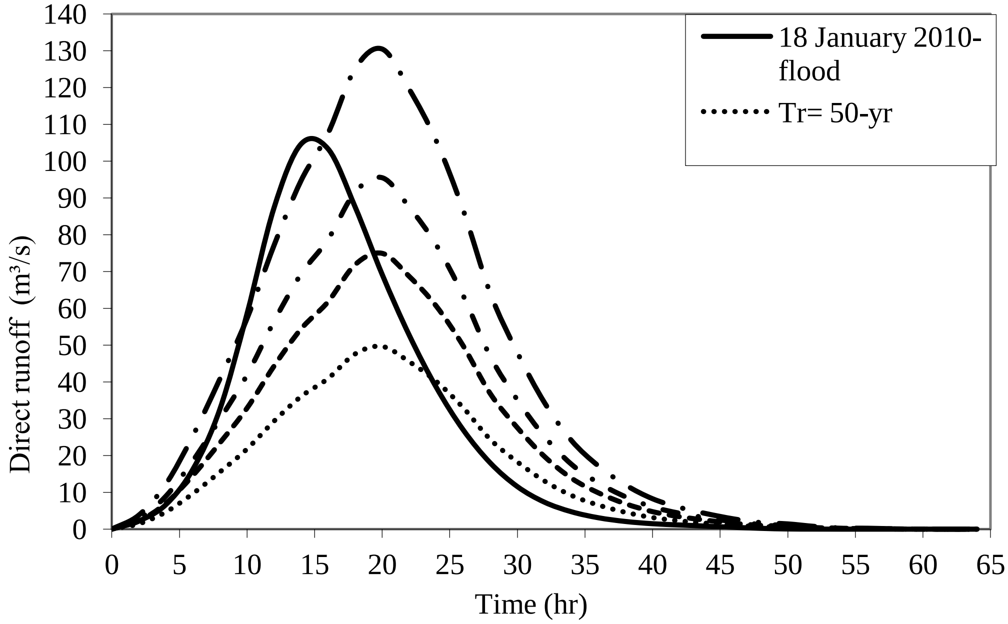


Figure 4.13 Different frequency flood hydrographs of Bostancı Creek basin (Akıntuğ et al., 2011)

# CHAPTER IV

# HYDRAULIC ANALYSIS

Hydraulic analysis is required for deciding the degree of protective works and flood management practices. This type of analysis depends on the quality of input data. In this study, two creeks are investigated. Input data, such as cross-sections of creeks and dimensions of hydraulic structures along them which were obtained by measuring one side using the aforementioned surveying devices. Therefore, the quality of topographic data is highly reliable. As a result of hydraulic analysis, flood inundation map is drawn and flow carrying capacities of the creeks and hydraulic structures are investigated.

## 5.1 Water Surface Profiles

Water surface profiles are determined for the Bostancı and Fabrika Creeks using HEC–RAS program, Version 4.0 (USACE, 2010). The US Army Corps Engineers’ River Analysis System (HEC-RAS) is a software that allows one to perform one dimensional hydraulic analysis for steady flow water surface profile computations, unsteady flow simulation, and movable boundary sediment transport computations (USACE, 2010). In this study, steady flow water surface profile computations are used. Necessary input data, such as cross-sections data, bed materials characteristics, details of the existing bridges and Manning’s roughness values are determined for these creeks.

## 5.2 Determination of the Manning’s Roughness Coefficient

Manning’s roughness coefficient gives information about stream bed resistance to flow. Therefore, this coefficient is needed in the HEC-RAS software.

The selection of Manning’s roughness coefficient requires experience and judgment. It depends on several factors, such as bed material, project site geometry, seasonal change of creek alignment, discharge variation, bed scour, etc. The overall roughness coefficient to account for these effects can be determined from Lagasse et al.(2001):

$$n = (n_b + n_1 + n_2 + n_3 + n_4)m \quad (5.1)$$

where $n_1$ is the roughness coefficient due to bed material size, $n_b$ is the roughness coefficient due to cross-sectional variation, $n_2$ is the roughness coefficient due to channel geometry, $n_3$ is the roughness coefficient according to undulations at river bed, $n_4$ is the roughness coefficient due to vegetation, and m is the coefficient due to sinuosity. Bed material samples are collected from Bostancı Creek which are further analyzed in Soil Mechanics Laboratory of the METU Northern Cyprus Campus. Nine samples are taken from the Bostancı Creek and gradation curves of them are obtained (See Figure 5.1). According to $D_{50}$ values of bed material samples of each section, essential data are chosen from Table 5.1 and Table 5.2.

Based on these data, the average roughness coefficient is taken as 0.056 for the main channel (Figure 5.2). Table 5.3 shows input data for Manning roughness coefficient by sections, which are designated by $N_i$. Bostancı Creek and Fabrika Creek are very close to each other and their surface properties are similar. The average value of Manning’s n is 0.056 with a standard deviation of 0.0069. Since the standard deviation is low, the representative Manning’s n value is assumed to 0.056 for both creeks.

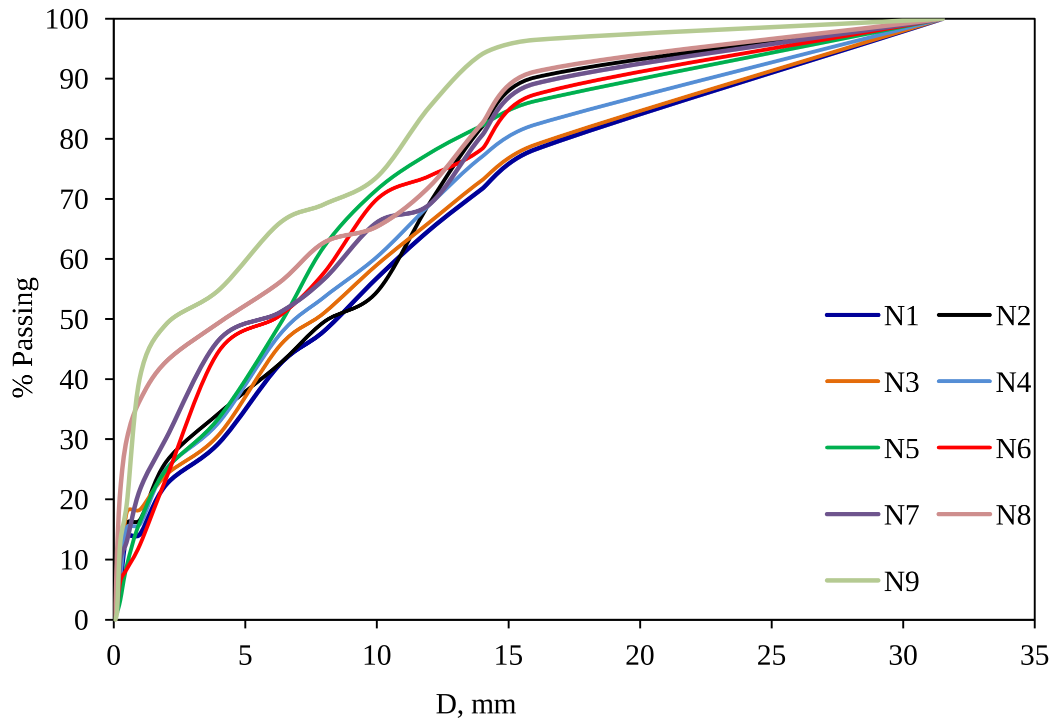


Figure 5.1 Gradation curves of bed material samples

Table 5.1 Manning's $n_b$ Coefficient (Lagasse et al., 2001)

| Type of the channel | $D_{50}$ (mm) | $n_b$ |
|---|---|---|
| River bed composed of sand | 0.2 | 0.012 |
| | 0.3 | 0.017 |
| | 0.4 | 0.020 |
| | 0.5 | 0.022 |
| | 0.6 | 0.023 |
| | 0.8 | 0.025 |
| | 1.0 | 0.026 |
| Immovable bed channel | | |
| Concrete | - | 0.012-0.018 |
| Rock Cuts | - | 0.025 |
| Hard Soil (Earth) | - | 0.025-0.032 |
| Coarse Sand | 1-2 | 0.026-0.035 |
| Fine Gravel | - | 0.024 |
| Gravel | 2-64 | 0.028-0.035 |
| Coarse Gravel | - | 0.026 |
| Coarse (Dimension) Stone | 64-256 | 0.030-0.050 |
| Rock | >256 | 0.040-0.070 |

Table 5.2 Correction factors for Manning roughness coefficient (Lagasse et al., 2001)

| $n_i$ | Validity Conditions | Value | Notes |
|---|---|---|---|
| $n_1$ | Smooth | 0 | Smooth Channel |
| | Minor | 0.001-0.005 | Excavated channel in good condition |
| | Moderate | 0.006-0.010 | Channels with considerable bed roughness and some bank erosion. |
| | Severe | 0.011-0.020 | Natural Channels: pools and riffles, exposed tree roots, boulders and/or irregular banks |
| $n_2$ | Uniform | 0 | Near – uniform channel sections. |
| | Gradual | 0.001-0.005 | Large and small cross sections alternate occasionally. |
| | Severe | 0.010-0.015 | Large and small cross sections alternate frequently. |
| $n_3$ | Negligible | 0-0.004 | A few scattered obstructions that occupy less than 5% of the channel. |
| | Minor | 0.005-0.015 | Obstructions occupy 5–15% of the channel and the obstructions are generally isolated |
| | Appreciable | 0.020-0.030 | Obstructions occupy 15–50% of the channel |
| | Severe | 0.040-0.060 | Obstructions occupy more than 50% of the channel |
| $n_4$ | Small | 0.002-0.01 | $y>2*$height of vegetation |
| | Medium | 0.01-0.025 | $y>$ height of vegetation |
| | Large | 0.025-0.050 | $y<$ height of vegetation |
| | Very Large | 0.050-0.100 | $y<0.5*$ height of vegetation |
| m | Minor | 1.0 | $S<1.2$ |
| | Appreciable | 1.15 | $1.2\leq S\leq 1.5$ |
| | Severe | 1.30 | $S>1.5$ |

Table 5.3 Input data for Manning's roughness coefficient for sections

| | N1 | N2 | N3 | N4 | N5 | N6 | N7 | N8 | N9 |
|---|---|---|---|---|---|---|---|---|---|
| **$D_{50}$ (mm)** | 8.5 | 8.2 | 7.8 | 7 | 6.3 | 6 | 5.1 | 4.15 | 3.4 |
| **$n_b$** | 0.026 | 0.026 | 0.026 | 0.026 | 0.026 | 0.026 | 0.026 | 0.026 | 0.026 |
| **$n_1$** | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 |
| **$n_2$** | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| **$n_3$** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **$n_4$** | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| **m** | 1 | 1 | 1 | 1.15 | 1 | 1.3 | 1.15 | 1.3 | 1.3 |
| **n** | 0.049 | 0.049 | 0.049 | 0.056 | 0.049 | 0.064 | 0.056 | 0.064 | 0.064 |

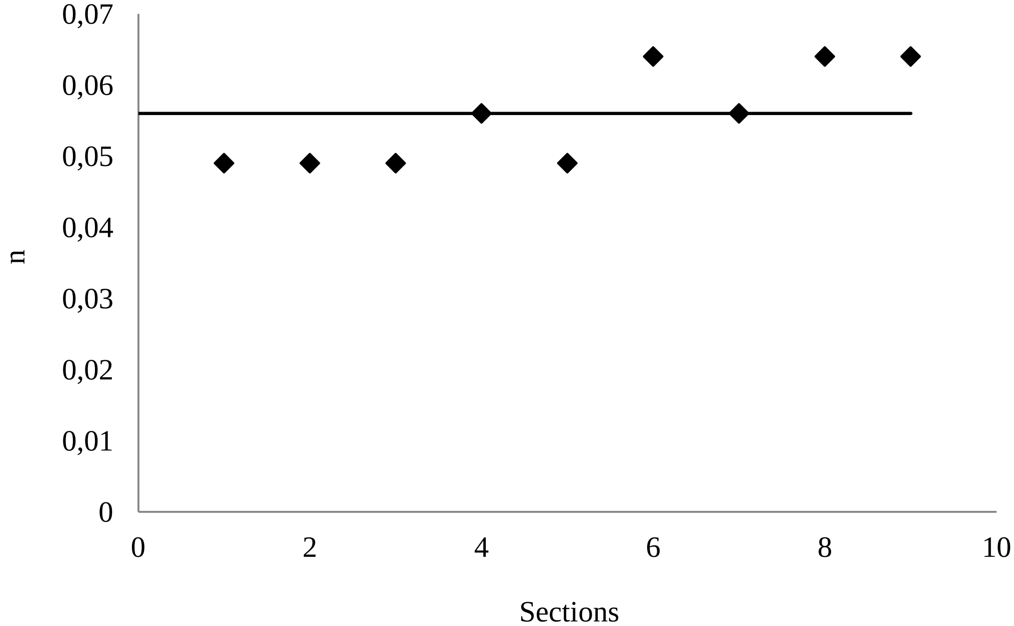


Figure 5.2 Distribution of Manning roughness coefficients by sections

**5.3 HEC- RAS Modeling**

After measuring coordinates of cross-sections at the field and calculating Manning’s roughness coefficient, the flows of Bostancı Creek and Fabrika Creek are simulated by using the HEC-RAS software. Section data are used as input in the software. Then the distance of downstream reach length between two sections are inserted. Figure 5.3 shows a photo of Section 9 from Bostancı Creek and simulated form of this section is indicated in Figure 5.4 as an example. Moreover, Figure 5.5 shows Section 24, which is from Fabrika Creek and the modeled form of Section 24 is shown in Figure 5.6.


Figure 5.3 Photo of Section 9 of the Bostancı Creek

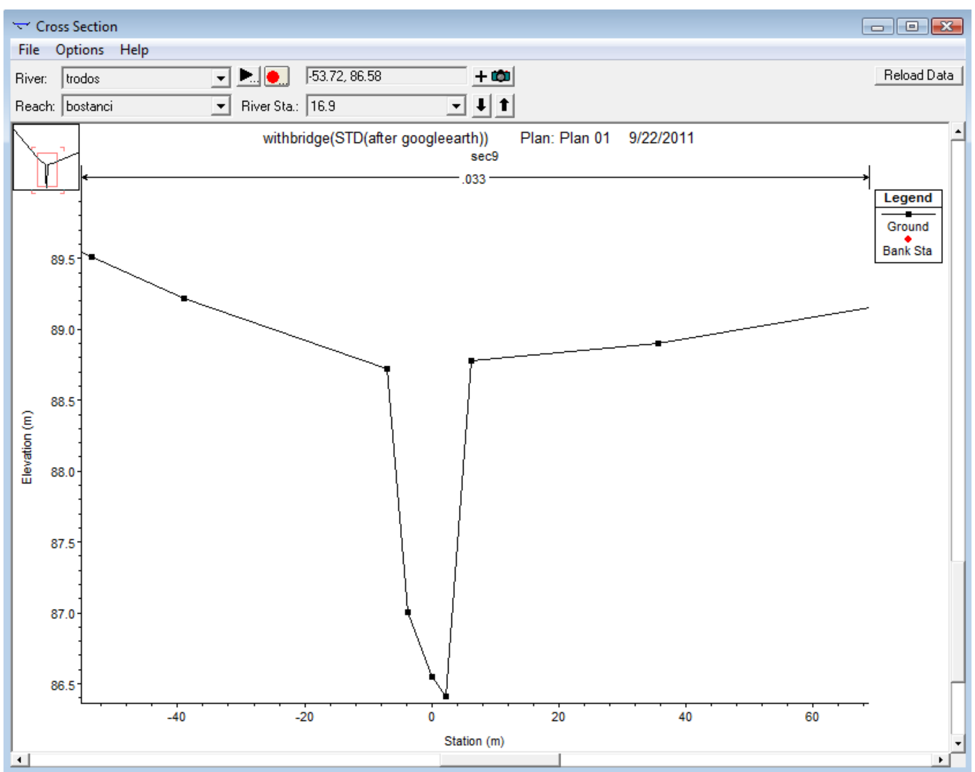


Figure 5.4 The simulated form of Section 9

Figure 5.5 Photo of Section 24 of Fabrika Creek

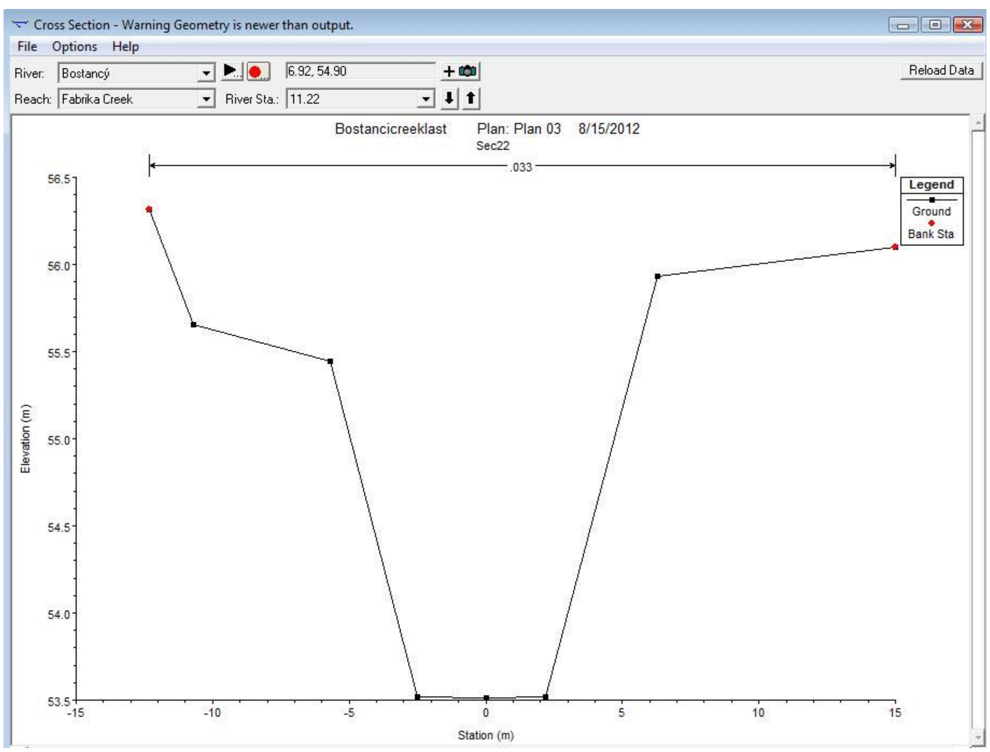


Figure 5.6 Modeled Section 24 of Fabrika Creek

While modeling bridges using the HEC-RAS software, option of bridges/culverts are used in which deck data and pier data are inserted. All the geometric details of hydraulic structures are measured at the site by instruments and drawn before the HEC-RAS modeling. Then all these data are inserted into HEC-RAS. Figure 5.7 shows a photo of bridge at Section 3 of Bostancı Creek. The location of this bridge is also marked in Google Earth Map (Figure 5.8). Details of this bridge can be seen in Figure 5.9 and the simulated bridge is given in Figure 5.10. Figure 5.11 and Figure 5.12 show layout of cross-sections of Fabrika Creek and Bostancı Creek.


Figure 5.7 Bridge at section 3 of Bostancı Creek

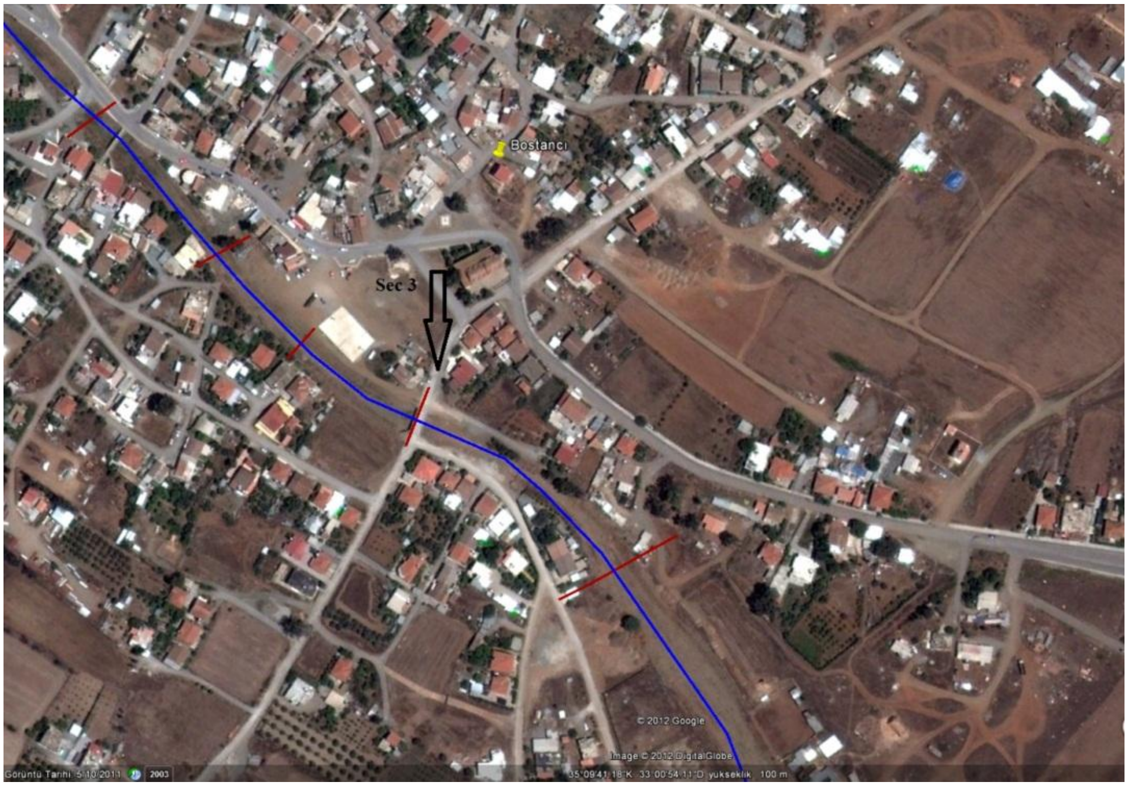


Figure 5.8 The location of Bridge at Section 3, Bostancı Creek (Google Earth, 2011)

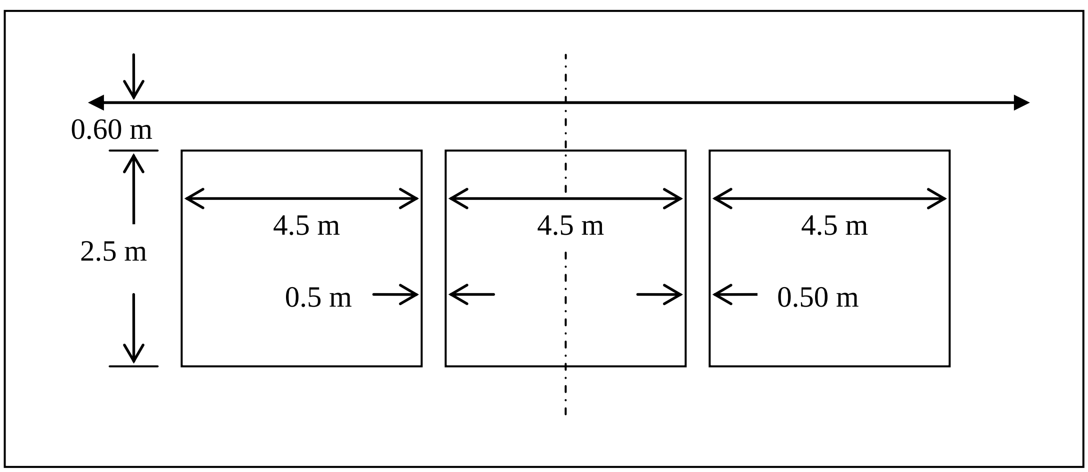


Figure 5.9 Dimensions of bridge at Section 3 of Bostancı Creek

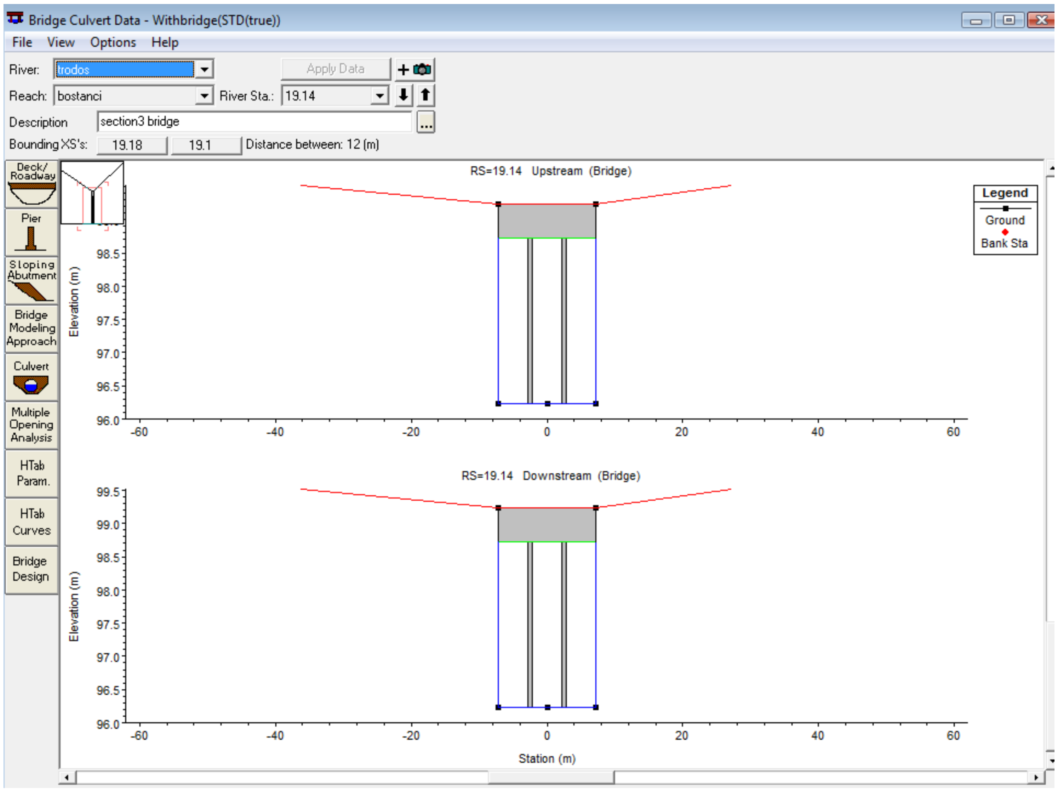


Figure 5.10 Simulated form of bridge at Section 3 of Bostancı Creek.

After all sections, bridges, and culverts are defined, the computed hydrographs are inserted into HEC-RAS for determining flood inundation maps of the creeks. The analyses for the water surface profile computations are carried out for the design flood (January 2010 flood). Since this flood corresponds to approximately 300 years for Bostancı Creek, the remedial measures will be developed for relatively conservative design conditions. The peak discharges, which are 90.3 $m^3/s$ for Fabrika Creek and 104.6 $m^3/s$ for Bostancı Creek, are used to determine the inundated areas. Figure 5.13 and Figure 5.14 show flood inundation maps which are modeled by the HEC-RAS software.

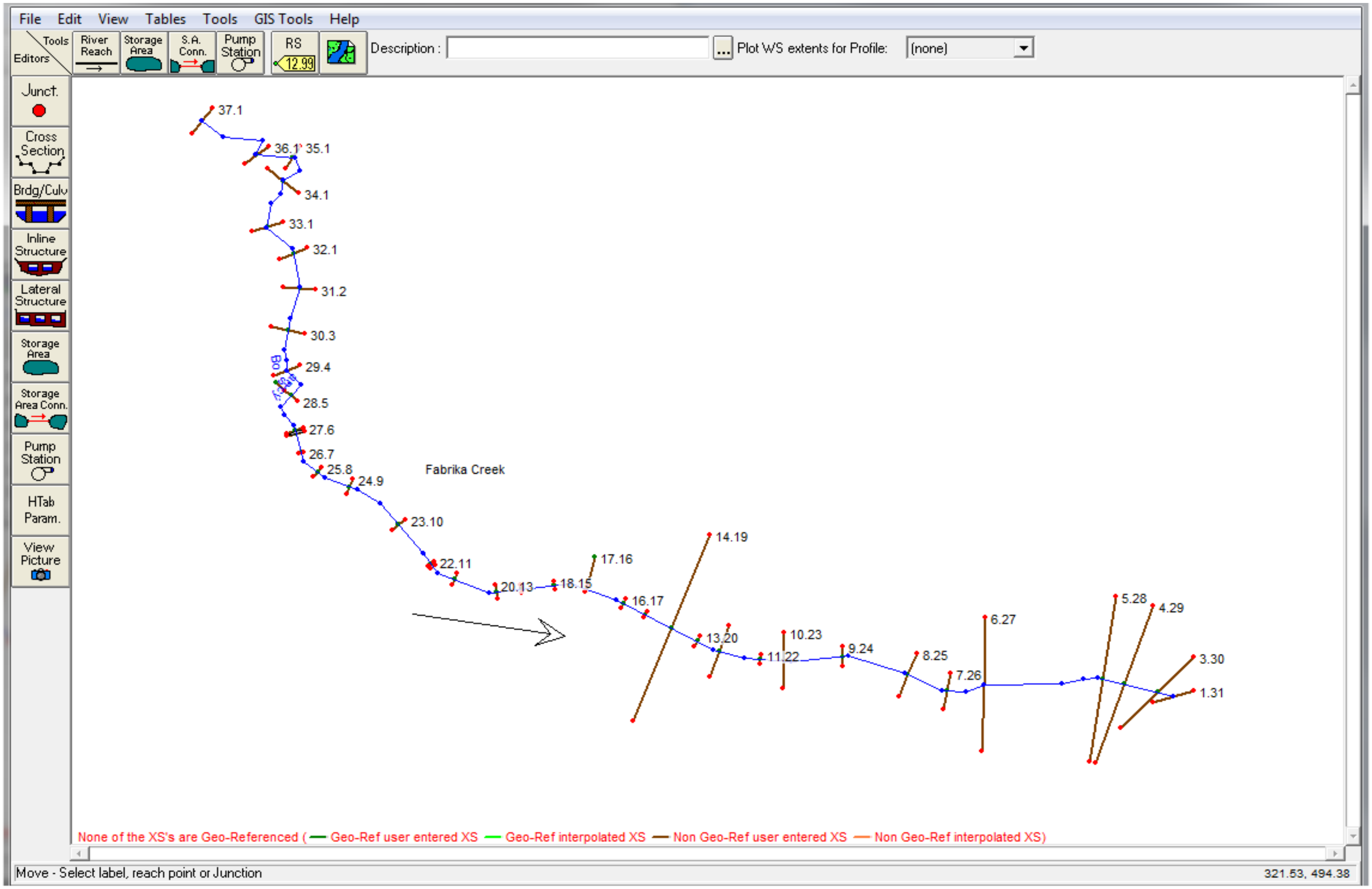


Figure 5.11 Layout of Fabrika Creek

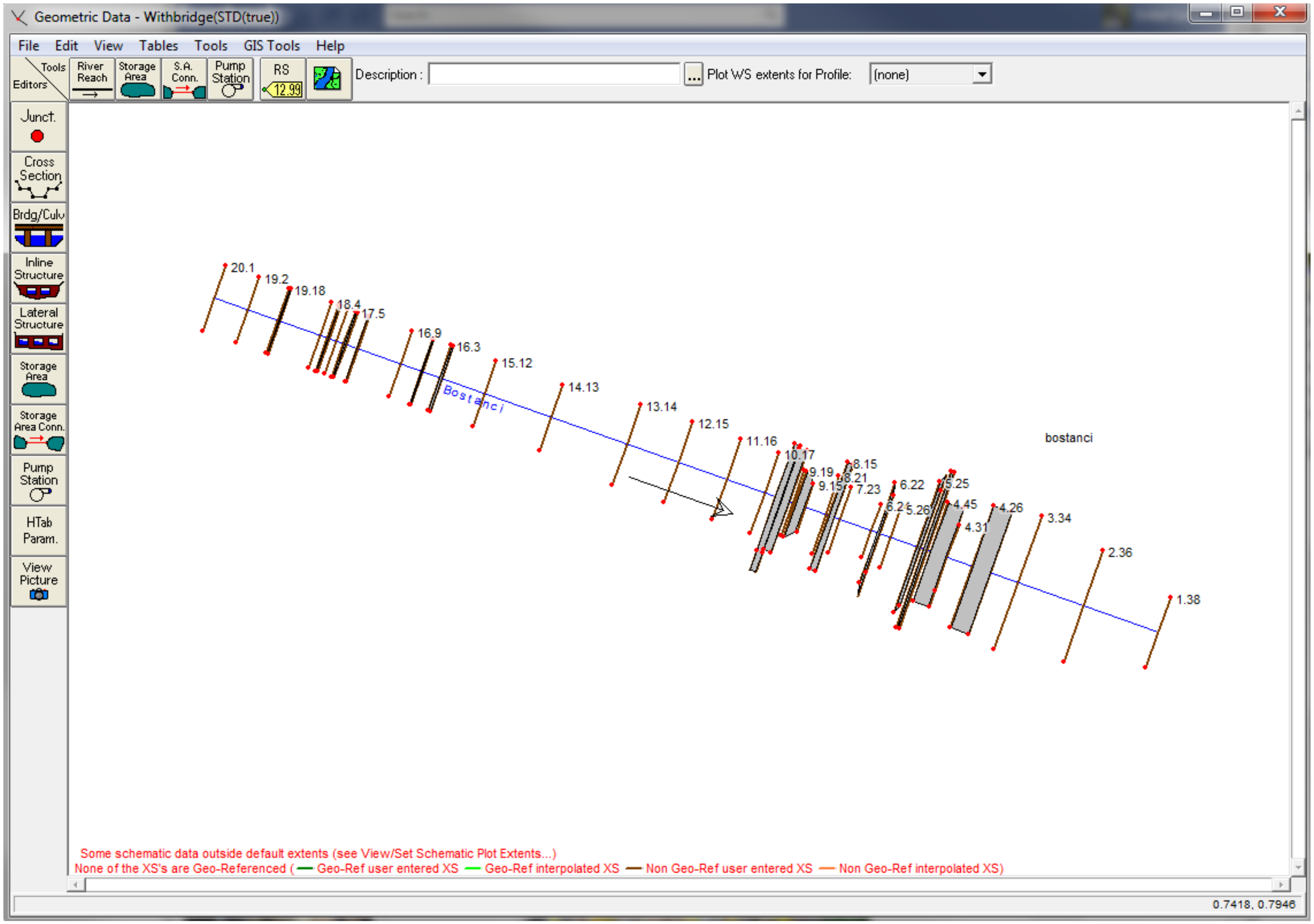


Figure 5.12 Layout of Bostancı Creek

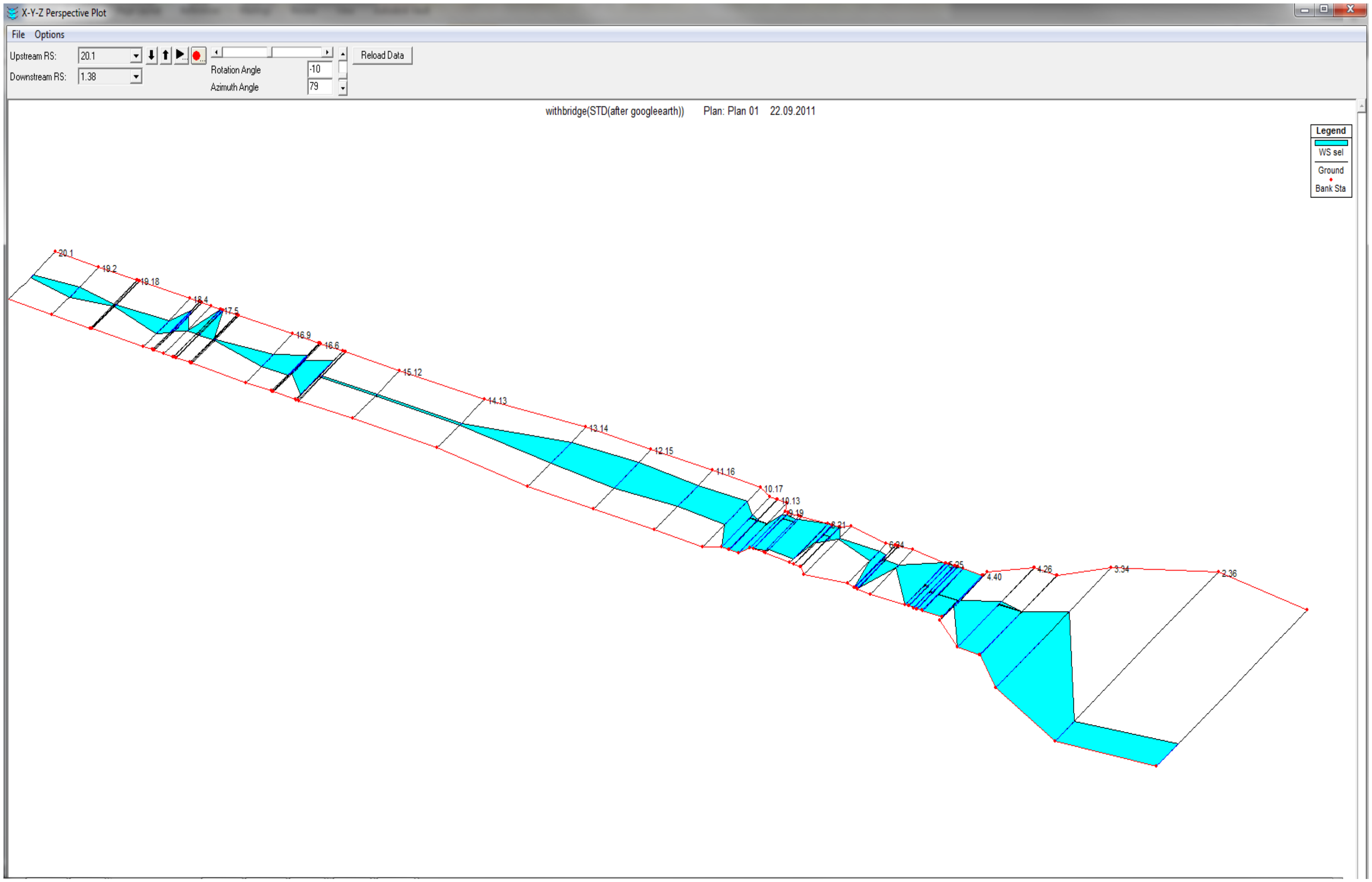


Figure 5.13 Flood inundation map of Bostancı Creek (HEC-RAS Output)

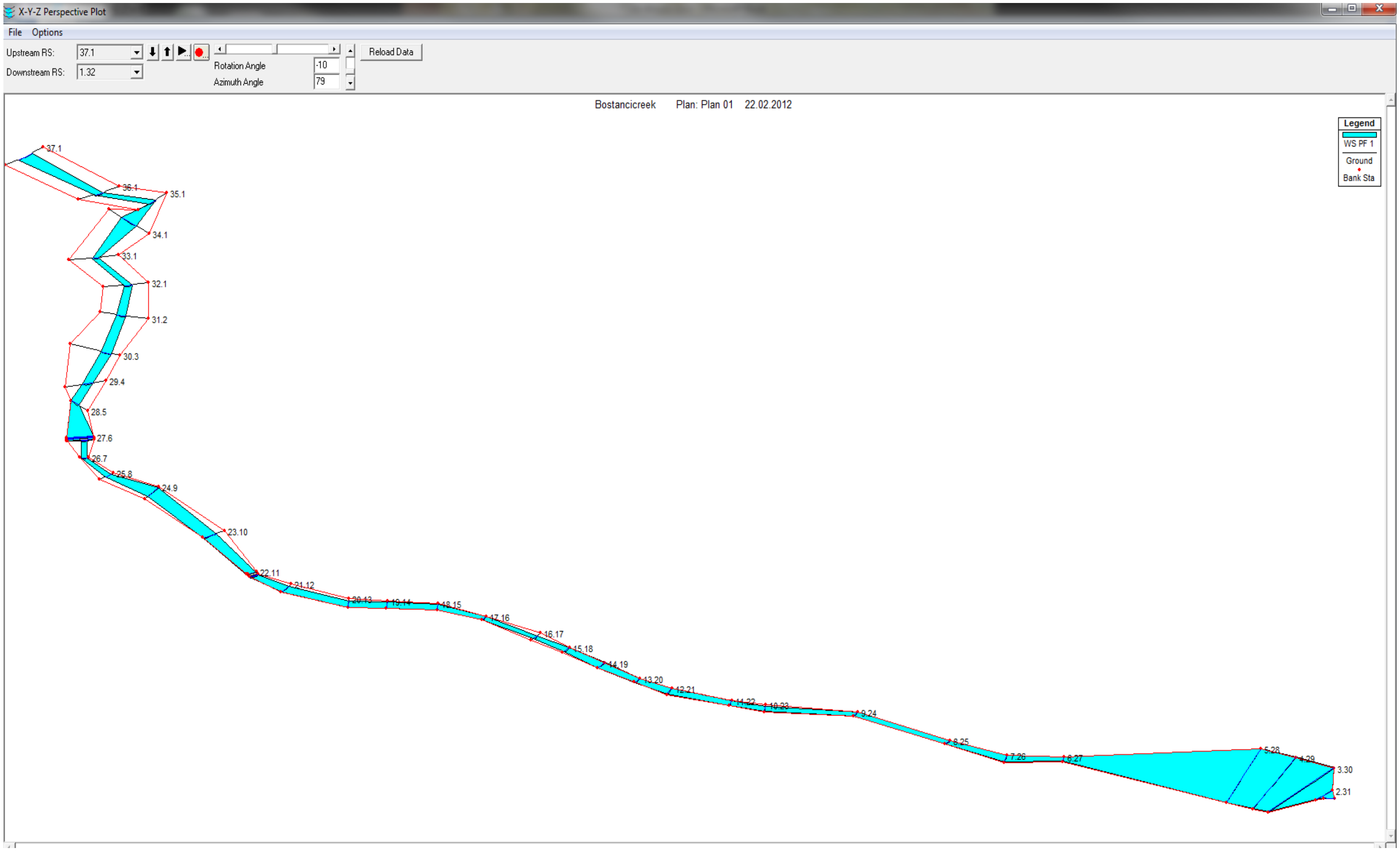


Figure 5.14 Flood inundation map of Fabrika Creek (HEC-RAS Output)

When the boundaries of these maps are plotted using Google Earth, flooded regions can be seen clearly. Figure 5.15 shows flooded region for Bostancı Creek. Light blue color shows the extent of flood inundation area and dark blue color shows the HEC-RAS model results. A rather good agreement can be seen between observation and model results. Hence solutions can be simulated by using this model. However for Fabrika Creek, when flood came, water could not pass through the culvert at Section 6 (See Figure 3.19) and flooded the surrounding area. This is also observed in the model. Water could not pass from the first culvert because of the small opening. Besides that, according to observations, inside of the culvert is full of garbage which prevents water to pass. Figure 5.16 shows modeled culvert which remain under water with a peak discharge of 90.3 $m^3$/s.

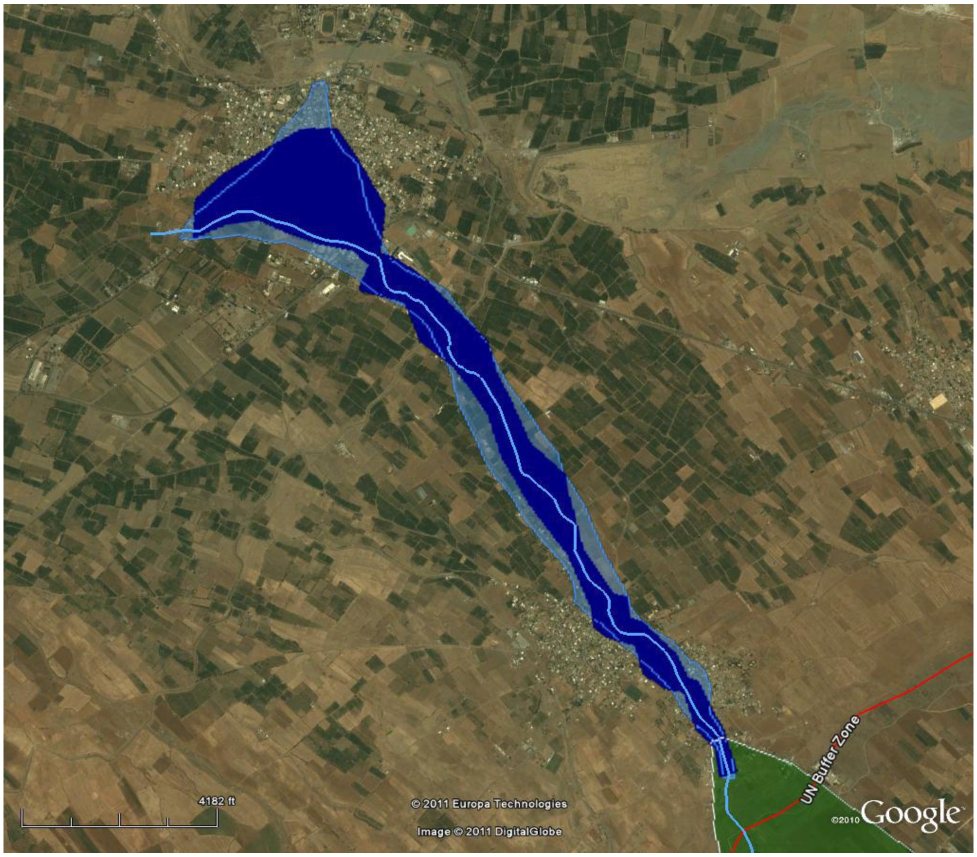


Figure 5.15 Flood map for Bostancı Creek on flood day (Akıntuğ et al., 2011)

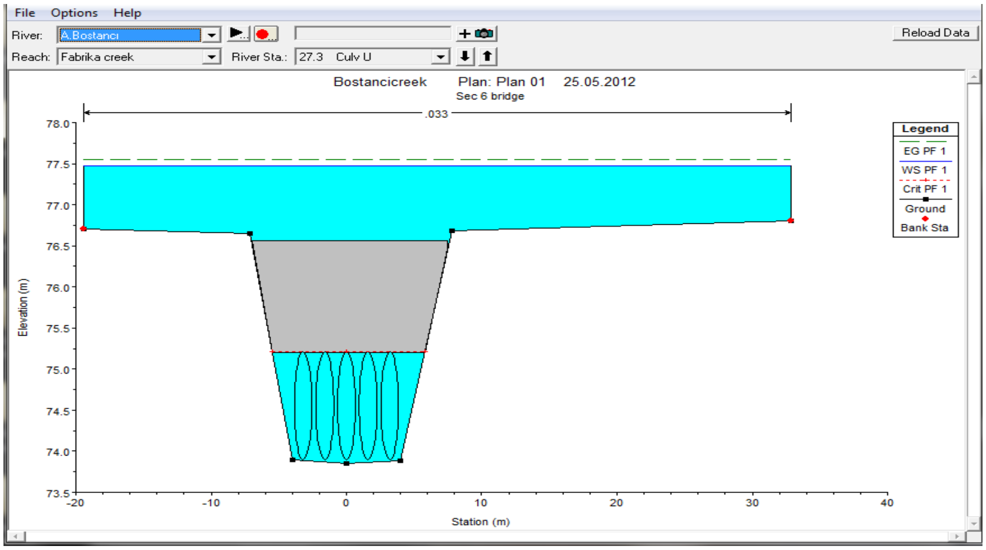


Figure 5.16 Simulated forms of culvert which are flooded on flood day in Fabrika Creek

Bank-full capacities of the Fabrika Creek and Bostancı Creek are calculated using a trial and error method by using HEC-RAS software. Two options are used for determining capacities of these creeks. The first one is determining the capacities of the creeks without any changes in the conditions of the hydraulic structures. The second option is modifying existing structures like culverts and bridges for increasing capacities of creeks. Based on the first option, Bostancı Creek is observed to transmit up to 5 $m^3/s$ without overtopping the channel sides. In this option, the original conditions of the creek are taken into account without any changes in the cross-sections (Figure 5.17). If Creeks are cleaned from impurities and garbage and channel widening and deepening are applied, Manning’s roughness coefficient is accepted to decrease. The new conditions are assumed to have a relatively lower coefficient i.e. 0.033. Besides that, some culverts having smaller capacities can be replaced with new ones of higher capacity. Diameters of culverts at sections 18, 20, 22 are 1 m, 0.5 m, and 0.5 m, respectively. If these culverts are replaced with new ones having diameters of 2 m, the capacity of Bostancı Creek will increase to 11 $m^3/s$ (Figure 5.18). The new inundation map of Bostancı Creek is drawn with respect to 11 $m^3/s$ (See Figure 5.19).

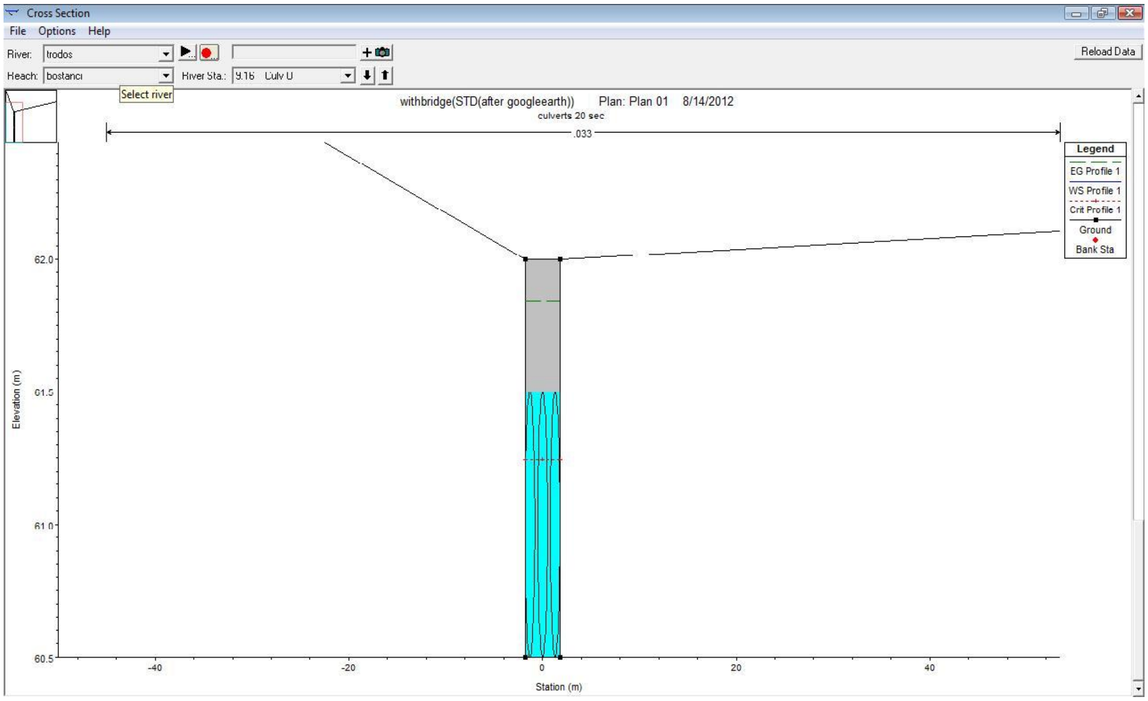


Figure 5.17 Culvert at Section 22 on Bostancı Creek with respect to 5 $m^3/s$

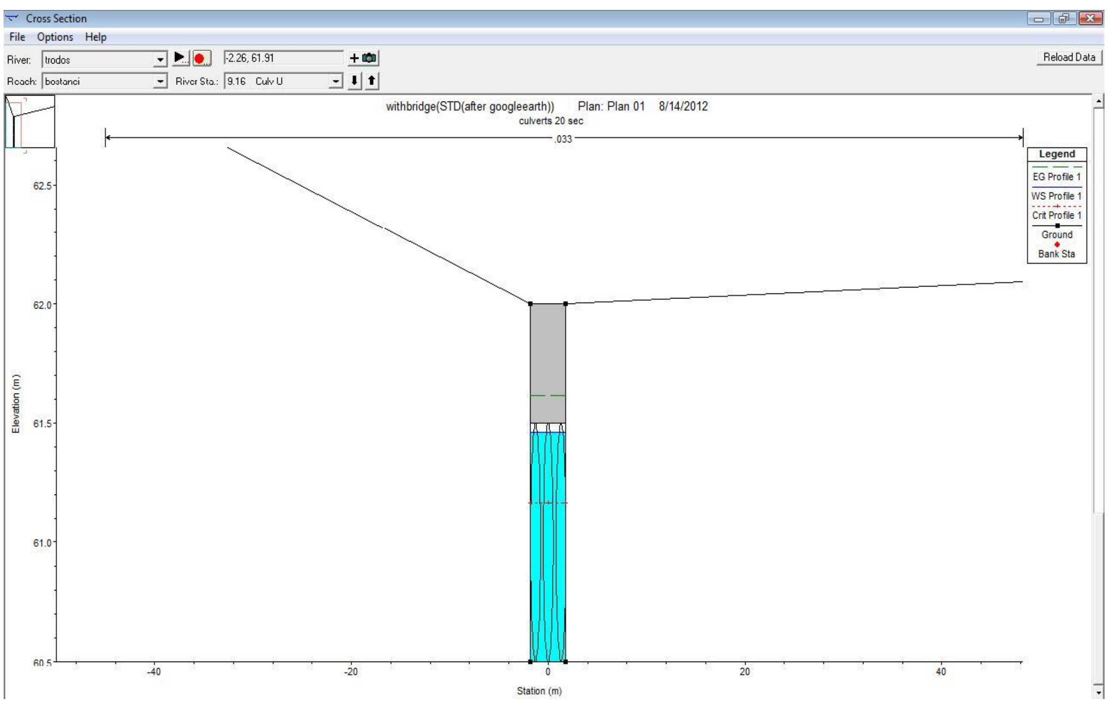


Figure 5.18 Culvert at Section 22 on Bostancı Creek with respect to 11 $m^3/s$

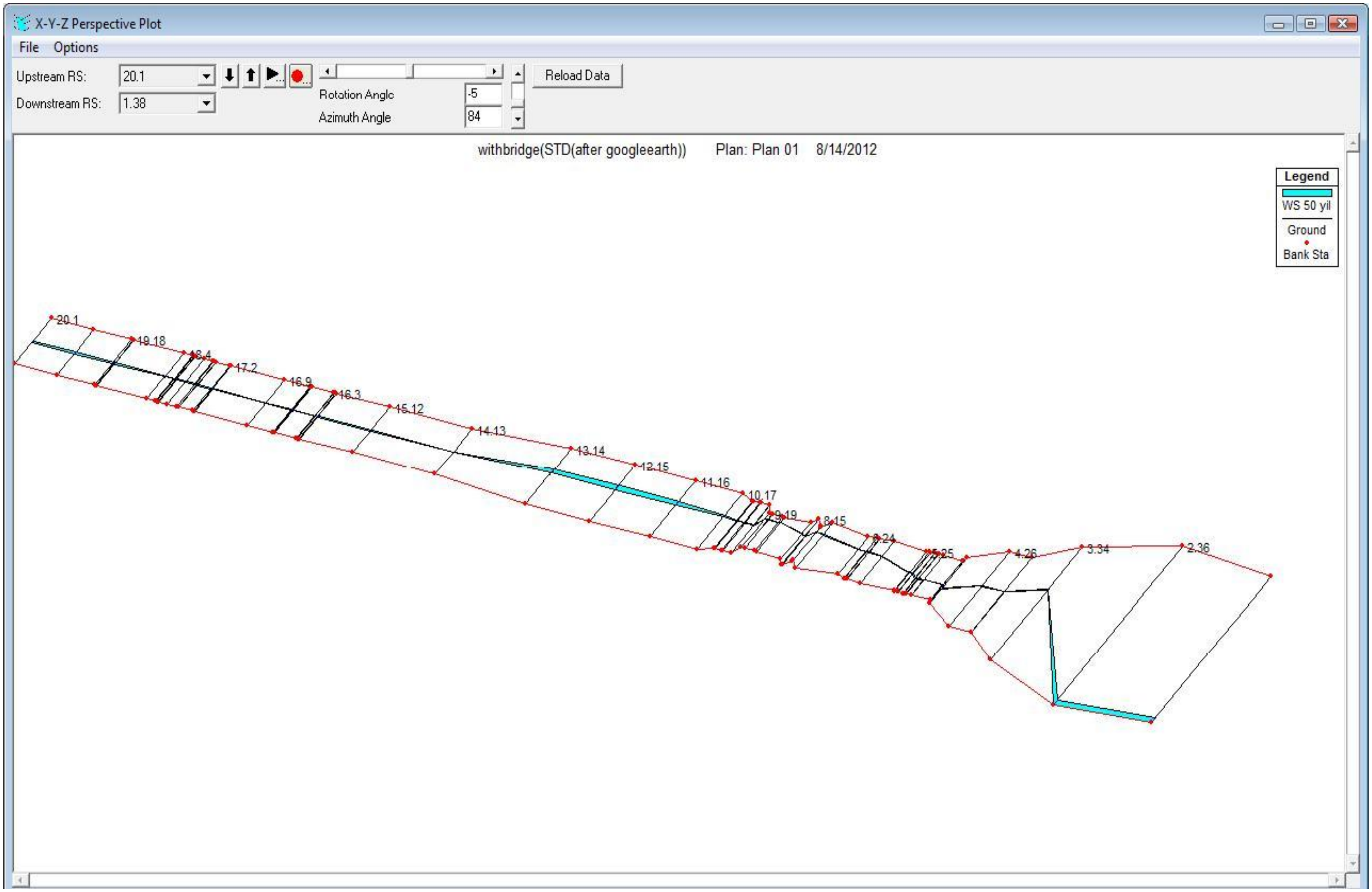


Figure 5.19 Inundation map of Bostancı Creek with respect to 11 $m^3/s$ discharge

The capacity of Fabrika Creek is high but culverts at Section 6 (Figure 3.24) decrease the ability to transmit flow because of inadequate capacity. If this culvert is not changed, Fabrika Creek can carry only 25 $m^3/s$. However, as it is explained before, the design peak discharge of Fabrika Creek is 90.27 $m^3/s$. Therefore, this culvert should be changed. If culverts are removed and a bridge whose dimensions are shown in Figure 5.20 is built, the capacity of Fabrika Creek will be increased to 180 $m^3/s$. The drastic increase in capacity results from the alteration of flow conditions from pressurized culvert flow to free-surface bridge flow (Yanmaz, 2002). The simulated form of bridge at Section 6 on Fabrika Creek is shown in Figure 5.21. This value is specifically chosen to solve the flooding problem of the region. Details of which will be given in the next chapter. Figure 5.22 shows inundation map of Fabrika Creek with respect to 180 $m^3/s$.

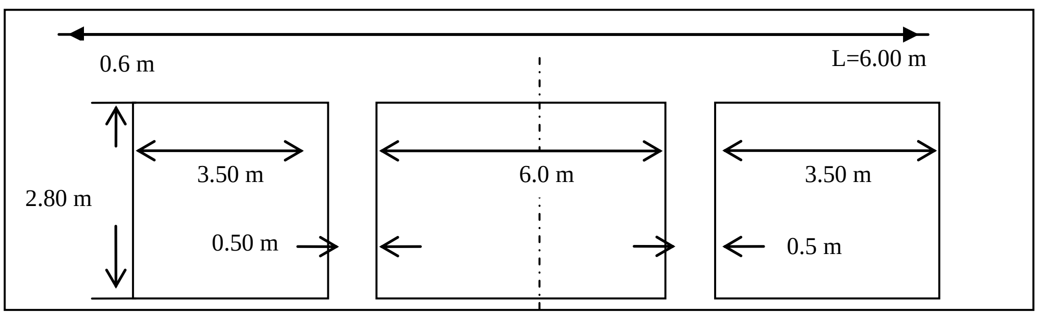


Figure 5.20 Dimensions of the proposed bridge at Section 6 on Fabrika Creek

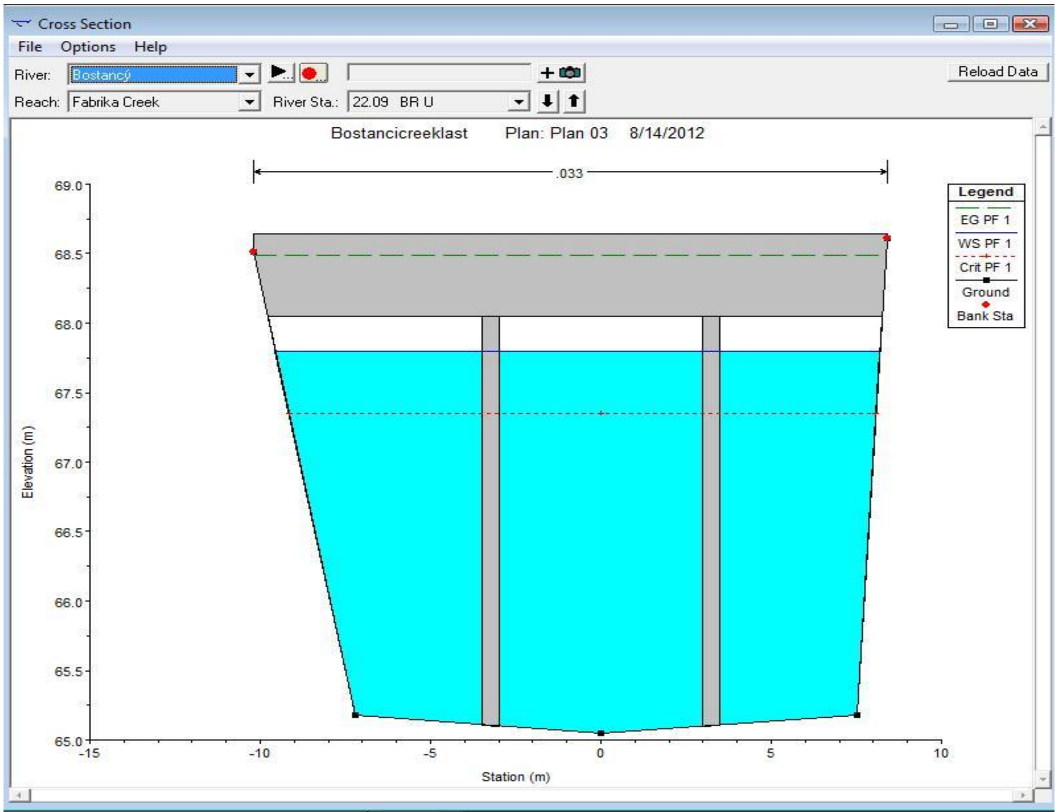


Figure 5.21 Simulated form of bridge at Section 6 on Fabrika Creek

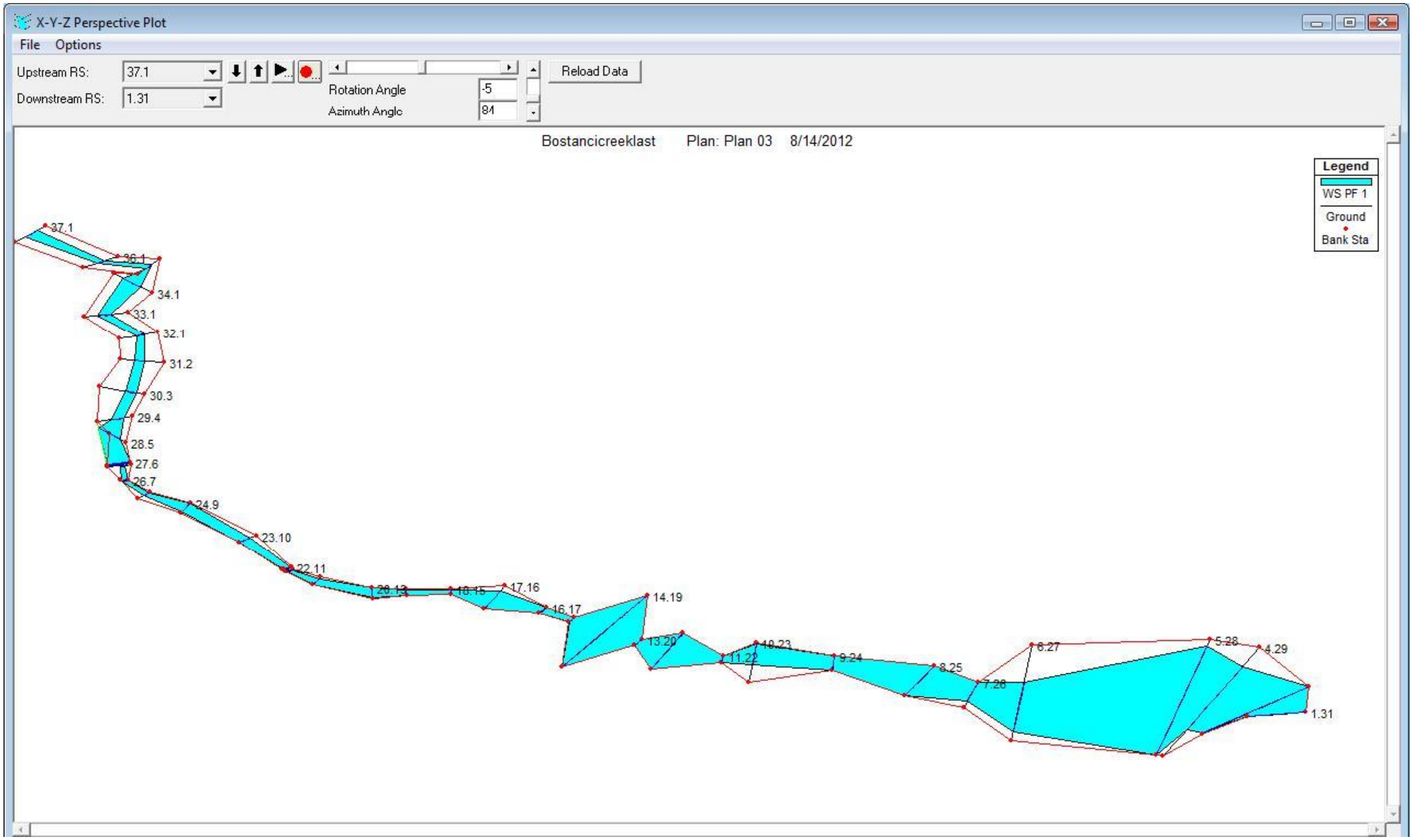


Figure 5.22 Inundation map of Fabrika Creek with respect to 180 m$^3$/s discharge

## 5.4 Scour Calculation

One of the challenges in design of river bridges is sizing the footing details, because flow can remove large amount of material around footing. As a result of removal of footing material, level of bridge safety decreases rapidly. A large scour hole may develop around the bridge piers and abutments and bridge may collapse. Hydraulic details of flow through bridges can be found in Yanmaz (2002). This part of the study is focused on the design and the application of armoring type scour countermeasures.

### 5.4.1 Governing Scouring Parameters

In this study, the HEC-18 procedure is used for determining the maximum scour depth at bridge piers. According to this procedure, the standard scour prediction equation of Colorado State University (CSU) is used. This equation is shown below (Richardson et al., 2001):

$$\frac{d_s}{b} = 2K_1K_2K_3K_4\left(\frac{y_1}{b}\right)^{0.35} F_r^{0.43} \qquad (5.1)$$

where, $d_s$ is the depth of maximum scour which normally occurs at the upstream face of the pier, b is the pier size which is perpendicular to the approach flow direction, $y_1$ is the flow depth just upstream of pier, $K_1$ is the correction factor for pier nose shape, $K_2$ is the correction factor for flow angle of attack, $K_3$ is the bed condition correction factor, $K_4$ is the correction factor for bed armoring, which can be characterized according to the value of $D_{95}$ grain size for which 95% of grains are finer than that size.

Eight soil samples are taken around bridge piers. These samples are analyzed in Soil Mechanics Laboratory of the METU Northern Cyprus Campus for obtaining gradation curves, which are used for calculating maximum scour depths at bridges. After plotting gradation curves, the median sediment size ($D_{50}$) and size of grain for 95% finer ($D_{95}$) are obtained. Figure 5.23 shows gradation curves of bridges on Bostancı Creek. Maximum scour depths ($d_s$) are obtained by using HEC-RAS software. The scoured bed profile at

Sections 3, 5, 7, 8, 10, 11, and 29 are designated by dotted curves as can be seen from Figure 5.24 to Figure 5.30. The values of median sediment size ($D_{50}$), size of grain for 95% finer ($D_{95}$), and the maximum scour depth ($d_s$) of bridges are shown in Table 5.4. A quite big scour depth is obtained i.e. 2.38 m at Section 11 because of severe hydraulic conditions.

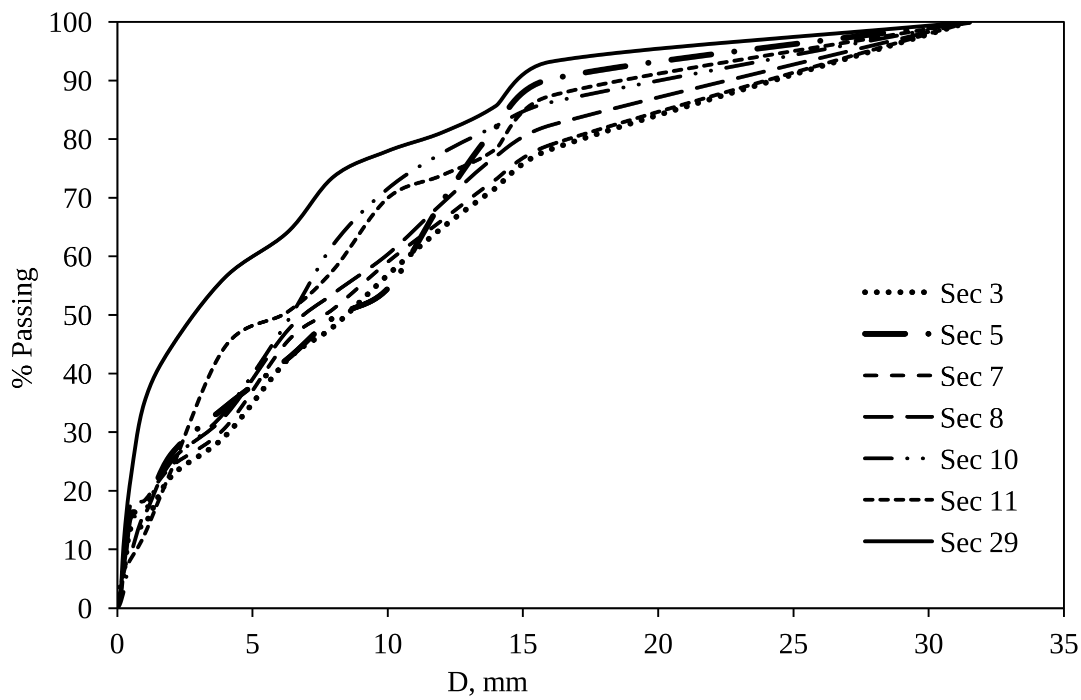


Figure 5.23 Gradation curves of bridges on Bostancı Creek

Table 5.4 Maximum scour depths ($d_s$) of bridge

| Bridges Sections | $D_{50}$ (mm) | $D_{95}$ (mm) | $d_s$ (m) |
|---|---|---|---|
| 3 | 8.5 | 28.2 | 0.83 |
| 5 | 8.2 | 28.0 | 0.90 |
| 7 | 7.8 | 28.0 | 0.90 |
| 8 | 7.0 | 27.6 | 0.95 |
| 10 | 6.3 | 26.0 | 0.95 |
| 11 | 6.0 | 25.8 | 2.38 |
| 29 | 2.8 | 20.4 | 0.42 |

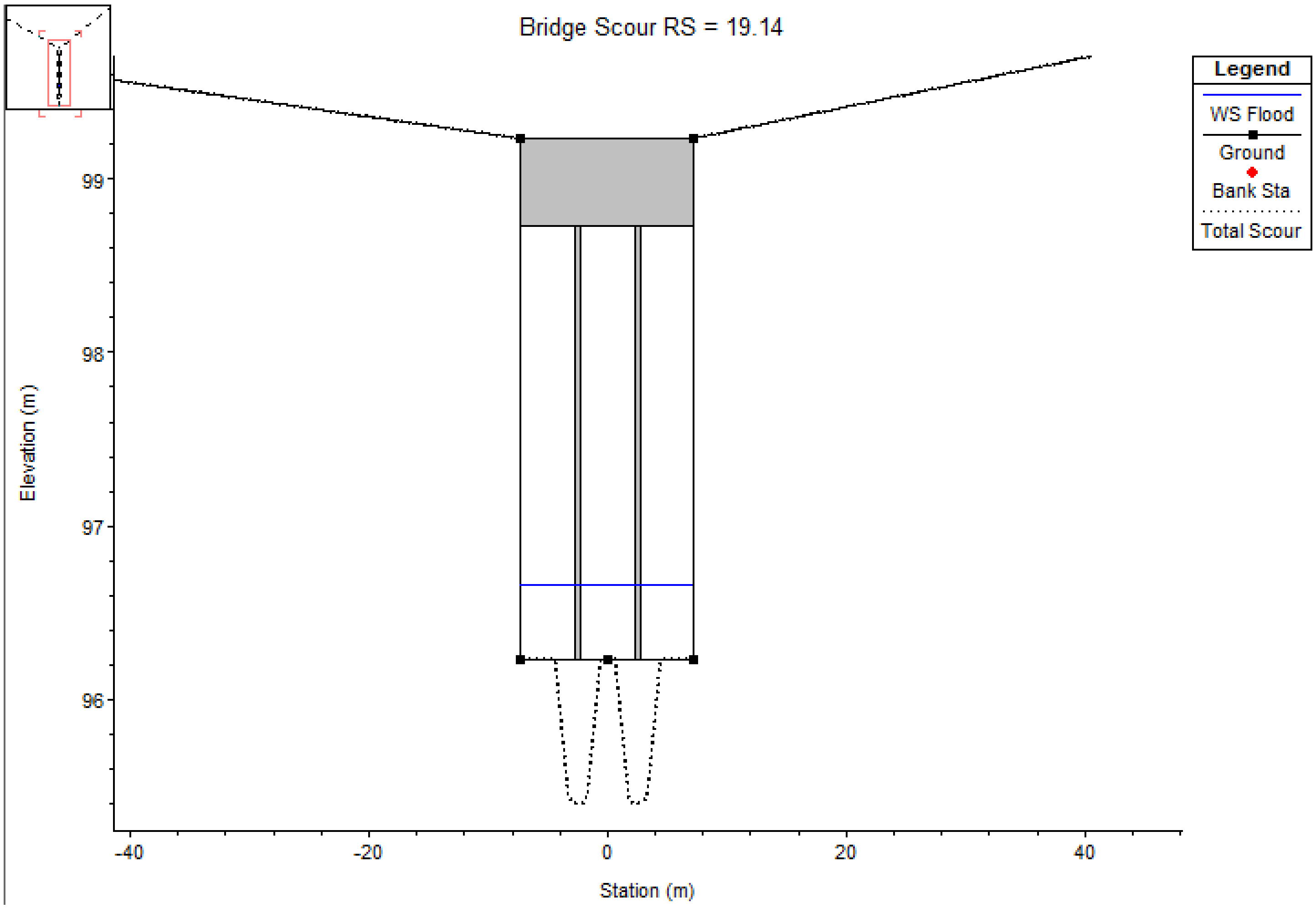


Figure 5.24 Scouring at bridge of Section 3 on Bostancı Creek in cross-sectional view

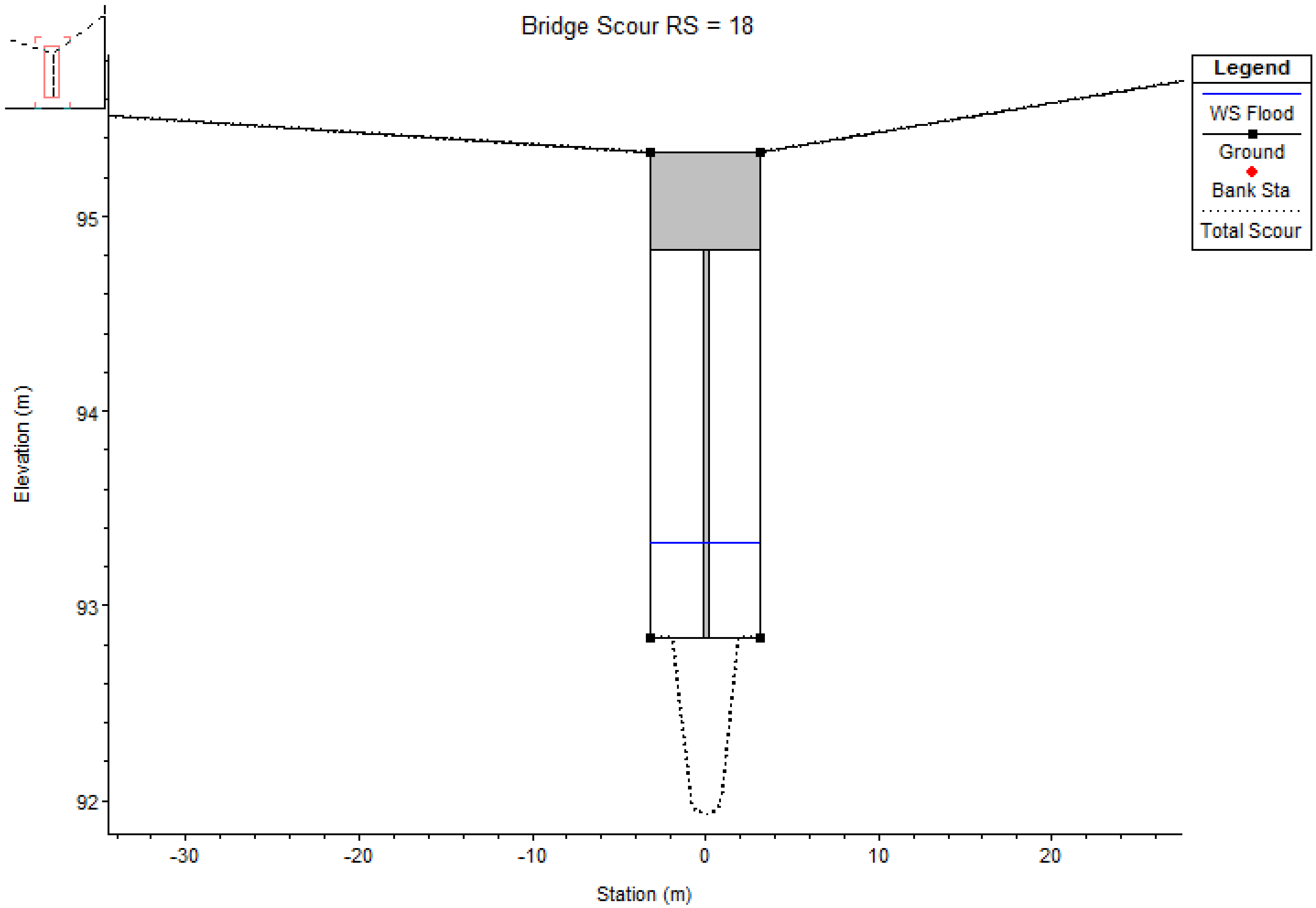


Figure 5.25 Scouring at bridge of Section 5 on Bostancı Creek in cross-sectional view

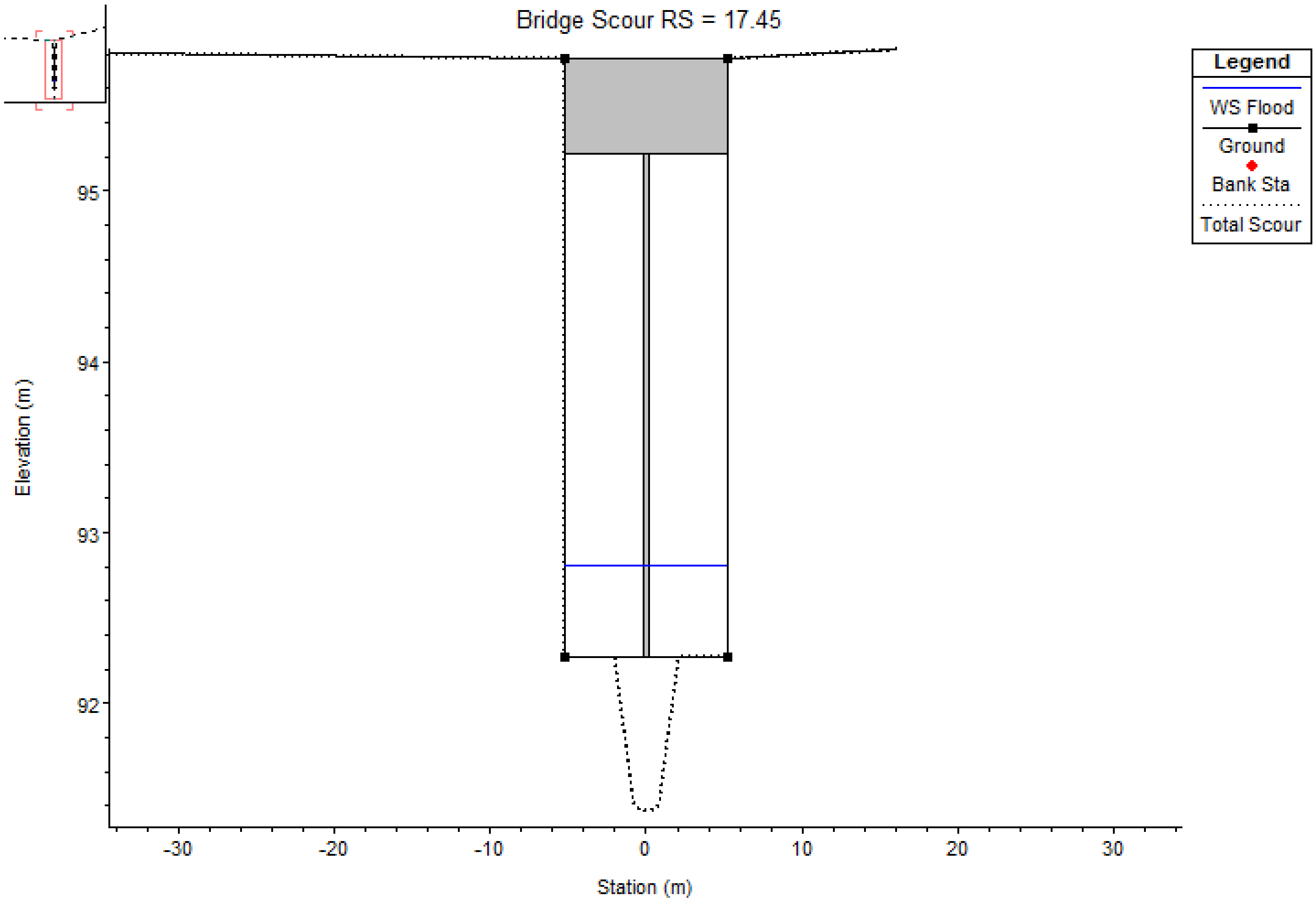


Figure 5.26 Scouring at bridge of Section 7 on Bostancı Creek in cross-sectional view

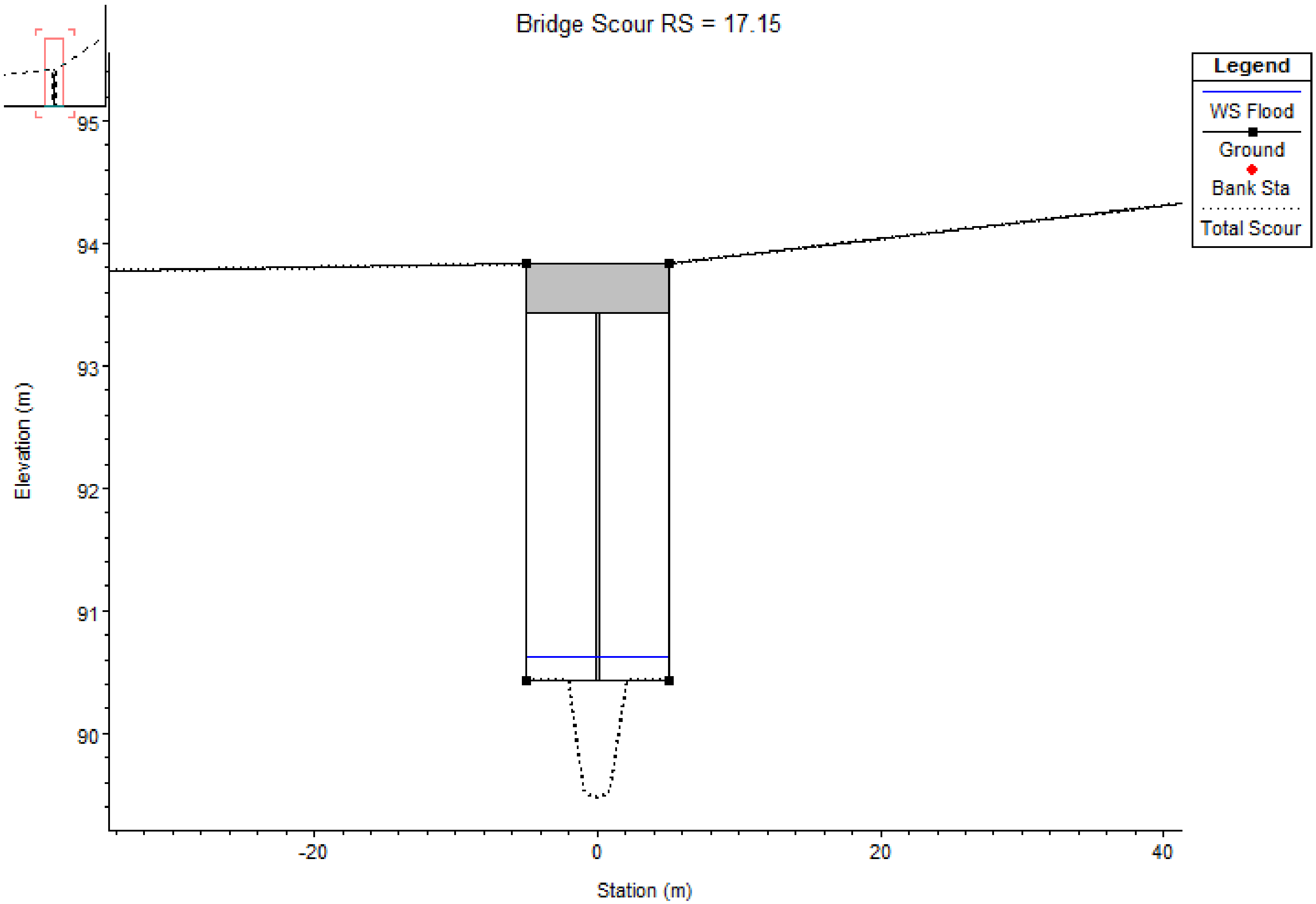


Figure 5.27 Scouring at bridge of Section 8 on Bostancı Creek in cross-sectional view

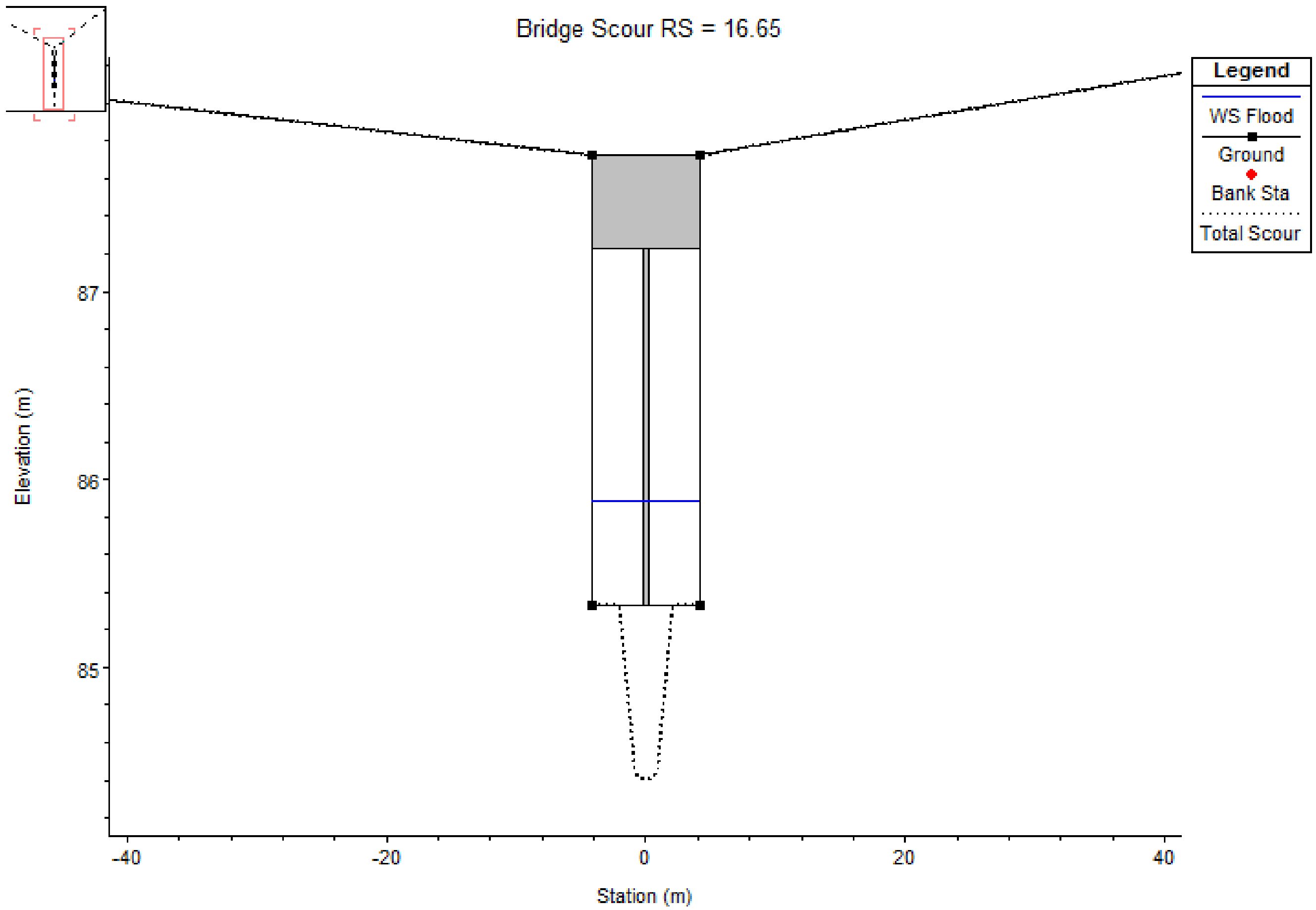


Figure 5.28 Scouring at bridge of Section 10 on Bostancı Creek in cross-sectional view

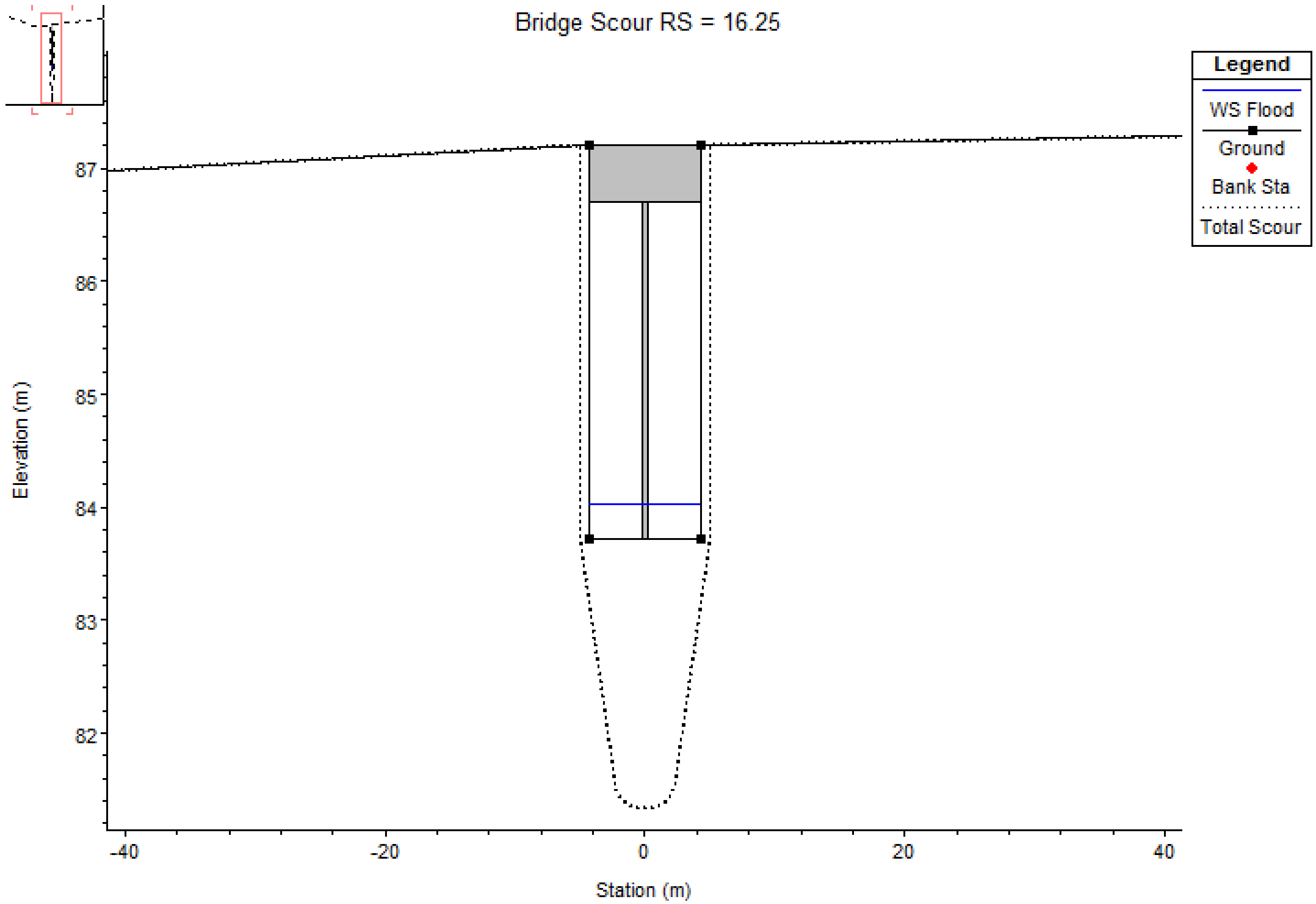


Figure 5.29 Scouring at bridge of Section 11 on Bostancı Creek in cross-sectional view

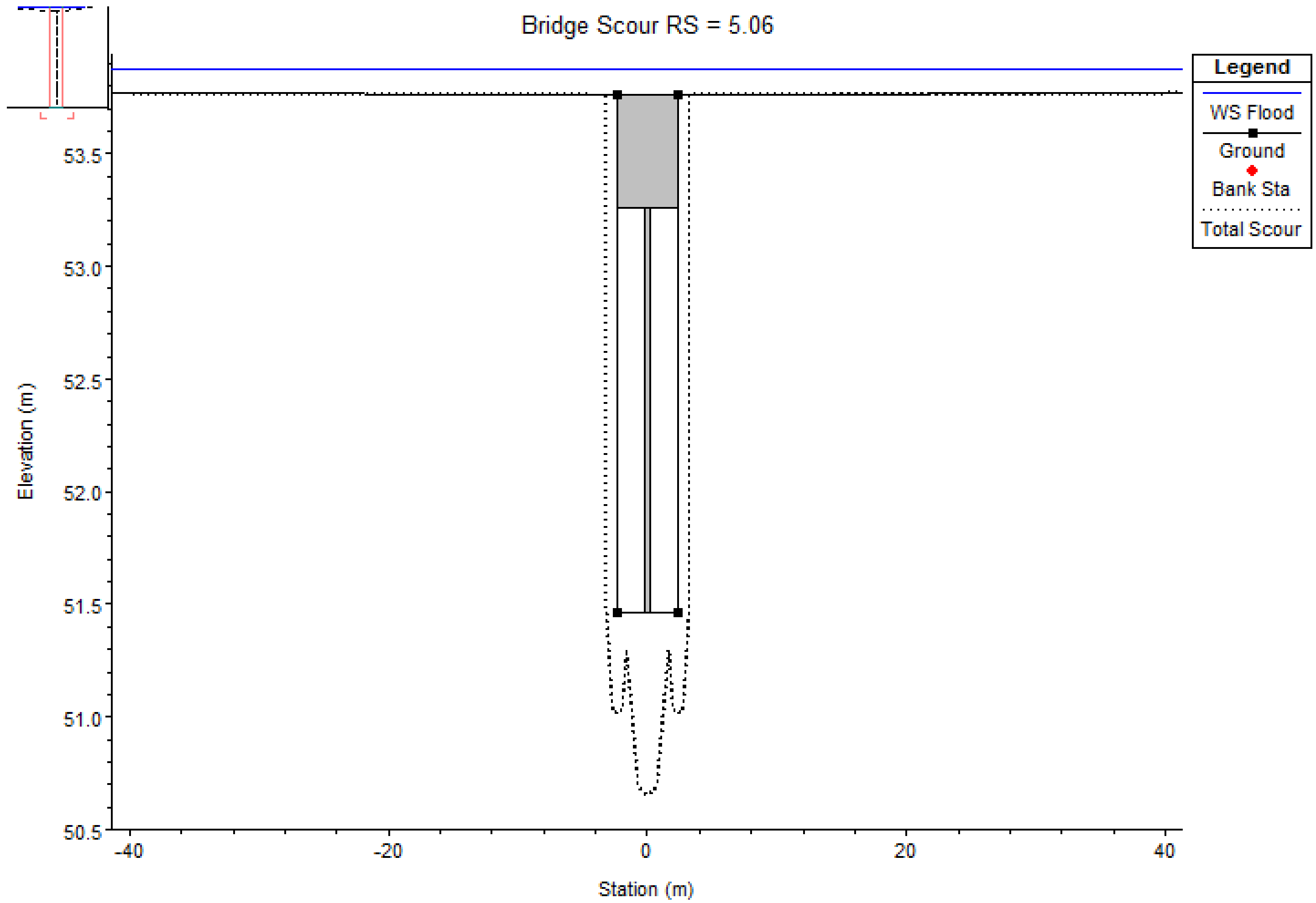


Figure 5.30 Scouring at bridge of Section 29 on Bostancı Creek in cross-sectional view

### 5.5 Riprap Protection at Bridge Piers

Among various types of protective measures with respect to excessive scouring around bridge piers, riprap is the most commonly applied material throughout the world because of ease in installation and economy (Yanmaz, 2002). The median stone diameter $D_{r50}$ needs to be determined for the design of rock riprap to be placed around the pier. In this study, Isbach equation is used for determining the riprap size. This equation is commonly used in American practice and is shown below (Lagasse et al., 2001);

$$D_{r50} = 0.692\frac{(K_p u)^2}{2g(S_s - 1)} \tag{5.2}$$

where u is the mean velocity under design conditions in m/s; $S_s$ is the specific gravity of riprap and it is commonly taken as 2.65, $K_p$ is the shape of the pier which is taken as 1.5 and 1.7 for round-nosed shaped pier and rectangular shaped pier, respectively. The maximum of all local velocities at the upstream face of piers is accepted to be design velocity ($U_{des}$). According to HEC-23 criterion (USACE, 2010), the maximum riprap size should not be greater than the value of $2D_{r50}$. Riprap should be placed carefully such that a good interlocking among the grains is satisfied. A typical detail of riprap placement can be seen in Figure 5.31.

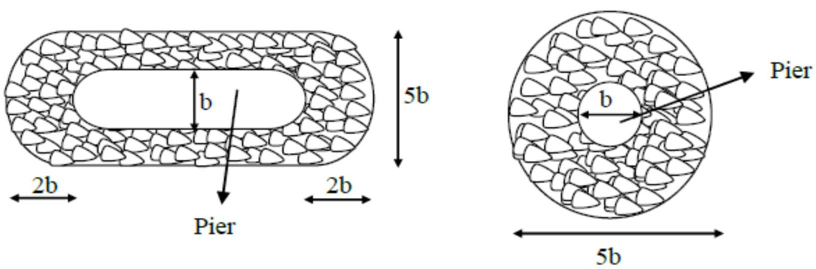


Figure 5.31 Typical placement details of riprap (Yanmaz, 2002)

Also filter placement details and thickness of riprap are significant for bridge piers. The thickness of riprap can be between $3D_{r50}$ and $5D_{r50}$ according to the severity of hydraulic conditions (Lagasse et al., 2007). A typical riprap placement around bridge pier can be seen in Figure 5.32. Table 5.5 shows the size of riprap in which $D_{r50}$ is the median stone diameter, $U_{des}$ is the design velocity, and $t_c$ is the thickness of riprap layer. The flow conditions at Section 29 are relatively tranquil, therefore no bed protection is required for that bridge.

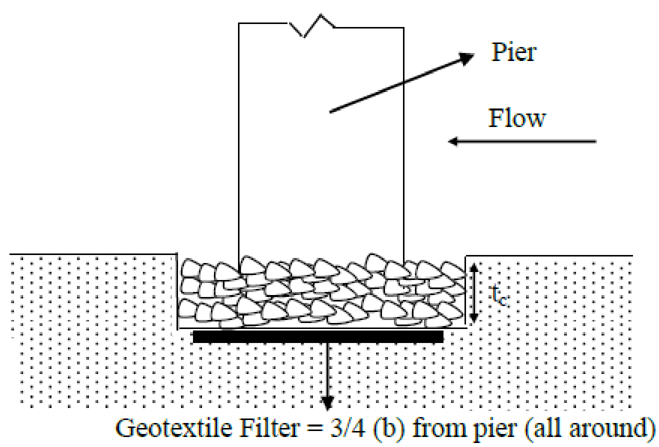


Figure 5.32 Dimensions and placement of riprap and filter (Yanmaz, 2002)

Table 5.5 Calculated riprap size

| **Section Name** | **U (m/s)** | **K** | **$U_{des}$ (m/s)** | **$D_{r50}$ (m)** | **$t_c=3*D_{r50}$ (m)** |
|---|---|---|---|---|---|
| **3** | 1.19 | 1.5 | 1.785 | 0.07 | 0.20 |
| **5** | 3.21 | 1.7 | 5.457 | 0.64 x | 1.91 x |
| **7** | 1.37 | 1.7 | 2.329 | 0.12 | 0.35 |
| **8** | 4.79 | 1.7 | 8.143 | 1.42 x | 4.25 x |
| **10** | 4.79 | 1.7 | 8.143 | 1.42 x | 4.25 x |
| **11** | 3.76 | 1.7 | 6.392 | 0.87 x | 2.62 x |

In Cyprus, it could be difficult to find big sized rock in Güzelyurt region. The sections requiring big riprap size and hence big placement thickness are marked with "x" in Table 5.5. Therefore, partially grouted riprap could be used around the piers of the bridges at sections 5, 8, 10, and 11. Partially grouted riprap has many advantages. First, it is used for increasing the stability of riprap by using cement slurry. Furthermore, it is appropriate for places that riprap size is too big or not available around the project site. Partially grouted riprap placement is similar to rock riprap. For partially grouted riprap application, Class 2 gradation according to Lagasse et al. (2007) classification can be used. Therefore, $D_{r50}$ value can be taken between 0.22 m and 0.27 m. Similar to riprap application, the thickness of the partially grouted riprap layer can be taken as $3D_{r50}$. Gradation details for riprap classes can be found in Lagasse et al. (2007). According to the design procedure, cement slurry is injected between stones matrix layer by layer. Recommended mix proportion by Lagasse et al. (2007) can be seen in Table 5.6. An example for partially grouted riprap placement is shown in Figure 5.33.

Table 5.6 Mixture for 0.765 m³ of Grout (Lagasse et al., 2007)

| Material | Quantity by Weight |
|---|---|
| Ordinary Portland Cement | 336 to 345 kg |
| Fine concrete aggregate (sand), dry | 535 to 545 kg |
| 1/4" crusher chips (very fine gravel), dry | 536 to 545 kg |
| Water | 190 to 205 kg |
| Air entrained | 5% to7 % |
| Anti-washout additive<br>(used only for placement under water) | 2.7 to 3.7 kg |

Figure 5.33 Placement of partially grouted riprap (Lagasse et al., 2007)

The detail of placement of partially grouted riprap is shown in Figure 5.34. The thickness of partially grouted riprap should be between $2D_{r50}$ to $4D_{r50.}$ Moreover, geotextile filter installation procedure is the same as the procedure which is used in rock riprap. It is depicted in Figure 5.35. The dimension of the geotextile filter is 3/4 of the projected width of the protection area.

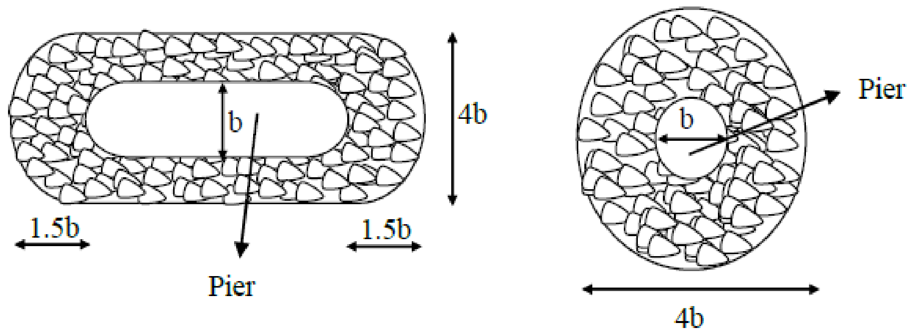


Figure 5.34 Design details of partially grouted riprap (Lagasse et al., 2007)

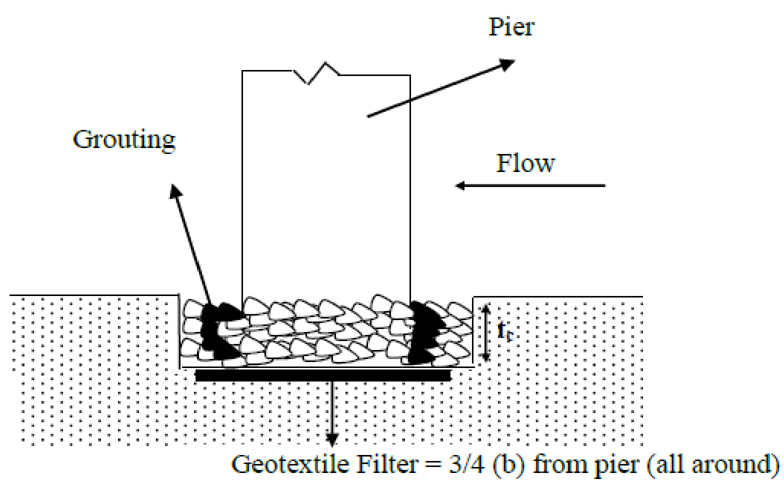


Figure 5.35 Details of geotextile filter placement (Lagasse et al., 2007)

# CHAPTER VI

# REMEDIAL MEASURES

In this chapter, two remedial measures are proposed for flood protection in proximity to Güzelyurt-Bostancı region. These measures are mainly categorized as

- storing a considerable flood volume at the upstream portions of these settlements by means of flood detention basin on Bostancı Creek and diverting a certain fraction of flows of Bostancı Creek to the neighboring Fabrika Creek by means of a diversion channel
- diverting a certain portion of flows of Bostancı Creek to the Güzelyurt Dam from a detention basin constructed on Bostancı Creek.

These measures are described in detail in the subsequent sections together with the corresponding analyses and their results in a comparative manner. For decision-making, cost analyses are aşso performed for these alternatives.

## 6.1 Alternative 1

As stated before, January 2010 flood caused significant damage to all types of properties in and around Güzelyurt and Bostancı regions. Construction of a flood detention basin at a suitable location is considered an effective measure as it can accommodate considerable flood volume behind its reservoir. Hence reduced flow rates can safely be transmitted to the downstream reaches. A detention basin is normally composed of a small embankment having an uncontrolled bottom outlet (See Figure 6.1). A riser pipe is connected to the bottom outlet in order to facilitate formation of a dead volume, $V_0$, in the reservoir. In

Figure 6.1, $V_s$ is the flood storage volume above the dead volume, K is the entrance elevation of the riser pipe which can be determined according to the sediment transport regime of the river concerned, $h_m$ is the maximum reservoir elevation, $h_s$ is the spillway crest elevation, $h_c$ is the embankment crest elevation, and D is the diameter of the bottom outlet.

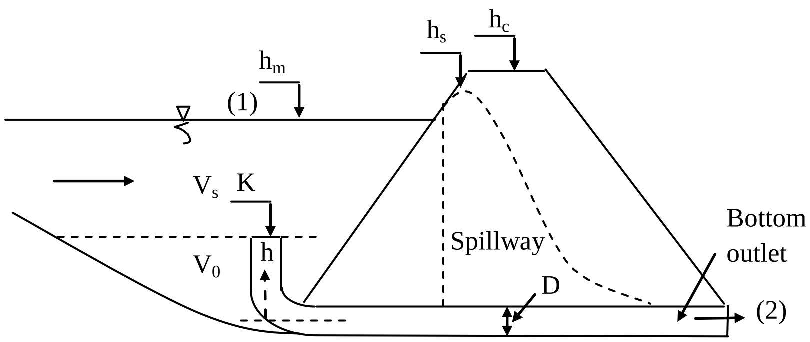


Figure 6.1 A typical flood detention basin (Yanmaz, 2006)

During low flows, river flow takes place through the bottom outlet without storing water in the reservoir. During high flows, as the capacity of the bottom outlet is limited, a considerable volume of flood is stored in the reservoir and only small discharges are evacuated to the downstream. To limit the height of the embankment and increase the safety against overtopping possibility of the body, an overflow spillway can also be supplemented (Yanmaz, 2006). Design of a detention basin is based on determination of the maximum reservoir elevation, $h_m$, under the passage of design flood. The crest elevation of detention basin, $h_c$, is then obtained by adding a proper freeboard to the maximum stage in the reservoir. In this study, a reservoir routing procedure dealing with a numerical solution is used. Temporal variation of reservoir surface elevation, h, measured from the axis of the bottom outlet as shown in Figure 6.1 is determined from the following routing equation (Yanmaz, 2006):

$$\frac{dh}{dt} = f(h,\mathrm{t}) = \frac{I(t) - Q(h)}{A(h)} \tag{6.1}$$

where t is time, I(t) is the inflow, Q(h) is the outflow, and A(h) is the area-elevation relationship of the reservoir. When I(t), Q(h), and A(h) are expressed mathematically, the temporal variation of h can be obtained in iterative manner using a numerical solution, such as Euler or Runge-Kutta solutions (Yanmaz, 2006).

This study is initiated by searching a suitable location for such a reservoir. The limitations associated with this problem are that a suitable topographic site should be found such that it has adequate storage ability as well as the extension of the reservoir area is kept within the borders of the Turkish Republic of Northern Cyprus. Adequacy of the storage volume of the reservoir can only be judged if the storage-elevation information is available, which is obtained by integrating the area-elevation relationship. To this end, detailed topographic investigations are conducted at the site using the GNSS device. Based on site investigations, two choices are found to be suitable for the reservoir location. The first choice is on the Bostancı Creek, whereas the second choice is on the Fabrika Creek. The contour lines need to be obtained so that the area-elevation relationship can be obtained by computing the areas enclosed by these contour lines. Elevations of the terrain are measured at the field and contours are plotted using the AutoCAD Civil 3D software. AutoCAD Civil 3D software is used for building information modeling for civil engineering design and documentation. AutoCAD Civil 3D includes geographic information system which runs on AutoCAD (Manual of AutoCAD, 2011). Figure 6.2 and Figure 6.4 show starting and end points of the surveyed area of Bostancı Creek and Fabrika Creek. The contours of areas around Bostancı Creek and Fabrika Creek can be seen in Figure 6.3 and Figure 6.5, respectively. These contour maps are drawn with 1 m interval up to the expected top level of the proposed reservoir.

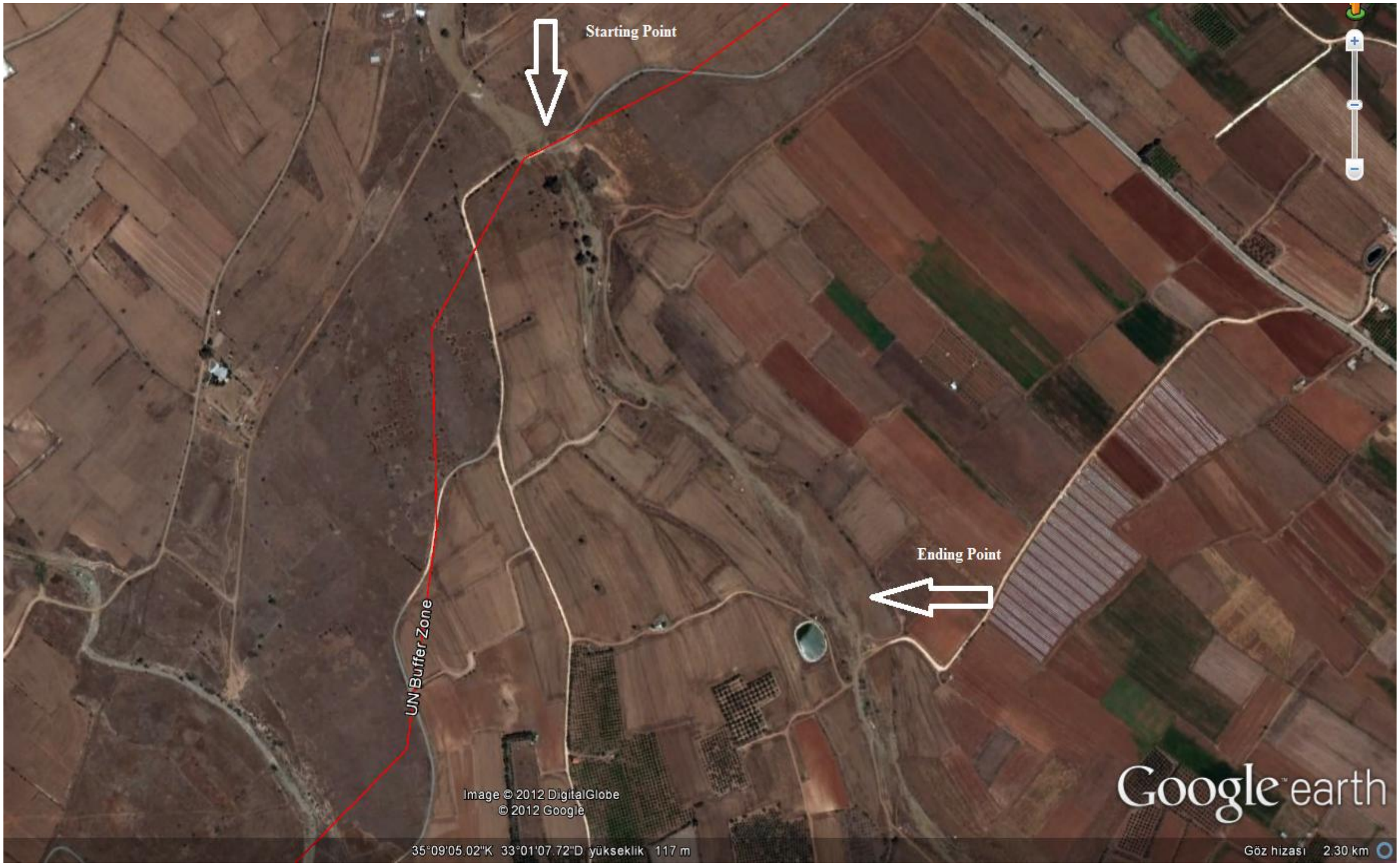


Figure 6.2 Initial and final point of surveyed area for reservoir of Bostancı Creek (Google Earth, 2011)

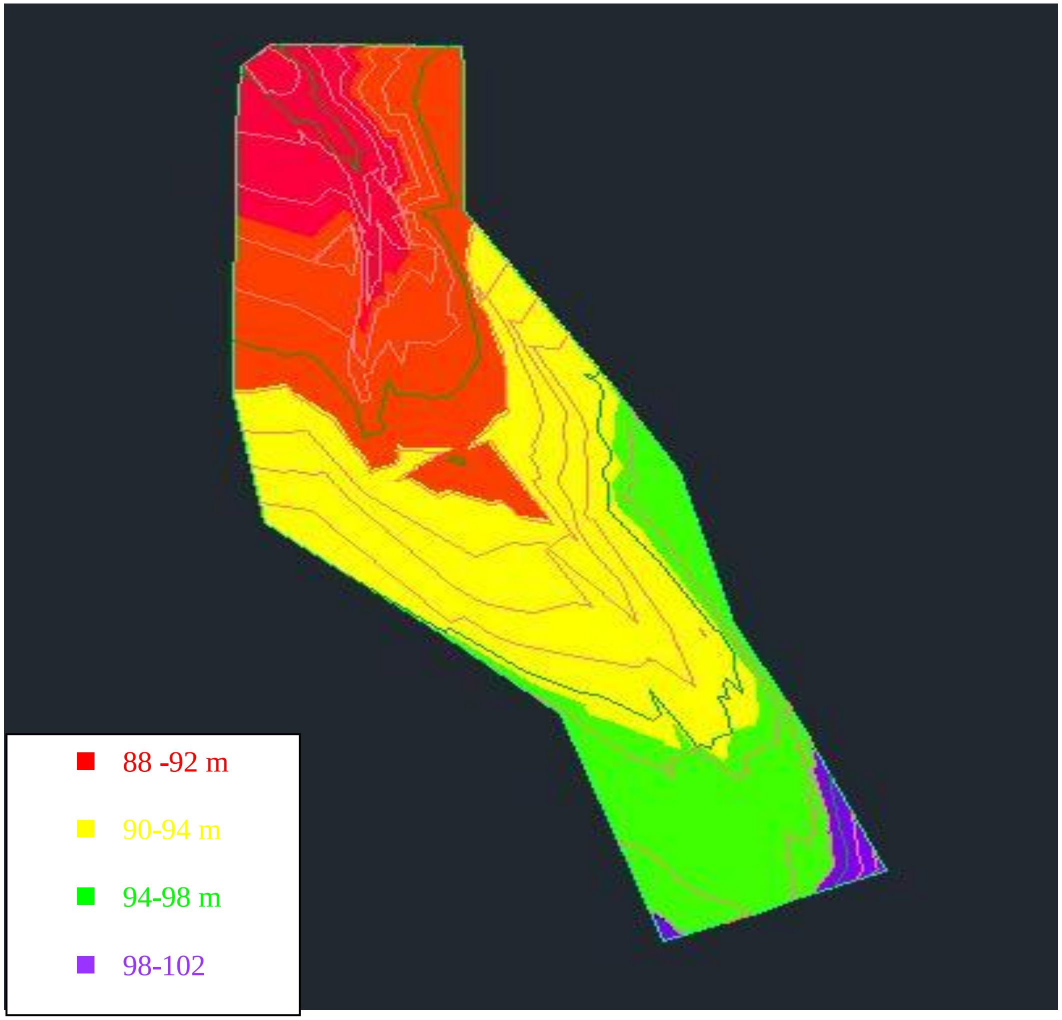


Figure 6.3 Contours of the area around Bostancı Creek in m


Figure 6.4 Start and end points of surveyed area for reservoir of Fabrika Creek (Google Earth, 2011)

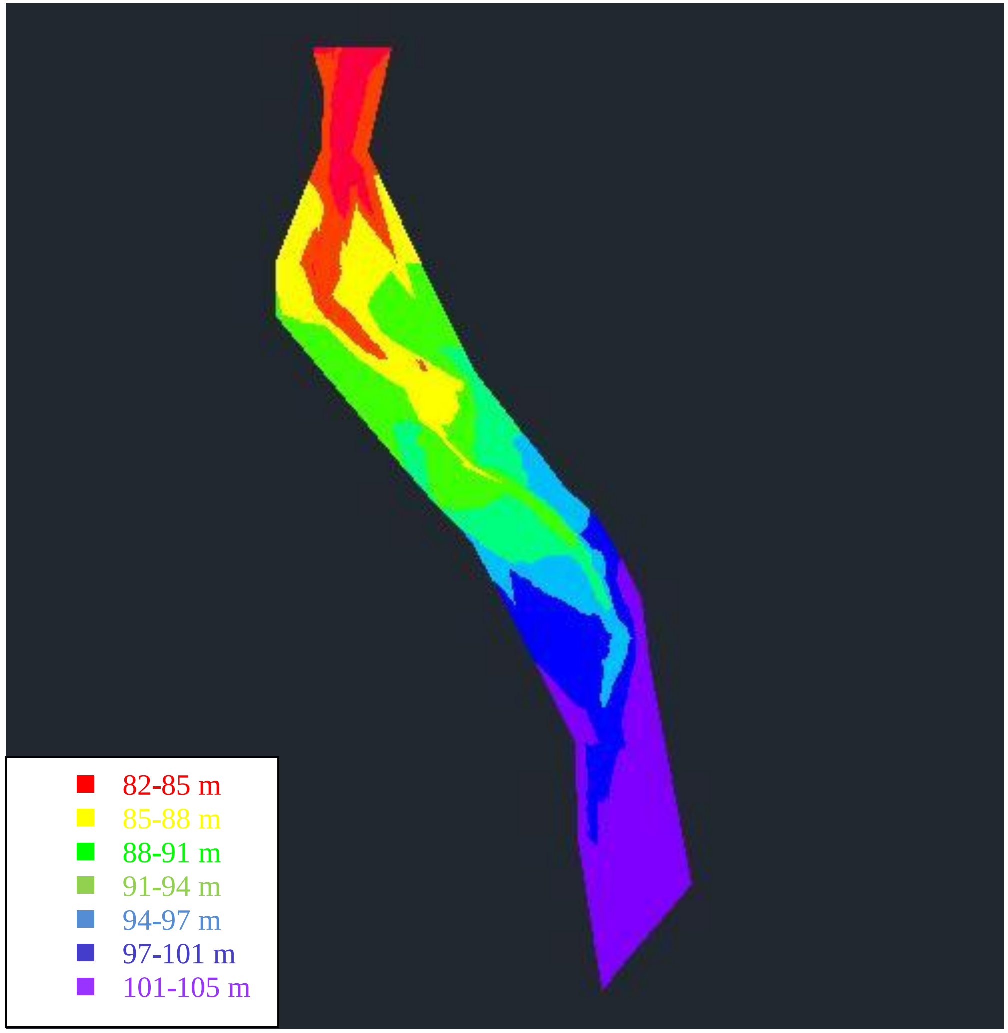


Figure 6.5 Contours of the area around Fabrika Creek in m

The areas between the contour lines are calculated using AutoCAD. The area-elevation curves are then obtained for both creeks starting from the minimum contour elevation (deepest level in the reservoir) to the maximum contour elevation (highest water level). After drawing these curves (Figures 6.6 and 6.7), the following polynomial trend lines are assigned for Bostancı Creek and Fabrika Creek sites, respectively:

$$A\ (h) = 9.2257h^4 - 100.92h^3 + 856.29h^2 - 20.904h \qquad R^2 = 0.9978 \tag{6.2}$$

$$A\ (h) = 5.1753h^3 + 308.66h^2 - 634.67h \qquad R^2 = 0.9985 \tag{6.3}$$

The total area of the possible location of reservoir along Bostancı Creek basin is equal to 156497 $m^2$, whereas this area is equal to 116174 $m^2$ along Fabrika Creek basin.

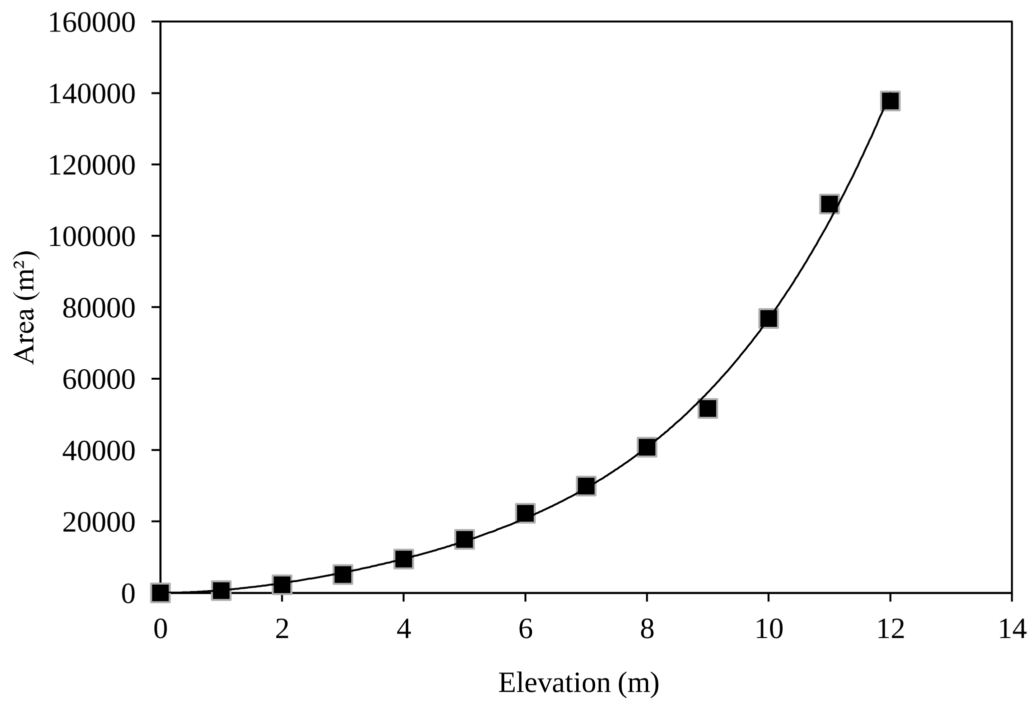


Figure 6.6 The area-elevation curve for Bostancı Creek

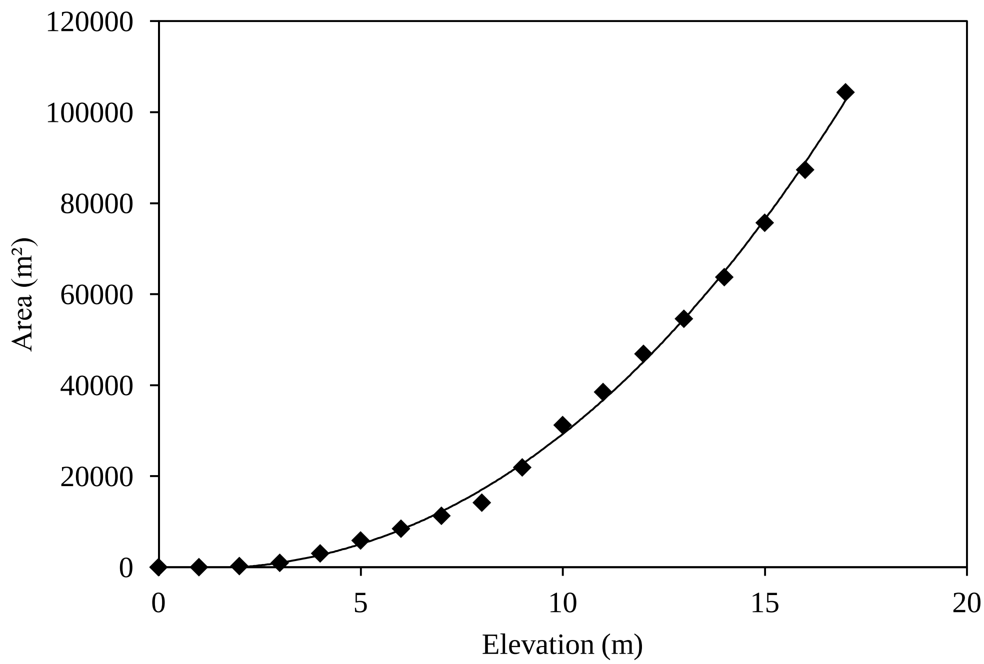


Figure 6.7 The area-elevation curve for Fabrika Creek

In this study a one-meter diameter bottom outlet and riser pipe is considered with the riser entrance height of 2 m. This is a preliminary approach. More realistically, the sediment transport regimes of these creeks need to be determined and a suitable value should be assigned to K-value. The length of the bottom outlet is approximately 55 m. The energy equation given below is used for calculating the outflow discharge.

$$z_1 + \frac{v_1^2}{2g} + \frac{P_1}{\gamma} = z_2 + \frac{v_2^2}{2g} + \frac{P_2}{\gamma} + h_{le} + h_{lb} + h_{ex} + h_f \tag{6.4}$$

in which v is the average velocity, P/γ is pressure head, z is elevation head, $h_{le}$ is the minor loss due to entrance of bottom outlet, $h_{lb}$ is the minor loss due to bend of the bottom outlet, $h_{ex}$ is the exit loss, and $h_f$ is the friction loss. Minor losses can be expressed as a loss coefficient multiplied by the velocity head. The following loss coefficients are taken for steel pipe with reference to Munson et al. (2006) as $K_{le}$ = 0.2, $K_{lb}$ = 0.2, and $K_{lex}$ = 1.0. With the given information the friction factor is taken as f = 0.02. Frictional headloss can be computed from the Darcy-Weisbach equation. Taking the datum as the centerline of the bottom outlet and assuming negligibly small velocity at Section (1) in Figure 6.1, Equation (6.3) gives the discharge as a function of h:

$$Q(h) = 1.859\sqrt{h} \tag{6.5}$$

The inflow hydrograph recommended by Horn (1987) can be used in routing process. This hydrograph is obtained by fitting the dimensionless unit hydrograph of US Soil Conservation Service (Chow et al., 1988) in the general form of a Pearson type 3 probability density function as

$$I(t) = I_p \left( \frac{t}{t_p} \right)^{3.5} \exp\left( -3.5\left( \frac{t}{t_p} - 1 \right) \right) \tag{6.6}$$

where $I_p$ is the peak discharge and $t_p$ is the peak time. Figure 6.8 shows graph of inflows calculated from design hydrograph and Equation (6.6) for Bostancı Creek. As it can be seen clearly, inflow data from Equation (6.6) is more conservative compared to the inflow data of the design hydrograph. Therefore, this equation can be used for reservoir routing.

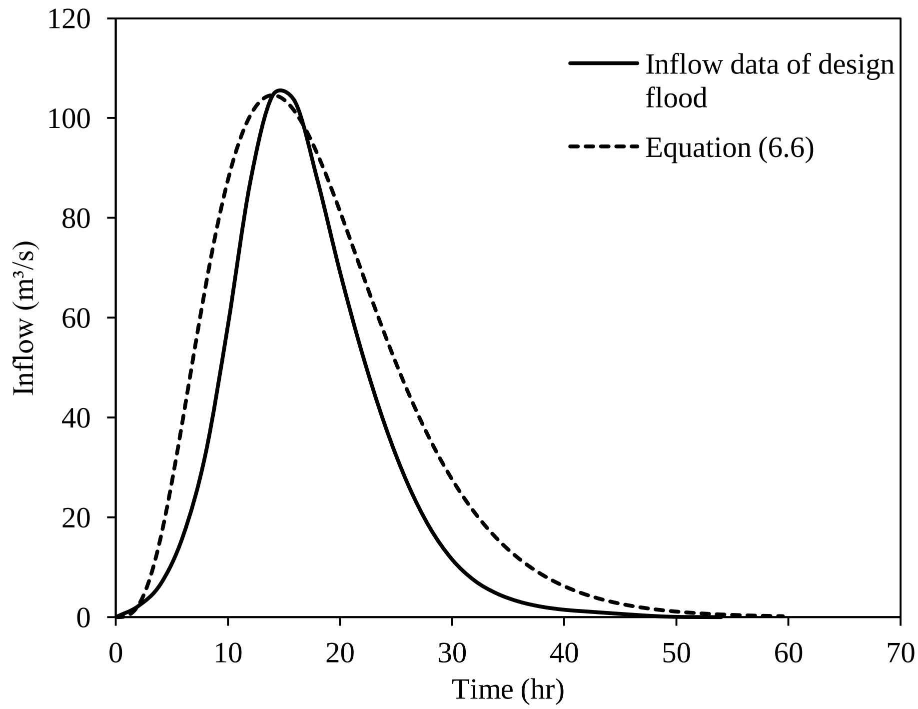


Figure 6.8 Inflow data of design flood hydrograph and inflow data from Equation (6.6)

Using the information presented in Chapter 4, the $I_p$ and $t_p$ values are taken as 104.59 $m^3/s$ and 14 hours for the Bostancı Creek and 90.26 $m^3/s$ and 14 hours for the Fabrika Creek. As explained before, the aforementioned flood for Bostancı Creek corresponds to a return period of $T_r$=300 years. Therefore, a conservative flood mitigation facility is considered in this study. Based on this data, flood routing can be performed using Euler's solution:

$$h_{n+1} \cong h_n + \Delta t * f(h, \mathrm{t}) \tag{6.7}$$

where $h_n$ and $h_{n+1}$ are the water levels in the reservoir at the beginning and end of the time interval Δt, which is taken as 5 minutes. A homogeneous embankment having a height of 9 m, a crest thickness of 3 m, and a base width of 53 m is assigned according to the guidelines presented in Yanmaz (2006). The side slopes corresponds to 1V:2.8H, where

V and H denote the vertical and horizontal values of the side inclinations. These values are reasonable for a homogeneous embankment (Yanmaz, 2006). Since the location of the inlet of the bottom outlet pipe is 2 m high from the ground level, water starts to flow when water level reaches to 2 m. With this alternative a diversion channel is proposed to divert a certain portion of flows of Bostancı Creek to Fabrika Creek. Therefore, a flood detention basin is to be built on both Bostancı Creek and Fabrika Creek. With this configuration, flow is to be diverted to Fabrika Creek where it is to be stored in the detention facility on the Fabrika Creek. In this option, no spillway is proposed for the Bostancı Detention Basin as it is desired to divert the majority of the flood waters to Fabrika Detention Basin. A trapezoidal canal whose length is approximately 600 m can be built between Fabrika Creek and Bostancı Creek (Figure 6.9).

Manning equation is used for determining the dimensions of a lined trapezoidal diversion channel. Manning's roughness coefficient is taken as 0.015. The bed elevation at the beginning of the channel is desired to be 94 m at the edge of the reservoir on Bostancı Creek, which finally joins to Fabrika Creek at an elevation of 86 m. Using these data, the slope of channel is calculated as 0.075. Side slopes of the channel are taken as 1V:2H according to the local soil characteristics. As a result, a trapezoidal channel having a bottom width of 3.5 m is found to be sufficient for this conveyance. The maximum flow depth in this channel is found to be 1.4 m from the reservoir routing computations. With sufficient freeboard, the height of the channel is taken to be 1.90 m. Flood routing computations are performed for both creeks. The minimum topographic elevations of the reservoir sites for Bostancı Creek and Fabrika Creek are 88 m and 82 m, respectively. As can be seen from the results of the routing computations (Table A.1 in Appendix), when water level reaches 94 m elevation at Bostancı Creek reservoir, water starts to flow from Bostancı Creek Detention basin to Fabrika Creek by means of the diversion channel. The operation period of the diversion channel is between 4.25 hr after the design rainfall starts and 42.33 hr (Table A.3 in Appendix). Therefore, inflow to Bostancı Creek basin decreases as a result of operation of the diversion channel during this period.

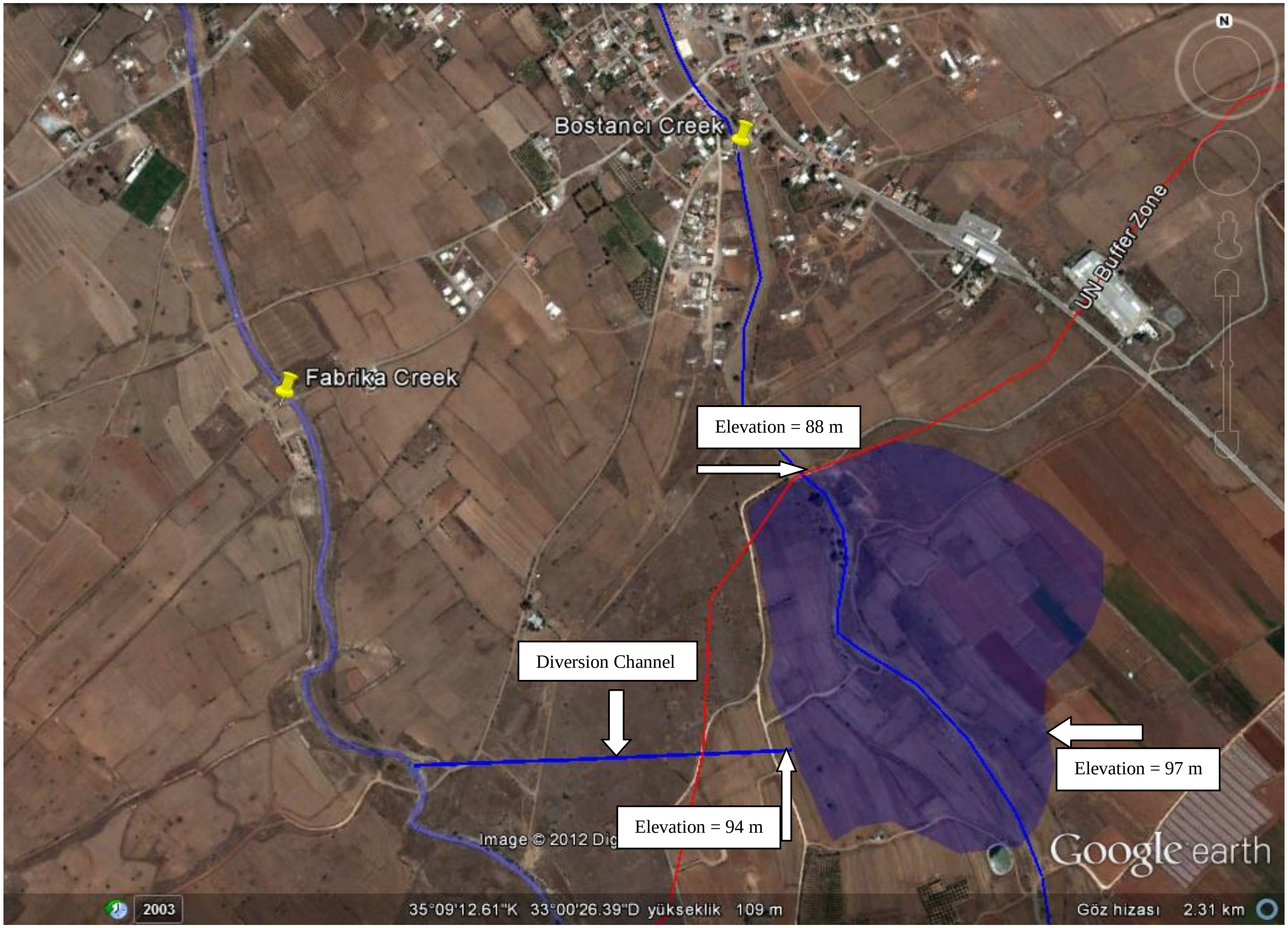


Figure 6.9 Locations of Fabrika Creek, Bostancı Creek and diversion channel (Google Earth, 2011)

After flood routing calculations of Fabrika Creek (Table A.2 in Appendix), stage hydrograph and inflow-outflow hydrographs of Fabrika Creek are generated as shown in Figures 6.10 and 6.11, respectively. The maximum water depth in the Fabrika Creek Detention basin is 13.91 m and maximum inflow is 183.80 $m^3/s$, which includes inflow coming from Bostancı Creek Detention basin. Furthermore, 5.33 hours later, outflow increases rapidly because considerable flow is transmitted by the aforementioned diversion channel. Therefore, almost negligibly small flood accommodation is achieved by the Fabrika Creek Detention Basin. In other words, it cannot attenuate the inflow (See Figure 6.11). It is, therefore, obvious that building a flood detention basin on Fabrika Creek will be useless.

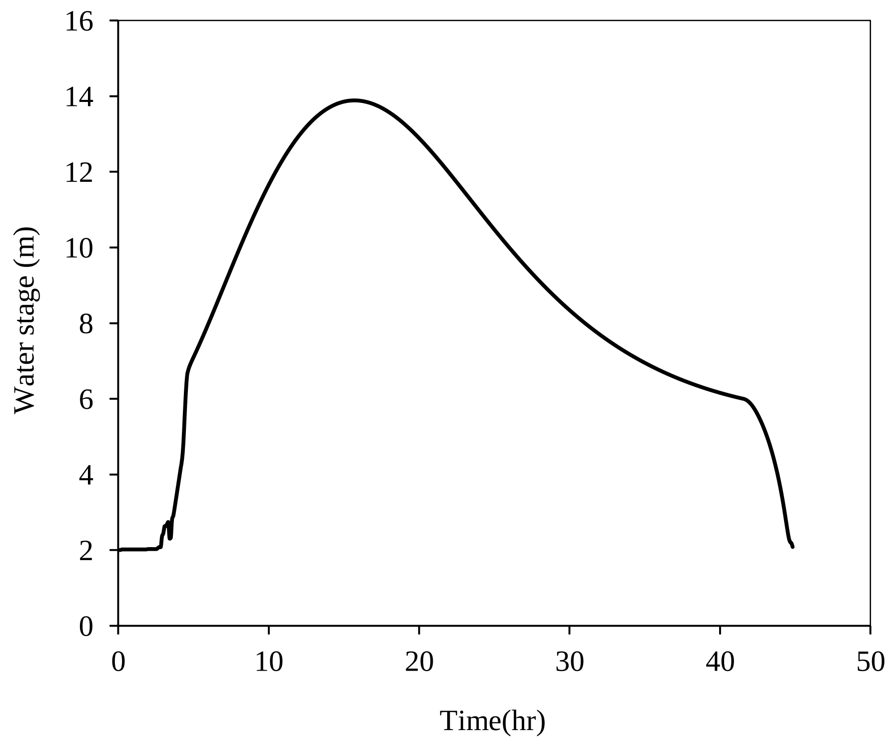


Figure 6.10 Stage hydrograph for the detention basin on Fabrika Creek

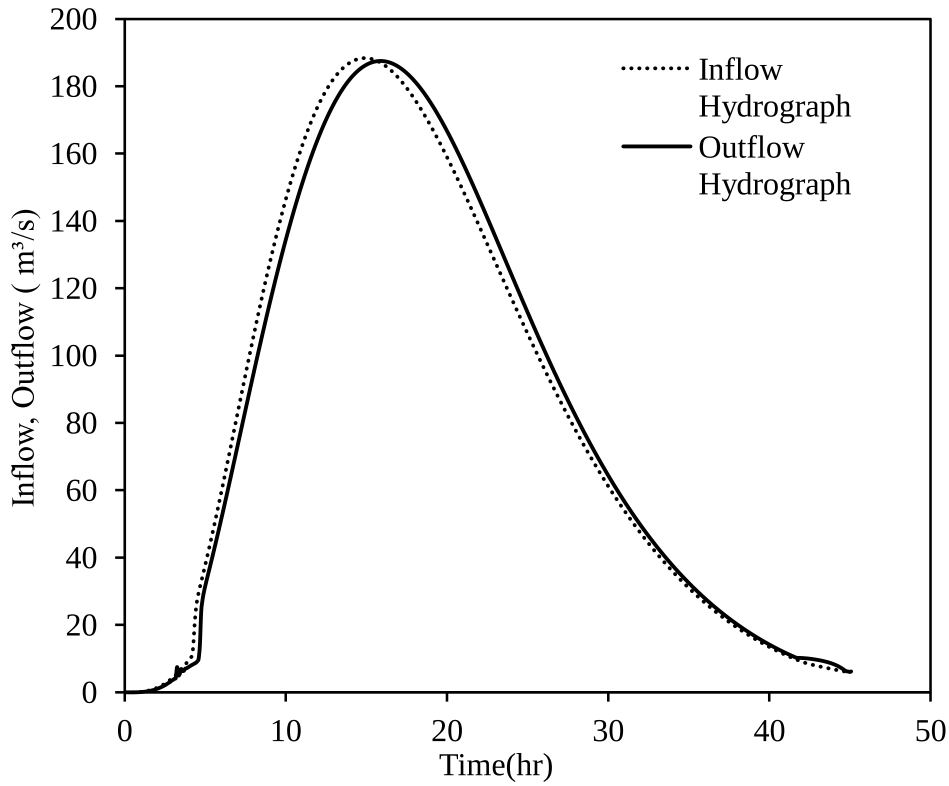


Figure 6.11 Inflow and outflow hydrograph for the detention basin on Fabrika Creek

Based on the flood routing calculations of Bostancı Creek Detention Basin, the maximum depth of water is 7.4 m and it reaches this value at 13.08 hours. It is important to know that inflows decrease rapidly because of diversion to Fabrika Creek at 4.25 hours. Moreover, the maximum outflow is obtained as 5 $m^3/s$ for Bostancı Creek and this discharge is reasonable when it is compared to capacity of this creek. Stage hydrograph and inflow-outflow hydrographs of Bostancı Creek Detention Basin are shown in Figures 6.12 and Figure 6.13, respectively. As can be seen from Figure 6.13, considerable attenuation is achieved in this basin. Therefore, it is obvious that Bostancı Creek Detention Basin can accommodate large quantities of flood volume. Hence it is recommended to built a flood detention basin on Bostancı Creek at the stated location.

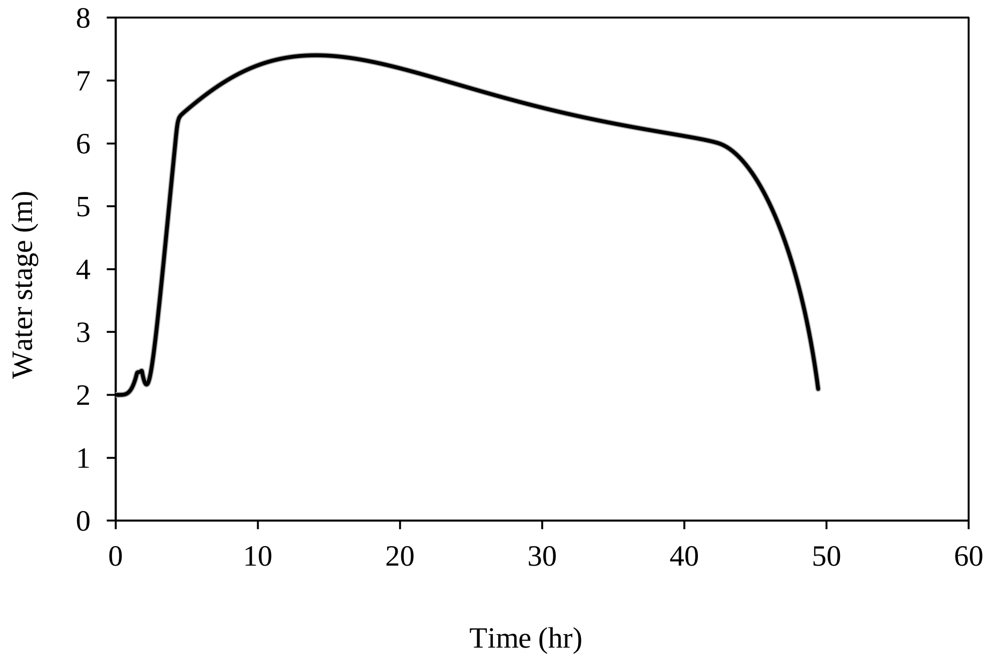


Figure 6.12 State hydrograph for the Detention Basin on Bostancı Creek

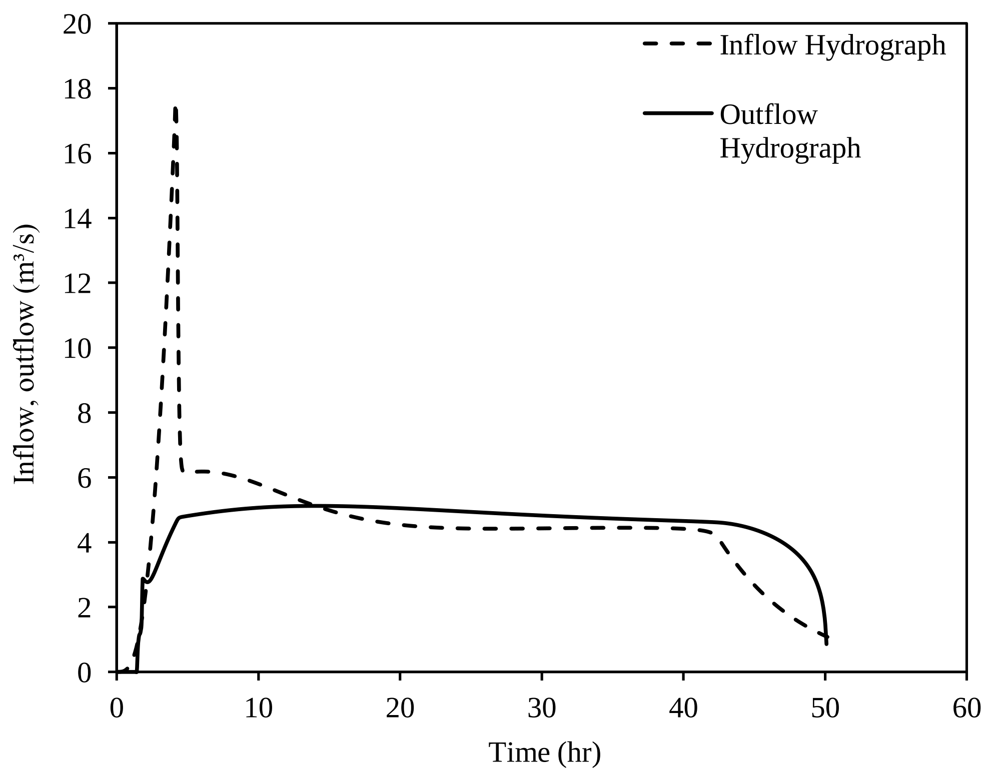


Figure 6.13 Inflow and outflow hydrograph for Bostancı Creek

It has already been calculated that the maximum discharge is 183.75 $m^3/s$ for Fabrika Creek. Based on this flow data, the flood inundation map of Fabrika Creek is drawn with the help of Google Earth (See Figure 6.14). The Fabrika Creek begins to disappear where it gets closer to Lefke-Güzelyurt diversion channel (Figure 6.15). At this point there is a large flat area having relatively pervious soil conditions that can partially absorb and retain large amount of water. It is like a natural reservoir at the end of Fabrika Creek. The upper elevation of the side of diversion channel is 45.28 m and maximum water elevation during this flood is 44.74 m at this side (Figure 6.16). The water level of the last section is shown in Figure 6.17. Regions that are under water at flood times for both Bostancı and Fabrika Creeks are drawn on Google Earth map (Figure 6.18).


Figure 6.14 Flood inundation map of Fabrika Creek for Q=183.75 $m^3/s$ (Google Earth, 2011)

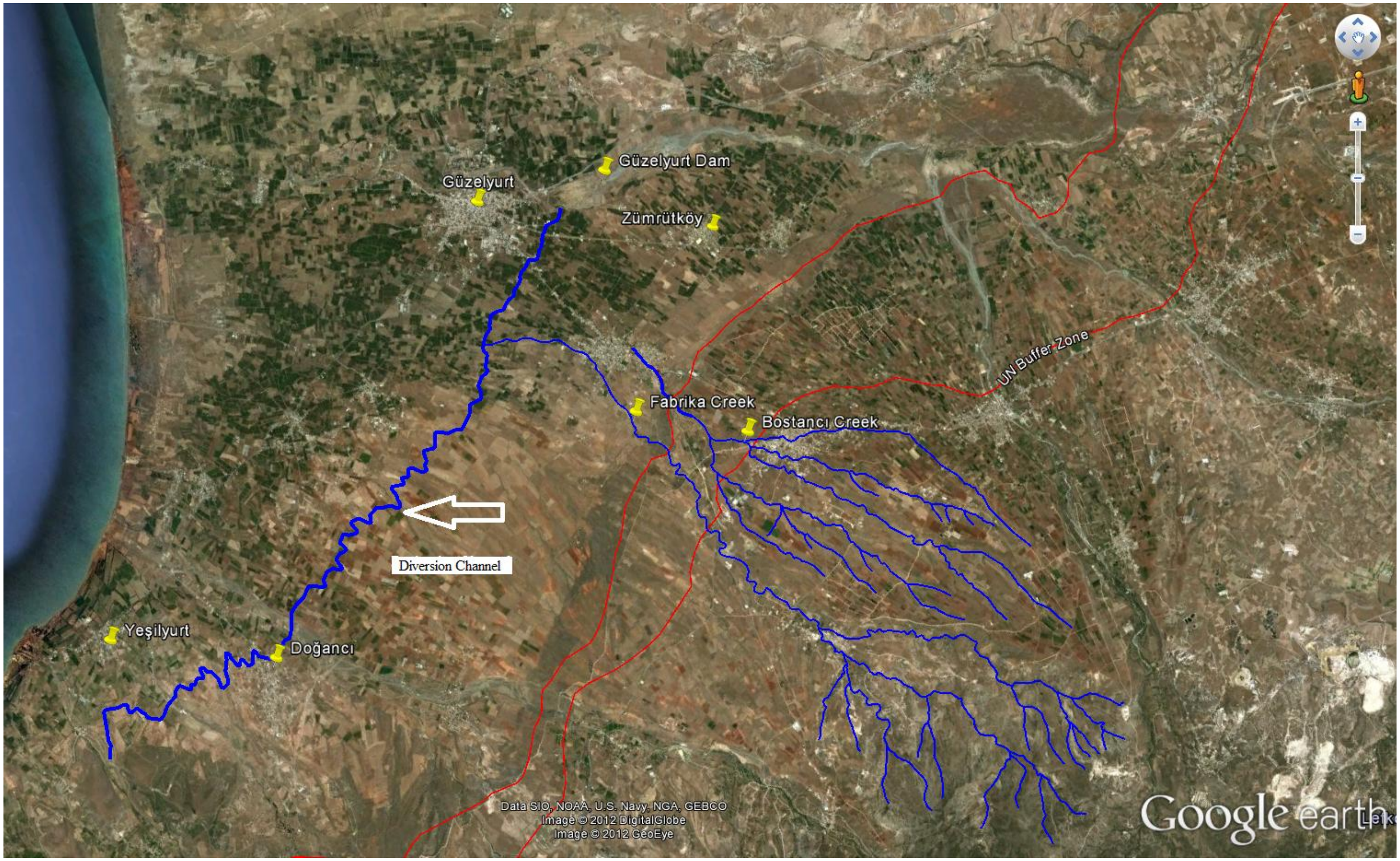


Figure 6.15 Layout of the diversion channel (Google Earth, 2011)

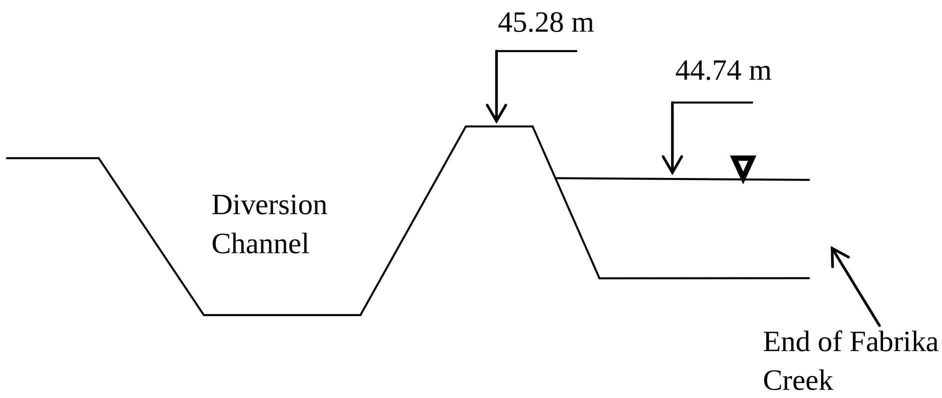


Figure 6.16 Elevation differences at the end of Fabrika Creek

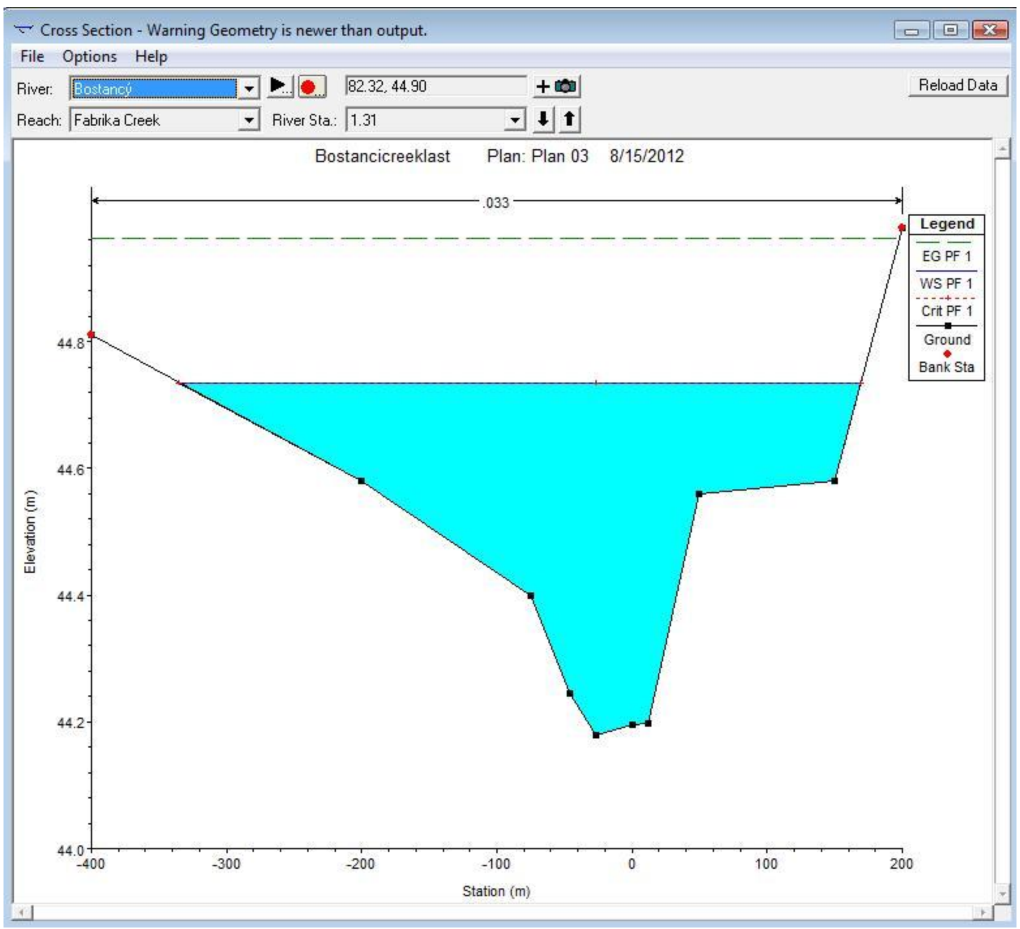


Figure 6.17 Last Section of Fabrika Creek

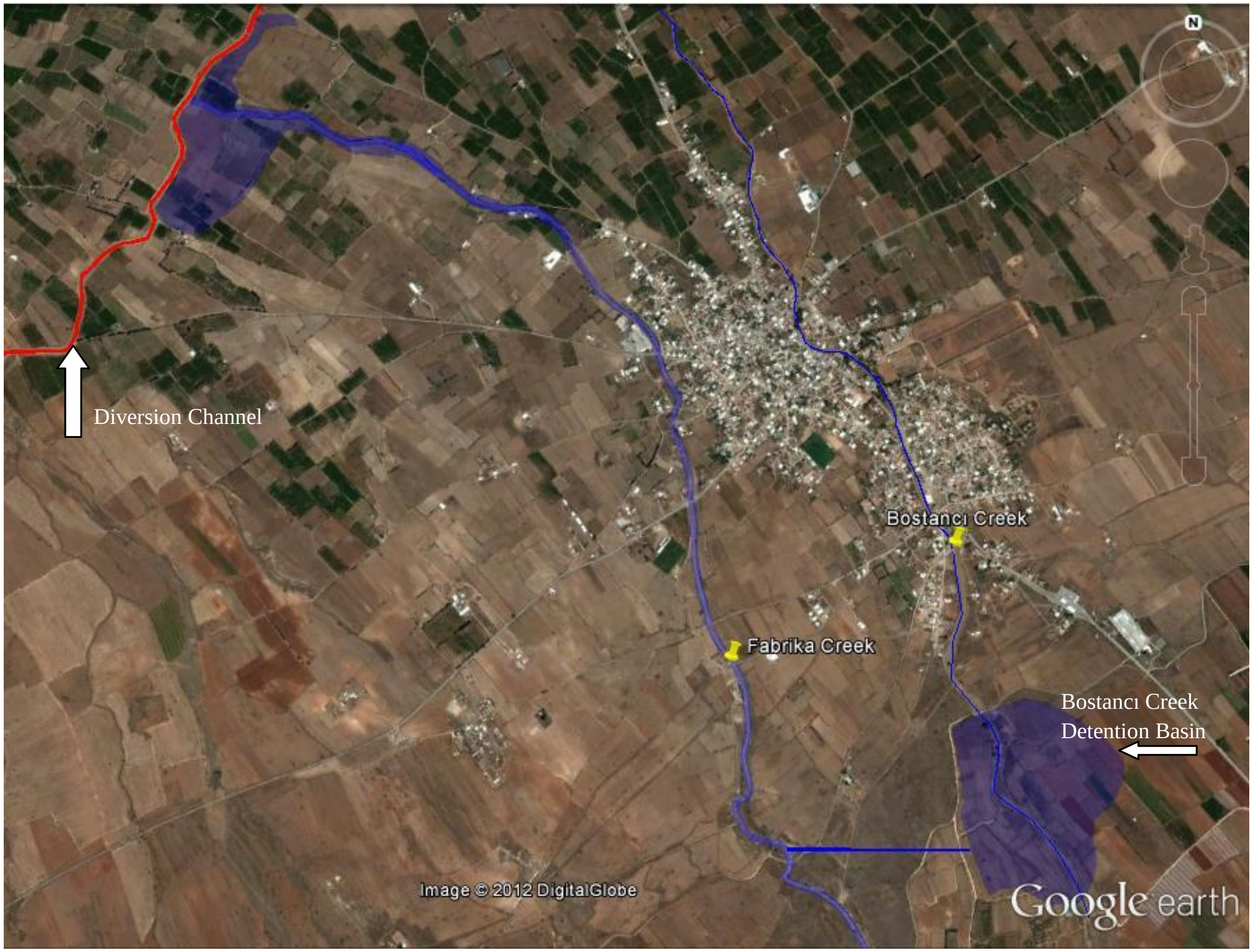


Figure 6.18 Flood inundation map of Bostancı Creek and Fabrika Creek for Alternative 1 (Google Earth, 2011)

### 6.1.1 Cost Calculations for Alternative 1

Based on the proposed solution, a detention basin, a spillway and a lined diversion channel need to be built. The cost items are as follows:

- Cost of lined diversion channel (3.5 m wide, 1.9 m high, and 600 m long)
- Cost of embankment of the detention basin
- Cost of spillway of the detention basin

The cost items for the diversion channel consist of cost of excavation, cost of lining, and cost of purchasing the land i.e. expropriation cost. The unit prices are obtained from the Birimfiyat.com website in TL. The total cost for excavation, $C_{ex}$, is computed from:

$$C_{ex} = (by^{*} + zy^{*})L_c C_{uex} \quad (6.8)$$

where; b is the width of the channel, $y^{*}$ is the total height of channel, z is the horizontal value of the side inclination, which is 2.0, $L_c$ is the total length of channel and $C_{uex}$ is the unit price of excavation 16 TL/m$^3$. A volume of 9015.5 m$^3$ of earth material should be excavated. The cost of excavation is obtained as 145401 TL. Cost of lined channel, $C_{lc}$, is calculated from;

$$C_{lc} = [b + 2(y^{*})\, 2\sqrt{1+z^2}\,]L_c C_{ul} \quad (6.9)$$

where $C_{ul}$ is the unit price of channel lining (40 TL/m$^2$). Therefore, the total cost of channel lining is determined as 311920 TL.

The expropriation cost, $C_{Exp}$, is determined from

$$C_{Exp} = [[b + 2zy^{*}] + 4]L_c\, C_{uexp} \quad (6.10)$$

The unit cost of expropriation can be taken as 14.3 $TL/m^2$ for the terrain concerned. The total cost of expropriation is then obtained as 140354 TL.

The approximate cost of the detention basin can be calculated from Equations (6.11) and (6.12) in terms of 1987 US dollars proposed by Akbaş (1987).

$$\text{Cost of embankment } (C_e) = 17270 \exp(0.13h_c) = 55647\ \$ \quad (6.11)$$

$$\text{Cost of spillway } (C_s) = 3700L - 16700 = 20300\ \$ \quad (6.12)$$

where L is the spillway crest length (10 m) and $h_c$ is the dam height (9 m). The total cost of the reservoir is 75947 $ or 136705 TL according to year 1987 prices. Adjustment for the inflation rate between 1987 and 2012, results in the total cost of the detention basin as 270677 TL in 2012 prices. The overall total cost is then obtained as 868352 TL. Approximately, 20% of the total cost is considered as possible undefined cost (Çam, 2012). The total project cost is eventually obtained as 1,042,022 TL.

## 6.2 Alternative 2

There is an alternative solution for solving the Güzelyurt flood problem. Bostancı Creek is considerably close to the Güzelyurt Dam. Therefore, the Bostancı Creek is considered to be transferred directly to the Güzelyurt Dam via a new lined channel. After field investigations, a channel, 5 km long with a bed slope of 0.0056, is observed to be built between the Bostancı Creek and the Güzelyurt Dam in the direction of decreasing elevation from 88 m to 60 m. Figure 6.19 shows the path of this channel, which needs a capacity of 104. 6 $m^3/s$ at flood times. Manning's roughness coefficient of the channel can be taken as 0.015. Considering the channel capacity, the width of the channel is 4 m and total height is 3 m. Along the direction of the channel, there are two roads. Therefore, two small bridges are proposed to be constructed.

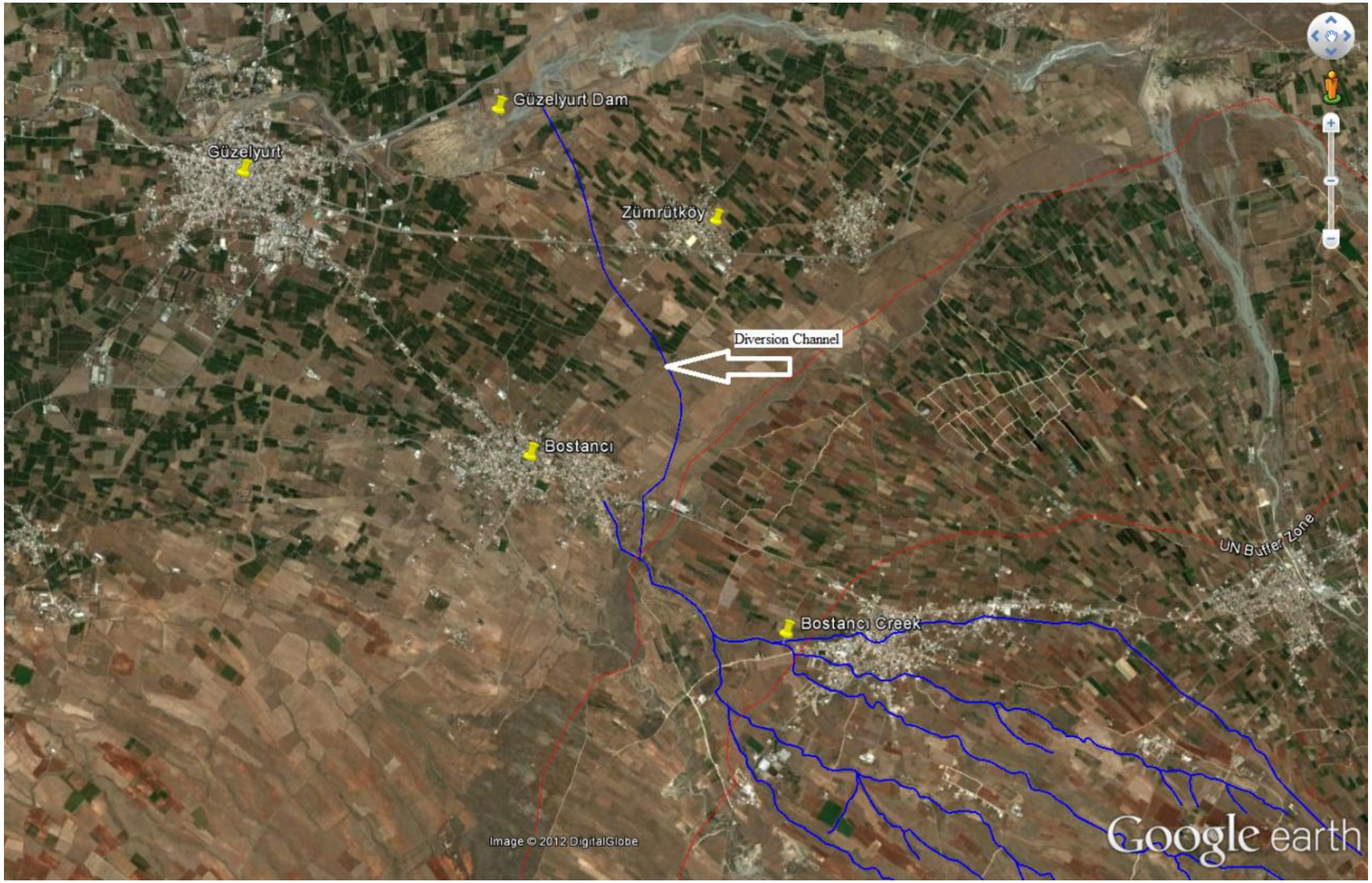


Figure 6.19 Direction of the diversion channel (Google Earth, 2011)

### 6.2.1 Cost Calculations for Alternative 2

The same cost items considered in the first alternative for the diversion channel are also applicable to this alternative. The results of the cost calculations are outlined in Table 6.1.

Table 6.1 Costs of the proposed solutions

| | **Alternative 1** | **Alternative 2** |
|---|---|---|
| Excavation Cost (TL) | 145,401 | 3,240,000 |
| Lined Channel Cost (TL) | 311,920 | 6,166,563 |
| Expropriated Cost (TL) | 140,354 | 1,300,000 |
| Spillway Cost (TL) | 36,540 | - |
| Embankment Cost (TL) | 100,164 | - |
| Undefined Cost (TL) | 173,670 | 2,141,312 |
| Total Cost (TL) | 1,042,022 | 12,847,875 |

Total cost of building only the diversion channel in the second alternative is 12,847,875 TL. However, this cost does not include the cost of bridges. For this reason, the cost of the second alternative is much higher than the cost of the first alternative (See Table 6.1). As a result, the first alternative seems to be effective and economical.

# CHAPTER VII

# SUMMARY AND CONCLUSIONS

This study deals with flood management practices in Güzelyurt-Bostancı region of North Cyprus. All the steps applied in this study, the conclusions and recommendations derived throughout the thesis can be summarized as follows:

Rainfall frequency calculations are performed for hydrological modeling. Basin properties are obtained by using ARC-GIS software. Percentage distribution of daily rainfall of Güzelyurt station is derived from the available rainfall data to obtain the rainfall hyetograph. Synthetic unit hydrograph (SCS method) is used for obtaining the design flood hydrographs for the basins.

Water surface profile computations are executed by using HEC-RAS 4.0 software. All geometric and topographic data for the channel and the terrain are measured at the site by using GNSS field measurement device. This information is introduced to HEC-RAS program together with the flow data to obtain flood inundation maps of the basins. All of hydraulic structures are defined and inserted into HEC-RAS software. Flood maps are compared to the maps which are plotted by observations. The obtained map from the software is quite similar to map which is developed according to field observations of the author. Flow carrying capacities of the creeks are observed and channel improvements concerning deepening and widening are tested to decrease Manning's roughness coefficient. The dimensions of some of the existing bridges and culverts are modified to increase flow transmission ability of the creeks. The possible scour depths at the bridges are computed. Hence, partially grouted riprap is proposed to be placed around bridge piers as a suitable scour countermeasure.

Two alternative solutions are tested according to practical and economic considerations. To this end, construction of flood detention basin(s) on Bostancı and Fabrika Creeks with a supplementary diversion channel is considered in the first alternative. However, construction of a flood detention basin on Fabrika Creek is observed to be ineffective in flood attenuation. That is why the first alternative is limited to a single detention basin on Bostancı Creek and the accompanying diversion channel. In the second alternative, Bostancı Creek is planned to be joined to the Güzelyurt Dam at a suitable location by means of a lined channel. Based on the cost computations, the first alternative is found to be feasible.

Depending on this study, it is recommended to implement some rehabilitation on both creeks, including removal of waste materials of any form and cleaning of vegetation along the channel perimeter. Besides that, some cross-sections of the creek need to be enlarged to facilitate passage of flood water without raising the water level in the surrounding.

As a future research, use of two dimensional models for water surface profile computations is recommended.

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# APPENDIX

# CALCULATIONS OF FLOOD ROUTING

Table A.1 Flood routing calculations of the Bostancı Creek

| t (hr) | h (m) | I(t) ($m^3/s$) | Q(h) ($m^3/s$) | A(h) ($m^2$) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 0.00 | 2.00 | 0.00 | 0.00 | 2742.51 | 0.00000 | 2.00 |
| 0.08 | 2.00 | 0.00 | 0.00 | 2742.51 | 0.00000 | 2.00 |
| 0.17 | 2.00 | 0.00 | 0.00 | 2742.52 | 0.00000 | 2.00 |
| 0.25 | 2.00 | 0.00 | 0.00 | 2742.69 | 0.00000 | 2.00 |
| 0.33 | 2.00 | 0.01 | 0.00 | 2743.37 | 0.00000 | 2.00 |
| 0.42 | 2.00 | 0.01 | 0.00 | 2745.19 | 0.00001 | 2.00 |
| 0.50 | 2.00 | 0.03 | 0.00 | 2749.08 | 0.00001 | 2.01 |
| 0.58 | 2.01 | 0.04 | 0.00 | 2756.30 | 0.00002 | 2.01 |
| 0.67 | 2.01 | 0.07 | 0.00 | 2768.40 | 0.00002 | 2.02 |
| 0.75 | 2.02 | 0.10 | 0.00 | 2787.28 | 0.00004 | 2.03 |
| 0.83 | 2.03 | 0.14 | 0.00 | 2815.11 | 0.00005 | 2.04 |
| 0.92 | 2.04 | 0.20 | 0.00 | 2854.31 | 0.00007 | 2.06 |
| 1.00 | 2.06 | 0.26 | 0.00 | 2907.54 | 0.00009 | 2.09 |
| 1.08 | 2.09 | 0.34 | 0.00 | 2977.53 | 0.00011 | 2.13 |
| 1.17 | 2.13 | 0.43 | 0.00 | 3067.09 | 0.00014 | 2.17 |
| 1.25 | 2.17 | 0.54 | 0.00 | 3178.96 | 0.00017 | 2.22 |
| 1.33 | 2.22 | 0.66 | 0.00 | 3315.72 | 0.00020 | 2.28 |
| 1.42 | 2.28 | 0.80 | 0.00 | 3479.70 | 0.00023 | 2.35 |
| 1.50 | 2.35 | 0.96 | 0.80 | 3672.95 | 0.00004 | 2.36 |
| 1.58 | 2.36 | 1.13 | 1.12 | 3709.62 | 0.00000 | 2.36 |
| 1.67 | 2.36 | 1.33 | 1.20 | 3712.87 | 0.00003 | 2.37 |
| 1.75 | 2.37 | 1.54 | 1.45 | 3742.58 | 0.00003 | 2.38 |
| 1.83 | 2.38 | 1.78 | 2.87 | 3764.13 | -0.00029 | 2.29 |
| 1.92 | 2.29 | 2.04 | 2.85 | 3519.41 | -0.00023 | 2.22 |
| 2.00 | 2.22 | 2.31 | 2.81 | 3329.06 | -0.00015 | 2.18 |
| 2.08 | 2.18 | 2.62 | 2.78 | 3209.81 | -0.00005 | 2.17 |
| 2.17 | 2.17 | 2.94 | 2.77 | 3169.32 | 0.00005 | 2.18 |
| 2.25 | 2.18 | 3.28 | 2.78 | 3212.37 | 0.00016 | 2.23 |
| 2.33 | 2.23 | 3.65 | 2.81 | 3339.86 | 0.00025 | 2.30 |

Table A.1 (Contd.)

| t (hr) | h (m) | I(t) (m³/s) | Q(h) (m³/s) | A(h) (m²) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 2.83 | 2.97 | 6.36 | 3.24 | 5607.16 | 0.00056 | 3.14 |
| 2.92 | 3.14 | 6.89 | 3.33 | 6183.87 | 0.00058 | 3.31 |
| 3.00 | 3.31 | 7.45 | 3.42 | 6807.82 | 0.00059 | 3.49 |
| 3.08 | 3.49 | 8.03 | 3.51 | 7477.56 | 0.00060 | 3.67 |
| 3.17 | 3.67 | 8.64 | 3.60 | 8192.38 | 0.00061 | 3.85 |
| 3.25 | 3.85 | 9.26 | 3.69 | 8952.11 | 0.00062 | 4.04 |
| 3.33 | 4.04 | 9.91 | 3.78 | 9757.09 | 0.00063 | 4.23 |
| 3.42 | 4.23 | 10.59 | 3.87 | 10608.07 | 0.00063 | 4.42 |
| 4.17 | 5.95 | 17.58 | 4.59 | 20598.69 | 0.00063 | 6.14 |
| 4.25 | 6.14 | 16.10 | 4.66 | 22006.36 | 0.00052 | 6.30 |
| 4.33 | 6.30 | 11.33 | 4.72 | 23224.43 | 0.00028 | 6.38 |
| 4.42 | 6.38 | 8.15 | 4.75 | 23914.63 | 0.00014 | 6.42 |
| 4.50 | 6.42 | 6.81 | 4.77 | 24265.73 | 0.00008 | 6.45 |
| 4.58 | 6.45 | 6.34 | 4.78 | 24475.27 | 0.00006 | 6.47 |
| 4.67 | 6.47 | 6.19 | 4.78 | 24635.28 | 0.00006 | 6.49 |
| 4.75 | 6.49 | 6.15 | 4.79 | 24779.32 | 0.00005 | 6.50 |
| 4.83 | 6.50 | 6.14 | 4.80 | 24918.38 | 0.00005 | 6.52 |
| 4.92 | 6.52 | 6.14 | 4.80 | 25055.87 | 0.00005 | 6.53 |
| 5.00 | 6.53 | 6.15 | 4.81 | 25192.78 | 0.00005 | 6.55 |
| 5.08 | 6.55 | 6.15 | 4.81 | 25329.37 | 0.00005 | 6.57 |
| 5.17 | 6.57 | 6.15 | 4.82 | 25465.69 | 0.00005 | 6.58 |
| 5.25 | 6.58 | 6.16 | 4.83 | 25601.75 | 0.00005 | 6.60 |
| 5.33 | 6.60 | 6.16 | 4.83 | 25737.53 | 0.00005 | 6.61 |
| 5.42 | 6.61 | 6.17 | 4.84 | 25872.99 | 0.00005 | 6.63 |
| 5.50 | 6.63 | 6.17 | 4.84 | 26008.12 | 0.00005 | 6.64 |
| 5.58 | 6.64 | 6.17 | 4.85 | 26142.88 | 0.00005 | 6.66 |
| 5.67 | 6.66 | 6.17 | 4.85 | 26277.23 | 0.00005 | 6.67 |
| 5.75 | 6.67 | 6.18 | 4.86 | 26411.15 | 0.00005 | 6.69 |
| 5.83 | 6.69 | 6.18 | 4.87 | 26544.60 | 0.00005 | 6.70 |
| 5.92 | 6.70 | 6.18 | 4.87 | 26677.56 | 0.00005 | 6.72 |
| 6.00 | 6.72 | 6.18 | 4.88 | 26809.97 | 0.00005 | 6.73 |
| 6.08 | 6.73 | 6.18 | 4.88 | 26941.82 | 0.00005 | 6.75 |
| 6.17 | 6.75 | 6.18 | 4.89 | 27073.07 | 0.00005 | 6.76 |
| 6.25 | 6.76 | 6.18 | 4.89 | 27203.67 | 0.00005 | 6.78 |
| 6.33 | 6.78 | 6.18 | 4.90 | 27333.60 | 0.00005 | 6.79 |
| 6.42 | 6.79 | 6.17 | 4.90 | 27462.83 | 0.00005 | 6.80 |
| 6.50 | 6.80 | 6.17 | 4.91 | 27591.31 | 0.00005 | 6.82 |
| 6.58 | 6.82 | 6.17 | 4.91 | 27719.02 | 0.00005 | 6.83 |
| 6.67 | 6.83 | 6.17 | 4.92 | 27845.91 | 0.00004 | 6.84 |
| 6.75 | 6.84 | 6.16 | 4.92 | 27971.97 | 0.00004 | 6.86 |
| 6.83 | 6.86 | 6.16 | 4.93 | 28097.15 | 0.00004 | 6.87 |
| 6.92 | 6.87 | 6.16 | 4.93 | 28221.42 | 0.00004 | 6.88 |

Table A.1 (Contd.)

| t (hr) | h (m) | I(t) (m³/s) | Q(h) (m³/s) | A(h) (m²) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 7.00 | 6.88 | 6.15 | 4.94 | 28344.75 | 0.00004 | 6.90 |
| 7.08 | 6.90 | 6.15 | 4.94 | 28467.11 | 0.00004 | 6.91 |
| 7.17 | 6.91 | 6.14 | 4.94 | 28588.47 | 0.00004 | 6.92 |
| 7.25 | 6.92 | 6.14 | 4.95 | 28708.80 | 0.00004 | 6.93 |
| 7.33 | 6.93 | 6.13 | 4.95 | 28828.06 | 0.00004 | 6.95 |
| 7.42 | 6.95 | 6.13 | 4.96 | 28946.24 | 0.00004 | 6.96 |
| 7.50 | 6.96 | 6.12 | 4.96 | 29063.30 | 0.00004 | 6.97 |
| 7.58 | 6.97 | 6.11 | 4.97 | 29179.22 | 0.00004 | 6.98 |
| 7.67 | 6.98 | 6.11 | 4.97 | 29293.97 | 0.00004 | 6.99 |
| 7.75 | 6.99 | 6.10 | 4.97 | 29407.52 | 0.00004 | 7.01 |
| 7.83 | 7.01 | 6.09 | 4.98 | 29519.84 | 0.00004 | 7.02 |
| 7.92 | 7.02 | 6.08 | 4.98 | 29630.92 | 0.00004 | 7.03 |
| 8.00 | 7.03 | 6.07 | 4.99 | 29740.73 | 0.00004 | 7.04 |
| 8.08 | 7.04 | 6.06 | 4.99 | 29849.25 | 0.00004 | 7.05 |
| 8.17 | 7.05 | 6.06 | 4.99 | 29956.45 | 0.00004 | 7.06 |
| 8.25 | 7.06 | 6.05 | 5.00 | 30062.32 | 0.00003 | 7.07 |
| 8.33 | 7.07 | 6.04 | 5.00 | 30166.83 | 0.00003 | 7.08 |
| 8.42 | 7.08 | 6.03 | 5.01 | 30269.97 | 0.00003 | 7.09 |
| 8.50 | 7.09 | 6.02 | 5.01 | 30371.71 | 0.00003 | 7.10 |
| 8.58 | 7.10 | 6.01 | 5.01 | 30472.03 | 0.00003 | 7.11 |
| 8.67 | 7.11 | 5.99 | 5.02 | 30570.93 | 0.00003 | 7.12 |
| 8.75 | 7.12 | 5.98 | 5.02 | 30668.38 | 0.00003 | 7.13 |
| 8.83 | 7.13 | 5.97 | 5.02 | 30764.36 | 0.00003 | 7.14 |
| 8.92 | 7.14 | 5.96 | 5.03 | 30858.87 | 0.00003 | 7.15 |
| 9.00 | 7.15 | 5.95 | 5.03 | 30951.89 | 0.00003 | 7.16 |
| 9.08 | 7.16 | 5.94 | 5.03 | 31043.40 | 0.00003 | 7.17 |
| 9.17 | 7.17 | 5.93 | 5.04 | 31133.39 | 0.00003 | 7.17 |
| 9.25 | 7.17 | 5.91 | 5.04 | 31221.86 | 0.00003 | 7.18 |
| 9.33 | 7.18 | 5.90 | 5.04 | 31308.78 | 0.00003 | 7.19 |
| 9.42 | 7.19 | 5.89 | 5.04 | 31394.15 | 0.00003 | 7.20 |
| 9.50 | 7.20 | 5.88 | 5.05 | 31477.96 | 0.00003 | 7.21 |
| 9.58 | 7.21 | 5.86 | 5.05 | 31560.20 | 0.00003 | 7.21 |
| 9.67 | 7.21 | 5.85 | 5.05 | 31640.86 | 0.00003 | 7.22 |
| 9.75 | 7.22 | 5.84 | 5.06 | 31719.94 | 0.00002 | 7.23 |
| 9.83 | 7.23 | 5.82 | 5.06 | 31797.43 | 0.00002 | 7.24 |
| 9.92 | 7.24 | 5.81 | 5.06 | 31873.31 | 0.00002 | 7.24 |
| 10.00 | 7.24 | 5.80 | 5.06 | 31947.59 | 0.00002 | 7.25 |
| 10.08 | 7.25 | 5.78 | 5.07 | 32020.27 | 0.00002 | 7.26 |
| 10.17 | 7.26 | 5.77 | 5.07 | 32091.33 | 0.00002 | 7.26 |
| 10.25 | 7.26 | 5.75 | 5.07 | 32160.78 | 0.00002 | 7.27 |
| 10.33 | 7.27 | 5.74 | 5.07 | 32228.61 | 0.00002 | 7.28 |
| 10.42 | 7.28 | 5.73 | 5.07 | 32294.82 | 0.00002 | 7.28 |

Table A.1 (Contd.)

| t (hr) | h (m) | I(t) (m³/s) | Q(h) (m³/s) | A(h) (m²) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 10.50 | 7.28 | 5.71 | 5.08 | 32359.40 | 0.00002 | 7.29 |
| 10.58 | 7.29 | 5.70 | 5.08 | 32422.37 | 0.00002 | 7.29 |
| 10.67 | 7.29 | 5.68 | 5.08 | 32483.71 | 0.00002 | 7.30 |
| 10.75 | 7.30 | 5.67 | 5.08 | 32543.43 | 0.00002 | 7.31 |
| 10.83 | 7.31 | 5.66 | 5.08 | 32601.53 | 0.00002 | 7.31 |
| 10.92 | 7.31 | 5.64 | 5.09 | 32658.01 | 0.00002 | 7.32 |
| 11.00 | 7.32 | 5.63 | 5.09 | 32712.88 | 0.00002 | 7.32 |
| 11.08 | 7.32 | 5.61 | 5.09 | 32766.12 | 0.00002 | 7.33 |
| 11.17 | 7.33 | 5.60 | 5.09 | 32817.76 | 0.00002 | 7.33 |
| 11.25 | 7.33 | 5.58 | 5.09 | 32867.79 | 0.00001 | 7.33 |
| 11.33 | 7.33 | 5.57 | 5.09 | 32916.22 | 0.00001 | 7.34 |
| 11.42 | 7.34 | 5.55 | 5.10 | 32963.05 | 0.00001 | 7.34 |
| 11.50 | 7.34 | 5.54 | 5.10 | 33008.28 | 0.00001 | 7.35 |
| 11.58 | 7.35 | 5.52 | 5.10 | 33051.93 | 0.00001 | 7.35 |
| 11.67 | 7.35 | 5.51 | 5.10 | 33094.00 | 0.00001 | 7.35 |
| 11.25 | 7.33 | 5.58 | 5.09 | 32867.79 | 0.00001 | 7.33 |
| 11.33 | 7.33 | 5.57 | 5.09 | 32916.22 | 0.00001 | 7.34 |
| 11.42 | 7.34 | 5.55 | 5.10 | 32963.05 | 0.00001 | 7.34 |
| 11.50 | 7.34 | 5.54 | 5.10 | 33008.28 | 0.00001 | 7.35 |
| 11.58 | 7.35 | 5.52 | 5.10 | 33051.93 | 0.00001 | 7.35 |
| 11.67 | 7.35 | 5.51 | 5.10 | 33094.00 | 0.00001 | 7.35 |
| 11.75 | 7.35 | 5.50 | 5.10 | 33134.49 | 0.00001 | 7.36 |
| 11.83 | 7.36 | 5.48 | 5.10 | 33173.42 | 0.00001 | 7.36 |
| 11.92 | 7.36 | 5.47 | 5.10 | 33210.78 | 0.00001 | 7.36 |
| 12.00 | 7.36 | 5.45 | 5.11 | 33246.60 | 0.00001 | 7.37 |
| 12.08 | 7.37 | 5.44 | 5.11 | 33280.87 | 0.00001 | 7.37 |
| 12.17 | 7.37 | 5.42 | 5.11 | 33313.60 | 0.00001 | 7.37 |
| 12.25 | 7.37 | 5.41 | 5.11 | 33344.81 | 0.00001 | 7.38 |
| 12.33 | 7.38 | 5.39 | 5.11 | 33374.51 | 0.00001 | 7.38 |
| 12.42 | 7.38 | 5.38 | 5.11 | 33402.70 | 0.00001 | 7.38 |
| 12.50 | 7.38 | 5.37 | 5.11 | 33429.39 | 0.00001 | 7.38 |
| 12.58 | 7.38 | 5.35 | 5.11 | 33454.60 | 0.00001 | 7.39 |
| 12.67 | 7.39 | 5.34 | 5.11 | 33478.33 | 0.00001 | 7.39 |
| 12.75 | 7.39 | 5.32 | 5.11 | 33500.60 | 0.00001 | 7.39 |
| 12.83 | 7.39 | 5.31 | 5.11 | 33521.42 | 0.00001 | 7.39 |
| 12.92 | 7.39 | 5.30 | 5.11 | 33540.79 | 0.00001 | 7.39 |
| 13.00 | 7.39 | 5.28 | 5.12 | 33558.74 | 0.00000 | 7.39 |
| 13.08 | 7.39 | 5.27 | 5.12 | 33575.28 | 0.00000 | 7.40 |
| 13.17 | 7.40 | 5.26 | 5.12 | 33590.41 | 0.00000 | 7.40 |
| 13.25 | 7.40 | 5.24 | 5.12 | 33604.15 | 0.00000 | 7.40 |
| 13.33 | 7.40 | 5.23 | 5.12 | 33616.51 | 0.00000 | 7.40 |
| 13.42 | 7.40 | 5.22 | 5.12 | 33627.51 | 0.00000 | 7.40 |

Table A.1 (Contd.)

| t (hr) | h (m) | I(t) (m³/s) | Q(h) (m³/s) | A(h) (m²) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 13.50 | 7.40 | 5.20 | 5.12 | 33637.15 | 0.00000 | 7.40 |
| 13.58 | 7.40 | 5.19 | 5.12 | 33645.46 | 0.00000 | 7.40 |
| 13.67 | 7.40 | 5.18 | 5.12 | 33652.45 | 0.00000 | 7.40 |
| 13.75 | 7.40 | 5.16 | 5.12 | 33658.13 | 0.00000 | 7.40 |
| 13.83 | 7.40 | 5.15 | 5.12 | 33662.51 | 0.00000 | 7.40 |
| 13.92 | 7.40 | 5.14 | 5.12 | 33665.61 | 0.00000 | 7.40 |
| 14.00 | 7.40 | 5.12 | 5.12 | 33667.44 | 0.00000 | 7.40 |
| 14.08 | 7.40 | 5.11 | 5.12 | 33668.02 | 0.00000 | 7.40 |
| 14.17 | 7.40 | 5.10 | 5.12 | 33667.37 | 0.00000 | 7.40 |
| 14.25 | 7.40 | 5.09 | 5.12 | 33665.49 | 0.00000 | 7.40 |
| 14.33 | 7.40 | 5.07 | 5.12 | 33662.41 | 0.00000 | 7.40 |
| 14.50 | 7.40 | 5.05 | 5.12 | 33652.67 | 0.00000 | 7.40 |
| 14.58 | 7.40 | 5.04 | 5.12 | 33646.06 | 0.00000 | 7.40 |
| 14.67 | 7.40 | 5.03 | 5.12 | 33638.29 | 0.00000 | 7.40 |
| 14.75 | 7.40 | 5.02 | 5.12 | 33629.40 | 0.00000 | 7.40 |
| 14.83 | 7.40 | 5.00 | 5.12 | 33619.39 | 0.00000 | 7.40 |
| 14.92 | 7.40 | 4.99 | 5.12 | 33608.28 | 0.00000 | 7.40 |
| 15.00 | 7.40 | 4.98 | 5.12 | 33596.09 | 0.00000 | 7.40 |
| 15.08 | 7.40 | 4.97 | 5.12 | 33582.82 | 0.00000 | 7.39 |
| 15.17 | 7.39 | 4.96 | 5.12 | 33568.51 | 0.00000 | 7.39 |
| 15.25 | 7.39 | 4.95 | 5.11 | 33553.15 | 0.00000 | 7.39 |
| 15.33 | 7.39 | 4.94 | 5.11 | 33536.77 | -0.00001 | 7.39 |
| 15.42 | 7.39 | 4.93 | 5.11 | 33519.39 | -0.00001 | 7.39 |
| 15.50 | 7.39 | 4.92 | 5.11 | 33501.02 | -0.00001 | 7.39 |
| 15.58 | 7.39 | 4.91 | 5.11 | 33481.67 | -0.00001 | 7.38 |
| 15.67 | 7.38 | 4.90 | 5.11 | 33461.36 | -0.00001 | 7.38 |
| 15.75 | 7.38 | 4.89 | 5.11 | 33440.11 | -0.00001 | 7.38 |
| 15.83 | 7.38 | 4.88 | 5.11 | 33417.93 | -0.00001 | 7.38 |
| 15.92 | 7.38 | 4.87 | 5.11 | 33394.84 | -0.00001 | 7.38 |
| 16.00 | 7.38 | 4.86 | 5.11 | 33370.85 | -0.00001 | 7.37 |
| 16.08 | 7.37 | 4.85 | 5.11 | 33345.98 | -0.00001 | 7.37 |
| 16.17 | 7.37 | 4.84 | 5.11 | 33320.24 | -0.00001 | 7.37 |
| 16.25 | 7.37 | 4.83 | 5.11 | 33293.66 | -0.00001 | 7.37 |
| 16.33 | 7.37 | 4.82 | 5.11 | 33266.24 | -0.00001 | 7.36 |
| 16.42 | 7.36 | 4.81 | 5.10 | 33238.00 | -0.00001 | 7.36 |
| 16.50 | 7.36 | 4.80 | 5.10 | 33208.95 | -0.00001 | 7.36 |
| 16.58 | 7.36 | 4.79 | 5.10 | 33179.12 | -0.00001 | 7.36 |
| 16.67 | 7.36 | 4.78 | 5.10 | 33148.51 | -0.00001 | 7.35 |
| 16.75 | 7.35 | 4.78 | 5.10 | 33117.15 | -0.00001 | 7.35 |
| 16.83 | 7.35 | 4.77 | 5.10 | 33085.04 | -0.00001 | 7.35 |
| 16.92 | 7.35 | 4.76 | 5.10 | 33052.20 | -0.00001 | 7.34 |
| 17.00 | 7.34 | 4.75 | 5.10 | 33018.65 | -0.00001 | 7.34 |

Table A.1 (Contd.)

| t (hr) | h (m) | I(t) (m³/s) | Q(h) (m³/s) | A(h) (m²) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 17.08 | 7.34 | 4.74 | 5.10 | 32984.40 | -0.00001 | 7.34 |
| 17.17 | 7.34 | 4.73 | 5.10 | 32949.47 | -0.00001 | 7.33 |
| 17.25 | 7.33 | 4.73 | 5.09 | 32913.87 | -0.00001 | 7.33 |
| 17.33 | 7.33 | 4.72 | 5.09 | 32877.61 | -0.00001 | 7.33 |
| 17.42 | 7.33 | 4.71 | 5.09 | 32840.71 | -0.00001 | 7.32 |
| 17.50 | 7.32 | 4.70 | 5.09 | 32803.18 | -0.00001 | 7.32 |
| 17.58 | 7.32 | 4.70 | 5.09 | 32765.04 | -0.00001 | 7.32 |
| 17.67 | 7.32 | 4.69 | 5.09 | 32726.31 | -0.00001 | 7.31 |
| 17.75 | 7.31 | 4.68 | 5.09 | 32686.99 | -0.00001 | 7.31 |
| 17.83 | 7.31 | 4.68 | 5.09 | 32647.09 | -0.00001 | 7.31 |
| 17.92 | 7.31 | 4.67 | 5.08 | 32606.65 | -0.00001 | 7.30 |
| 18.00 | 7.30 | 4.66 | 5.08 | 32565.66 | -0.00001 | 7.30 |
| 18.08 | 7.30 | 4.66 | 5.08 | 32524.13 | -0.00001 | 7.29 |
| 18.25 | 7.29 | 4.64 | 5.08 | 32439.56 | -0.00001 | 7.29 |
| 18.33 | 7.29 | 4.64 | 5.08 | 32396.53 | -0.00001 | 7.28 |
| 18.42 | 7.28 | 4.63 | 5.08 | 32353.02 | -0.00001 | 7.28 |
| 18.50 | 7.28 | 4.63 | 5.07 | 32309.05 | -0.00001 | 7.27 |
| 18.58 | 7.27 | 4.62 | 5.07 | 32264.63 | -0.00001 | 7.27 |
| 18.67 | 7.27 | 4.61 | 5.07 | 32219.77 | -0.00001 | 7.27 |
| 18.75 | 7.27 | 4.61 | 5.07 | 32174.48 | -0.00001 | 7.26 |
| 18.83 | 7.26 | 4.60 | 5.07 | 32128.78 | -0.00001 | 7.26 |
| 18.92 | 7.26 | 4.60 | 5.07 | 32082.68 | -0.00001 | 7.25 |
| 19.00 | 7.25 | 4.59 | 5.07 | 32036.18 | -0.00001 | 7.25 |
| 19.08 | 7.25 | 4.59 | 5.06 | 31989.31 | -0.00001 | 7.24 |
| 19.17 | 7.24 | 4.58 | 5.06 | 31942.08 | -0.00002 | 7.24 |
| 19.25 | 7.24 | 4.58 | 5.06 | 31894.49 | -0.00002 | 7.23 |
| 19.33 | 7.23 | 4.57 | 5.06 | 31846.55 | -0.00002 | 7.23 |
| 19.42 | 7.23 | 4.57 | 5.06 | 31798.29 | -0.00002 | 7.23 |
| 19.50 | 7.23 | 4.56 | 5.06 | 31749.70 | -0.00002 | 7.22 |
| 19.58 | 7.22 | 4.56 | 5.05 | 31700.81 | -0.00002 | 7.22 |
| 19.67 | 7.22 | 4.55 | 5.05 | 31651.62 | -0.00002 | 7.21 |
| 19.75 | 7.21 | 4.55 | 5.05 | 31602.14 | -0.00002 | 7.21 |
| 19.83 | 7.21 | 4.55 | 5.05 | 31552.38 | -0.00002 | 7.20 |
| 19.92 | 7.20 | 4.54 | 5.05 | 31502.36 | -0.00002 | 7.20 |
| 20.00 | 7.20 | 4.54 | 5.05 | 31452.09 | -0.00002 | 7.19 |
| 20.08 | 7.19 | 4.53 | 5.04 | 31401.56 | -0.00002 | 7.19 |
| 20.17 | 7.19 | 4.53 | 5.04 | 31350.80 | -0.00002 | 7.18 |
| 20.25 | 7.18 | 4.53 | 5.04 | 31299.82 | -0.00002 | 7.18 |
| 20.33 | 7.18 | 4.52 | 5.04 | 31248.62 | -0.00002 | 7.17 |
| 20.42 | 7.17 | 4.52 | 5.04 | 31197.22 | -0.00002 | 7.17 |
| 20.50 | 7.17 | 4.51 | 5.04 | 31145.62 | -0.00002 | 7.16 |
| 20.58 | 7.16 | 4.51 | 5.03 | 31093.83 | -0.00002 | 7.16 |

Table A.1 (Contd.)

| **t (hr)** | **h (m)** | **I(t) ($m^3$/s)** | **Q(h) ($m^3$/s)** | **A(h) ($m^2$)** | **f(h, t)** | **$h(n+1)$ (m)** |
|---|---|---|---|---|---|---|
| 20.67 | 7.16 | 4.51 | 5.03 | 31041.86 | -0.00002 | 7.15 |
| 20.75 | 7.15 | 4.50 | 5.03 | 30989.73 | -0.00002 | 7.15 |
| 20.83 | 7.15 | 4.50 | 5.03 | 30937.43 | -0.00002 | 7.14 |
| 20.92 | 7.14 | 4.50 | 5.03 | 30884.99 | -0.00002 | 7.14 |
| 21.00 | 7.14 | 4.49 | 5.03 | 30832.40 | -0.00002 | 7.13 |
| 21.08 | 7.13 | 4.49 | 5.02 | 30779.68 | -0.00002 | 7.13 |
| 21.17 | 7.13 | 4.49 | 5.02 | 30726.84 | -0.00002 | 7.12 |
| 21.25 | 7.12 | 4.49 | 5.02 | 30673.88 | -0.00002 | 7.12 |
| 21.33 | 7.12 | 4.48 | 5.02 | 30620.81 | -0.00002 | 7.11 |
| 21.42 | 7.11 | 4.48 | 5.02 | 30567.64 | -0.00002 | 7.11 |
| 21.50 | 7.11 | 4.48 | 5.01 | 30514.37 | -0.00002 | 7.10 |
| 21.58 | 7.10 | 4.48 | 5.01 | 30461.03 | -0.00002 | 7.09 |
| 21.67 | 7.09 | 4.47 | 5.01 | 30407.60 | -0.00002 | 7.09 |
| 21.75 | 7.09 | 4.47 | 5.01 | 30354.11 | -0.00002 | 7.08 |
| 21.83 | 7.08 | 4.47 | 5.01 | 30300.55 | -0.00002 | 7.08 |
| 21.92 | 7.08 | 4.47 | 5.00 | 30246.94 | -0.00002 | 7.07 |
| 22.00 | 7.07 | 4.46 | 5.00 | 30193.28 | -0.00002 | 7.07 |
| 22.08 | 7.07 | 4.46 | 5.00 | 30139.58 | -0.00002 | 7.06 |
| 22.17 | 7.06 | 4.46 | 5.00 | 30085.84 | -0.00002 | 7.06 |
| 22.25 | 7.06 | 4.46 | 5.00 | 30032.08 | -0.00002 | 7.05 |
| 22.33 | 7.05 | 4.46 | 5.00 | 29978.30 | -0.00002 | 7.05 |
| 22.42 | 7.05 | 4.45 | 4.99 | 29924.50 | -0.00002 | 7.04 |
| 22.50 | 7.04 | 4.45 | 4.99 | 29870.70 | -0.00002 | 7.04 |
| 22.58 | 7.04 | 4.45 | 4.99 | 29816.89 | -0.00002 | 7.03 |
| 22.67 | 7.03 | 4.45 | 4.99 | 29763.09 | -0.00002 | 7.02 |
| 22.75 | 7.02 | 4.45 | 4.99 | 29709.30 | -0.00002 | 7.02 |
| 22.83 | 7.02 | 4.44 | 4.98 | 29655.52 | -0.00002 | 7.01 |
| 22.92 | 7.01 | 4.44 | 4.98 | 29601.77 | -0.00002 | 7.01 |
| 23.00 | 7.01 | 4.44 | 4.98 | 29548.04 | -0.00002 | 7.00 |
| 23.08 | 7.00 | 4.44 | 4.98 | 29494.35 | -0.00002 | 7.00 |
| 23.17 | 7.00 | 4.44 | 4.98 | 29440.70 | -0.00002 | 6.99 |
| 23.25 | 6.99 | 4.44 | 4.97 | 29387.09 | -0.00002 | 6.99 |
| 23.33 | 6.99 | 4.44 | 4.97 | 29333.53 | -0.00002 | 6.98 |
| 23.42 | 6.98 | 4.44 | 4.97 | 29280.02 | -0.00002 | 6.98 |
| 23.50 | 6.98 | 4.43 | 4.97 | 29226.58 | -0.00002 | 6.97 |
| 23.58 | 6.97 | 4.43 | 4.97 | 29173.20 | -0.00002 | 6.96 |
| 23.67 | 6.96 | 4.43 | 4.96 | 29119.88 | -0.00002 | 6.96 |
| 23.75 | 6.96 | 4.43 | 4.96 | 29066.64 | -0.00002 | 6.95 |
| 23.83 | 6.95 | 4.43 | 4.96 | 29013.48 | -0.00002 | 6.95 |
| 23.92 | 6.95 | 4.43 | 4.96 | 28960.40 | -0.00002 | 6.94 |
| 24.00 | 6.94 | 4.43 | 4.96 | 28907.41 | -0.00002 | 6.94 |
| 24.08 | 6.94 | 4.43 | 4.95 | 28854.51 | -0.00002 | 6.93 |

Table A.1 (Contd.)

| **t (hr)** | **h (m)** | **I(t) (m³/s)** | **Q(h) (m³/s)** | **A(h) (m²)** | **f(h, t)** | **$h(n+1)$ (m)** |
|---|---|---|---|---|---|---|
| 24.17 | 6.93 | 4.43 | 4.95 | 28801.71 | -0.00002 | 6.93 |
| 24.25 | 6.93 | 4.43 | 4.95 | 28749.00 | -0.00002 | 6.92 |
| 24.33 | 6.92 | 4.42 | 4.95 | 28696.40 | -0.00002 | 6.92 |
| 24.42 | 6.92 | 4.42 | 4.95 | 28643.90 | -0.00002 | 6.91 |
| 24.50 | 6.91 | 4.42 | 4.94 | 28591.52 | -0.00002 | 6.90 |
| 24.58 | 6.90 | 4.42 | 4.94 | 28539.25 | -0.00002 | 6.90 |
| 24.67 | 6.90 | 4.42 | 4.94 | 28487.10 | -0.00002 | 6.89 |
| 24.75 | 6.89 | 4.42 | 4.94 | 28435.07 | -0.00002 | 6.89 |
| 24.83 | 6.89 | 4.42 | 4.94 | 28383.16 | -0.00002 | 6.88 |
| 24.92 | 6.88 | 4.42 | 4.94 | 28331.38 | -0.00002 | 6.88 |
| 25.00 | 6.88 | 4.42 | 4.93 | 28279.74 | -0.00002 | 6.87 |
| 25.08 | 6.87 | 4.42 | 4.93 | 28228.23 | -0.00002 | 6.87 |
| 25.17 | 6.87 | 4.42 | 4.93 | 28176.86 | -0.00002 | 6.86 |
| 25.25 | 6.86 | 4.42 | 4.93 | 28125.63 | -0.00002 | 6.86 |
| 25.33 | 6.86 | 4.42 | 4.93 | 28074.54 | -0.00002 | 6.85 |
| 25.42 | 6.85 | 4.42 | 4.92 | 28023.60 | -0.00002 | 6.84 |
| 25.50 | 6.84 | 4.42 | 4.92 | 27972.80 | -0.00002 | 6.84 |
| 25.58 | 6.84 | 4.42 | 4.92 | 27922.16 | -0.00002 | 6.83 |
| 25.67 | 6.83 | 4.42 | 4.92 | 27871.68 | -0.00002 | 6.83 |
| 25.75 | 6.83 | 4.42 | 4.92 | 27821.35 | -0.00002 | 6.82 |
| 25.83 | 6.82 | 4.42 | 4.91 | 27771.18 | -0.00002 | 6.82 |
| 25.92 | 6.82 | 4.42 | 4.91 | 27721.17 | -0.00002 | 6.81 |
| 26.00 | 6.81 | 4.42 | 4.91 | 27671.32 | -0.00002 | 6.81 |
| 26.08 | 6.81 | 4.42 | 4.91 | 27621.64 | -0.00002 | 6.80 |
| 26.17 | 6.80 | 4.42 | 4.91 | 27572.13 | -0.00002 | 6.80 |
| 26.25 | 6.80 | 4.42 | 4.90 | 27522.79 | -0.00002 | 6.79 |
| 26.33 | 6.79 | 4.42 | 4.90 | 27473.62 | -0.00002 | 6.79 |
| 26.42 | 6.79 | 4.42 | 4.90 | 27424.63 | -0.00002 | 6.78 |
| 26.50 | 6.78 | 4.42 | 4.90 | 27375.81 | -0.00002 | 6.77 |
| 26.58 | 6.77 | 4.42 | 4.90 | 27327.17 | -0.00002 | 6.77 |
| 26.67 | 6.77 | 4.42 | 4.89 | 27278.71 | -0.00002 | 6.76 |
| 26.75 | 6.76 | 4.42 | 4.89 | 27230.43 | -0.00002 | 6.76 |
| 26.83 | 6.76 | 4.42 | 4.89 | 27182.33 | -0.00002 | 6.75 |
| 26.92 | 6.75 | 4.42 | 4.89 | 27134.41 | -0.00002 | 6.75 |
| 27.00 | 6.75 | 4.42 | 4.89 | 27086.68 | -0.00002 | 6.74 |
| 27.08 | 6.74 | 4.42 | 4.88 | 27039.14 | -0.00002 | 6.74 |
| 27.17 | 6.74 | 4.42 | 4.88 | 26991.79 | -0.00002 | 6.73 |
| 27.25 | 6.73 | 4.42 | 4.88 | 26944.62 | -0.00002 | 6.73 |
| 27.33 | 6.73 | 4.42 | 4.88 | 26897.65 | -0.00002 | 6.72 |
| 27.42 | 6.72 | 4.42 | 4.88 | 26850.87 | -0.00002 | 6.72 |
| 27.50 | 6.72 | 4.42 | 4.88 | 26804.28 | -0.00002 | 6.71 |
| 27.58 | 6.71 | 4.42 | 4.87 | 26757.88 | -0.00002 | 6.71 |

Table A.1 (Contd.)

| t (hr) | h (m) | I(t) ($m^3/s$) | Q(h) ($m^3/s$) | A(h) ($m^2$) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 27.67 | 6.71 | 4.42 | 4.87 | 26711.68 | -0.00002 | 6.70 |
| 27.75 | 6.70 | 4.42 | 4.87 | 26665.68 | -0.00002 | 6.70 |
| 27.83 | 6.70 | 4.42 | 4.87 | 26619.87 | -0.00002 | 6.69 |
| 27.92 | 6.69 | 4.42 | 4.87 | 26574.26 | -0.00002 | 6.69 |
| 28.00 | 6.69 | 4.42 | 4.86 | 26528.85 | -0.00002 | 6.68 |
| 28.08 | 6.68 | 4.42 | 4.86 | 26483.64 | -0.00002 | 6.68 |
| 28.17 | 6.68 | 4.42 | 4.86 | 26438.63 | -0.00002 | 6.67 |
| 28.25 | 6.67 | 4.42 | 4.86 | 26393.82 | -0.00002 | 6.67 |
| 28.33 | 6.67 | 4.42 | 4.86 | 26349.21 | -0.00002 | 6.66 |
| 28.42 | 6.66 | 4.42 | 4.86 | 26304.80 | -0.00002 | 6.66 |
| 28.50 | 6.66 | 4.42 | 4.85 | 26260.59 | -0.00002 | 6.65 |
| 28.58 | 6.65 | 4.42 | 4.85 | 26216.59 | -0.00002 | 6.65 |
| 28.67 | 6.65 | 4.42 | 4.85 | 26172.79 | -0.00002 | 6.64 |
| 28.75 | 6.64 | 4.42 | 4.85 | 26129.19 | -0.00002 | 6.64 |
| 28.83 | 6.64 | 4.42 | 4.85 | 26085.80 | -0.00002 | 6.63 |
| 28.92 | 6.63 | 4.42 | 4.84 | 26042.61 | -0.00002 | 6.63 |
| 29.00 | 6.63 | 4.42 | 4.84 | 25999.62 | -0.00002 | 6.62 |
| 29.08 | 6.62 | 4.42 | 4.84 | 25956.84 | -0.00002 | 6.62 |
| 29.17 | 6.62 | 4.42 | 4.84 | 25914.27 | -0.00002 | 6.61 |
| 29.25 | 6.61 | 4.42 | 4.84 | 25871.90 | -0.00002 | 6.61 |
| 29.33 | 6.61 | 4.42 | 4.84 | 25829.73 | -0.00002 | 6.60 |
| 29.42 | 6.60 | 4.42 | 4.83 | 25787.77 | -0.00002 | 6.60 |
| 29.50 | 6.60 | 4.42 | 4.83 | 25746.01 | -0.00002 | 6.59 |
| 29.58 | 6.59 | 4.42 | 4.83 | 25704.46 | -0.00002 | 6.59 |
| 29.67 | 6.59 | 4.42 | 4.83 | 25663.12 | -0.00002 | 6.58 |
| 29.75 | 6.58 | 4.42 | 4.83 | 25621.98 | -0.00002 | 6.58 |
| 29.83 | 6.58 | 4.42 | 4.83 | 25581.04 | -0.00002 | 6.57 |
| 29.92 | 6.57 | 4.42 | 4.82 | 25540.31 | -0.00002 | 6.57 |
| 30.00 | 6.57 | 4.42 | 4.82 | 25499.78 | -0.00002 | 6.56 |
| 30.08 | 6.56 | 4.43 | 4.82 | 25459.46 | -0.00002 | 6.56 |
| 30.17 | 6.56 | 4.43 | 4.82 | 25419.34 | -0.00002 | 6.56 |
| 30.25 | 6.56 | 4.43 | 4.82 | 25379.43 | -0.00002 | 6.55 |
| 30.33 | 6.55 | 4.43 | 4.81 | 25339.71 | -0.00002 | 6.55 |
| 30.42 | 6.55 | 4.43 | 4.81 | 25300.21 | -0.00002 | 6.54 |
| 30.50 | 6.54 | 4.43 | 4.81 | 25260.90 | -0.00002 | 6.54 |
| 30.58 | 6.54 | 4.43 | 4.81 | 25221.80 | -0.00002 | 6.53 |
| 30.67 | 6.53 | 4.43 | 4.81 | 25182.89 | -0.00002 | 6.53 |
| 30.75 | 6.53 | 4.43 | 4.81 | 25144.19 | -0.00002 | 6.52 |
| 30.83 | 6.52 | 4.43 | 4.80 | 25105.70 | -0.00001 | 6.52 |
| 30.92 | 6.52 | 4.43 | 4.80 | 25067.40 | -0.00001 | 6.51 |
| 31.00 | 6.51 | 4.43 | 4.80 | 25029.30 | -0.00001 | 6.51 |
| 31.08 | 6.51 | 4.43 | 4.80 | 24991.40 | -0.00001 | 6.51 |

Table A.1 (Contd.)

| t (hr) | h (m) | I(t) ($m^3/s$) | Q(h) ($m^3/s$) | A(h) ($m^2$) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 31.17 | 6.51 | 4.43 | 4.80 | 24953.70 | -0.00001 | 6.50 |
| 31.25 | 6.50 | 4.43 | 4.80 | 24916.20 | -0.00001 | 6.50 |
| 31.33 | 6.50 | 4.43 | 4.79 | 24878.89 | -0.00001 | 6.49 |
| 31.42 | 6.49 | 4.43 | 4.79 | 24841.79 | -0.00001 | 6.49 |
| 31.50 | 6.49 | 4.43 | 4.79 | 24804.87 | -0.00001 | 6.48 |
| 31.58 | 6.48 | 4.43 | 4.79 | 24768.16 | -0.00001 | 6.48 |
| 31.67 | 6.48 | 4.43 | 4.79 | 24731.64 | -0.00001 | 6.48 |
| 31.75 | 6.48 | 4.43 | 4.79 | 24695.31 | -0.00001 | 6.47 |
| 31.83 | 6.47 | 4.43 | 4.79 | 24659.18 | -0.00001 | 6.47 |
| 31.92 | 6.47 | 4.43 | 4.78 | 24623.24 | -0.00001 | 6.46 |
| 32.00 | 6.46 | 4.43 | 4.78 | 24587.49 | -0.00001 | 6.46 |
| 32.08 | 6.46 | 4.43 | 4.78 | 24551.93 | -0.00001 | 6.45 |
| 32.17 | 6.45 | 4.43 | 4.78 | 24516.56 | -0.00001 | 6.45 |
| 32.25 | 6.45 | 4.44 | 4.78 | 24481.38 | -0.00001 | 6.45 |
| 32.33 | 6.45 | 4.44 | 4.78 | 24446.39 | -0.00001 | 6.44 |
| 32.42 | 6.44 | 4.44 | 4.77 | 24411.59 | -0.00001 | 6.44 |
| 32.50 | 6.44 | 4.44 | 4.77 | 24376.97 | -0.00001 | 6.43 |
| 32.58 | 6.43 | 4.44 | 4.77 | 24342.54 | -0.00001 | 6.43 |
| 32.67 | 6.43 | 4.44 | 4.77 | 24308.29 | -0.00001 | 6.42 |
| 32.75 | 6.42 | 4.44 | 4.77 | 24274.23 | -0.00001 | 6.42 |
| 32.83 | 6.42 | 4.44 | 4.77 | 24240.35 | -0.00001 | 6.42 |
| 32.92 | 6.42 | 4.44 | 4.77 | 24206.65 | -0.00001 | 6.41 |
| 33.00 | 6.41 | 4.44 | 4.76 | 24173.13 | -0.00001 | 6.41 |
| 33.08 | 6.41 | 4.44 | 4.76 | 24139.79 | -0.00001 | 6.40 |
| 33.25 | 6.40 | 4.44 | 4.76 | 24073.65 | -0.00001 | 6.40 |
| 33.33 | 6.40 | 4.44 | 4.76 | 24040.84 | -0.00001 | 6.39 |
| 33.42 | 6.39 | 4.44 | 4.76 | 24008.21 | -0.00001 | 6.39 |
| 33.50 | 6.39 | 4.44 | 4.75 | 23975.75 | -0.00001 | 6.38 |
| 33.58 | 6.38 | 4.44 | 4.75 | 23943.46 | -0.00001 | 6.38 |
| 33.67 | 6.38 | 4.44 | 4.75 | 23911.34 | -0.00001 | 6.38 |
| 33.75 | 6.38 | 4.44 | 4.75 | 23879.40 | -0.00001 | 6.37 |
| 33.83 | 6.37 | 4.44 | 4.75 | 23847.62 | -0.00001 | 6.37 |
| 33.92 | 6.37 | 4.44 | 4.75 | 23816.01 | -0.00001 | 6.37 |
| 34.00 | 6.37 | 4.44 | 4.75 | 23784.57 | -0.00001 | 6.36 |
| 34.08 | 6.36 | 4.44 | 4.74 | 23753.29 | -0.00001 | 6.36 |
| 34.17 | 6.36 | 4.44 | 4.74 | 23722.18 | -0.00001 | 6.35 |
| 34.25 | 6.35 | 4.44 | 4.74 | 23691.23 | -0.00001 | 6.35 |
| 34.33 | 6.35 | 4.44 | 4.74 | 23660.44 | -0.00001 | 6.35 |
| 34.42 | 6.35 | 4.44 | 4.74 | 23629.81 | -0.00001 | 6.34 |
| 34.50 | 6.34 | 4.44 | 4.74 | 23599.34 | -0.00001 | 6.34 |
| 34.58 | 6.34 | 4.44 | 4.74 | 23569.02 | -0.00001 | 6.34 |

Table A.1 (Contd.)

| **t (hr)** | **h (m)** | **I(t) ($m^3/s$)** | **Q(h) ($m^3/s$)** | **A(h) ($m^2$)** | **f(h, t)** | **$h(n+1)$ (m)** |
|---|---|---|---|---|---|---|
| 34.67 | 6.34 | 4.44 | 4.73 | 23538.86 | -0.00001 | 6.33 |
| 34.75 | 6.33 | 4.44 | 4.73 | 23508.86 | -0.00001 | 6.33 |
| 34.83 | 6.33 | 4.44 | 4.73 | 23479.00 | -0.00001 | 6.32 |
| 34.92 | 6.32 | 4.44 | 4.73 | 23449.30 | -0.00001 | 6.32 |
| 35.00 | 6.32 | 4.44 | 4.73 | 23419.75 | -0.00001 | 6.32 |
| 35.08 | 6.32 | 4.44 | 4.73 | 23390.35 | -0.00001 | 6.31 |
| 35.17 | 6.31 | 4.44 | 4.73 | 23361.09 | -0.00001 | 6.31 |
| 35.25 | 6.31 | 4.44 | 4.73 | 23331.98 | -0.00001 | 6.31 |
| 35.33 | 6.31 | 4.44 | 4.72 | 23303.01 | -0.00001 | 6.30 |
| 35.42 | 6.30 | 4.44 | 4.72 | 23274.18 | -0.00001 | 6.30 |
| 35.50 | 6.30 | 4.44 | 4.72 | 23245.49 | -0.00001 | 6.29 |
| 35.58 | 6.29 | 4.44 | 4.72 | 23216.94 | -0.00001 | 6.29 |
| 35.67 | 6.29 | 4.44 | 4.72 | 23188.53 | -0.00001 | 6.29 |
| 35.75 | 6.29 | 4.44 | 4.72 | 23160.26 | -0.00001 | 6.28 |
| 35.83 | 6.28 | 4.44 | 4.72 | 23132.11 | -0.00001 | 6.28 |
| 35.92 | 6.28 | 4.44 | 4.71 | 23104.10 | -0.00001 | 6.28 |
| 36.00 | 6.28 | 4.44 | 4.71 | 23076.22 | -0.00001 | 6.27 |
| 36.08 | 6.27 | 4.44 | 4.71 | 23048.46 | -0.00001 | 6.27 |
| 36.17 | 6.27 | 4.44 | 4.71 | 23020.83 | -0.00001 | 6.27 |
| 36.25 | 6.27 | 4.44 | 4.71 | 22993.33 | -0.00001 | 6.26 |
| 36.33 | 6.26 | 4.44 | 4.71 | 22965.95 | -0.00001 | 6.26 |
| 36.42 | 6.26 | 4.44 | 4.71 | 22938.68 | -0.00001 | 6.26 |
| 36.50 | 6.26 | 4.44 | 4.71 | 22911.54 | -0.00001 | 6.25 |
| 36.58 | 6.25 | 4.44 | 4.70 | 22884.51 | -0.00001 | 6.25 |
| 36.67 | 6.25 | 4.44 | 4.70 | 22857.60 | -0.00001 | 6.25 |
| 36.75 | 6.25 | 4.44 | 4.70 | 22830.79 | -0.00001 | 6.24 |
| 36.83 | 6.24 | 4.44 | 4.70 | 22804.10 | -0.00001 | 6.24 |
| 36.92 | 6.24 | 4.44 | 4.70 | 22777.52 | -0.00001 | 6.24 |
| 37.00 | 6.24 | 4.44 | 4.70 | 22751.03 | -0.00001 | 6.23 |
| 37.08 | 6.23 | 4.44 | 4.70 | 22724.66 | -0.00001 | 6.23 |
| 37.17 | 6.23 | 4.44 | 4.70 | 22698.38 | -0.00001 | 6.23 |
| 37.25 | 6.23 | 4.44 | 4.69 | 22672.20 | -0.00001 | 6.22 |
| 37.33 | 6.22 | 4.44 | 4.69 | 22646.12 | -0.00001 | 6.22 |
| 37.42 | 6.22 | 4.44 | 4.69 | 22620.13 | -0.00001 | 6.22 |
| 37.50 | 6.22 | 4.44 | 4.69 | 22594.23 | -0.00001 | 6.21 |
| 37.58 | 6.21 | 4.44 | 4.69 | 22568.41 | -0.00001 | 6.21 |
| 37.67 | 6.21 | 4.44 | 4.69 | 22542.68 | -0.00001 | 6.21 |
| 37.75 | 6.21 | 4.44 | 4.69 | 22517.04 | -0.00001 | 6.20 |
| 37.83 | 6.20 | 4.44 | 4.69 | 22491.47 | -0.00001 | 6.20 |
| 37.92 | 6.20 | 4.44 | 4.68 | 22465.98 | -0.00001 | 6.20 |
| 38.00 | 6.20 | 4.44 | 4.68 | 22440.56 | -0.00001 | 6.19 |
| 38.08 | 6.19 | 4.44 | 4.68 | 22415.21 | -0.00001 | 6.19 |

Table A.1 (Contd.)

| **t (hr)** | **h (m)** | **I(t) (m³/s)** | **Q(h) (m³/s)** | **A(h) (m²)** | **f(h, t)** | ***h*(*n*+1) (m)** |
|---|---|---|---|---|---|---|
| 38.17 | 6.19 | 4.44 | 4.68 | 22389.93 | -0.00001 | 6.19 |
| 38.25 | 6.19 | 4.44 | 4.68 | 22364.71 | -0.00001 | 6.18 |
| 38.33 | 6.18 | 4.44 | 4.68 | 22339.55 | -0.00001 | 6.18 |
| 38.42 | 6.18 | 4.44 | 4.68 | 22314.44 | -0.00001 | 6.18 |
| 38.50 | 6.18 | 4.43 | 4.68 | 22289.39 | -0.00001 | 6.17 |
| 38.58 | 6.17 | 4.43 | 4.67 | 22264.38 | -0.00001 | 6.17 |
| 38.67 | 6.17 | 4.43 | 4.67 | 22239.42 | -0.00001 | 6.17 |
| 38.83 | 6.16 | 4.43 | 4.67 | 22189.61 | -0.00001 | 6.16 |
| 38.92 | 6.16 | 4.43 | 4.67 | 22164.75 | -0.00001 | 6.16 |
| 39.00 | 6.16 | 4.43 | 4.67 | 22139.92 | -0.00001 | 6.15 |
| 39.08 | 6.15 | 4.43 | 4.67 | 22115.11 | -0.00001 | 6.15 |
| 39.17 | 6.15 | 4.43 | 4.67 | 22090.31 | -0.00001 | 6.15 |
| 39.25 | 6.15 | 4.43 | 4.66 | 22065.52 | -0.00001 | 6.14 |
| 39.33 | 6.14 | 4.42 | 4.66 | 22040.73 | -0.00001 | 6.14 |
| 39.42 | 6.14 | 4.42 | 4.66 | 22015.94 | -0.00001 | 6.14 |
| 39.50 | 6.14 | 4.42 | 4.66 | 21991.14 | -0.00001 | 6.13 |
| 39.58 | 6.13 | 4.42 | 4.66 | 21966.33 | -0.00001 | 6.13 |
| 39.67 | 6.13 | 4.42 | 4.66 | 21941.48 | -0.00001 | 6.13 |
| 39.75 | 6.13 | 4.42 | 4.66 | 21916.61 | -0.00001 | 6.12 |
| 39.83 | 6.12 | 4.42 | 4.66 | 21891.70 | -0.00001 | 6.12 |
| 39.92 | 6.12 | 4.41 | 4.65 | 21866.73 | -0.00001 | 6.12 |
| 40.00 | 6.12 | 4.41 | 4.65 | 21841.71 | -0.00001 | 6.12 |
| 40.08 | 6.12 | 4.41 | 4.65 | 21816.61 | -0.00001 | 6.11 |
| 40.17 | 6.11 | 4.41 | 4.65 | 21791.44 | -0.00001 | 6.11 |
| 40.25 | 6.11 | 4.41 | 4.65 | 21766.17 | -0.00001 | 6.11 |
| 40.33 | 6.11 | 4.40 | 4.65 | 21740.80 | -0.00001 | 6.10 |
| 40.42 | 6.10 | 4.40 | 4.65 | 21715.30 | -0.00001 | 6.10 |
| 40.50 | 6.10 | 4.40 | 4.65 | 21689.68 | -0.00001 | 6.09 |
| 40.58 | 6.09 | 4.40 | 4.64 | 21663.90 | -0.00001 | 6.09 |
| 40.67 | 6.09 | 4.39 | 4.64 | 21637.96 | -0.00001 | 6.09 |
| 40.75 | 6.09 | 4.39 | 4.64 | 21611.82 | -0.00001 | 6.08 |
| 40.83 | 6.08 | 4.39 | 4.64 | 21585.48 | -0.00001 | 6.08 |
| 40.92 | 6.08 | 4.38 | 4.64 | 21558.90 | -0.00001 | 6.08 |
| 41.00 | 6.08 | 4.38 | 4.64 | 21532.07 | -0.00001 | 6.07 |
| 41.08 | 6.07 | 4.37 | 4.64 | 21504.94 | -0.00001 | 6.07 |
| 41.17 | 6.07 | 4.37 | 4.63 | 21477.50 | -0.00001 | 6.07 |
| 41.25 | 6.07 | 4.36 | 4.63 | 21449.69 | -0.00001 | 6.06 |
| 41.33 | 6.06 | 4.36 | 4.63 | 21421.48 | -0.00001 | 6.06 |
| 41.42 | 6.06 | 4.35 | 4.63 | 21392.83 | -0.00001 | 6.05 |
| 41.50 | 6.05 | 4.35 | 4.63 | 21363.67 | -0.00001 | 6.05 |
| 41.58 | 6.05 | 4.34 | 4.63 | 21333.95 | -0.00001 | 6.05 |
| 41.67 | 6.05 | 4.33 | 4.63 | 21303.58 | -0.00001 | 6.04 |

Table A.1 (Contd.)

| t (hr) | h (m) | I(t) (m³/s) | Q(h) (m³/s) | A(h) (m²) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 41.75 | 6.04 | 4.32 | 4.62 | 21272.49 | -0.00001 | 6.04 |
| 41.83 | 6.04 | 4.31 | 4.62 | 21240.57 | -0.00001 | 6.03 |
| 41.92 | 6.03 | 4.30 | 4.62 | 21207.70 | -0.00002 | 6.03 |
| 42.00 | 6.03 | 4.28 | 4.62 | 21173.72 | -0.00002 | 6.02 |
| 42.08 | 6.02 | 4.27 | 4.62 | 21138.45 | -0.00002 | 6.02 |
| 42.17 | 6.02 | 4.25 | 4.62 | 21101.65 | -0.00002 | 6.01 |
| 42.25 | 6.01 | 4.22 | 4.61 | 21063.01 | -0.00002 | 6.01 |
| 41.75 | 6.04 | 4.32 | 4.62 | 21272.49 | -0.00001 | 6.04 |
| 42.33 | 6.01 | 4.19 | 4.61 | 21022.12 | -0.00002 | 6.00 |
| 42.42 | 6.00 | 4.16 | 4.61 | 20978.38 | -0.00002 | 6.00 |
| 42.50 | 6.00 | 4.10 | 4.61 | 20930.86 | -0.00002 | 5.99 |
| 42.58 | 5.99 | 4.05 | 4.60 | 20877.90 | -0.00003 | 5.98 |
| 42.67 | 5.98 | 3.99 | 4.60 | 20819.24 | -0.00003 | 5.97 |
| 42.75 | 5.97 | 3.93 | 4.60 | 20754.95 | -0.00003 | 5.96 |
| 42.83 | 5.96 | 3.88 | 4.59 | 20685.16 | -0.00003 | 5.95 |
| 42.92 | 5.95 | 3.83 | 4.59 | 20609.95 | -0.00004 | 5.94 |
| 43.00 | 5.94 | 3.77 | 4.59 | 20529.41 | -0.00004 | 5.93 |
| 43.08 | 5.93 | 3.72 | 4.58 | 20443.65 | -0.00004 | 5.92 |
| 43.17 | 5.92 | 3.67 | 4.58 | 20352.76 | -0.00004 | 5.90 |
| 43.25 | 5.90 | 3.62 | 4.57 | 20256.82 | -0.00005 | 5.89 |
| 43.33 | 5.89 | 3.57 | 4.57 | 20155.92 | -0.00005 | 5.87 |
| 43.42 | 5.87 | 3.52 | 4.56 | 20050.16 | -0.00005 | 5.86 |
| 43.50 | 5.86 | 3.47 | 4.55 | 19939.61 | -0.00005 | 5.84 |
| 43.58 | 5.84 | 3.42 | 4.55 | 19824.35 | -0.00006 | 5.83 |
| 43.67 | 5.83 | 3.37 | 4.54 | 19704.48 | -0.00006 | 5.81 |
| 43.75 | 5.81 | 3.32 | 4.53 | 19580.07 | -0.00006 | 5.79 |
| 43.83 | 5.79 | 3.28 | 4.53 | 19451.20 | -0.00006 | 5.77 |
| 43.92 | 5.77 | 3.23 | 4.52 | 19317.94 | -0.00007 | 5.75 |
| 44.00 | 5.75 | 3.18 | 4.51 | 19180.37 | -0.00007 | 5.73 |
| 44.08 | 5.73 | 3.14 | 4.50 | 19038.57 | -0.00007 | 5.71 |
| 44.17 | 5.71 | 3.09 | 4.49 | 18892.61 | -0.00007 | 5.69 |
| 44.25 | 5.69 | 3.05 | 4.49 | 18742.55 | -0.00008 | 5.66 |
| 44.33 | 5.66 | 3.01 | 4.48 | 18588.47 | -0.00008 | 5.64 |
| 44.42 | 5.64 | 2.96 | 4.47 | 18430.44 | -0.00008 | 5.61 |
| 44.50 | 5.61 | 2.92 | 4.46 | 18268.52 | -0.00008 | 5.59 |
| 44.58 | 5.59 | 2.88 | 4.45 | 18102.78 | -0.00009 | 5.56 |
| 44.67 | 5.56 | 2.84 | 4.44 | 17933.27 | -0.00009 | 5.54 |
| 44.75 | 5.54 | 2.80 | 4.43 | 17760.07 | -0.00009 | 5.51 |
| 44.83 | 5.51 | 2.76 | 4.42 | 17583.23 | -0.00009 | 5.48 |
| 44.92 | 5.48 | 2.72 | 4.40 | 17402.81 | -0.00010 | 5.45 |
| 45.00 | 5.45 | 2.68 | 4.39 | 17218.87 | -0.00010 | 5.42 |
| 45.08 | 5.42 | 2.64 | 4.38 | 17031.46 | -0.00010 | 5.39 |

Table A.1 (Contd.)

| **t (hr)** | **h (m)** | **I(t) ($m^3/s$)** | **Q(h) ($m^3/s$)** | **A(h) ($m^2$)** | **f(h, t)** | **$h(n+1)$ (m)** |
|---|---|---|---|---|---|---|
| 45.17 | 5.39 | 2.61 | 4.37 | 16840.64 | -0.00010 | 5.36 |
| 45.25 | 5.36 | 2.57 | 4.36 | 16646.46 | -0.00011 | 5.33 |
| 45.33 | 5.33 | 2.53 | 4.34 | 16448.97 | -0.00011 | 5.29 |
| 45.42 | 5.29 | 2.50 | 4.33 | 16248.21 | -0.00011 | 5.26 |
| 45.50 | 5.26 | 2.46 | 4.31 | 16044.24 | -0.00012 | 5.23 |
| 45.58 | 5.23 | 2.43 | 4.30 | 15837.10 | -0.00012 | 5.19 |
| 45.67 | 5.19 | 2.39 | 4.29 | 15626.83 | -0.00012 | 5.15 |
| 45.75 | 5.15 | 2.36 | 4.27 | 15413.48 | -0.00012 | 5.12 |
| 45.92 | 5.08 | 2.29 | 4.24 | 14977.66 | -0.00013 | 5.04 |
| 46.00 | 5.04 | 2.26 | 4.22 | 14755.28 | -0.00013 | 5.00 |
| 46.08 | 5.00 | 2.22 | 4.21 | 14529.95 | -0.00014 | 4.96 |
| 46.17 | 4.96 | 2.19 | 4.19 | 14301.70 | -0.00014 | 4.92 |
| 46.25 | 4.92 | 2.16 | 4.17 | 14070.57 | -0.00014 | 4.87 |
| 46.33 | 4.87 | 2.13 | 4.15 | 13836.58 | -0.00015 | 4.83 |
| 46.42 | 4.83 | 2.10 | 4.13 | 13599.76 | -0.00015 | 4.79 |
| 46.50 | 4.79 | 2.07 | 4.11 | 13360.11 | -0.00015 | 4.74 |
| 46.58 | 4.74 | 2.04 | 4.10 | 13117.66 | -0.00016 | 4.69 |
| 46.67 | 4.69 | 2.01 | 4.07 | 12872.42 | -0.00016 | 4.64 |
| 46.75 | 4.64 | 1.98 | 4.05 | 12624.41 | -0.00016 | 4.59 |
| 46.83 | 4.59 | 1.95 | 4.03 | 12373.62 | -0.00017 | 4.54 |
| 46.92 | 4.54 | 1.92 | 4.01 | 12120.07 | -0.00017 | 4.49 |
| 47.00 | 4.49 | 1.89 | 3.99 | 11863.74 | -0.00018 | 4.44 |
| 47.08 | 4.44 | 1.87 | 3.96 | 11604.64 | -0.00018 | 4.39 |
| 47.50 | 4.15 | 1.73 | 3.83 | 10267.02 | -0.00020 | 4.09 |
| 47.58 | 4.09 | 1.71 | 3.81 | 9990.89 | -0.00021 | 4.03 |
| 47.67 | 4.03 | 1.68 | 3.78 | 9711.82 | -0.00022 | 3.97 |
| 47.75 | 3.97 | 1.66 | 3.75 | 9429.74 | -0.00022 | 3.90 |
| 47.83 | 3.90 | 1.64 | 3.71 | 9144.60 | -0.00023 | 3.83 |
| 47.92 | 3.83 | 1.61 | 3.68 | 8856.33 | -0.00023 | 3.76 |
| 48.00 | 3.76 | 1.59 | 3.65 | 8564.87 | -0.00024 | 3.69 |
| 48.08 | 3.69 | 1.56 | 3.61 | 8270.11 | -0.00025 | 3.61 |
| 48.17 | 3.61 | 1.54 | 3.58 | 7971.98 | -0.00026 | 3.54 |
| 48.25 | 3.54 | 1.52 | 3.54 | 7670.36 | -0.00026 | 3.46 |
| 48.33 | 3.46 | 1.50 | 3.50 | 7365.13 | -0.00027 | 3.38 |
| 48.42 | 3.38 | 1.47 | 3.46 | 7056.15 | -0.00028 | 3.29 |
| 48.50 | 3.29 | 1.45 | 3.41 | 6743.29 | -0.00029 | 3.21 |
| 48.58 | 3.21 | 1.43 | 3.37 | 6426.37 | -0.00030 | 3.12 |
| 48.67 | 3.12 | 1.41 | 3.32 | 6105.22 | -0.00031 | 3.02 |
| 48.75 | 3.02 | 1.39 | 3.27 | 5779.62 | -0.00033 | 2.92 |
| 48.83 | 2.92 | 1.37 | 3.22 | 5449.37 | -0.00034 | 2.82 |
| 48.92 | 2.82 | 1.35 | 3.16 | 5114.20 | -0.00035 | 2.72 |
| 49.00 | 2.72 | 1.33 | 3.10 | 4773.85 | -0.00037 | 2.60 |

Table A.1 (Contd.)

| **t (hr)** | **h (m)** | **I(t) ($m^3/s$)** | **Q(h) ($m^3/s$)** | **A(h) ($m^2$)** | **f(h, t)** | ***h*(*n*+1) (m)** |
|---|---|---|---|---|---|---|
| 49.08 | 2.60 | 1.31 | 3.04 | 4428.03 | -0.00039 | 2.49 |
| 49.17 | 2.49 | 1.29 | 2.97 | 4076.41 | -0.00041 | 2.36 |
| 49.25 | 2.36 | 1.27 | 2.89 | 3718.66 | -0.00044 | 2.23 |
| 49.33 | 2.23 | 1.25 | 2.81 | 3354.43 | -0.00046 | 2.09 |
| 47.50 | 4.15 | 1.73 | 3.83 | 10267.02 | -0.00020 | 4.09 |
| 47.58 | 4.09 | 1.71 | 3.81 | 9990.89 | -0.00021 | 4.03 |
| 47.67 | 4.03 | 1.68 | 3.78 | 9711.82 | -0.00022 | 3.97 |
| 47.75 | 3.97 | 1.66 | 3.75 | 9429.74 | -0.00022 | 3.90 |
| 47.92 | 3.83 | 1.61 | 3.68 | 8856.33 | -0.00023 | 3.76 |
| 48.00 | 3.76 | 1.59 | 3.65 | 8564.87 | -0.00024 | 3.69 |
| 48.08 | 3.69 | 1.56 | 3.61 | 8270.11 | -0.00025 | 3.61 |
| 48.17 | 3.61 | 1.54 | 3.58 | 7971.98 | -0.00026 | 3.54 |
| 48.25 | 3.54 | 1.52 | 3.54 | 7670.36 | -0.00026 | 3.46 |
| 48.33 | 3.46 | 1.50 | 3.50 | 7365.13 | -0.00027 | 3.38 |
| 48.42 | 3.38 | 1.47 | 3.46 | 7056.15 | -0.00028 | 3.29 |
| 48.50 | 3.29 | 1.45 | 3.41 | 6743.29 | -0.00029 | 3.21 |
| 48.58 | 3.21 | 1.43 | 3.37 | 6426.37 | -0.00030 | 3.12 |
| 48.67 | 3.12 | 1.41 | 3.32 | 6105.22 | -0.00031 | 3.02 |
| 48.75 | 3.02 | 1.39 | 3.27 | 5779.62 | -0.00033 | 2.92 |
| 48.83 | 2.92 | 1.37 | 3.22 | 5449.37 | -0.00034 | 2.82 |
| 48.92 | 2.82 | 1.35 | 3.16 | 5114.20 | -0.00035 | 2.72 |
| 49.00 | 2.72 | 1.33 | 3.10 | 4773.85 | -0.00037 | 2.60 |
| 49.08 | 2.60 | 1.31 | 3.04 | 4428.03 | -0.00039 | 2.49 |
| 49.17 | 2.49 | 1.29 | 2.97 | 4076.41 | -0.00041 | 2.36 |
| 49.25 | 2.36 | 1.27 | 2.89 | 3718.66 | -0.00044 | 2.23 |
| 49.33 | 2.23 | 1.25 | 2.81 | 3354.43 | -0.00046 | 2.09 |

Table A.2 Flood routing calculations of the Fabrika Creek

| t (hr) | h (m) | I(t) (m³/s) | Q(h) (m³/s) | A(h) (m²) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 0.00 | 2.00 | 0.00 | 0.00 | 6.70 | 0.00000 | 2.00 |
| 0.08 | 2.00 | 0.00 | 0.00 | 6.70 | 0.00000 | 2.00 |
| 0.17 | 2.00 | 0.00 | 0.00 | 7.59 | 0.00004 | 2.01 |
| 0.25 | 2.01 | 0.00 | 0.00 | 16.36 | 0.00000 | 2.01 |
| 0.33 | 2.01 | 0.00 | 0.00 | 16.36 | 0.00000 | 2.01 |
| 0.42 | 2.01 | 0.01 | 0.01 | 16.36 | 0.00000 | 2.01 |
| 0.50 | 2.01 | 0.01 | 0.01 | 16.36 | 0.00000 | 2.01 |
| 0.58 | 2.01 | 0.02 | 0.02 | 16.36 | 0.00000 | 2.01 |
| 0.67 | 2.01 | 0.04 | 0.04 | 16.36 | 0.00000 | 2.01 |
| 0.75 | 2.01 | 0.06 | 0.06 | 5.30 | 0.00000 | 2.01 |
| 0.83 | 2.01 | 0.08 | 0.08 | 16.36 | 0.00000 | 2.01 |
| 0.92 | 2.01 | 0.11 | 0.11 | 16.36 | 0.00000 | 2.01 |
| 1.00 | 2.01 | 0.15 | 0.15 | 4.10 | 0.00000 | 2.01 |
| 1.08 | 2.01 | 0.19 | 0.19 | 16.36 | 0.00000 | 2.01 |
| 1.17 | 2.01 | 0.24 | 0.24 | 16.36 | 0.00000 | 2.01 |
| 1.25 | 2.01 | 0.30 | 0.30 | 16.36 | 0.00000 | 2.01 |
| 1.33 | 2.01 | 0.37 | 0.37 | 16.36 | 0.00000 | 2.01 |
| 1.42 | 2.01 | 0.45 | 0.45 | 16.36 | 0.00000 | 2.01 |
| 1.50 | 2.01 | 0.54 | 0.54 | 16.36 | 0.00000 | 2.01 |
| 1.58 | 2.01 | 0.64 | 0.64 | 16.36 | 0.00000 | 2.01 |
| 1.67 | 2.01 | 0.76 | 0.76 | 16.36 | 0.00000 | 2.01 |
| 1.75 | 2.01 | 0.88 | 0.88 | 16.36 | 0.00000 | 2.01 |
| 1.83 | 2.01 | 1.02 | 1.02 | 16.36 | 0.00002 | 2.02 |
| 1.92 | 2.02 | 1.17 | 1.17 | 19.45 | 0.00002 | 2.02 |
| 2.00 | 2.02 | 1.33 | 1.33 | 22.76 | 0.00000 | 2.02 |
| 2.08 | 2.02 | 1.51 | 1.51 | 22.76 | 0.00000 | 2.02 |
| 2.17 | 2.02 | 1.70 | 1.70 | 22.76 | 0.00000 | 2.02 |
| 2.25 | 2.02 | 1.91 | 1.91 | 22.76 | 0.00000 | 2.02 |
| 2.33 | 2.02 | 2.12 | 2.12 | 22.76 | 0.00000 | 2.02 |
| 2.42 | 2.02 | 2.36 | 2.36 | 22.76 | 0.00000 | 2.02 |
| 2.50 | 2.02 | 2.61 | 2.65 | 22.76 | -0.00163 | 1.54 |
| 2.58 | 1.54 | 2.87 | 2.87 | -227.74 | -0.00001 | 1.53 |
| 2.67 | 1.53 | 3.15 | 3.15 | -229.06 | -0.00001 | 1.53 |
| 2.75 | 1.53 | 3.45 | 3.49 | -230.20 | 0.00018 | 1.58 |
| 2.83 | 1.58 | 3.76 | 3.70 | -210.08 | -0.00028 | 1.50 |
| 2.92 | 1.50 | 4.08 | 4.01 | -239.55 | -0.00031 | 1.41 |
| 3.00 | 1.41 | 4.43 | 4.20 | -267.14 | -0.00085 | 1.15 |
| 3.08 | 1.15 | 4.78 | 7.50 | -313.36 | 0.00867 | 3.76 |
| 3.17 | 3.76 | 5.16 | 5.05 | 2243.10 | 0.00005 | 3.77 |
| 3.25 | 3.77 | 5.55 | 5.45 | 2270.33 | 0.00004 | 3.78 |
| 3.33 | 3.78 | 5.95 | 8.14 | 2294.53 | -0.00095 | 3.50 |
| 3.42 | 3.50 | 6.37 | 7.82 | 1774.89 | -0.00082 | 3.25 |

Table A.2 (Contd.)

| t (hr) | h (m) | I(t) ($m^3/s$) | Q(h) ($m^3/s$) | A(h) ($m^2$) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 3.50 | 3.25 | 6.81 | 7.54 | 1375.85 | -0.00054 | 3.09 |
| 3.58 | 3.09 | 7.26 | 7.35 | 1137.95 | -0.00009 | 3.06 |
| 3.67 | 3.06 | 7.72 | 7.32 | 1101.37 | 0.00036 | 3.17 |
| 3.75 | 3.17 | 8.20 | 7.45 | 1257.80 | 0.00060 | 3.35 |
| 3.83 | 3.35 | 8.70 | 7.66 | 1534.33 | 0.00068 | 3.55 |
| 3.92 | 3.55 | 9.21 | 7.89 | 1876.13 | 0.00070 | 3.77 |
| 4.00 | 3.77 | 9.73 | 8.12 | 2263.31 | 0.00071 | 3.98 |
| 4.08 | 3.98 | 10.27 | 8.35 | 2689.15 | 0.00072 | 4.19 |
| 4.17 | 4.19 | 10.83 | 8.57 | 3150.92 | 0.00072 | 4.41 |
| 4.25 | 4.41 | 13.75 | 8.79 | 3647.29 | 0.00136 | 4.82 |
| 4.33 | 4.82 | 19.99 | 9.18 | 4686.01 | 0.00231 | 5.51 |
| 4.42 | 5.51 | 24.67 | 9.82 | 6739.17 | 0.00220 | 6.17 |
| 4.50 | 6.17 | 27.54 | 14.12 | 9053.02 | 0.00148 | 6.62 |
| 4.58 | 6.62 | 29.57 | 24.18 | 10809.12 | 0.00050 | 6.77 |
| 4.67 | 6.77 | 31.30 | 27.56 | 11435.61 | 0.00033 | 6.86 |
| 4.75 | 6.86 | 32.96 | 29.78 | 11856.78 | 0.00027 | 6.94 |
| 4.83 | 6.94 | 34.60 | 31.60 | 12207.72 | 0.00025 | 7.02 |
| 4.92 | 7.02 | 36.27 | 33.27 | 12535.15 | 0.00024 | 7.09 |
| 5.00 | 7.09 | 37.95 | 34.89 | 12857.58 | 0.00024 | 7.16 |
| 5.08 | 7.16 | 39.65 | 36.50 | 13182.63 | 0.00024 | 7.23 |
| 5.17 | 7.23 | 41.38 | 38.12 | 13513.53 | 0.00024 | 7.30 |
| 5.25 | 7.30 | 43.13 | 39.75 | 13851.62 | 0.00024 | 7.38 |
| 5.33 | 7.38 | 44.89 | 41.40 | 14197.46 | 0.00025 | 7.45 |
| 5.42 | 7.45 | 46.68 | 43.07 | 14551.29 | 0.00025 | 7.53 |
| 5.50 | 7.53 | 48.48 | 44.75 | 14913.18 | 0.00025 | 7.60 |
| 5.58 | 7.60 | 50.31 | 46.44 | 15283.14 | 0.00025 | 7.68 |
| 5.67 | 7.68 | 52.14 | 48.15 | 15661.14 | 0.00025 | 7.75 |
| 5.75 | 7.75 | 53.99 | 49.88 | 16047.12 | 0.00026 | 7.83 |
| 5.83 | 7.83 | 55.86 | 51.61 | 16441.01 | 0.00026 | 7.91 |
| 5.92 | 7.91 | 57.74 | 53.36 | 16842.74 | 0.00026 | 7.99 |
| 6.00 | 7.99 | 59.63 | 55.12 | 17252.21 | 0.00026 | 8.06 |
| 6.08 | 8.06 | 61.53 | 56.88 | 17669.32 | 0.00026 | 8.14 |
| 6.17 | 8.14 | 63.44 | 58.66 | 18093.98 | 0.00026 | 8.22 |
| 6.25 | 8.22 | 65.36 | 60.44 | 18526.07 | 0.00027 | 8.30 |
| 6.33 | 8.30 | 67.28 | 62.24 | 18965.46 | 0.00027 | 8.38 |
| 6.42 | 8.38 | 69.21 | 64.03 | 19412.03 | 0.00027 | 8.46 |
| 6.50 | 8.46 | 71.15 | 65.84 | 19865.65 | 0.00027 | 8.54 |
| 6.58 | 8.54 | 73.10 | 67.65 | 20326.16 | 0.00027 | 8.62 |
| 6.67 | 8.62 | 75.04 | 69.46 | 20793.42 | 0.00027 | 8.70 |
| 6.75 | 8.70 | 76.99 | 71.27 | 21267.28 | 0.00027 | 8.78 |
| 6.83 | 8.78 | 78.95 | 73.09 | 21747.56 | 0.00027 | 8.86 |
| 6.92 | 8.86 | 80.90 | 74.91 | 22234.10 | 0.00027 | 8.95 |

Table A.2 (Contd.)

| t (hr) | h (m) | I(t) ($m^3/s$) | Q(h) ($m^3/s$) | A(h) ($m^2$) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 7.00 | 8.95 | 82.85 | 76.73 | 22726.72 | 0.00027 | 9.03 |
| 7.08 | 9.03 | 84.80 | 78.54 | 23225.24 | 0.00027 | 9.11 |
| 7.17 | 9.11 | 86.75 | 80.36 | 23729.47 | 0.00027 | 9.19 |
| 7.25 | 9.19 | 88.70 | 82.18 | 24239.22 | 0.00027 | 9.27 |
| 7.33 | 9.27 | 90.64 | 83.99 | 24754.29 | 0.00027 | 9.35 |
| 7.42 | 9.35 | 92.58 | 85.80 | 25274.47 | 0.00027 | 9.43 |
| 7.50 | 9.43 | 94.51 | 87.61 | 25799.55 | 0.00027 | 9.51 |
| 7.58 | 9.51 | 96.44 | 89.42 | 26329.33 | 0.00027 | 9.59 |
| 7.67 | 9.59 | 98.36 | 91.21 | 26863.57 | 0.00027 | 9.67 |
| 7.75 | 9.67 | 100.27 | 93.01 | 27402.06 | 0.00027 | 9.75 |
| 7.83 | 9.75 | 102.17 | 94.79 | 27944.58 | 0.00026 | 9.83 |
| 7.92 | 9.83 | 104.07 | 96.57 | 28490.89 | 0.00026 | 9.91 |
| 8.00 | 9.91 | 105.95 | 98.35 | 29040.75 | 0.00026 | 9.99 |
| 8.08 | 9.99 | 107.82 | 100.11 | 29593.93 | 0.00026 | 10.06 |
| 8.17 | 10.06 | 109.69 | 101.87 | 30150.18 | 0.00026 | 10.14 |
| 8.25 | 10.14 | 111.54 | 103.61 | 30709.28 | 0.00026 | 10.22 |
| 8.33 | 10.22 | 113.37 | 105.35 | 31270.95 | 0.00026 | 10.30 |
| 8.42 | 10.30 | 115.19 | 107.08 | 31834.97 | 0.00025 | 10.37 |
| 8.50 | 10.37 | 117.00 | 108.80 | 32401.08 | 0.00025 | 10.45 |
| 8.58 | 10.45 | 118.80 | 110.50 | 32969.03 | 0.00025 | 10.52 |
| 8.67 | 10.52 | 120.57 | 112.20 | 33538.55 | 0.00025 | 10.60 |
| 8.75 | 10.60 | 122.34 | 113.88 | 34109.40 | 0.00025 | 10.67 |
| 8.83 | 10.67 | 124.08 | 115.55 | 34681.33 | 0.00025 | 10.75 |
| 8.92 | 10.75 | 125.81 | 117.20 | 35254.06 | 0.00024 | 10.82 |
| 9.00 | 10.82 | 127.52 | 118.85 | 35827.35 | 0.00024 | 10.89 |
| 9.08 | 10.89 | 129.21 | 120.48 | 36400.94 | 0.00024 | 10.97 |
| 9.17 | 10.97 | 130.89 | 122.09 | 36974.56 | 0.00024 | 11.04 |
| 9.25 | 11.04 | 132.54 | 123.69 | 37547.96 | 0.00024 | 11.11 |
| 9.33 | 11.11 | 134.18 | 125.28 | 38120.87 | 0.00023 | 11.18 |
| 9.42 | 11.18 | 135.79 | 126.85 | 38693.05 | 0.00023 | 11.25 |
| 9.50 | 11.25 | 137.39 | 128.40 | 39264.23 | 0.00023 | 11.32 |
| 9.58 | 11.32 | 138.96 | 129.94 | 39834.15 | 0.00023 | 11.38 |
| 9.67 | 11.38 | 140.51 | 131.47 | 40402.56 | 0.00022 | 11.45 |
| 9.75 | 11.45 | 142.04 | 132.97 | 40969.21 | 0.00022 | 11.52 |
| 9.83 | 11.52 | 143.55 | 134.46 | 41533.83 | 0.00022 | 11.58 |
| 9.92 | 11.58 | 145.03 | 135.93 | 42096.18 | 0.00022 | 11.65 |
| 10.00 | 11.65 | 146.50 | 137.39 | 42656.01 | 0.00021 | 11.71 |
| 10.08 | 11.71 | 147.94 | 138.82 | 43213.07 | 0.00021 | 11.77 |
| 10.17 | 11.77 | 149.35 | 140.24 | 43767.11 | 0.00021 | 11.84 |
| 10.25 | 11.84 | 150.75 | 141.64 | 44317.89 | 0.00021 | 11.90 |
| 10.33 | 11.90 | 152.11 | 143.02 | 44865.17 | 0.00020 | 11.96 |
| 10.42 | 11.96 | 153.46 | 144.38 | 45408.70 | 0.00020 | 12.02 |

Table A.2 (Contd.)

| **t (hr)** | **h (m)** | **I(t) ($m^3$/s)** | **Q(h) ($m^3$/s)** | **A(h) ($m^2$)** | **f(h, t)** | **$h(n+1)$ (m)** |
|---|---|---|---|---|---|---|
| 10.50 | 12.02 | 154.78 | 145.73 | 45948.25 | 0.00020 | 12.08 |
| 10.58 | 12.08 | 156.08 | 147.05 | 46483.60 | 0.00019 | 12.14 |
| 10.67 | 12.14 | 157.35 | 148.36 | 47014.49 | 0.00019 | 12.19 |
| 10.75 | 12.19 | 158.59 | 149.64 | 47540.72 | 0.00019 | 12.25 |
| 10.83 | 12.25 | 159.81 | 150.91 | 48062.06 | 0.00019 | 12.31 |
| 10.92 | 12.31 | 161.01 | 152.15 | 48578.28 | 0.00018 | 12.36 |
| 11.00 | 12.36 | 162.18 | 153.38 | 49089.17 | 0.00018 | 12.41 |
| 11.08 | 12.41 | 163.32 | 154.58 | 49594.51 | 0.00018 | 12.47 |
| 11.17 | 12.47 | 164.44 | 155.76 | 50094.10 | 0.00017 | 12.52 |
| 11.25 | 12.52 | 165.53 | 156.93 | 50587.73 | 0.00017 | 12.57 |
| 11.33 | 12.57 | 166.60 | 158.07 | 51075.20 | 0.00017 | 12.62 |
| 11.42 | 12.62 | 167.64 | 159.19 | 51556.31 | 0.00016 | 12.67 |
| 11.50 | 12.67 | 168.65 | 160.29 | 52030.86 | 0.00016 | 12.72 |
| 11.58 | 12.72 | 169.64 | 161.37 | 52498.67 | 0.00016 | 12.77 |
| 11.67 | 12.77 | 170.60 | 162.43 | 52959.56 | 0.00015 | 12.81 |
| 11.75 | 12.81 | 171.54 | 163.47 | 53413.34 | 0.00015 | 12.86 |
| 11.83 | 12.86 | 172.45 | 164.48 | 53859.84 | 0.00015 | 12.90 |
| 11.92 | 12.90 | 173.33 | 165.48 | 54298.89 | 0.00014 | 12.94 |
| 12.00 | 12.94 | 174.19 | 166.45 | 54730.31 | 0.00014 | 12.99 |
| 12.08 | 12.99 | 175.02 | 167.40 | 55153.96 | 0.00014 | 13.03 |
| 12.17 | 13.03 | 175.83 | 168.33 | 55569.67 | 0.00014 | 13.07 |
| 12.25 | 13.07 | 176.61 | 169.23 | 55977.29 | 0.00013 | 13.11 |
| 12.33 | 13.11 | 177.36 | 170.12 | 56376.67 | 0.00013 | 13.15 |
| 12.42 | 13.15 | 178.09 | 170.98 | 56767.68 | 0.00013 | 13.18 |
| 12.50 | 13.18 | 178.79 | 171.82 | 57150.18 | 0.00012 | 13.22 |
| 12.58 | 13.22 | 179.46 | 172.64 | 57524.03 | 0.00012 | 13.26 |
| 12.67 | 13.26 | 180.11 | 173.43 | 57889.10 | 0.00012 | 13.29 |
| 12.75 | 13.29 | 180.73 | 174.21 | 58245.29 | 0.00011 | 13.33 |
| 12.83 | 13.33 | 181.33 | 174.96 | 58592.47 | 0.00011 | 13.36 |
| 12.92 | 13.36 | 181.90 | 175.69 | 58930.53 | 0.00011 | 13.39 |
| 13.00 | 13.39 | 182.45 | 176.40 | 59259.36 | 0.00010 | 13.42 |
| 13.08 | 13.42 | 182.97 | 177.08 | 59578.87 | 0.00010 | 13.45 |
| 13.17 | 13.45 | 183.46 | 177.75 | 59888.96 | 0.00010 | 13.48 |
| 13.25 | 13.48 | 183.94 | 178.39 | 60189.55 | 0.00009 | 13.51 |
| 13.33 | 13.51 | 184.38 | 179.00 | 60480.54 | 0.00009 | 13.53 |
| 13.42 | 13.53 | 184.80 | 179.60 | 60761.86 | 0.00009 | 13.56 |
| 13.50 | 13.56 | 185.20 | 180.18 | 61033.43 | 0.00008 | 13.58 |
| 13.58 | 13.58 | 185.57 | 180.73 | 61295.19 | 0.00008 | 13.61 |
| 13.67 | 13.61 | 185.92 | 181.26 | 61547.08 | 0.00008 | 13.63 |
| 13.75 | 13.63 | 186.24 | 181.77 | 61789.04 | 0.00007 | 13.65 |
| 13.83 | 13.65 | 186.54 | 182.25 | 62021.01 | 0.00007 | 13.67 |
| 13.92 | 13.67 | 186.82 | 182.72 | 62242.96 | 0.00007 | 13.69 |

Table A.2 (Contd.)

| t (hr) | h (m) | I(t) (m³/s) | Q(h) (m³/s) | A(h) (m²) | f(h, t) | *h*(*n*+1) (m) |
|---|---|---|---|---|---|---|
| 14.00 | 13.69 | 187.07 | 183.16 | 62454.83 | 0.00006 | 13.71 |
| 14.08 | 13.71 | 187.30 | 183.58 | 62656.59 | 0.00006 | 13.73 |
| 14.17 | 13.73 | 187.51 | 183.98 | 62848.22 | 0.00006 | 13.75 |
| 14.25 | 13.75 | 187.69 | 184.35 | 63029.68 | 0.00005 | 13.76 |
| 14.33 | 13.76 | 187.85 | 184.71 | 63200.97 | 0.00005 | 13.78 |
| 14.42 | 13.78 | 187.99 | 185.04 | 63362.05 | 0.00005 | 13.79 |
| 14.50 | 13.79 | 188.10 | 185.35 | 63512.93 | 0.00004 | 13.80 |
| 14.58 | 13.80 | 188.20 | 185.64 | 63653.59 | 0.00004 | 13.81 |
| 14.67 | 13.81 | 188.27 | 185.91 | 63784.05 | 0.00004 | 13.83 |
| 14.75 | 13.83 | 188.32 | 186.16 | 63904.30 | 0.00003 | 13.84 |
| 14.83 | 13.84 | 188.35 | 186.39 | 64014.36 | 0.00003 | 13.85 |
| 14.92 | 13.85 | 188.35 | 186.59 | 64114.23 | 0.00003 | 13.85 |
| 15.00 | 13.85 | 188.34 | 186.78 | 64203.95 | 0.00002 | 13.86 |
| 15.08 | 13.86 | 188.30 | 186.94 | 64283.54 | 0.00002 | 13.87 |
| 15.17 | 13.87 | 188.25 | 187.08 | 64353.03 | 0.00002 | 13.87 |
| 15.25 | 13.87 | 188.18 | 187.20 | 64412.45 | 0.00002 | 13.88 |
| 15.33 | 13.88 | 188.08 | 187.30 | 64461.85 | 0.00001 | 13.88 |
| 15.42 | 13.88 | 187.97 | 187.39 | 64501.26 | 0.00001 | 13.88 |
| 15.50 | 13.88 | 187.83 | 187.45 | 64530.75 | 0.00001 | 13.89 |
| 15.58 | 13.89 | 187.68 | 187.49 | 64550.35 | 0.00000 | 13.89 |
| 15.67 | 13.89 | 187.51 | 187.51 | 64560.14 | 0.00000 | 13.89 |
| 15.75 | 13.89 | 187.32 | 187.51 | 64560.17 | 0.00000 | 13.89 |
| 15.83 | 13.89 | 187.11 | 187.49 | 64550.51 | -0.00001 | 13.88 |
| 15.92 | 13.88 | 186.88 | 187.45 | 64531.23 | -0.00001 | 13.88 |
| 16.00 | 13.88 | 186.63 | 187.39 | 64502.41 | -0.00001 | 13.88 |
| 16.08 | 13.88 | 186.37 | 187.31 | 64464.12 | -0.00001 | 13.87 |
| 16.17 | 13.87 | 186.09 | 187.21 | 64416.46 | -0.00002 | 13.87 |
| 16.25 | 13.87 | 185.79 | 187.10 | 64359.50 | -0.00002 | 13.86 |
| 16.33 | 13.86 | 185.48 | 186.96 | 64293.35 | -0.00002 | 13.85 |
| 16.42 | 13.85 | 185.15 | 186.81 | 64218.09 | -0.00003 | 13.85 |
| 16.50 | 13.85 | 184.80 | 186.63 | 64133.82 | -0.00003 | 13.84 |
| 16.58 | 13.84 | 184.44 | 186.44 | 64040.65 | -0.00003 | 13.83 |
| 16.67 | 13.83 | 184.06 | 186.23 | 63938.69 | -0.00003 | 13.82 |
| 16.75 | 13.82 | 183.67 | 186.00 | 63828.03 | -0.00004 | 13.81 |
| 16.83 | 13.81 | 183.26 | 185.76 | 63708.80 | -0.00004 | 13.80 |
| 16.92 | 13.80 | 182.83 | 185.49 | 63581.11 | -0.00004 | 13.78 |
| 17.00 | 13.78 | 182.39 | 185.21 | 63445.08 | -0.00004 | 13.77 |
| 17.08 | 13.77 | 181.94 | 184.92 | 63300.84 | -0.00005 | 13.76 |
| 17.17 | 13.76 | 181.47 | 184.60 | 63148.50 | -0.00005 | 13.74 |
| 17.25 | 13.74 | 180.99 | 184.27 | 62988.19 | -0.00005 | 13.73 |
| 17.33 | 13.73 | 180.49 | 183.92 | 62820.05 | -0.00005 | 13.71 |
| 17.42 | 13.71 | 179.99 | 183.55 | 62644.20 | -0.00006 | 13.69 |

Table A.2 (Contd.)

| t (hr) | h (m) | I(t) ($m^3/s$) | Q(h) ($m^3/s$) | A(h) ($m^2$) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 17.50 | 13.69 | 179.46 | 183.17 | 62460.79 | -0.00006 | 13.67 |
| 17.58 | 13.67 | 178.93 | 182.77 | 62269.96 | -0.00006 | 13.66 |
| 17.67 | 13.66 | 178.38 | 182.36 | 62071.83 | -0.00006 | 13.64 |
| 17.75 | 13.64 | 177.82 | 181.93 | 61866.55 | -0.00007 | 13.62 |
| 17.83 | 13.62 | 177.25 | 181.48 | 61654.28 | -0.00007 | 13.60 |
| 17.92 | 13.60 | 176.67 | 181.02 | 61435.15 | -0.00007 | 13.57 |
| 18.00 | 13.57 | 176.07 | 180.55 | 61209.31 | -0.00007 | 13.55 |
| 18.08 | 13.55 | 175.46 | 180.06 | 60976.91 | -0.00008 | 13.53 |
| 18.17 | 13.53 | 174.85 | 179.55 | 60738.10 | -0.00008 | 13.51 |
| 18.25 | 13.51 | 174.22 | 179.03 | 60493.04 | -0.00008 | 13.48 |
| 18.33 | 13.48 | 173.58 | 178.50 | 60241.88 | -0.00008 | 13.46 |
| 18.42 | 13.46 | 172.93 | 177.95 | 59984.77 | -0.00008 | 13.43 |
| 18.50 | 13.43 | 172.27 | 177.39 | 59721.87 | -0.00009 | 13.41 |
| 18.58 | 13.41 | 171.60 | 176.81 | 59453.34 | -0.00009 | 13.38 |
| 18.67 | 13.38 | 170.92 | 176.22 | 59179.33 | -0.00009 | 13.35 |
| 18.75 | 13.35 | 170.23 | 175.62 | 58900.01 | -0.00009 | 13.33 |
| 18.83 | 13.33 | 169.54 | 175.01 | 58615.53 | -0.00009 | 13.30 |
| 18.92 | 13.30 | 168.83 | 174.38 | 58326.05 | -0.00010 | 13.27 |
| 19.00 | 13.27 | 168.12 | 173.74 | 58031.74 | -0.00010 | 13.24 |
| 19.08 | 13.24 | 167.39 | 173.09 | 57732.75 | -0.00010 | 13.21 |
| 19.17 | 13.21 | 166.66 | 172.43 | 57429.24 | -0.00010 | 13.18 |
| 19.25 | 13.18 | 165.92 | 171.76 | 57121.38 | -0.00010 | 13.15 |
| 19.33 | 13.15 | 165.17 | 171.07 | 56809.33 | -0.00010 | 13.12 |
| 19.42 | 13.12 | 164.42 | 170.37 | 56493.23 | -0.00011 | 13.09 |
| 19.50 | 13.09 | 163.66 | 169.67 | 56173.26 | -0.00011 | 13.06 |
| 19.58 | 13.06 | 162.89 | 168.95 | 55849.58 | -0.00011 | 13.02 |
| 19.67 | 13.02 | 162.11 | 168.22 | 55522.34 | -0.00011 | 12.99 |
| 19.75 | 12.99 | 161.33 | 167.48 | 55191.69 | -0.00011 | 12.96 |
| 19.83 | 12.96 | 160.54 | 166.73 | 54857.81 | -0.00011 | 12.92 |
| 19.92 | 12.92 | 159.75 | 165.98 | 54520.84 | -0.00011 | 12.89 |
| 20.00 | 12.89 | 158.95 | 165.21 | 54180.94 | -0.00012 | 12.85 |
| 20.08 | 12.85 | 158.14 | 164.43 | 53838.26 | -0.00012 | 12.82 |
| 20.17 | 12.82 | 157.33 | 163.65 | 53492.96 | -0.00012 | 12.78 |
| 20.25 | 12.78 | 156.51 | 162.85 | 53145.19 | -0.00012 | 12.75 |
| 20.33 | 12.75 | 155.69 | 162.05 | 52795.10 | -0.00012 | 12.71 |
| 20.42 | 12.71 | 154.86 | 161.24 | 52442.84 | -0.00012 | 12.68 |
| 20.50 | 12.68 | 154.03 | 160.43 | 52088.55 | -0.00012 | 12.64 |
| 20.58 | 12.64 | 153.19 | 159.60 | 51732.38 | -0.00012 | 12.60 |
| 20.67 | 12.60 | 152.35 | 158.77 | 51374.48 | -0.00012 | 12.56 |
| 20.75 | 12.56 | 151.50 | 157.93 | 51014.98 | -0.00013 | 12.53 |
| 20.83 | 12.53 | 150.66 | 157.08 | 50654.03 | -0.00013 | 12.49 |
| 20.92 | 12.49 | 149.80 | 156.23 | 50291.77 | -0.00013 | 12.45 |

Table A.2 (Contd.)

| t (hr) | h (m) | I(t) (m³/s) | Q(h) (m³/s) | A(h) (m²) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 21.00 | 12.45 | 148.95 | 155.37 | 49928.33 | -0.00013 | 12.41 |
| 21.08 | 12.41 | 148.08 | 154.51 | 49563.85 | -0.00013 | 12.37 |
| 21.17 | 12.37 | 147.22 | 153.64 | 49198.45 | -0.00013 | 12.33 |
| 21.25 | 12.33 | 146.35 | 152.76 | 48832.27 | -0.00013 | 12.29 |
| 21.33 | 12.29 | 145.49 | 151.88 | 48465.44 | -0.00013 | 12.25 |
| 21.42 | 12.25 | 144.61 | 150.99 | 48098.08 | -0.00013 | 12.21 |
| 21.50 | 12.21 | 143.74 | 150.10 | 47730.31 | -0.00013 | 12.17 |
| 21.58 | 12.17 | 142.86 | 149.21 | 47362.25 | -0.00013 | 12.13 |
| 21.67 | 12.13 | 141.98 | 148.31 | 46994.02 | -0.00013 | 12.09 |
| 21.75 | 12.09 | 141.10 | 147.40 | 46625.74 | -0.00014 | 12.05 |
| 21.83 | 12.05 | 140.22 | 146.49 | 46257.51 | -0.00014 | 12.01 |
| 21.92 | 12.01 | 139.33 | 145.58 | 45889.46 | -0.00014 | 11.97 |
| 22.00 | 11.97 | 138.44 | 144.67 | 45521.68 | -0.00014 | 11.93 |
| 22.08 | 11.93 | 137.56 | 143.75 | 45154.28 | -0.00014 | 11.89 |
| 22.17 | 11.89 | 136.67 | 142.83 | 44787.37 | -0.00014 | 11.85 |
| 22.25 | 11.85 | 135.78 | 141.90 | 44421.03 | -0.00014 | 11.81 |
| 22.58 | 11.68 | 132.20 | 138.18 | 42963.41 | -0.00014 | 11.64 |
| 22.67 | 11.64 | 131.31 | 137.24 | 42601.39 | -0.00014 | 11.60 |
| 22.75 | 11.60 | 130.41 | 136.31 | 42240.48 | -0.00014 | 11.56 |
| 22.83 | 11.56 | 129.52 | 135.37 | 41880.78 | -0.00014 | 11.52 |
| 22.92 | 11.52 | 128.62 | 134.43 | 41522.36 | -0.00014 | 11.47 |
| 23.00 | 11.47 | 127.73 | 133.49 | 41165.29 | -0.00014 | 11.43 |
| 23.08 | 11.43 | 126.83 | 132.55 | 40809.66 | -0.00014 | 11.39 |
| 23.17 | 11.39 | 125.94 | 131.61 | 40455.52 | -0.00014 | 11.35 |
| 23.25 | 11.35 | 125.05 | 130.66 | 40102.94 | -0.00014 | 11.31 |
| 23.33 | 11.31 | 124.15 | 129.72 | 39752.00 | -0.00014 | 11.26 |
| 23.42 | 11.26 | 123.26 | 128.78 | 39402.75 | -0.00014 | 11.22 |
| 23.50 | 11.22 | 122.37 | 127.84 | 39055.25 | -0.00014 | 11.18 |
| 23.58 | 11.18 | 121.48 | 126.89 | 38709.56 | -0.00014 | 11.14 |
| 23.67 | 11.14 | 120.58 | 125.95 | 38365.74 | -0.00014 | 11.10 |
| 23.75 | 11.10 | 119.70 | 125.01 | 38023.83 | -0.00014 | 11.05 |
| 23.83 | 11.05 | 118.81 | 124.07 | 37683.88 | -0.00014 | 11.01 |
| 23.92 | 11.01 | 117.92 | 123.13 | 37345.95 | -0.00014 | 10.97 |
| 24.00 | 10.97 | 117.04 | 122.19 | 37010.08 | -0.00014 | 10.93 |
| 24.08 | 10.93 | 116.15 | 121.25 | 36676.32 | -0.00014 | 10.89 |
| 24.17 | 10.89 | 115.27 | 120.32 | 36344.69 | -0.00014 | 10.84 |
| 24.25 | 10.84 | 114.39 | 119.38 | 36015.25 | -0.00014 | 10.80 |
| 24.33 | 10.80 | 113.51 | 118.45 | 35688.02 | -0.00014 | 10.76 |
| 24.42 | 10.76 | 112.63 | 117.52 | 35363.04 | -0.00014 | 10.72 |
| 24.50 | 10.72 | 111.76 | 116.59 | 35040.35 | -0.00014 | 10.68 |
| 24.58 | 10.68 | 110.89 | 115.66 | 34719.98 | -0.00014 | 10.64 |
| 24.67 | 10.64 | 110.01 | 114.73 | 34401.95 | -0.00014 | 10.60 |

Table A.2 (Contd.)

| **t (hr)** | **h (m)** | **I(t) ($m^3/s$)** | **Q(h) ($m^3/s$)** | **A(h) ($m^2$)** | **f(h, t)** | ***h*(*n*+1) (m)** |
|---|---|---|---|---|---|---|
| 24.75 | 10.60 | 109.15 | 113.81 | 34086.28 | -0.00014 | 10.55 |
| 24.83 | 10.55 | 108.28 | 112.89 | 33773.01 | -0.00014 | 10.51 |
| 24.92 | 10.51 | 107.42 | 111.97 | 33462.16 | -0.00014 | 10.47 |
| 25.00 | 10.47 | 106.55 | 111.05 | 33153.75 | -0.00014 | 10.43 |
| 25.08 | 10.43 | 105.70 | 110.14 | 32847.79 | -0.00014 | 10.39 |
| 25.17 | 10.39 | 104.84 | 109.23 | 32544.31 | -0.00013 | 10.35 |
| 25.25 | 10.35 | 103.98 | 108.32 | 32243.32 | -0.00013 | 10.31 |
| 25.33 | 10.31 | 103.13 | 107.41 | 31944.84 | -0.00013 | 10.27 |
| 25.42 | 10.27 | 102.29 | 106.51 | 31648.87 | -0.00013 | 10.23 |
| 25.50 | 10.23 | 101.44 | 105.61 | 31355.44 | -0.00013 | 10.19 |
| 25.58 | 10.19 | 100.60 | 104.72 | 31064.54 | -0.00013 | 10.15 |
| 25.67 | 10.15 | 99.76 | 103.82 | 30776.20 | -0.00013 | 10.11 |
| 25.75 | 10.11 | 98.92 | 102.93 | 30490.41 | -0.00013 | 10.07 |
| 25.83 | 10.07 | 98.09 | 102.05 | 30207.18 | -0.00013 | 10.03 |
| 25.92 | 10.03 | 97.26 | 101.16 | 29926.52 | -0.00013 | 9.99 |
| 26.00 | 9.99 | 96.43 | 100.28 | 29648.44 | -0.00013 | 9.95 |
| 26.08 | 9.95 | 95.61 | 99.41 | 29372.92 | -0.00013 | 9.92 |
| 26.17 | 9.92 | 94.79 | 98.54 | 29099.98 | -0.00013 | 9.88 |
| 26.25 | 9.88 | 93.97 | 97.67 | 28829.62 | -0.00013 | 9.84 |
| 26.33 | 9.84 | 93.16 | 96.80 | 28561.83 | -0.00013 | 9.80 |
| 26.42 | 9.80 | 92.35 | 95.94 | 28296.61 | -0.00013 | 9.76 |
| 26.50 | 9.76 | 91.54 | 95.09 | 28033.97 | -0.00013 | 9.72 |
| 26.58 | 9.72 | 90.74 | 94.23 | 27773.89 | -0.00013 | 9.69 |
| 26.67 | 9.69 | 89.94 | 93.39 | 27516.37 | -0.00013 | 9.65 |
| 26.75 | 9.65 | 89.14 | 92.54 | 27261.41 | -0.00012 | 9.61 |
| 26.83 | 9.61 | 88.35 | 91.70 | 27009.00 | -0.00012 | 9.57 |
| 26.92 | 9.57 | 87.56 | 90.86 | 26759.13 | -0.00012 | 9.54 |
| 27.00 | 9.54 | 86.78 | 90.03 | 26511.80 | -0.00012 | 9.50 |
| 27.08 | 9.50 | 86.00 | 89.20 | 26267.00 | -0.00012 | 9.46 |
| 27.17 | 9.46 | 85.22 | 88.38 | 26024.71 | -0.00012 | 9.43 |
| 27.25 | 9.43 | 84.45 | 87.56 | 25784.94 | -0.00012 | 9.39 |
| 27.33 | 9.39 | 83.68 | 86.75 | 25547.66 | -0.00012 | 9.36 |
| 27.42 | 9.36 | 82.91 | 85.94 | 25312.88 | -0.00012 | 9.32 |
| 27.50 | 9.32 | 82.15 | 85.13 | 25080.56 | -0.00012 | 9.28 |
| 27.58 | 9.28 | 81.40 | 84.33 | 24850.72 | -0.00012 | 9.25 |
| 27.67 | 9.25 | 80.64 | 83.53 | 24623.32 | -0.00012 | 9.21 |
| 27.75 | 9.21 | 79.89 | 82.74 | 24398.36 | -0.00012 | 9.18 |
| 27.83 | 9.18 | 79.15 | 81.95 | 24175.83 | -0.00012 | 9.14 |
| 27.92 | 9.14 | 78.41 | 81.17 | 23955.71 | -0.00012 | 9.11 |
| 28.00 | 9.11 | 77.67 | 80.39 | 23737.99 | -0.00011 | 9.07 |
| 28.08 | 9.07 | 76.94 | 79.62 | 23522.65 | -0.00011 | 9.04 |
| 28.17 | 9.04 | 76.21 | 78.85 | 23309.68 | -0.00011 | 9.01 |

Table A.2 (Contd.)

| t (hr) | h (m) | I(t) ($m^3$/s) | Q(h) ($m^3$/s) | A(h) ($m^2$) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 28.25 | 9.01 | 75.49 | 78.09 | 23099.06 | -0.00011 | 8.97 |
| 28.33 | 8.97 | 74.77 | 77.33 | 22890.78 | -0.00011 | 8.94 |
| 28.42 | 8.94 | 74.05 | 76.57 | 22684.81 | -0.00011 | 8.91 |
| 28.50 | 8.91 | 73.34 | 75.82 | 22481.16 | -0.00011 | 8.87 |
| 28.58 | 8.87 | 72.63 | 75.08 | 22279.79 | -0.00011 | 8.84 |
| 28.67 | 8.84 | 71.93 | 74.34 | 22080.69 | -0.00011 | 8.81 |
| 28.75 | 8.81 | 71.23 | 73.60 | 21883.85 | -0.00011 | 8.77 |
| 28.83 | 8.77 | 70.54 | 72.87 | 21689.24 | -0.00011 | 8.74 |
| 28.92 | 8.74 | 69.85 | 72.14 | 21496.85 | -0.00011 | 8.71 |
| 29.00 | 8.71 | 69.16 | 71.42 | 21306.67 | -0.00011 | 8.68 |
| 29.08 | 8.68 | 68.48 | 70.70 | 21118.67 | -0.00011 | 8.65 |
| 29.17 | 8.65 | 67.80 | 69.99 | 20932.83 | -0.00010 | 8.61 |
| 29.25 | 8.61 | 67.13 | 69.29 | 20749.15 | -0.00010 | 8.58 |
| 29.33 | 8.58 | 66.46 | 68.58 | 20567.59 | -0.00010 | 8.55 |
| 29.42 | 8.55 | 65.80 | 67.89 | 20388.15 | -0.00010 | 8.52 |
| 29.50 | 8.52 | 65.14 | 67.19 | 20210.80 | -0.00010 | 8.49 |
| 29.58 | 8.49 | 64.48 | 66.51 | 20035.53 | -0.00010 | 8.46 |
| 29.67 | 8.46 | 63.83 | 65.82 | 19862.31 | -0.00010 | 8.43 |
| 29.75 | 8.43 | 63.18 | 65.15 | 19691.13 | -0.00010 | 8.40 |
| 29.83 | 8.40 | 62.54 | 64.47 | 19521.97 | -0.00010 | 8.37 |
| 29.92 | 8.37 | 61.90 | 63.80 | 19354.82 | -0.00010 | 8.34 |
| 30.00 | 8.34 | 61.27 | 63.14 | 19189.64 | -0.00010 | 8.31 |
| 30.08 | 8.31 | 60.64 | 62.48 | 19026.43 | -0.00010 | 8.28 |
| 30.17 | 8.28 | 60.02 | 61.83 | 18865.17 | -0.00010 | 8.26 |
| 30.25 | 8.26 | 59.40 | 61.18 | 18705.83 | -0.00010 | 8.23 |
| 30.33 | 8.23 | 58.78 | 60.54 | 18548.40 | -0.00009 | 8.20 |
| 30.42 | 8.20 | 58.17 | 59.90 | 18392.85 | -0.00009 | 8.17 |
| 30.50 | 8.17 | 57.56 | 59.26 | 18239.18 | -0.00009 | 8.14 |
| 30.58 | 8.14 | 56.96 | 58.63 | 18087.36 | -0.00009 | 8.11 |
| 30.67 | 8.11 | 56.36 | 58.01 | 17937.38 | -0.00009 | 8.09 |
| 30.75 | 8.09 | 55.77 | 57.39 | 17789.20 | -0.00009 | 8.06 |
| 30.83 | 8.06 | 55.18 | 56.77 | 17642.83 | -0.00009 | 8.03 |
| 30.92 | 8.03 | 54.59 | 56.16 | 17498.23 | -0.00009 | 8.01 |
| 31.00 | 8.01 | 54.01 | 55.56 | 17355.39 | -0.00009 | 7.98 |
| 31.08 | 7.98 | 53.44 | 54.96 | 17214.29 | -0.00009 | 7.95 |
| 31.17 | 7.95 | 52.86 | 54.36 | 17074.91 | -0.00009 | 7.93 |
| 31.25 | 7.93 | 52.30 | 53.77 | 16937.24 | -0.00009 | 7.90 |
| 31.33 | 7.90 | 51.73 | 53.18 | 16801.26 | -0.00009 | 7.87 |
| 31.42 | 7.87 | 51.17 | 52.60 | 16666.94 | -0.00009 | 7.85 |
| 31.50 | 7.85 | 50.62 | 52.02 | 16534.27 | -0.00008 | 7.82 |
| 31.58 | 7.82 | 50.07 | 51.45 | 16403.24 | -0.00008 | 7.80 |
| 31.67 | 7.80 | 49.52 | 50.88 | 16273.82 | -0.00008 | 7.77 |

Table A.2 (Contd.)

| t (hr) | h (m) | I(t) ($m^3/s$) | Q(h) ($m^3/s$) | A(h) ($m^2$) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 31.75 | 7.77 | 48.98 | 50.31 | 16146.00 | -0.00008 | 7.75 |
| 31.83 | 7.75 | 48.44 | 49.76 | 16019.75 | -0.00008 | 7.72 |
| 31.92 | 7.72 | 47.91 | 49.20 | 15895.07 | -0.00008 | 7.70 |
| 32.00 | 7.70 | 47.38 | 48.65 | 15771.94 | -0.00008 | 7.67 |
| 32.08 | 7.67 | 46.85 | 48.11 | 15650.33 | -0.00008 | 7.65 |
| 32.17 | 7.65 | 46.33 | 47.56 | 15530.23 | -0.00008 | 7.63 |
| 32.25 | 7.63 | 45.82 | 47.03 | 15411.62 | -0.00008 | 7.60 |
| 32.33 | 7.60 | 45.30 | 46.50 | 15294.49 | -0.00008 | 7.58 |
| 32.42 | 7.58 | 44.80 | 45.97 | 15178.83 | -0.00008 | 7.56 |
| 32.50 | 7.56 | 44.29 | 45.45 | 15064.60 | -0.00008 | 7.53 |
| 32.58 | 7.53 | 43.79 | 44.93 | 14951.80 | -0.00008 | 7.51 |
| 32.67 | 7.51 | 43.30 | 44.41 | 14840.41 | -0.00008 | 7.49 |
| 32.75 | 7.49 | 42.80 | 43.90 | 14730.41 | -0.00007 | 7.47 |
| 32.83 | 7.47 | 42.32 | 43.40 | 14621.80 | -0.00007 | 7.44 |
| 32.92 | 7.44 | 41.83 | 42.90 | 14514.54 | -0.00007 | 7.42 |
| 33.00 | 7.42 | 41.35 | 42.40 | 14408.63 | -0.00007 | 7.40 |
| 33.08 | 7.40 | 40.88 | 41.91 | 14304.05 | -0.00007 | 7.38 |
| 33.17 | 7.38 | 40.40 | 41.42 | 14200.79 | -0.00007 | 7.36 |
| 33.25 | 7.36 | 39.94 | 40.94 | 14098.82 | -0.00007 | 7.34 |
| 33.33 | 7.34 | 39.47 | 40.46 | 13998.14 | -0.00007 | 7.31 |
| 33.42 | 7.31 | 39.01 | 39.98 | 13898.72 | -0.00007 | 7.29 |
| 33.50 | 7.29 | 38.56 | 39.51 | 13800.56 | -0.00007 | 7.27 |
| 33.58 | 7.27 | 38.11 | 39.04 | 13703.64 | -0.00007 | 7.25 |
| 33.67 | 7.25 | 37.66 | 38.58 | 13607.95 | -0.00007 | 7.23 |
| 33.83 | 7.21 | 36.77 | 37.67 | 13420.16 | -0.00007 | 7.19 |
| 33.92 | 7.19 | 36.34 | 37.22 | 13328.05 | -0.00007 | 7.17 |
| 34.00 | 7.17 | 35.90 | 36.77 | 13237.10 | -0.00007 | 7.15 |
| 34.08 | 7.15 | 35.48 | 36.33 | 13147.31 | -0.00006 | 7.13 |
| 34.17 | 7.13 | 35.05 | 35.89 | 13058.65 | -0.00006 | 7.11 |
| 34.25 | 7.11 | 34.63 | 35.45 | 12971.12 | -0.00006 | 7.10 |
| 34.33 | 7.10 | 34.21 | 35.02 | 12884.70 | -0.00006 | 7.08 |
| 34.42 | 7.08 | 33.80 | 34.60 | 12799.38 | -0.00006 | 7.06 |
| 34.50 | 7.06 | 33.39 | 34.17 | 12715.14 | -0.00006 | 7.04 |
| 34.58 | 7.04 | 32.98 | 33.76 | 12631.97 | -0.00006 | 7.02 |
| 34.67 | 7.02 | 32.58 | 33.34 | 12549.86 | -0.00006 | 7.00 |
| 34.75 | 7.00 | 32.18 | 32.93 | 12468.79 | -0.00006 | 6.98 |
| 34.83 | 6.98 | 31.79 | 32.52 | 12388.75 | -0.00006 | 6.97 |
| 34.92 | 6.97 | 31.40 | 32.12 | 12309.74 | -0.00006 | 6.95 |
| 35.00 | 6.95 | 31.01 | 31.72 | 12231.73 | -0.00006 | 6.93 |
| 35.08 | 6.93 | 30.62 | 31.33 | 12154.71 | -0.00006 | 6.91 |
| 35.17 | 6.91 | 30.24 | 30.93 | 12078.68 | -0.00006 | 6.90 |
| 35.25 | 6.90 | 29.86 | 30.55 | 12003.62 | -0.00006 | 6.88 |

Table A.2 (Contd.)

| t (hr) | h (m) | I(t) (m³/s) | Q(h) (m³/s) | A(h) (m²) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 35.33 | 6.88 | 29.49 | 30.16 | 11929.51 | -0.00006 | 6.86 |
| 35.42 | 6.86 | 29.12 | 29.78 | 11856.35 | -0.00006 | 6.85 |
| 35.50 | 6.85 | 28.75 | 29.40 | 11784.13 | -0.00006 | 6.83 |
| 35.58 | 6.83 | 28.39 | 29.03 | 11712.82 | -0.00005 | 6.81 |
| 35.67 | 6.81 | 28.03 | 28.66 | 11642.43 | -0.00005 | 6.80 |
| 35.75 | 6.80 | 27.67 | 28.29 | 11572.94 | -0.00005 | 6.78 |
| 35.83 | 6.78 | 27.32 | 27.93 | 11504.33 | -0.00005 | 6.77 |
| 35.92 | 6.77 | 26.97 | 27.57 | 11436.61 | -0.00005 | 6.75 |
| 36.00 | 6.75 | 26.62 | 27.21 | 11369.75 | -0.00005 | 6.73 |
| 36.17 | 6.72 | 25.94 | 26.51 | 11238.59 | -0.00005 | 6.70 |
| 36.25 | 6.70 | 25.60 | 26.17 | 11174.26 | -0.00005 | 6.69 |
| 36.33 | 6.69 | 25.27 | 25.82 | 11110.76 | -0.00005 | 6.67 |
| 36.42 | 6.67 | 24.94 | 25.49 | 11048.08 | -0.00005 | 6.66 |
| 36.50 | 6.66 | 24.61 | 25.15 | 10986.19 | -0.00005 | 6.64 |
| 36.58 | 6.64 | 24.29 | 24.82 | 10925.10 | -0.00005 | 6.63 |
| 36.67 | 6.63 | 23.97 | 24.49 | 10864.80 | -0.00005 | 6.61 |
| 36.75 | 6.61 | 23.65 | 24.16 | 10805.27 | -0.00005 | 6.60 |
| 36.83 | 6.60 | 23.34 | 23.84 | 10746.50 | -0.00005 | 6.59 |
| 36.92 | 6.59 | 23.02 | 23.52 | 10688.49 | -0.00005 | 6.57 |
| 37.00 | 6.57 | 22.72 | 23.21 | 10631.22 | -0.00005 | 6.56 |
| 37.08 | 6.56 | 22.41 | 22.89 | 10574.69 | -0.00005 | 6.54 |
| 37.17 | 6.54 | 22.11 | 22.58 | 10518.88 | -0.00005 | 6.53 |
| 37.25 | 6.53 | 21.81 | 22.28 | 10463.79 | -0.00004 | 6.52 |
| 37.33 | 6.52 | 21.51 | 21.97 | 10409.41 | -0.00004 | 6.50 |
| 37.58 | 6.48 | 20.64 | 21.08 | 10250.44 | -0.00004 | 6.47 |
| 37.67 | 6.47 | 20.36 | 20.79 | 10198.80 | -0.00004 | 6.45 |
| 37.75 | 6.45 | 20.08 | 20.50 | 10147.83 | -0.00004 | 6.44 |
| 37.83 | 6.44 | 19.80 | 20.22 | 10097.52 | -0.00004 | 6.43 |
| 37.92 | 6.43 | 19.52 | 19.93 | 10047.86 | -0.00004 | 6.42 |
| 38.00 | 6.42 | 19.25 | 19.66 | 9998.84 | -0.00004 | 6.40 |
| 38.08 | 6.40 | 18.98 | 19.38 | 9950.45 | -0.00004 | 6.39 |
| 38.17 | 6.39 | 18.71 | 19.11 | 9902.68 | -0.00004 | 6.38 |
| 38.25 | 6.38 | 18.45 | 18.83 | 9855.54 | -0.00004 | 6.37 |
| 38.33 | 6.37 | 18.18 | 18.57 | 9809.00 | -0.00004 | 6.36 |
| 38.42 | 6.36 | 17.92 | 18.30 | 9763.06 | -0.00004 | 6.34 |
| 38.50 | 6.34 | 17.67 | 18.04 | 9717.72 | -0.00004 | 6.33 |
| 38.58 | 6.33 | 17.41 | 17.78 | 9672.97 | -0.00004 | 6.32 |
| 38.67 | 6.32 | 17.16 | 17.52 | 9628.80 | -0.00004 | 6.31 |
| 38.75 | 6.31 | 16.91 | 17.27 | 9585.20 | -0.00004 | 6.30 |
| 38.83 | 6.30 | 16.67 | 17.02 | 9542.16 | -0.00004 | 6.29 |
| 38.92 | 6.29 | 16.42 | 16.77 | 9499.69 | -0.00004 | 6.28 |
| 39.00 | 6.28 | 16.18 | 16.52 | 9457.77 | -0.00004 | 6.27 |

Table A.2 (Contd.)

| t (hr) | h (m) | I(t) (m³/s) | Q(h) (m³/s) | A(h) (m²) | f(h, t) | $h(n+1)$ (m) |
|---|---|---|---|---|---|---|
| 39.08 | 6.27 | 15.95 | 16.28 | 9416.39 | -0.00004 | 6.26 |
| 39.17 | 6.26 | 15.71 | 16.04 | 9375.55 | -0.00004 | 6.25 |
| 39.25 | 6.25 | 15.48 | 15.80 | 9335.25 | -0.00003 | 6.23 |
| 39.33 | 6.23 | 15.25 | 15.56 | 9295.47 | -0.00003 | 6.22 |
| 39.42 | 6.22 | 15.02 | 15.33 | 9256.22 | -0.00003 | 6.21 |
| 39.50 | 6.21 | 14.79 | 15.10 | 9217.48 | -0.00003 | 6.20 |
| 39.58 | 6.20 | 14.57 | 14.87 | 9179.24 | -0.00003 | 6.19 |
| 39.67 | 6.19 | 14.35 | 14.65 | 9141.52 | -0.00003 | 6.18 |
| 39.75 | 6.18 | 14.13 | 14.42 | 9104.28 | -0.00003 | 6.17 |
| 39.92 | 6.17 | 13.70 | 13.99 | 9031.29 | -0.00003 | 6.16 |
| 40.00 | 6.16 | 13.49 | 13.77 | 8995.52 | -0.00003 | 6.15 |
| 40.08 | 6.15 | 13.28 | 13.56 | 8960.23 | -0.00003 | 6.14 |
| 40.17 | 6.14 | 13.07 | 13.35 | 8925.40 | -0.00003 | 6.13 |
| 40.25 | 6.13 | 12.87 | 13.14 | 8891.05 | -0.00003 | 6.12 |
| 40.33 | 6.12 | 12.67 | 12.93 | 8857.16 | -0.00003 | 6.11 |
| 40.42 | 6.11 | 12.47 | 12.73 | 8823.73 | -0.00003 | 6.10 |
| 40.50 | 6.10 | 12.27 | 12.53 | 8790.75 | -0.00003 | 6.09 |
| 40.58 | 6.09 | 12.08 | 12.33 | 8758.23 | -0.00003 | 6.08 |
| 40.67 | 6.08 | 11.88 | 12.13 | 8726.15 | -0.00003 | 6.07 |
| 40.75 | 6.07 | 11.69 | 11.94 | 8694.52 | -0.00003 | 6.07 |
| 40.83 | 6.07 | 11.51 | 11.75 | 8663.33 | -0.00003 | 6.06 |
| 40.92 | 6.06 | 11.32 | 11.56 | 8632.59 | -0.00003 | 6.05 |
| 41.00 | 6.05 | 11.14 | 11.37 | 8602.29 | -0.00003 | 6.04 |
| 41.08 | 6.04 | 10.96 | 11.19 | 8572.42 | -0.00003 | 6.03 |
| 41.17 | 6.03 | 10.78 | 11.00 | 8543.00 | -0.00003 | 6.03 |
| 41.25 | 6.03 | 10.60 | 10.82 | 8514.01 | -0.00003 | 6.02 |
| 39.92 | 6.17 | 13.70 | 13.99 | 9031.29 | -0.00003 | 6.16 |
| 41.33 | 6.02 | 10.43 | 10.65 | 8485.47 | -0.00003 | 6.01 |
| 41.42 | 6.01 | 10.26 | 10.47 | 8457.38 | -0.00003 | 6.00 |
| 41.50 | 6.00 | 10.09 | 10.30 | 8429.74 | -0.00002 | 5.99 |
| 41.58 | 5.99 | 9.92 | 10.24 | 8402.56 | -0.00004 | 5.98 |
| 41.67 | 5.98 | 9.76 | 10.23 | 8361.08 | -0.00006 | 5.97 |
| 41.75 | 5.97 | 9.60 | 10.22 | 8299.68 | -0.00007 | 5.94 |
| 41.83 | 5.94 | 9.44 | 10.20 | 8219.21 | -0.00009 | 5.92 |
| 41.92 | 5.92 | 9.29 | 10.18 | 8120.43 | -0.00011 | 5.88 |
| 42.00 | 5.88 | 9.14 | 10.15 | 8004.10 | -0.00013 | 5.85 |
| 42.08 | 5.85 | 8.99 | 10.12 | 7870.95 | -0.00014 | 5.80 |
| 42.17 | 5.80 | 8.85 | 10.08 | 7721.75 | -0.00016 | 5.76 |
| 42.25 | 5.76 | 8.72 | 10.04 | 7557.29 | -0.00017 | 5.70 |
| 42.33 | 5.70 | 8.59 | 9.99 | 7378.50 | -0.00019 | 5.65 |
| 42.42 | 5.65 | 8.47 | 9.94 | 7186.49 | -0.00020 | 5.58 |
| 42.50 | 5.58 | 8.37 | 9.89 | 6982.83 | -0.00022 | 5.52 |

Table A.2 (Contd.)

| **t (hr)** | **h (m)** | **I(t) ($m^3/s$)** | **Q(h) ($m^3/s$)** | **A(h) ($m^2$)** | **f(h, t)** | **$h(n+1)$ (m)** |
|---|---|---|---|---|---|---|
| 42.58 | 5.52 | 8.28 | 9.83 | 6770.02 | -0.00023 | 5.45 |
| 42.67 | 5.45 | 8.18 | 9.77 | 6548.81 | -0.00024 | 5.38 |
| 42.75 | 5.38 | 8.09 | 9.70 | 6319.38 | -0.00025 | 5.30 |
| 42.83 | 5.30 | 8.00 | 9.63 | 6081.95 | -0.00027 | 5.22 |
| 42.92 | 5.22 | 7.91 | 9.56 | 5836.74 | -0.00028 | 5.14 |
| 43.00 | 5.14 | 7.82 | 9.48 | 5583.99 | -0.00030 | 5.05 |
| 43.08 | 5.05 | 7.73 | 9.40 | 5323.92 | -0.00031 | 4.95 |
| 43.17 | 4.95 | 7.64 | 9.31 | 5056.80 | -0.00033 | 4.85 |
| 43.25 | 4.85 | 7.55 | 9.22 | 4782.93 | -0.00035 | 4.75 |
| 43.42 | 4.64 | 7.38 | 9.01 | 4216.23 | -0.00039 | 4.52 |
| 43.50 | 4.52 | 7.30 | 8.90 | 3924.19 | -0.00041 | 4.40 |
| 43.58 | 4.40 | 7.21 | 8.78 | 3627.00 | -0.00043 | 4.27 |
| 43.67 | 4.27 | 7.13 | 8.65 | 3325.25 | -0.00046 | 4.14 |
| 43.75 | 4.14 | 7.05 | 8.51 | 3019.66 | -0.00048 | 3.99 |
| 43.83 | 3.99 | 6.97 | 8.36 | 2711.14 | -0.00051 | 3.84 |
| 43.92 | 3.84 | 6.89 | 8.20 | 2400.84 | -0.00054 | 3.67 |
| 44.00 | 3.67 | 6.81 | 8.02 | 2090.24 | -0.00058 | 3.50 |
| 44.08 | 3.50 | 6.73 | 7.83 | 1781.33 | -0.00062 | 3.32 |
| 44.17 | 3.32 | 6.65 | 7.62 | 1476.79 | -0.00065 | 3.12 |
| 44.25 | 3.12 | 6.58 | 7.39 | 1180.38 | -0.00069 | 2.91 |
| 44.33 | 2.91 | 6.50 | 7.14 | 897.57 | -0.00071 | 2.70 |
| 44.42 | 2.70 | 6.42 | 6.87 | 636.58 | -0.00070 | 2.49 |
| 44.50 | 2.49 | 6.35 | 6.60 | 410.44 | -0.00060 | 2.31 |
| 44.58 | 2.31 | 6.28 | 6.35 | 240.96 | -0.00032 | 2.21 |
| 44.67 | 2.21 | 6.20 | 6.22 | 160.86 | -0.00010 | 2.18 |
| 44.75 | 2.18 | 6.13 | 6.18 | 136.14 | -0.00033 | 2.08 |

Table A.3 Discharge through the diversion channel

| **t (hr)** | **b (m)** | **y (m)** | **A ($m^2$)** | **P (m)** | **R (m)** | **Q ($m^3/s$)** |
|---|---|---|---|---|---|---|
| 4.25 | 3.5 | 0.140 | 0.50 | 3.81 | 0.13 | 2.35 |
| 4.33 | 3.5 | 0.296 | 1.08 | 4.16 | 0.26 | 8.01 |
| 4.42 | 3.5 | 0.381 | 1.41 | 4.35 | 0.32 | 12.10 |
| 4.50 | 3.5 | 0.424 | 1.57 | 4.45 | 0.35 | 14.37 |
| 4.58 | 3.5 | 0.449 | 1.67 | 4.50 | 0.37 | 15.77 |
| 4.67 | 3.5 | 0.468 | 1.75 | 4.55 | 0.38 | 16.87 |
| 4.75 | 3.5 | 0.485 | 1.82 | 4.59 | 0.40 | 17.88 |
| 4.83 | 3.5 | 0.502 | 1.88 | 4.62 | 0.41 | 18.87 |
| 4.92 | 3.5 | 0.518 | 1.95 | 4.66 | 0.42 | 19.87 |
| 5.00 | 3.5 | 0.534 | 2.01 | 4.69 | 0.43 | 20.87 |
| 5.08 | 3.5 | 0.550 | 2.08 | 4.73 | 0.44 | 21.88 |
| 5.17 | 3.5 | 0.566 | 2.14 | 4.76 | 0.45 | 22.91 |
| 5.25 | 3.5 | 0.581 | 2.20 | 4.80 | 0.46 | 23.95 |
| 5.33 | 3.5 | 0.597 | 2.27 | 4.83 | 0.47 | 24.99 |
| 5.42 | 3.5 | 0.612 | 2.33 | 4.87 | 0.48 | 26.05 |
| 5.50 | 3.5 | 0.628 | 2.39 | 4.90 | 0.49 | 27.11 |
| 5.58 | 3.5 | 0.643 | 2.46 | 4.94 | 0.50 | 28.18 |
| 5.67 | 3.5 | 0.658 | 2.52 | 4.97 | 0.51 | 29.26 |
| 5.75 | 3.5 | 0.673 | 2.58 | 5.01 | 0.52 | 30.35 |
| 5.83 | 3.5 | 0.688 | 2.65 | 5.04 | 0.53 | 31.44 |
| 5.92 | 3.5 | 0.703 | 2.71 | 5.07 | 0.53 | 32.54 |
| 6.00 | 3.5 | 0.718 | 2.77 | 5.11 | 0.54 | 33.65 |
| 6.08 | 3.5 | 0.732 | 2.83 | 5.14 | 0.55 | 34.76 |
| 6.17 | 3.5 | 0.747 | 2.89 | 5.17 | 0.56 | 35.87 |
| 6.25 | 3.5 | 0.761 | 2.95 | 5.20 | 0.57 | 36.98 |
| 6.33 | 3.5 | 0.775 | 3.01 | 5.23 | 0.58 | 38.10 |
| 6.42 | 3.5 | 0.789 | 3.07 | 5.27 | 0.58 | 39.22 |
| 6.50 | 3.5 | 0.803 | 3.13 | 5.30 | 0.59 | 40.34 |
| 6.58 | 3.5 | 0.817 | 3.19 | 5.33 | 0.60 | 41.46 |
| 6.67 | 3.5 | 0.831 | 3.25 | 5.36 | 0.61 | 42.58 |
| 6.75 | 3.5 | 0.844 | 3.31 | 5.39 | 0.61 | 43.70 |
| 6.83 | 3.5 | 0.858 | 3.37 | 5.42 | 0.62 | 44.81 |
| 6.92 | 3.5 | 0.871 | 3.43 | 5.45 | 0.63 | 45.93 |
| 7.00 | 3.5 | 0.884 | 3.48 | 5.48 | 0.64 | 47.05 |
| 7.08 | 3.5 | 0.897 | 3.54 | 5.50 | 0.64 | 48.16 |
| 7.17 | 3.5 | 0.909 | 3.60 | 5.53 | 0.65 | 49.26 |
| 7.25 | 3.5 | 0.922 | 3.65 | 5.56 | 0.66 | 50.37 |
| 7.33 | 3.5 | 0.934 | 3.71 | 5.59 | 0.66 | 51.47 |
| 7.42 | 3.5 | 0.947 | 3.76 | 5.62 | 0.67 | 52.56 |
| 7.50 | 3.5 | 0.959 | 3.82 | 5.64 | 0.68 | 53.65 |
| 7.58 | 3.5 | 0.971 | 3.87 | 5.67 | 0.68 | 54.73 |
| 7.67 | 3.5 | 0.982 | 3.92 | 5.70 | 0.69 | 55.81 |

Table A.3 (Contd.)

| t (hr) | b (m) | y (m) | A ($m^2$) | P (m) | R (m) | Q ($m^3/s$) |
|---|---|---|---|---|---|---|
| 7.75 | 3.5 | 0.994 | 3.97 | 5.72 | 0.69 | 56.88 |
| 7.83 | 3.5 | 1.006 | 4.02 | 5.75 | 0.70 | 57.94 |
| 7.92 | 3.5 | 1.017 | 4.08 | 5.77 | 0.71 | 59.00 |
| 8.00 | 3.5 | 1.028 | 4.13 | 5.80 | 0.71 | 60.04 |
| 8.08 | 3.5 | 1.039 | 4.18 | 5.82 | 0.72 | 61.08 |
| 8.17 | 3.5 | 1.050 | 4.22 | 5.85 | 0.72 | 62.11 |
| 8.25 | 3.5 | 1.060 | 4.27 | 5.87 | 0.73 | 63.13 |
| 8.33 | 3.5 | 1.071 | 4.32 | 5.89 | 0.73 | 64.14 |
| 8.42 | 3.5 | 1.081 | 4.37 | 5.92 | 0.74 | 65.13 |
| 8.50 | 3.5 | 1.091 | 4.41 | 5.94 | 0.74 | 66.12 |
| 8.58 | 3.5 | 1.101 | 4.46 | 5.96 | 0.75 | 67.10 |
| 8.67 | 3.5 | 1.111 | 4.50 | 5.98 | 0.75 | 68.07 |
| 8.75 | 3.5 | 1.120 | 4.55 | 6.01 | 0.76 | 69.02 |
| 8.83 | 3.5 | 1.130 | 4.59 | 6.03 | 0.76 | 69.96 |
| 8.92 | 3.5 | 1.139 | 4.64 | 6.05 | 0.77 | 70.89 |
| 9.00 | 3.5 | 1.148 | 4.68 | 6.07 | 0.77 | 71.81 |
| 9.08 | 3.5 | 1.157 | 4.72 | 6.09 | 0.78 | 72.72 |
| 9.17 | 3.5 | 1.166 | 4.76 | 6.11 | 0.78 | 73.61 |
| 9.25 | 3.5 | 1.174 | 4.80 | 6.13 | 0.78 | 74.49 |
| 9.33 | 3.5 | 1.183 | 4.84 | 6.14 | 0.79 | 75.35 |
| 9.42 | 3.5 | 1.191 | 4.88 | 6.16 | 0.79 | 76.21 |
| 9.50 | 3.5 | 1.199 | 4.92 | 6.18 | 0.80 | 77.04 |
| 9.58 | 3.5 | 1.207 | 4.95 | 6.20 | 0.80 | 77.87 |
| 9.67 | 3.5 | 1.215 | 4.99 | 6.22 | 0.80 | 78.68 |
| 9.75 | 3.5 | 1.222 | 5.03 | 6.23 | 0.81 | 79.47 |
| 9.83 | 3.5 | 1.230 | 5.06 | 6.25 | 0.81 | 80.25 |
| 9.92 | 3.5 | 1.237 | 5.09 | 6.27 | 0.81 | 81.02 |
| 10.00 | 3.5 | 1.244 | 5.13 | 6.28 | 0.82 | 81.77 |
| 10.08 | 3.5 | 1.251 | 5.16 | 6.30 | 0.82 | 82.51 |
| 10.17 | 3.5 | 1.258 | 5.19 | 6.31 | 0.82 | 83.23 |
| 10.25 | 3.5 | 1.264 | 5.22 | 6.33 | 0.83 | 83.93 |
| 10.33 | 3.5 | 1.271 | 5.25 | 6.34 | 0.83 | 84.62 |
| 10.42 | 3.5 | 1.277 | 5.28 | 6.35 | 0.83 | 85.30 |
| 10.50 | 3.5 | 1.283 | 5.31 | 6.37 | 0.83 | 85.95 |
| 10.58 | 3.5 | 1.289 | 5.34 | 6.38 | 0.84 | 86.60 |
| 10.67 | 3.5 | 1.294 | 5.37 | 6.39 | 0.84 | 87.22 |
| 10.75 | 3.5 | 1.300 | 5.40 | 6.41 | 0.84 | 87.84 |
| 10.83 | 3.5 | 1.305 | 5.42 | 6.42 | 0.84 | 88.43 |
| 10.92 | 3.5 | 1.311 | 5.45 | 6.43 | 0.85 | 89.01 |
| 11.00 | 3.5 | 1.316 | 5.47 | 6.44 | 0.85 | 89.57 |
| 11.08 | 3.5 | 1.321 | 5.49 | 6.45 | 0.85 | 90.12 |
| 11.17 | 3.5 | 1.326 | 5.52 | 6.46 | 0.85 | 90.65 |

Table A.3 (Contd.)

| **t (hr)** | **b (m)** | **y (m)** | **A ($m^2$)** | **P (m)** | **R (m)** | **Q ($m^3/s$)** |
|---|---|---|---|---|---|---|
| 11.25 | 3.5 | 1.330 | 5.54 | 6.47 | 0.86 | 91.17 |
| 11.33 | 3.5 | 1.335 | 5.56 | 6.48 | 0.86 | 91.67 |
| 11.42 | 3.5 | 1.339 | 5.58 | 6.49 | 0.86 | 92.15 |
| 11.50 | 3.5 | 1.343 | 5.60 | 6.50 | 0.86 | 92.62 |
| 11.58 | 3.5 | 1.347 | 5.62 | 6.51 | 0.86 | 93.07 |
| 11.67 | 3.5 | 1.351 | 5.64 | 6.52 | 0.87 | 93.50 |
| 11.75 | 3.5 | 1.355 | 5.66 | 6.53 | 0.87 | 93.92 |
| 11.83 | 3.5 | 1.358 | 5.68 | 6.54 | 0.87 | 94.33 |
| 11.92 | 3.5 | 1.362 | 5.69 | 6.54 | 0.87 | 94.71 |
| 12.00 | 3.5 | 1.365 | 5.71 | 6.55 | 0.87 | 95.08 |
| 12.08 | 3.5 | 1.368 | 5.72 | 6.56 | 0.87 | 95.44 |
| 12.17 | 3.5 | 1.371 | 5.74 | 6.57 | 0.87 | 95.78 |
| 12.25 | 3.5 | 1.374 | 5.75 | 6.57 | 0.88 | 96.10 |
| 12.33 | 3.5 | 1.377 | 5.77 | 6.58 | 0.88 | 96.41 |
| 12.42 | 3.5 | 1.379 | 5.78 | 6.58 | 0.88 | 96.71 |
| 12.50 | 3.5 | 1.382 | 5.79 | 6.59 | 0.88 | 96.98 |
| 12.58 | 3.5 | 1.384 | 5.80 | 6.59 | 0.88 | 97.25 |
| 12.67 | 3.5 | 1.386 | 5.81 | 6.60 | 0.88 | 97.49 |
| 12.75 | 3.5 | 1.388 | 5.82 | 6.60 | 0.88 | 97.72 |
| 12.83 | 3.5 | 1.390 | 5.83 | 6.61 | 0.88 | 97.94 |
| 12.92 | 3.5 | 1.392 | 5.84 | 6.61 | 0.88 | 98.14 |
| 13.00 | 3.5 | 1.393 | 5.85 | 6.62 | 0.88 | 98.33 |
| 13.08 | 3.5 | 1.395 | 5.85 | 6.62 | 0.88 | 98.50 |
| 13.17 | 3.5 | 1.396 | 5.86 | 6.62 | 0.89 | 98.66 |
| 13.25 | 3.5 | 1.398 | 5.87 | 6.62 | 0.89 | 98.80 |
| 13.33 | 3.5 | 1.399 | 5.87 | 6.63 | 0.89 | 98.93 |
| 13.42 | 3.5 | 1.400 | 5.88 | 6.63 | 0.89 | 99.05 |
| 13.50 | 3.5 | 1.400 | 5.88 | 6.63 | 0.89 | 99.15 |
| 13.58 | 3.5 | 1.401 | 5.89 | 6.63 | 0.89 | 99.24 |
| 13.67 | 3.5 | 1.402 | 5.89 | 6.63 | 0.89 | 99.31 |
| 13.75 | 3.5 | 1.402 | 5.89 | 6.64 | 0.89 | 99.37 |
| 13.83 | 3.5 | 1.403 | 5.89 | 6.64 | 0.89 | 99.41 |
| 13.92 | 3.5 | 1.403 | 5.90 | 6.64 | 0.89 | 99.45 |
| 14.00 | 3.5 | 1.403 | 5.90 | 6.64 | 0.89 | 99.47 |
| 14.08 | 3.5 | 1.403 | 5.90 | 6.64 | 0.89 | 99.47 |
| 14.17 | 3.5 | 1.403 | 5.90 | 6.64 | 0.89 | 99.46 |
| 14.25 | 3.5 | 1.403 | 5.90 | 6.64 | 0.89 | 99.45 |
| 14.33 | 3.5 | 1.403 | 5.89 | 6.64 | 0.89 | 99.41 |
| 14.42 | 3.5 | 1.402 | 5.89 | 6.64 | 0.89 | 99.37 |
| 14.50 | 3.5 | 1.402 | 5.89 | 6.63 | 0.89 | 99.31 |
| 14.58 | 3.5 | 1.401 | 5.89 | 6.63 | 0.89 | 99.24 |
| 14.67 | 3.5 | 1.401 | 5.88 | 6.63 | 0.89 | 99.16 |

Table A.3 (Contd.)

| t (hr) | b (m) | y (m) | A ($m^2$) | P (m) | R (m) | Q ($m^3/s$) |
|---|---|---|---|---|---|---|
| 14.75 | 3.5 | 1.400 | 5.88 | 6.63 | 0.89 | 99.07 |
| 14.83 | 3.5 | 1.399 | 5.87 | 6.63 | 0.89 | 98.96 |
| 14.92 | 3.5 | 1.398 | 5.87 | 6.63 | 0.89 | 98.85 |
| 15.00 | 3.5 | 1.397 | 5.86 | 6.62 | 0.89 | 98.72 |
| 15.08 | 3.5 | 1.396 | 5.86 | 6.62 | 0.88 | 98.58 |
| 15.17 | 3.5 | 1.394 | 5.85 | 6.62 | 0.88 | 98.43 |
| 15.25 | 3.5 | 1.393 | 5.85 | 6.61 | 0.88 | 98.27 |
| 15.33 | 3.5 | 1.391 | 5.84 | 6.61 | 0.88 | 98.10 |
| 15.42 | 3.5 | 1.390 | 5.83 | 6.61 | 0.88 | 97.92 |
| 15.50 | 3.5 | 1.388 | 5.82 | 6.60 | 0.88 | 97.73 |
| 15.58 | 3.5 | 1.386 | 5.81 | 6.60 | 0.88 | 97.53 |
| 15.67 | 3.5 | 1.385 | 5.80 | 6.60 | 0.88 | 97.32 |
| 15.75 | 3.5 | 1.383 | 5.79 | 6.59 | 0.88 | 97.09 |
| 15.83 | 3.5 | 1.381 | 5.79 | 6.59 | 0.88 | 96.86 |
| 15.92 | 3.5 | 1.378 | 5.77 | 6.58 | 0.88 | 96.62 |
| 16.00 | 3.5 | 1.376 | 5.76 | 6.58 | 0.88 | 96.37 |
| 16.08 | 3.5 | 1.374 | 5.75 | 6.57 | 0.88 | 96.12 |
| 16.17 | 3.5 | 1.372 | 5.74 | 6.57 | 0.87 | 95.85 |
| 16.25 | 3.5 | 1.369 | 5.73 | 6.56 | 0.87 | 95.57 |
| 16.33 | 3.5 | 1.367 | 5.72 | 6.56 | 0.87 | 95.29 |
| 16.42 | 3.5 | 1.364 | 5.71 | 6.55 | 0.87 | 94.99 |
| 16.50 | 3.5 | 1.362 | 5.69 | 6.54 | 0.87 | 94.69 |
| 16.58 | 3.5 | 1.359 | 5.68 | 6.54 | 0.87 | 94.38 |
| 16.67 | 3.5 | 1.356 | 5.67 | 6.53 | 0.87 | 94.07 |
| 16.75 | 3.5 | 1.353 | 5.65 | 6.53 | 0.87 | 93.74 |
| 16.83 | 3.5 | 1.350 | 5.64 | 6.52 | 0.86 | 93.41 |
| 16.92 | 3.5 | 1.347 | 5.62 | 6.51 | 0.86 | 93.07 |
| 17.00 | 3.5 | 1.344 | 5.61 | 6.51 | 0.86 | 92.72 |
| 17.08 | 3.5 | 1.341 | 5.59 | 6.50 | 0.86 | 92.37 |
| 17.17 | 3.5 | 1.338 | 5.58 | 6.49 | 0.86 | 92.01 |
| 17.25 | 3.5 | 1.334 | 5.56 | 6.48 | 0.86 | 91.64 |
| 17.33 | 3.5 | 1.331 | 5.54 | 6.48 | 0.86 | 91.27 |
| 17.42 | 3.5 | 1.328 | 5.53 | 6.47 | 0.85 | 90.89 |
| 17.50 | 3.5 | 1.324 | 5.51 | 6.46 | 0.85 | 90.50 |
| 17.58 | 3.5 | 1.321 | 5.49 | 6.45 | 0.85 | 90.11 |
| 17.67 | 3.5 | 1.317 | 5.48 | 6.44 | 0.85 | 89.71 |
| 17.75 | 3.5 | 1.313 | 5.46 | 6.44 | 0.85 | 89.31 |
| 17.83 | 3.5 | 1.310 | 5.44 | 6.43 | 0.85 | 88.90 |
| 17.92 | 3.5 | 1.306 | 5.42 | 6.42 | 0.84 | 88.48 |
| 18.00 | 3.5 | 1.302 | 5.41 | 6.41 | 0.84 | 88.06 |
| 18.08 | 3.5 | 1.298 | 5.39 | 6.40 | 0.84 | 87.64 |
| 18.17 | 3.5 | 1.294 | 5.37 | 6.39 | 0.84 | 87.21 |

Table A.3 (Contd.)

| t (hr) | b (m) | y (m) | A ($m^2$) | P (m) | R (m) | Q ($m^3/s$) |
|---|---|---|---|---|---|---|
| 18.25 | 3.5 | 1.290 | 5.35 | 6.39 | 0.84 | 86.77 |
| 18.33 | 3.5 | 1.286 | 5.33 | 6.38 | 0.84 | 86.33 |
| 18.42 | 3.5 | 1.282 | 5.31 | 6.37 | 0.83 | 85.89 |
| 18.50 | 3.5 | 1.278 | 5.29 | 6.36 | 0.83 | 85.44 |
| 18.58 | 3.5 | 1.274 | 5.27 | 6.35 | 0.83 | 84.99 |
| 18.67 | 3.5 | 1.270 | 5.25 | 6.34 | 0.83 | 84.53 |
| 18.75 | 3.5 | 1.265 | 5.23 | 6.33 | 0.83 | 84.07 |
| 18.83 | 3.5 | 1.261 | 5.21 | 6.32 | 0.82 | 83.61 |
| 18.92 | 3.5 | 1.257 | 5.19 | 6.31 | 0.82 | 83.14 |
| 19.00 | 3.5 | 1.252 | 5.17 | 6.30 | 0.82 | 82.67 |
| 19.08 | 3.5 | 1.248 | 5.15 | 6.29 | 0.82 | 82.19 |
| 19.17 | 3.5 | 1.243 | 5.13 | 6.28 | 0.82 | 81.71 |
| 19.25 | 3.5 | 1.239 | 5.10 | 6.27 | 0.81 | 81.23 |
| 19.33 | 3.5 | 1.234 | 5.08 | 6.26 | 0.81 | 80.75 |
| 19.42 | 3.5 | 1.230 | 5.06 | 6.25 | 0.81 | 80.26 |
| 19.50 | 3.5 | 1.225 | 5.04 | 6.24 | 0.81 | 79.77 |
| 19.58 | 3.5 | 1.220 | 5.02 | 6.23 | 0.81 | 79.28 |
| 19.67 | 3.5 | 1.216 | 4.99 | 6.22 | 0.80 | 78.79 |
| 19.75 | 3.5 | 1.211 | 4.97 | 6.21 | 0.80 | 78.29 |
| 19.83 | 3.5 | 1.206 | 4.95 | 6.20 | 0.80 | 77.79 |
| 19.92 | 3.5 | 1.201 | 4.93 | 6.19 | 0.80 | 77.29 |
| 20.00 | 3.5 | 1.197 | 4.90 | 6.18 | 0.79 | 76.78 |
| 20.08 | 3.5 | 1.192 | 4.88 | 6.16 | 0.79 | 76.28 |
| 20.17 | 3.5 | 1.187 | 4.86 | 6.15 | 0.79 | 75.77 |
| 20.25 | 3.5 | 1.182 | 4.84 | 6.14 | 0.79 | 75.26 |
| 20.33 | 3.5 | 1.177 | 4.81 | 6.13 | 0.78 | 74.75 |
| 20.42 | 3.5 | 1.172 | 4.79 | 6.12 | 0.78 | 74.24 |
| 20.50 | 3.5 | 1.167 | 4.77 | 6.11 | 0.78 | 73.73 |
| 20.58 | 3.5 | 1.162 | 4.74 | 6.10 | 0.78 | 73.22 |
| 20.67 | 3.5 | 1.157 | 4.72 | 6.09 | 0.78 | 72.70 |
| 20.75 | 3.5 | 1.152 | 4.70 | 6.08 | 0.77 | 72.19 |
| 20.83 | 3.5 | 1.147 | 4.67 | 6.06 | 0.77 | 71.67 |
| 20.92 | 3.5 | 1.142 | 4.65 | 6.05 | 0.77 | 71.15 |
| 21.00 | 3.5 | 1.137 | 4.62 | 6.04 | 0.77 | 70.63 |
| 21.08 | 3.5 | 1.131 | 4.60 | 6.03 | 0.76 | 70.11 |
| 21.17 | 3.5 | 1.126 | 4.58 | 6.02 | 0.76 | 69.59 |
| 21.25 | 3.5 | 1.121 | 4.55 | 6.01 | 0.76 | 69.07 |
| 21.33 | 3.5 | 1.116 | 4.53 | 5.99 | 0.76 | 68.55 |
| 21.42 | 3.5 | 1.111 | 4.50 | 5.98 | 0.75 | 68.03 |
| 21.50 | 3.5 | 1.105 | 4.48 | 5.97 | 0.75 | 67.51 |
| 21.58 | 3.5 | 1.100 | 4.45 | 5.96 | 0.75 | 66.99 |
| 21.67 | 3.5 | 1.095 | 4.43 | 5.95 | 0.74 | 66.47 |

Table A.3 (Contd.)

| t (hr) | b (m) | y (m) | A ($m^2$) | P (m) | R (m) | Q ($m^3/s$) |
|---|---|---|---|---|---|---|
| 21.75 | 3.5 | 1.089 | 4.41 | 5.94 | 0.74 | 65.95 |
| 21.83 | 3.5 | 1.084 | 4.38 | 5.92 | 0.74 | 65.43 |
| 21.92 | 3.5 | 1.079 | 4.36 | 5.91 | 0.74 | 64.91 |
| 22.00 | 3.5 | 1.073 | 4.33 | 5.90 | 0.73 | 64.39 |
| 22.08 | 3.5 | 1.068 | 4.31 | 5.89 | 0.73 | 63.87 |
| 22.17 | 3.5 | 1.063 | 4.28 | 5.88 | 0.73 | 63.35 |
| 22.25 | 3.5 | 1.057 | 4.26 | 5.86 | 0.73 | 62.83 |
| 22.33 | 3.5 | 1.052 | 4.23 | 5.85 | 0.72 | 62.32 |
| 22.42 | 3.5 | 1.046 | 4.21 | 5.84 | 0.72 | 61.80 |
| 22.50 | 3.5 | 1.041 | 4.19 | 5.83 | 0.72 | 61.28 |
| 22.58 | 3.5 | 1.036 | 4.16 | 5.82 | 0.72 | 60.77 |
| 22.67 | 3.5 | 1.030 | 4.14 | 5.80 | 0.71 | 60.26 |
| 22.75 | 3.5 | 1.025 | 4.11 | 5.79 | 0.71 | 59.74 |
| 22.83 | 3.5 | 1.019 | 4.09 | 5.78 | 0.71 | 59.23 |
| 22.92 | 3.5 | 1.014 | 4.06 | 5.77 | 0.70 | 58.72 |
| 22.17 | 3.5 | 1.063 | 4.28 | 5.88 | 0.73 | 63.35 |
| 22.25 | 3.5 | 1.057 | 4.26 | 5.86 | 0.73 | 62.83 |
| 23.00 | 3.5 | 1.008 | 4.04 | 5.75 | 0.70 | 58.21 |
| 23.08 | 3.5 | 1.003 | 4.01 | 5.74 | 0.70 | 57.70 |
| 23.17 | 3.5 | 0.997 | 3.99 | 5.73 | 0.70 | 57.19 |
| 23.25 | 3.5 | 0.992 | 3.96 | 5.72 | 0.69 | 56.69 |
| 23.33 | 3.5 | 0.987 | 3.94 | 5.71 | 0.69 | 56.18 |
| 23.42 | 3.5 | 0.981 | 3.91 | 5.69 | 0.69 | 55.68 |
| 23.50 | 3.5 | 0.976 | 3.89 | 5.68 | 0.68 | 55.18 |
| 23.58 | 3.5 | 0.970 | 3.87 | 5.67 | 0.68 | 54.68 |
| 23.67 | 3.5 | 0.965 | 3.84 | 5.66 | 0.68 | 54.18 |
| 23.75 | 3.5 | 0.959 | 3.82 | 5.64 | 0.68 | 53.68 |
| 23.83 | 3.5 | 0.954 | 3.79 | 5.63 | 0.67 | 53.19 |
| 23.92 | 3.5 | 0.948 | 3.77 | 5.62 | 0.67 | 52.69 |
| 24.00 | 3.5 | 0.943 | 3.74 | 5.61 | 0.67 | 52.20 |
| 24.08 | 3.5 | 0.937 | 3.72 | 5.60 | 0.66 | 51.71 |
| 24.17 | 3.5 | 0.932 | 3.69 | 5.58 | 0.66 | 51.22 |
| 24.25 | 3.5 | 0.926 | 3.67 | 5.57 | 0.66 | 50.74 |
| 24.33 | 3.5 | 0.921 | 3.65 | 5.56 | 0.66 | 50.25 |
| 24.42 | 3.5 | 0.915 | 3.62 | 5.55 | 0.65 | 49.77 |
| 24.50 | 3.5 | 0.910 | 3.60 | 5.53 | 0.65 | 49.29 |
| 24.58 | 3.5 | 0.904 | 3.57 | 5.52 | 0.65 | 48.81 |
| 24.67 | 3.5 | 0.899 | 3.55 | 5.51 | 0.64 | 48.34 |
| 24.75 | 3.5 | 0.893 | 3.53 | 5.50 | 0.64 | 47.87 |
| 24.83 | 3.5 | 0.888 | 3.50 | 5.49 | 0.64 | 47.39 |
| 24.92 | 3.5 | 0.882 | 3.48 | 5.47 | 0.64 | 46.92 |
| 25.00 | 3.5 | 0.877 | 3.45 | 5.46 | 0.63 | 46.46 |

Table A.3 (Contd.)

| t (hr) | b (m) | y (m) | A ($m^2$) | P (m) | R (m) | Q ($m^3/s$) |
|---|---|---|---|---|---|---|
| 25.08 | 3.5 | 0.871 | 3.43 | 5.45 | 0.63 | 45.99 |
| 25.17 | 3.5 | 0.866 | 3.41 | 5.44 | 0.63 | 45.53 |
| 25.25 | 3.5 | 0.861 | 3.38 | 5.42 | 0.62 | 45.07 |
| 25.33 | 3.5 | 0.855 | 3.36 | 5.41 | 0.62 | 44.61 |
| 25.42 | 3.5 | 0.850 | 3.33 | 5.40 | 0.62 | 44.16 |
| 25.50 | 3.5 | 0.844 | 3.31 | 5.39 | 0.61 | 43.70 |
| 25.58 | 3.5 | 0.839 | 3.29 | 5.38 | 0.61 | 43.25 |
| 25.67 | 3.5 | 0.833 | 3.26 | 5.36 | 0.61 | 42.81 |
| 25.75 | 3.5 | 0.828 | 3.24 | 5.35 | 0.61 | 42.36 |
| 25.83 | 3.5 | 0.823 | 3.22 | 5.34 | 0.60 | 41.92 |
| 25.92 | 3.5 | 0.817 | 3.19 | 5.33 | 0.60 | 41.48 |
| 26.00 | 3.5 | 0.812 | 3.17 | 5.32 | 0.60 | 41.04 |
| 26.08 | 3.5 | 0.807 | 3.15 | 5.30 | 0.59 | 40.60 |
| 26.17 | 3.5 | 0.801 | 3.13 | 5.29 | 0.59 | 40.17 |
| 26.25 | 3.5 | 0.796 | 3.10 | 5.28 | 0.59 | 39.74 |
| 26.33 | 3.5 | 0.791 | 3.08 | 5.27 | 0.58 | 39.31 |
| 26.42 | 3.5 | 0.785 | 3.06 | 5.26 | 0.58 | 38.89 |
| 26.50 | 3.5 | 0.780 | 3.03 | 5.24 | 0.58 | 38.46 |
| 26.58 | 3.5 | 0.775 | 3.01 | 5.23 | 0.58 | 38.04 |
| 26.67 | 3.5 | 0.769 | 2.99 | 5.22 | 0.57 | 37.63 |
| 26.75 | 3.5 | 0.764 | 2.97 | 5.21 | 0.57 | 37.21 |
| 26.83 | 3.5 | 0.759 | 2.94 | 5.20 | 0.57 | 36.80 |
| 26.92 | 3.5 | 0.754 | 2.92 | 5.19 | 0.56 | 36.39 |
| 27.00 | 3.5 | 0.748 | 2.90 | 5.17 | 0.56 | 35.98 |
| 27.08 | 3.5 | 0.743 | 2.88 | 5.16 | 0.56 | 35.58 |
| 27.17 | 3.5 | 0.738 | 2.86 | 5.15 | 0.55 | 35.18 |
| 27.25 | 3.5 | 0.733 | 2.83 | 5.14 | 0.55 | 34.78 |
| 27.33 | 3.5 | 0.728 | 2.81 | 5.13 | 0.55 | 34.38 |
| 27.42 | 3.5 | 0.722 | 2.79 | 5.12 | 0.55 | 33.99 |
| 27.50 | 3.5 | 0.717 | 2.77 | 5.10 | 0.54 | 33.60 |
| 27.58 | 3.5 | 0.712 | 2.75 | 5.09 | 0.54 | 33.21 |
| 27.67 | 3.5 | 0.707 | 2.72 | 5.08 | 0.54 | 32.83 |
| 27.75 | 3.5 | 0.702 | 2.70 | 5.07 | 0.53 | 32.45 |
| 27.83 | 3.5 | 0.697 | 2.68 | 5.06 | 0.53 | 32.07 |
| 27.92 | 3.5 | 0.692 | 2.66 | 5.05 | 0.53 | 31.69 |
| 28.00 | 3.5 | 0.687 | 2.64 | 5.04 | 0.52 | 31.32 |
| 28.08 | 3.5 | 0.682 | 2.62 | 5.02 | 0.52 | 30.94 |
| 28.17 | 3.5 | 0.676 | 2.60 | 5.01 | 0.52 | 30.58 |
| 28.25 | 3.5 | 0.671 | 2.58 | 5.00 | 0.51 | 30.21 |
| 28.33 | 3.5 | 0.666 | 2.55 | 4.99 | 0.51 | 29.85 |
| 28.42 | 3.5 | 0.661 | 2.53 | 4.98 | 0.51 | 29.49 |
| 28.50 | 3.5 | 0.656 | 2.51 | 4.97 | 0.51 | 29.13 |

Table A.3 (Contd.)

| t (hr) | b (m) | y (m) | A ($m^2$) | P (m) | R (m) | Q ($m^3/s$) |
|---|---|---|---|---|---|---|
| 28.58 | 3.5 | 0.652 | 2.49 | 4.96 | 0.50 | 28.78 |
| 28.67 | 3.5 | 0.647 | 2.47 | 4.95 | 0.50 | 28.42 |
| 28.75 | 3.5 | 0.642 | 2.45 | 4.93 | 0.50 | 28.08 |
| 28.83 | 3.5 | 0.637 | 2.43 | 4.92 | 0.49 | 27.73 |
| 28.92 | 3.5 | 0.632 | 2.41 | 4.91 | 0.49 | 27.39 |
| 29.00 | 3.5 | 0.627 | 2.39 | 4.90 | 0.49 | 27.04 |
| 29.17 | 3.5 | 0.617 | 2.35 | 4.88 | 0.48 | 26.37 |
| 29.25 | 3.5 | 0.612 | 2.33 | 4.87 | 0.48 | 26.04 |
| 29.33 | 3.5 | 0.608 | 2.31 | 4.86 | 0.48 | 25.71 |
| 29.42 | 3.5 | 0.603 | 2.29 | 4.85 | 0.47 | 25.38 |
| 29.50 | 3.5 | 0.598 | 2.27 | 4.84 | 0.47 | 25.06 |
| 29.58 | 3.5 | 0.593 | 2.25 | 4.83 | 0.47 | 24.74 |
| 29.67 | 3.5 | 0.588 | 2.23 | 4.82 | 0.46 | 24.42 |
| 29.75 | 3.5 | 0.584 | 2.21 | 4.81 | 0.46 | 24.10 |
| 29.83 | 3.5 | 0.579 | 2.19 | 4.79 | 0.46 | 23.79 |
| 29.92 | 3.5 | 0.574 | 2.17 | 4.78 | 0.45 | 23.48 |
| 30.00 | 3.5 | 0.570 | 2.16 | 4.77 | 0.45 | 23.17 |
| 30.08 | 3.5 | 0.565 | 2.14 | 4.76 | 0.45 | 22.86 |
| 30.17 | 3.5 | 0.560 | 2.12 | 4.75 | 0.45 | 22.56 |
| 30.25 | 3.5 | 0.556 | 2.10 | 4.74 | 0.44 | 22.26 |
| 30.33 | 3.5 | 0.551 | 2.08 | 4.73 | 0.44 | 21.96 |
| 30.42 | 3.5 | 0.546 | 2.06 | 4.72 | 0.44 | 21.67 |
| 30.50 | 3.5 | 0.542 | 2.04 | 4.71 | 0.43 | 37.21 |
| 30.58 | 3.5 | 0.537 | 2.02 | 4.70 | 0.43 | 36.80 |
| 30.67 | 3.5 | 0.533 | 2.01 | 4.69 | 0.43 | 36.39 |
| 30.75 | 3.5 | 0.528 | 1.99 | 4.68 | 0.42 | 35.98 |
| 30.83 | 3.5 | 0.524 | 1.97 | 4.67 | 0.42 | 35.58 |
| 30.92 | 3.5 | 0.519 | 1.95 | 4.66 | 0.42 | 35.18 |
| 31.00 | 3.5 | 0.515 | 1.93 | 4.65 | 0.42 | 34.78 |
| 31.08 | 3.5 | 0.510 | 1.92 | 4.64 | 0.41 | 34.38 |
| 31.17 | 3.5 | 0.506 | 1.90 | 4.63 | 0.41 | 33.99 |
| 31.25 | 3.5 | 0.501 | 1.88 | 4.62 | 0.41 | 33.60 |
| 31.33 | 3.5 | 0.497 | 1.86 | 4.61 | 0.40 | 33.21 |
| 31.42 | 3.5 | 0.493 | 1.85 | 4.60 | 0.40 | 32.83 |
| 31.50 | 3.5 | 0.488 | 1.83 | 4.59 | 0.40 | 32.45 |
| 31.58 | 3.5 | 0.484 | 1.81 | 4.58 | 0.40 | 32.07 |
| 31.67 | 3.5 | 0.480 | 1.79 | 4.57 | 0.39 | 31.69 |
| 31.75 | 3.5 | 0.475 | 1.78 | 4.56 | 0.39 | 31.32 |
| 31.83 | 3.5 | 0.471 | 1.76 | 4.55 | 0.39 | 30.94 |
| 31.92 | 3.5 | 0.467 | 1.74 | 4.54 | 0.38 | 30.58 |
| 32.00 | 3.5 | 0.462 | 1.73 | 4.53 | 0.38 | 30.21 |
| 32.08 | 3.5 | 0.458 | 1.71 | 4.52 | 0.38 | 29.85 |

Table A.3 (Contd.)

| t (hr) | b (m) | y (m) | A ($m^2$) | P (m) | R (m) | Q ($m^3/s$) |
|---|---|---|---|---|---|---|
| 32.17 | 3.5 | 0.454 | 1.69 | 4.52 | 0.37 | 29.49 |
| 32.25 | 3.5 | 0.450 | 1.68 | 4.51 | 0.37 | 29.13 |
| 32.33 | 3.5 | 0.446 | 1.66 | 4.50 | 0.37 | 28.78 |
| 32.42 | 3.5 | 0.441 | 1.64 | 4.49 | 0.37 | 28.42 |
| 32.50 | 3.5 | 0.437 | 1.63 | 4.48 | 0.36 | 28.08 |
| 32.58 | 3.5 | 0.433 | 1.61 | 4.47 | 0.36 | 27.73 |
| 32.67 | 3.5 | 0.429 | 1.59 | 4.46 | 0.36 | 27.39 |
| 32.75 | 3.5 | 0.425 | 1.58 | 4.45 | 0.35 | 27.04 |
| 32.83 | 3.5 | 0.421 | 1.56 | 4.44 | 0.35 | 26.71 |
| 32.92 | 3.5 | 0.417 | 1.55 | 4.43 | 0.35 | 26.37 |
| 33.00 | 3.5 | 0.413 | 1.53 | 4.42 | 0.35 | 26.04 |
| 33.08 | 3.5 | 0.409 | 1.51 | 4.41 | 0.34 | 25.71 |
| 33.17 | 3.5 | 0.405 | 1.50 | 4.40 | 0.34 | 25.38 |
| 33.25 | 3.5 | 0.401 | 1.48 | 4.40 | 0.34 | 25.06 |
| 33.33 | 3.5 | 0.397 | 1.47 | 4.39 | 0.33 | 24.74 |
| 33.42 | 3.5 | 0.393 | 1.45 | 4.38 | 0.33 | 24.42 |
| 33.50 | 3.5 | 0.389 | 1.44 | 4.37 | 0.33 | 24.10 |
| 33.58 | 3.5 | 0.385 | 1.42 | 4.36 | 0.33 | 23.79 |
| 33.67 | 3.5 | 0.381 | 1.41 | 4.35 | 0.32 | 23.48 |
| 33.75 | 3.5 | 0.377 | 1.39 | 4.34 | 0.32 | 23.17 |
| 33.83 | 3.5 | 0.373 | 1.38 | 4.33 | 0.32 | 22.86 |
| 33.92 | 3.5 | 0.369 | 1.36 | 4.33 | 0.31 | 22.56 |
| 34.00 | 3.5 | 0.365 | 1.35 | 4.32 | 0.31 | 22.26 |
| 34.08 | 3.5 | 0.361 | 1.33 | 4.31 | 0.31 | 21.96 |
| 34.17 | 3.5 | 0.358 | 1.32 | 4.30 | 0.31 | 21.67 |
| 34.25 | 3.5 | 0.354 | 1.30 | 4.29 | 0.30 | 10.72 |
| 34.33 | 3.5 | 0.350 | 1.29 | 4.28 | 0.30 | 10.53 |
| 34.42 | 3.5 | 0.346 | 1.27 | 4.27 | 0.30 | 10.35 |
| 34.50 | 3.5 | 0.342 | 1.26 | 4.27 | 0.29 | 10.17 |
| 34.58 | 3.5 | 0.339 | 1.24 | 4.26 | 0.29 | 9.99 |
| 34.67 | 3.5 | 0.335 | 1.23 | 4.25 | 0.29 | 9.81 |
| 34.75 | 3.5 | 0.331 | 1.21 | 4.24 | 0.29 | 9.63 |
| 34.83 | 3.5 | 0.328 | 1.20 | 4.23 | 0.28 | 9.46 |
| 34.92 | 3.5 | 0.324 | 1.19 | 4.22 | 0.28 | 9.29 |
| 35.00 | 3.5 | 0.320 | 1.17 | 4.22 | 0.28 | 9.12 |
| 35.08 | 3.5 | 0.317 | 1.16 | 4.21 | 0.28 | 8.95 |
| 35.17 | 3.5 | 0.313 | 1.14 | 4.20 | 0.27 | 8.78 |
| 35.25 | 3.5 | 0.309 | 1.13 | 4.19 | 0.27 | 8.61 |
| 35.33 | 3.5 | 0.306 | 1.12 | 4.18 | 0.27 | 8.45 |
| 35.42 | 3.5 | 0.302 | 1.10 | 4.18 | 0.26 | 8.29 |
| 35.50 | 3.5 | 0.299 | 1.09 | 4.17 | 0.26 | 8.13 |
| 35.58 | 3.5 | 0.295 | 1.08 | 4.16 | 0.26 | 7.97 |

Table A.3 (Contd.)

| t (hr) | b (m) | y (m) | A ($m^2$) | P (m) | R (m) | Q ($m^3/s$) |
|---|---|---|---|---|---|---|
| 35.67 | 3.5 | 0.291 | 1.06 | 4.15 | 0.26 | 7.82 |
| 35.75 | 3.5 | 0.288 | 1.05 | 4.14 | 0.25 | 7.66 |
| 35.83 | 3.5 | 0.284 | 1.04 | 4.14 | 0.25 | 7.51 |
| 35.92 | 3.5 | 0.281 | 1.02 | 4.13 | 0.25 | 7.36 |
| 36.00 | 3.5 | 0.277 | 1.01 | 4.12 | 0.24 | 7.21 |
| 36.08 | 3.5 | 0.274 | 1.00 | 4.11 | 0.24 | 7.06 |
| 36.17 | 3.5 | 0.270 | 0.98 | 4.10 | 0.24 | 6.92 |
| 36.25 | 3.5 | 0.267 | 0.97 | 4.10 | 0.24 | 6.77 |
| 36.33 | 3.5 | 0.263 | 0.96 | 4.09 | 0.23 | 6.63 |
| 36.42 | 3.5 | 0.260 | 0.94 | 4.08 | 0.23 | 6.49 |
| 36.50 | 3.5 | 0.256 | 0.93 | 4.07 | 0.23 | 6.35 |
| 36.58 | 3.5 | 0.253 | 0.92 | 4.07 | 0.23 | 6.21 |
| 36.67 | 3.5 | 0.250 | 0.90 | 4.06 | 0.22 | 6.08 |
| 36.75 | 3.5 | 0.246 | 0.89 | 4.05 | 0.22 | 5.94 |
| 36.83 | 3.5 | 0.243 | 0.88 | 4.04 | 0.22 | 5.81 |
| 36.92 | 3.5 | 0.239 | 0.87 | 4.04 | 0.21 | 5.68 |
| 37.00 | 3.5 | 0.236 | 0.85 | 4.03 | 0.21 | 5.55 |
| 37.08 | 3.5 | 0.233 | 0.84 | 4.02 | 0.21 | 5.42 |
| 37.17 | 3.5 | 0.229 | 0.83 | 4.01 | 0.21 | 5.29 |
| 37.25 | 3.5 | 0.226 | 0.82 | 4.01 | 0.20 | 5.17 |
| 37.33 | 3.5 | 0.223 | 0.80 | 4.00 | 0.20 | 5.04 |
| 37.42 | 3.5 | 0.219 | 0.79 | 3.99 | 0.20 | 4.92 |
| 37.50 | 3.5 | 0.216 | 0.78 | 3.98 | 0.20 | 4.80 |
| 37.58 | 3.5 | 0.213 | 0.77 | 3.98 | 0.19 | 4.68 |
| 37.67 | 3.5 | 0.209 | 0.76 | 3.97 | 0.19 | 4.56 |
| 37.75 | 3.5 | 0.206 | 0.74 | 3.96 | 0.19 | 4.44 |
| 37.83 | 3.5 | 0.203 | 0.73 | 3.95 | 0.18 | 4.33 |
| 37.92 | 3.5 | 0.200 | 0.72 | 3.95 | 0.18 | 4.22 |
| 38.00 | 3.5 | 0.196 | 0.71 | 3.94 | 0.18 | 4.10 |
| 38.08 | 3.5 | 0.193 | 0.69 | 3.93 | 0.18 | 3.99 |
| 38.17 | 3.5 | 0.190 | 0.68 | 3.92 | 0.17 | 3.88 |
| 38.25 | 3.5 | 0.187 | 0.67 | 3.92 | 0.17 | 3.77 |
| 38.33 | 3.5 | 0.183 | 0.66 | 3.91 | 0.17 | 3.67 |
| 38.42 | 3.5 | 0.180 | 0.65 | 3.90 | 0.17 | 3.56 |
| 38.50 | 3.5 | 0.177 | 0.63 | 3.90 | 0.16 | 3.46 |
| 38.58 | 3.5 | 0.174 | 0.62 | 3.89 | 0.16 | 3.35 |
| 38.67 | 3.5 | 0.170 | 0.61 | 3.88 | 0.16 | 3.25 |
| 38.75 | 3.5 | 0.167 | 0.60 | 3.87 | 0.15 | 3.15 |
| 38.83 | 3.5 | 0.164 | 0.59 | 3.87 | 0.15 | 3.05 |
| 38.92 | 3.5 | 0.161 | 0.58 | 3.86 | 0.15 | 2.95 |
| 39.00 | 3.5 | 0.157 | 0.56 | 3.85 | 0.15 | 2.86 |
| 39.08 | 3.5 | 0.154 | 0.55 | 3.84 | 0.14 | 2.76 |

Table A.3 (Contd.)

| **t (hr)** | **b (m)** | **y (m)** | **A ($m^2$)** | **P (m)** | **R (m)** | **Q ($m^3/s$)** |
|---|---|---|---|---|---|---|
| 39.17 | 3.5 | 0.151 | 0.54 | 3.84 | 0.14 | 2.67 |
| 39.25 | 3.5 | 0.148 | 0.53 | 3.83 | 0.14 | 2.57 |
| 39.33 | 3.5 | 0.144 | 0.52 | 3.82 | 0.14 | 2.48 |
| 39.42 | 3.5 | 0.141 | 0.50 | 3.82 | 0.13 | 2.39 |
| 39.50 | 3.5 | 0.138 | 0.49 | 3.81 | 0.13 | 2.30 |
| 39.58 | 3.5 | 0.135 | 0.48 | 3.80 | 0.13 | 2.21 |
| 39.67 | 3.5 | 0.132 | 0.47 | 3.79 | 0.12 | 2.12 |
| 39.75 | 3.5 | 0.128 | 0.46 | 3.79 | 0.12 | 2.04 |
| 39.83 | 3.5 | 0.125 | 0.45 | 3.78 | 0.12 | 1.95 |
| 39.92 | 3.5 | 0.122 | 0.43 | 3.77 | 0.11 | 1.87 |
| 40.00 | 3.5 | 0.118 | 0.42 | 3.76 | 0.11 | 1.79 |
| 40.08 | 3.5 | 0.115 | 0.41 | 3.76 | 0.11 | 1.71 |
| 40.17 | 3.5 | 0.112 | 0.40 | 3.75 | 0.11 | 1.62 |
| 40.25 | 3.5 | 0.108 | 0.39 | 3.74 | 0.10 | 1.55 |
| 40.33 | 3.5 | 0.105 | 0.37 | 3.73 | 0.10 | 1.47 |
| 40.42 | 3.5 | 0.102 | 0.36 | 3.73 | 0.10 | 1.39 |
| 40.50 | 3.5 | 0.098 | 0.35 | 3.72 | 0.09 | 1.32 |
| 40.58 | 3.5 | 0.095 | 0.34 | 3.71 | 0.09 | 1.24 |
| 40.67 | 3.5 | 0.091 | 0.32 | 3.70 | 0.09 | 1.17 |
| 40.75 | 3.5 | 0.088 | 0.31 | 3.70 | 0.08 | 1.10 |
| 40.83 | 3.5 | 0.084 | 0.30 | 3.69 | 0.08 | 1.02 |
| 40.92 | 3.5 | 0.081 | 0.29 | 3.68 | 0.08 | 0.95 |
| 41.00 | 3.5 | 0.077 | 0.27 | 3.67 | 0.07 | 0.89 |
| 41.08 | 3.5 | 0.074 | 0.26 | 3.66 | 0.07 | 0.82 |
| 41.17 | 3.5 | 0.070 | 0.25 | 3.66 | 0.07 | 0.75 |
| 41.25 | 3.5 | 0.066 | 0.23 | 3.65 | 0.06 | 0.69 |
| 41.33 | 3.5 | 0.063 | 0.22 | 3.64 | 0.06 | 0.62 |
| 41.42 | 3.5 | 0.059 | 0.21 | 3.63 | 0.06 | 0.56 |
| 41.50 | 3.5 | 0.055 | 0.19 | 3.62 | 0.05 | 0.50 |
| 41.58 | 3.5 | 0.051 | 0.18 | 3.61 | 0.05 | 0.44 |
| 41.67 | 3.5 | 0.047 | 0.16 | 3.60 | 0.05 | 0.39 |
| 41.75 | 3.5 | 0.043 | 0.15 | 3.60 | 0.04 | 0.33 |
| 41.83 | 3.5 | 0.038 | 0.13 | 3.59 | 0.04 | 0.28 |
| 41.92 | 3.5 | 0.034 | 0.12 | 3.58 | 0.03 | 0.23 |
| 42.00 | 3.5 | 0.029 | 0.10 | 3.57 | 0.03 | 0.18 |
| 42.08 | 3.5 | 0.025 | 0.09 | 3.55 | 0.02 | 0.13 |
| 42.17 | 3.5 | 0.020 | 0.07 | 3.54 | 0.02 | 0.09 |
| 42.25 | 3.5 | 0.014 | 0.05 | 3.53 | 0.01 | 0.05 |
| 42.33 | 3.5 | 0.009 | 0.03 | 3.52 | 0.01 | 0.02 |