

FLOOD MAPPING IN GREATER NOIDA USING ArcGIS AND HECRAS

A MAJOR PROJECT REPORT

*Submitted in fulfilment of the requirement for the award of degree
of*

MASTER OF TECHNOLOGY

in

HYDRAULICS AND FLOOD CONTROL ENGINEERING

Submitted by

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Under the guidance of

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to the



DEPARTMENT OF CIVIL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

JULY, 2014

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CERTIFICATE

This is to certify that the Major Project entitled “FLOOD MAPPING IN GREATER NOIDA USING Arc-GIS AND HECRAS” submitted by VARSHA BISHT Roll no 2K12/HFE/10, towards the fulfilment of the requirements for the award of the degree of Master of Technology, Hydraulics and Flood control Engineering in Civil Engineering Department, Delhi Technological University, Delhi was carried out under my supervision and guidance and has not been submitted elsewhere for the award of any other degree. She has fulfilled the requirements for the submission of this report, which to the best of my knowledge has reached the requisite standard.

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I, VARSHA BISHT, hereby certify that the work which is being presented in the Major Project entitled “FLOOD MAPPING IN GREATER NOIDA USING ARCGIS AND HEC-RAS” in the partial fulfilment of requirement for the award of degree of MASTER OF ENGINEERING submitted in the Department of Civil Engineering at DELHI TECHNOLOGICAL UNIVERSITY, DELHI, is an authentic record of my own work carried out under the supervision of Prof RAKESH MEHROTRA, Department of Civil Engineering. The matter presented in this report has not been submitted in any other University/Institute for the award of any degree as per my knowledge and belief.

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ABSTRACT

Floods are considered major hazardous processes, given the rising number of events, the large number of people affected, the associated damage and losses and the growing socioeconomic impacts which cause widespread disturbance. Hydraulic modeling is an important tool for a reliable flood forecasting system. Simulation results from hydraulic modelling can be used to produce flood inundation mapping that community officials or the general public can deploy to evaluate their flood risk. Mapping a floodplain requires the forecasting of the stream behaviour for various recurrence intervals, storm events and the ability to translate the forecasted results into an extent of flooding plan view. With the companion GIS utility HEC-Geo RAS, water surface profile can easily be converted into flood inundation maps.

The present work discusses general hydraulic modelling and softwares as applied to some select area of western of Uttar Pradesh. 1-D hydraulic model HEC-RAS of steady flow, using a higher resolution topographic surface including hydro geomorphological details and other features influencing hydraulic characteristics, was applied to Hasanpur drain as well as urban and rural areas in order to determine the flood prone areas for a return period of 2,10 and 25 years.

Keywords: Hydraulic modelling, HEC-RAS, Flood Inundation Maps, Geo-RAS

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LIST OF ACRONYM

ArcGIS	Arc Geographic Information System(Software package)
CNTRLIN.shp	Contour Line Shape File
DTM	Digital Terrain Model
HEC-HMS	Hydrologic Engineering Centre-Hydrologic Modeling System
HEC-GeoRAS	Hydrologic Engineering Centre-Geospatial River Analysis System
HEC-RAS	Hydrologic Engineering Centre-River Analysis System
LIDAR	Light Detection And Ranging
RAS	River Analysis System
TIN	Triangulated Irregular Network
USACE	United States Army Corps of Engineers

Chapter 1

INTRODUCTION

1.1 GENERAL

Different methods can be approximated for the movement of flood waters through the landscape. For the description of natural physical phenomena using numerical methods broad assumptions are used to develop governing equations. The method simple hydraulic modelling may be sufficient for approximating propagation of flood peaks through river channels, more complex hydraulic analyses is required to include effects of infrastructure or complex overland flow. The more detailed physical phenomena can be achieved by advanced models, but this does not correspond to a decrease in uncertainty.

The factors affecting Flood inundation mapping are quality of terrain data (digital elevation model, DEM), the cross-sectional configuration, and the use of a one (1D) or two-dimensional (2D) hydraulic model. The transformation of the flood inundation mapping process is achieved by, the increased availability of high resolution topographic data, development of two- and three- dimensional hydrodynamic models, and access to fast computing computers.

In one-dimensional hydraulic modeling, it is supposed that all water flows in the longitudinal direction. They represent the terrain as a sequence of cross-sections and simulate flow to predict the average velocity and water depth at each of the cross section. In two-dimensional models, water moves both in the longitudinal and lateral directions, while velocity is neglected in the vertical direction. In contrast to the one-dimensional models, two-dimensional models represent areas in a continuous surface through the finite element mesh. The two-dimensional models due to the continuous representation of terrain are able to distinguish the lateral interaction of flow between the main channel and the floodplain. One-dimensional models are generally very efficient but have disadvantage lies in the inability to simulate the lateral diffusion of the flood wave and the representation of topography as cross-sections rather than as a surface (Hunter et al., 2007).

The limitation in one-dimensional model can be overcome by Two dimensional model given that flow can be simulated in one or two-dimensions by using either a series of

cross-sections or a continuous surface, the assumptions made in hydraulic modeling as well as the quality of the terrain data and the cross-sectional configuration for a one-dimensional model or mesh resolution for a two-dimensional model will have a large impact on the resulting inundation.

The difficulty lies in the fact that each program describes the data by using different coordinate system. HECRAS is a 1- Dimensional model for the hydraulic analysis of river channels. In HEC-RAS, the stream morphology showed by a series of cross section called drain stations. As we proceed from upstream to downstream, the drain stations numbering decreases. The distance between adjacent cross section is known as the reach length. Each cross section is defined by a series of lateral and elevation coordinates, which are typically found from land surveys.

1.2 OBJECTIVES

The present study involves connecting hydraulic modeling with GIS to get spatial distribution of flood. The main research objective is:

- To develop a DEM of the study area from contour map.
- Water surface profiles are developed from the HEC-RAS hydraulic model and draw a map of the resulting floodplain in ArcView GIS from a discharge of a storm event.
- Hydraulic modeling output from HEC-RAS to Arc View gives hydraulic parameters and hydraulic profiles.
- To obtain the flood map using HEC Geo RAS.

1.3 SCOPE

Flood inundation models are a major tool for diminishing the effects of flooding. The prediction of flood extent is provided by them and depth that are used in the development of spatially accurate hazard maps. These allow the assessment of risk to life and property in the floodplain, and the prioritisation of either the maintenance of existing flood defences or the construction of new ones. Progress has been made in the concept of the processes controlling runoff and flood wave propagation, in simulation techniques, in low cost high power computing, in uncertainty handling, and in the provision of new data sources. The testing of flow conditions and severity together with the development of models for the calculation and expression mapping of inundation

areas are fundamental to the implementation of prevention, reduction and risk mitigation tools and also the implementation of early warning systems.

1.4 ORGANISATION OF REPORT

The study described in this report provides an approach for processing the output of hydraulic modeling in HEC-RAS and to enable the mapping of floods in Arc View GIS. The report consists of six chapters. Chapter 2 provides an overview of a detailed review of the relevant literature. Chapter 3 gives the brief introduction of Study Area. Chapter 4 provides the methodology of the processing of HECRAS output data, terrain modeling and flood delineation. Chapter5 is about the results and discussion of the Hydraulic Modeling analysis. Chapter 6 describes Conclusion.

An important by product of this thesis is a GIS program that can be used for flood mapping and terrain model development such as Digital Elevation Map (DEM).

Chapter 2

LITERATURE REVIEW

2.1 FLOOD INUNDATION MODELING

Hydraulic modeling is not easily solved by continuity equations. Saint Venant Equations are used for solving the Hydraulic modeling. By 1976, The methods used for solving the Saint Venant Equations seen to be satisfactory result with mathematical models found to be adequate for large number of practical applications. (Priessmann, 1976). Bates et al (1997) mention the further development of 2-Dimensional finite elements models of river flood flow. He applied the 2-Dimensional finite elements model to the Missouri river, Nebraskan with integration of hydraulic modelling and remote sensing.

With the rapid development of GIS in 1980, the flow of water on the surface of the earth could be represented in Spatial Format. In GIS much of the initial work dealt with the analysis of DEM (Digital Elevation Model) in which square grids of regularly spaced elevation data are analyzed for hydrologic applications. Beavers (1994) worked on hydraulic modeling of river channels using GIS for flood plain analysis. GIS tool, called ARC / HEC2, was designed to help a hydrologist in the floodplain analysis.

Han et al. (1998) and Chang et al. (2000) have also reported 1-D, 2-D coupled modeling of river flood plain flow. The models have used a full dynamic equation for the channel flow for the two-dimensional flood plain flow, here a diffusion wave approximation is utilized. Anderson (2000), Robayo et al. (2004) and Knebl et al (2005) discussed that flood inundation modelling involves hydrologic modeling to estimate peak flows from storm events, hydraulic modeling to estimate water surface elevations and terrain analysis to estimate the inundation area. Wrigh et al. (2008) gives a methodology for using remotely sensed data to both generate and determine a hydraulic model of floodplain inundation for a rural case study in the United Kingdom-Upton-Upon Seven. Zheng et al. (2008) developed a distributed model for simulating flood inundation integrating with rainfall runoff processes using SRTM-DEM data and some remote sensing data sets in the environment of GIS for Maruyama River basin, Japan. Simulated results in the Maruyama River basin demonstrate an acceptable agreement with the flooded area observed.

Bhatt et al.(2010) studied the operational use of remote sensing technology for near real-time flood mapping, monitoring Kosi floods and the satellite based observations made for the Kosi river breach.Patro et al.(2009) used a coupled 1-D and 2-D hydrodynamic model ,MIKE FLOOD to simulate the flood inundation extent and flooding depth in the delta region of Mahanadi River basin in India .They used SRTM –DEM to prepare a bathymetry of the study area and provided as an input to the 2D model,MIKE21.Using lateral links in MIKE 11 and MIKE 21 models flood inundated area was obtained .Results were compares with actual inundated area obtained area from IRS -1D WiFS image Samarasinghe et al.(2010) derived flood extent obtained for the 50 –year rainfall using HEC-HMS and HEC-RAS in Kalu –Ganga ,Sri Lanka.

Ahmad et al. (2010) generated flood map for Nullah Lai in Rawalpindi using HEC-RAS and HEC-Geo RAS hydrological models with GIS .They established relationship between inundation depth and specific discharge value. Shaohong et.al (2010)developed a real-time flood monitoring system that allows integrated handling of hydrological data coming from a wireless monitoring system. They found water inundation depth using spatial analysis technology on the basis of hydrological data. Then, flood area was found by minus water surface elevation and DEM.

2.2 PREVIOUS HYDRAULIC MODELING USING HECRAS

Tate E.C, 1999, Floodplain Mapping Using HEC-RAS and ArcView GIS.

Tate developed the HEC-RAS hydraulic modeling and 2 D and 3D flood plain mapping using Arc View GIS. His thesis represents the direct approach for processing the output of the model and analysis of HEC-RAS in ArcView geographic information system. This methodology is used to a reach of Waller Creek, located in Austin, Texas. A flood plain view is developed in Arc View. This proves that GIS is an effective tool for flood plain mapping analysis. [1].

Werner MGF (2001). Impact of grid size in GIS based flood extent mapping using a 1 D flow model

Werner has found in this research that, the GeoRAS is supportive software of HEC-RAS, has simple import and export competences to smooth the transition between

generating the geometric file, running the model rapidly and presenting the results. GeoRAS has based on two processing work Pre Processing and Post Processing. Post Processing gives the flood inundation mapping. The end result of the process is not only quicker floodplain delineation with greater accuracy than traditional methods, but also a flow depth grid indicating to the user the level of inundation of any area in the model [2].

Earles TA, Wright RK, Brown C, Langan TAE (2004). Los alamos forest fire impact modeling

This paper outlined the implementation of the HEC-geoRAS model for floodplain determination and delineation of key hydraulic parameters and also, HEC-RAS capability of creating hydraulic results in Los Alamos, New Mexico, USA. [3]

Williams TM (2006). Incorporating GIS in river hydraulic modeling: Assessing the Ability to Predict Ecological Consequences of River

In this paper Williams found the flooding regime on Santee River in which the advantages of integration to model the impact of the Santee River re diversion are outlined. HEC-RAS 3.2 and the HEC-geoRAS extension for ARC-View were used to analyze the flooding regime prior and subsequent to red version operations. ARC-GIS 8.3 was used to reduce Real Time Kinematics and LIDAR elevation surveys of the river bottom elevations into data usable by the program. The huge amount of high exactitude data resulted in highly calibrated model that was well validated; it stressed the limitations of the GIS software [4].

ChuanT, Jing Z (2006). Torrent risk zonation in the Upstream Red River Basin

It is based on study of GIS Chuan and Jing in 2006 the methodology for accumulating the torrent hazard and risk zonation map by mode of GIS technique for the Red River Basin in Yunnan province of China, where was prone to torrent. The risk evaluation result in the upper Red River Basin showed that the extremely high risk area of 13,150 km² takes up 17.9% of the total inundated area, the high risk area of 33,783 km² is 45.9%, the moderate risk area of 18,563 km² was 25.2% and the low risk area of 8115 km² is 11 % [6].

There are also software packages available in Industry which combines GIS and hydraulic modeling of a river. Danish Institute for Water has developed MIKE 11 GIS system that connects dimensional MIKE11 hydraulic model and Arc View GIS. By

using MIKE11 GIS, we can be obtained floodplain topography from DEM and imported into the MIKE 11. After running the model, it can prepare three types of floodplain maps, For display and analysis in Arc View , Flood area, duration and Comparison (DHI, 1999) .MIKE11 GIS can also be used to produce result timelines water level data series, terrain and water level profiles, and statistics flood zone.

Chapter 3

STUDY AREA

3.1 LOCATION

The site for project area is 2500 acres adjoining Greater Noida (UP). Project site is surrounded by NH-91 on the north East, Delhi Aligarh Railway Line on the South West, Kot Escape (Canal) on the South East and Main Kalda Distributary on the west side. It seems that the project area is locked by all ridge line features subsequent to the high intensity rainfall season the entire study area was subjected to water logging due to lack of suitable surface water drainage system.

Main Kalda Distributary canal / Drain from UP upstream of NH-91 and connected to Kota escape channel / Hasanpur Drain (after railway culvert), this irrigation channel located on ridge line have various across drain like Pallla drain, Bheel Minor etc. Hasanpur Drain lies between 77°36'5.94" East Longitudes and 28°28'36.46" North latitudes.

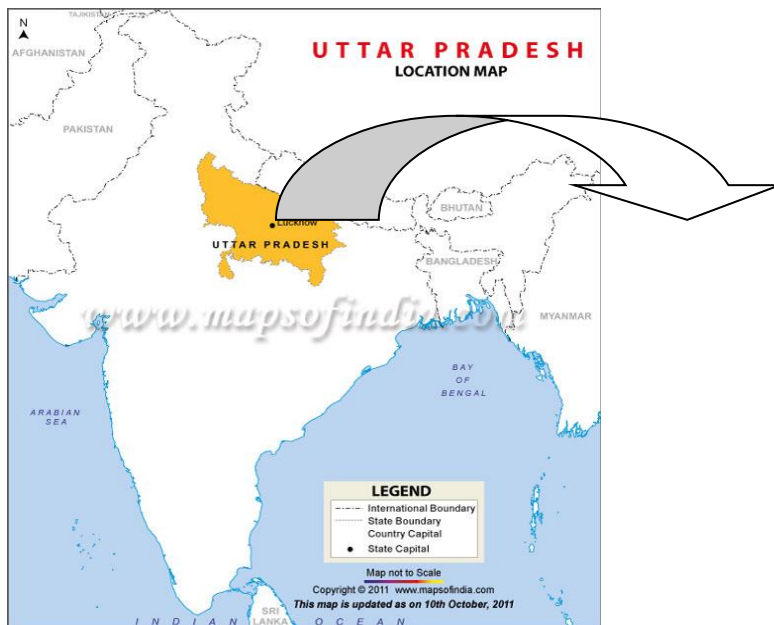




Figure 3.1 Map of Uttar Pradesh

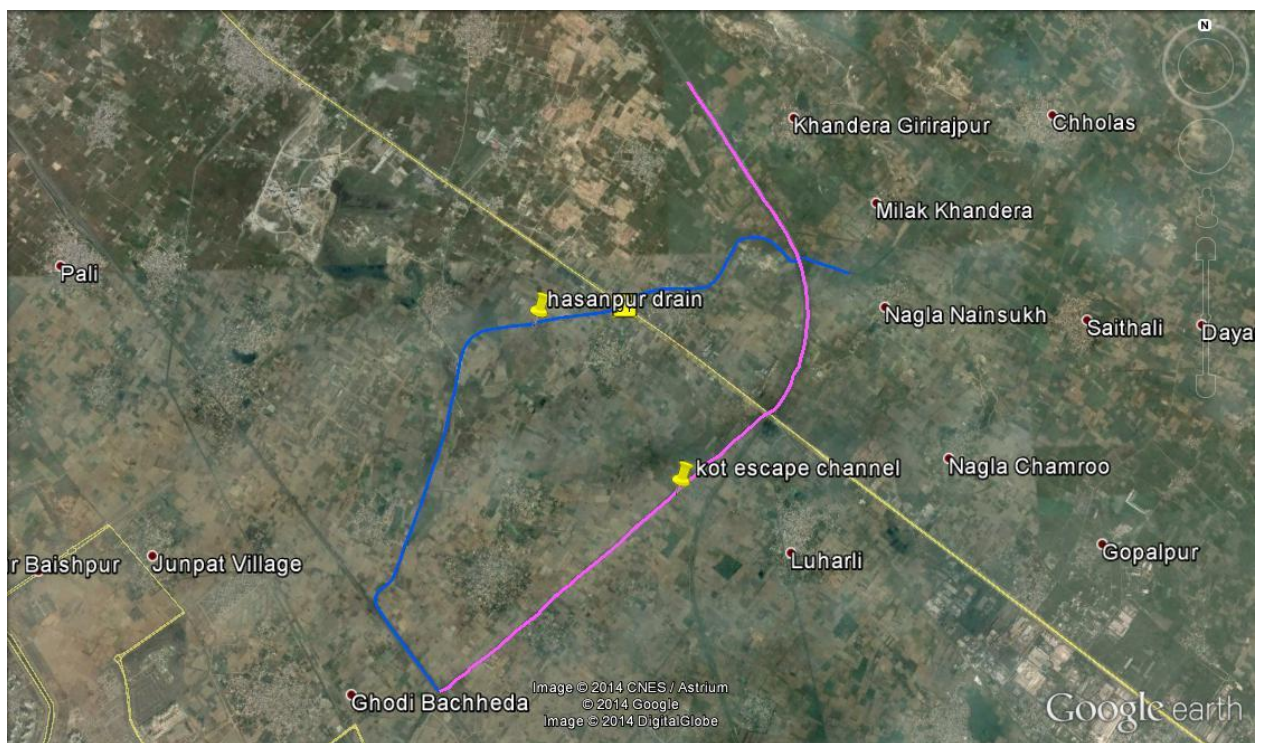


Figure3.2 Location of Hasanpur Drain

3.2 RAINFALL DATA

24 hour Rainfall Data Maximum rainfall- Based on IMD data.

serial no.	Return period	mm/day
1	2 years	100-200

2	5 years	160-200
3	10 years	200-240
4	25 years	240-280
5	50 years	280-320
6	100 years	320-360

Table 3-1 Rainfall data

3.4 RATIONAL METHOD FOR PEAK DISCHARGE

This method is used for peak flow estimation for small rural drainage basins and is the most widely used method for urban drainage design. The rational method equation is given below:

$$Q = CiA/3.6$$

Q= Peak Discharge (m³/sec)

i = Rainfall Intensity in mm/hr for a duration equal to t_c and an exceedance probability

A = Drainage Area (km²)

C= Runoff co-efficient

(a)RUNOFF CO-EFFICIENT

Runoff co-efficient represents the integrated effect of the catchment losses and hence depends upon the nature of the surface, surface slope and rainfall intensity. Equation for the peak flow (Rational Method) assumes a homogeneous catchment surface. If however, the catchment is non homogeneous but can be divided into distinct sub areas each having a different runoff co-efficient.

Land Use	Runoff co-eff
Pavement	0.9
Earth shoulders	0.5
Drives & Walks	0.75
Gravel Pavement	0.85
City Bussiness Area	0.8
Apartment Dwelling Area	0.5
Lawns	0.17
Side Slopes ,Earth	0.6
Side Slopes ,Turf	0.3
Median Areas,Turf	0.25
Cultivated Areas	0.25
Woodland& Forest	0.1

Table 3-2 Run-off co-efficient

The project site is half developed and undeveloped area so for homogeneous catchment area runoff –coefficient is taken as 0.4.The Run off co-efficient may be different for other area.For developed area the value may be change by 50% and discharge can be change or increases.

(b) **Manning’s n value:** Manning’s n is essentially a coefficient represents the integrated effect of a large number of factors contributing to the energy loss in a reach. It depends on Surface Runoff, vegetation, cross section irregularity and irregular alignment of channel. For this location Manning’s co-efficient was taken as.015.

(c) **Drainage Area:** For maximum discharge, drainage area was taken into account.

S.NO	Chainage km		Drainage area (sq km)	Runoff Co- efficient
	Start (km)	End (km)		
1	8	6.40	8.6	0.4
2	6.40	4.00	2	0.4
3	4.00	3.00	9.2	0.4
4	3.00	2.00	11	0.4
5	2.00	1.60	4.1	0.4
6	1.60	1.00	3.7	0.4
7	1.00	0.00	0.5	0.4
			39.1	

Table 3-3 Analysis of catchment area

Peak Discharge can be determined using rational method for return period of 2 years ,10 years and 25 years.

$Q_p = 20 \text{ m}^3/\text{sec}$ for return period of 2 years

$Q_p = 40 \text{ m}^3/\text{sec}$ for return period of 10 years

$Q_p = 47 \text{ m}^3/\text{sec}$ for return period of 25 years

In this report Hydraulic modeling analysis can be done and flood inundation maps are obtained for different return period and discharge.

Chapter 4

METHODOLOGY AND INPUTING DATA INTO HEC RAS

4.1 GENERAL

This chapter explains in detail the methodology applied in flood mapping under the climate under change. This process of flood mapping using hydraulic modeling .In the hydraulic modeling calculation of water surface elevation was adopted for the local data conditions. The main objective was to bring the process into digital format for use of software tools for spatial analyses .The methodology used in the project work consist of three steps:

- (i) To develop a Digital Elevation Map using Arc GIS.
- (ii) Pre –Processing of geometric data for HECRAS using HEC-GEORAS
- (iii)Hydraulic Analysis in HECRAS and
- (iv)Post processing of HECRAS results and flood mapping Using HEC-GeoRAS.

For efficient use of multiple use of multiple software packages, data preparation procedure is implemented in the study:

4.2 TO DEVELOP A DIGITAL ELEVATION MAP USING ArcGIS

“ GIS is a computer based information system which attempts to capture ,store ,manipulate ,analyze and displaying spatially referenced and associated attribute data for solving complex research ,planning and management problems”. It is formerly established as a tool for mapping, GIS has recently received a huge application in engineering design and analysis, in particular in the area of water resources and water quality.GIS is capable of acquiring spatially indexed data from a variety of sources, changing the data into useful formats, storing the data, retrieving and manipulating the data for analysis,and then generating the output required by the user. The acquired special indexed data are known as layers. Each layer describes thematic approach to a particular purpose. Results can be set digitally and planning, and to facilitate efficient analysis and decision-making.GISs are the information systems which offer the functionality and tools to collect ,analyze and displaying geographical

information. Features, events and activities with spatial components are modeled, as points, lines, polygons to form the geographical database under georelation scheme. For example, from the viewpoint of GIS river network graphic elements represent the location and shape of rivers, while the attribute may describe the name of stream, and length and flow rate.

ArcView: It is Geographic Information system software for visualizing managing analyzing and creating the geographic data. By using Arc view users can understand the geographic context of any data. It organized with a project, which may contain a number of tables, views, layouts, charts. Files create in Arc View is called project. Vector data files are called shape file. Vector data can be edited by use of editor tools such as line, polygon etc.

4.3 PRE PROCESSING OF GEOMETRIC DATA

4.3.1 GENERATION OF DIGITAL TERRAIN (DTM)

The first step in preprocessing to obtain a Digital Terrain Model (DTM) of the drain system in a Triangulated Irregular Network (TIN) format. For accurate analysis TIN must be generated with a special care. Elevation data for each cross section is extracted from the TIN. The TIN also serves for determining the floodplain area and calculation of flood inundation depths.

It is a representation of the topographic surface in terms of regular spaced x,y,z coordinates. The DTM can be obtained from a number of sources including ground survey, photogrammetry, surface sensing and cartography. High resolution DTM of 1 meter was obtained by ground survey data such as contour maps. Contour map is converted into raster format in Arc GIS 10.1 by the use of 3D spatial analyst tool. Spatial reference should be change in WGS-1984-UTM-zone 43 North.



Figure 4.1 Contour Map

The contour lines at an interval of 0.5 meter (CNTRL.SHP) in digital format shape file are used in Digital Elevation Map (DEM) and TIN development. The data source of CNTRLIN.shp is Hasanpur Drain. By the use 3D analyst in conversion tools convert the raster data into the TIN form. The TIN development process starts by opening in the Arc Map.

The TIN based model has a vector based data structure, but it can be converted into grid cells. In the TIN model, each point has defined x,y,z coordinates. The coordinate z indicates the height. These points are connected by their edges to form a network of overlapping triangles (finite surfaces) that represent the terrain surface (Lo and Yeung, 2005). The basis of TIN based DTM is that large series of these finite surfaces, sharing common horizontal edges, can be linked together and used to interpolate the XYZ coordinate of any point, even though actual measurement have not been obtained at that point.

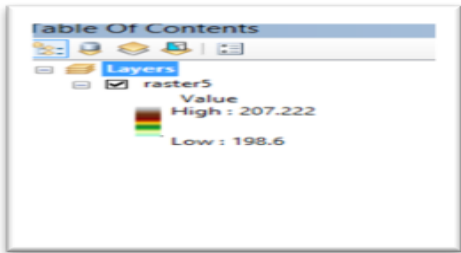
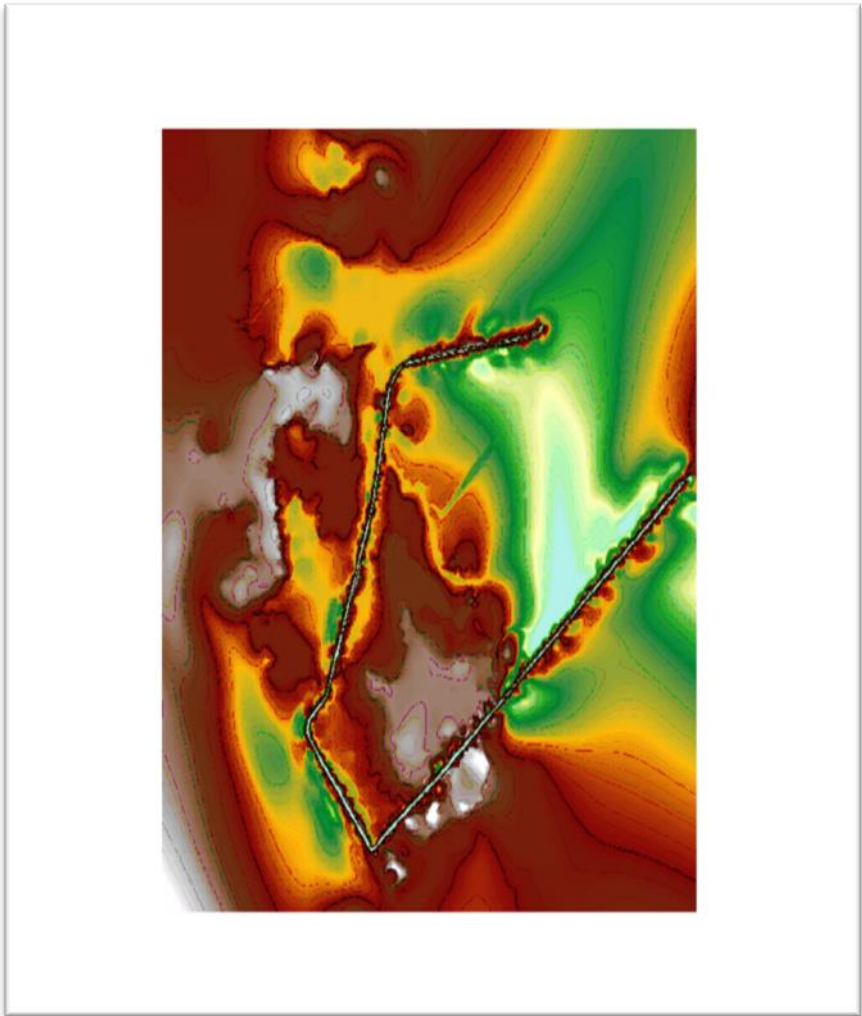


Figure 4. 2 Digital Elevation Map

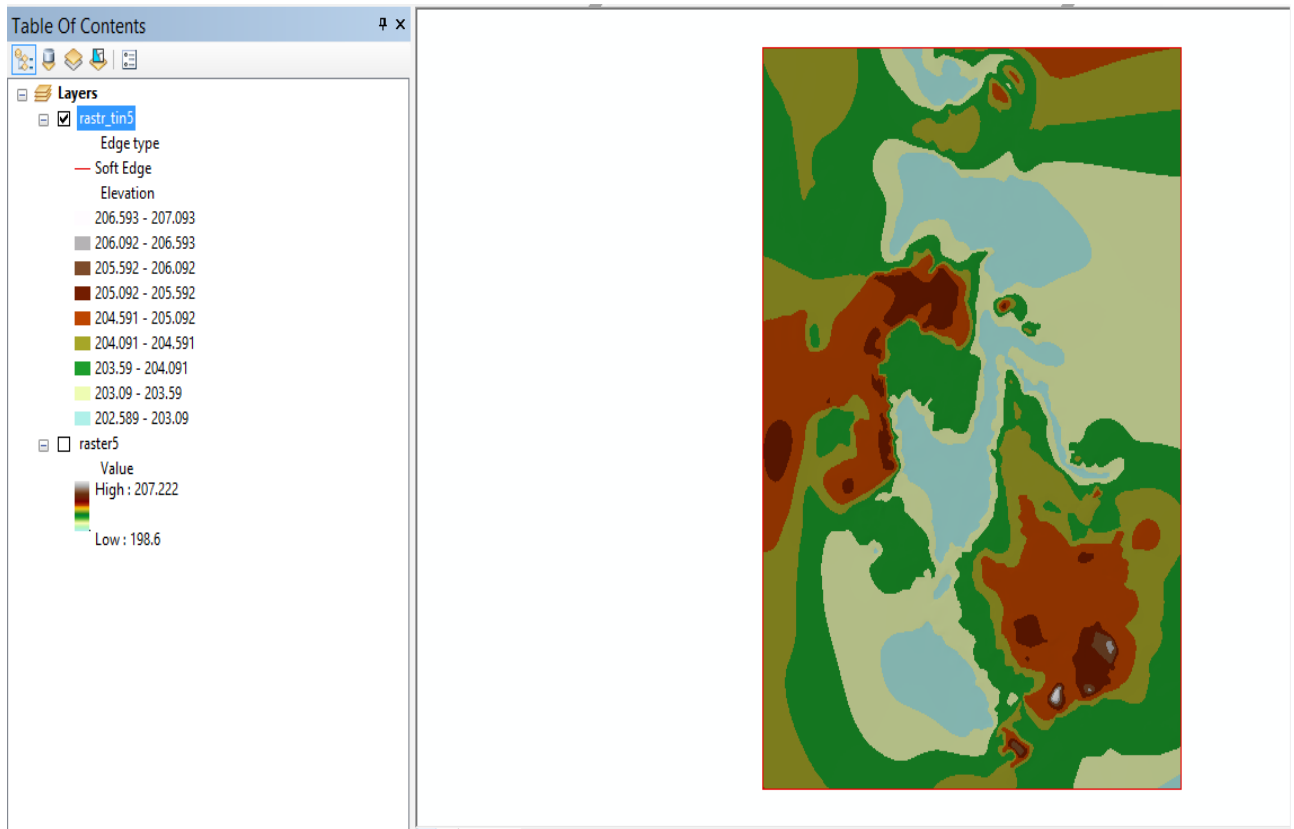


Figure4. 3 Triangular Irregular Network

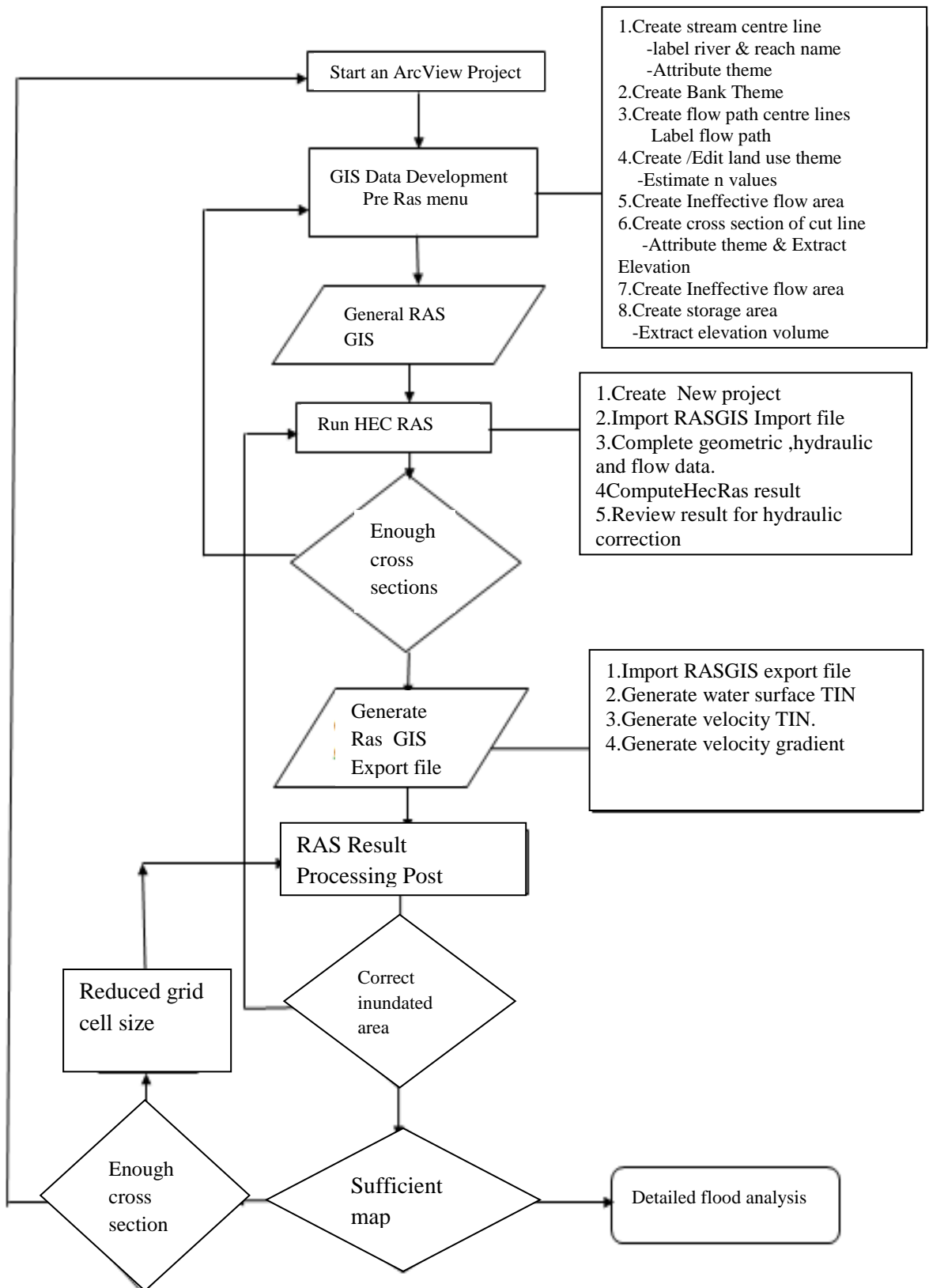


Figure4.4 Flow Chart for Hydraulic Modeling

4.3.2 CREATING OF GEOMETRY DATA

The Arc Map is saved in the working directory and the TIN is added. As a result of this step, the appropriate coordinate system is automatically assigned in the arc map for the greater Noida.1983_UTM_zone_43N.

The main work of the preprocessing is to create the geometry data file for use with HEC-RAS. The geometry data file contains important information about cross sections, riverbanks, flow path lines, hydraulic structures and other physical attributes of river channels (Merwade,2006). The pre-processing is done using the HEC-Geo RAS for creating physical attributes in GIS, and then exporting them to the HECRAS geometry file. In HEC-Geo RAS, each attribute is stored in a separate feature class referred to as a RAS layer (Merwade,2006). Before creating river attributes in GIS, it was necessary to create empty GIS layers using the RAS Geometry menu on the HEC-GeoRAS tool bar. The RAS layers were created in one step and stored collectively in a GeoData base, which HEC-GeoRAS creates automatically. The RAS layers are created by selecting from HECGeo RAS toolbar.

RAS Geometry → Create RAS layers → all

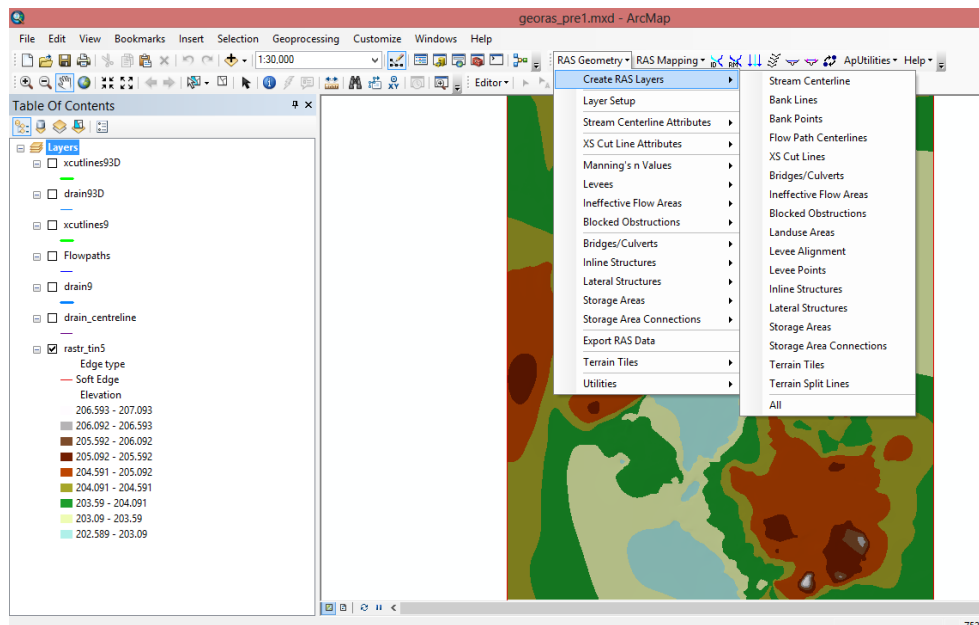


Figure4.5 Ras Layer in Preprocessing step

Fig shows all available RAS layers. The following layers are used in this project: Drain, Banks, Flowpaths, X cutlines.

(a) CREATING DRAIN CENTRELINE: The river centerline layer is very important, because it corresponds the river network for HEC-RAS .Digitizing of the stream centerline starts with selecting the sketch tool from the Editor Toolbar, and digitization proceeds in the direction of drain flow .Therefore, the process begins at the uppermost end of the stream (defined by the project extent), and ends at the DEM.Stream centerline must follow the path of lowest elevation. The elevation from the TIN must be checked, too.

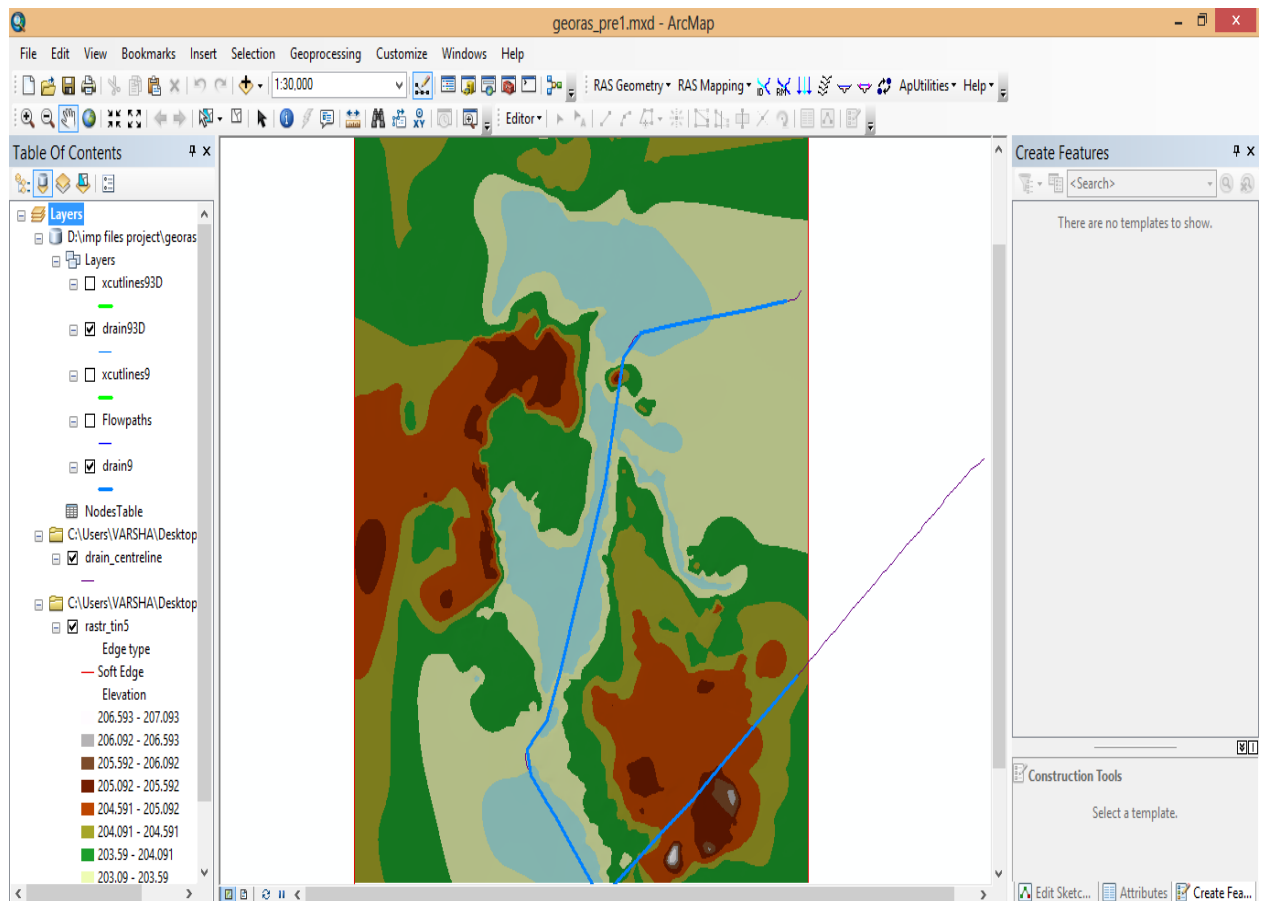


Figure4.6Centre Drain Line

After digitizing the centre stream line and reaches, the next step is to name them or assign them. This was done by the selection of assign the drain code/reach code menu

item assigning them appropriate names such as Drain9. The next task is to check the created reaches are connected, and then populated the remaining attributes of the drain layer. This is accomplished by selecting RAS

“Geometry” → “Stream Centerline Attributes” → “Topology”.

This function is populated by the From Node and To Node attribute of the drain layer. The length/stations fields are populated in a similar way. Fig shows an attribute table for drain9 GIS layer.

Shape*	OID*	Shape_Length	Riv2DID	HydrolID	River	Reach	FromNode	ToNode	ArcLength	FromSta	ToSta
► Polyline Z	3	7447.234328	1	55	drain9	drain_9	1	2	7447.234	0	7447.234

Figure4.7 Attributes data

The meaning of each attributes is explained below;

Hydro Id is a unique number for a given feature in a geodatabase. The drain and reach attributes contain unique names for drain and reaches respectively. The from Node and To node attributes delimitate the connectivity between reaches. Arc Length is the actual length of the reach in map units, and is equal to Shape Length. In HECRAS, distances are represented using station numbers measured from downstream to upstream. For example, each river has a station number of zero at the downstream end, and it is equal to the length of the river at the upstream end.

(b) CREATING FLOWPATH: The flow path lines layer is used to determine the downstream reach lengths between cross section in the channel and overbank areas. A flow path line should be created in the centre of mass of flow in the main channel, left overbank, and right overbank for water surface profile of interest. Flow path lines are digitized in the downstream direction, following the movement of water by the use of editor tool (line or polygon). Label of flow path line is assigned using flow path tool as left line, main channel and right line.

The flow path is a set of lines that follows the centre of mass of the water flowing down the river, during the flood event (Meyer and Olivera,2007).The flow path layer represents three types of lines : Centre line ,Left Overbank, and Right Overbank .For the main channel ,the flow path centreline is defined to be as the drain centreline. For floodplains, the flow path centrelines are digitized to represent assumed water flow within the floodplain. The flow path layer is used to determine the length between two neighbouring cross sections (required by HEC-RAS).Flow path centrelines are also created in the upstream to downstream direction. To create left and right flow paths, it is necessary to start Editing,then choose Create New Feature as the task, followed by Flow paths as the Target.

By using the Assign Line type button, the flow path is given the names as left ,Channel, Right looking in downstream direction.

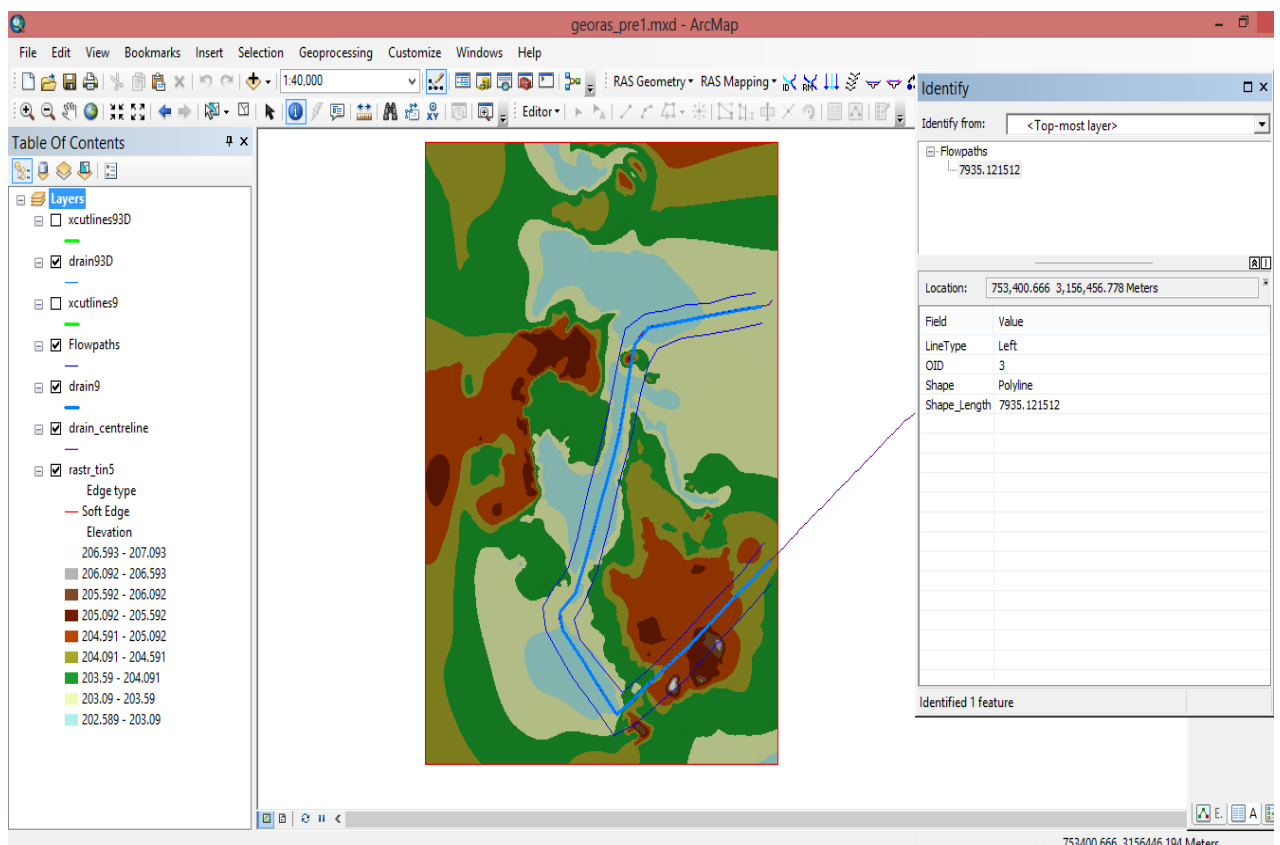


Figure4.8 Flow path lines

(c) CREATING CROSS SECTIONS:

Cross-section cut lines are used to determine the locations where cross-sectional data are extracted from the Digital terrain Model (DTM). The intersection of the cut lines with the other RAS layers will determine bank station locations, downstream reach lengths, Manning's n values, ineffective areas, blocked obstructions and levee positions. Cut lines should always be located perpendicular to the direction of flow and drawn from the left to right bank. Cutline must cover the entire extent area of the flood plain to be modeled. River/ reach name, station to each cross sections to each cross section are assigned. Lastly, reach length is assigned based on the flow path lines using downstream reach length menu. The elevation for each cross-section is extracted from the terrain model. The elevation extraction process will convert the 2-D features to 3-D features. This will result in the generation of a new feature class.

Cross Section Shape files (line), which show location, shape and length of surveyed cross sections, are used in the creation of this layer. Some of the cross section was modified to meet criteria for the appropriate drawing of cut lines. Few important rules were followed during the process of drawing cross section cut lines (Meyer and Olivera,2007):

- X Cut lines are drawn perpendicular the direction of the drain flow .At some locations, “dog-leg” shapes of cross section may also use.
- X Cut lines are drawn directionally from left to right bank, looking at downstream directions.
- Cut lines are extended far enough on either side of the channel to encompass the entire portion of floodplain. Where it is possible, they end at the same elevation at both ends.
- Cut lines do not intersect each other.
- Cut lines are close enough to account for significant changes in the hydraulic or flow geometry, such as changes in the discharge, slope, cross-sectional shape, roughness, or the presence of hydraulic structures.

To draw cross sections ,it is necessary to start an editing session and select Create New feature from the Task menu and X cutlines from the target menu .The next important step is to populate the attribute table of the XCutlines feature class, which is digitized . From the HEC-Geo RAS toolbar,

“RAS Geometry” → “XS Cut Line Attributes ” → “All” is selected.

The XS CutLines Profile is a new feature class that is created in the following:

The 2D feature XSCutlines is intersected with the TIN to make a feature class with 3D cross section. After that, the attribute table and cross sections are examined in order to check their correctness.

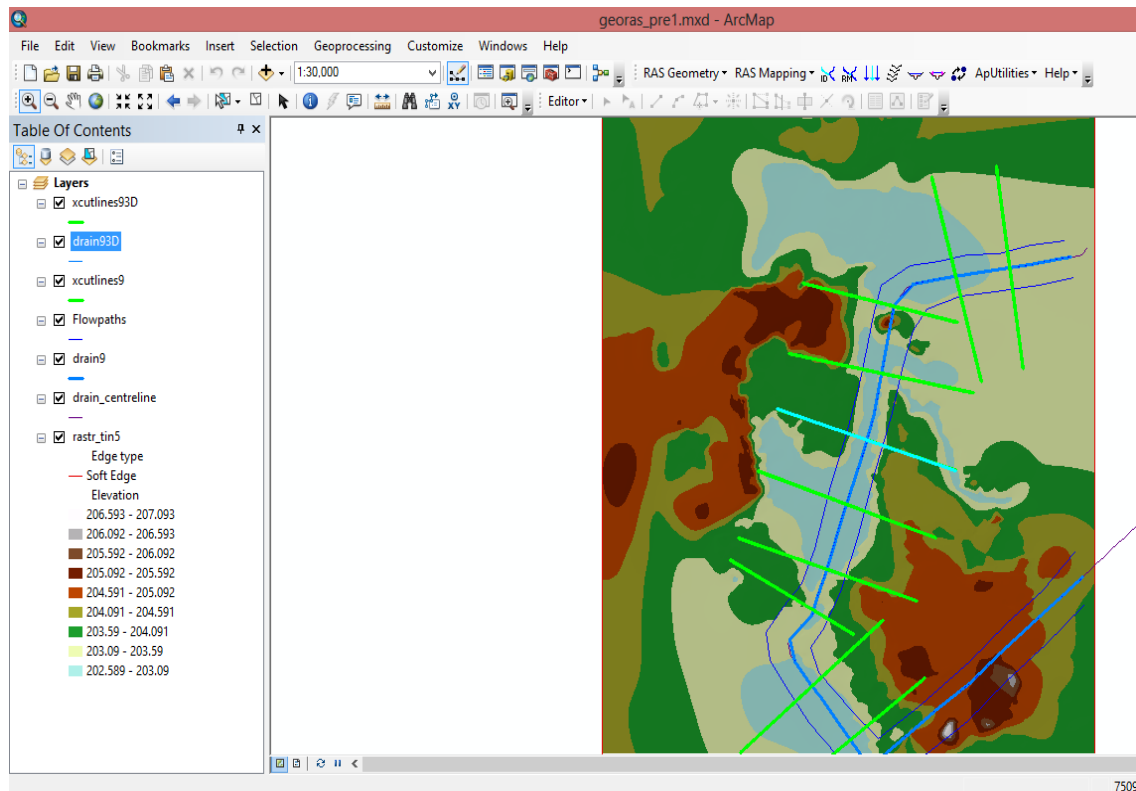


Figure4.9 X- cutlines for crosssections

4.4 HYDRAULIC ANALYSIS

4.4.1 HEC-RAS BASIC CONCEPTS AND EQUATIONS

HEC-RAS is an integrated system of software, designed for interactive use of multi-tasking. It is 1-Dimensional software for water surface calculations. HEC-RAS system is comprised of a graphical user interface, separate hydraulic analysis components, data storage and management capabilities, graphing and reporting facilities (USACE,

2002b).The most version of HEC-RAS supports steady and unsteady flow of water surface profile calculations ,sediment transport computations,and unsteady flow water temperature analysis(USACE,2002b) .Within a steady flow it can be model subcritical, supercritical or mixed flow regime. Computational equations are based on Energy Equations. Energy losses are calculated by friction (Mannings formula), contraction, and expansion. In cases where the water surface profile is rapidly varied, use of the momentum equation is necessary. These cases include mixed flow regime calculations effect of bridges, culverts, dams, weir and other structure in the river and flood plain. The brief introduction of main concept and equations follows.

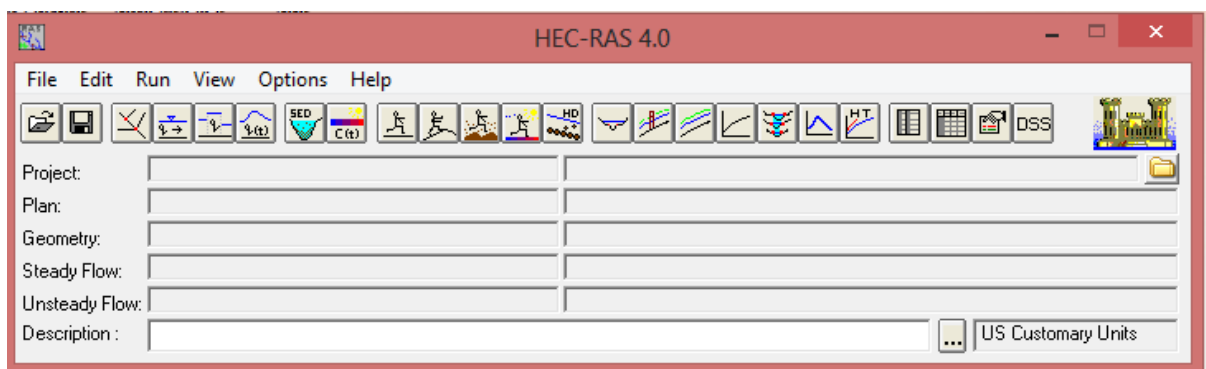


Figure4.10 HecRAS 4.0 version

(a)Steady and non steady flow:

In open channel, If the depth, discharge, and mean velocity of flow at particular locations does not changes with time, the flow is called steady flow. If the depth, discharge and velocity of flow at some point changes with time, the flow is called unsteady flow.

(b)Uniform and Non Uniform Flow: If the depth, discharge and mean velocity do not change with respect to the space, such type of flow called as Uniform Flow. This implies that the energy grade line water surface elevation and channel bottom are all parallel for uniform flow. This type of flow rarely occurs in reality. Non uniform flow is sometimes shows as varied flow can be further classified as gradually varied and rapidly varied .The flow is rapidly varied if the spatial changes to the flow occur

rapidly and the pressure distribution is not hydrostatic, otherwise it is gradually varied flow.

Based on these classifications the steady flow can be uniform or varied. The unsteady flow is usually varied, as the unsteady uniform flow is practically impossible, because it would require that the water surface fluctuates from time to time while remaining parallel to the channel bottom (Chow, 1959). The basic assumption of the gradually varied flow computation is that the streamlines are practically parallel and hydrostatic pressure distribution prevails over the channel section. The head loss at a section is the same as with a uniform flow that has the same hydraulic radius of the section. Accordingly, the uniform flow equation may be used to evaluate the energy slope of a gradually varied flow, while the corresponding coefficient of roughness developed primarily for uniform flow is applicable to the gradually varied flow (Chow, 1959). These assumptions are valid for most river flows including flood flows. The assumption of hydrostatic pressure distribution requires the stream to have a small slope of 1:10 or less. Most floodplain studies are performed on streams which meet this requirement (USACE,2002).

(c) Subcritical and Supercritical Flow: Dimensionless Froude number is defined by a ratio of inertial force to gravitational force :

$$F = \frac{V}{gL}$$

where,

F = Froude number (dimensionless)

V = Mean channel flow velocity (m/s)

g = Acceleration due to gravity (m/s²) and

L = Characteristic length (m).

In open channel flow, the characteristic length is taken as the hydraulic depth D, which is defined as the cross sectional area channel normal to the direction of flow divided by the width of the free surface water. The flow is classified as subcritical, critical or supercritical, depending on the Froude number. When the Froude number is less than 1, the effect of gravitational force is less than the inertial force and the flow is referred to as subcritical flow. When inertial and the gravitational forces are equal, the Froude number is equal to unity and the flow is said to be at the critical stage. When the inertial forces exceed the gravitational force, the Froude number is greater than 1, and

the flow is referred to as supercritical flow. The flow regime is an important criterion for the calculation of water surface profiles. When the state of flow is subcritical, the state of flow is controlled by channel characteristics at the downstream end of the river reach. In the case of supercritical flow, the flow is governed by the upstream end of the river reach.

(d) Continuity Equation: In the steady open channel flow analysis, the continuity equation states that flow remain constant between adjacent cross sections.

$$Q = A_1V_1 = A_2V_2$$

Where Q =Flow rate/Discharge (m^3/sec)

A_1,A_2 =Cross sectional flow area (m^2)

V_1,V_2 =Mean flow (m/sec)

This equation allows tracing of changes in a cross-sectional area and velocity from location to location.

(d)Energy Equation: Gradually varied water surface profiles are based on the principle of the conservation of energy, which states that the sum of the kinetic energy and potential energy at a particular cross section is equal to the sum of the potential and kinetic energy at any other cross section plus or minus energy loss or gains between the sections (Fig). Water surface is calculated from one cross section to the next by solving the energy equation written as

$$Y_2 + Z_2 + \frac{\alpha_2 V_2^2}{2g} = Y_1 + Z_1 + \frac{\alpha_1 V_1^2}{2g} + h_e$$

Where,

Y_1,Y_2 = Depth of water at cross sections (m)

Z_1,Z_2 = Elevation of main channel inverts (m)

V_1,V_2 = Average velocities (Total discharge / Total flow area)

g = gravitational acceleration

α_1 , α_2 = velocity weighting coefficients (dimensionless)and

h_e = energy head loss (m)

Based on the energy equation, the energy head loss is the sum of friction losses and expansion, or contraction of coefficient.

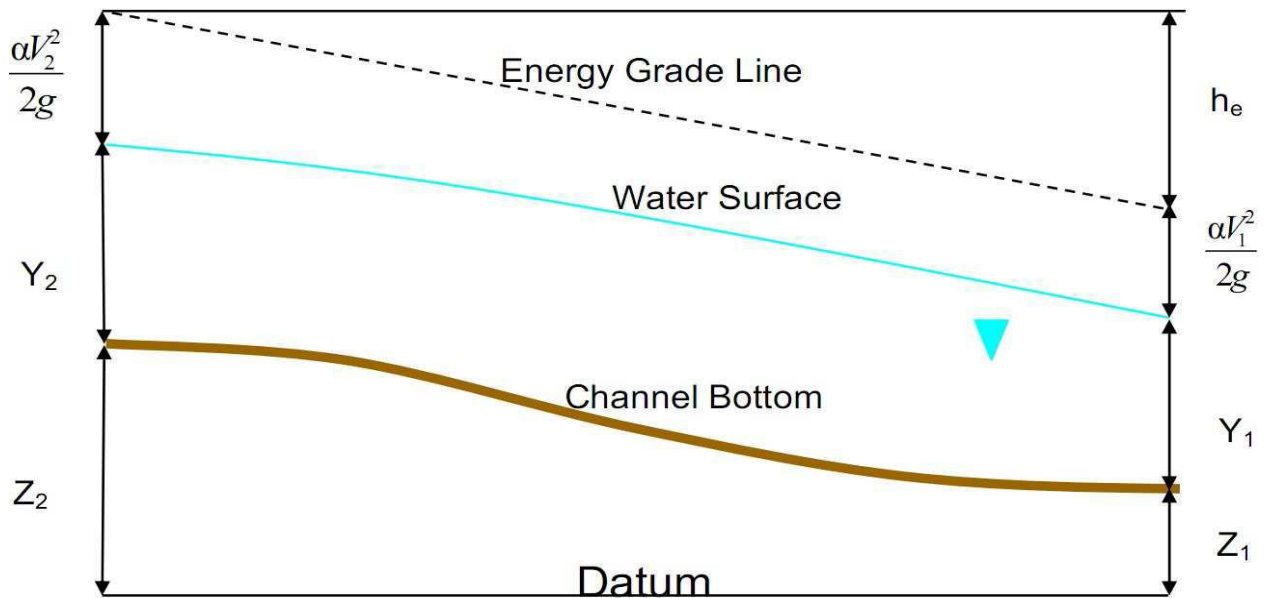


Figure4.11 Representation of terms in the energy head loss equation

$$h_e = L\bar{S}_f + C \left| \frac{\alpha_2 V_2^2}{2g} - \frac{\alpha_1 V_1^2}{2g} \right|$$

(e) Manning's Coefficient :

The energy losses due to the roughness of the river bed are usually calculated in terms of Manning's Equation:

Selecting the appropriate Manning's n value is very important for accurate computation of water surface profiles. Manning's n is highly variable and depends upon a number of factors including: surface roughness, vegetation, cross section irregularities, channel alignment, scour and deposition, obstructions, stage and discharge, seasonal change, temperature, suspended materials and bed load. The n value decreases with increases in stage and discharge. When the water depth is shallow, irregularities of the channel bottom are exposed and their effect may become

pronounced. However, the n value may be large at high stages if the banks are rough and grassy (Chow, 1959). If there is observed water surface data (high water marks, gaged data), Manning's n values should be calibrated. If there is no observed data (like in this study), then values of n obtained from another stream with similar conditions should be used. There are several references available listing the typical n values. Excerpts of the n value from Chow (1959) for natural streams are given in the Table .

Land-Use Characteristic	n Value
Backlick Run	0.045
Lower Backlick Run	0.045
Lower Cameron Run	0.035
Concrete Canal	0.018
Field 1, Open and maintained fields. Parks	0.030
Field 2, Open fields with scattered brush. Not mowed	0.045
Field 3, Fields with thick vegetation. Not maintained	0.065
Forest 1, Light trees and underbrush	0.070
Forest 2, Medium trees and dense underbrush	0.085
Forest 3, Thick trees and very dense underbrush	0.120
Industrial	0.100
Pavement	0.015
Railways	0.020
Reservoirs	0.030
Residential, typically landscaped backyards	0.050
Sparse Residential, forested backyards	0.085

Table 4-1Manning's Co-efficient values

4.4.2 STEP BY STEP MODELING USING HEC-RAS

The following section presents brief procedure of HEC-RAS program for computation of water surface profiles. The main objective of this presentation is to provide assistance to those who may not be familiar with the HEC-RAS computer program.

(a)Creating HEC-RAS Project: The first step for using the program contains opening of the main HEC-RAS interface window and entering the title and file name.

The Geometric Data Window opens from the main HEC-RAS user window. To enter the geometry select: “File” → “Import Geometry Data” → “GIS Format” → “ Browse” for Desired RAS GIS Import File (GIS2RAS.RASImport.sdf)”. Firstly, from the Import Options window, units should be changed ,SI(metric) units are selected. Then, “River and Reach Stream Lines” are selected. Cross section for importing are checked by selecting tab “Cross Sections and IB Nodes” (Figure). The Geometry Data are saved in the Geometric Data window. Figure 2.22 shows the Geometric Data window with the georeferenced Drain system.

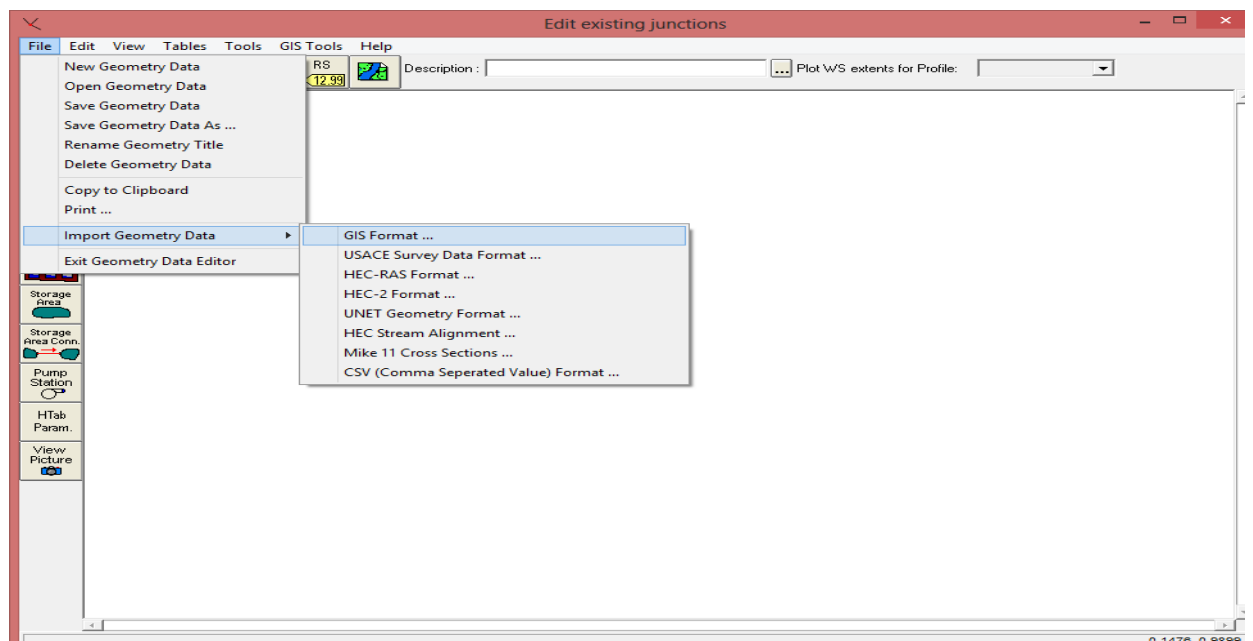


Figure4.12 Import Geometry Data

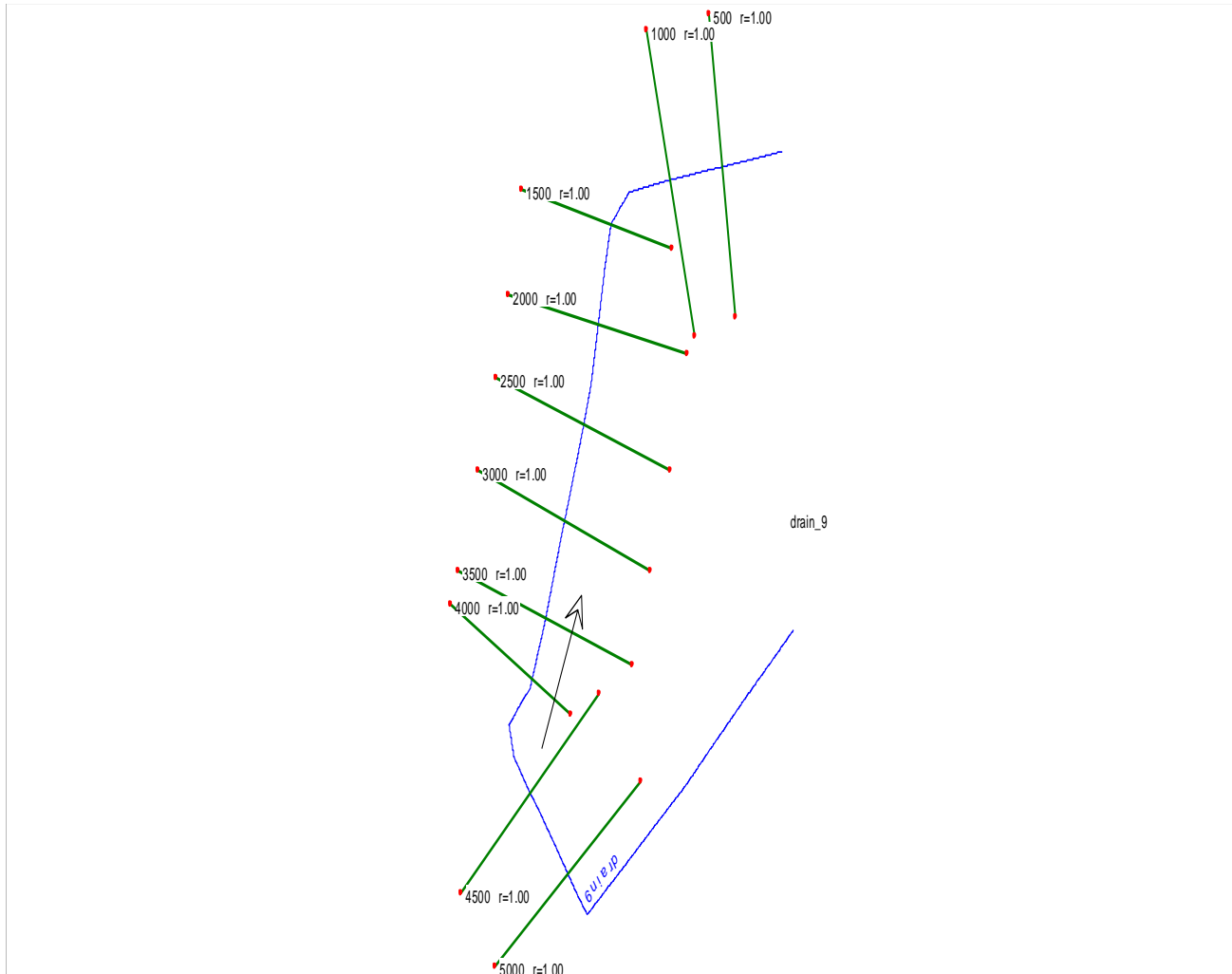


Figure 4.13 Georeferenced Geometry System of Drain

The next step involves the use of Cross Section Points Filter, because some cross-sections may have duplicate points or a high number of points (over 500). “Tools” and then the “Cross Section Points Filter” are selected from the Geometric Data window.

From the Geometric Data window, Graphical Cross Sections Edit option is chosen from the Tools tab, to start the editing process. First, the editing of cross-sections, which have corresponding Drain (surveyed) cross-sections at the same locations, has been done. In order to increase the accuracy of HEC-RAS modelling and floodplain

mapping for this project, more cross-sections are generated between the existing Drain cross-sections. Channel bottom elevations of these cross-sections are edited using the interpolation between 2 already edited cross sections. After the completion of this task, the geometric data completion continues.

(b)Determination of bank points : In some cross sections, the bank stations are found to be improperly located. Some of them ended on the river bottom and some at different elevations.

First, the HEC-RAS model is run with a small return period. Then bank stations were corrected manually based on the water surface elevation results. The bank stations of surveyed Drain cross-sections are also used to perform these manual corrections.

(c)Manning's n values: Manning's n values are part of the Geometry data required for HECRAS modelling. Since HEC-RAS models are from the 1980's, revision of Manning's n values is necessary. In some cases, a horizontal variation in n values is used to increase accuracy for Manning's value. For this project, Manning's n values are adopted based on Chow (1959), For residential areas, $n = 0.08 - 0.12$ is used, and for industrial areas, $n = 0.1$,for concrete canal it should be .015, For this project manning's coeff value taken as .015 for Hasanpur drain cross section.

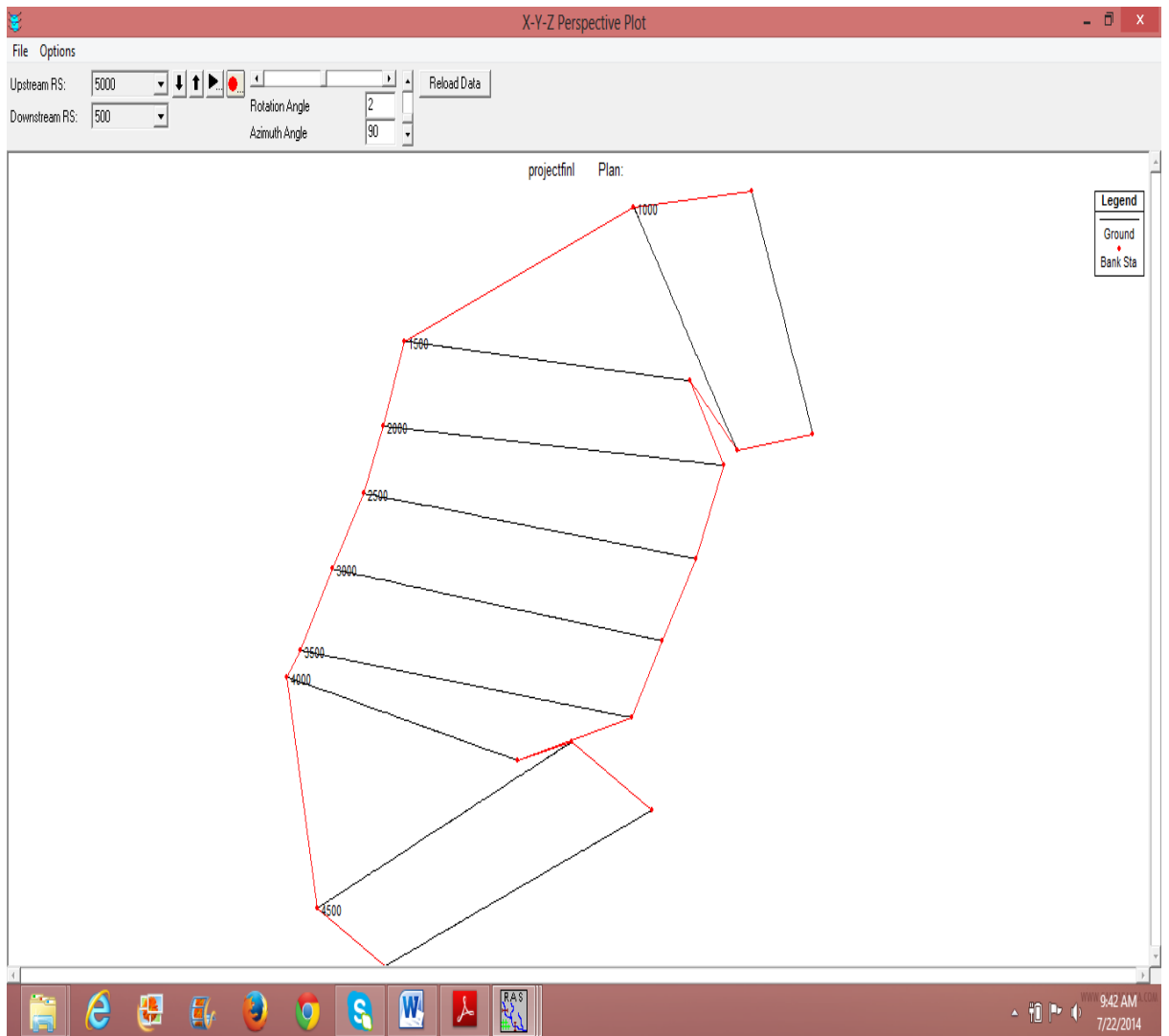


Figure4.14 Profiles plot of cross sections

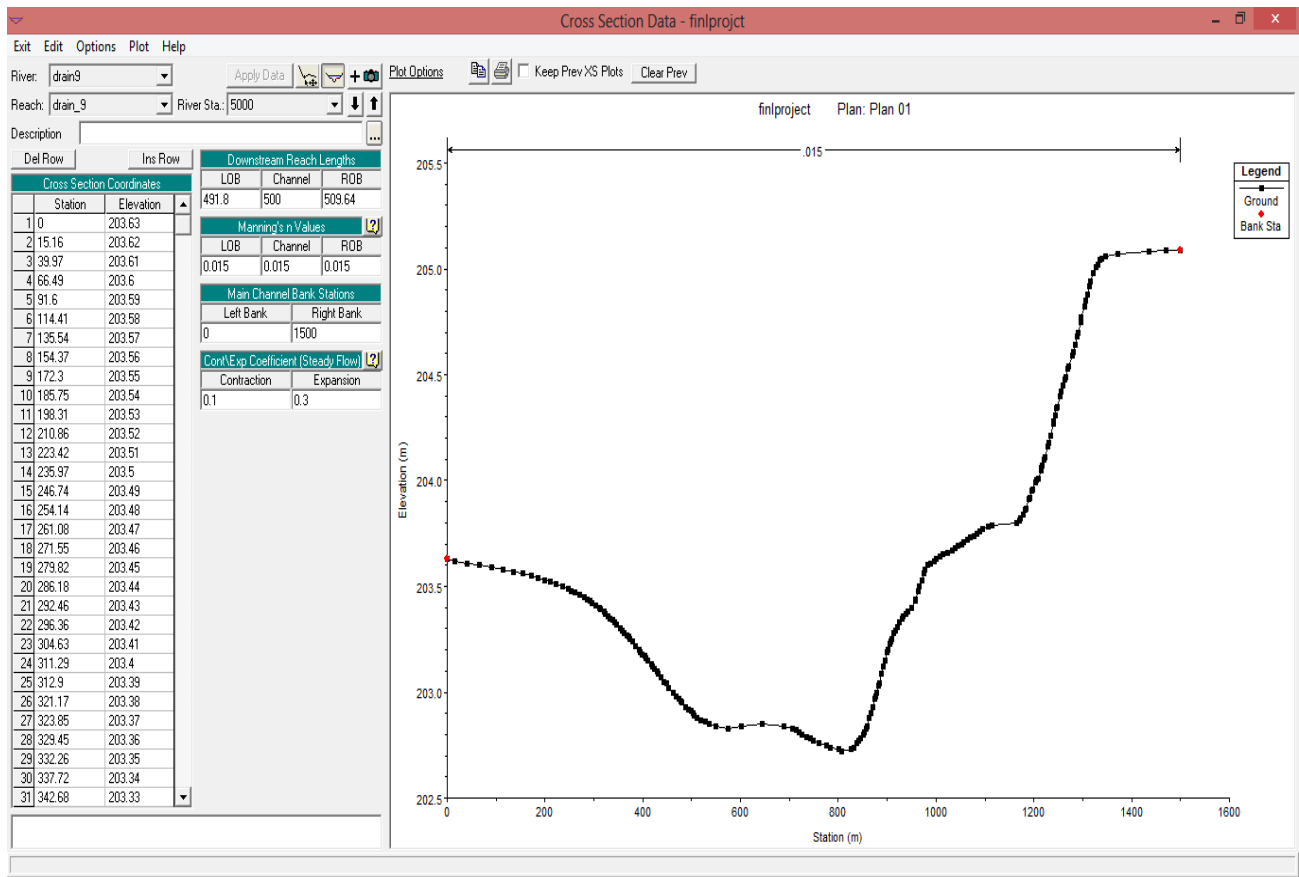


Figure4.15 Cross Section for station 5000

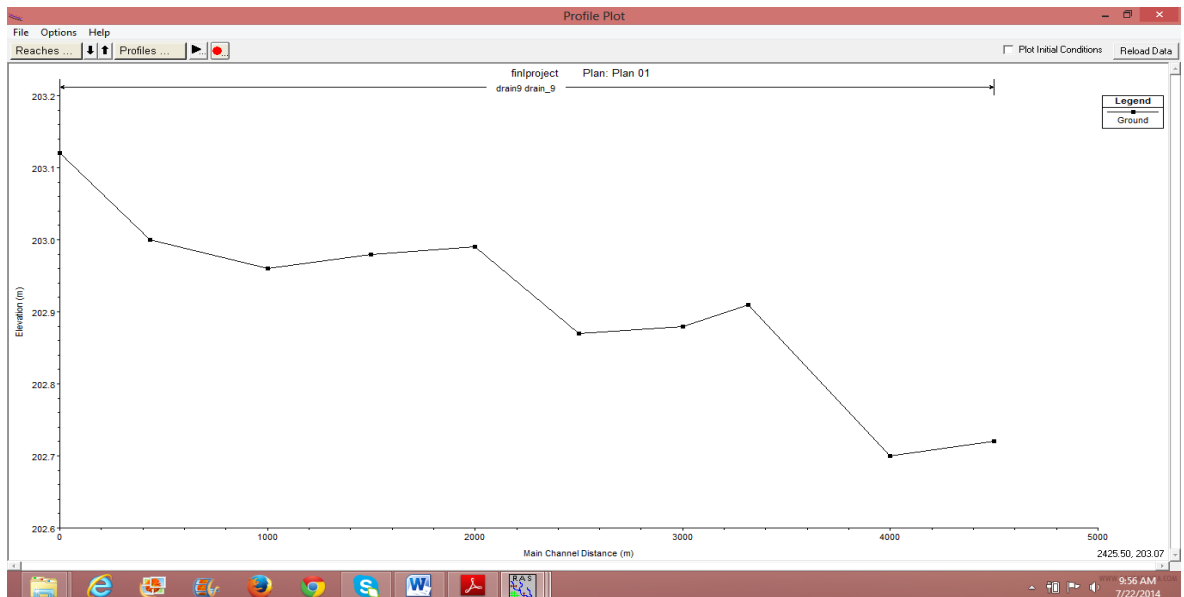


Figure4.16 Profile Plot of Cross sections

(d) Flow data and boundary conditions: The hydraulic analysis is performed using flow data for climate scenarios named: Historic Climate Scenario and Wet Climate Scenario. For both climate scenarios, steady flow data are entered for the flow return period of 2 years, 10 years, 15 years, 25 years. In this report flow discharge had taken 20,30,40 and 50 as m^3/sec respectively PF1, PF2, PF3, PF4. Flow changes are entered at the same locations as in the existing HEC-RAS models.

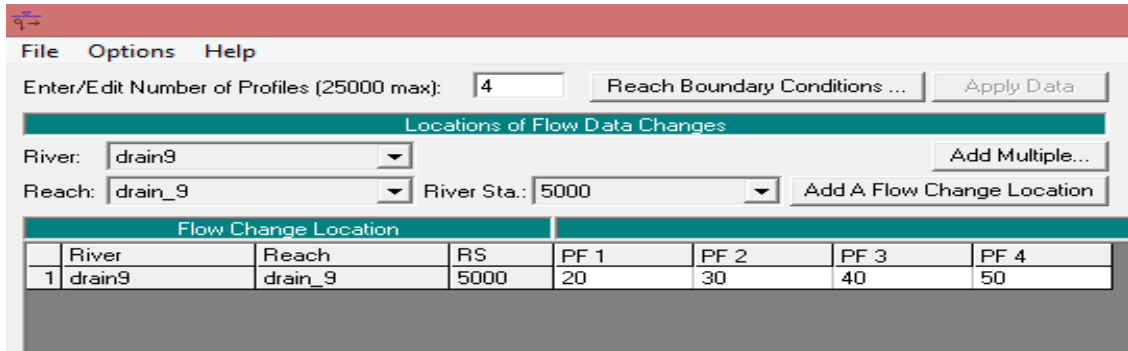


Figure4.17Flow Data Condition for 4 Profiles

Since no observed flow data (Known Water Surface) is available, it was very important to choose appropriate Steady Flow Boundary Conditions. Usually, if there is no observed data, the normal depth is used. $S=0.00028$ was taken for normal depth. However, another approach for setting the boundary conditions is used in this study. First, the existing HEC-RAS model “Hasanpur drain” is run with new flow data for both various profile. The above mentioned HEC-RAS model is long enough (about 9km) so the influence of boundary conditions at the first cross section do not affect the upstream results. Since the metric system is used, Known Water Surface is in meters.

After these two models were run with the discharge flow data, boundary conditions are determined for each tributary.

(e) HEC-RAS computation and data export.

After the geometric data is completed and the steady flow data and new boundary conditions are entered, the HEC-RAS system is executed for the subcritical flow profile. The output results are checked for hydraulic correctness.

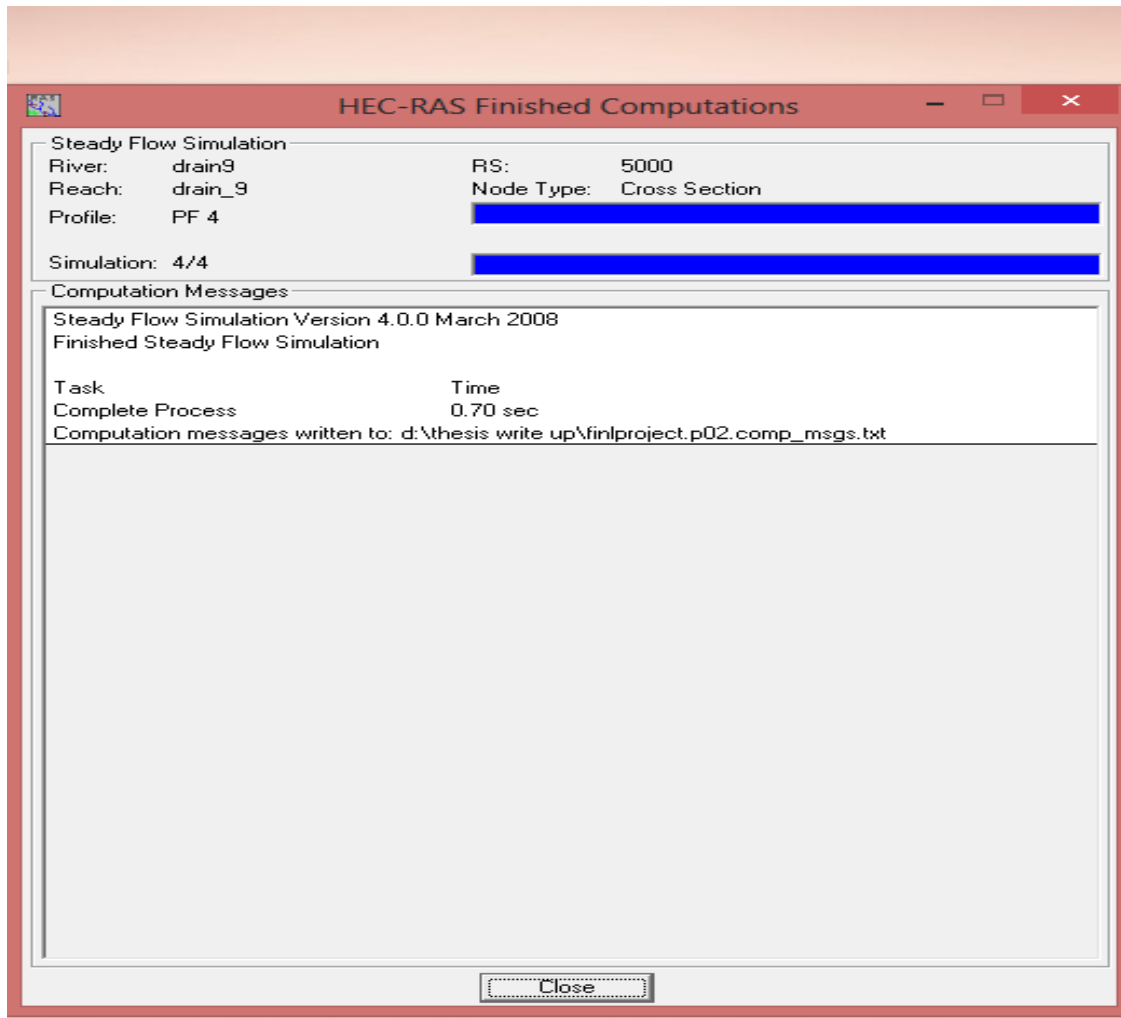


Figure4.18 Steady Flow Analysis

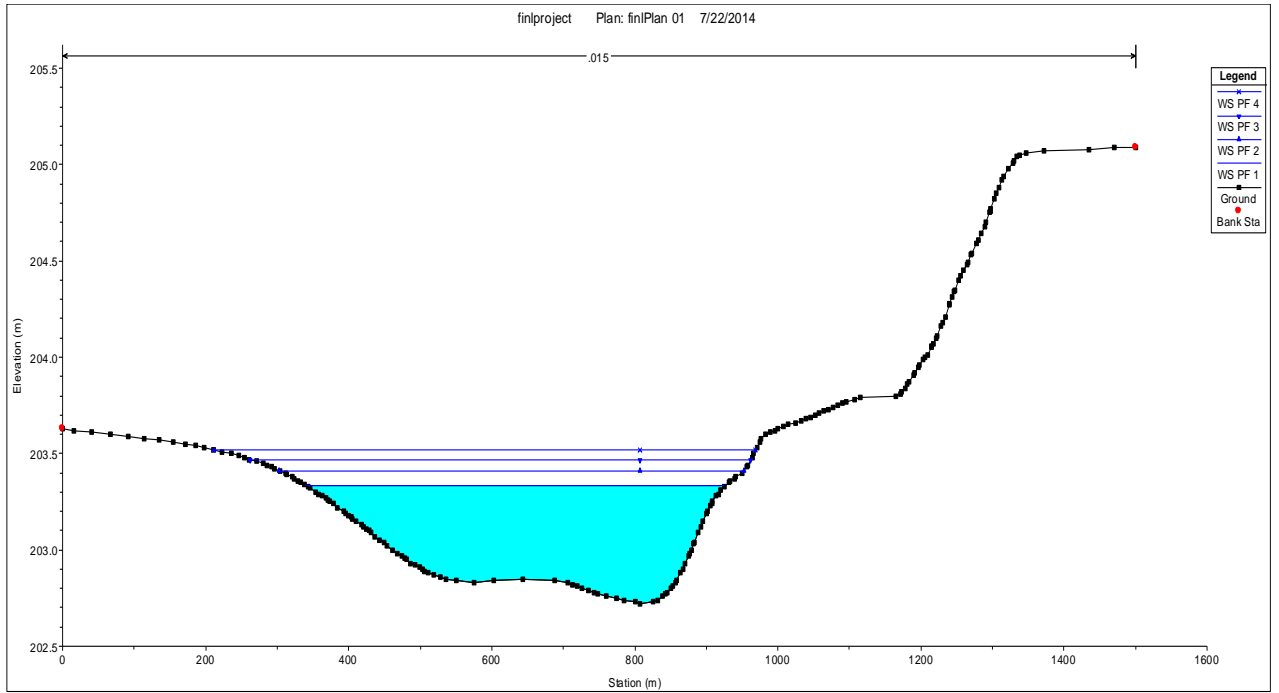


Figure 4.19 Water Surface Profile For Station 5000

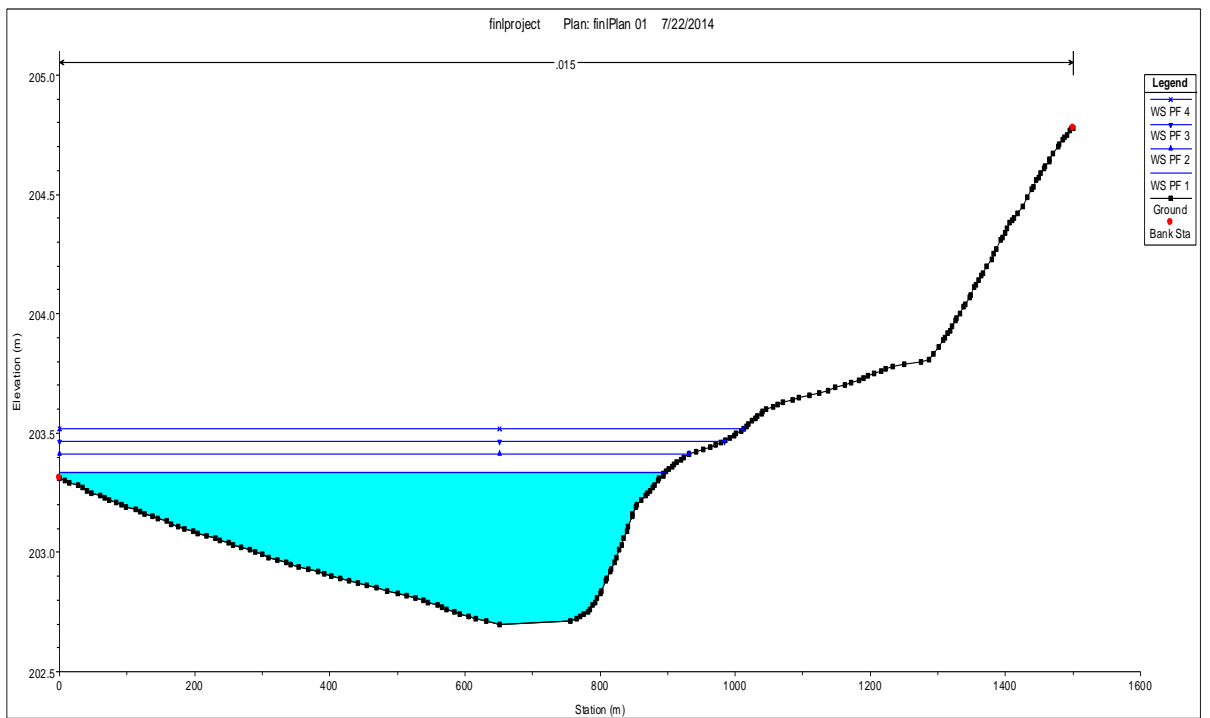


Figure 4.20 Water Surface Profile Station 4500

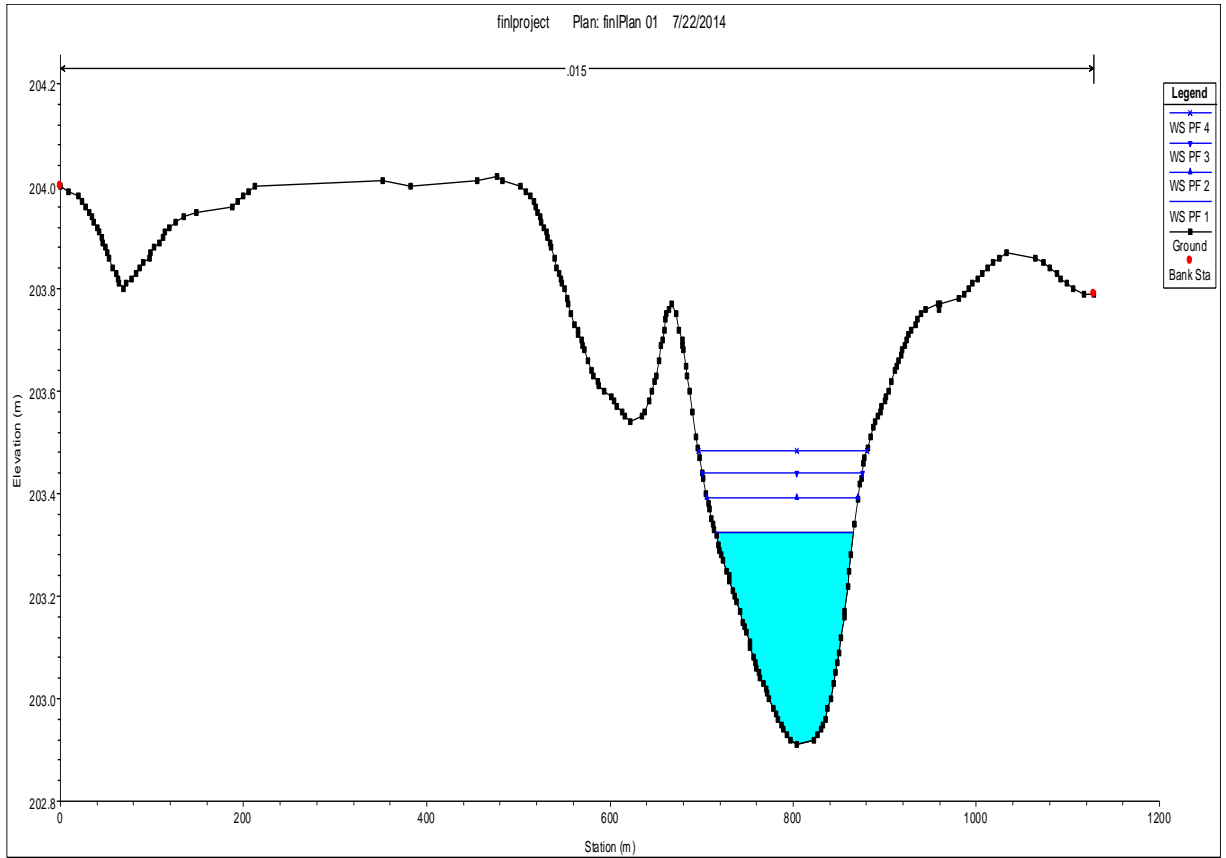


Figure4.21 Water Surface Profile For Station 4000

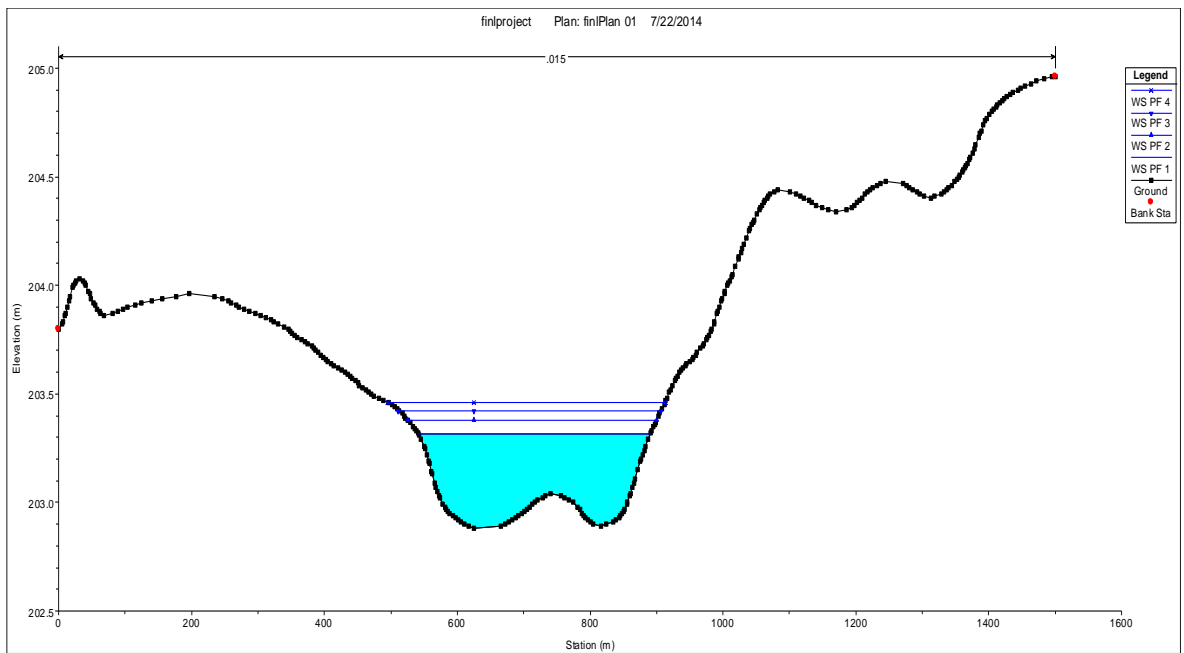


Figure4.22 Wter Surface Profile For Station 3500

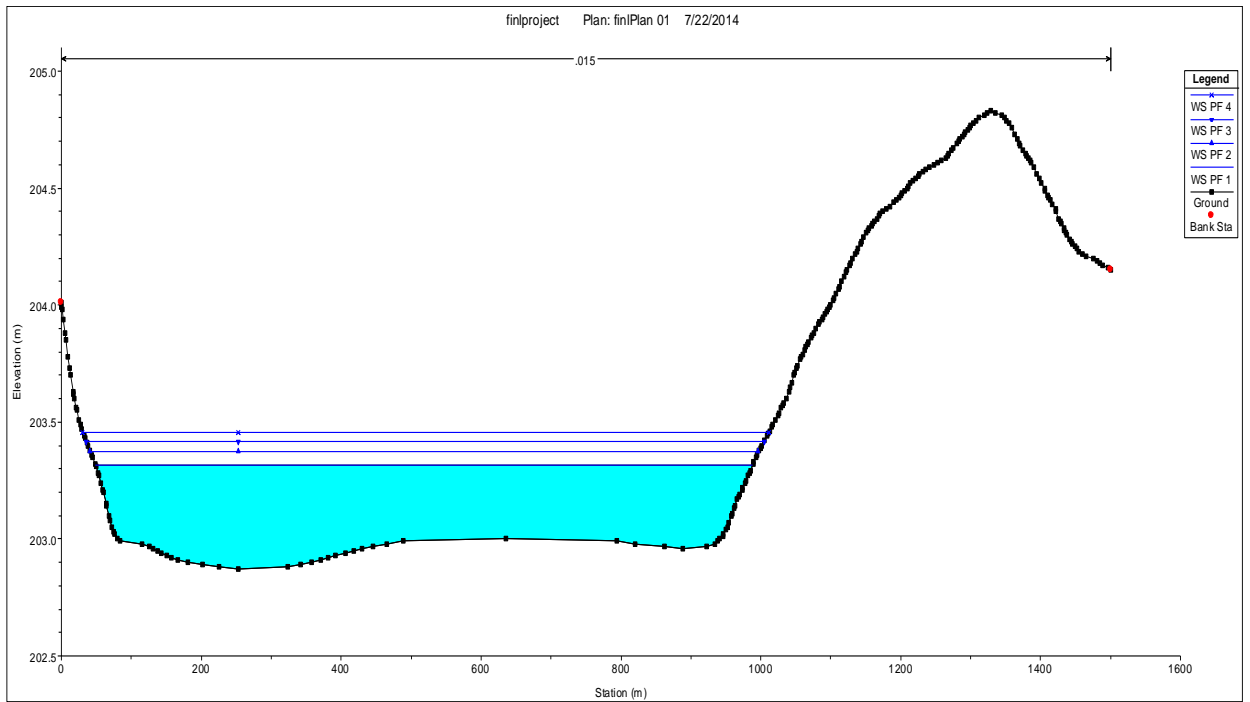


Figure4.23 Water Surface Profile For Station 3000

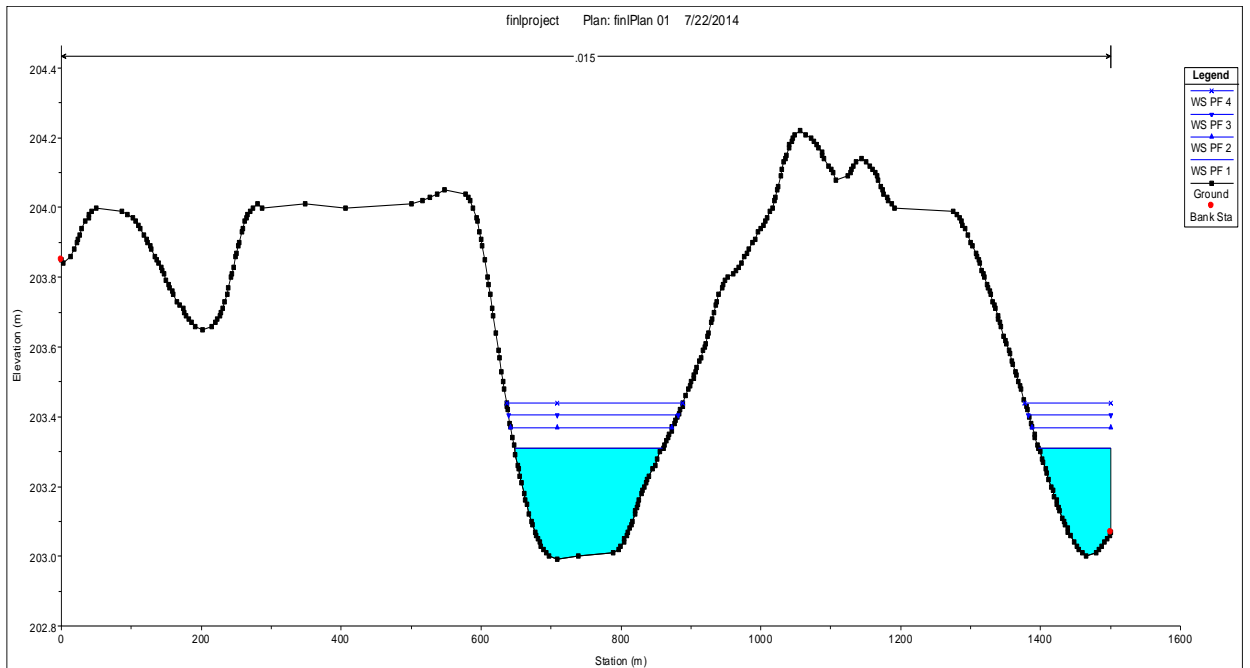


Figure4.24 Water Surface Profile Station 2500

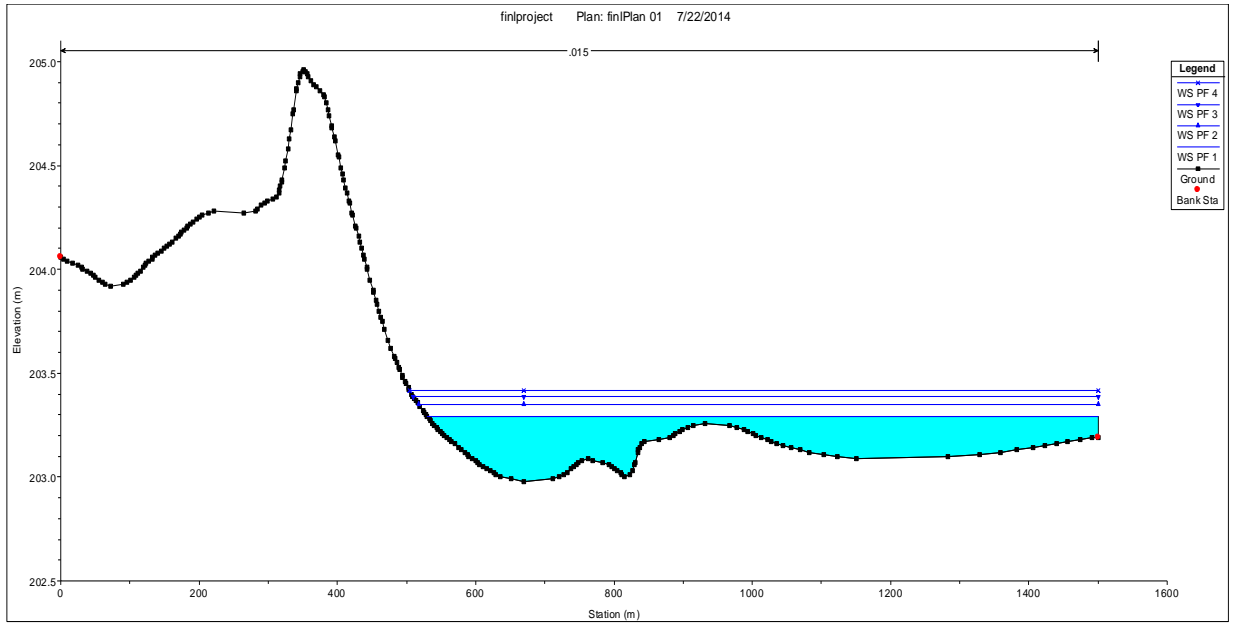


Figure4.25 Water Surface Profile For Station 2000

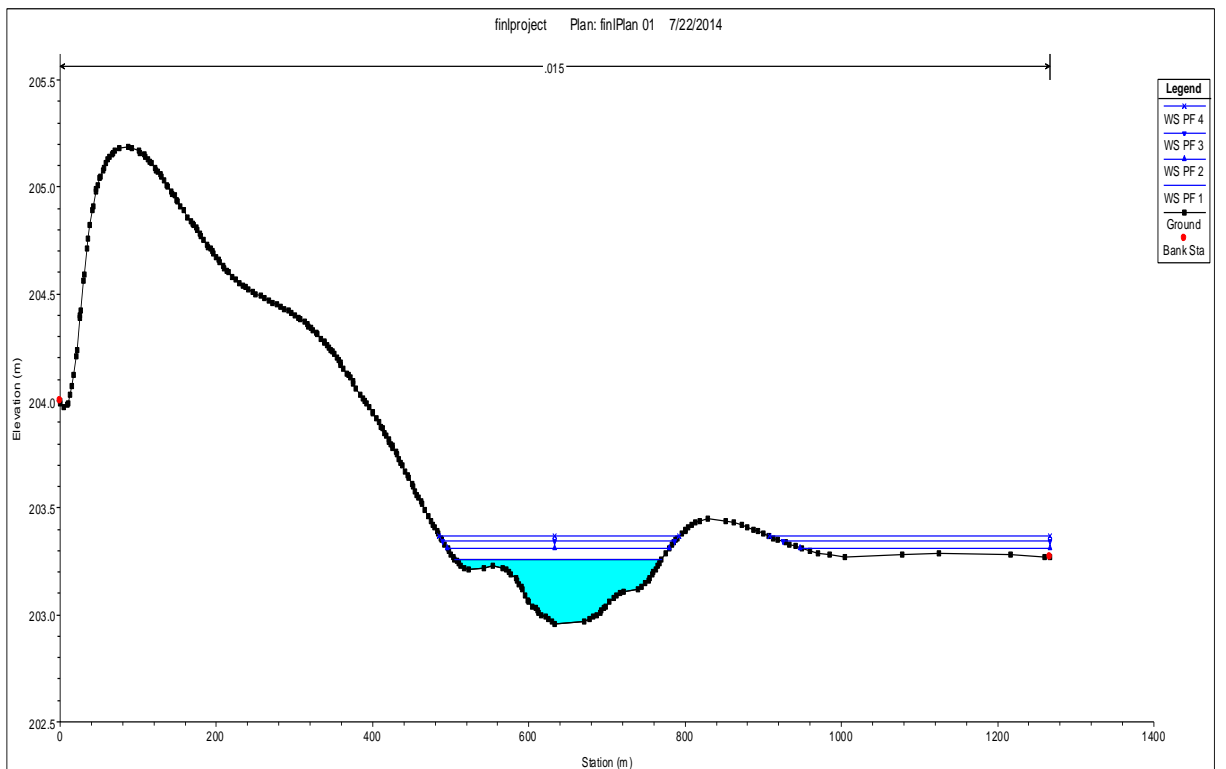


Figure4.25 Water Surface Profile Station 1500

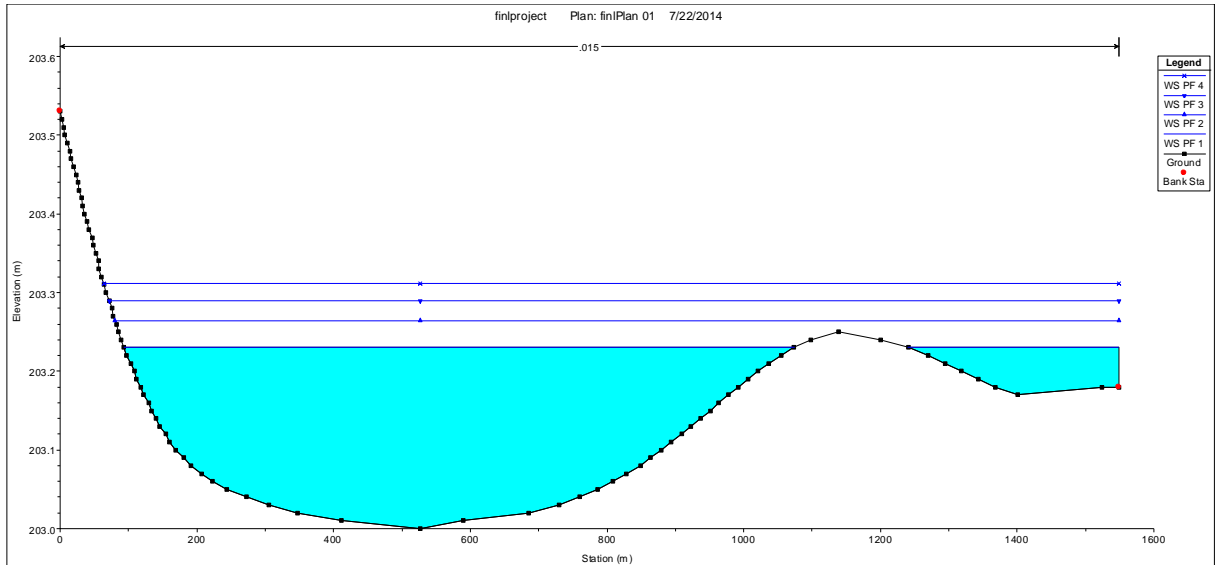


Figure4.26 Water Surface Profile for Station 1000

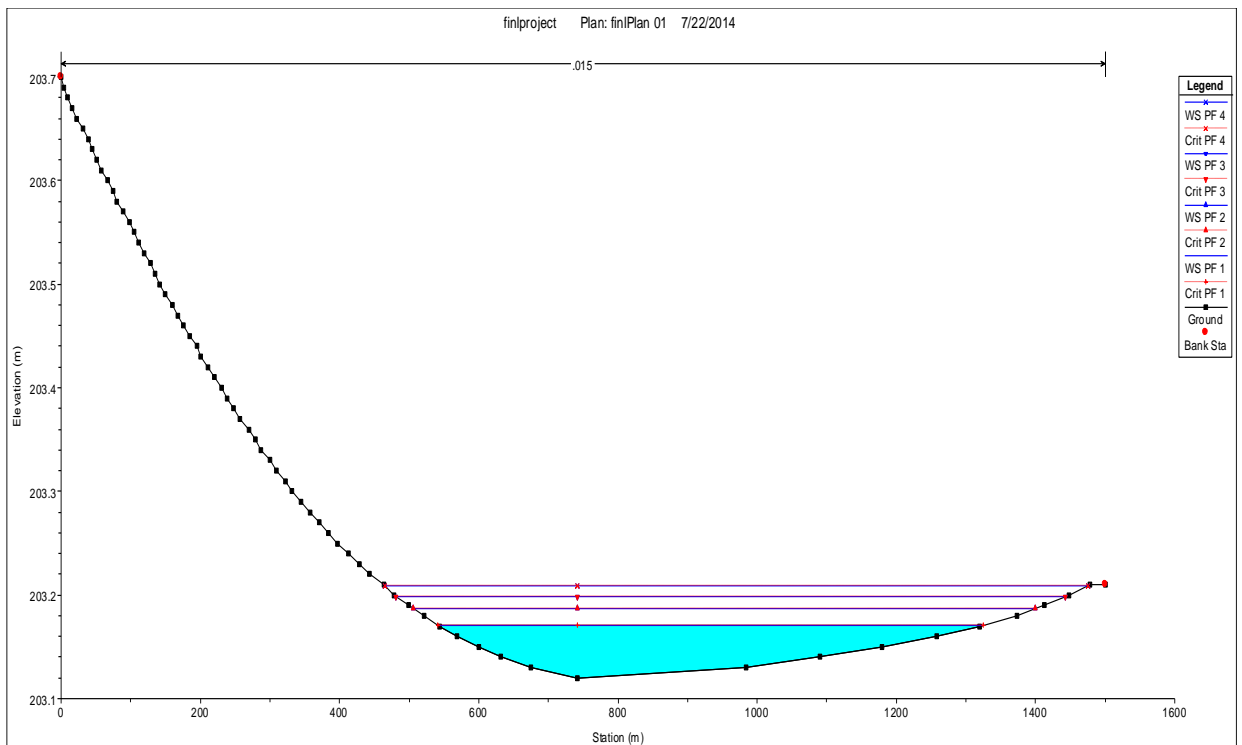


Figure4.27 Water Surface Profile for Station 500

The final step involves export of the computation results (water surface elevation) back to GIS. The following computational steps are used from the main HEC-RAS window “File” “Export GIS Data”. In the GIS export window, all four profile results (for the

four flow scenarios) are selected and exported using the default format “RASexport.sdf”. Figure shows the GIS Export window and the selected profiles used for export.

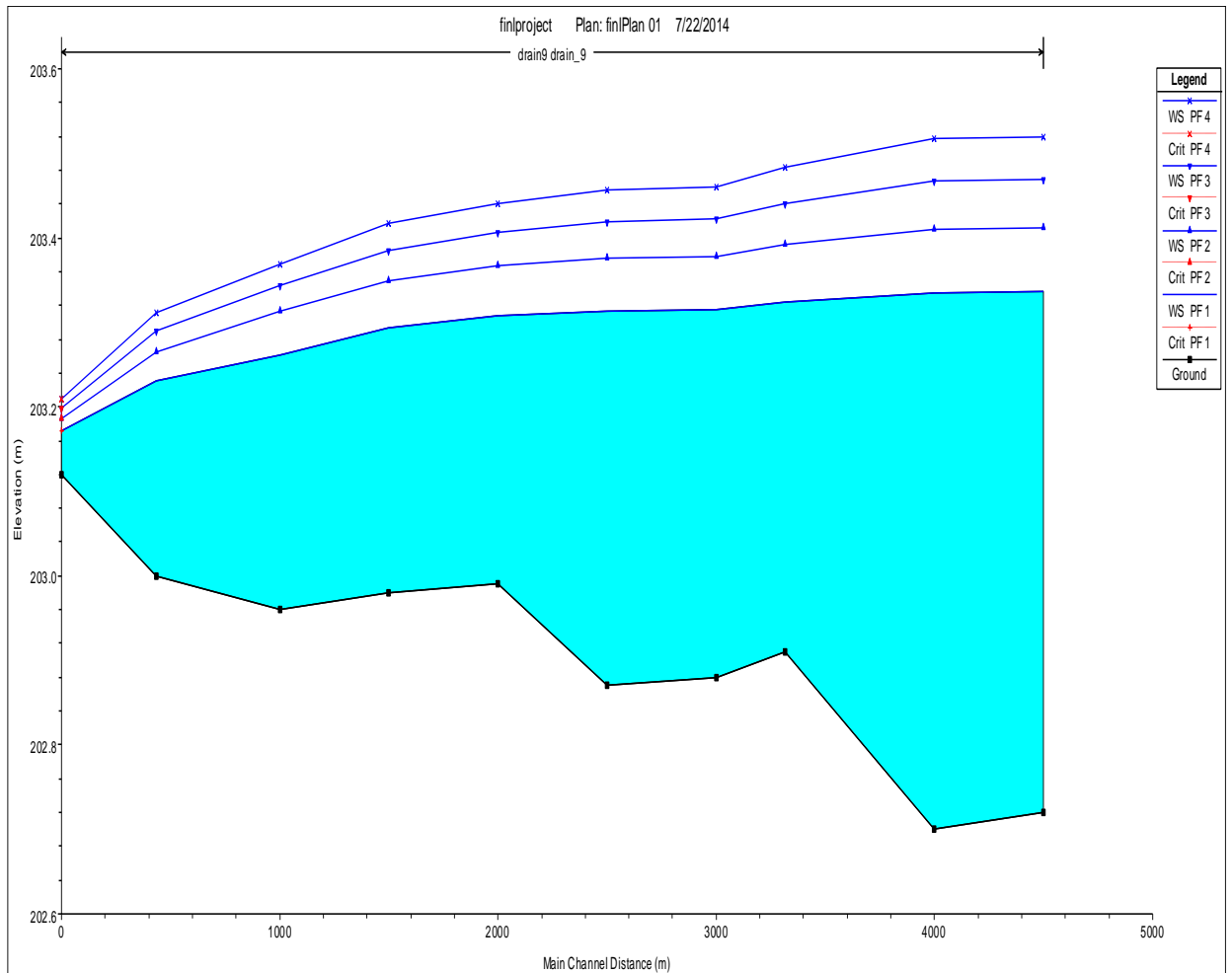


Figure4.28 Water Surface Profile for all four Profiles

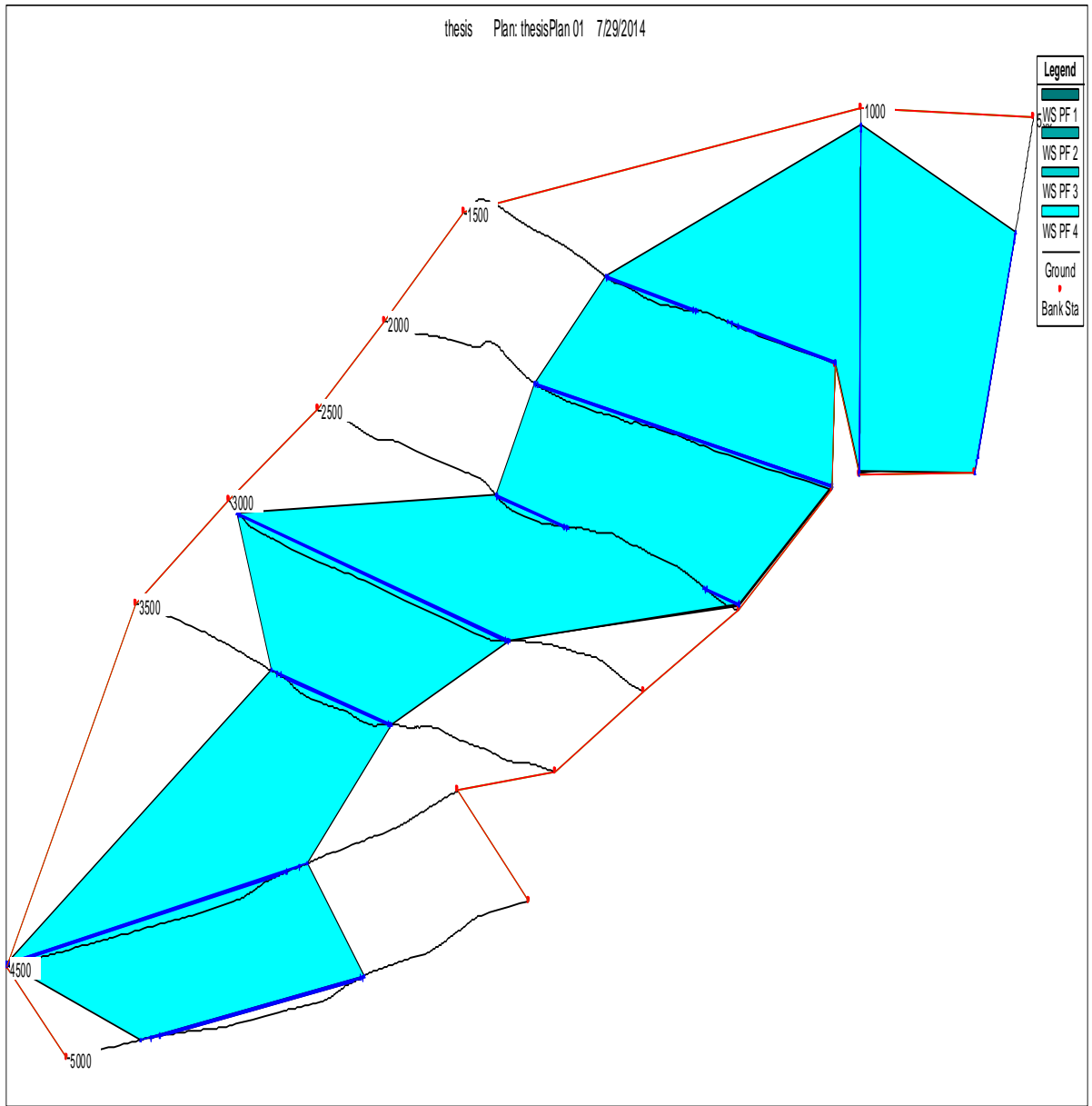


Figure 4.29 Water Surface Profile for Entire Cross Section

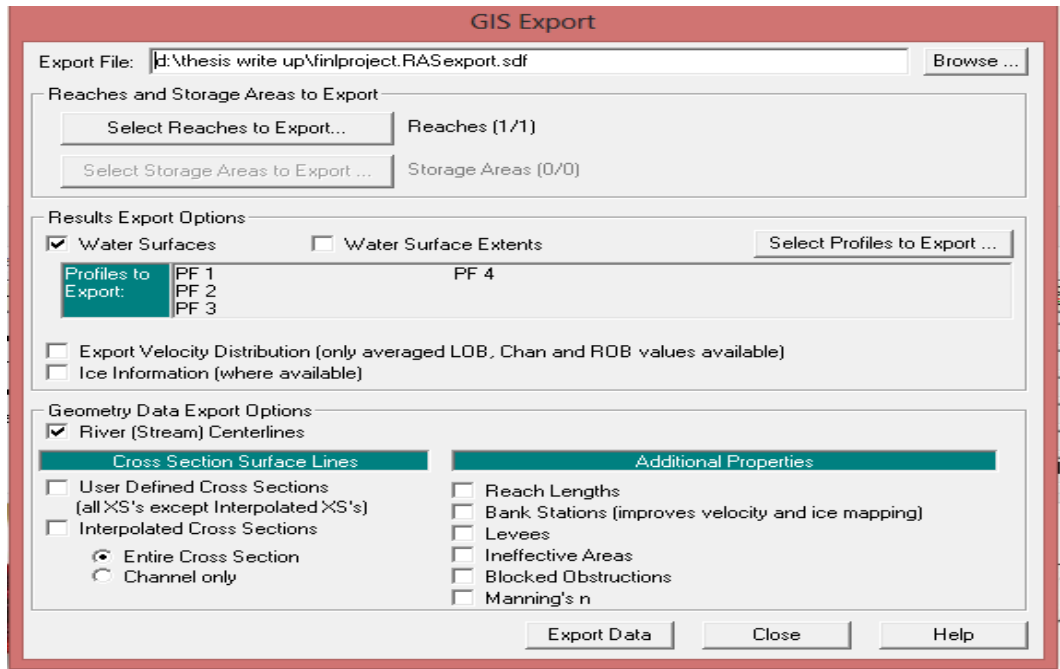


Figure4.30 Export the Profiles

4.5 POST PROCESSING OF HYDRAULIC RESULTS AND FLOOD PLAIN MAPPING

The post-processing of computation results was performed by using the same maps are used for the pre-processing of geometry data. The only additions to these maps are new map layers.

4.5.1 DATA IMPORT FROM HEC-RAS

Formatting: The process starts with opening a desired ArcMap for post-processing. Since the HEC-GeoRAS cannot read the proprietary spatial data format (.RASExport.sdf) file created in the HEC-RAS, it is necessary to convert it into the XML file format, supported by HECGeoRAS. This was achieved by selecting the “Import RAS SDF File” option from the HEC-Geo RAS Toolbar.

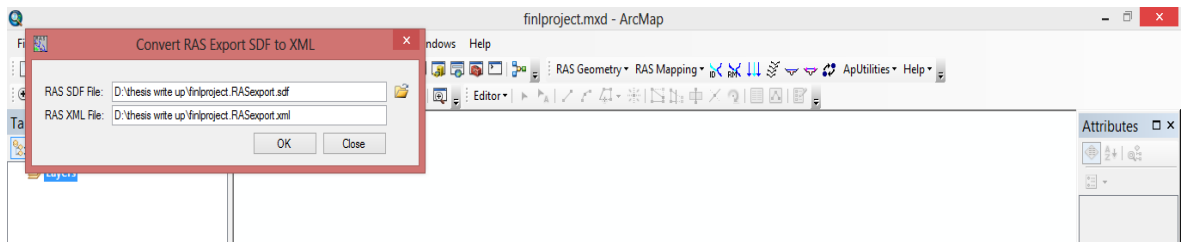


Figure4.31 Convert RAS export SDF to XML

(a) Layer setup: Establish the Layer Setup is a necessary step for processing the HEC-RAS results. In the Layer Setup window, the type of analysis and the input and output data are identified. Figure shows a typical Layer Setup window from the data post-processing. For the post-processing analyses, the rasterization cell size is set to 2 map units. Basically, a smaller number of map units results in a better representation of the resulting floodplain boundary during the floodplain delineation. Since at some places the floodplain lines are too coarse, an attempt is made to rasterization cell size to 1 map unit. However, the program is not able to handle this resolution, and two map units are used as the best possible rasterization cell size Reading RAS GIS export file. After input data is entered in the layer setup, the HEC-RAS results have to be imported into the GIS in order to continue with the post-processing. The following computational steps are selected from the HEC-GeoRAS toolbar:

“RAS Mapping” → “Read RAS GIS Export File”.

This selection introduces a new data frame with the following feature classes: Drain3D, XS Cut Lines, and Bounding Polygon.

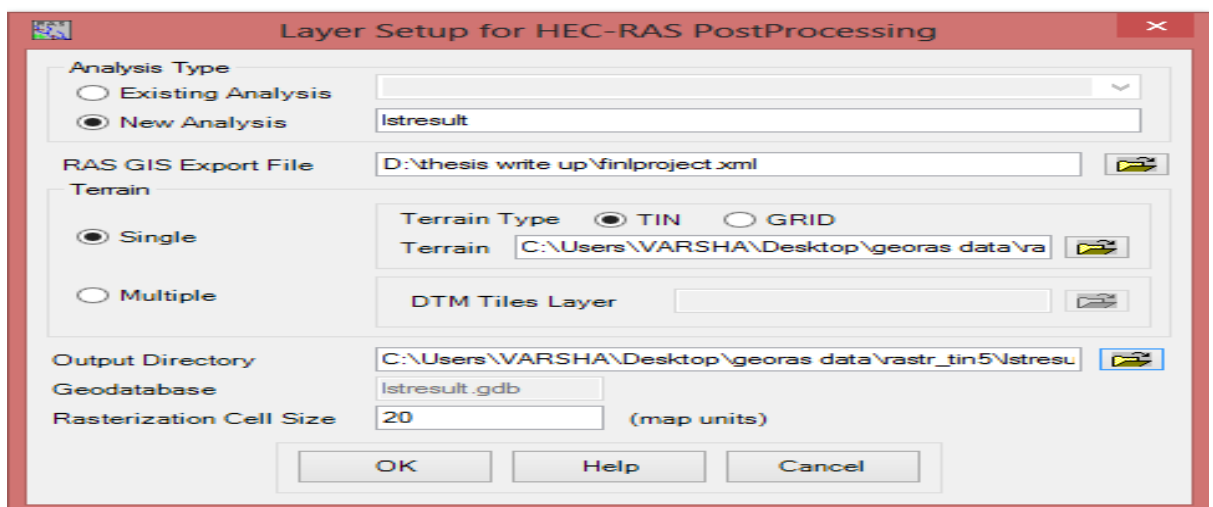


Figure4.33 Layer setup for HEC-RAS Post Processing

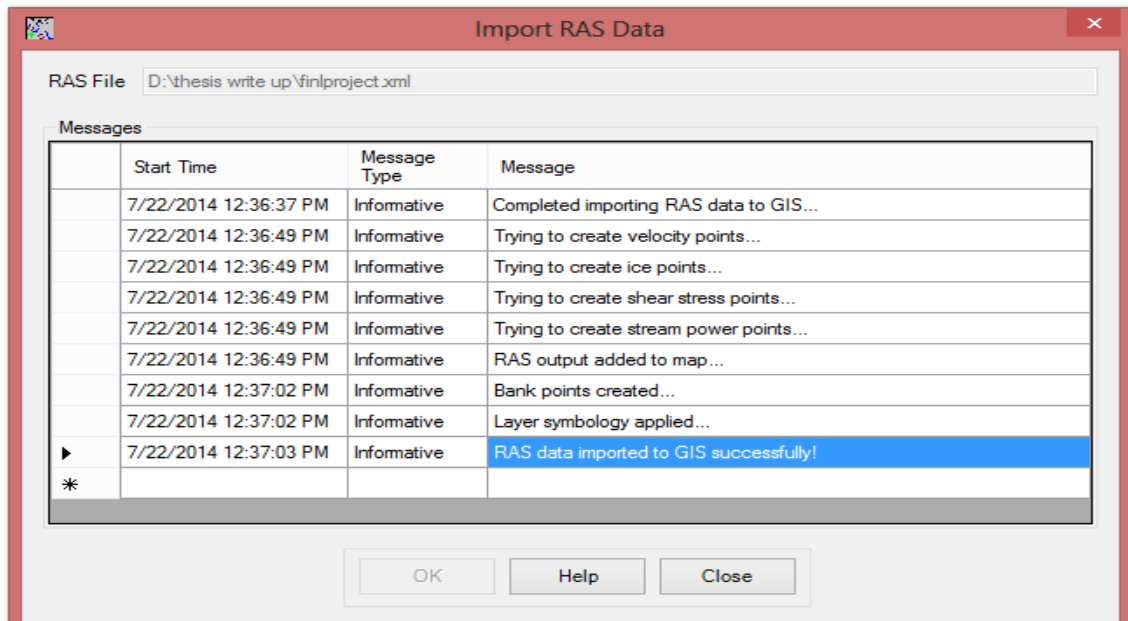


Figure4.34 Import RAS data

4.5.2 FLOOD PLAIN MAPPING

Floodplain mapping is performed using the water surface elevations on the XS cut lines, within the limits of the bounding polygon. Floodplain mapping is completed in two steps, which are explained in following paragraphs.

(a)Water surface TIN: The first step is to generate a water surface TIN from the cross section water surface elevations. The following computational steps are selected from the HEC-GeoRAS toolbar:

“RAS Mapping” → “Inundation Mapping” → “Water Surface Generation”.

All four water surface profiles are selected from the window, as shown in Fig. For each selected water surface profile, a water surface TIN is created without consideration of the terrain model. The TIN is created using the ArcGIS triangulation method. This allowed for the creation of a surface using cut lines as hard break lines with constant elevation. Also, areas which are of little interest are still included in the water surface TIN. These areas are removed in the process of delineation with the bounding polygon.



Figure4.35 Bounding Polygon

(b) **Floodplain delineation:** The following computational procedure is used from the HECGeoRAS toolbar:

“RAS Mapping” → “InundationMapping” → “Floodplain Delineation” → “GRID Intersection”.

Again, all four water surface profiles are selected from the window. The water surface TIN is converted into a grid based on the rasterization cell size. Then, it is compared with the TIN terrain model, which is also in grid format, allowing the elevation difference to be calculated within the bounding polygon. The areas with positive results (where water surface is higher than the terrain elevation) are included in the floodplain area (inundation depth grid), and the areas with negative results are considered as dry. The depth grid has prefix “d” (“d” is for depth) before the profile name. It represent the water inundation depths within the delineated floodplains.

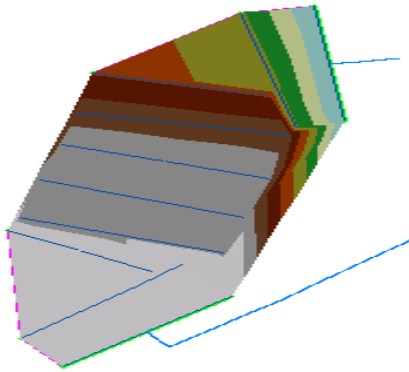


Figure4.36 TIN for Profile 1

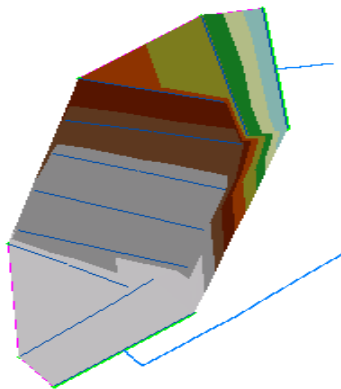


Figure 4.37 TIN for Profile 2

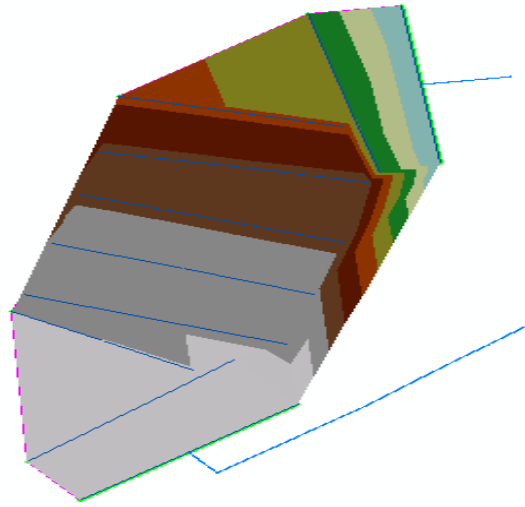


Figure4.38 TIN for Profile 3

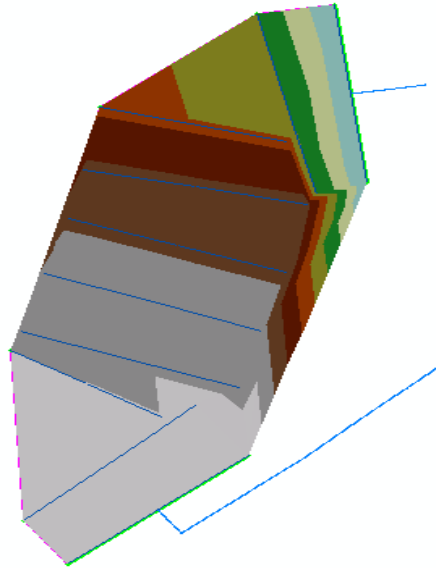


Figure4.39 TIN for Profile 4

After the analysis extent is defined water surface profile is generated using profile with highest flow. This creates a surface with water surface elevation for the selected profile. The TIN that is created in this step will define a zone that will connect the outer points of the bounding polygon, which means the TIN will include area outside the possible inundation.

Using inundation mapping (floodplain Delineation) button water surface TIN is first converted to a GRID, and then DTM grid is subtracted from the water surface grid. The area with positive results (meaning water surface is higher than the terrain) is flood area, and the area with negative results is dry. All the cells in water surface grid that result in positive values after subtraction are converted to a polygon, which is the final flood inundation polygon.

Chapter 5

RESULT AND DISCUSSION

HEC-RAS results consist of cross section water surface elevations for flows of PF1,PF2,PF3,PF4. Results are obtained after addition of discharge. Water surface elevation and hydraulic parameters are available for each cross section from HEC-RAS output. These parameters include: flows, minimum channel elevation, water surface elevation, critical water surface elevation, Energy gradient slopes. HEC-RAS outputs are available in both, tabular and graphical form.

In graphical form, HEC-RAS output can be viewed as water surface profiles, general profiles, rating curves, and X-Y-Z perspective plots.

Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # C
drain_9	5000	PF 1	20	202.72	203.36		203.36	0.000005	0.08	251.43	603.15	0.04
drain_9	5000	PF 2	30	202.72	203.41		203.41	0.000008	0.11	284.44	649.21	0.05
drain_9	5000	PF 3	40	202.72	203.46		203.46	0.00001	0.13	314.35	685.77	0.06
drain_9	5000	PF 4	50	202.72	203.5		203.5	0.000013	0.15	342.1	725.19	0.07
drain_9	4500	PF 1	20	202.7	203.36		203.36	0.000002	0.06	363.36	905.65	0.03
drain_9	4500	PF 2	30	202.7	203.41		203.41	0.000004	0.07	410.87	931.43	0.04
drain_9	4500	PF 3	40	202.7	203.45		203.45	0.000005	0.09	452.8	973.12	0.04
drain_9	4500	PF 4	50	202.7	203.49		203.49	0.000006	0.1	490.86	999.61	0.05
drain_9	3500	PF 1	20	202.88	203.35		203.35	0.000022	0.16	128.05	362.94	0.08
drain_9	3500	PF 2	30	202.88	203.4		203.4	0.000034	0.2	146.37	383.87	0.11
drain_9	3500	PF 3	40	202.88	203.44		203.45	0.000046	0.25	162.53	404.95	0.12
drain_9	3500	PF 4	50	202.88	203.48		203.48	0.000058	0.28	177.49	432.06	0.14

drain_9	3000 PF 1	20	202.87	203.35		203.35	0.000003	0.06	355.24	948.73	0.03
drain_9	3000 PF 2	30	202.87	203.4		203.4	0.000004	0.07	401.05	962.92	0.04
drain_9	3000 PF 3	40	202.87	203.44		203.44	0.000005	0.09	439.91	976.04	0.04
drain_9	3000 PF 4	50	202.87	203.47		203.47	0.000007	0.11	474.19	986.15	0.05
drain_9	2500 PF 1	20	202.99	203.34		203.35	0.000084	0.24	82.75	331.11	0.15
drain_9	2500 PF 2	30	202.99	203.39		203.39	0.000117	0.31	97.8	351.77	0.19
drain_9	2500 PF 3	40	202.99	203.42		203.43	0.000145	0.36	110.9	367.94	0.21
drain_9	2500 PF 4	50	202.99	203.46		203.46	0.00017	0.41	122.66	381.52	0.23
drain_9	2000 PF 1	20	202.98	203.33		203.33	0.000018	0.1	201.01	978.07	0.07
drain_9	2000 PF 2	30	202.98	203.37		203.37	0.000023	0.12	240.39	985.85	0.08
drain_9	2000 PF 3	40	202.98	203.4		203.4	0.000027	0.15	273.29	993.08	0.09
drain_9	2000 PF 4	50	202.98	203.43		203.43	0.00003	0.17	301.92	997.16	0.1
drain_9	1500 PF 1	20	202.96	203.3		203.3	0.000658	0.36	55.73	579.73	0.37
drain_9	1500 PF 2	30	202.96	203.33		203.34	0.000576	0.39	76.2	624.07	0.36
drain_9	1500 PF 3	40	202.96	203.36		203.37	0.000539	0.42	94.13	654.34	0.36
drain_9	1500 PF 4	50	202.96	203.38		203.39	0.000523	0.45	110.31	680.83	0.36
drain_9	1000 PF 1	20	203	203.25		203.25	0.000032	0.1	199.13	1464.37	0.09
drain_9	1000 PF 2	30	203	203.28		203.28	0.00004	0.13	239.48	1472.28	0.1
drain_9	1000 PF 3	40	203	203.3		203.3	0.000045	0.15	274.28	1482.1	0.11
drain_9	1000 PF 4	50	203	203.32		203.32	0.000051	0.16	303.55	1489.21	0.12
drain_9	500 PF 1	20	203.12	203.18	203.18	203.2	0.006549	0.61	32.65	853.46	1
drain_9	500 PF 2	30	203.12	203.19	203.19	203.22	0.006049	0.68	44.17	931.5	1
drain_9	500 PF 3	40	203.12	203.2	203.2	203.23	0.006427	0.76	52.56	978.11	1.05
drain_9	500 PF 4	50	203.12	203.21	203.21	203.24	0.005702	0.78	63.91	1043.14	1.01

Table 5-1 Output data of HEC-RAS

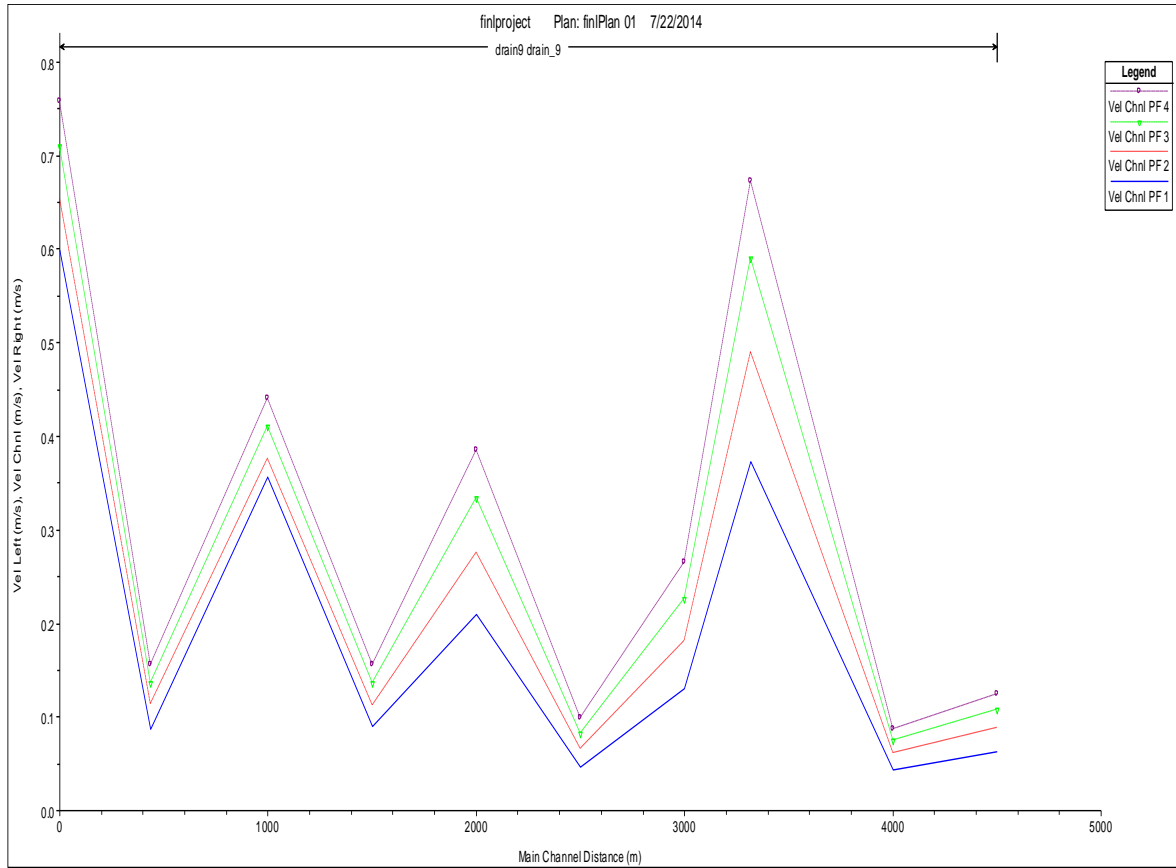


Figure 5.1 General Profile Plot for Velocity

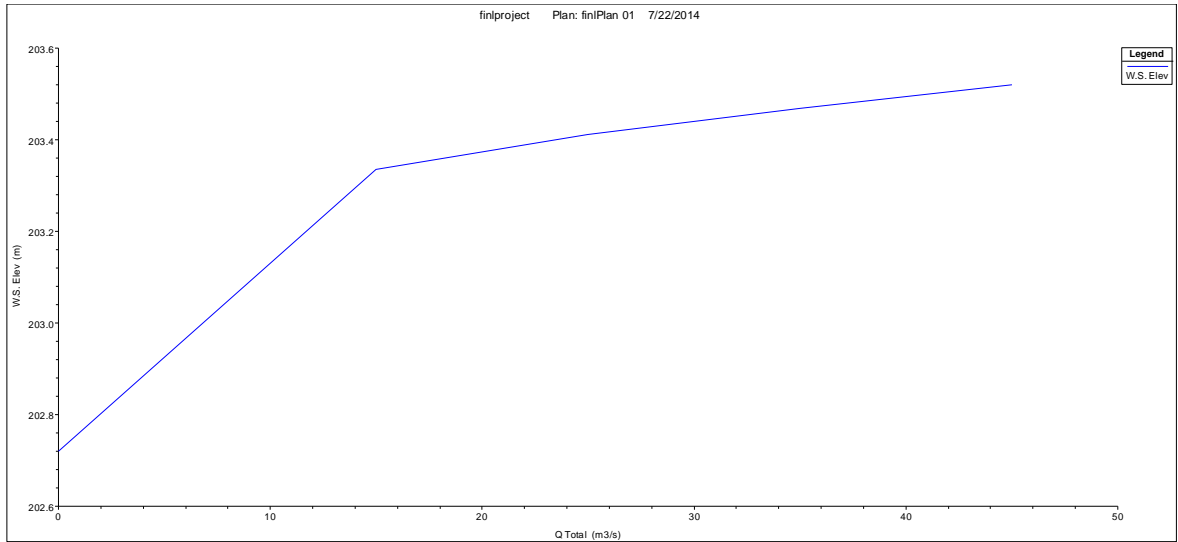


Figure5.2 Rating Curve for Cross section 5000

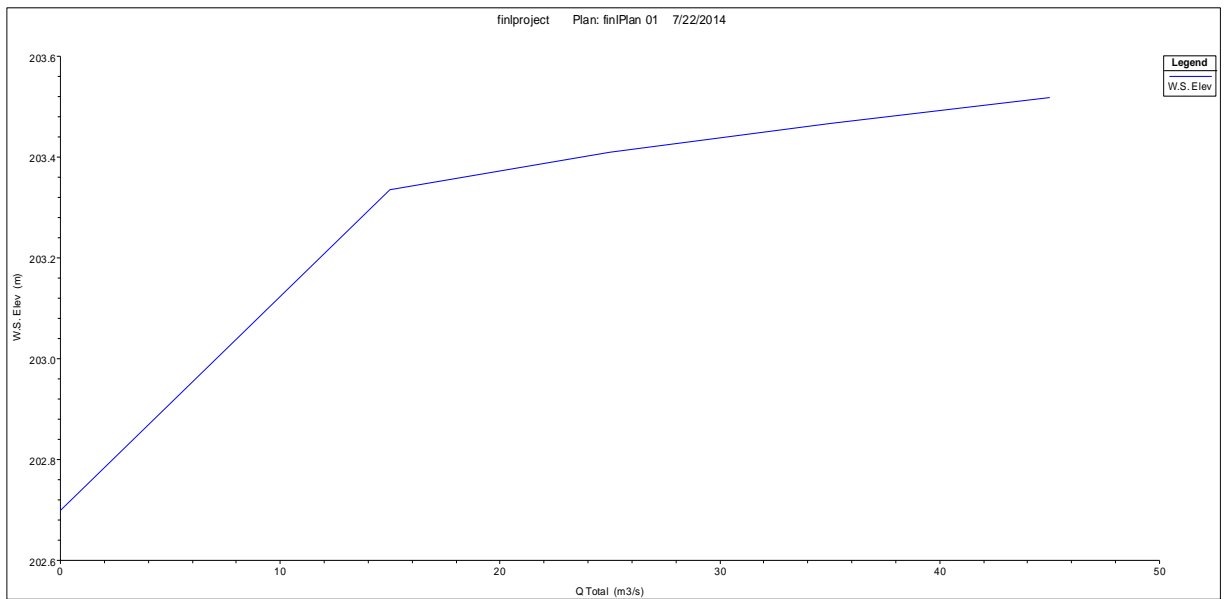


Figure5.3 Rating Curve for Cross Section 4500

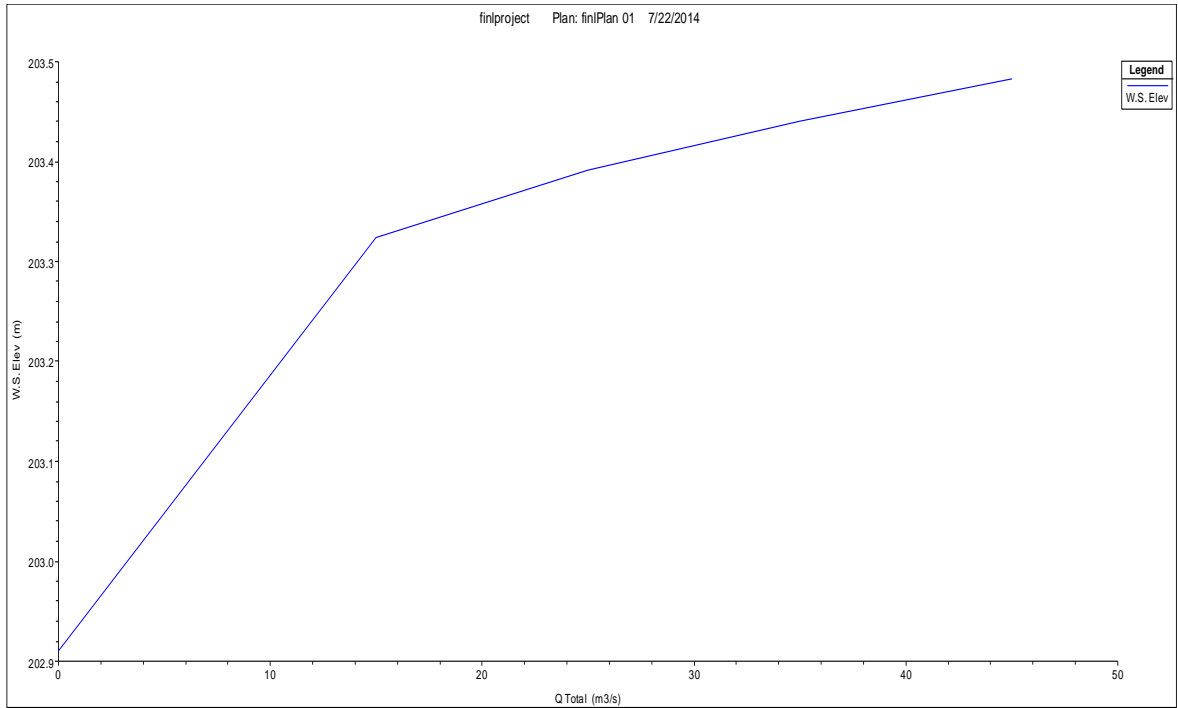


Figure 5.4 Rating curve for cross section 4000

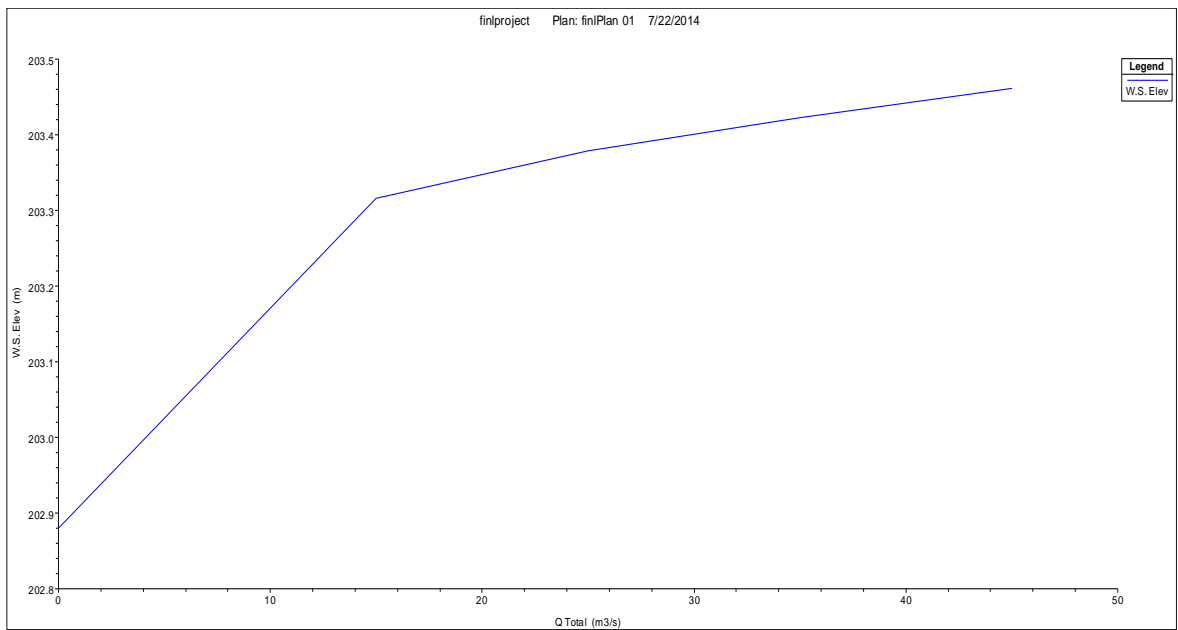


Figure 5.5 Rating curve for cross section 3500

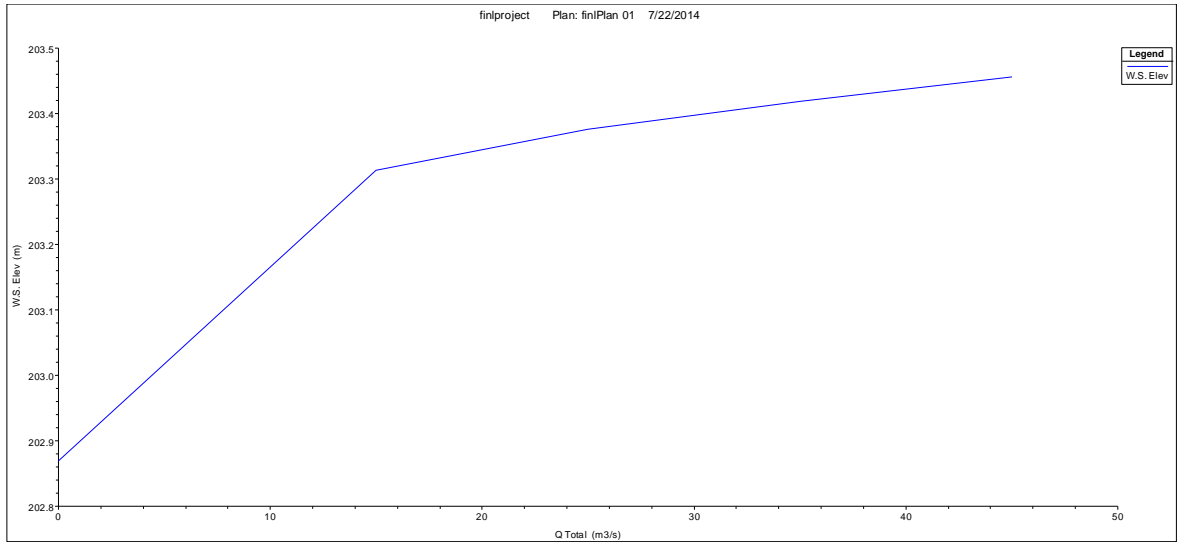


Figure 5.6 Rating Curve for Cross section 3000

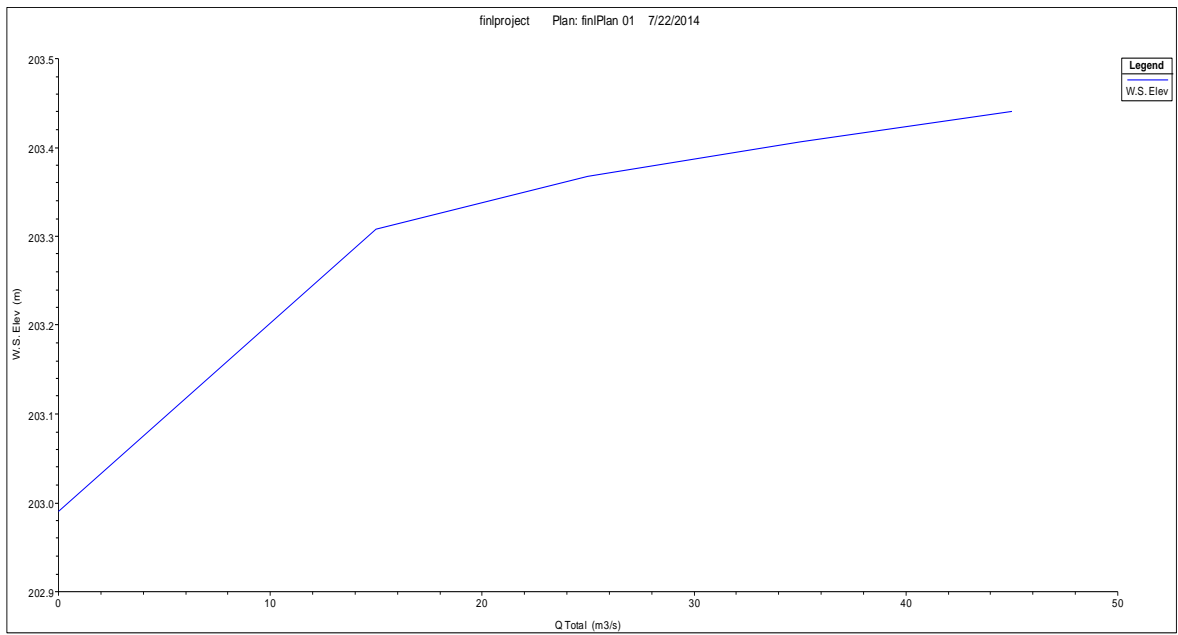


Figure 5.7 Rating Curve for cross section 2500

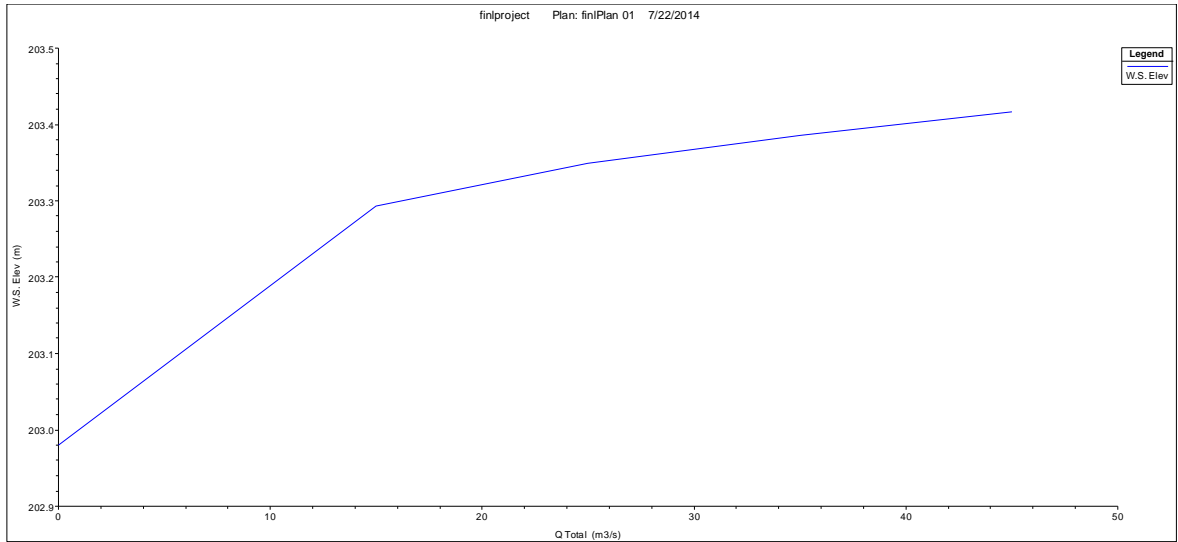


Figure 5.8 Rating Curve for Cross section 2000

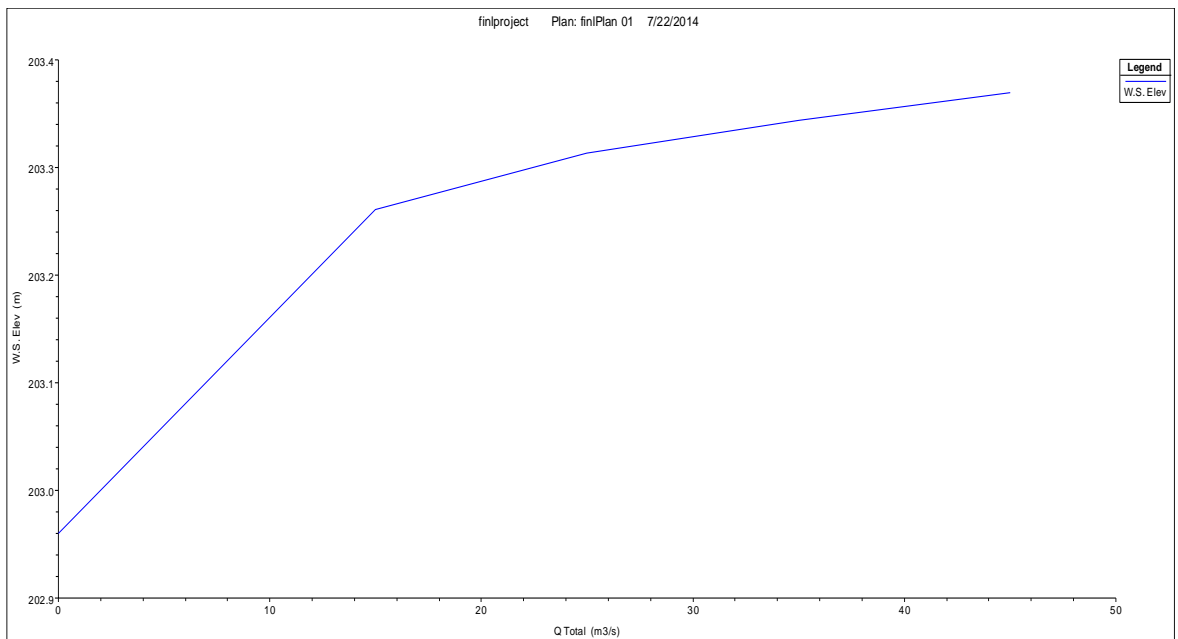


Figure 5.9 Rating curve for Cross section 1500

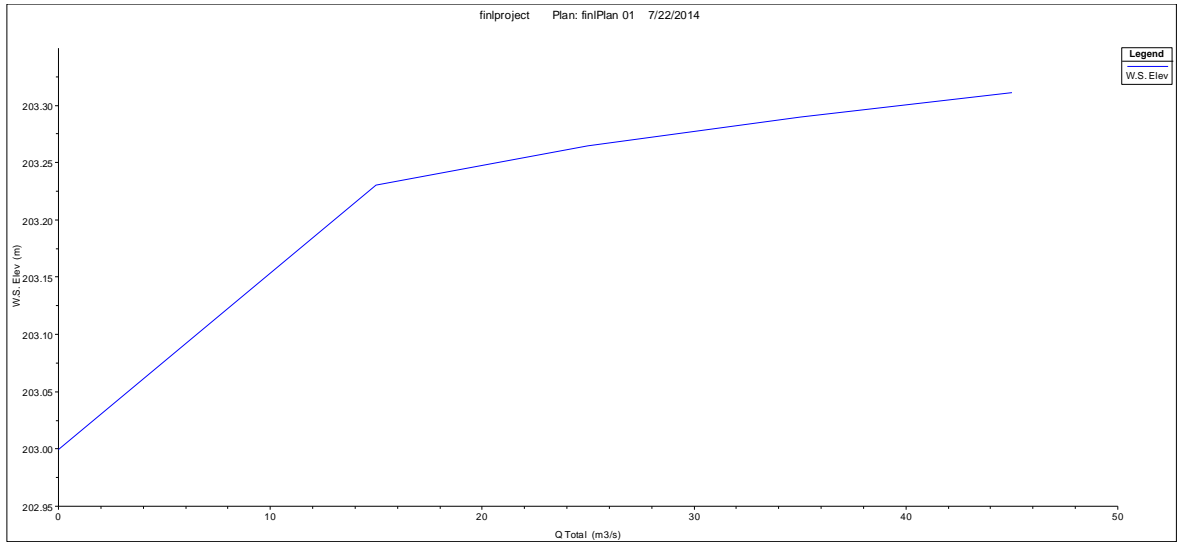


Figure 5.10 Rating Curve for Cross section 1000

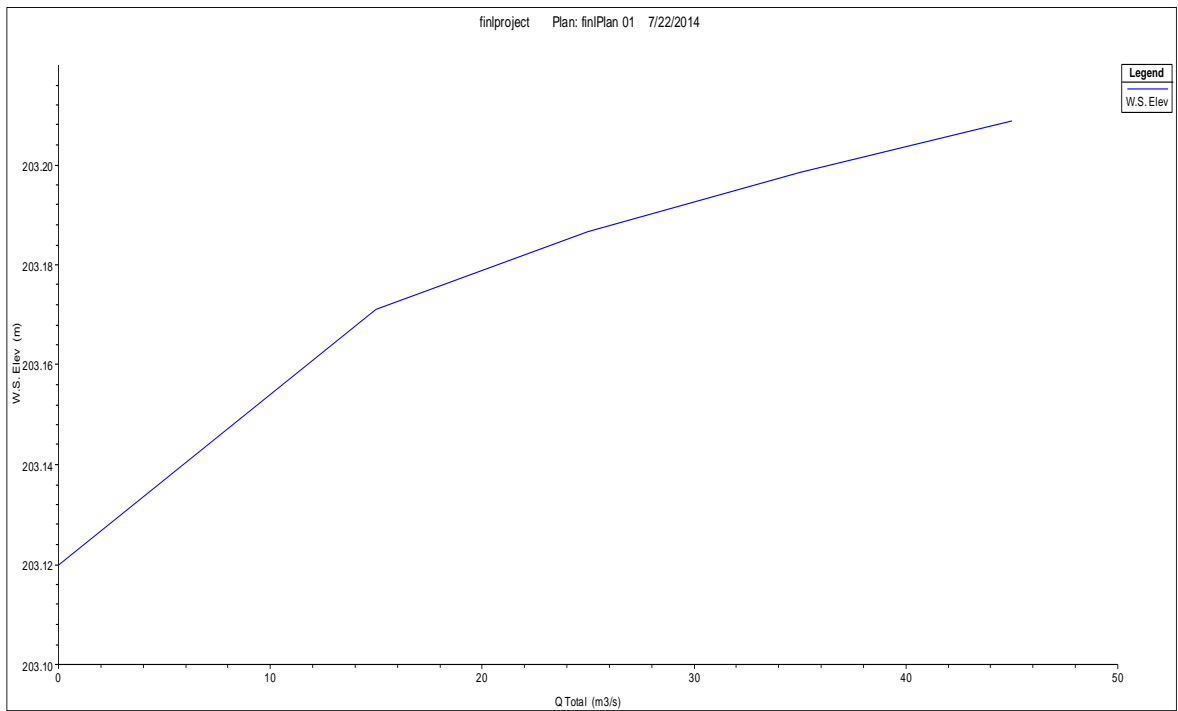


Figure 5.11 Rating Curve for Cross section 500

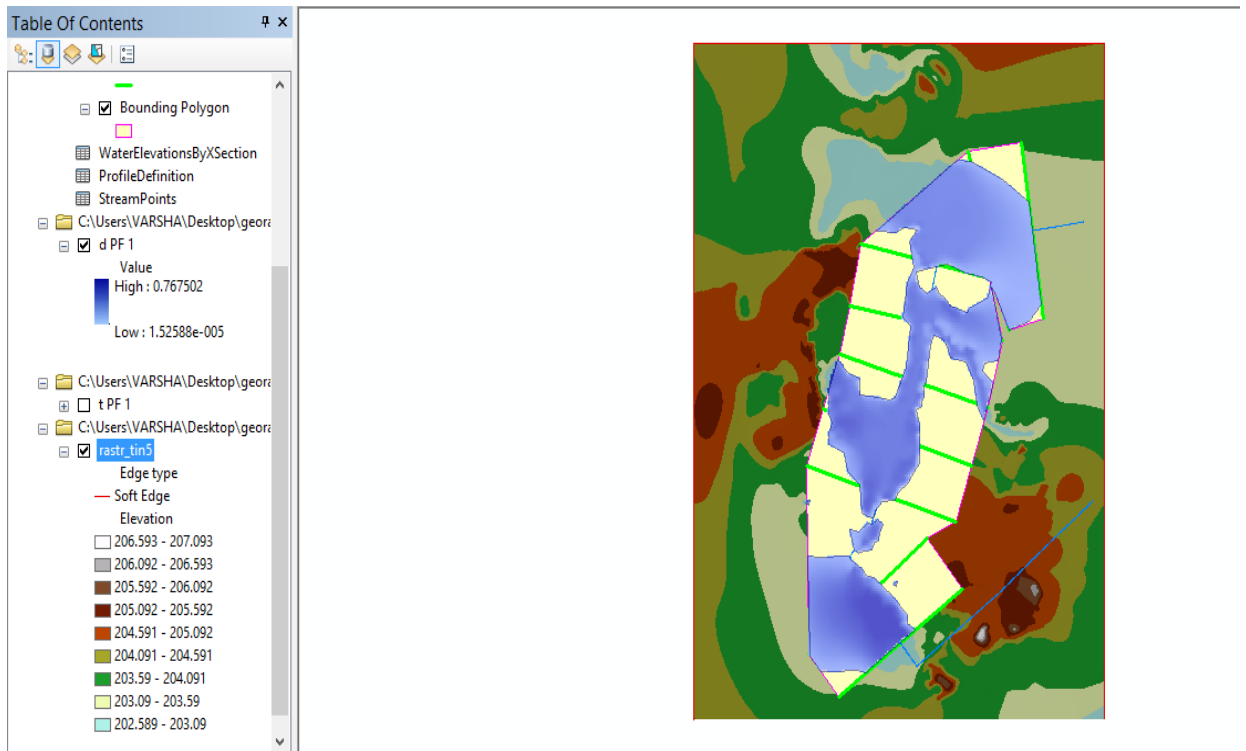


Figure5.12 Flood Inundation Delineation for PF1



Figure5.13 Flood inundation map for profile 1

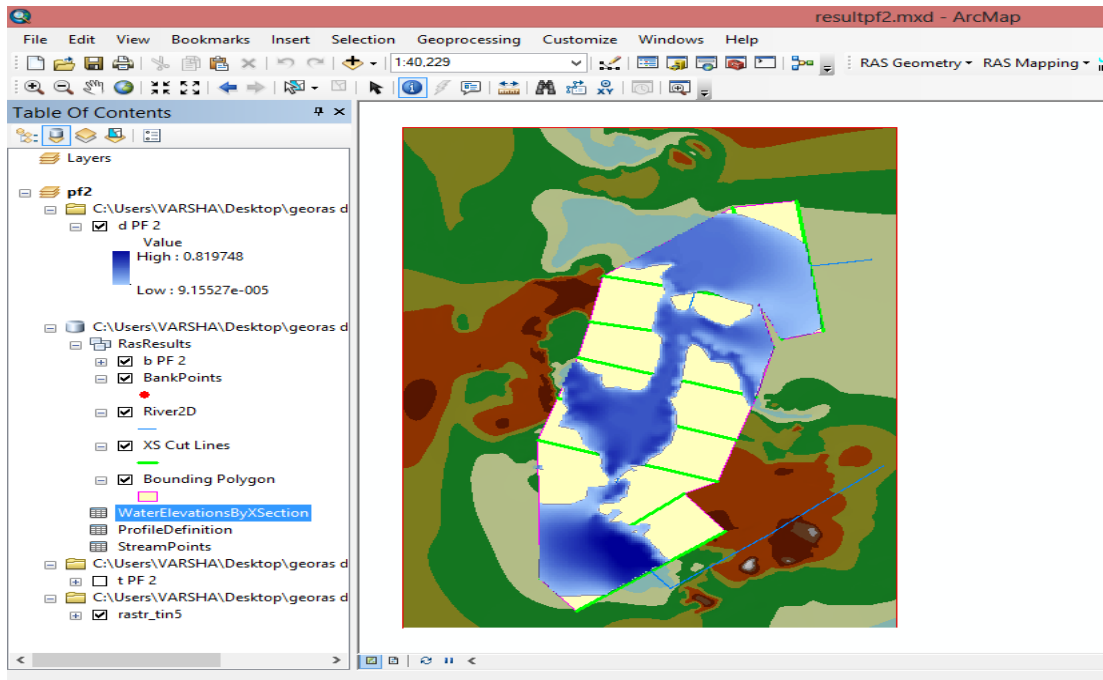


Figure5.14 Flood inundation delineation for PF2



Figure5.15 Flood Inundation Map for PF2

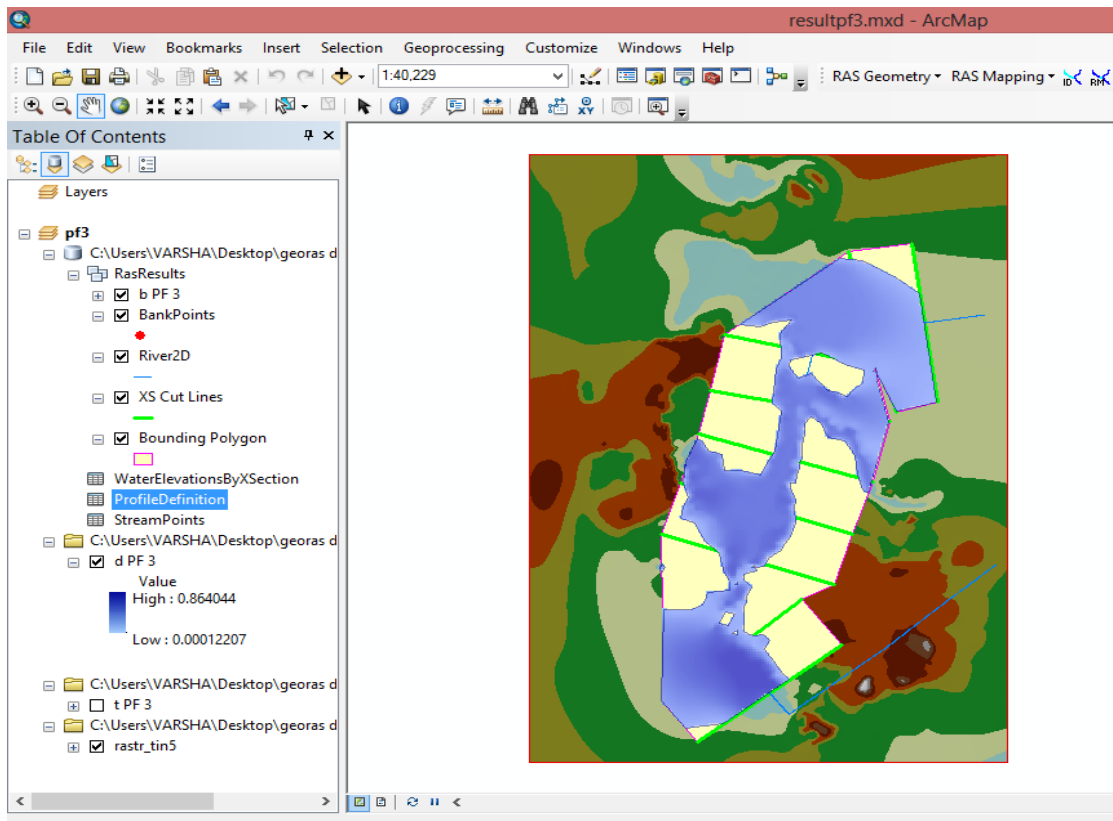


Figure5.16 Flood Plain Delineation for PF 3



Figure5.17 Flood Map for PF3

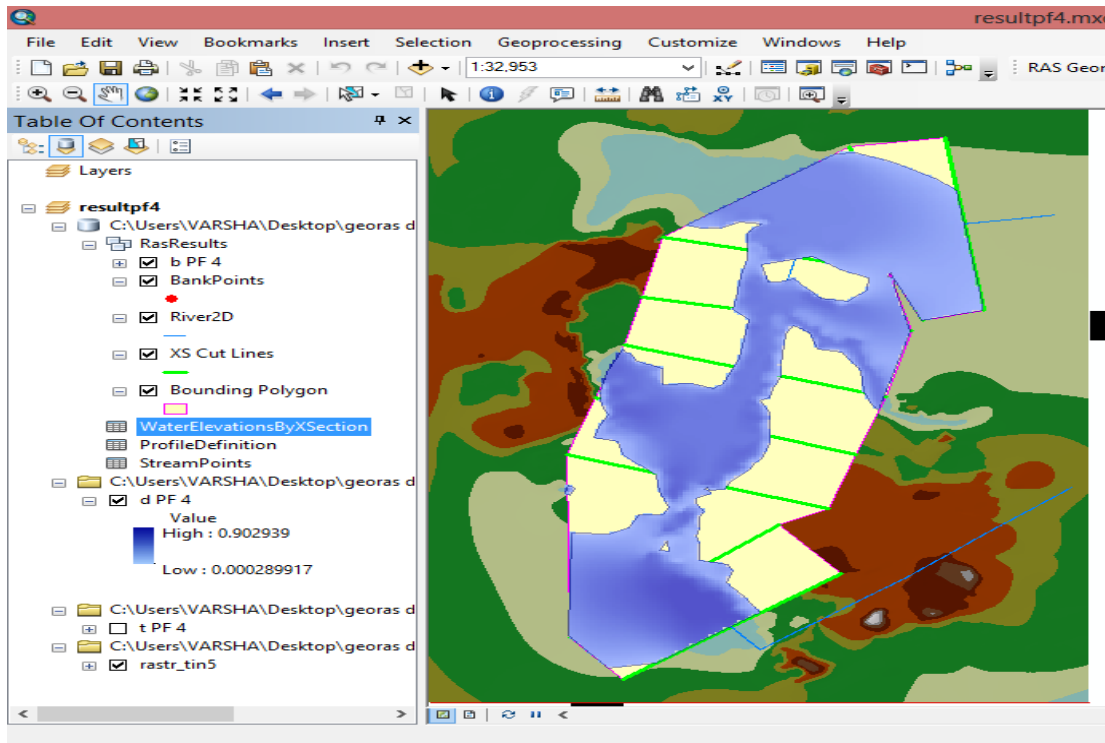


Figure5.16 Flood Plain Delineation for PF4



Figure5.017 Flood Map for PF4

The floodplain boundary is represented by a yellow line. The inundation depth grid is represented with different hues of blue. The largest value of water depth is represented by a dark blue, and the smallest value of water depth is represented by a light blue. By using the “identify tool” button, water depth at any point can be easily identified. Maximum depth found for PF1, PF2, PF3 and PF4 are 76.70, 82.70 86.40 and 92.30 centimetres respectively.

Results obtained from the analysis of HEC-RAS were used in HEC-GeoRAS to generate the water surface profile as shown in figure 4.19 to 4.28. The water surface profiles were obtained for the river reach showing for 1500m cross section. Therefore the results obtained are indicating the flood inundation at low lying areas within the drain 1500m. Water Surface profile in Hasanpur Drain.

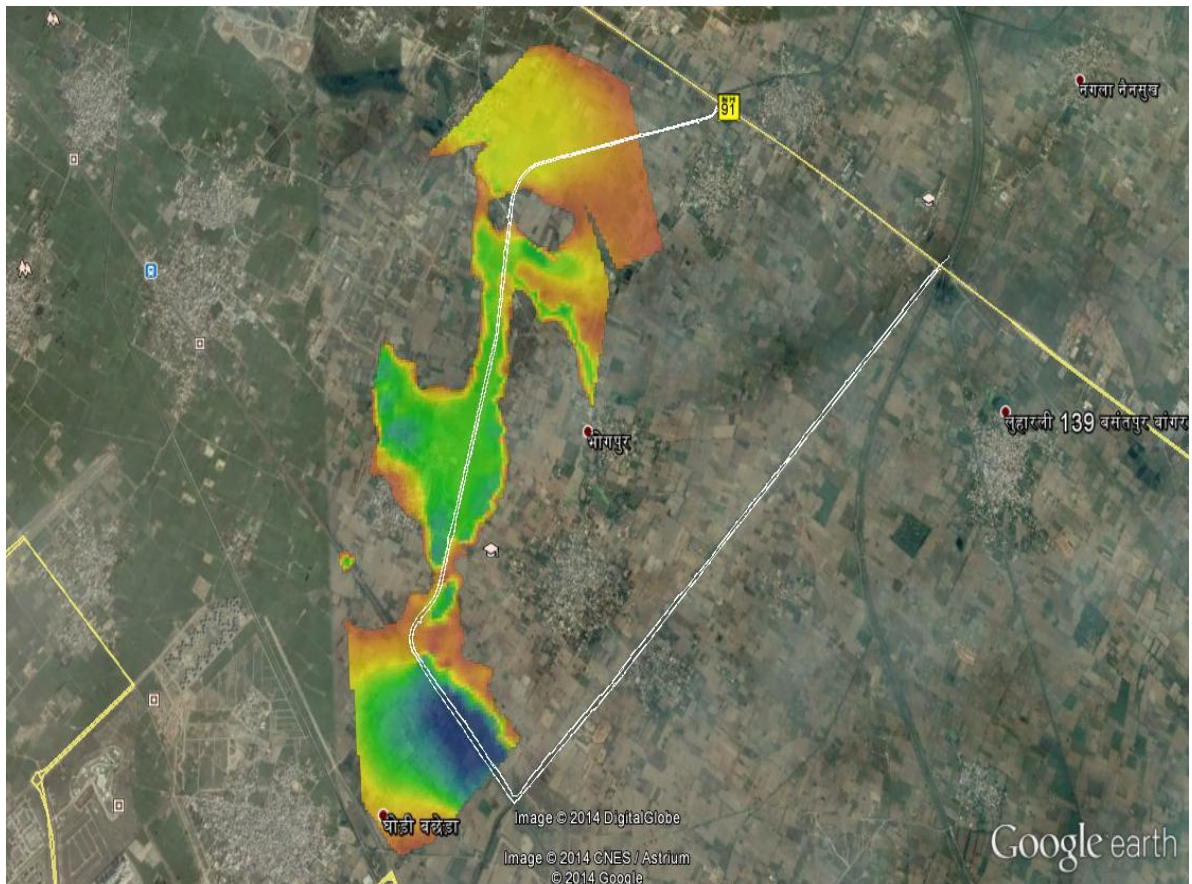


Figure5.18Flood Map for all Profiles

The flood map indicates that the areas Beel Akbarpur, Chamrawali Ramgarh and Ghodi Bachera gets flooded for discharge of PF1. Bhogpur remains unflooded for the discharge of 20 and 30 m³/sec .Flood is about to reach Bhogpur as deduced from profile PF4 as shown in fig 5.19.

Chapter 6

CONCLUSION

The following conclusions are drawn on the basis of results of previous chapter:

- Flood inundated area obtained using HEC-RAS is successful for the Hasanpur Drain. GEO-RAS is a supporting tool of HEC-RAS for flood mapping which gives quick result for flood plain delineation.
- The maximum water depth can be found out with the help of HEC-GEO-RAS on the basis of the various return period hence discharges.
- The result shows in the form of Arc View as shape file polygons and lines are generated in the steady flow version of HEC-RAS 1-D model.
- It is interesting to observe and quantify the differences in the representation of the terrain provided by 1 meter DEM and integrated TIN model developed this research.
- For the plain area, high resolution of Digital Elevation Map is necessary for the modeling. Higher Resolution DEM gives the best result for flood map. High resolution elevation data is used for the flood extent calculations.
- The result shows the flooded area around the Hasanpur Drain for different discharge profiles which can be useful for flood risk analysis.

REFERENCES

- [1] Tate E.C.,(1999). Floodplain mapping using HEC-RAS and ArcView GIS. University of Texas at Austin, Austin.
- [2] Werner MGF (2001). Impact of grid size in GIS based flood extent mapping using a 1D flow model. *J. Phys. Chem. Earth, Part B: Hydrol. Oceans, Atmosphere.* 26: 517-522.
- [3] Earles TA, Wright RK, Brown C, Langan TE (2004). Los alamos forest fire impact modeling. *J. Am. Water. Resour. Assoc. (JAWRA)* 40(2):371-384.
- [4] Williams TM (2006). In corporating GIS in river hydraulic modeling: assessing the ability to predict ecological consequences of river modification on floodplain forests. *Hydrology and Management of Forested Wetlands Proceedings of the International Conference Published by the American Society of Agricultural and Biological Engineers.*
- [5] Yang J, Townsend RD, Daneshfar B (2006). Applying the HEC-RAS model and GIS techniques in river network floodplain delineation. *Canadian.J. Civil. Eng.* 33(1): 19-28.
- [6] Chuan T, Jing Z (2006). Torrent risk zonation in the Upstream Red River Basin based on GIS, *J.Geogr. Sci.* 16(4): 479-486.
- [7] Keren J. Cepero-Pérez , J. P. Liu, Sean Reed, Cecile Aschwande North Carolina State University, Raleigh NC. Inundation mapping employing hydraulic modeling and GIS .Case study Tar River during Hurricanr Floyd.
- [8] U.S. Army Corps of Engineers (USACE). HEC-RAS, User's Manual Version 4.1, 2010. Hydrologic Engineering Centre, Davis, CA, USA.
- [9] U.S. Army Corps of Engineers (USACE), HEC-GeoRAS, User's manual Version 4.3.93, 2011. Hydrologic Engineering Centre, Davis, CA, USA.

- [10] Han K.Y., Lee J.T., and Park J.K. Flood inundation analysis resulting from levee break, *Journal of Hydraulic Research*, 36 (1998): pp. 747-759.
- [11] Prasuhn, A.L. *Fundamentals of Hydraulic Engineering*. Oxford University Press, New York, NY, 1992.
- [12] Chow, V. T. (1959). *Open-Channel Hydraulics*. McGraw-Hill Book Company, New York.
- [13] Meyer, S., Olivera, F. (2007). "Floodplain Mapping & Hydraulic Analysis with HECGeoRAS4.1.1 and ArcGIS9.1." Retrieved from: <https://ceprofs.civil.tamu.edu/.../GeoRAS411/HECGeoRAS%20-20Meyer%20and%20Olivera.pdf> - on 27 January 2008.
- [14] Methods, H., Dyhouse, G., Hatchelt, J., Benn, J. (2003). *Floodplain Modeling Using HEC-RAS*. Heasted Methods, Inc. Waterbury, USA.
- [15] USACE (2005). *HEC-GeoRAS, GIS Tools for support of HEC-RAS using ArcGIS, Users Manual, Version 4*. United States Army Corps of Engineers, Hydrologic Engineering Centre, Davis, California.
- [16] Pappenberger, F., K. Beven, M. Horritt, and S. Blazkova. "Uncertainty in the calibration of effective roughness parameters in HEC-RAS using inundation and downstream level observations." *Journal of Hydrology*, 2004: 46-69.
- [17] Horritt, M. S. (2006b). A methodology for the validation of uncertain flood inundation models. *Journal of Hydrology* 326, 153–165.
- [18] Garnara, C. J., Patel V. M. and Patel D. P, *Urban Flood Mapping by Geospatial technique - A case study of Vadodara city*, National Conference on Current challenges in Civil engineering-2009, Vellamal Engineering College, Chennai.
- [19] Chusit Apirumanekul, Ole Mark, *Modelling of Urban Flooding in Dhaka City*, *Water Engineering & Management*, Asian Inst. of Technology.

[20] HEC 2005. HEC-GeoRAS, GIS Tools for Support of HEC-RAS using ArcGIS. User's Manual. Hydrologic Engineering Center—US Army Corps of Engineers, Davis, California.

APPENDIX I

Table							
WaterElevationsByXSection							
	RiverCode	ReachCode	ProfileM	Profile	Elevation	XSOID	OBJECTID *
▶	drain9	drain_9	5000	P001	203.3589	1	1
	drain9	drain_9	4500	P001	203.3574	2	2
	drain9	drain_9	3500	P001	203.3526	3	3
	drain9	drain_9	3000	P001	203.3505	4	4
	drain9	drain_9	2500	P001	203.3436	5	5
	drain9	drain_9	2000	P001	203.3283	6	6
	drain9	drain_9	1500	P001	203.295	7	7
	drain9	drain_9	1000	P001	203.2502	8	8
	drain9	drain_9	500	P001	203.1803	9	9

For profile 1

Table							
WaterElevationsByXSection							
	RiverCode	ReachCode	ProfileM	Profile	Elevation	XSOID	OBJECTID *
▶	drain9	drain_9	5000	P001	203.4116	1	1
	drain9	drain_9	4500	P001	203.4093	2	2
	drain9	drain_9	3500	P001	203.4016	3	3
	drain9	drain_9	3000	P001	203.3984	4	4
	drain9	drain_9	2500	P001	203.3877	5	5
	drain9	drain_9	2000	P001	203.3684	6	6
	drain9	drain_9	1500	P001	203.329	7	7
	drain9	drain_9	1000	P001	203.2776	8	8
	drain9	drain_9	500	P001	203.1932	9	9

For Profile 2

Table

WaterElevationsByXSection

	RiverCode	ReachCode	ProfileM	Profile	Elevation	XSOID	OBJECTID *
▶	drain9	drain_9	5000	P001	203.4564	1	1
	drain9	drain_9	4500	P001	203.4532	2	2
	drain9	drain_9	3500	P001	203.4426	3	3
	drain9	drain_9	3000	P001	203.4385	4	4
	drain9	drain_9	2500	P001	203.4241	5	5
	drain9	drain_9	2000	P001	203.4017	6	6
	drain9	drain_9	1500	P001	203.3571	7	7
	drain9	drain_9	1000	P001	203.3012	8	8
	drain9	drain_9	500	P001	203.202	9	9

For Profile 3

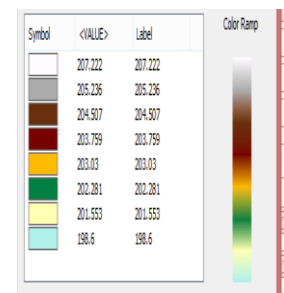
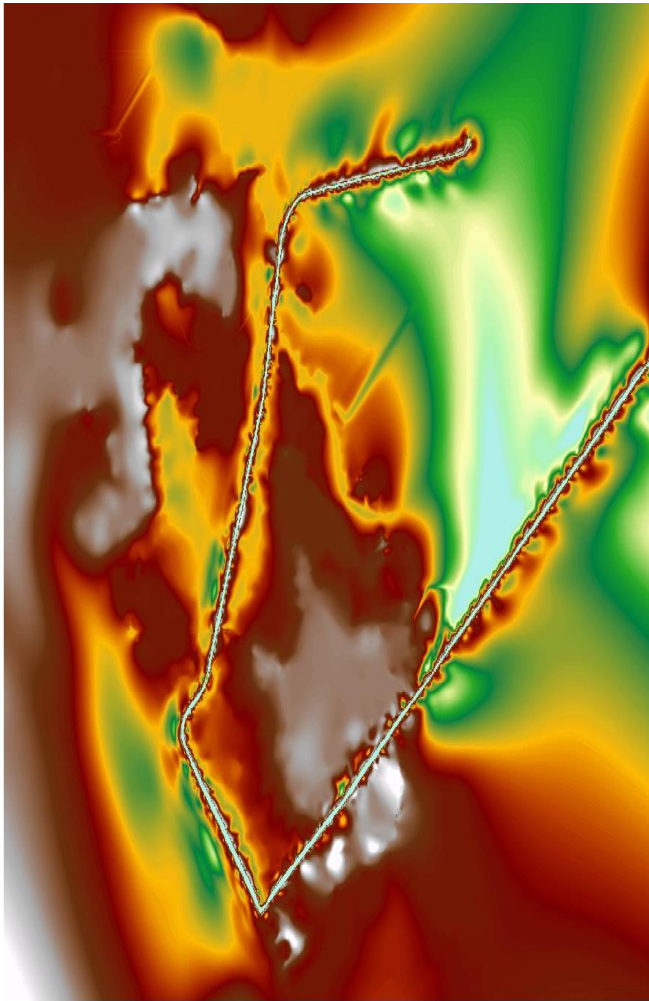
Table

WaterElevationsByXSection

	RiverCode	ReachCode	ProfileM	Profile	Elevation	XSOID	OBJECTID *
▶	drain9	drain_9	5000	P001	203.4957	1	1
	drain9	drain_9	4500	P001	203.4918	2	2
	drain9	drain_9	3500	P001	203.4785	3	3
	drain9	drain_9	3000	P001	203.4734	4	4
	drain9	drain_9	2500	P001	203.4555	5	5
	drain9	drain_9	2000	P001	203.4304	6	6
	drain9	drain_9	1500	P001	203.3814	7	7
	drain9	drain_9	1000	P001	203.3209	8	8
	drain9	drain_9	500	P001	203.2133	9	9

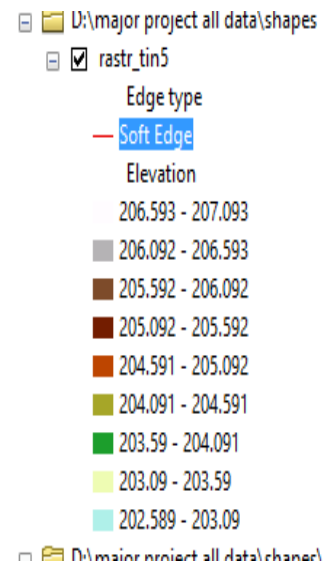
For Profile 4

APPENDIX II



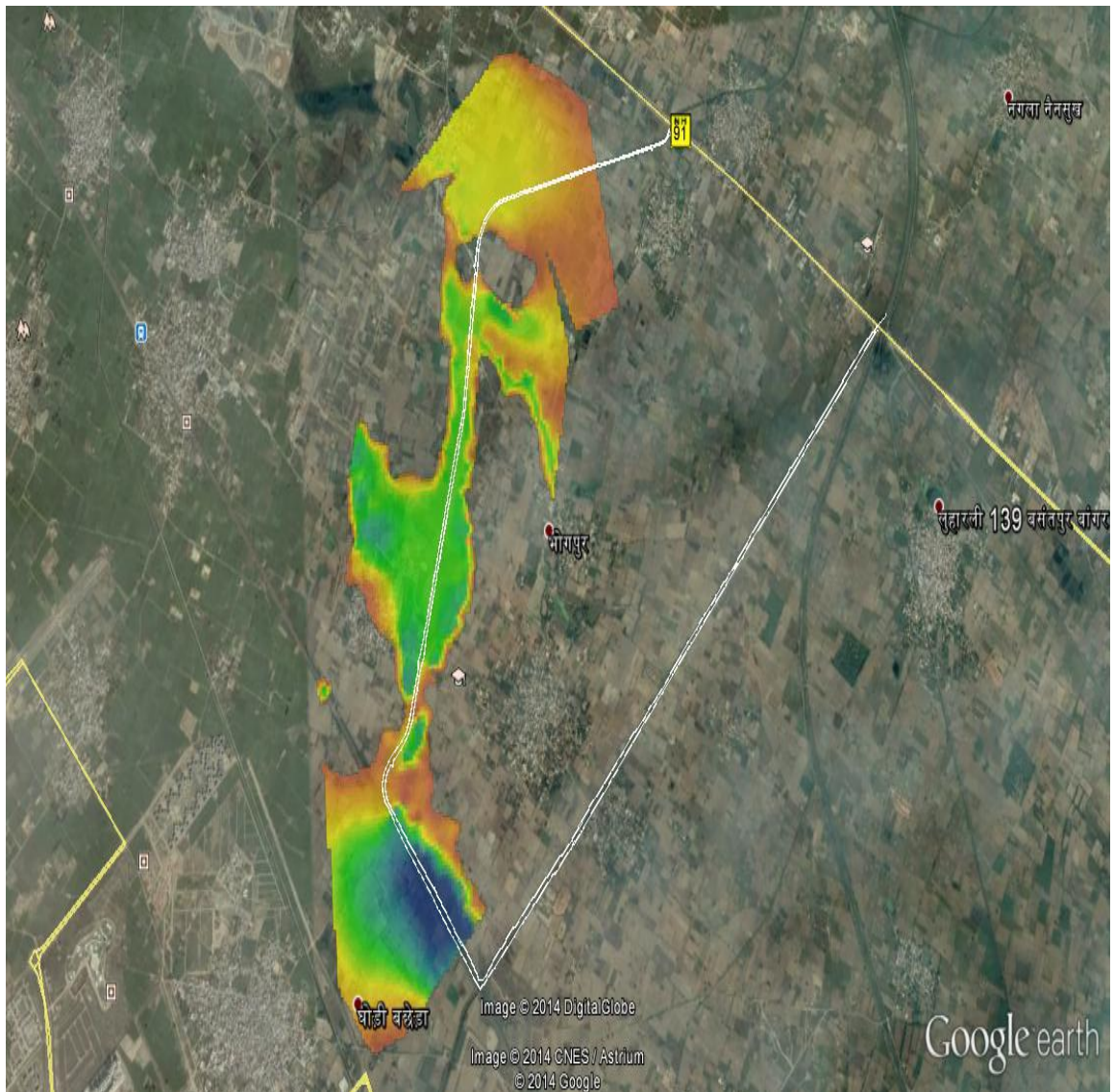
Digital Terrain Model

APPENDIX III



Triangular Irregular Network (TIN)

APPENDIX IV



Flood Map for All Profiles

