INUNDATION MODELING USING HEC-RAS SOFTWARE
FARKA STREAM CASE STUDY

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Approval sheet of the Thesis

This is to certify that we have read this thesis entitled **"Inundation modeling using HEC-RAS software. Farka steam case study"** and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

INUNDATION MODELING USING HEC-RAS SOFTWARE
FARKA STREAM CASE STUDY

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This study analysis how water flow corresponding to maximum discharge of Q=240m^3/s is distributed along Farka stream.

To visualize flow dispersion, two modeling approaches 1-dimensional and 2-dimensional HEC-RAS models is implemented and unsteady flow analysis is simulated. HEC-RAS models and hydraulic analysis are used to analyze water depth planimetry, flow hydrograph, water surface elevation and velocity against terrain of each stream segment.

The first objective is to develop three 2-dimensional models, representing possible stream rehabilitation scenarios and to perform unsteady flow analysis in order to identify the most convenient case, for real application. Furthermore, the aim is to elaborate 1-dimensional model of the first scenario and to compare its results with the corresponding 2-dimensional model. In this study, it is concluded that all three 2-dmensional proposed cases, differ in terms of flow distribution along stream but, on the other hand, all of them are valid and efficient solutions for stream rehabilitation. Also, the generated results showed that flow distribution was not the same for 1 and 2-dimensional models. These two modeling approaches, under the same conditions, produces different results and only engineering experience together with project aim can decide which one of them to use.

Keywords: *rehabilitation, unsteady flow, hydraulic analysis, flow hydrograph, simulation*

ABSTRAKT

MODELIMI I PËRMBYTJES DUKE PËRDORUR PROGRAMIN KOMPJUTERIK HEC-RAS
RASTI NË STUDIM, PËRRROI I FARKËS

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Master Shkencor, Departamenti I Inxhinierisë së Ndërtimit
Udhëheqësi: Assoc. Prof. Dr. Miriam Ndini

Ky studim analizon shpërndarjen e rrjedhës ujore në Përroin e Farkes duke konsideruar prurjen maksimale Q=240m^3/s.

Për të gjeneruar shpërndarjen uroje, dy lloje modelesh të HEC-RAS, 1-dimensinal dhe 2-dimensional janë ndërtuar, gjithashtu është simuluar edhe analiza e rrjedhës së paqëndrueshme. Modelet e ndërtuara në HEC-RAS dhe analiza hidraulike e performuar, janë përdorur për të analizuar, planimetrinë e shpërndarjes ujore, hidrografin e rrjedhës, lartësinë e siperfaqes ujore dhe shpejtësinë e ujit kundrejt terrenit të seksioneve tërthore që i korrespondojnë secilit segment të rrjedhës.

Objektivi i parë është zhvillimi i tre modeleve 2-dimensionale që përfaqesojnë skenarë të mundshëm per rehabilitimin e Përroit te Farkes dhe simulimi i analizës peë rrjedhë te paqëndrueshme, në mënyrë që të identifikohet rasti më i përshtatshëm për zbatim real. Gjithashtu, qëllimi është të elaborohet modeli 1-dimensional për skenarin e parë të rehabilitimit dhe rezultatet të krahasohen me modelin përkatës 2-dimensional. Në këtë studim, është arritur në përfundimin se, të tre skenarët 2-dimensionalë të propozuar ndryshojnë lidhur me mënyrën e shpërndarjes së prurjes përgjatë rrjedhës por, nga ana tjetër, të gjitha modelet janë zgjidhje të vlefshme dhe efikase për rehabilitimin e Përroit. Gjithashtu, rezultatet e gjeneruara treguan se shpërndarja ujore nuk është e njëjtë për modelet 1dhe 2D. Këto dy mënyra modelimi prodhojnë resultate të ndryshme për kushte të njëjta, zgjedhja e tyre varet nga përvoja inxhinierike dhe qëllimi i projektit.

Keywords: *rehabilitim, rrjedhë e paqëndrueshme, analizë hidraulike, hidrografi i rrjedhës, simulim*

Dedicated to my beloved family

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Mirjeta Blloshmi

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CHAPTER 1

INTRODUCTION

1.1 Background

Flooding is defined to be the highest water level on a water stream that overcomes the stream banks and inundates the regions located nearby. There may be several factors that provoke flooding including, high rainfall intensity, long duration of rainfall, dam destruction, land slide etc. Flood mitigation has become very important nowadays due to negative impact of this phenomenon on people's lives and activities.

Albania is located in the western part of the Balkan Peninsula, and it is characterized by Mediterranean climate, combined with continental climate in some regions such as norther, southern and central part. Moreover, Albania is a combination of coastal regions in Western part of the country with relatively high mountains located in northern, southern and central regions. The total area of hydrographic basin of rivers located inside the territory of Albania is 43 305 km^2. Climate characteristic, water streams intensity and topographical features classify Albania as a region of high risk of river flood hazard.

Based on recorded and available data there have been several river floods events that have caused considerable environmental, social and economic loses. Here it can be mentioned the 2010-2011 river flood occurred in Shkodra region due to intense rainfall the water level on Drini River was high enough to force the responsible authorities to open the gates of dams constructed on that river. This caused a major flooding event, where water level on the area below Shkodra was measured to be more than 1m and the inundated area was over 14000 hectares of land, more than 1200 buildings were flooded and over 12 000 people were evacuated [1].

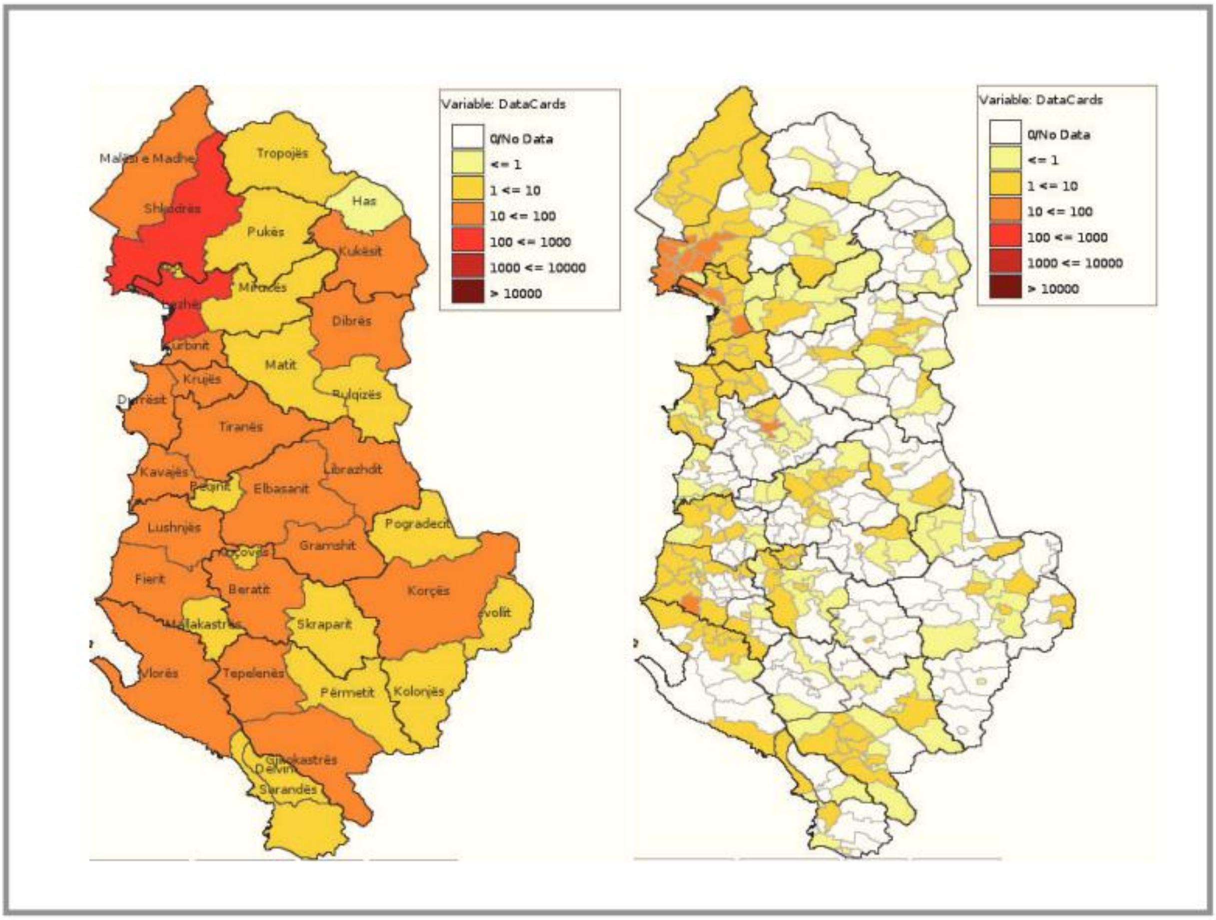


Figure 1. Flood Geographical Distribution in Albania During 1851-2013 Period [2]

While considering economic losses due to natural hazards in Albania, flooding generates the highest contribution compared to other natural disasters. 72% of total economic losses caused by natural factors on 10-year period of 1993-2013 was due to flooding [2].

In different periods, there have been taken particular precautions not only to reduce the negative effect of flooding but also to avoid river flooding. Before 1990's different type of hydraulic structures has been projected and constructed in various regions and rivers of Albania. These structures included dams, drainage channels, irrigation channels etc. Moreover, during this period serious studies were conducted to define the areas that required intervention regarding to flooding.

After 1990's some of the existing structures were destroyed and many poorly projected works were developed on river basins such as dams, bridges etc., which encouraged river flooding [3].

Nowadays engineers are trying to develop hydraulic and hydrologic software flood models to predict and prevent flooding. Also, flood maps have been developed, which serves as a guide to identify the high-risk areas.

To sum up there will always exist the risk of river flooding in Albania due to its geographical position, intensive water streams and topographical characteristics [3] [4]. Although different engineers have conducted studies related to floods and many important precautions have been taken, there is a lot more to do and to improve in such a way that the negative effects of this very dangerous natural hazard can be minimized.

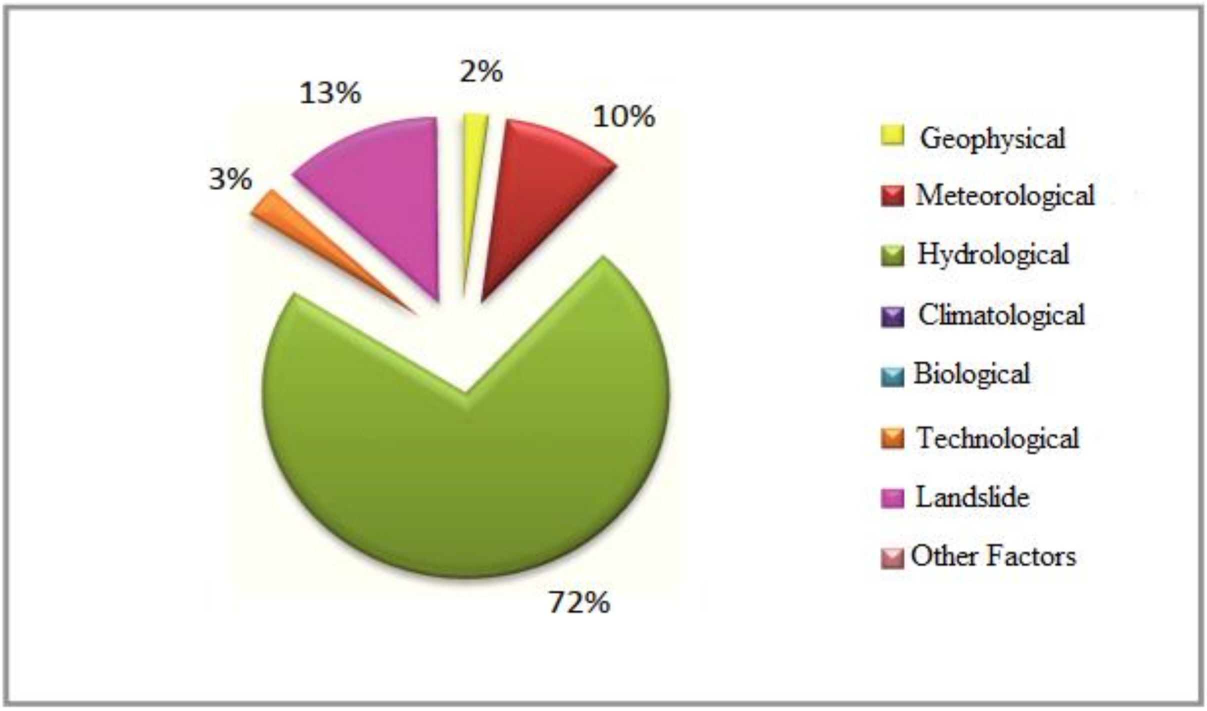


Figure 2. Economical Looses Due to Diverse Factors in Albania [2]

1.2 Problem Statement

As it was formerly mentioned, river floods in Albania have a dominant negative impact on social, economic and environmental losses. But the problem does not lie only on main streams of the rivers, also small streams that feed them, have a huge potential on becoming threatening under specific conditions.

Engineers are paying more attention to flood mitigation by conducting studies, on areas that are defined as high risk flooding areas. The main focus of these studies has been, the development of flood models based on hydraulic and hydrologic principles. A variety of software and modeling approaches have been used to produce flood models, between them HEC RAS software can be mentioned, used to develop 1D, 2D or a combined 1D-2D flood models.

On the wide range of available software and modeling approaches there exist a confusion while dealing with the selection of appropriate model for specific study cases. For a better understanding of each flood modeling approach it is necessary to carefully study and compare their results.

Hopefully, this study will provide an in deep understanding on how 1D and 2D HEC-RAS flood modeling function and under which criterions it can be chosen to be developed. This study aims to help engineers to better define their type of model in order to save them time and effort and also to suggest solution for the rehabilitation of the are under study.

Floods have been and will be always present, our job is to reduce to minimum their negative effects and the only way to achieve that is by conducting studies and developing flood models.

1.3 Thesis Objective

In the presented study, HEC RAS software is used to develop two types of models, 1-dimensional model where the flow is modeled within the river, and 2-dimensional model where stream and flood plain are entirely modeled in two dimensions. The area under study, Farka stream is located near Tirana city. The banks of Farka stream have been damaged due to past intense water flow, this has caused a major problem on that region because, during heavy precipitation the area is completely flooded by causing major damages.

The aim is to, propose a perpetual solution for Farka stream rehabilitation. Based on hydraulic analysis results, there will be proposed three cases of possible rehabilitation of the stream. All those cases, will be presented as 2-dimensional models. The comparison of three cases will be made in terms of Water Flow on each specified segment of each stream, Water Surface Elevation, Terrain and Velocity Against Terrain.

Also, the focus of this study is, to compare 1 D and 2 D models developed using HEC RAS 5.07 software. The stream at which the simulation is conducted or at which the study is based has 2 junctions, one junction located upstream which consists of a separation of reaches and the other junction located downstream which consists of reaches combination.

Furthermore, the main idea is to study the distribution of flow in the first junction, so how much flow will be distributed on each reach, on the place where the split occurs. The comparison will be made in between 1D model and 2 D model of variant 1.

Moreover, the identification of advantages, disadvantages, potentials and limitations of 1D and 2D HEC RAS models, is on focus of the presented study. The priority, is to provide a better understanding of hydraulic modeling and their capabilities, especially 1D and 2 D HEC-RAS modeling.

More specifically the study will include:

- Development of two different hydraulic modeling, 1D modeling and 2D modeling.
- Proposal of three possible rehabilitation cases for the area under study.
- The approaches and theoretical background behind modeling, recognizing mathematical and physical principles ruling hydraulic processes in HEC-RAS software.
- Stating the capabilities of each model, comparing their advantages and disadvantages in terms of data requirements, model set-up, and simulation results.
- Examination (investigation) of the gained results, inspecting the efficiency and effectiveness of each model and thus deciding which one of the models is more convenient for flood modeling.
- To sum up there is also presented the discussion for the obtained results.

1.4 Organization of the thesis

Generally, the presented study is organized in 6 chapters as described in the following paragraphs:

In Chapter 2, a literature review on researches conducted related to the topic of interest is presented. Furthermore, this chapter provides, theoretical principles associated with HEC RAS 5.07 software and 1 D and 2 D modeling using this software.

Chapter 3 provides, a brief description of area under study characteristics. Also, there are presented the topographic data used to carry out the study together with the hydrological data required as an input for the models.

Methodology of the study is presented on Chapter 4 where, the model set up for generating 1D and 2 D flood models on HEC RAS 5.07 is described in details.

In the upcoming chapter, Chapter 5 the results obtained from two models are provided. Also, in this chapter a discussion on the obtained results is provided.

Chapter 6 displays, conclusions generated from this research study and also the recommendations for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section of the thesis represents an expanded literature review regarding available methods to perform water streams modeling. An in deep research was conducted to provide an insight into flood modeling studies with the aim to explain common approaches to flood modeling, difficulties faced on each study and the mostly used software. Attention is paid to researches displaying comparison between 1D and 2D hydraulic modeling using HEC RAS.

To start with, a brief description of flood as a phenomenon is provided, associated with its social, economic and environmental effects. Furthermore, there are displayed and discussed research studies published on this field. Evaluating these research skeletons, different models are suggested, the major part of studies applies hydrodynamic model, including 1D, 2D and a combination of 1D and 2D models. On this presented study, to model the water stream, Farka stream which is the studying are, 1D and 2D models are used.

Furthermore, in this section theoretical background of 1D and 2D HEC RAS models is elaborated. Also, a detailed comparison between two models is presented with the intention to highlight advantages, limitations and common usage of them. There are specified strong points for each model based on what the model can be selected to perform flood analysis for a specific project.

HEC RAS 1D, 2D and combined 1D-2D models are commonly used to perform hydraulic analysis and to develop flood modeling. Research studies published on the above-mentioned areas are described and analyzed at the end of this section.

2.2 Flood mitigation approaches

By definition, flood is the highest water elevation into a water stream, usually the stage at which the stream outflows its banks by flooding the areas located nearby. Throughout history flooding has proved to be one of the most devastating natural hazards all over the world due to intense distribution of water streams. Societies have constructed residential and economical areas nearby water streams based on suitable geographical conditions and economical facilities offered by these areas. On the other hand, these water streams have become a source of life losses, economic crisis and also environmental destructions, due to uncontrolled changes, fluctuations of water level and water spreading.

The high probability of flooding events on these areas has developed the necessity for flood protection. There has been a great, consistent effort to comprehend, rate and anticipate flooding events and their effect. Flood mitigation approach which is primary based on flood modeling has gained more attention nowadays providing societies the necessary information to prevent and reduce flood consequences.

Several studies have been conducted related to flood modeling, their priorities and their deficiencies also [5]. It is crucial to have a clear understanding of flood modeling approaches and to precisely distinguish them from one another. Only in this way the selection of the appropriate model will be easier.

2.2.1 Researches related to flooding modeling

For example, Teng, Jakeman and Croke [6], displays an in deep description of all methods used to develop a flood inundation model, associated with each model advantages, limitations and analysis uncertainties. Besides different ways of classifications, here the models were classified in three main categories, including: empirical models, hydrodynamic models which were subclassified as 1D models, 2D models and 3D models and simplified nonphysical based models. For each of the above-mentioned model there were also described, presented their recent improvements. Empirical models are considered to be effective for flood observation, hydrodynamic models are mostly used to show accurate flow dynamics to explore effects of dam break. Finally, simplified computational models can be used for multi-scenario modelling on relatively big floodplain with good definition of channels.

Food modelling will always be a challenging not only for the complexity and chaotic nature of the system but also for the large number of available software and uncertainties associating each of them.

Researches has shown that, encouraging mechanisms of flooding should be examined carefully and long-lasting precautions should be taken. The necessity to protect areas from flooding and to prevent social, economic losses, has encouraged researches to develop integrated approaches for flood modeling and mapping to estimate flooded areas.

Fosu at [7], uses a combination of GIS and HEC-RAS software to develop an inundation or vulnerability map cause by Susan River. In this study the geometric data implemented on HEC RAS and GIS were received from DEM, topographic charts and ground dimensions. HEC RAS and GIS that produced a schematic of stage discharge as a consequence of flooding activity. The vulnerability map produced show that the flooded are were located mostly at regions having low relief.

The research conducted by Okoye [8], aimed not only to produce a flooding map for the inundated area in Surulere region but also to define and describe the factors encouraging it. The software used in this case was GIS and the resultant map showed that the major part of that region was prone to flooding due to high precipitation, urban expansion, human act. [9]

Khalil, Khan and Rehman at [10], have used HEC -RAS, ArcGIS and Hec-GeoRas to develop flood hydraulic modeling and floodplain map for Indus river considering as an input the flooding event occurred on 2010. The input data for HEC RAS cross section data were obtained from SRTM DEM and the surveyed data of 1999 was used for this study. For more accuracy the authors recommend the usage of latest river survey data and a combination of 1D and 2 D model to better understand of the flow in lateral direction, depth and velocity on inundated areas. Among the above-mentioned difficulties during this particular study, lacking of gauges located nearby the river also affected the efficiency of the analysis. It was suggested to provide more gauges along the river stream for seasonal flood monitoring.

Researchers have also suggested to use floodplain maps generated from their study to develop flood zoning, in preparation of a particular plan for reuse of land located on floodplain area.

Flood maps are also developed with the intention to investigate the impact of structures located nearby the floodplain area, during flooding events.

For example, **G**ülbar, Kazezyilmaz-Alhan, Bahçeçi and Boyraz at [11], had developed a hydrodynamic model of the Ayamama River by using Watershed Modeling System (WMS) and EPA SWMM (US Environmental Protection Agency Storm Water Management Model). The flood considered as an input data was that of September 2009. By interpreting the results gained from the model, is was concluded that, the high intensity of structures located on that area had a great impact on flooding. The hazard map developed by this study was used to predict and manage future activities on flooding.

Numerous research studies have shown that flood modeling, flood mapping, flood risk assessment models etc. are not easy to be developed. All this modeling approaches faces major difficulties not only on combination of data to produce an output but also on calibration a validation of the model itself.

Flood evolution, prediction needs accumulation and organization of all accessible data which can be gathered by field investigation, remote sensing information for the past flooding activities. The main issue connected to information absorption is to link all sources of data in such a way that the river state at a given period or time can be generated as an output. This is considered as the main problem and difficulty while performing or developing a flood model, regardless of the type of software and methodology to be used.

To select the right model to use, the primary thing is model simplicity, avoiding unnecessary complications of the model, always by totally achieving the initial intention and objectives of the project.

Despite the abundant number of opportunities available to develop flood models, the choice of the model to be used on a specific project will always be affected not only on the output reliability and validity but also on data and resources availability and on computation and projection time.

As flooding remains a sensitive topic due to the strong impact on society life, different types of software have been developed throughout the years. Some of the mostly used software based on literature review are TUFLOW classic 1D developed by WBM Pty Ltd and The University of Queensland, FASTER developed by Cardiff University, Flood Modeler Pro 1D&2D Solver developed by CH2M Hill (formerly Halcrow Group), SOBERK developed by DELTARES, HEC-RAS developed by US Army of Corps of Engineers etc.

The presented study is mainly focused on HEC RAS flood modeling software, especially on 1D and 2 D modeling. Based on literature review HEC RAS is considered to be very effective and efficient software for performing hydrodynamic simulation of water streams.

2.3 Hydraulic engineering center river analysis system (hec-ras) flood model

HEC-RAS (Hydraulic Engineering Center River Analysis System) is an integrated system of software, developed by U.S Army Corps of Engineers. The HEC-RAS model is considered to be one of the most commonly flood modeling piece of software in hydromechanics simulation. HEC-RAS is designed to perform one-dimensional (1D) steady, unsteady flow, two-dimensional (2D) unsteady flow or combined 1D-2D flow simulations for a river flow analysis, as well as sedimentation transport, water temperature and water quality modeling. [12]

The focus of this study, among proposing alternative solution for preventing flooding, is performing 1D and 2D unsteady flow analysis of Farka Stream, considering in 1D the junctions formed along the water stream.

2.3.1 One-dimensional 1D hydraulic flow modeling

One-dimensional 1D hydraulic flow modeling assumes the flow of water to occur in a longitudinal direction. This model is developed by representing the terrain as a sequence of cross-sections and simulating the flow in order to provide estimates of flow parameters such as flow velocity and water depth. To simplify the computation, HEC-RAS assumed a horizontal water surface at each cross-section normal to the direction of the flow in order to neglect the momentum exchange between the channel and the floodplain [13]. The one-dimensional equations of motion are represented by:

$$\frac{\partial A}{\partial t} + \frac{\partial(\Phi Q)}{\partial x_c} + \frac{\partial[(1-\Phi)Q]}{\partial x_f} = 0$$

$$\frac{\partial Q}{\partial t} + \frac{\partial\left(\Phi^2 Q^2/A_c\right)}{\partial x_c} + \frac{\partial\left[(1-\Phi)^2 Q^2/A_f\right]}{\partial x_f} + gA_c\left[\frac{\partial Z}{\partial x_c} + S_{fc}\right] + gA_f\left[\frac{\partial z}{\partial x_f} + S_{ff}\right] = 0$$

Equation 1. One-dimensional equations of motion [13]

Q is the total flow,

A is the flow area,

F is the quotient of channel conveyance over the total conveyance,

z is the elevation of water surface,

S_f is the friction slope, (the subscripts c and f refer to the channel and floodplain, respectively). A four-point implicit scheme was used to solve unsteady flow equations for the 1D model. Based on this scheme the space derivatives and function values were evaluated at an interior point (n + θ)Δt [13] [12].

2.3.1.1 1D unsteady flow

The flow of water into a stream is controlled by two physical laws that include: the principle of mass conservation and the principle of conservation of momentum. The mathematical expression of these two laws is a partial differential equation denoted as continuity and momentum equation.

For 1D unsteady flow a semi-implicit finite difference solution scheme is used to provide the solution for continuity and momentum equation.

In this section besides a brief theoretical explanation of HEC RAS 1D program it will also be presented the required data, including geometric data and boundary conditions, to set up and run a 1D unsteady flow model.

2.3.1.2 Geometric data

The geometry plan is predominant in order to define the river schematics such as the stream, bank lines, cross section, junctions and various hydraulic structures if present on the area of study.

2.3.1.3 The river system schematic

Each geometric data set within HEC-RAS system necessitates a river system schematic that represent the relationship, connection, between numerous rivers reaches and storage areas. The process of drawing and linking different hydraulic elements in geometric data editor establishes the river system schematic which is required to be defined before any other data can be added.

Reaches start or end at the locations where two or more streams join together or split apart also start or end at the open ends of the river system being modeled [13].

A different name is specified for each river reach on the schematic, in such a way that when the other reach data are added, they can be referred to a single reach. For example, each cross section must have a river and reach name that represents the reach where the cross section is placed, and the river station name to show the specific location of the cross section compared to the other cross sections located on that reach. River reaches are required to be drawn from upstream to downstream and the connection between them is very important for the program to interpret the procedure to be followed in order to perform the calculations.

The location where two or more streams are grouped together or are split apart is identified as a Junction which is automatically established when this connection occurs. Same as river reaches also junctions are identified by a specific unique name.

HEC-RAS is not only able to model simple river systems with a single reach but also it can model complex networks where reaches come together and split apart several times.

2.3.1.4 Cross section geometry

Cross sections are used in order to perform the analysis of flow in natural streams where the measured distance between them defines the reach lengths. It is required for the cross sections to be positioned at representative locations along the stream reach, for example, locations where discharge, shape, slope or roughness of the stream changes. At locations where immediate changes occur, a large number of cross sections are required for better representation of that change on the stream. It is very important for the cross sections to be perpendicular to the flow lines. To draw perfectly perpendicular cross sections several steps are followed: initially a stream center line is drawn along the main channel or river representing the center of mass of flow, the same procedure is followed for the right and left-over bank also for the flow path. All five lines drawn are connected by lines that goes perpendicular representing cross sections.

There are several factors that influence cross section spacing and intensity, for example, stream size, slope and uniformity of cross section shape. In cases of large, uniform, flat slope rivers, the number of cross sections required is smaller compared to the number of cross sections required for rivers where abrupt changes occur.

After implementing the projection file on RAS MAP, which in this study was WGS 1984 UMT Zone 34, the map of the area under study, Farka stream was called on RAS MAP. The next step was to add new geometric data which: included the river stream, river banks and cross sections which are required to be perpendicular to the direction of flow, or river stream.

Farka stream it is composed of the main stream and a channel which is constructed around Central Archive of Social Security. This means that the stream under study is composed overall by four reaches. The main reach named Perroi I Farkes is subdivided in Reach 1, Reach 1 Lower and Reach 1 Lower -Lower. The fourth reach is reach 2 representing the channel. These four reaches are connected to each other by two junctions, the upstream junction is a split one, where Perroi I Farkes is divided into Reach 1 Lower and into Reach 2 of the channel. On the other hand, the downstream junction is a combined one, where reach 1 lower joins reach 2 of the channels, into reach 1 lower lower.

2.3.1.5 Junction

In the presented study attention is payed to junction modeling, or junction data implementation (editor) as a crucial factor on flow distribution over the reaches.

By definition junctions are locations, points at which two or more streams come together known as combining junction or split apart known as split junction. Based on the type of analysis to be performed junction data are divided in two groups, reach lengths across the junction and the tributary angles which is added only under steady flow simulation when the momentum equation is selected [14].

Two options are available for hydraulic modeling at junctions under unsteady flow hydraulics. The first option consists of Force Equal WS (water surface) Elevations which provides some intelligible assumptions for the junction hydraulics. In the case of combining junction cross sections that bound the junction have the same water surface based on the computed water surface at downstream part of the junction. On the other hand, in the case of a split junction the junction water surface is based on the calculated upstream side of the junction water surface. The second option known as Energy Balance Method [15], performs an energy balance crosswise the junction, to calculate the water surface instead of equalizing them all [16].

2.3.1.6 Boundary conditions

Boundary conditions are specified based on the analysis to be performed. For unsteady flow simulations HEC RAS requires to specify upstream and downstream boundary conditions. Flow hydrograph, stage hydrograph, or coupled stage/hydrograph can be used as upstream boundary condition. In this study the flow hydrograph is used as upstream boundary condition. Moreover, downstream boundary conditions include normal depth and rating curve [17]. The presented study uses as downstream boundary condition normal depth which requires to enter a friction slope nearby the boundary condition.

2.4 Two-Dimensional flood models

In two-dimensional 2D flood models the water is assumed to move in both longitudinal and lateral directions and velocity in the z-direction is assumed (considered) to be negligible. The terrain in two-dimensional models is represented as a continuous surface through a mesh or grid. These models different from 1D models require continuous topographical data including the whole area intended to be modeled. This modeling approach requires long computation time and in order to improve (minimize) it, the software uses a sub-grid approach, which consists of using a relatively coarse computational grid and finer scale information underlying the topography. The sub-grid bathymetry equations are derived based on both; the full shallow water and diffusion wave equations.

2.5 1-dimensional versus 2-dimensional model HEC-RAS 5.0.7

In this section an identification of potentials, limitations and intended use for both 1 D and 2 D HEC RAS model is presented. For engineers that deal with flood modeling, is very important, crucial to comprehend the advantages and disadvantages of both models compared to one another in order to define the best model that mostly suits their project.

When comparing 1 dimensional and 2 dimensional models the principal advantage of 1D model is the relatively short computation time. 1D model provides the opportunity of modeling large project with a short simulation time, meanwhile, the computation time for 2 D model is much longer than 1 D model [18].

Moreover, modeling hydraulic structures such as bridges, culverts is easy in 1D. Although this model displays a large variety of methods for flow modeling through culverts, under bridges, the implementation of the required data is simple because, ground plain and elevation data are easily accessible. The results obtained from 1D modeling of hydraulic structure are more reliable and trustworthy. On the other hand, modeling bridges, culverts and other hydraulic structures in 2D model, is associated with model instabilities, uncertainties and errors that produce unreliable result.

Furthermore, as 1D model is constructed based on cross sections, it is not a must for the topography data of the area under study to be highly detailed, it is only required to be available at the cross sections, whereas for 2D model needs detailed topographic data.

Finally, the type of model to be developed for a specified project strongly depends on input data, area features, level of output complexity, the aim of the specified project and also the financial conditions.

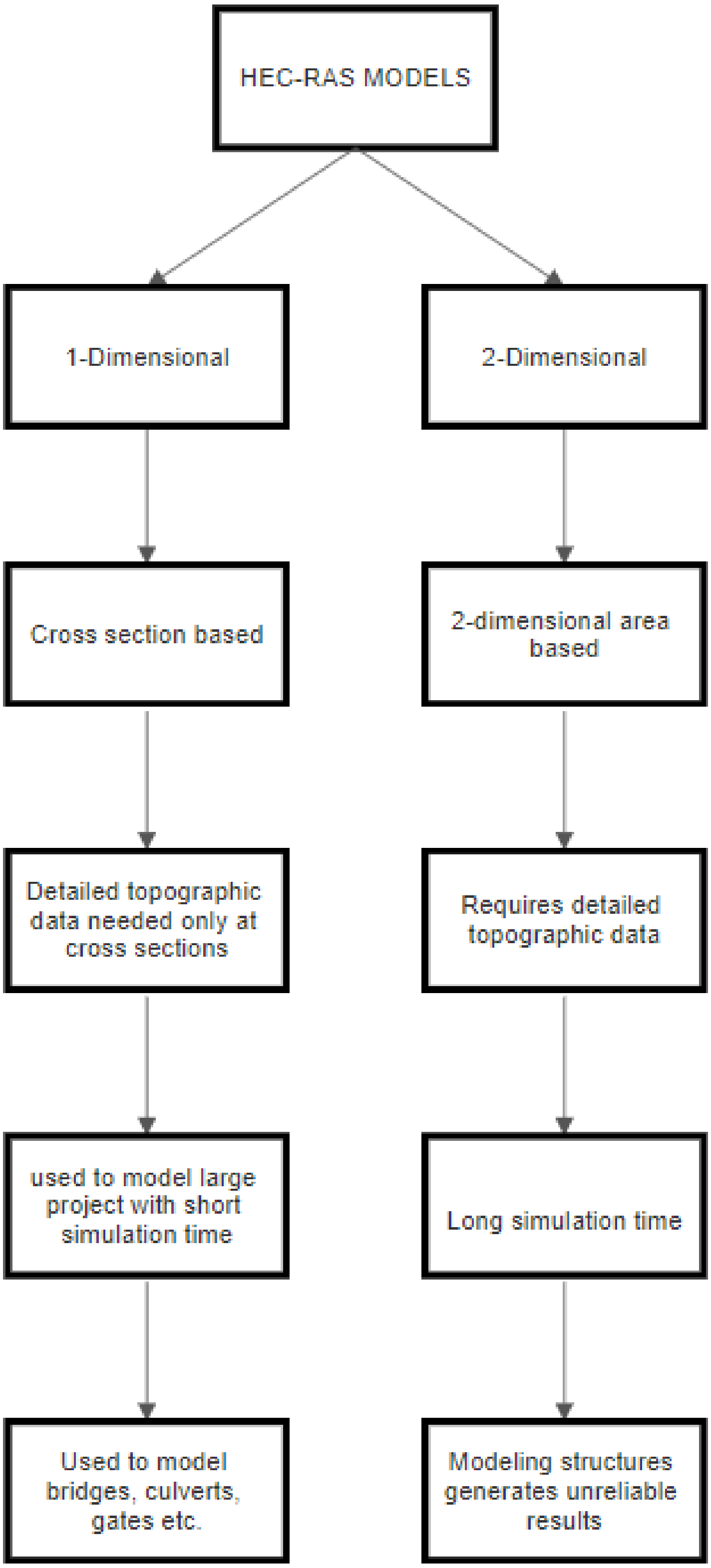


Figure 3. Flowchart of 1D and 2D HEC-RAS Models Potentials and Limitations

2.6 Other research studies related to proposed topic

HEC RAS offers different models for performing hydraulic analysis of a water stream or river. Unsteady flow analysis can be developed using 1D, 2D or a combination of both 1 D and 2 D model. There exists a confusion related to appropriate selection of model that best suits the need and objectives of a specific project.

Different researchers have payed attention to the comparison of these model, and they have also suggested or provided some guidelines to be followed while intended to select a model.

Other authors have carried out real case studies using 1D, 2D, or a combination of 1D and 2D model, to develop flood analysis or to produce floodplain maps for a specific region.

Rubiu at [19] employed three types of hydraulic models to simulate the flood occurred at Minija River, including: (i) 1-dimensional (1D) model, where river and floodplain flow was modeled in 1D, (ii) combined 1D-2D model, where river flow was modeled in 1D and floodplain flow in 2D, and (iii) pure 2D model, where river and floodplain flow was modeled in 2D, followed by a comparison between simulated models. At the end, the study presented a guideline related to crucial differences between data requirements, pre-processing, model set-up and results obtained from each individual model. Furthermore, it was observed from the results of each model that all three of them could be profitably employed to recreate significant flooding events.

Lea, Yeonsu and Hyunuk at [20] conducted a study with the purpose to evaluate the capability of Hydrologic Engineering Center River Analysis System (HEC-RAS) model's in simulating the river overflow inundation. In this study the combined 1D-2D hydraulic computation model was implemented. To verify the effectiveness, efficiency and accuracy of the combined model the simulation was applied to the Baeksan river levee breach event in South Korea in 2011. The simulation results show similarities of the observed data and the outputs from widely used flood models. This serves as an approval of HEC-RAS 1D–2D coupling method capability to simulate flooding. [20]

Romali and Yusop at [21], proposed the development of floodplain maps for the area of Segamat town in Malaysia by using (HEC-RAS model. As the main modeling input data, Interferometric Synthetic Aperture Radar (IFSAR) was used. Meanwhile to calculate the extreme flows with different return periods, five distribution models were tested, including;

Generalized Pareto, Generalized Extreme Value, Log-Pearson 3, Log-Normal (3P) and Weibull (3P). Among those five distribution models, the Generalized Pareto resulted to be the most appropriate distribution for the Segamat River, by using Kolmogorov-Smirnov (KS) test. To calculate (find) the expected corresponding flood level, peak floods for defined return periods, resulting from frequency analysis were used as an input to (for) the HEC-RAS model. Furthermore, ArcGIS was used to prepare floodplain maps for different return periods by implementing there the results obtained form HEC-RAS model. At the end, results showed that the major part of flooded areas in the simulated 100-year return period were also affected by 2011 historical floods. For 100 years flood simulation, the inundated area was almost 5 times larger than the simulated 10 years flood. [21]

Pathan and Agnihotri at [22], proposed a 1D modeling approach using ArcGIS, HEC-RAS and HEC-GeoRAS software, to determine the water surface elevation height of Purna River, Navsari district, Gujarat, India. The first part of the study represents the development of pre-processing, including generation of D.E.M (digital elevation model), Geo referencing of Navsari District and Purna River, using ArcGIS and HEC-GeoRAS software. Geometry stream centerline, flow path and its centerline and cross section cut lines were defined from the HEC-GeoRAS. Furthermore. to the continuation of modeling process all GIS data were exported to HEC-RAS which will give as an output the water surface elevation height, after providing slope and peak discharge of particular cross section. [22]

Azouagh, El Bardai and Hilal at [23], describes creation of floodplain maps for Martil River, by employing Hec-RAS model. Among other variables, simulating with Hec-Ras provides estimation of, flow velocities, depths and water levels for the different a different cross-sections and flow configurations along Martil River. At the end of the study flood mapping were presented and areas of risk were classified due to integration of GeoRas and Hec-Ras hydraulic modelling tools with Arcgis information system. The usage of designed maps and also of knowledge’s related to morphology and physical characteristics of the river will be a huge help to prevent flooding of the urban area of Tetuan.

Indira Bose and Umme Kulsum Navera at [24] conducted a study, using coupled 1D/2D HEC-RAS based hydrodynamic model, to determine areas of low elevation near Dharla River, characterized by a high flooding probability and to minimize the uncertainty in flood mitigation measures. The water level of Kurigram station was used as boundary condition for downstream, while discharge of Taluk-Simulbari station was used as boundary conditions for upstream. Flow simulation was Flood Inundation maps have been generated in the RAS mapper for the years 2010, 2013 and 2014 from the month June to October for highest water levels of each month. Maps generated by using 1D/2D coupled model were compared with those generated previously using HEC-RAS 1D model and Arc-GIS and a relationship between them was assigned. This study was of a great importance in proper management and planning of floods caused by Dharla River.

V. Moya Quirogaa, S. Kurea, K. Udoa and A. Mano at [25], presented a 2D simulation of the flood event in Bolivian Amazonia occurred at February 2014. To perfume that simulation a new version of HEC-RAS was used and additional information like water depth, flow velocity and a temporal variation of the flood was obtained. Simulation results (flood depth) identified Mamore river west plain as the most exposed to flood due to bigger flood extent, longer flood duration and deeper water depth. Furthermore, Trinidad city resulted to be threatened by a flood originated form two directions: 32 km at the north and 10 km at the south west. Also, the city of San Javier resulted to be flooded five days after overflow of water.

Assessing the studies, all models provided by HEC RAS seem to produce reliable results for hydrodynamic analysis, based on input data used for each case study. Most of them uses a combination of HEC RAS models with ARC GIS in order to develop floodplain maps. All authors validate HEC RAS models capability for performing unsteady flow analysis. Also, most of them, approve the competence of ARC GIS combined with HEC RAS on producing trustful results related to floodplain maps.

In the presented study, both 1 D and 2 D models are used to simulate unsteady flow analysis for Farka stream, and the result received from each model are compared to examine their performance.

CHAPTER 3

3.1 Area Features and Data required

This section will include a brief description of the area where the water stream case study is located. As the presented thesis consists of a specific case study, developing 1 D and 2D unsteady flow analysis of Farka stream, gathering particular information related to that specific region is of a great importance, and requires appropriate attention.

Firstly, a general description of the location, geological composition of terrain and hydrological condition will be displayed.

Furthermore, there will be provided some explanations regarding flood history, damages caused by it and investments conducted stream rehabilitation and areal reuse.

Climate conditions of the region will be shortly described, in order to create an idea of the amount of precipitation and water flow.

Before starting to develop 1D and 2D HEC RAS model topographical data are required. This part of the presented study will also include a brief presentation of topographical data of the region which were gathered due to site surveying conducted before.

Moreover, as unsteady flow simulations are intended to be performed, data resulted from a Hydrological study are used as an input. On this section these hydrological data, consisting of flow hydrographs will be presented, described and analyzed.

3.2 General description

The region of the studying area is located in the middle part of Albania, corresponding to Φ41 20’06”, Λ19 45’ 55” geographical coordinates.

The area under study is surrounded in north by the City of Tirana, in east by the Farka stream watershed, in South by Erzeni River and in West by hilly area with the highest hill reaching the altitude +210m above the sea level.

According to the administrative division the area is included in Tirana Prefecture, municipality of Farka and Petrela. Tirana is the capital city of Albania for this reason it is the administrative, economic and cultural center of the country, where the major part of the Albanian citizens lives. The first meteorological center in Tirana was established in year 1925.

Based on the climatic perspective the area under study belongs to Mediterranean Climatic Subarea which is strongly affected by Adriatic Sea.

The average temperature of January, the coldest month of the year is 6. During July and August, the average air temperature is 24 meanwhile the annually average temperature reaches 15. The average annually rainfall reaches 1280 mm and the maximum rainfall ever registered was 240mm in 24 hours.

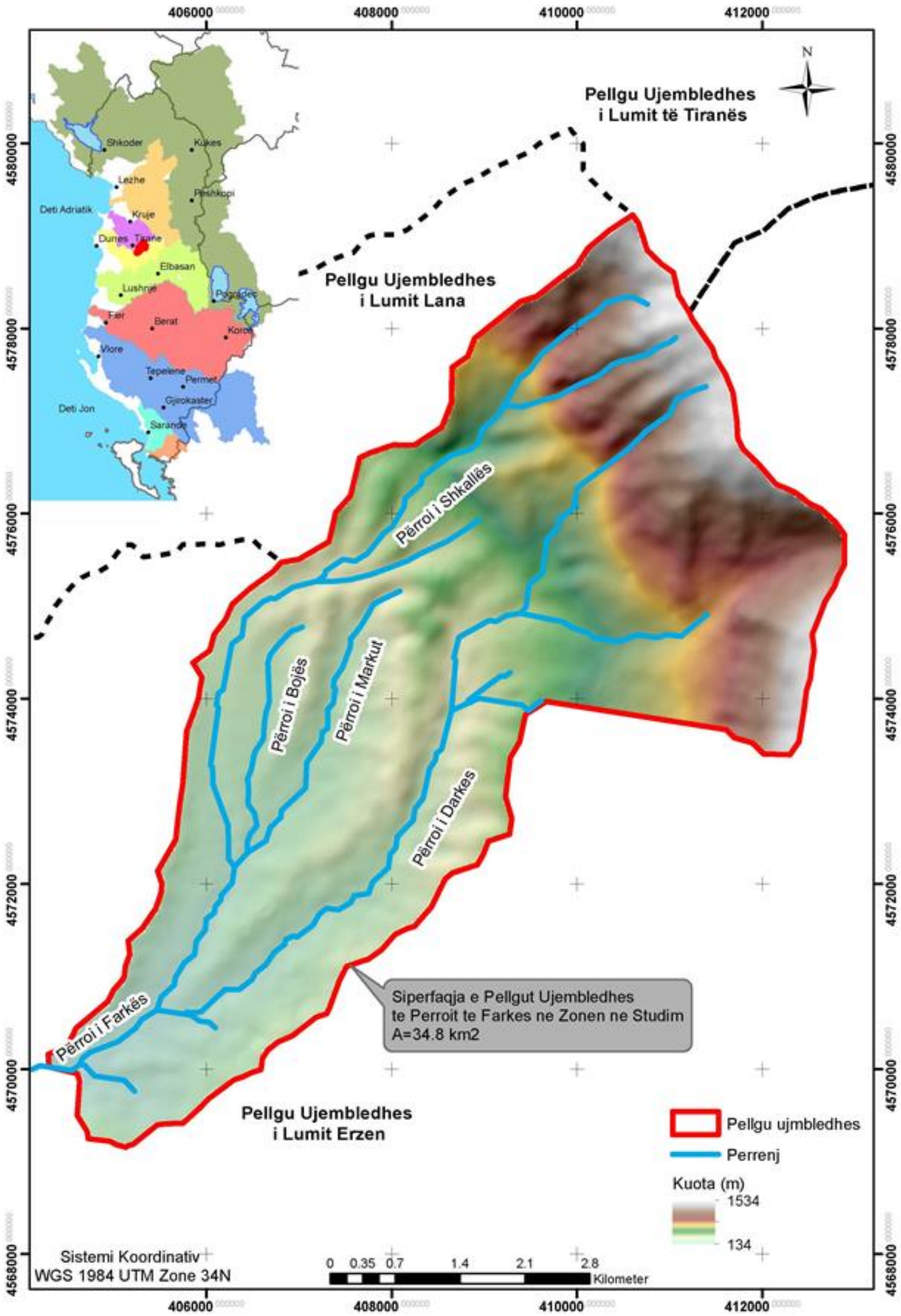
From the geologic perspective hills are constructed from conglomerate formations, sandstones and clays.

The hydrographic network composed by streams and water lines, cut through the hill range creating a series of isolated hills. The erosive structure of the isolated hills relieves which is composed by conglomerate sandstone and clay layers, is the morphologic characteristic of the area.

The main lands on region are the brown ones. Before 6 and 7-nth decade of the last century the area’s vegetation was represented by Mediterranean bushes. After that period deforestation occurred and the land was covered with vineyard (grapevines). After 1990 year the destruction of vineyards plantations produced an increase in the erosive activities.

Nowadays the area is converted into an urban region.

All above mentioned watershed conditions affect the shape and flow of the maximum (water flow) discharge from rainfall. Rainfall (Precipitation) data were obtained from archival sources and periodicals of Hydrometeorological Institute of Tirana.



Figure

Figure 4. Location of the Case Study, Farka Stream

3.3 Specific Features of the Study Area

Farka stream (rivulet or brook) traverses' part of the valley in Lundra area also passes nearby "ROLLING HILLS" residential complex, State Reserve Depots and Archives building (ISSH).

It starts flowing on the western side of Dajti and Priska mountain, defined in north side by the south part of Tirana city and Lanabregasit hills. in south by Fikasin -Mangull and Mullet and also with Erzeni river basin, in the eastern direction by Sauk, Picall and Stermas.

The total area of Farka stream basin until the point where intersects Tirana-Elbasan highway is measured to be A=34.8 m^2. The stream length is L=11.3km, the average latitude is H=834m, and the average slope of the stream is i=7.4%.

The primary contributors on Farka stream water flow are Darka stream which joins Farka stream nearby the area of study, Kabeti stream including numerous smaller streams located close to its banks. Farka stream ends in Erzeni river, near a small village called Stermas, close to Tirana-Elbasan highway. The eastern part of the area together with hilly regions receive a huge amount of precipitation due to Adriatik sea influence. During the wet period (May-October) study area receives 83% of the annual precipitation.

The largest water flows are created during long lasting and intensive rainfall events. The study area is prone to urbanization and the human impact has played a crucial role on modifying the hydrological ratios.

It must be emphasized that, due to fast and intense urbanization the maximal flow considered in this study may undergo some changes and may be increased after several years.

3.4 Flood history of the area

In year 2011 a government investment was made (has been made) with the intention to rehabilitate the stream bed, by constructing a (concrete covered trapezoidal cross section) trapezoidal cross section into the stream covered with concrete at a length of 140m, and by implementing a culvert with dimensions base b=5m, height h=3m and length l=90m to pass near the State Reserve Depots. Trapezoidal cross section has suffered numerous damages and water has found its path outside banks of stream, generating risk for the areas located nearby including "ROLLING HILLS" villas and also ISSH building.

The most critical discharge was registered in 30 November 2014, which based on the maximum water level measurements turns out to have been $Q=240m^3/s$. This unusual discharge caused considerable damage to the left concrete covered stream bank and to the bad of the stream. Considering the damages caused by the flow some extra works have been done to provisionally protect the left bank of the stream.

The temporary interventions in Farka stream could neither provide an effective protection for the stream itself nor for the abovementioned structures located there. That is why conducting a deep and integrated study related to the complete rehabilitation of the Farka stream in that area had such a great importance.

In order to, provide an effective and efficient (a thorough and in-deep) evaluation of the Farka stream rehabilitation this project is based on hydrologic study, hydraulic computations modeling and also the corresponding static calculations.

3.5 Climatic Features

The Western Lowlands represent a single climatic region due to limited dimensions and relieve which in dominant part is almost flat.

All climate forming factors are interrelated and conditional on each other. The performance of one factor leads to significant changes in the other factor. This is the main reason why, even if the factor effects are analyzed separately, in overall, they cannot be divided from each other.

Western lowland boundary ends in the waters of Adriatic Sea, that why all the area is under its effect. Below sections represent climatic data registered in meteorological stations inside and around Farka stream watershed. Furthermore, figures below represent the meteorological stations which are considered in this study.

3.5.1 Rainfall Distribution

Precipitation regime in the western lowland is closely related to cyclonic and anticyclonic activity. There are some factors that strongly effect the rainfall distribution for example, Adriatic Sea, geographic position of the western lowland and its relieve.

Based on the annual rainfall analysis, half warm and cold period also season rainfall, a distribution rainfall law can be generated which strongly depends on the relieve characteristics. In this region, rainfall heights have a different tendency from those corresponding to the other territory of the country, moving from west to east the rainfall height increases in contradiction with the decrease that occurs in other regions.

The atmospheric circulation has a strong seasonal character, and it gradually changes from month to month. This change in circulation is represented in monthly rainfall amount. Cyclonic activity dominates during the winter season especially (particularly, peculiarly) during October-February. The cyclonic activity is reduced during transitional seasons like spring and autumn, and in summer is completely replaced by the anticyclonic activity. Following the above-mentioned reasons, the months with the highest amount of rainfall are November, December, January and February, among which November is listed as the wettest month. Meanwhile, July is the driest month.

3.6 Hydrologic Study data

To develop the hydraulic model of Farka stream and to perform 1D and 1D unsteady flow analysis, hydrological analysis of the area needed to be conducted in order to produce flow hydrographs which will be used as input data, boundary condition on HEC RAS software.

The above-mentioned hydrologic analysis was performed from other researchers, they develop flow hydrographs for the study area using HEC-HMS software.

Hydrological Engineering Centers Hydrologic Modeling System expressed in abbreviated form as HEC-HMS is a software used to simulate the process of converting precipitation into water stream flow. This software uses mathematical models to compute different hydrological components such as precipitation, infiltration, flow etc.

After performing the simulation flow hydrographs were obtained as on output, including, flow hydrographs with, 1 in 50-year repetition and 1 in 100-year repetition.

In the presented study the data from 1 in 100-year repetition flow hydrograph was used and an input in HEC RAS hydraulic modeling, for performing unsteady flow analysis.

Results obtained from Hydrological Study of Farka Stream.

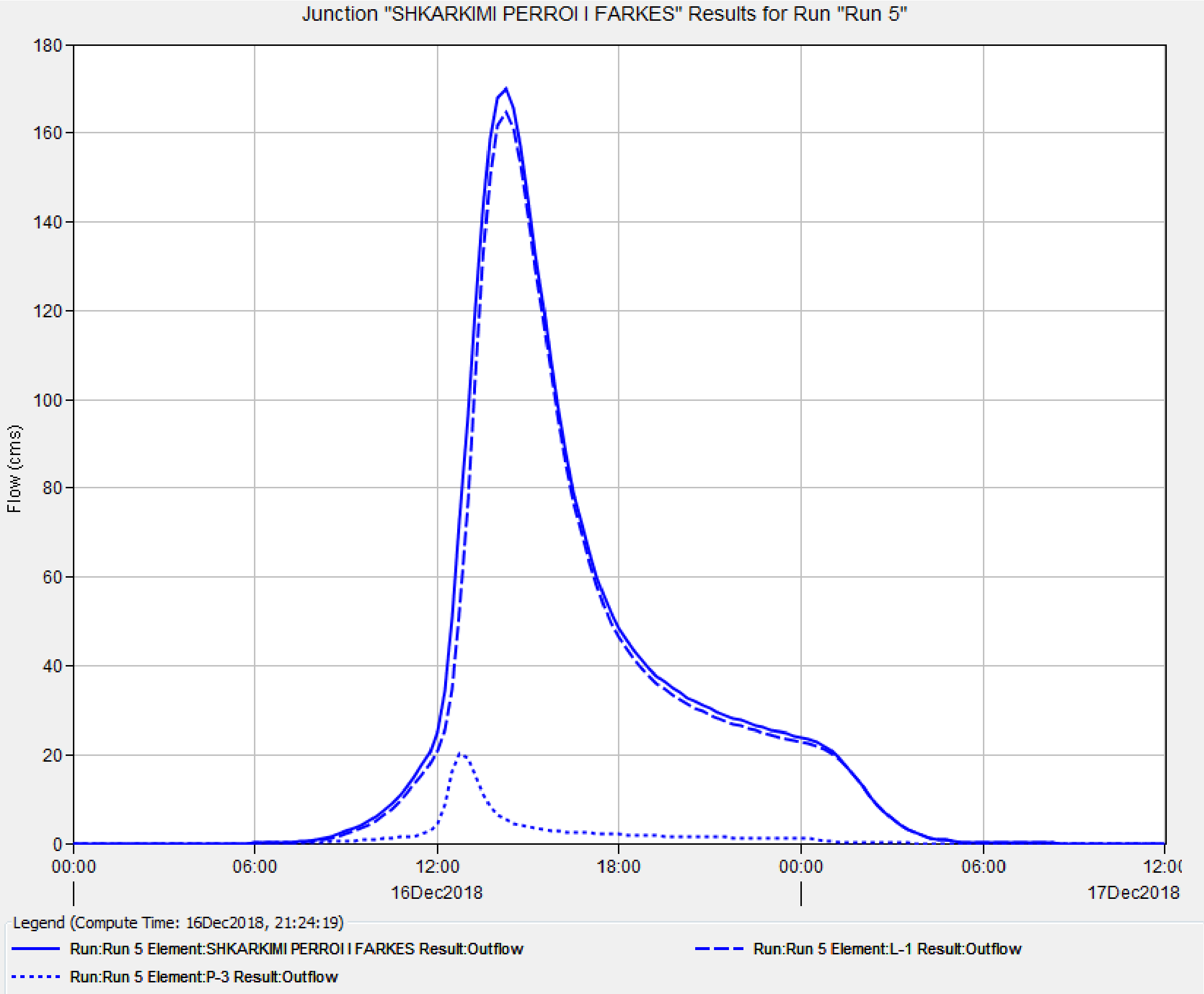


Figure 5. Hydrograph of Farka Stream, 1 time in 50 years repetition, Q=170m^3/*s*

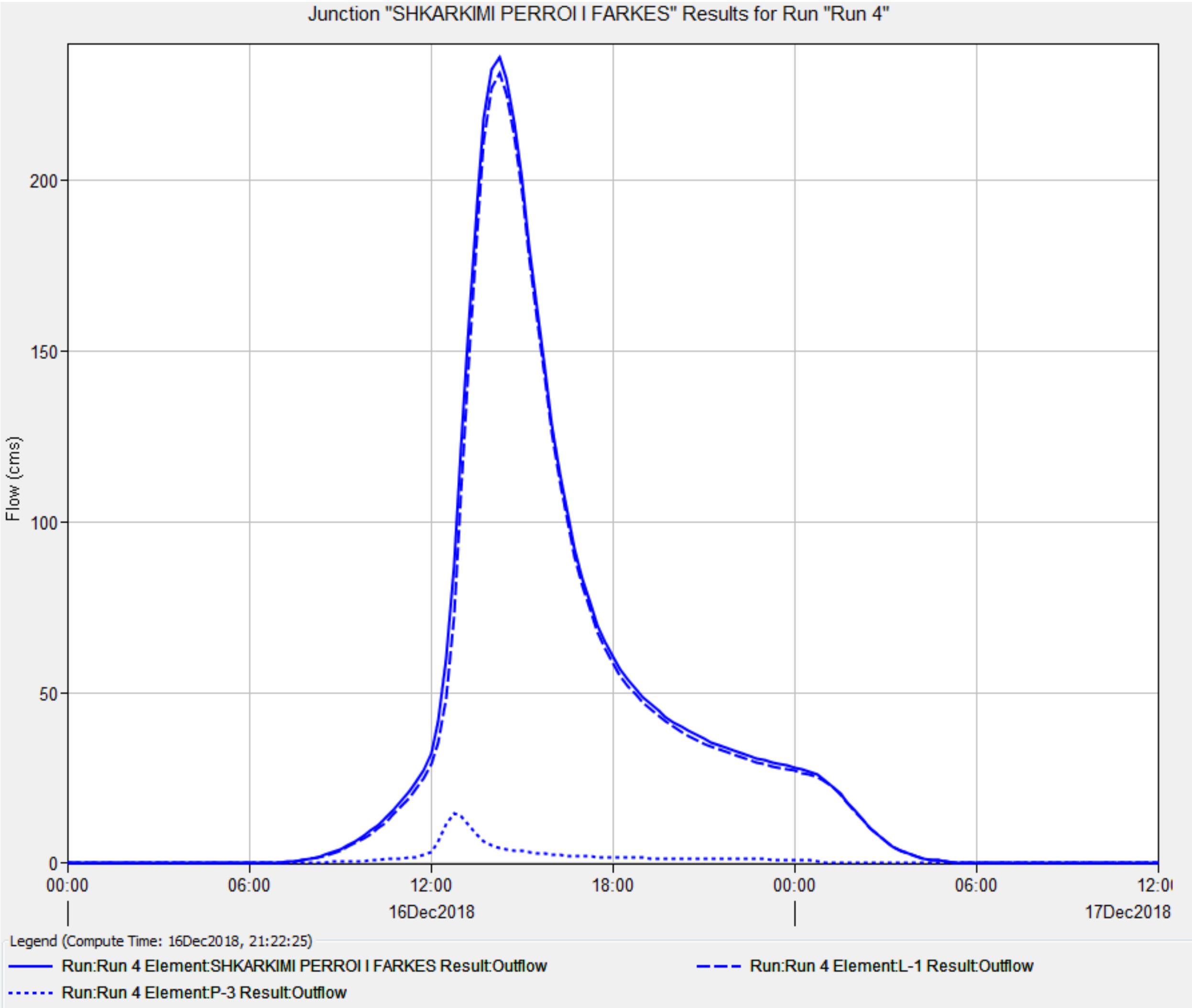


Figure 6. Hydrograph of Farka Stream, 1 time in 100-year repetition, Q=236m^3/s

3.7 Topographic Data

In order to develop intended hydraulic models and to perform unsteady flow analysis using HEC RAS, topographic data of the are needed.

These data are obtained from topographic measurement of the study are dome by MANETCI Company. The reference system used is WGS 1984/UTM zone 34 and the topographic data for regions where topographic measurements were not conducted, were completed by DTM generated from ALUIZM using aerial photography.

Besides HEC RAS software in this study ARC-GIS was used to generate 3-dimensional terrain model which is used on HEC-RAS 5.07 software to develop 1D and 2D models. The 3-dimensional terrain includes existing terrain and cross sections used to rehabilitate Farka Stream.

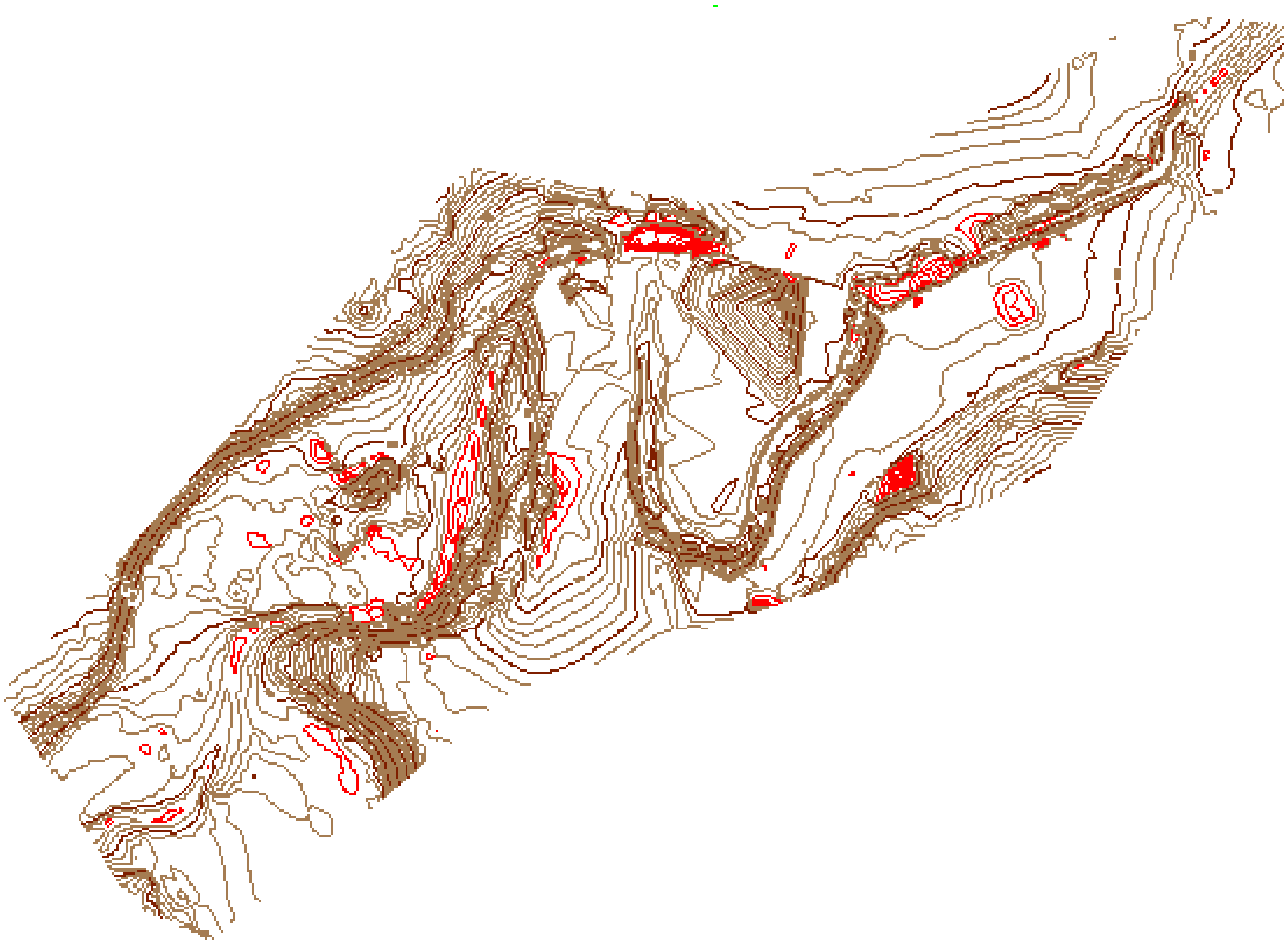


Figure 7. Topographical Data of Area Under Study, Farka Stream

CHAPTER 4

METHODOLOGY

4.1 General Framework

On this section there will be display a brief description of the steps followed to develop hydraulic model, the software used to set up the model and to perform the analysis.

First of all, it is important to define that the models develop for this study are established for Farka Stream, along a segment of 200 m North-East of ISSH and approximately 100 m on its Western side.

Topographical data, received from previous studies, conducted from other researchers were used as the bases for setting up hydraulic model in the presented study. This data together with cross sections were elaborated on ARC-GIS 10.6.1 and then were incorporated on geometric HEC RAS model. To develop hydraulic model presented on this study two main software was used, ARC -GIS 10.6.1 and HEC-RAS 5.07.

In the presented study ARC-GIS 10.6.1 was used to establish 3-dimensional terrain model using the available topographical data of the area under study.

HEC-RAS 5.07 in this study was used to model the water flowing into the streams as an Unsteady flow. Both 1D and 2D models were developed with the aim to compare their respective results.

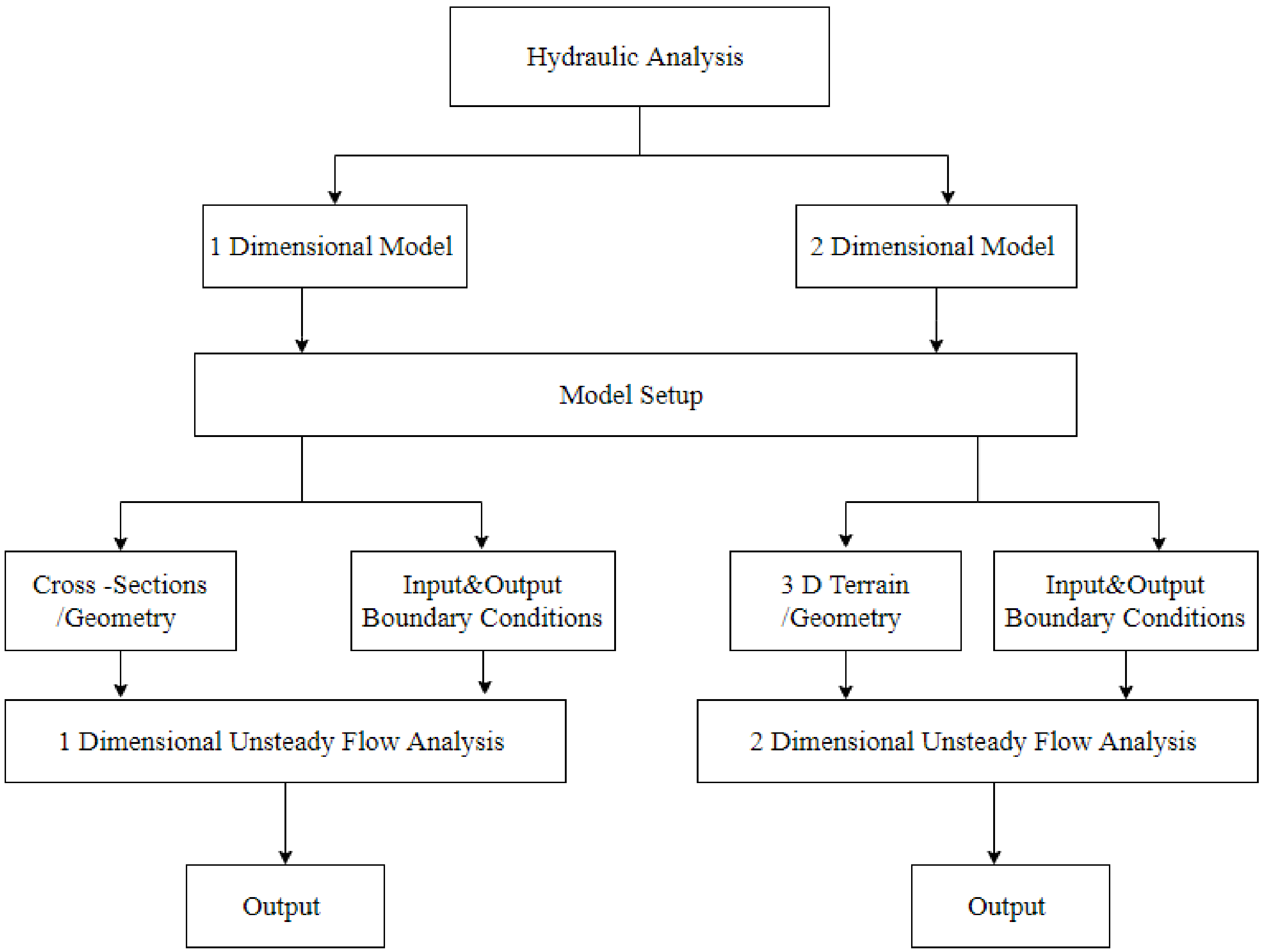


Figure 8. Flowchart of Hydraulic Analysis of Modeling Approach Using HEC-RAS 5.0.7

4.2 Hydraulic Model Setup

4.2.1 Creation of Terrain file (.flt) and Projection file (.prj)

To start modeling with HEC RAS in order to develop 1D and 2 D models, a projection file (.prj) is required to be imported on HER-RAS Mapper, together with the terrain file (.flt) corresponding to study area terrain. This section will provide a step by step procedure on how to create a projection (.prj) and terrain (.flt) file and how to import them on HEC-RAS Mapper.

Triangulated irregular networks expressed in abbreviation form as (TIN) are a form of vector-based digital geographic data built up by triangulating a set of vertices. The network of vertices with series of edges produces a system of triangles. TIN areas can be generated from vector, raster and terrain datasets.

In the presented study, terrain datasets or contour lines were provided to produce projection (.prj) and terrain (.flt) file by using ARC-GIS. A step by step procedure on developing projection (.prj) and terrain (.flt) file, from contour lines using ARC-GIS will be displayed below.

To start with, in ARC-GIS, the cad file created from survey measurements conducted by MANETIC company, is opened (Add>Select Acad file>Add). Then, Create TIN is opened in Catalog window by navigating to (Toolboxes>System Toolboxes>3D Analyst Toolbox> Data Management>TIN> Create TIN). We need to make sure that the data begin created are aligned, so select the corresponding coordinate system by clicking the button nest to Coordinate System Text box (Select the Feature> Point and Polylines. At output Tin select folder>at Coordinate System enter the reference system used for this study >WGS_1984_UTM_Zone_34N>). After this procedure the TIN data are Displayed on map. Furthermore, to this first step it is required to convert TIN into a Delineate TIN file. To do that, in Catalog window the Delineate TIN Data Area tool is opened by navigating to (Toolboxes>System Toolboxes>3D Analyst Toolbox> Data Management>TIN> Delineate TIN Area TIN). A Delineate TIN data Area box need to be filled (Input TIN (tin)>Maximum Edge Length (100)>Method (PERIMETER_ONLY).

After creating TIN file, it is needed to convert it into Raster file, by interpolating the cell values from the input TIN data elevation at defined sampling distance. While converting TIN to

Raster some information may be lost due to the fact that interpolation occurs at regular intervals. The representation of the raster to the TIN strongly depends on Raster resolution and degree, interval of TIN area variation. Higher the raster resolution, higher the representation of raster to TIN will be produced.

To convert TIN to Raster format, TIN to Raster is opened on Catalog window by navigating to (Toolboxes>System Toolboxes>3D Analyst Toolbox> Conversion> From TIN> TIN to Raster). A TIN to Raster box is opened and it is completed (TIN to Raster box,>Input TIN (tin)> Output (the raster folder for raster file is selected)> Sampling Distance (CELLSIZE 2). The cell size is required to be small in such a way to have better resolution.

Furthermore, to the continuation of the procedure, Raster needs to be converted into a Float (.flt) file. To do so TIN to Raster is opened on Catalog window by navigating to (Toolboxes>System Toolboxes> Conversion Tools> From Raster> Raster to Float). A Raster to Float box was displayed where Input Raster (raster file) is specified and the Output folder for float file is selected.

When starting a new project on HEC-RAS Mapper a projection file should be specified for that specific project. In the presented study the projection file is copied from ARC-GIS. The reference system used on this study was UTM reference system, and particularly for Albania, where the study area is located, the reference system needed was WGS 1984 UTM Zone 34 N. In order to copy the projection, the following steps was followed, on a new file of ARC-GIS, by right clicking on layer, properties are opened and then Coordinate System UMT>WGS 1984>Northern Hemisphere, the WGS 1984 UTM Zone 34N coordinate system was saved at the folder where HEC-RAS model was intended to be saved.

After following all steps mentioned above, the projection file (.prj) for the presented project and the terrain file (.flt) which is used to generate 1D and 2D models on HEC-RAS are created and were ready to be imported on HEC-RAS Mapper 5.07 program used to develop the presented study.

4.2.2 Modification of original terrain

Before starting to construct 2D model on HEC-RAS 5.07, the original terrain, Farka stream should be modified according to the intended rehabilitation to be performed.

In this section of the presented study there will be displayed a step by step procedure on how to modify the original terrain of Farka stream. To accomplish that, HEC-RAS 5.07, HER-RAS Mapper 5.07 and ARC-GIS 10.6.1 software will be used.

To start with, after importing on HEC-RAS Mapper 5.07 the projection (.prj) and terrain (.flt) file created before using ARC-GIS 10.6.1, new geometry will be added to the stream, including here the river stream geometry located on the center of the stream.

It is important to clarify that ARC-GIS 10.6.1 was used to construct cross sections for all the reaches of Farka stream, as the distance from the main stream of the banks needed to be equalized and this is difficult to be achieved on HEC-RAS.

After stream centerline implementation, river geometry data was saved as a shapefile, so as it can be easily imported on ARC-GIS 10.6.1, where the cross sections were constructed. To create the cross sections initially, on ARC-GIS 10.6.1 the stream centerline was parallelly copied in a distance corresponding to half of the width of rehabilitated reaches. Each reach has specific dimension, based on rehabilitation intended to be performed. For example, Farka stream which is dividend in three reaches, the first reach was suggested to be reconstructed as a channel with rectangular cross sections having a width of 8m which means that the stream centerline will be parallelly copied on both sides on a distance of 4 m. The same logic was followed for the two other reaches of Farka stream and for the channel, respectively 2.5m, 4m, 4m. Then by going perpendicular to the main stream axis, cross sections were drawn, corresponding to widths of 8m Farka stream reach 1, 5m Farka stream reach 1 lower, 8m Farka stream reach 1 lower-lower and 8m channel. Cross sections were saved on a specific shapefile so as they can be imported on HEC-RAS Mapper.

After all the sections have been created, they will be imported on HEC RAS Mapper together with the original map and by using cross section geometry editor option, the same cross sections will be constructed again in HEC RAS Mapper. Attention is paid in order for the cross sections to overlap. It is very important to draw cross sections in the same direction, for example from left to right. If this direction of drawing is not fully respected than the program will detect problems while interpolating them.

For better representation of the reaches and their rehabilitation, drawn cross section will be interpolated, using the XS interpolation tool on Geometric Data Editor. The distance between interpolated cross section is defined to be 0.2.

Under the Cross-Section Data tool, each of the cross sections will undergo a modification, for better definition of rectangular cross section of each reach.

After modifying the cross sections and saving geometric data, on HEC RAS Mapper the layer on which we have worked, was exported to create terrain Geo Tiff from XS's (overbanks and channel), the name of the exported terrain was defined together with the Cell Size which was 0.1m. by concluding this step, the modified channel was saved and it was imported on HEC RAS Mapper together with the original terrain.

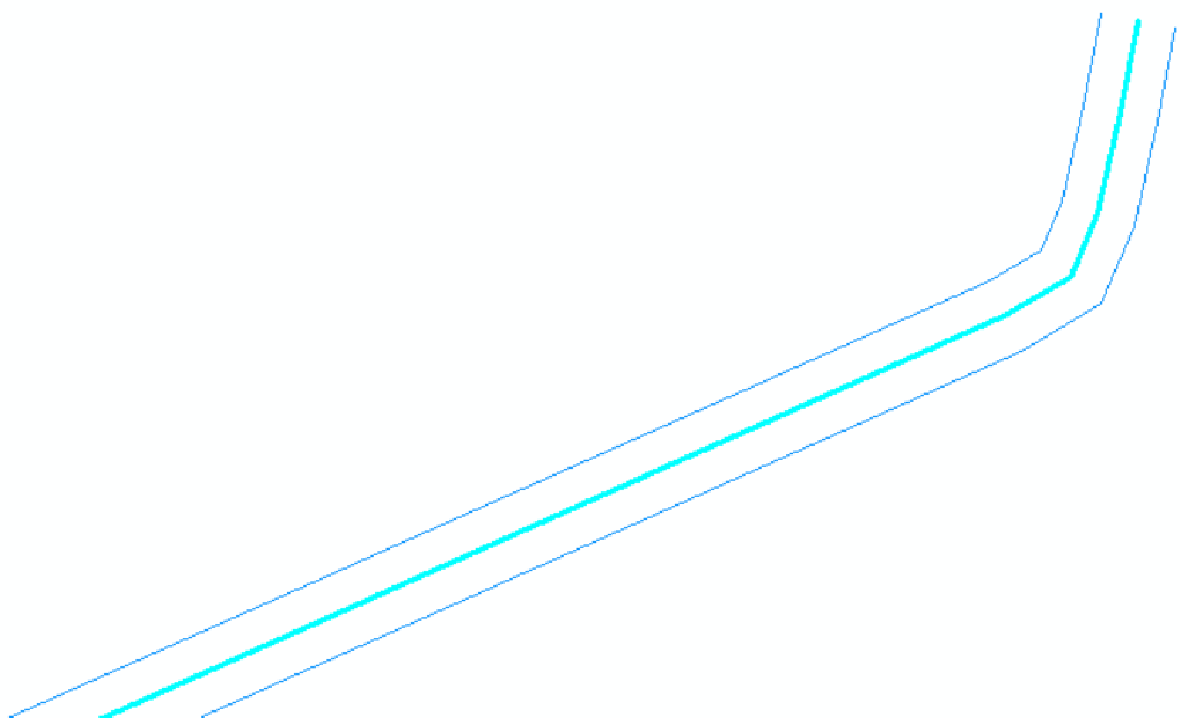


Figure 9. Stream Centerline imported on ARC GIS 10.6.1 & Helping Lines Drown

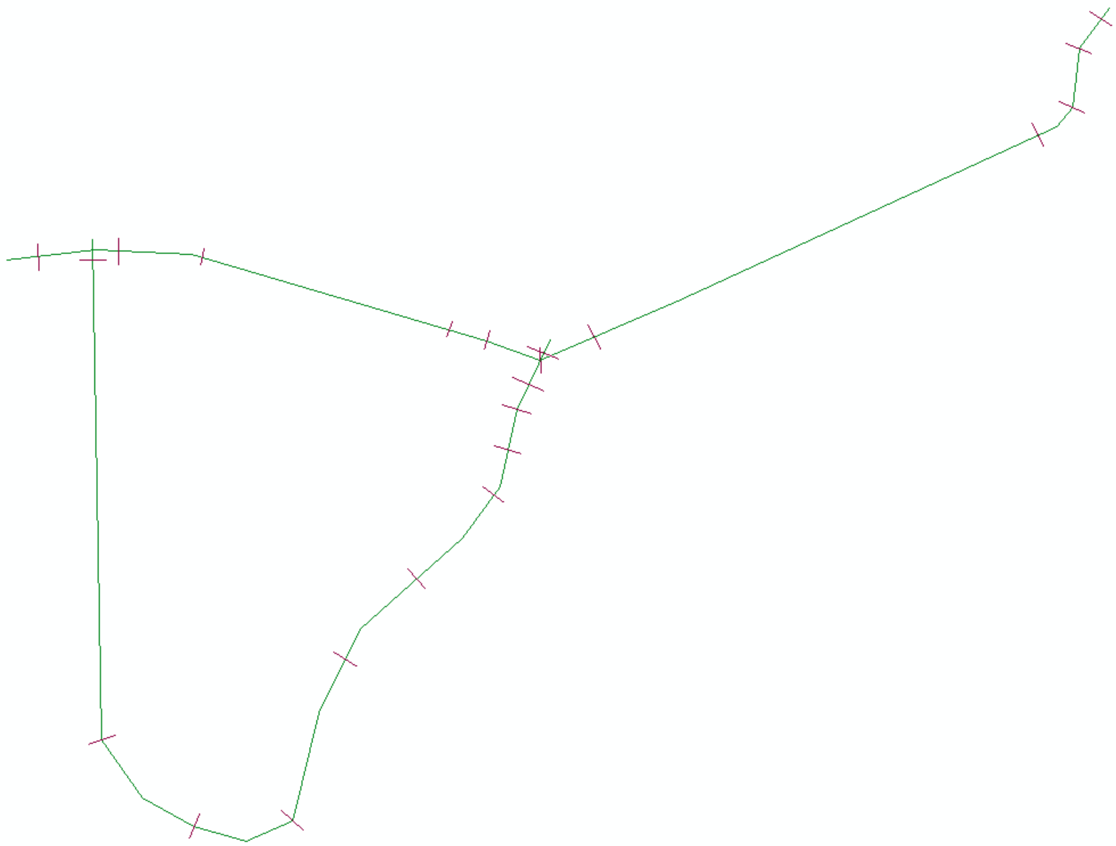


Figure 10. Stream Centerline and Cross Sections Drown in ARC GIS 10.6.1

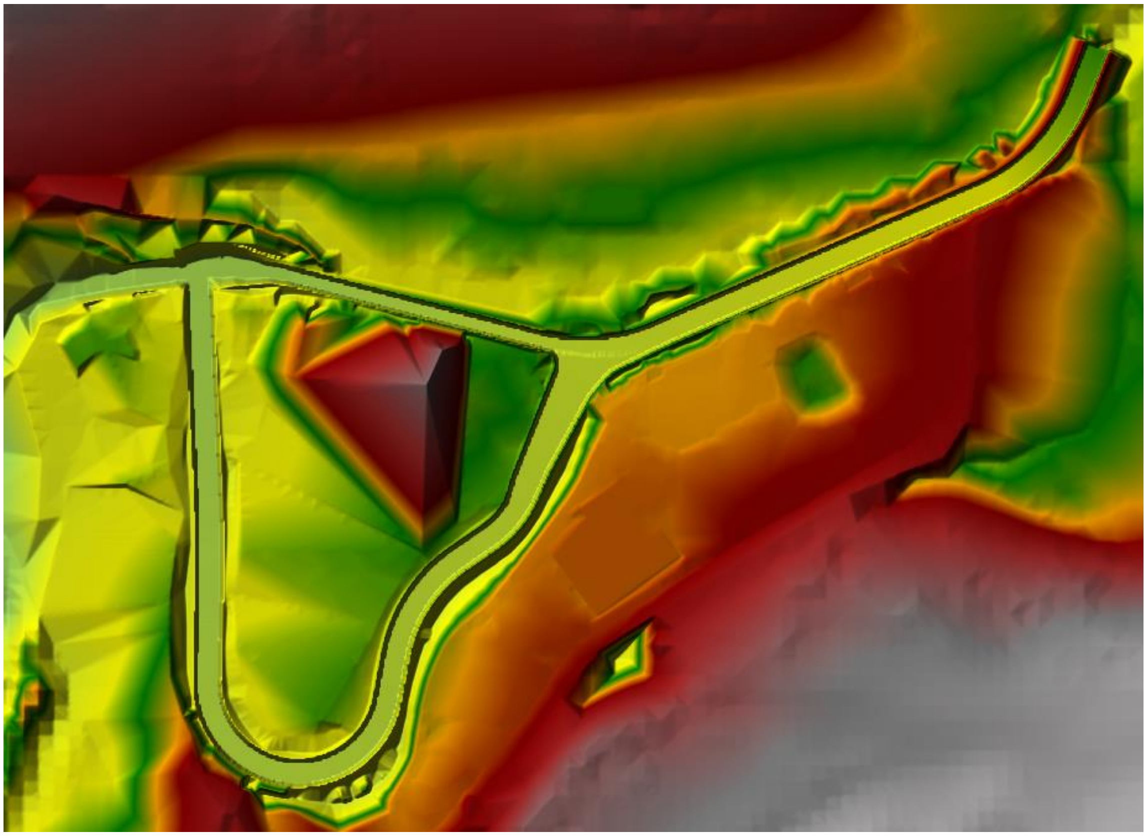


Figure 11. 3-Dimensional Terrain Modification

All above-mentioned data including, projection file (.prj), terrain file (.flt), the modified channel, are used as input data to set up 1-dimensionam and 2-dimensional models. Both models are developed under SI unit, initially defined.

4.3 1-Dimensional model set up

HEC RAS besides other functions, is also capable of performing 1-dimensional steady and unsteady flow analysis. This section will provide an in deep explanation of 1-dimensional model set up, boundary conditions used and also simulation of unsteady flow analysis always related to the area under study.

4.3.1 Cross-Section and Geometry

1D model uses cross sections to perform the analysis, so while setting up this model attention was paid to cross section implementation.

Farka stream it is composed of the main stream and a channel which is constructed around Central Archive of Social Security. This means that the stream under study is composed overall by four reaches. The main reach named Përroi I Farkes is subdivided in Reach 1, Reach 1 Lower and Reach 1 Lower -Lower. The fourth reach is reach 2 representing the channel. These four reaches are connected to each other by two junctions, the upstream junction is a split one, where Përroi I Farkes is divided into Reach 1 Lower and into Reach 2 of the channel. On the other hand, the downstream junction is a combined one, where reach 1 lower joins reach 2 of the channels, into reach 1 lower lower. So, there are located two junctions on the stream under study, which requires specific attention on modeling and setting up, because they directly influence the amount of water flowing on each corresponding reach.

To initiate the development of 1D model, the existing terrain map and modified channel were imported into HEC RAS Mapper. Then under Geometries, new geometries were implemented including, river, stream centerline, bank lines, at points, locations where streams meat each other junctions were added, and the most important geometry, cross sections were drawn. Cross sections are drawn in the same direction, starting from left to right, in order not to have problems while interpolation them. Furthermore, cross sections are perpendicular to stream centerline, and intersects both banks of the stream.

After editing all geometries on HEC RAS Mapper, the data were saved and the map layer were displayed on Geometric Data. The number of cross sections created on HEC RAS Mapper was not enough to adequately represent the stream geometry, for this reason cross sections were interpolated using the option under Tools button, XS interpolation, Between 2'XS's with a corresponding distance between XS's of 0.2.

As the stream is composed of two junctions, one is a split junction and the other is a combined junction, it was important to edit data for them. the presented study aims to simulate unsteady flow analysis that is why the data for junctions was edit under unsteady flow computation option. By selecting this option, only junction length was required as an input for each junction.

An important input while developing the model is, defining the Manning's coefficient, as this coefficient has a great impact of water level computations, and also affects the simulation results. In this study, was considered one value corresponding to Manning's coefficient for the whole segment, that value was 0.02.

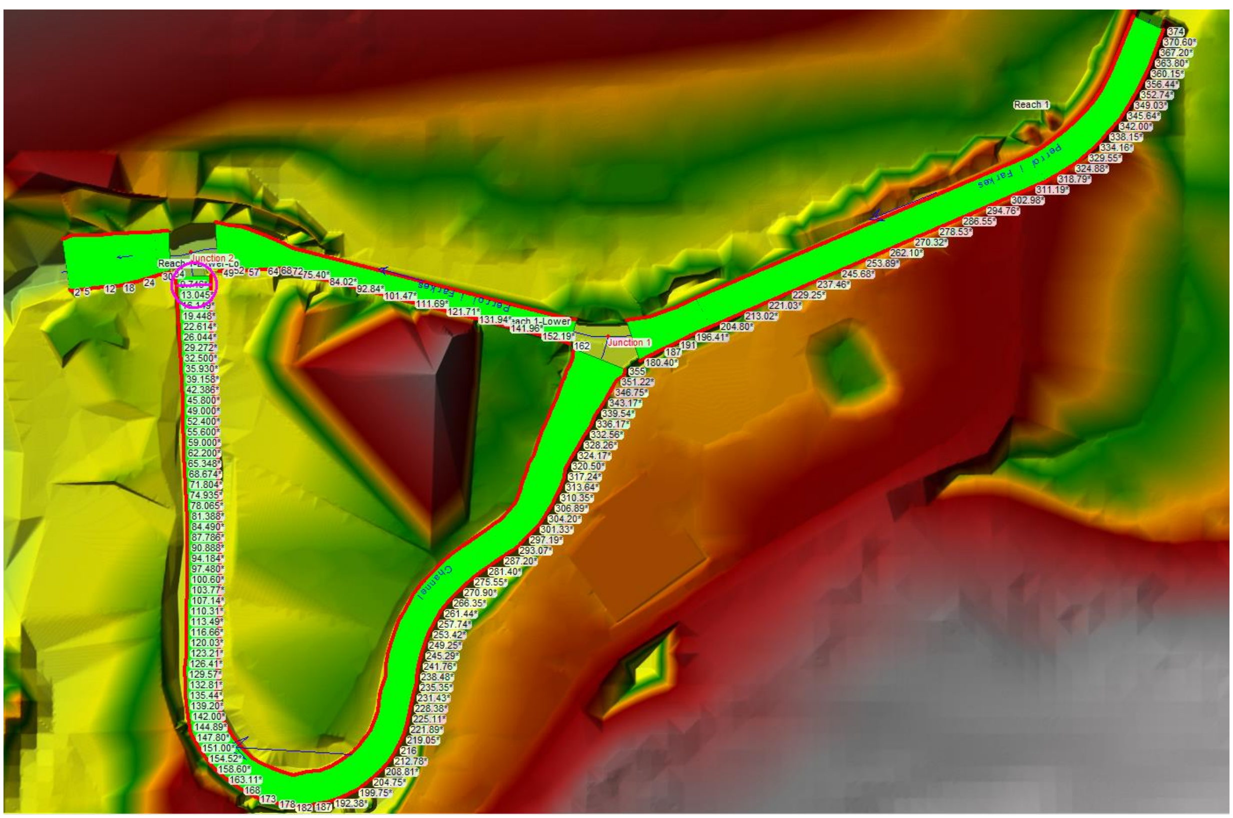


Figure 12. 1-Dimensional Model Setup, Cross Sections, Junctions

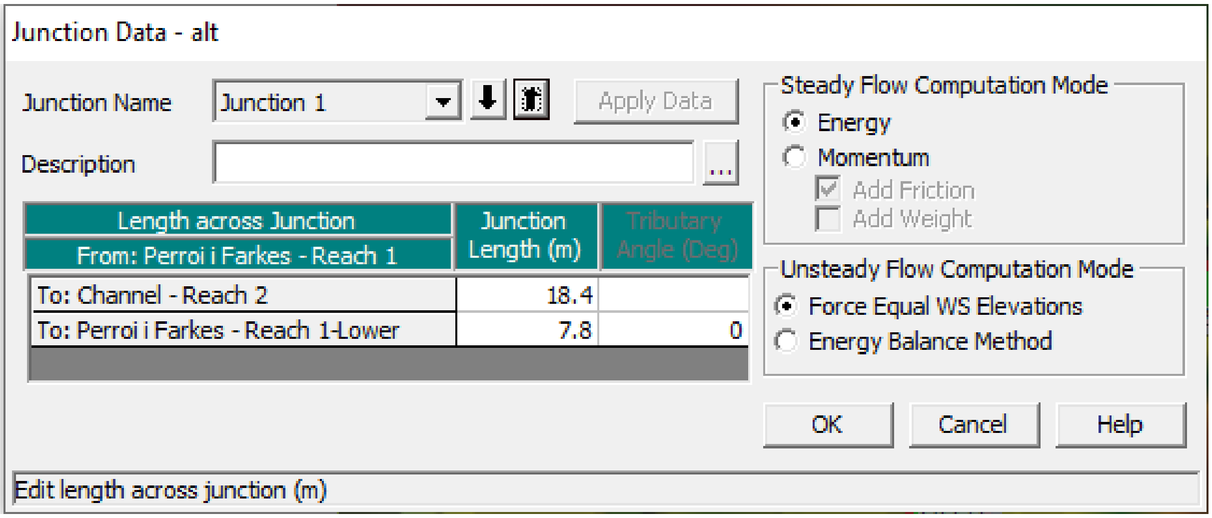


Figure 13. Junctions Data Editor

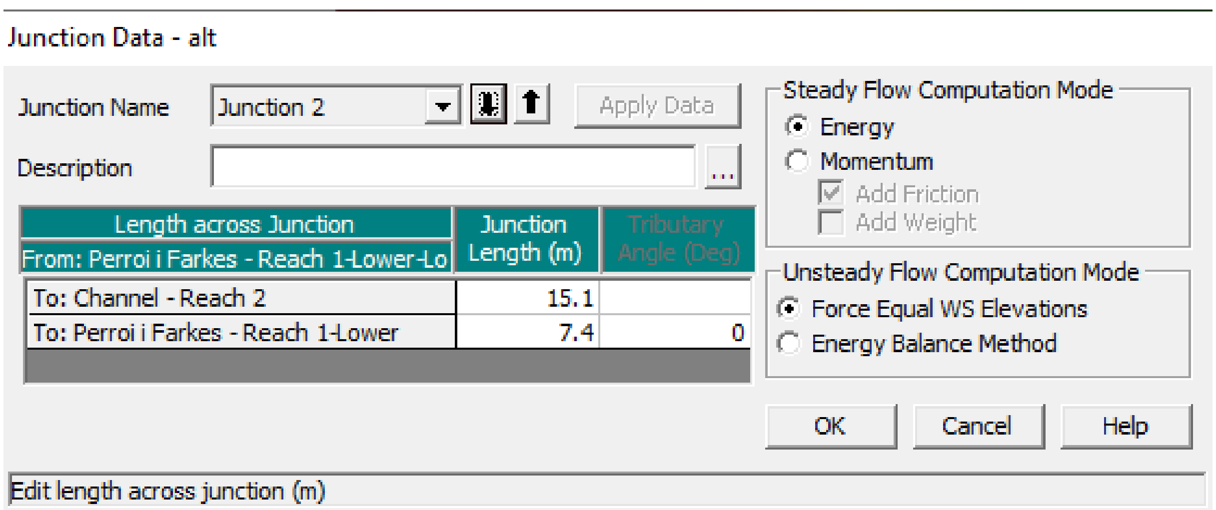


Figure 14. Junctions Data Editor

4.3.2 Input and Output Boundary Conditions

Moreover, the boundary conditions needed to be defined, in order to perform unsteady flow analysis. For unsteady flow analysis only two boundary conditions are displayed, upstream boundary condition which in this case was represented by Flow Hydrograph and downstream boundary condition which was represented by Normal Depth.

Flow hydrograph used as upstream boundary condition was obtained from Hydrologic study conducted by other researchers. The maximum calculated flow was 240 m^3 /s and the time interval were defined, 5 minutes.

Normal Depth used as downstream boundary condition was calculated to be 0.025.

As all the data required to perform the simulation were set up, the model was run and the results from the simulation were obtained.

4.3.3 Unsteady Flow analysis and Output

After setting up the boundary conditions the model was run to perform unsteady flow analysis. Some calibrations were required to be conducted in order to avoid errors during simulation.

For 1 dimensional model, flow distribution on junctions were received as result after finishing the simulation. The first junction is a split one, so, the flow will be rearranged into corresponding streams. Meanwhile, the second junction is a combined one so the flow will be the same as the initial value $Q=240m^3/s$.

4.4 2-Dimensional Model Set Up

Two-dimensional model works based on finite volume cell or bathometry, so there is no need to add cross sections, only the 2D flow area was drawn.

4.4.1 3-Dimensional Terrain

To start setting up 2D model, same as 1 D model the projection file(.prj), original terrain file (.flt) and the modified channel was imported as input on HEC RAS Mapper.

Then on geometric data, the 2 D flow area was defined initiating from upstream to downstream. A 2D flow area box was required to be filled, defining Manning's coefficient which also in this case was selected to be 0.02. the computation point space, spacing between DX, DY were specified to be each 0.5.

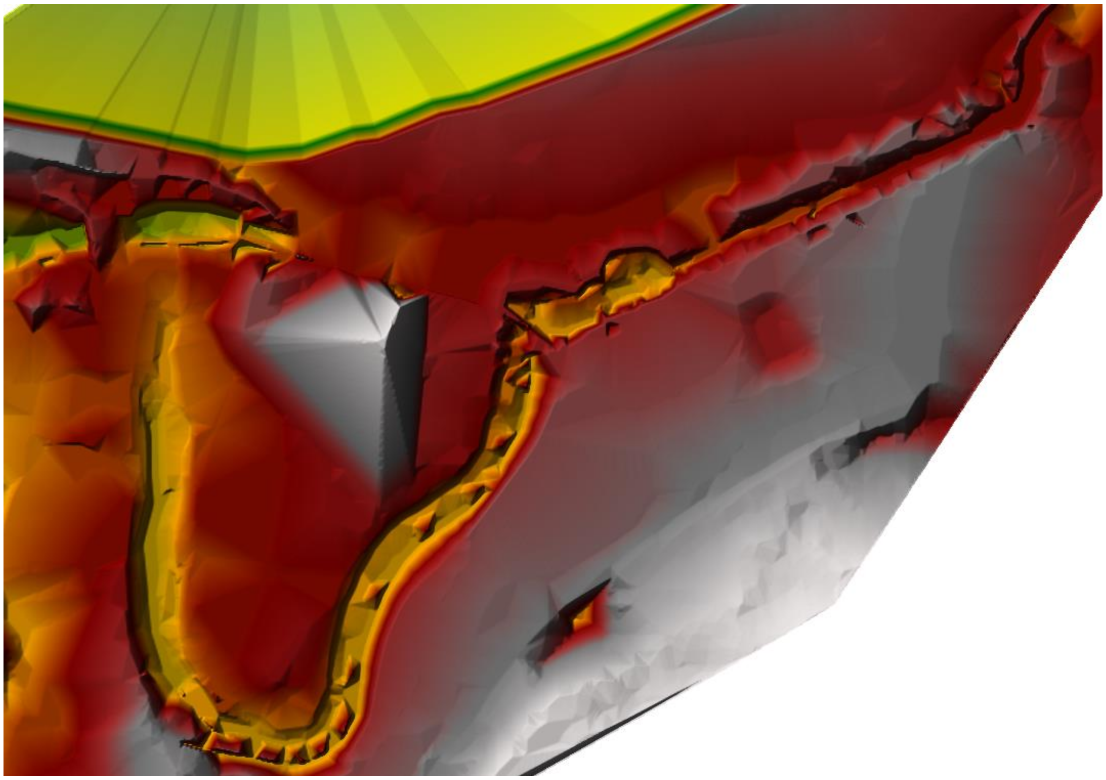


Figure 15. Original Terrain

Figure 16. Original Terrain Google Satellite View

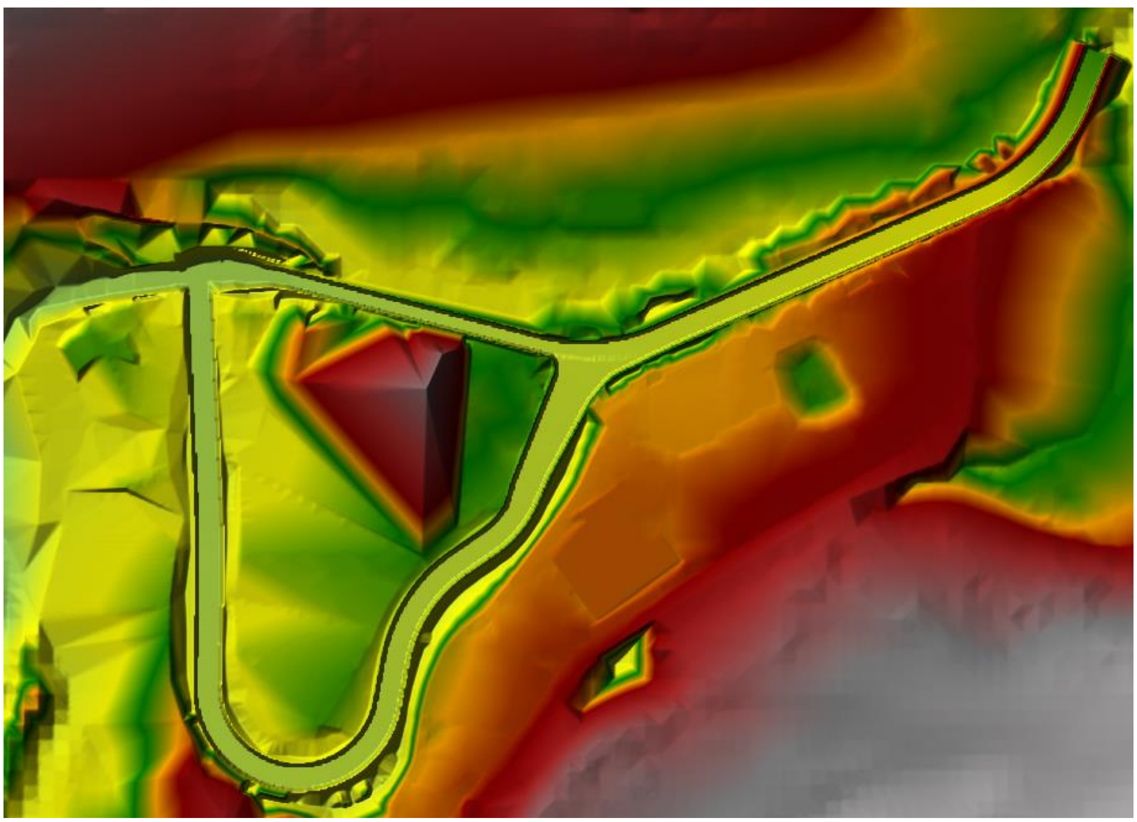


Figure 17. 3-Dimensional Terrain Modification

4.4.2 Input and Output Boundary Conditions

Furthermore, the 2D Area boundary condition lines (BC lines) were defined, these lines will serve to define boundary condition while editing unsteady flow data.

Boundary conditions used on this model were the same as for 1D model, Flow Hydrograph generated from Hydrologic study was used as upstream boundary condition with maximum flow 240 m^3/s while Normal Depth was used as downstream boundary condition defined as 0.025.

4.4.3 Unsteady Flow analysis and Output

After setting up the boundary conditions the model was run to perform unsteady flow analysis. Some calibrations were required to be conducted in order to avoid errors during simulation.

For 2-dimensional models, the results will be presented in terms of, Flow, Water surface elevation, Terrain and Velocity against terrain.

4.5 Three Proposed Cases for Farka Stream Rehabilitation Modeled in 2 Dimensional

One of the aims of this study is to propose solution to prevent the inundation of the area around Farka stream. The solution will be represented by three scenarios, cases of possible rehabilitation of the stream. All scenarios will be analyzed considering the maximum water flow as $Q=240m^3/s$ which corresponds to the highest water flow occurred in 30 of November 2014, and also, it is approximately the same with the flow resulting from hydrologic study conducted by other researchers.

Moreover, for all three proposed solutions Farka stream will be divided into three segments where:

Segment 1- corresponds to the existing stream arranged with a trapezoidal concrete channel that is damaged during the floods.

Segment 2- corresponds to the old bed of the stream that passes around the Central Archive of Social Security.

Segment 3- corresponds to the area that passes near the State Reserve Depots, where a culvert with dimensions BxH=5x3m is constructed.

The proposed cases are generated from the hydraulic model results that are as presented below.

4.5.1 The Proposed Solution, Case 1

For this case it is proposed that in segment 1 of the stream which corresponds to the existing stream bed, the trapezoidal concrete cross section to be replaced with rectangular section with dimensions BxH=8x3m. The rectangular section will be constructed by two reinforced concrete wall with a height of 3 m. Flow capacity of this segment will be Q=240m^3/s which at the end of the section will be divided into segment 2 with a flow capacity of Q=127.7m^3/s and segment 3 with flow capacity Q=112.3m^3/s.

Furthermore, in segment 2 corresponding to the old stream bed will also be constructed the same rectangular reinforced concrete section as in segment 1. The flow capacity of this segment will be Q=127.7m^3/s.

The third segment where a culvert of dimensions BxH=5x3m is constructed will remain untouched for this case. Flow capacity of this segment will be Q=112.3m^3/s.

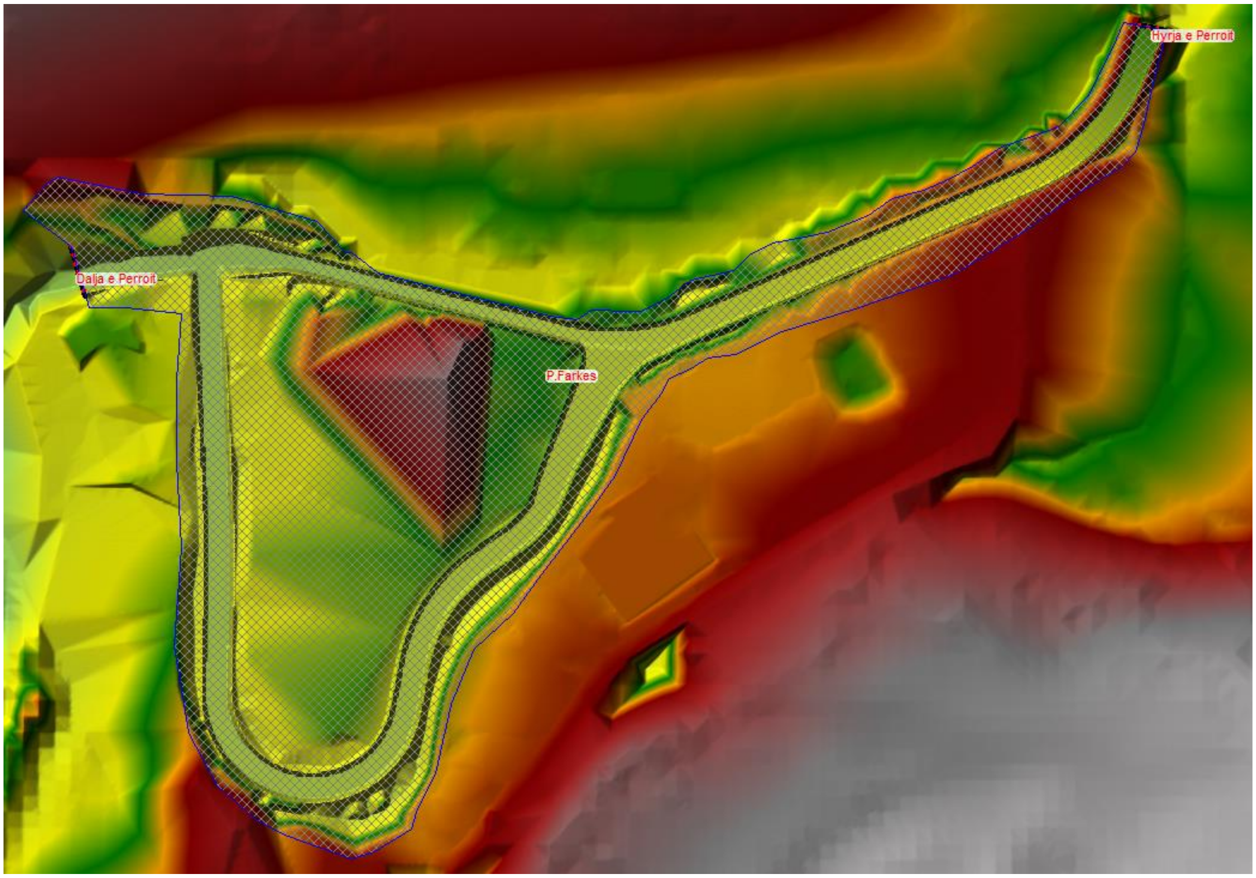


Figure 18. HEC RAS 2D Model, Case 1

4.5.2 The Proposed Solution, Case 2

It is proposed that for this case in segment 1 which corresponds to the existing stream bed the trapezoidal concrete section will be destroyed and replaced with a rectangular reinforced concrete section as in case 1. The flow capacity for this segment will be $Q=240m^3/s$.

Moreover, segment two of this case the old stream bed will be rehabilitated and a trapezoidal concrete cross section will be constructed. The flow capacity will be $Q=58.6m^3/s$.

In the third segment, the capacity of the stream will be increased by constructing another culvert on the side of Central Archive of Social Security area, with dimensions BxH=2.5x3m.

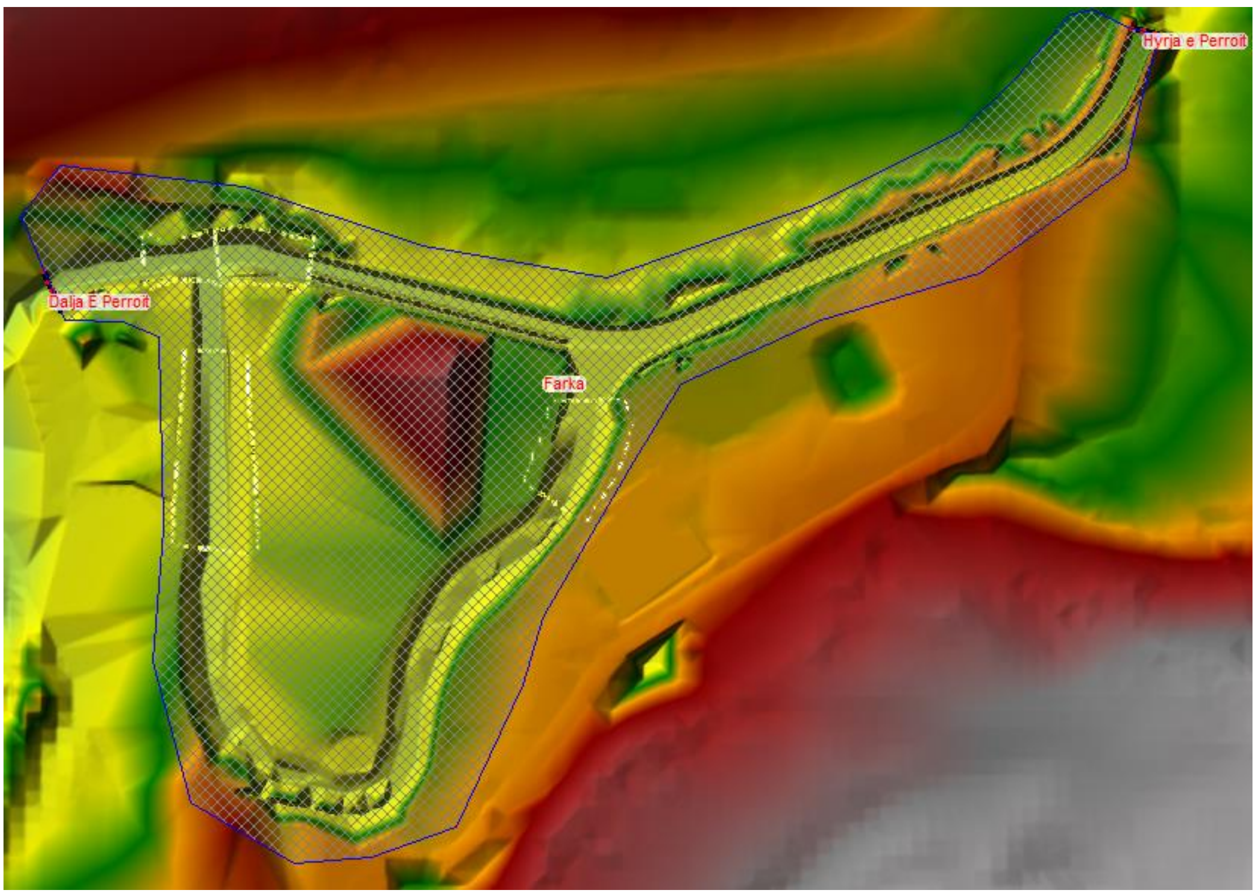


Figure 19. HEC RAS 2D Model, Case 2

4.5.3 The Proposed Solution, Case 3

In this case, it is taken into consideration the idea to rehabilitate Farka stream as an open channel into its natural stream, without constructing closed structures.

Segment 1 which will have a flow capacity of $Q=240m^3/s$ will be constructed the same as in case 1. The trapezoidal concrete section will be replaced with a rectangular reinforced concrete section.

Moreover, in segment 3 the existing culvert will be destroyed and it will be replaced by a rectangular reinforced concrete channel, as in segment 1.

The second segment that passes along Central Archive of Social Security in half of its length will be filled with soil or other construction materials. In the lower part of this channel, a roc covered trapezoidal channel B=2m will be constructed to allow the flow of atmospheric water.

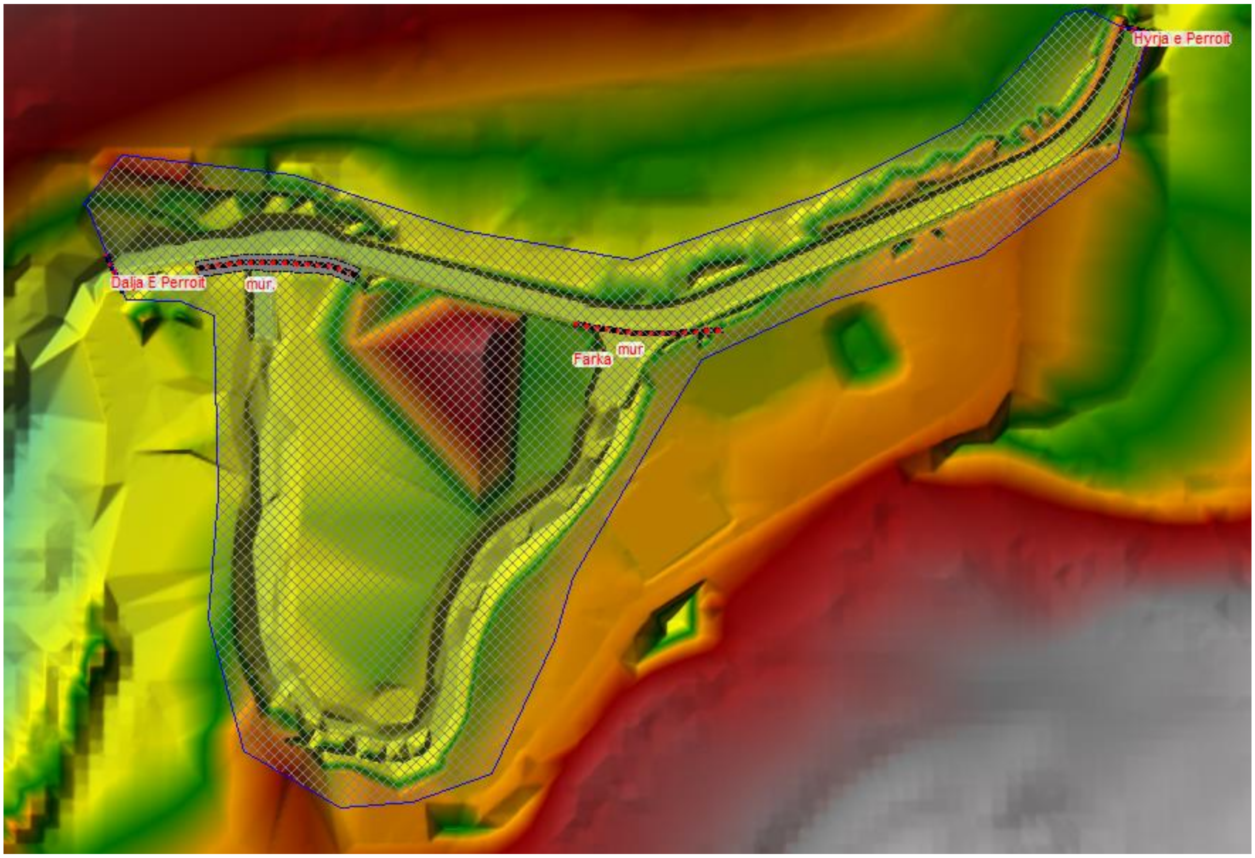


Figure 20. HEC RAS 2D Model, Case 3

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Visualization of results obtained from hydraulic simulation

In the presented study there were developed 1 dimensional and 2 dimensional hydraulic models, where 2 dimensional models are represented by three optional cases of rehabilitation of area under study, Farka stream. Meanwhile, 1 dimensional model correspond only to the first case of 2-dimensional model in order to compare their results.

The results, obtained from the unsteady flow analysis corresponding to the maximum calculated flow of $240m^3/s$ for each case will be displayed in terms of water depth planimetry, flow on each segment taken into consideration for each case, water surface elevation corresponding to each segment for each case, terrain and also velocity against terrain for each segment.

5.1.1 Hydraulic simulation results case 1 of 2-dimensional model.

In order to study whether the flow will inundate the rehabilitated channel it is important to carefully interpret the results obtained from the simulations. Water depth planimetry represents the distribution of water into the channel and the areas nearby it, and visualizes if the water inundated the area or not.

More over to create a better idea of water distribution and flow, three segments are defined on each corresponding stream of the channel and for each segment there are obtained results corresponding to flow capacity, water surface elevation, terrain and velocity against terrain.

The simulation is developed based on maximum water flow $240m^3/s$ which occurs 1 in 100 years, generated from the hydrological study.

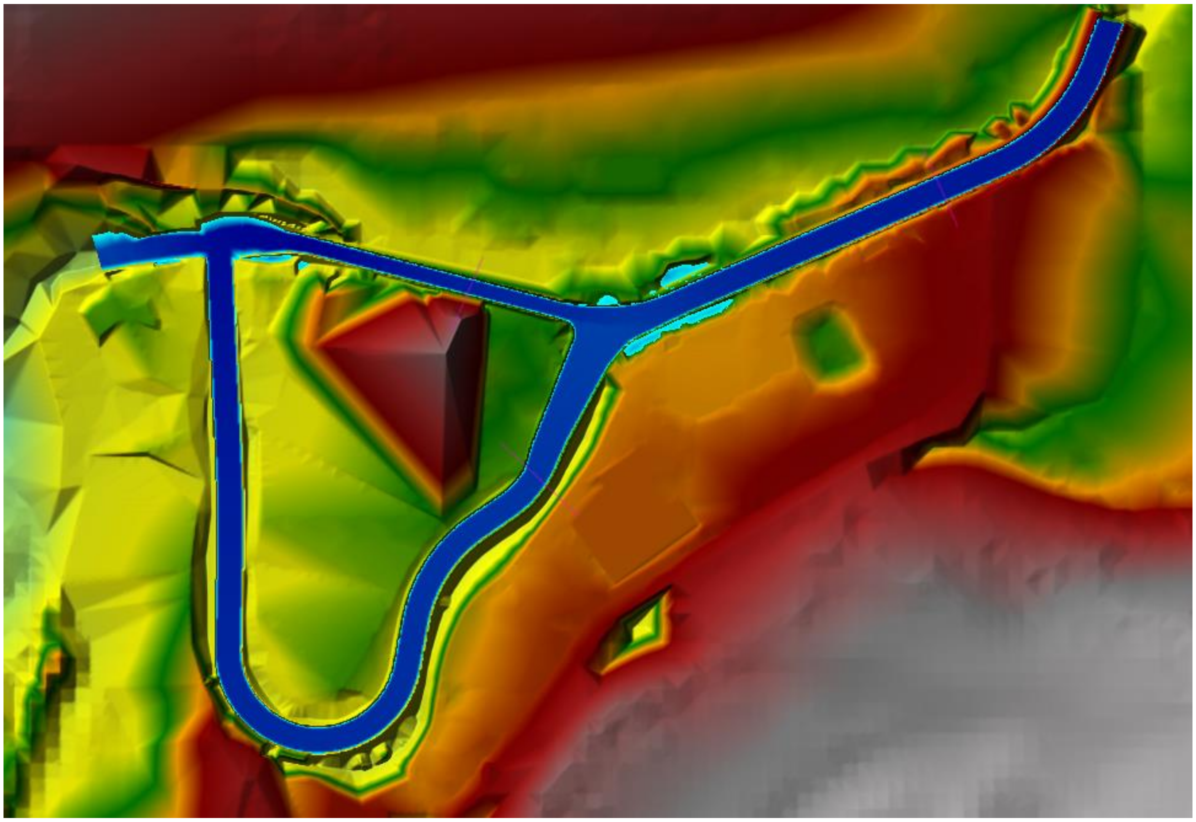


Figure 21. Water Depth Planimetry, Variant 1, 2-Dimensional Model

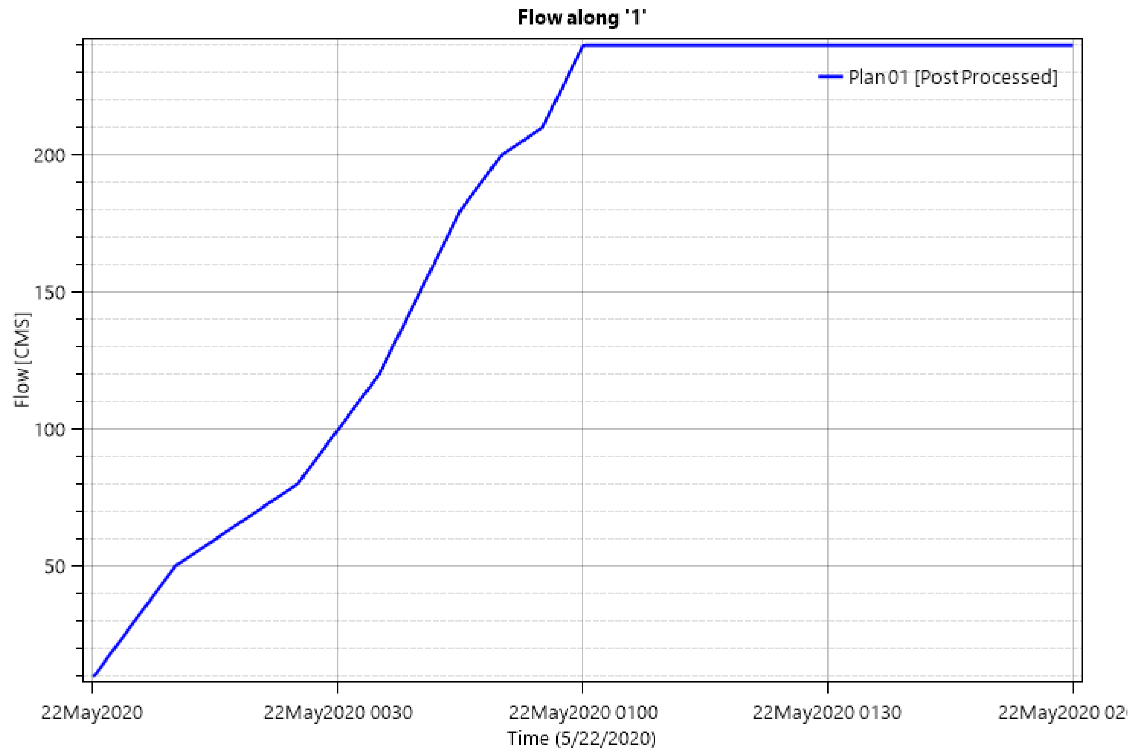


Figure 22.Flow Along Section 1 Q=240 m³/s, Variant 1, 2-Dimensional Model

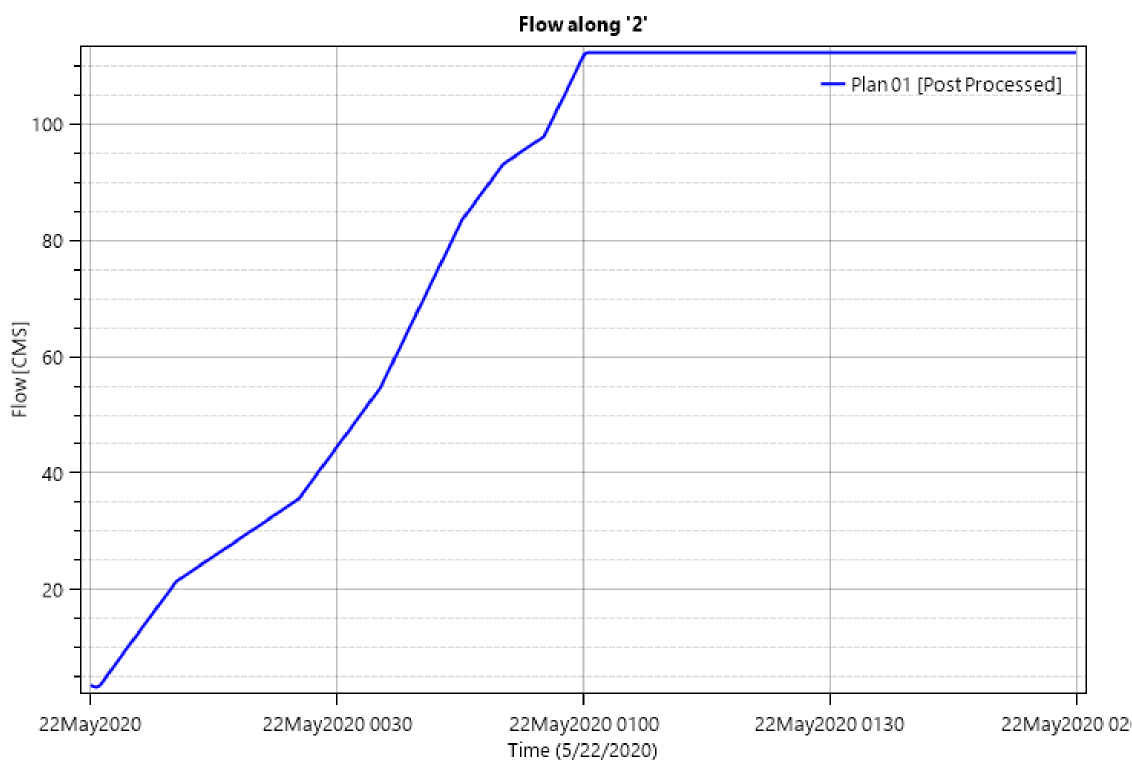


Figure 23. Flow Along Section 2 Q=112.3 m³/s, Variant 1, 2-Dimensional Model

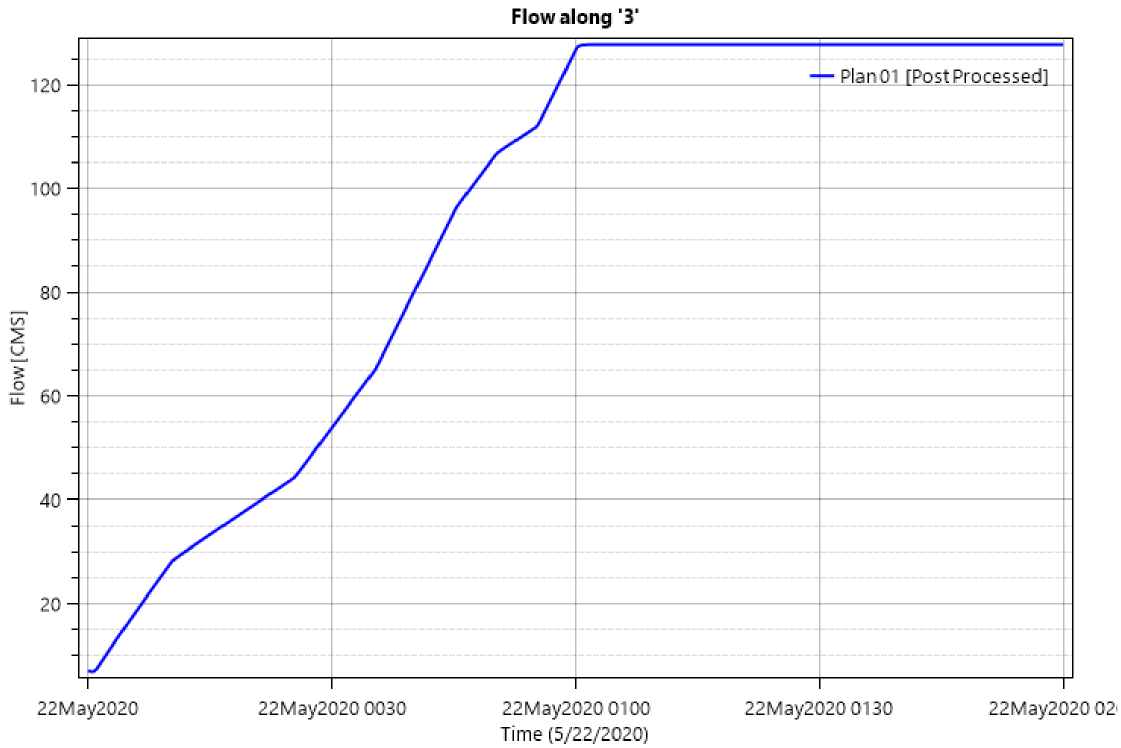


Figure 24. Flow Along Section 3 Q=127.7 m^3/s, Variant 1, 2-Dimensional Model

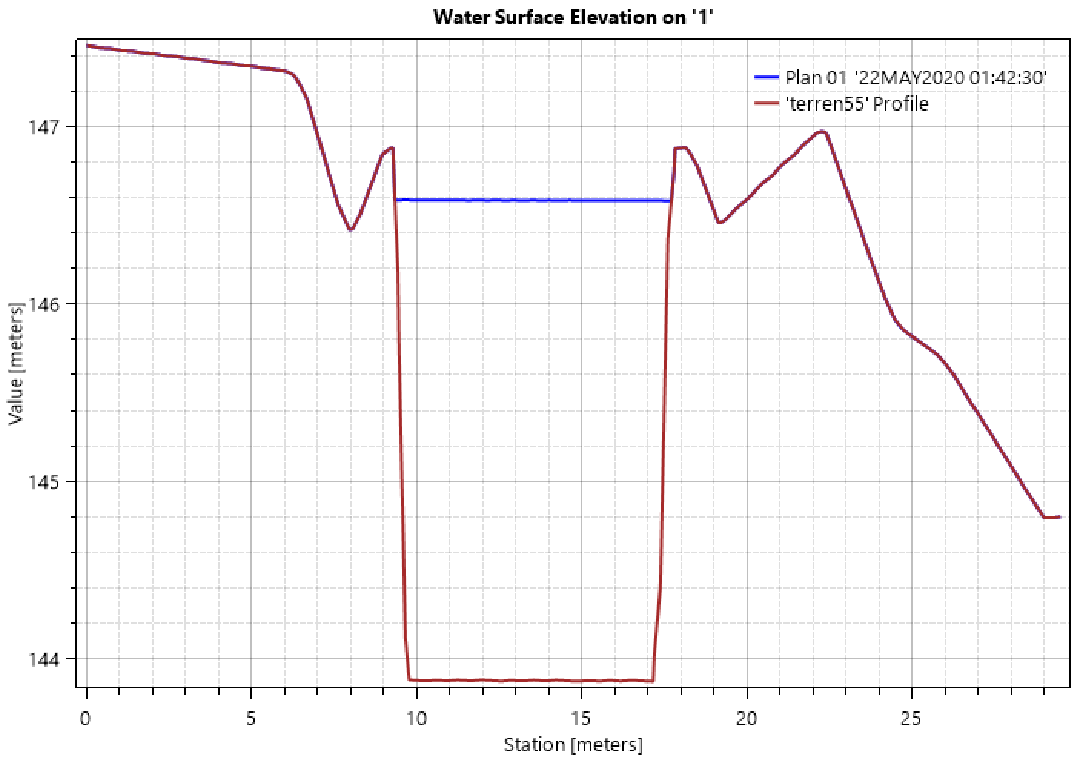


Figure 25. Water Surface Elevation Section 1, Variant 1, 2-Dimensional Model

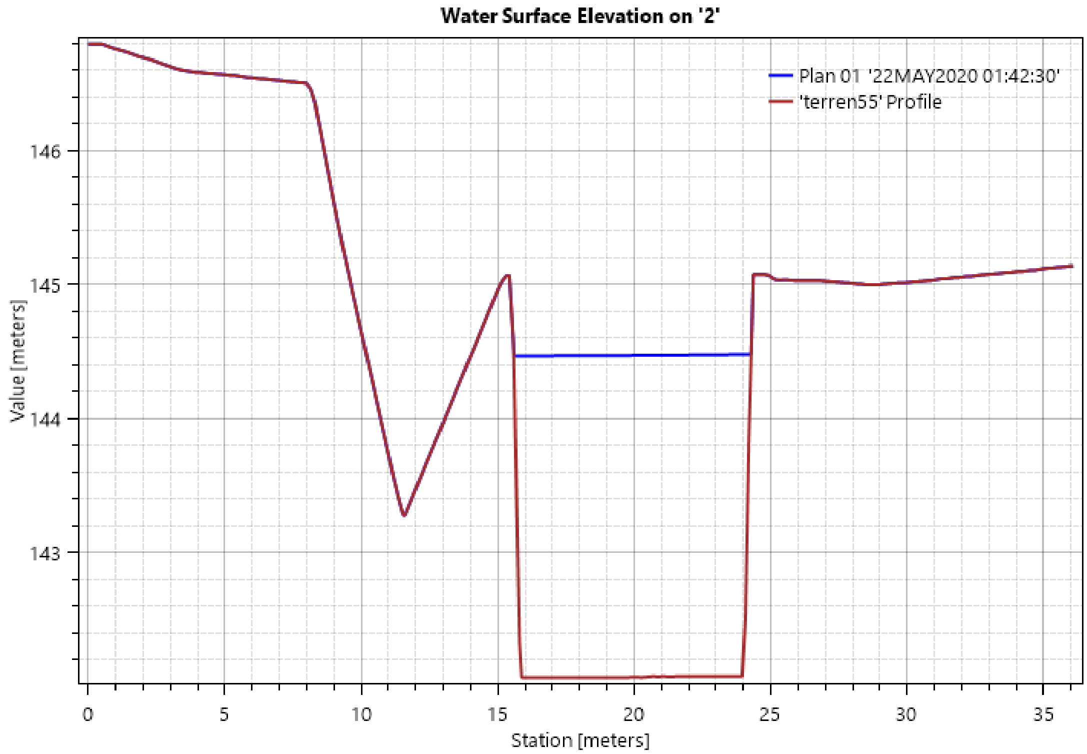


Figure 26. Water Surface Elevation Section 2, Variant 1, 2-Dimensional Model

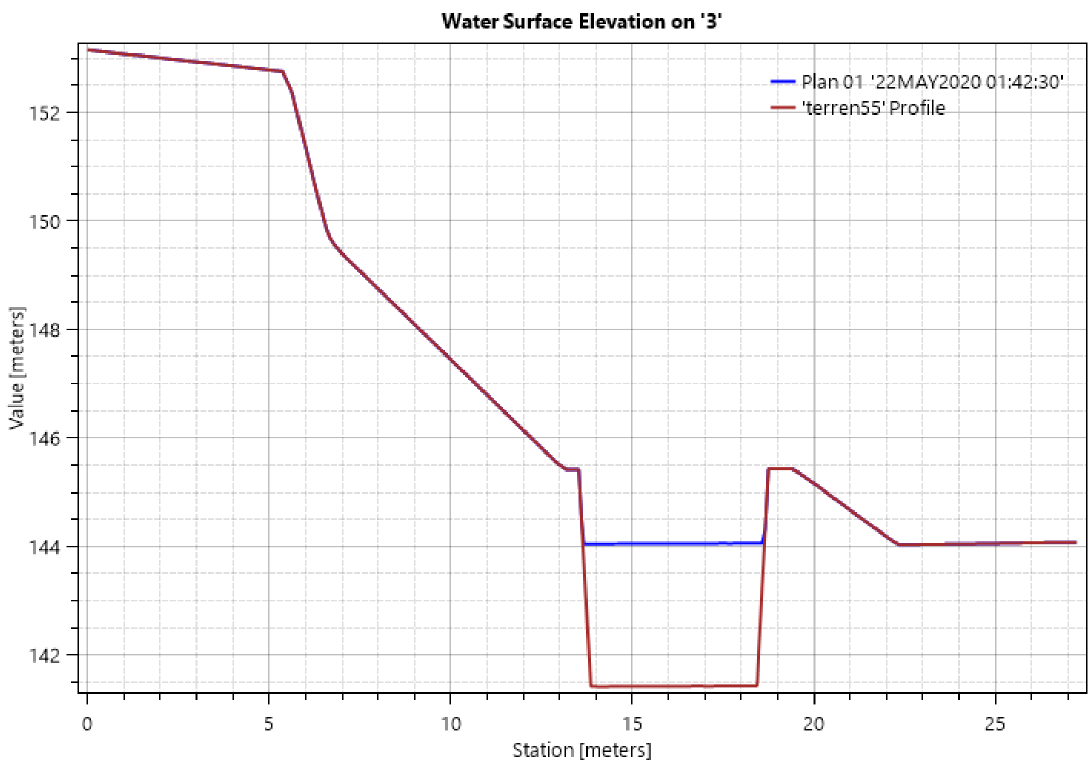


Figure 27. Water Surface Elevation Section 3, Variant 1, 2-Dimensional Model

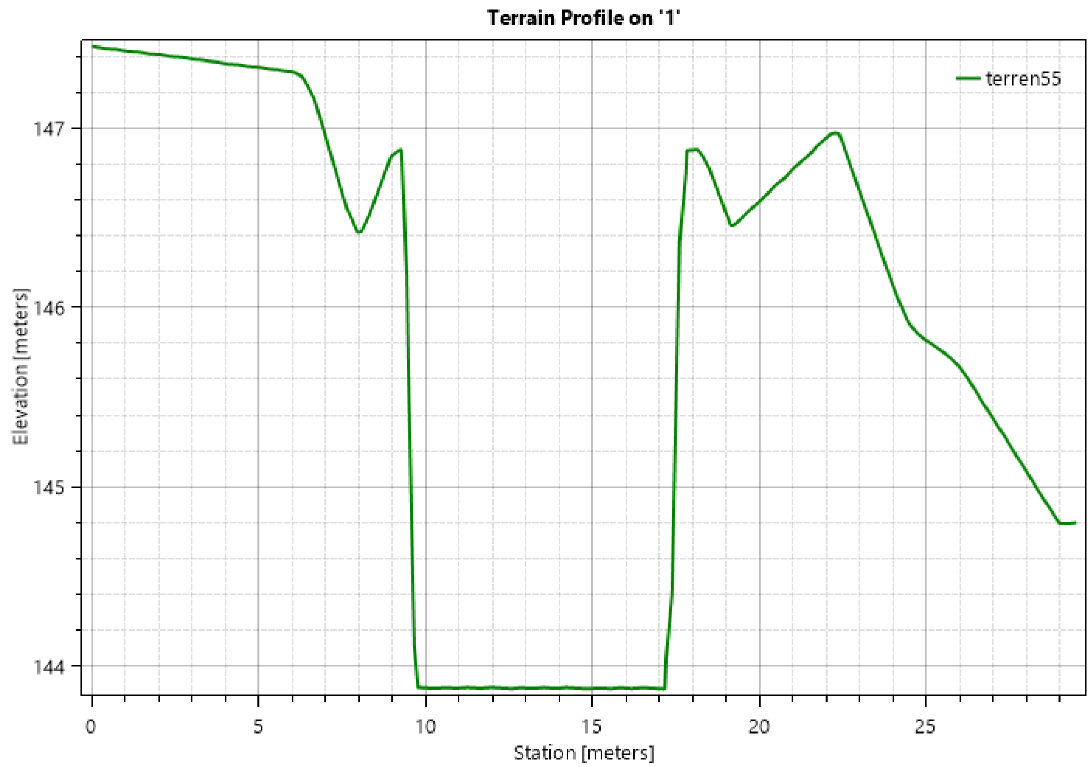


Figure 28. Terrain Profile Section 1, Variant 1, 2-Dimensional Model

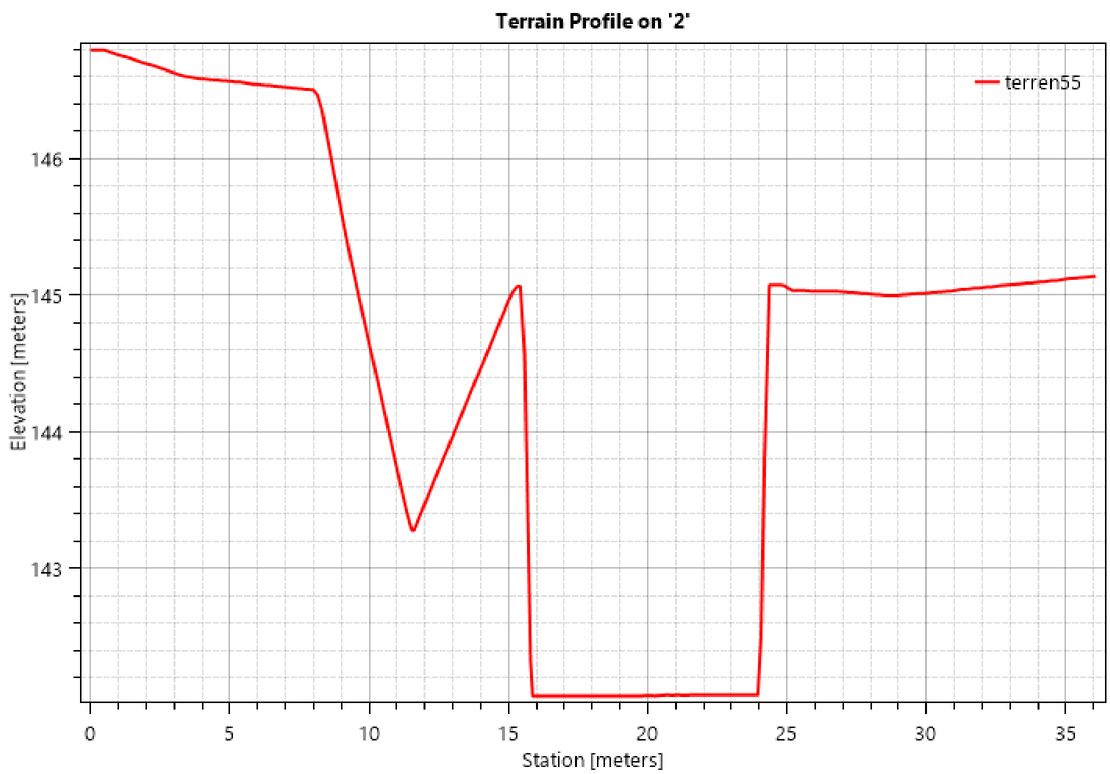


Figure 29. Terrain Profile Section 2, Variant 1, 2-Dimensional Model

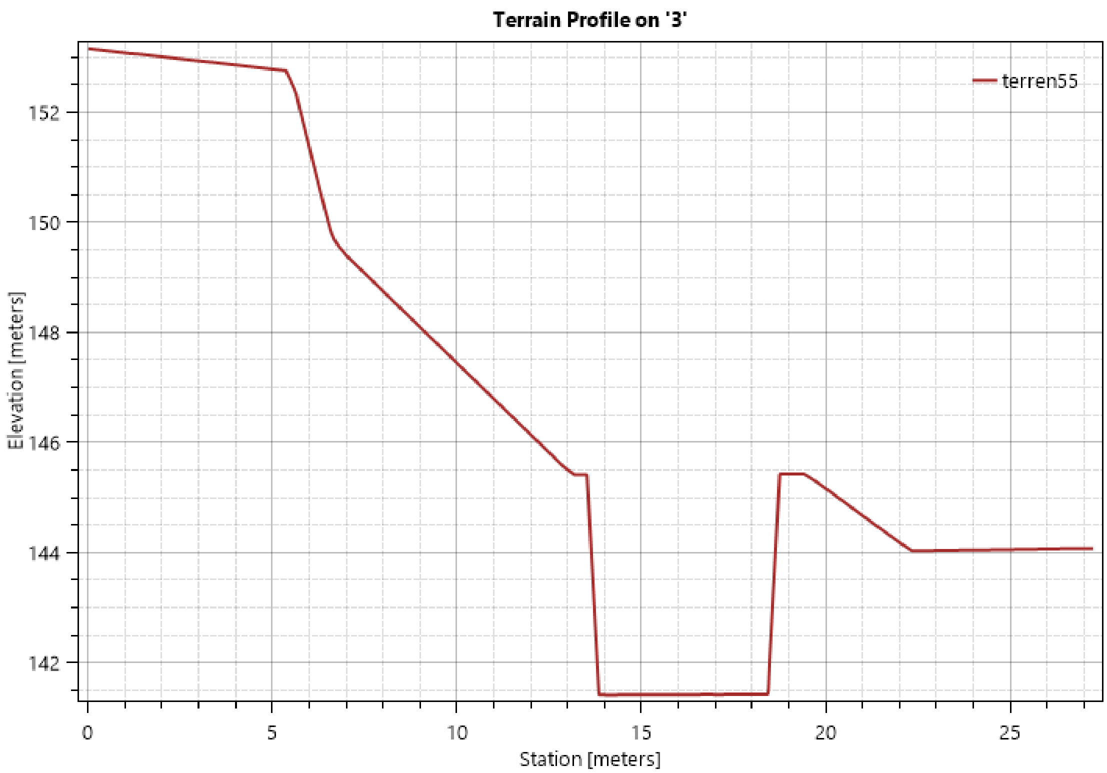


Figure 30. Terrain Profile Section 3, Variant 1, 2-Dimensional Model

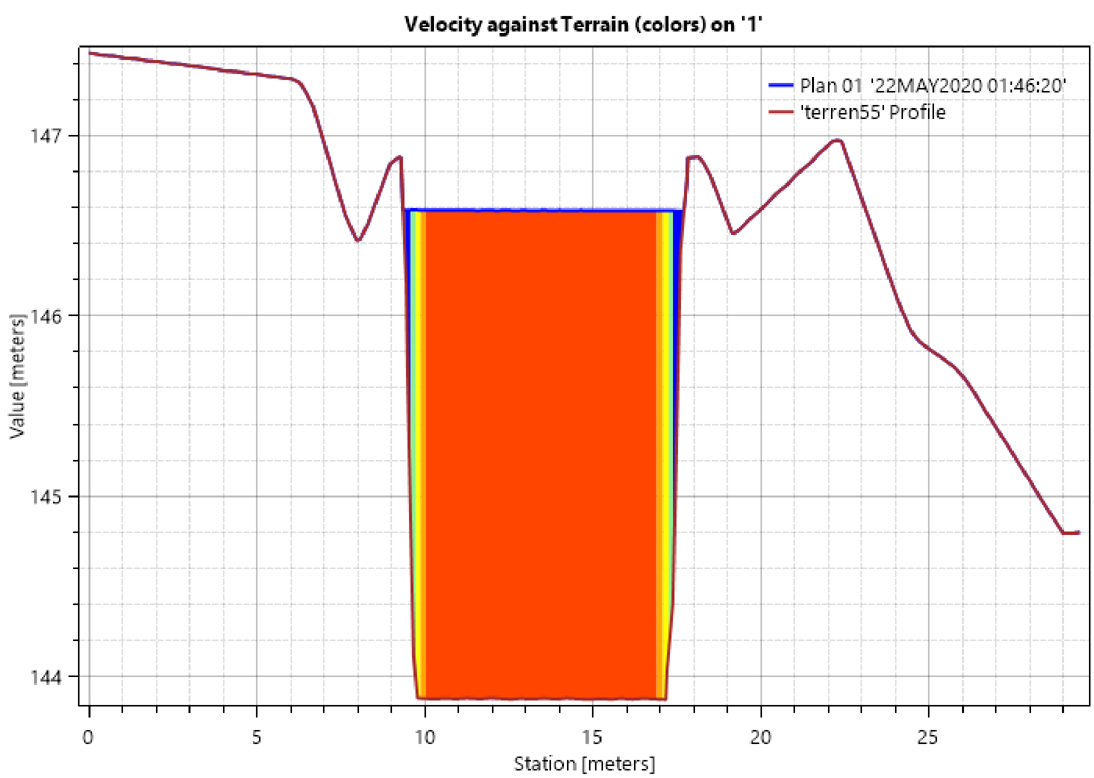


Figure 31. Velocity Against Terrain Section 1, Variant 1, 2-Dimensional Model

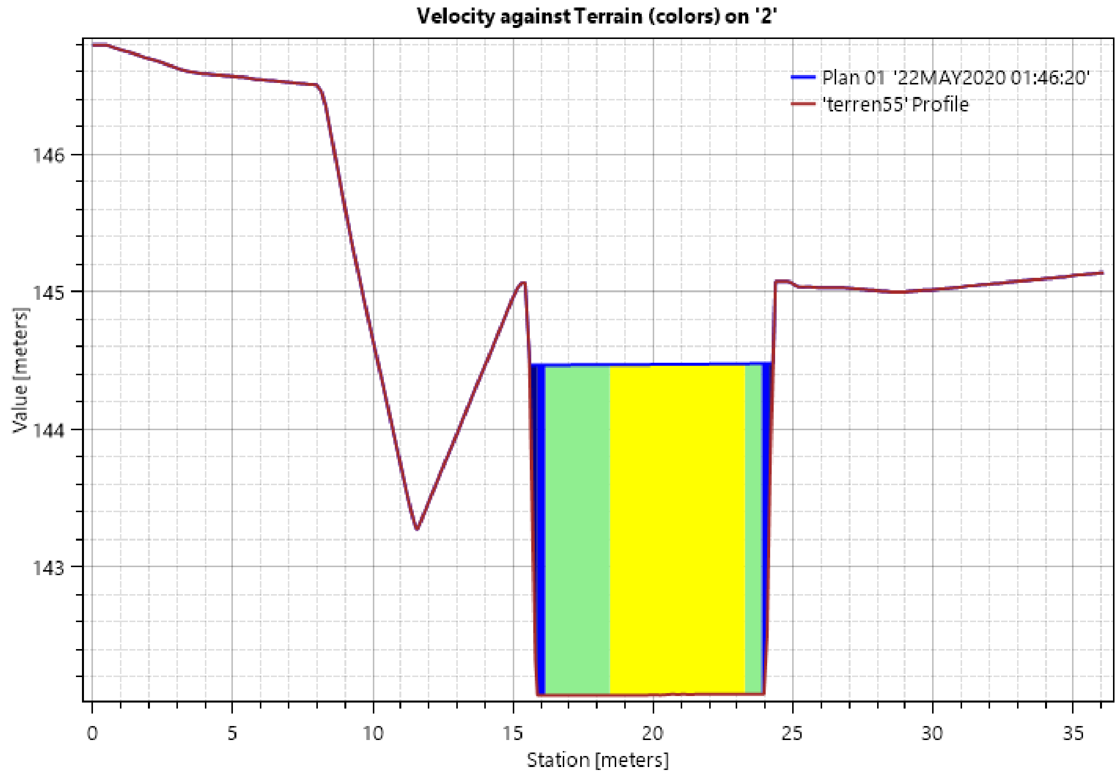


Figure 32. Velocity Against Terrain Section 2, Variant 1, 2-Dimensional Model

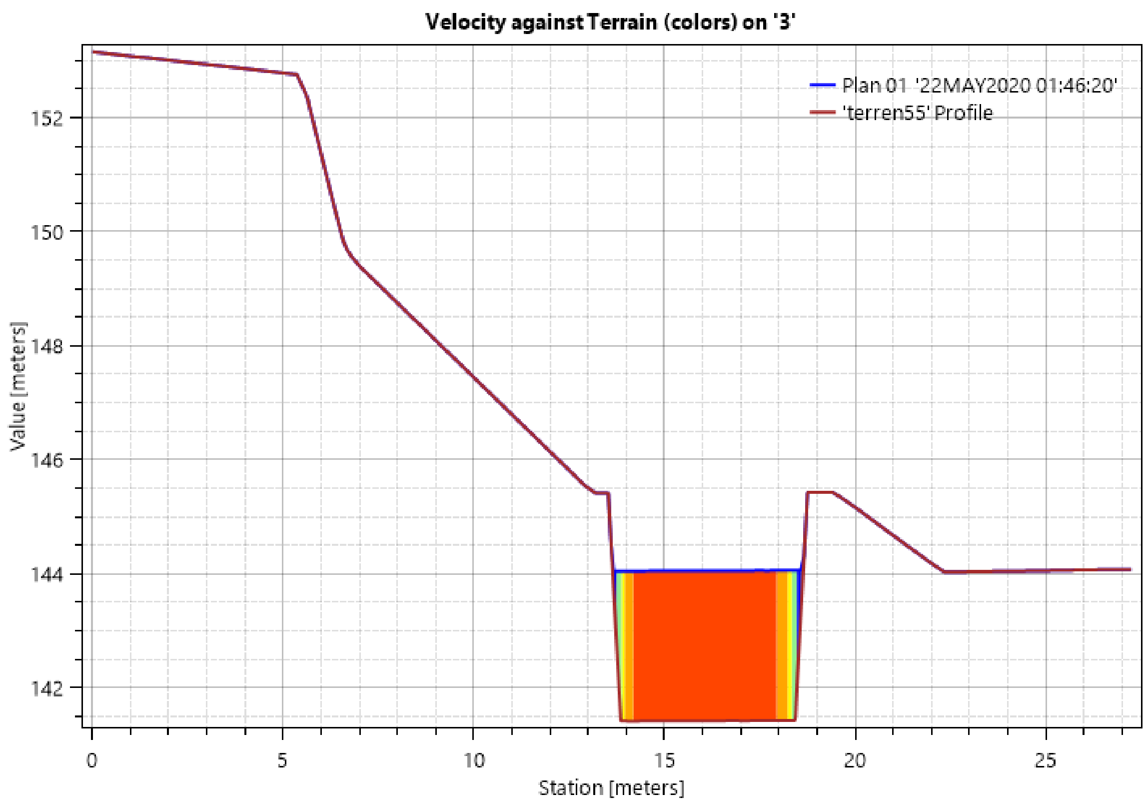


Figure 33. Velocity Against Terrain Section 3, Variant 1, 2-Dimensional Model

5.1.2 Hydraulic simulation results case 2 of 2-dimensional model

In order to study whether the flow will inundate the rehabilitated channel it is important to carefully interpret the results obtained from the simulations. Water depth planimetry represents the distribution of water into the channel and the areas nearby it, and visualizes if the water inundated the area or not.

More over to create a better idea of water distribution and flow, three segments are defined on each corresponding stream of the channel and for each segment there are obtained results corresponding to flow capacity, water surface elevation, terrain and velocity against terrain.

The simulation is developed based on maximum water flow 240m^3/s which occurs 1 in 100 years, generated from the hydrological study.

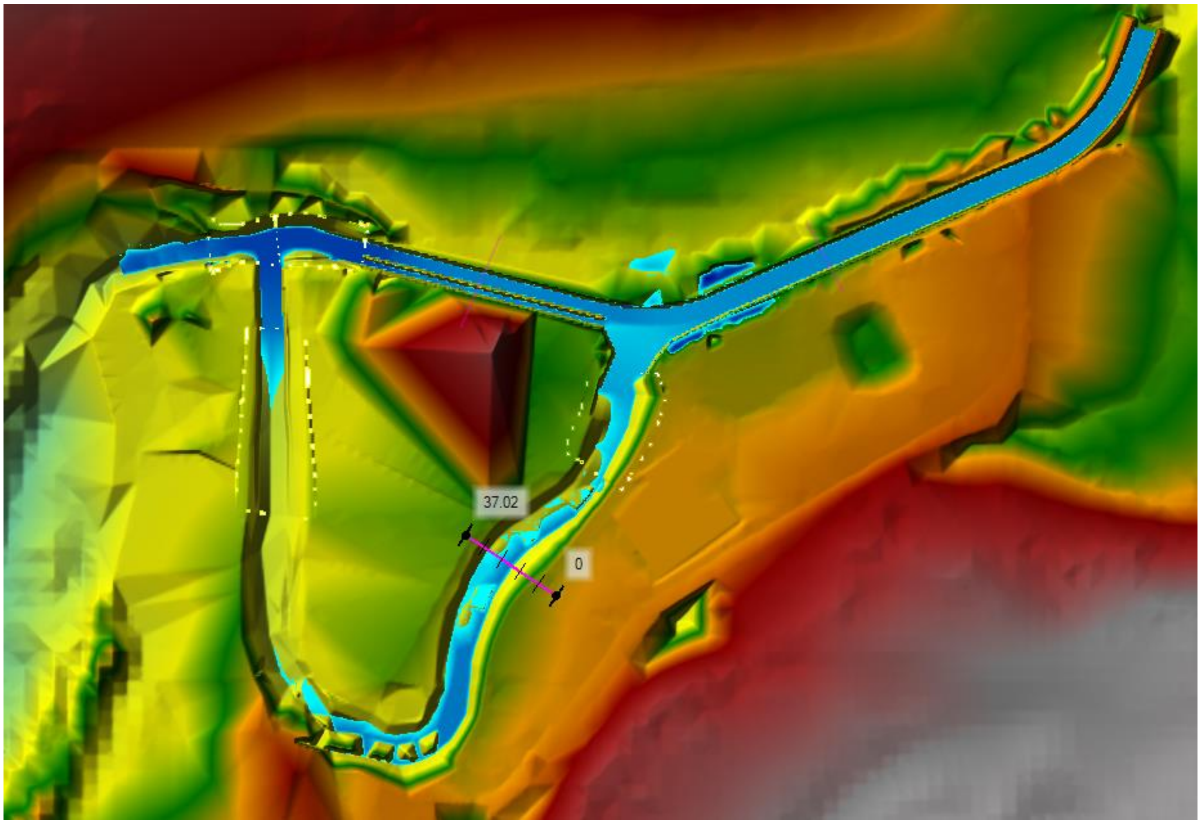


Figure 34. Water Depth Planimetry, Variant 2, 2-Dimensional Model

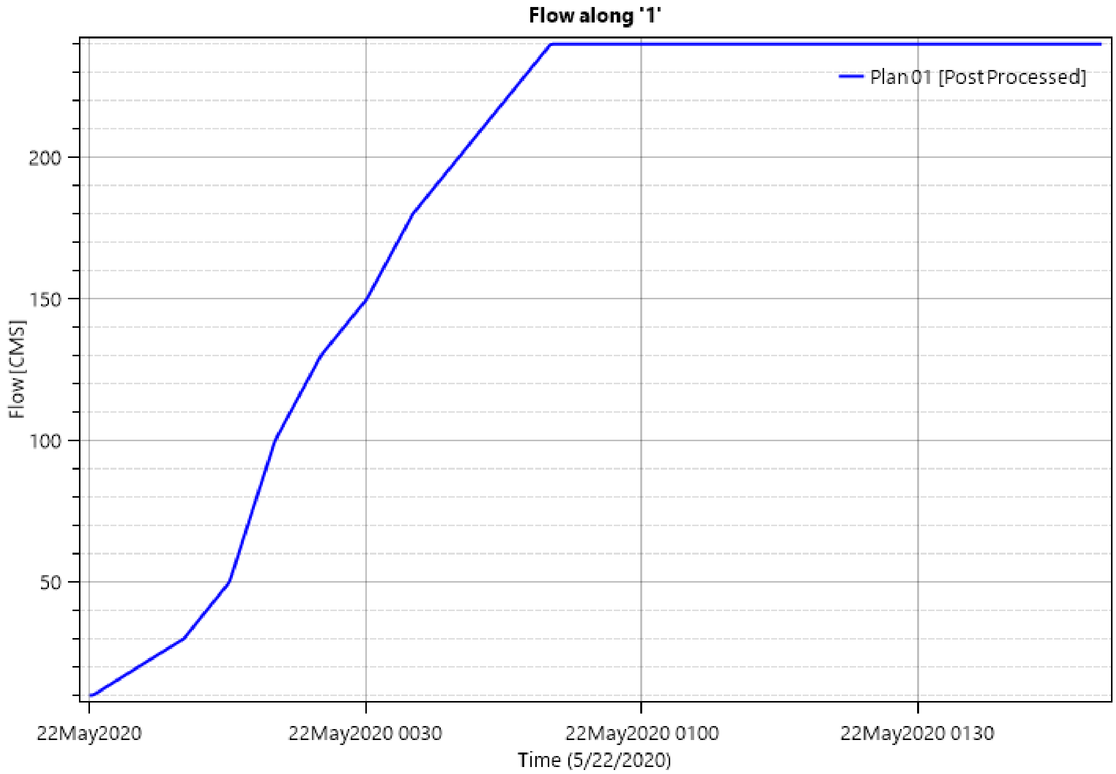


Figure 35. Flow Along Section 1 Q=240 m^3/s, Variant 2, 2-Dimensional Model

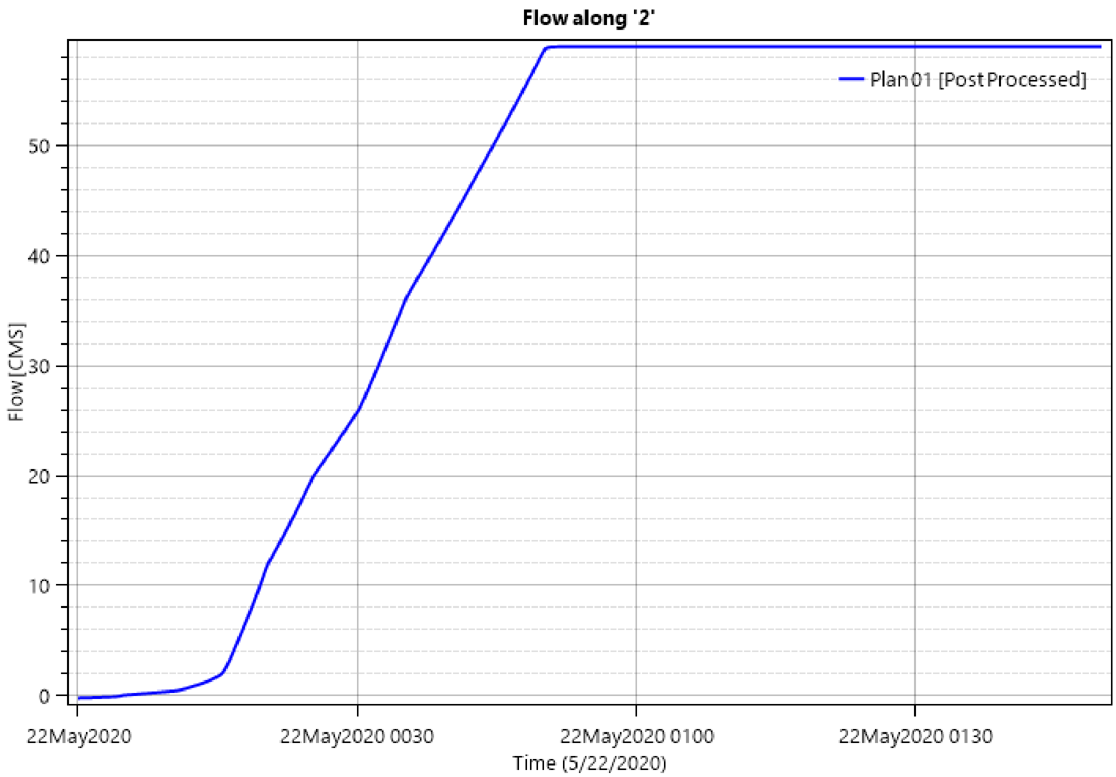


Figure 36. Flow Along Section 2 Q=58.6 m^3/s, Variant 2, 2-Dimensional Model

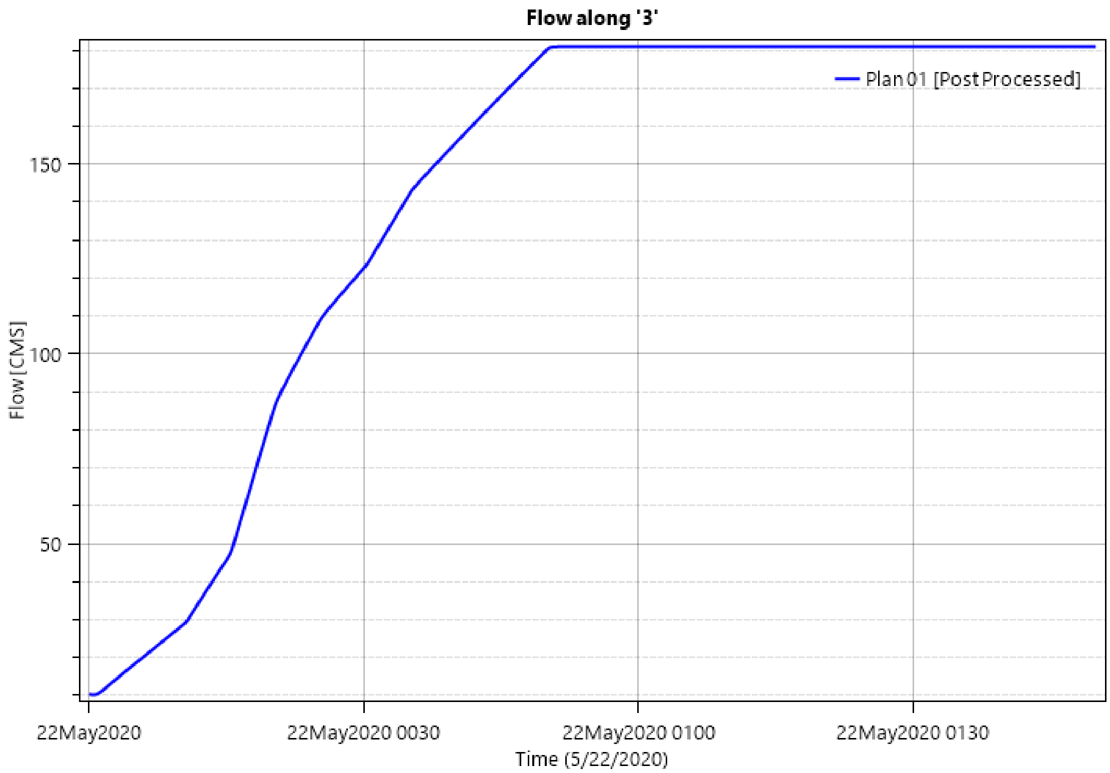


Figure 37. Flow Along Section 3 Q=181.6 m^3/s, Variant 2, 2-Dimensional Model

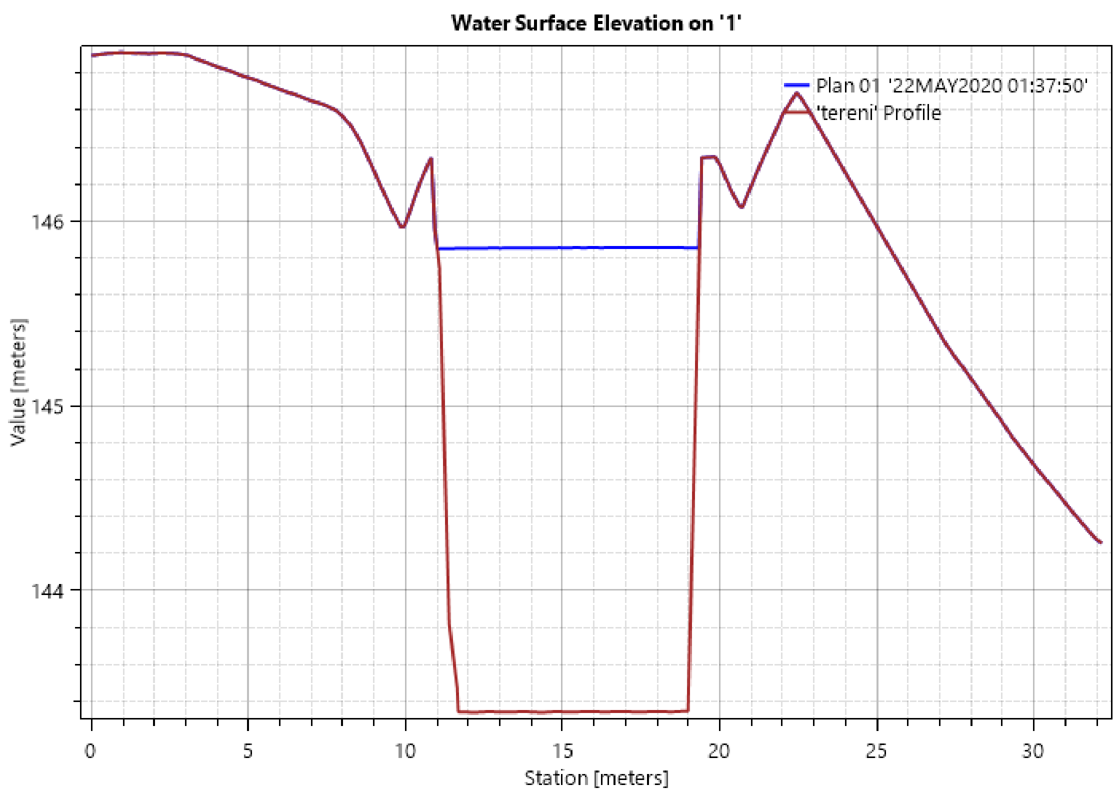


Figure 38. Water Surface Elevation Section 1, Variant 2, 2-Dimensional Model

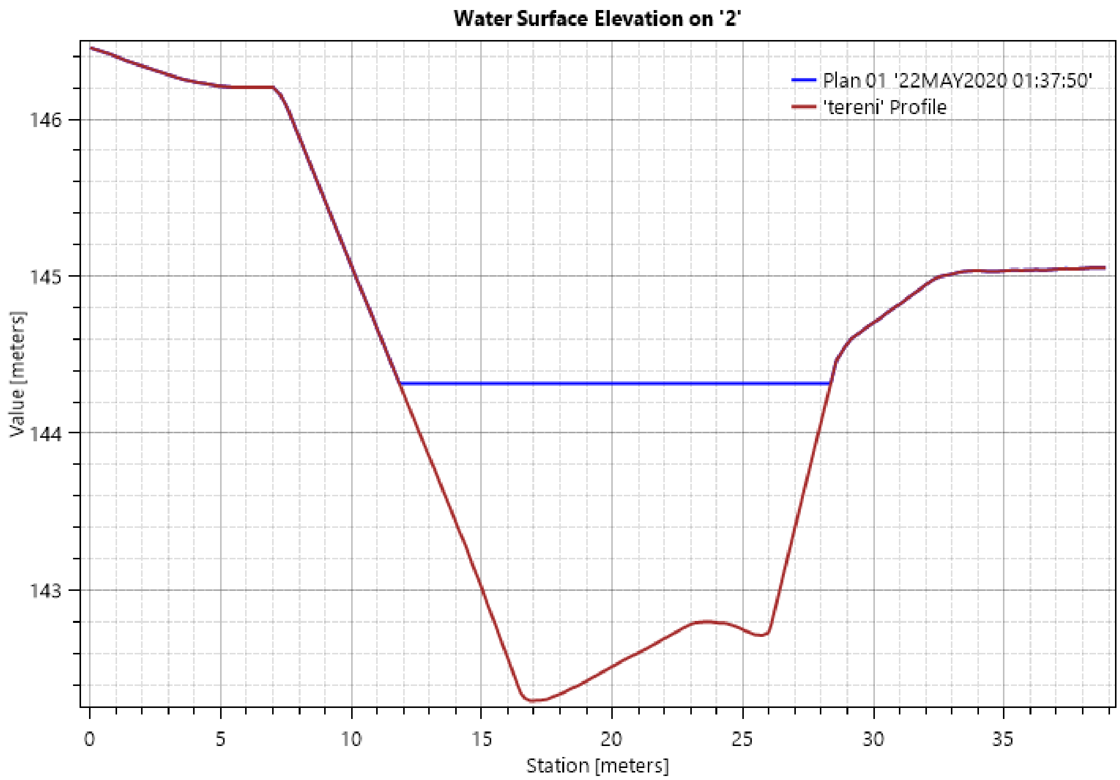


Figure 39. Water Surface Elevation Section 2, Variant 2, 2-Dimensional Model

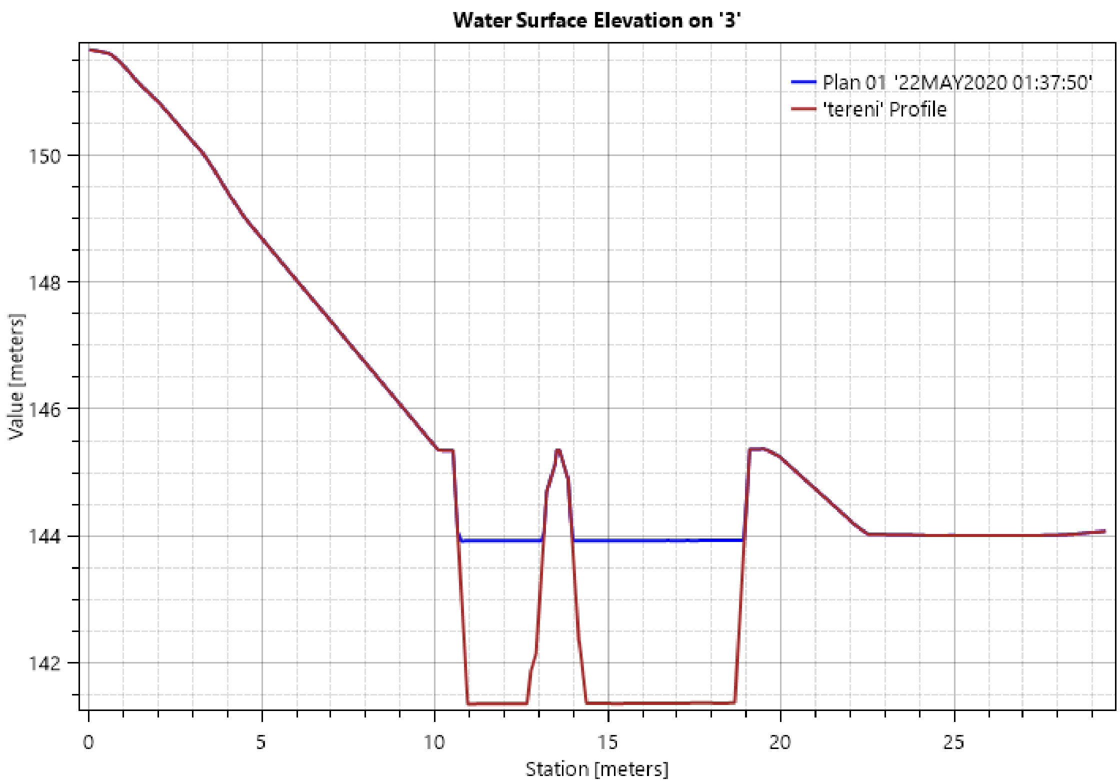


Figure 40. Water Surface Elevation Section 3, Variant 2, 2-Dimensional Model

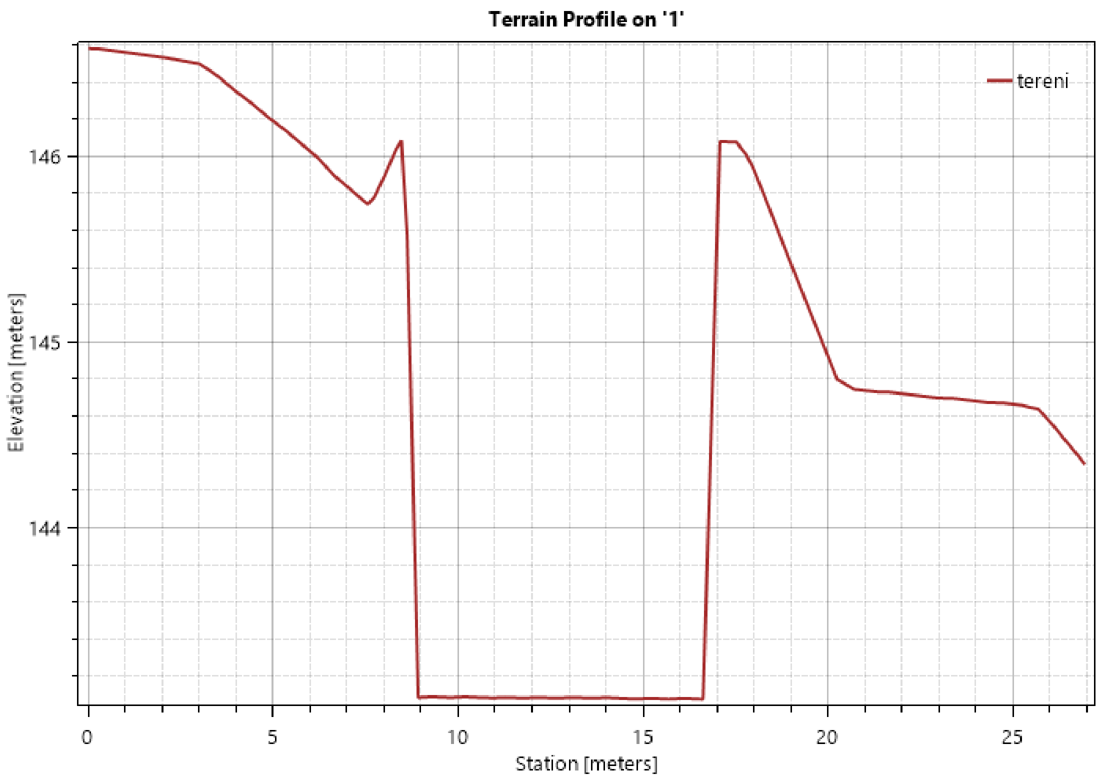


Figure 41. Terrain Profile Section 1, Variant 2, 2-Dimensional Model

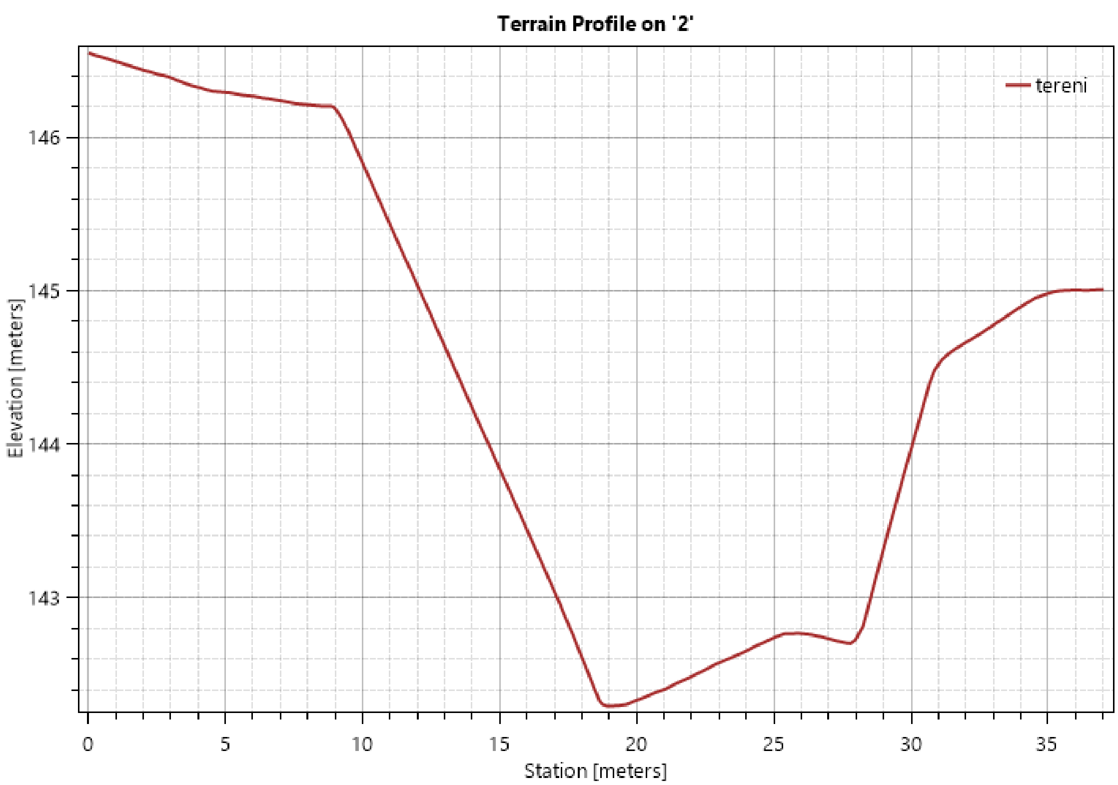


Figure 42. Terrain Profile Section 2, Variant 2, 2-Dimensional Model

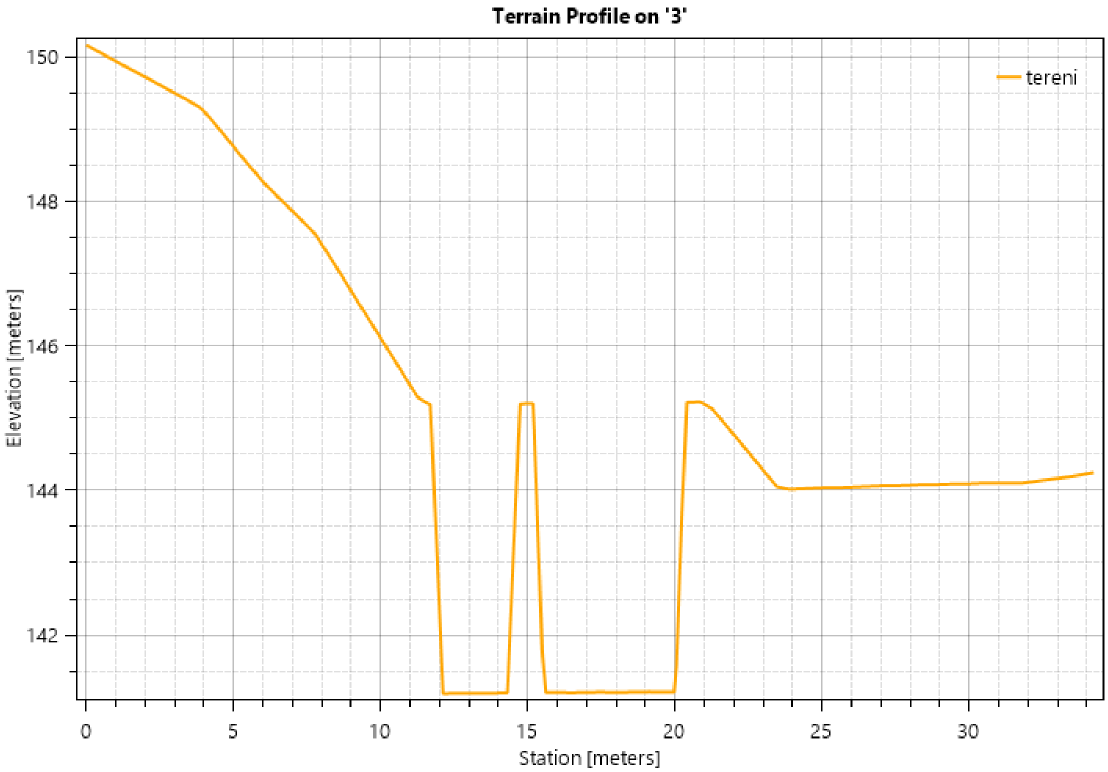


Figure 43. Terrain Profile Section 3, Variant 2, 2-Dimensional Model

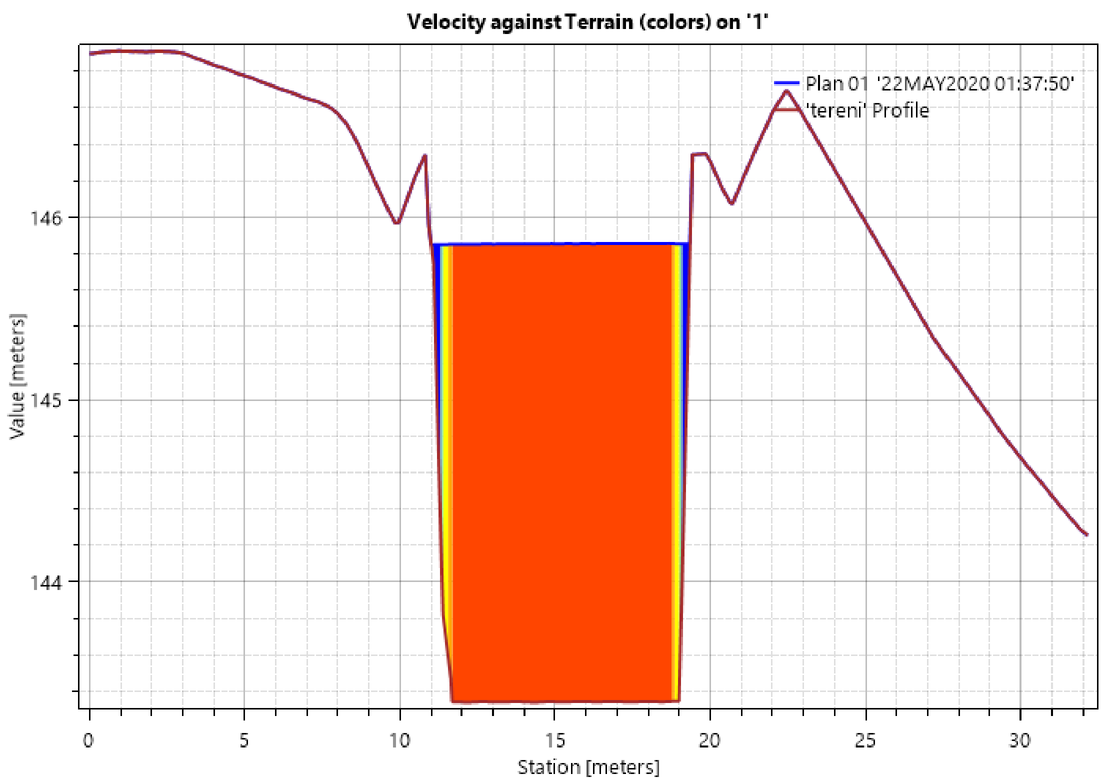


Figure 44. Velocity Against Terrain Section 1, Variant 2, 2-Dimensional Model

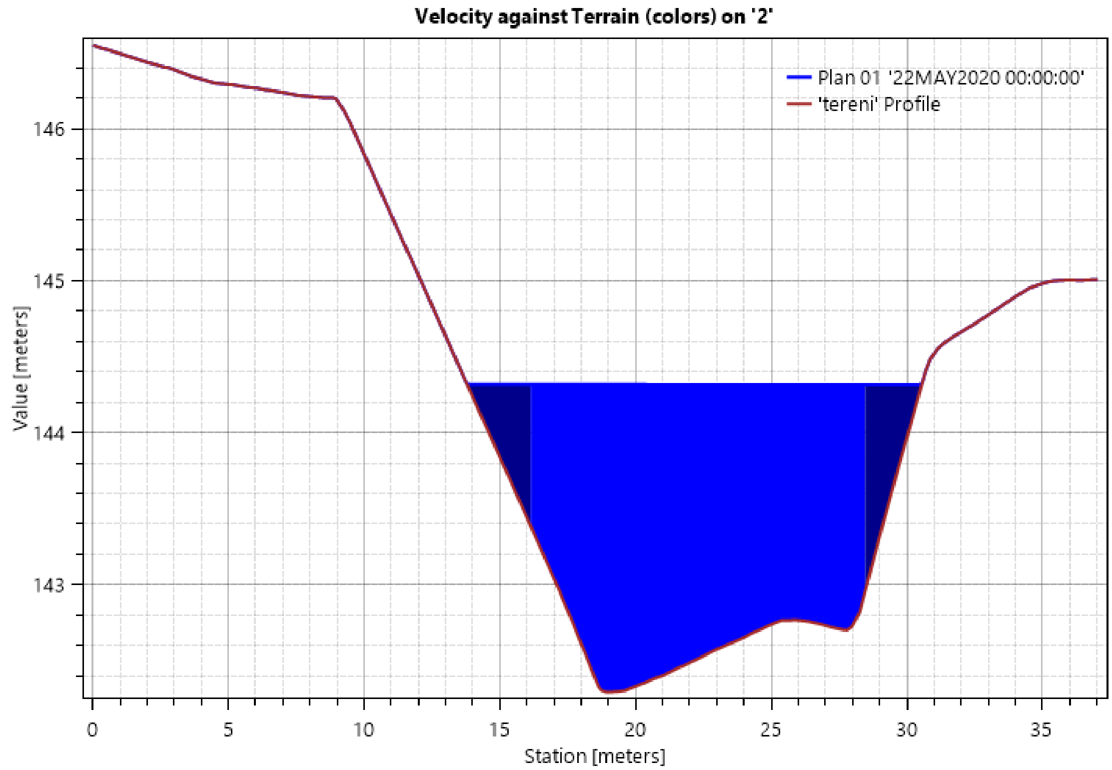


Figure 45. Velocity Against Terrain Section 2, Variant 2, 2-Dimensional Model

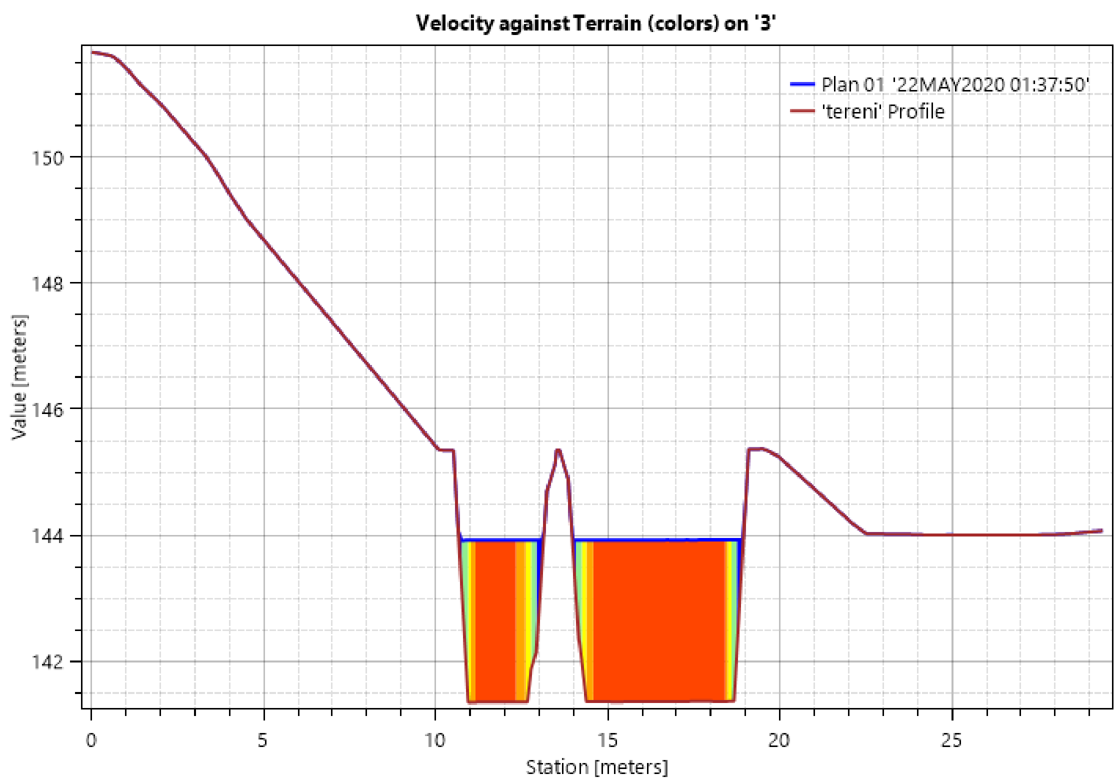


Figure 46. Velocity Against Terrain Section 3, Variant 2, 2-Dimensional Model

5.1.3 Hydraulic simulation results case 3 of 2-dimensional model

In order to study whether the flow will inundate the rehabilitated channel it is important to carefully interpret the results obtained from the simulations. Water depth planimetry represents the distribution of water into the channel and the areas nearby it, visualizes if the water inundated the area or not.

Moreover, to create a better idea of water distribution and flow, two segments are defined on each corresponding stream of the channel and for each segment there are obtained results corresponding to flow capacity, water surface elevation, terrain and velocity against terrain.

The simulation is developed based on maximum water flow 240m^3/s which occurs 1 in 100 years, generated from the hydrological study.

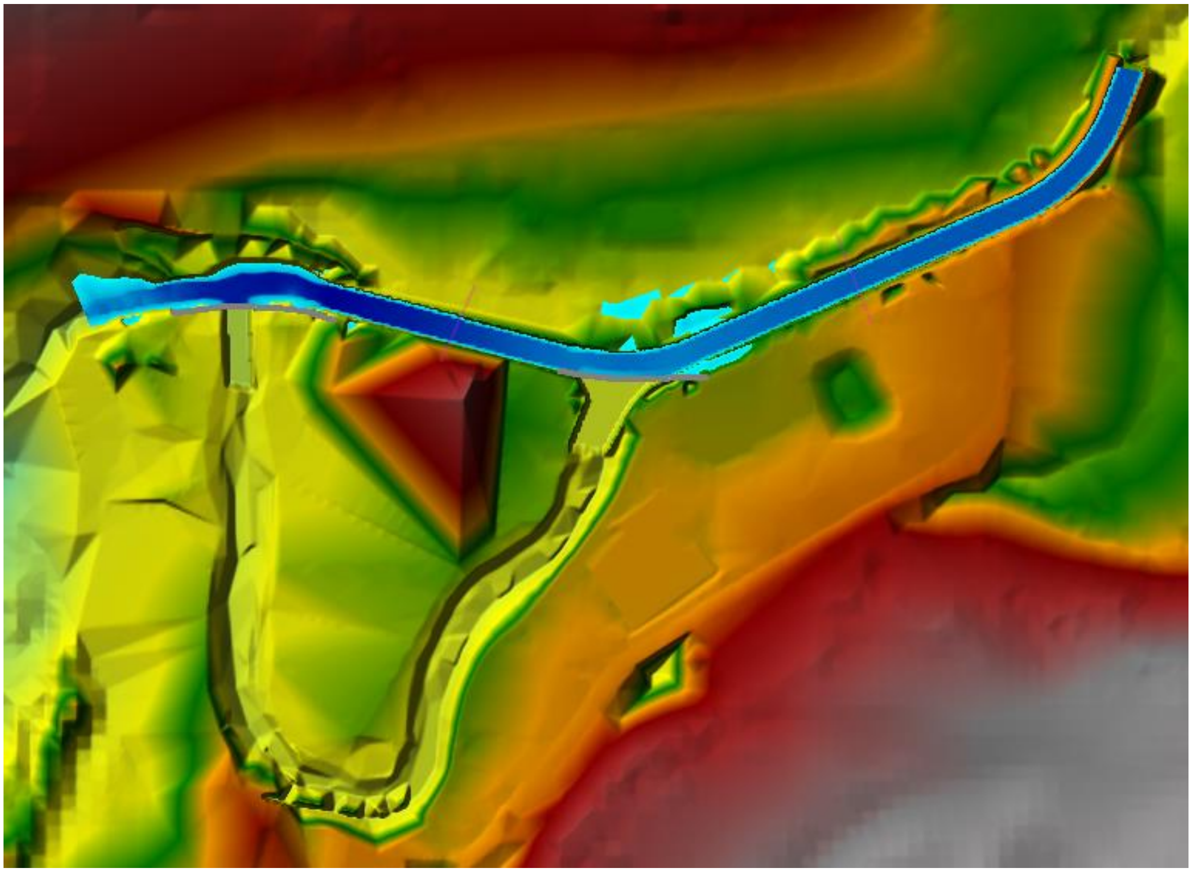


Figure 47. Water Depth Planimetry, Variant 3, 2-Dimensional Model

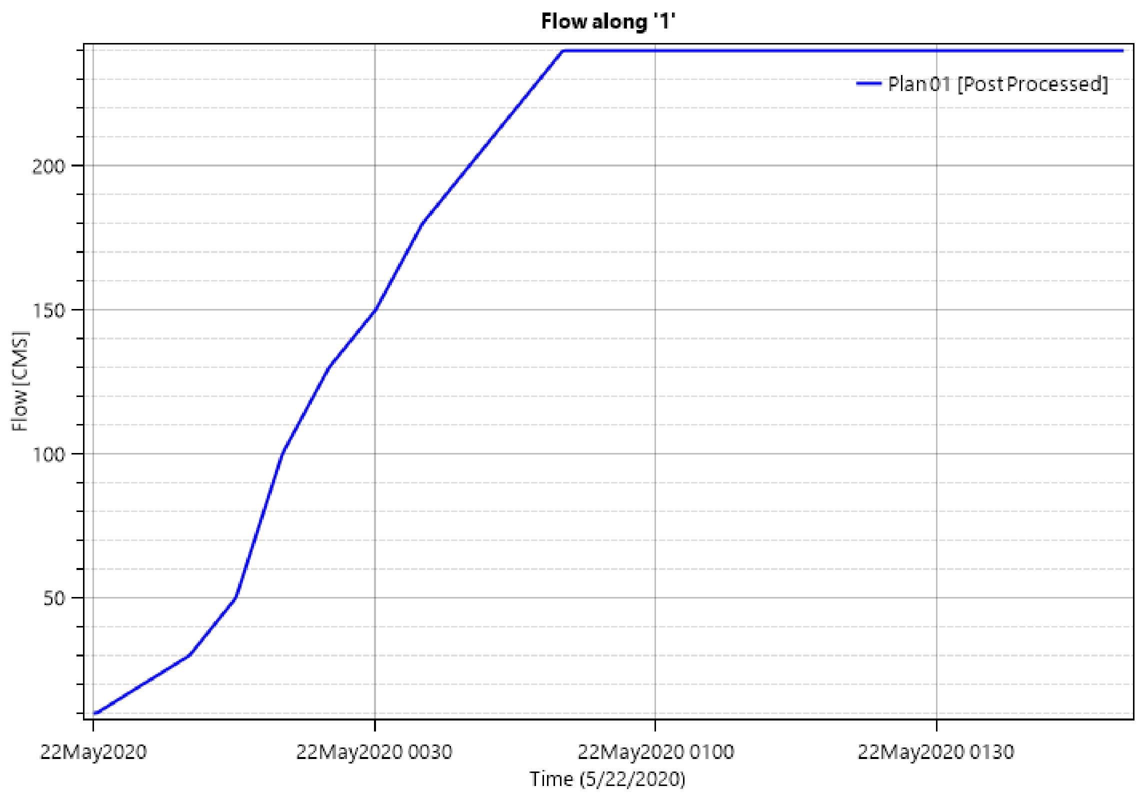


Figure 48. Flow Along Section 1 Q=240 m^3/s, Variant 3, 2-Dimensional Model

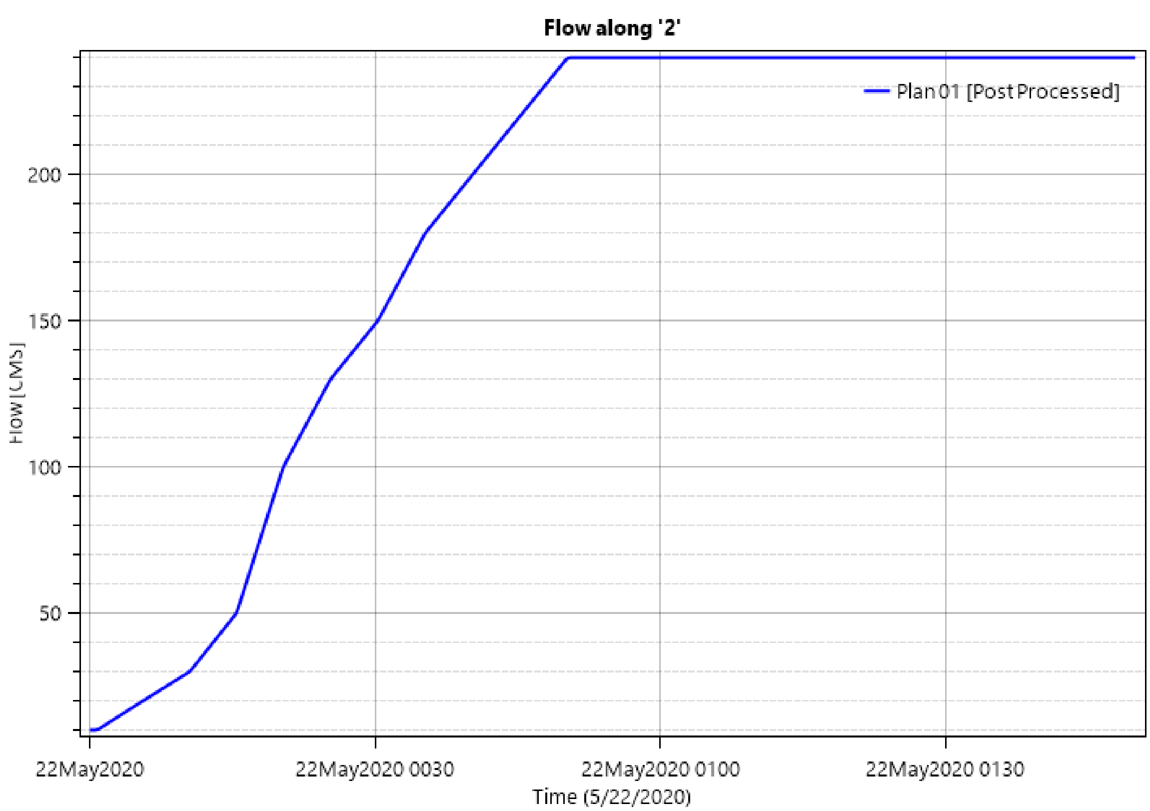


Figure 49. Flow Along Section 2 Q=240 m^3/s, Variant 3, 2-Dimensional Model

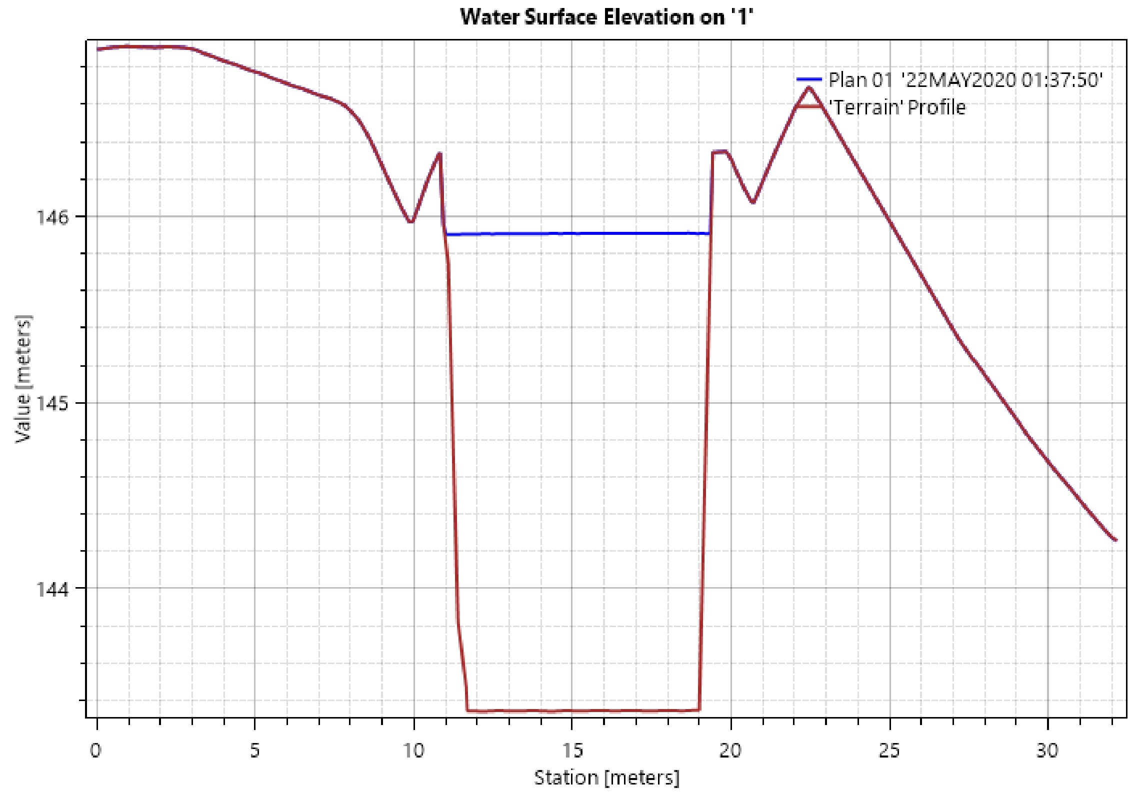


Figure 50. Water Surface Elevation Section 1, Variant 3, 2-Dimensional Model

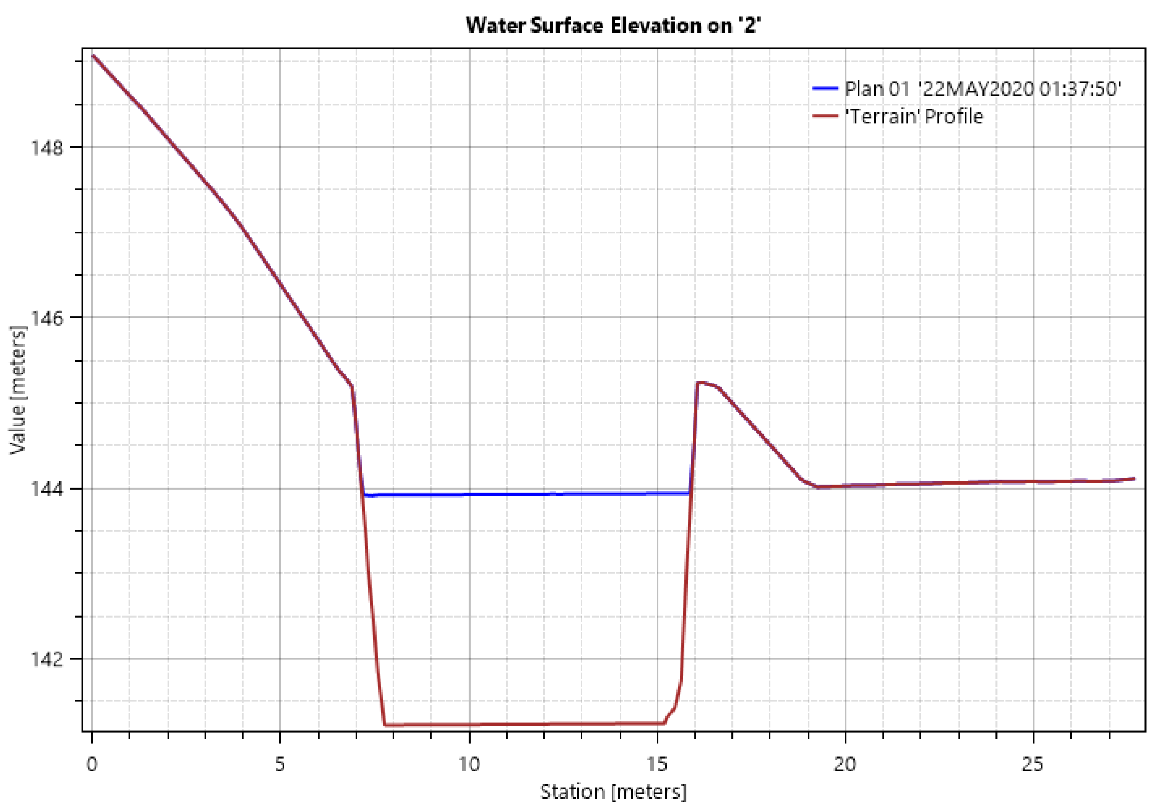


Figure 51. Water Surface Elevation Section 2, Variant 3, 2-Dimensional Model

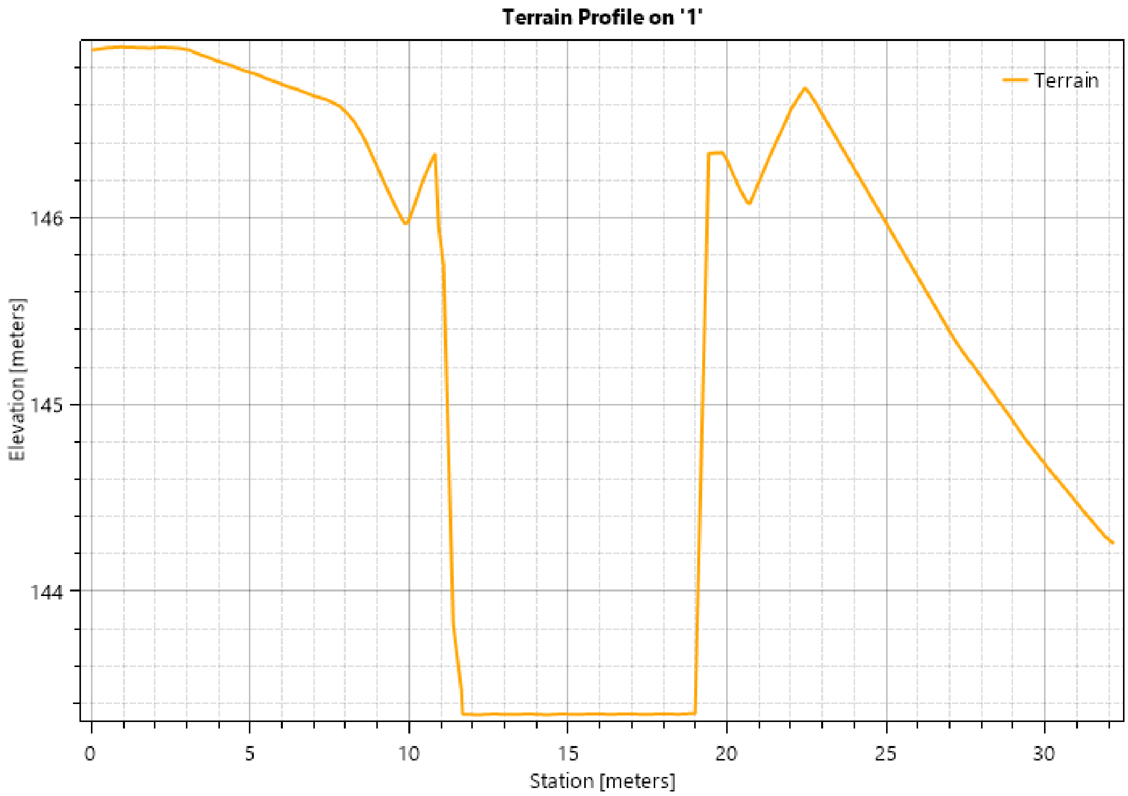


Figure 52. Terrain Profile Section 1, Variant 3, 2-Dimensional Model

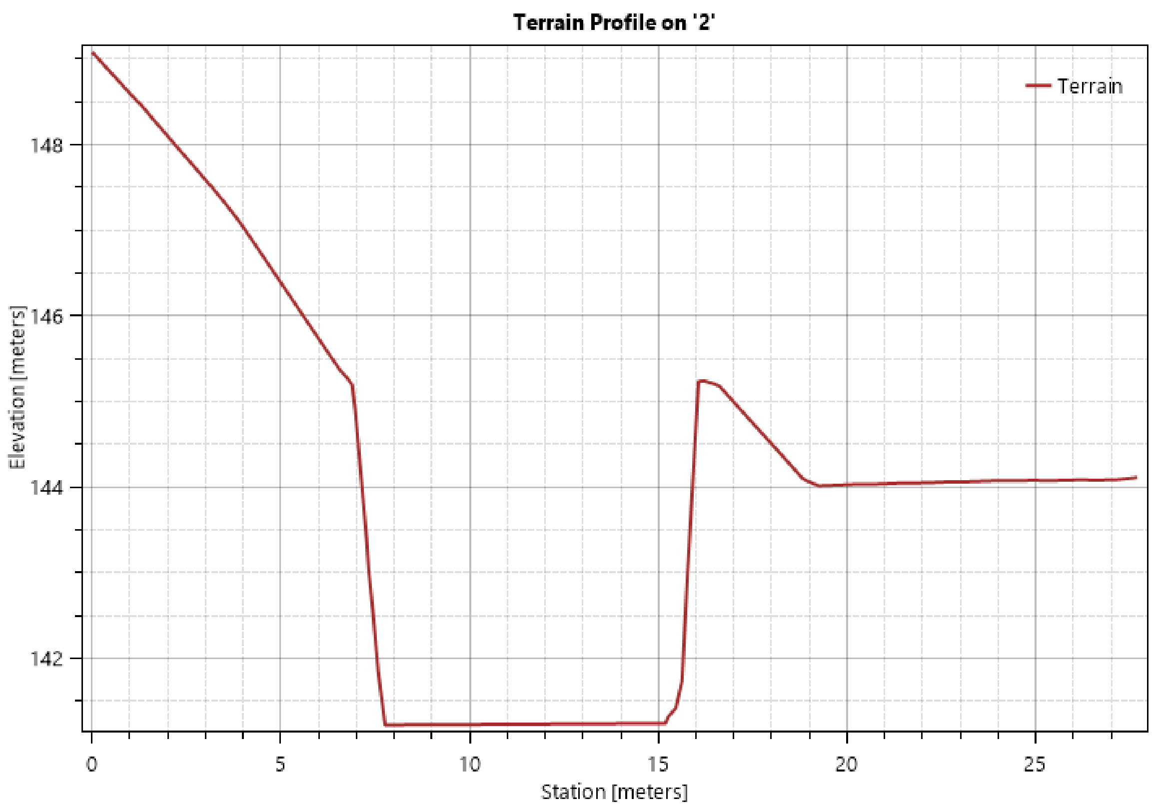


Figure 53. Terrain Profile Section 2, Variant 3, 2-Dimensional Model

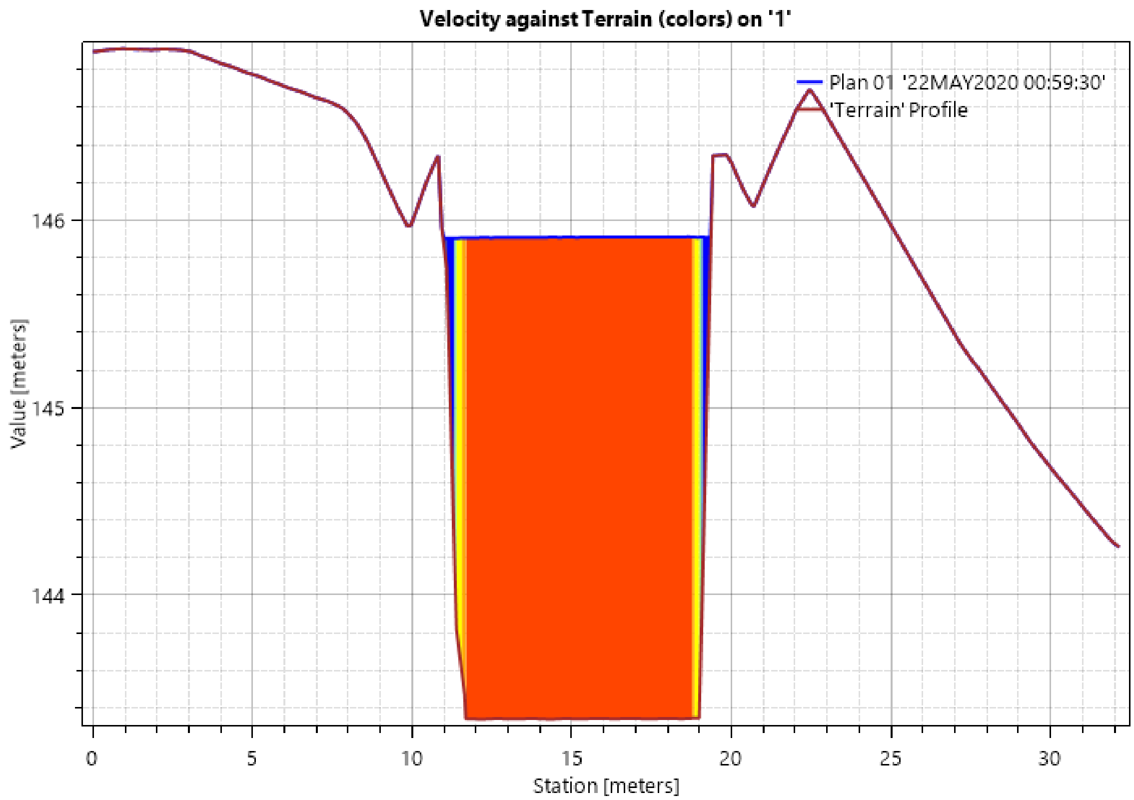


Figure 54. Velocity Against Terrain Section 1, Variant 3, 2-Dimensional Model

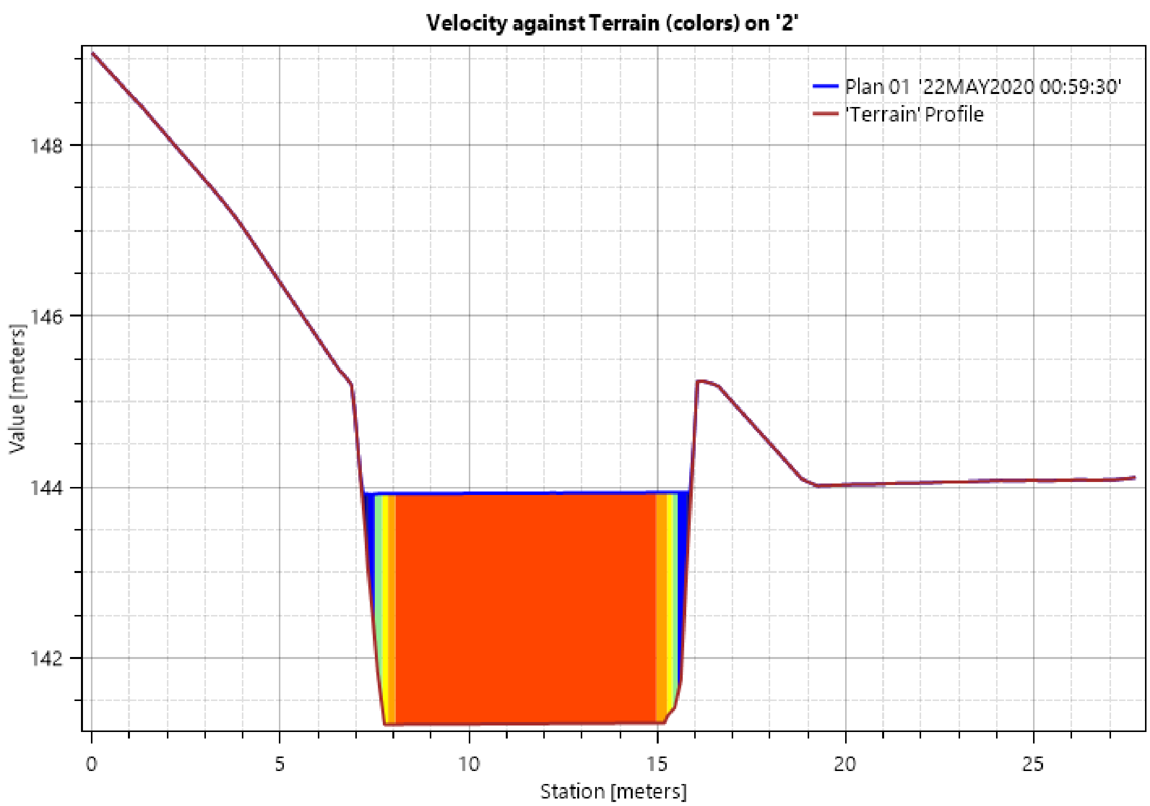


Figure 55. Velocity Against Terrain Section 2, Variant 3, 2-Dimensional Model

5.1.4 Hydraulic simulation results case 1, 1-dimensional model

Visualization of results, obtained from unsteady flow simulation, to define flow distriution among junctions, requires generation of flow versus time graphs also known as Hydrographs. Four segments, three of which corresponds to exact location of respective segments on 2-dimensional model, are defined as water flow monitoring points.

Furthermore, in order to study whether the flow will inundate the rehabilitated stream, water depth planimetry will be generated as a representation of water distribution into stream.

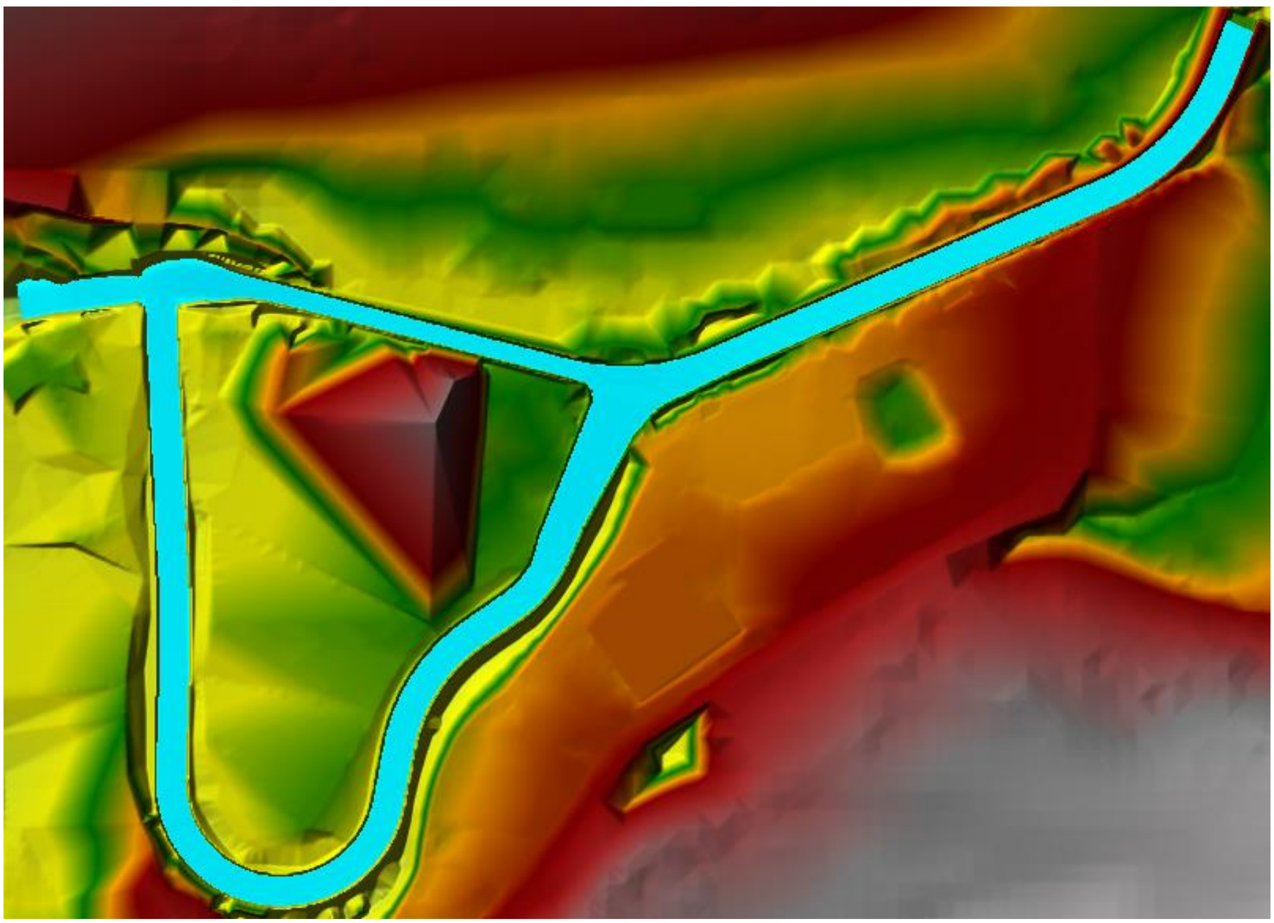


Figure 56. Water Depth Planimetry, Variant 1, 1-Dimensional Model

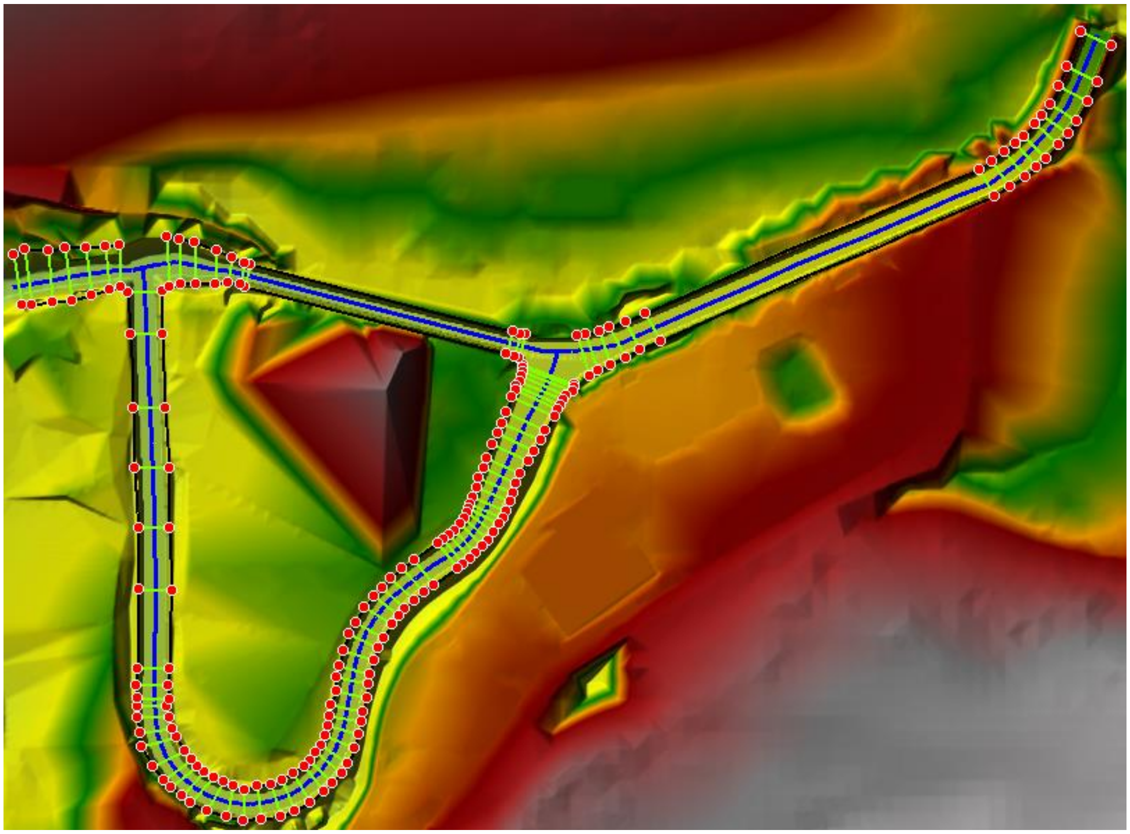
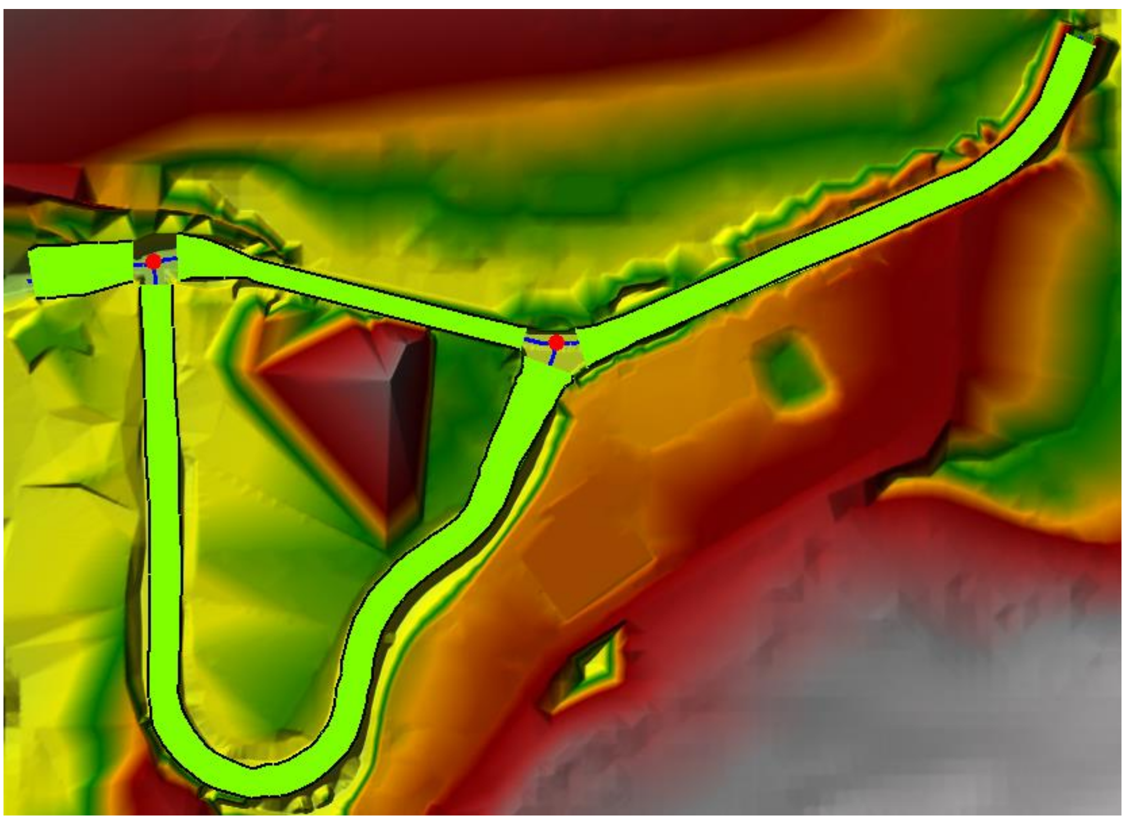


Figure 57. & Figure 58. Cross Section Geometry & Interpolation Variant 1, 1-D Model



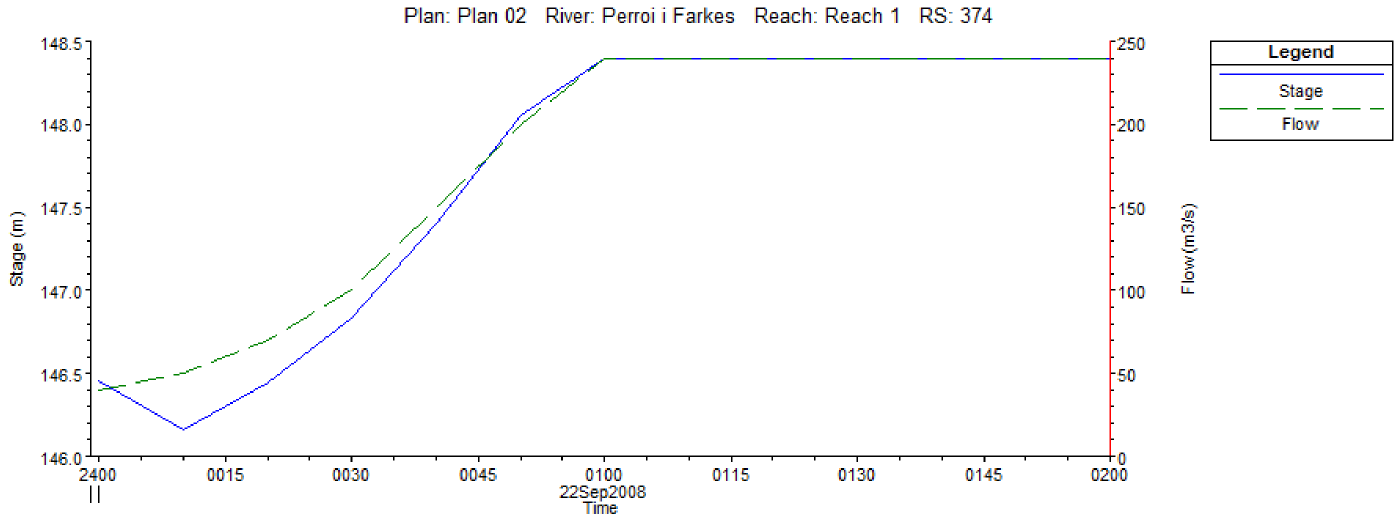


Figure 59. Stage & Flow Hydrograph, Q=240m^3/s, Section 1, 1-Dimensional Model (Variant 1)

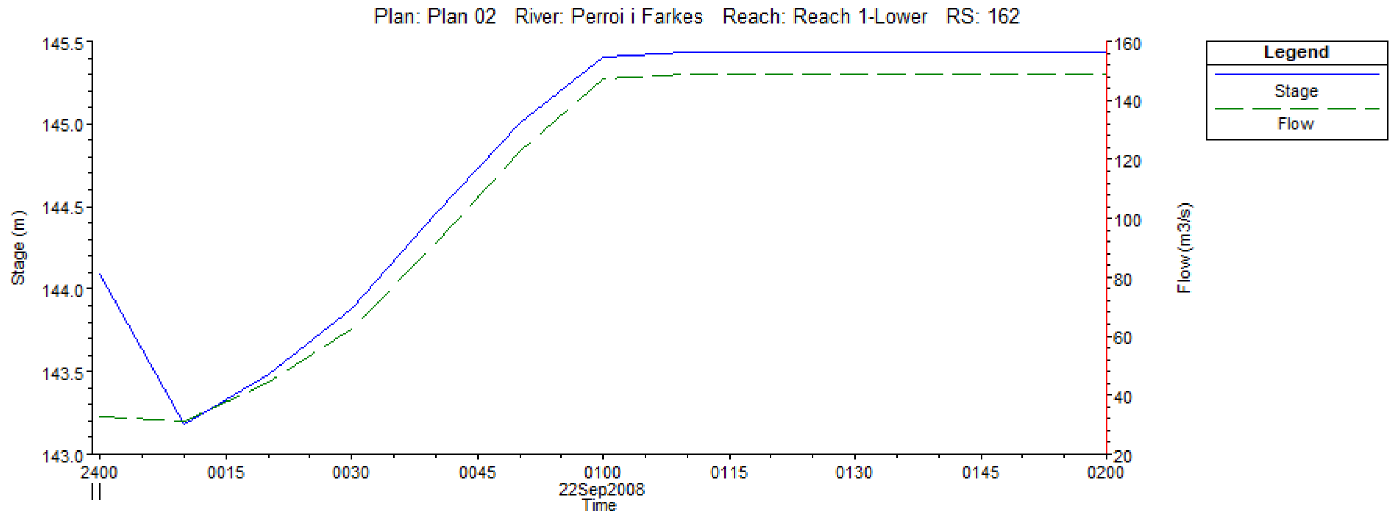


Figure 60. Stage & Flow Hydrograph, Q=149.09m^3/s, Section 3, 1-Dimensional Model (Variant 1)

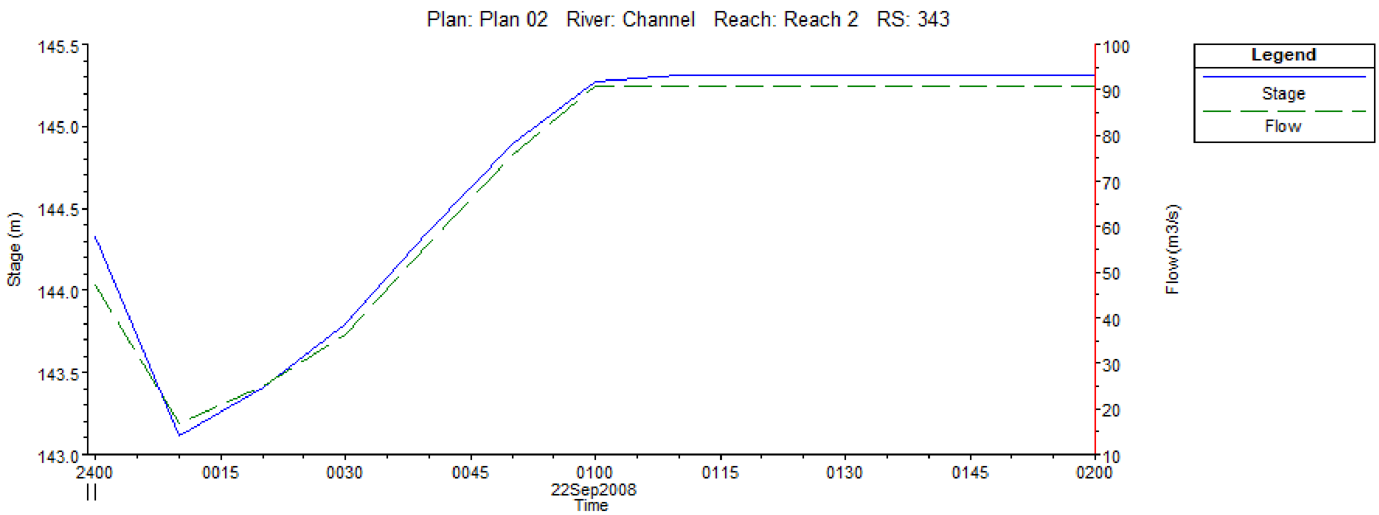


Figure 61. Stage & Flow Hydrograph, Q=90.91m^3/s, Section 2, 1-Dimensional Model (Variant 1)

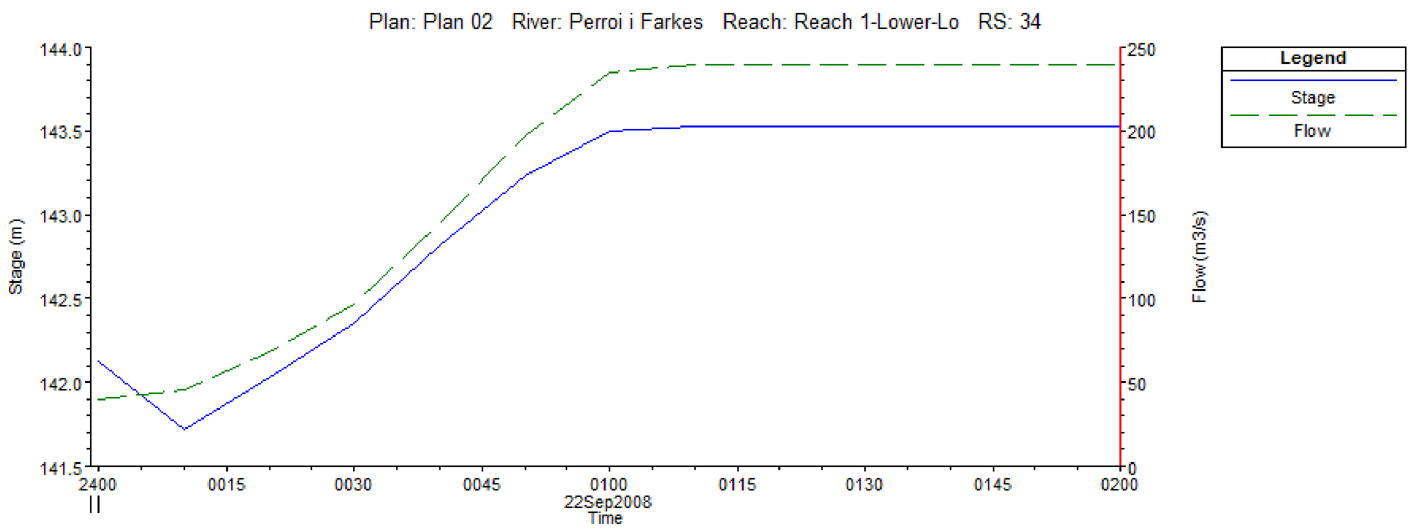


Figure 62. Stage & Flow Hydrograph, Q=240m^3/s, Section 4, 1-Dimensional Model (Variant 1)

Section	1D Maximum Q m^3/s	2D Maximum Q m^3/s	Difference
1	240	240	0
2	90.91	112.3	21.39
3	149.09	127.7	-21.39
4	240	240	0
		Maximum Difference	21.39

Table 1. Flow on Respective Sections of 1D&2D Models, Variant 1

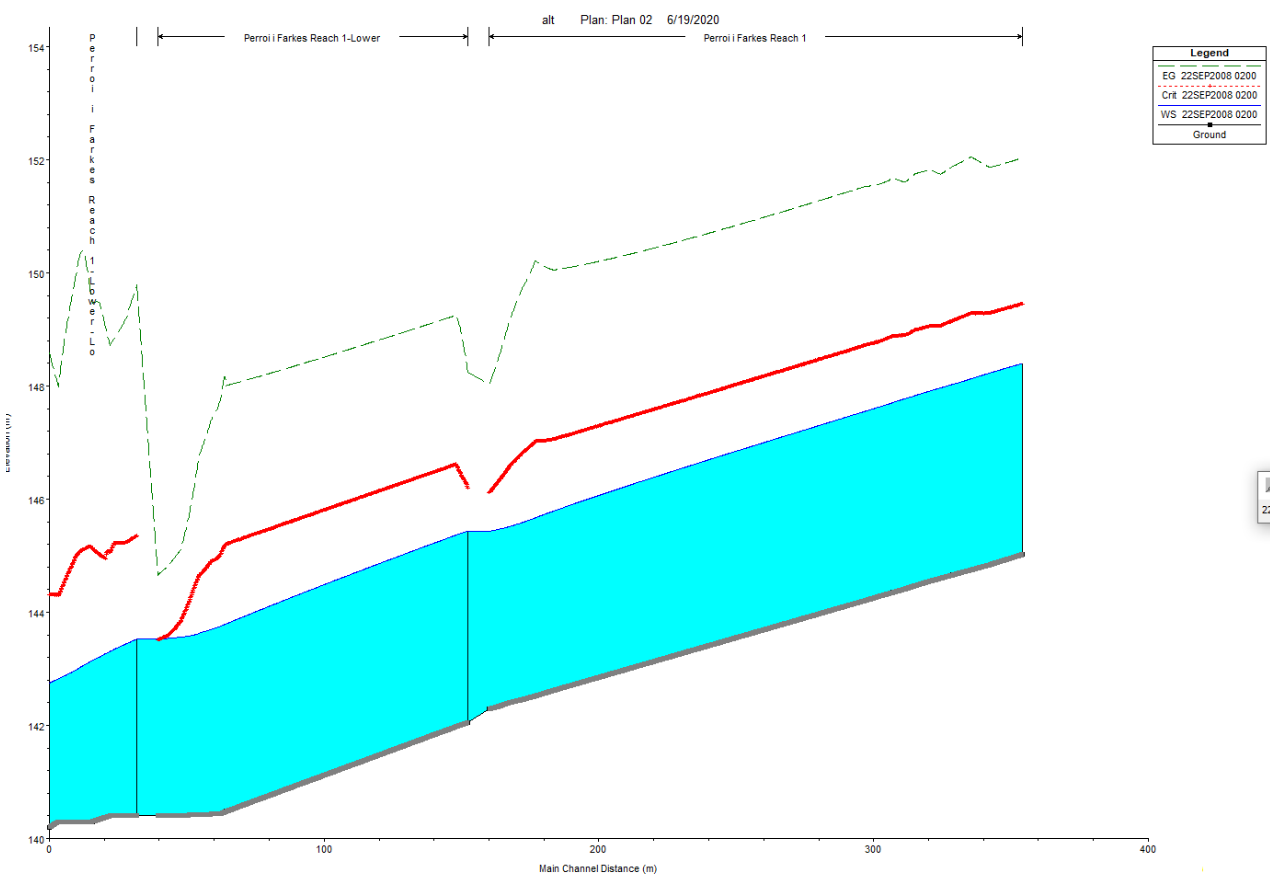


Figure 63. Profile Plot of Farka Stream, 1-Dimensional Model (Variant 1)

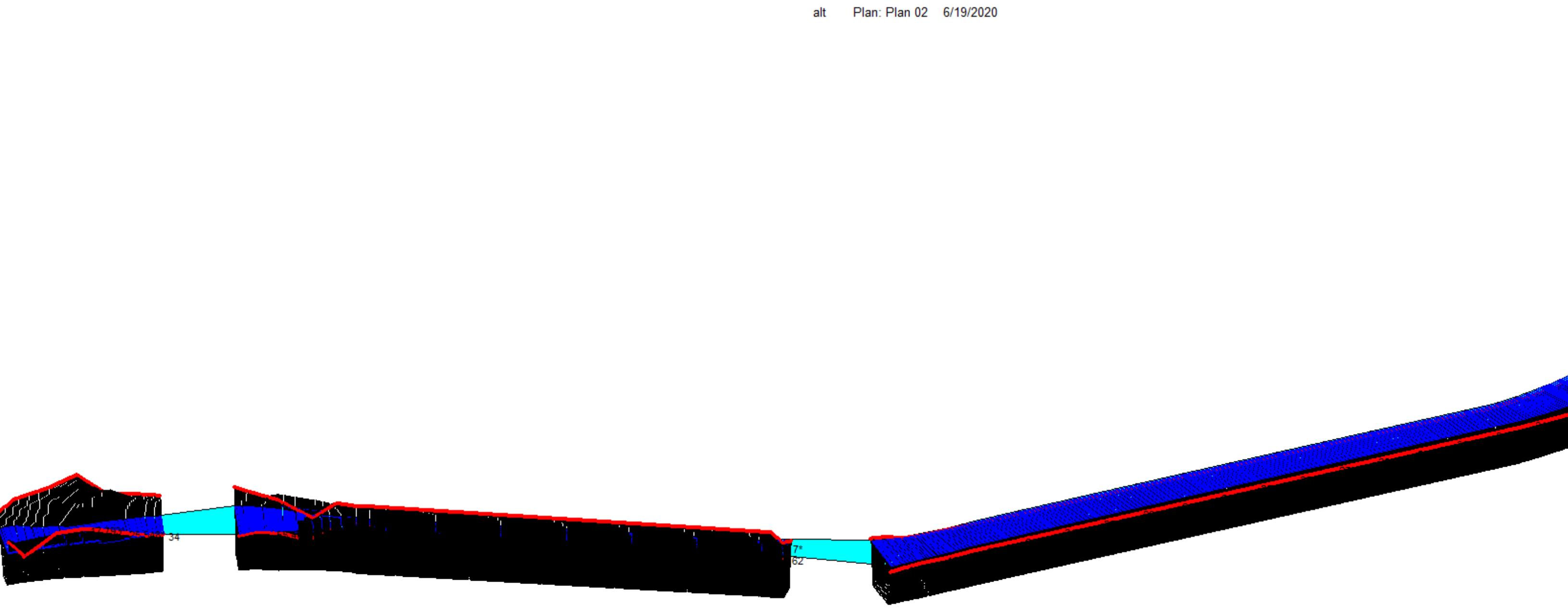
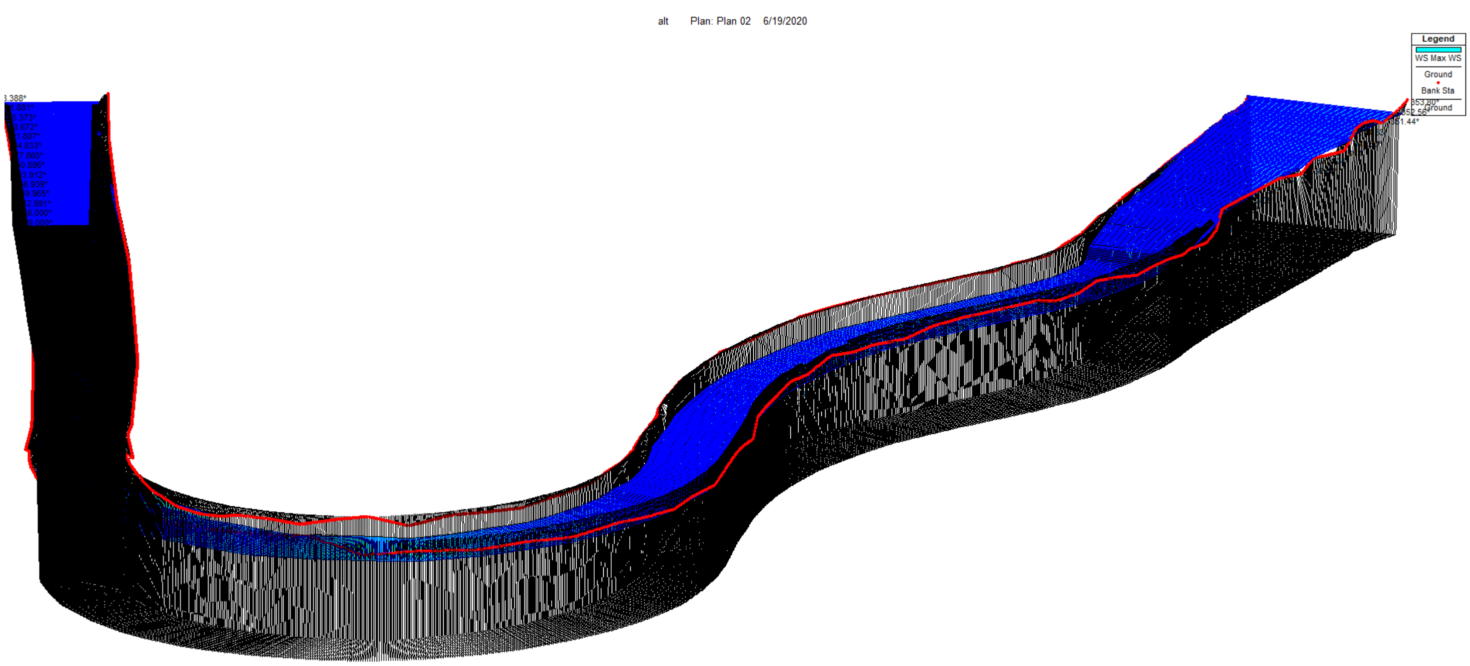


Figure 64. & Figure 65. 3D Plot of Farka Stream & Channel1-Dimensional Model (Variant 1)



5.2 Interpretations of results

5.2.1 Water Depth Planimetry, Flow Capacity, Water Surface Elevation Results

Initiating with, Water Depth Planimetry, Figure 21 (Figure 21), Figure 34 (Figure 34) and Figure 47 (Figure 47), it can be said that for all of three 2-dimensional proposed cases of rehabilitation, the area around Farka Stream is no longer inundated. This means that the proposed rehabilitation cases provide sufficient conditions for the maximum water flow to be correctly distributed along the stream and to flow within the bad stream.

Considering flow capacity, Figure 22 (Figure 22), Figure 23 (Figure 23), Figure 24 (Figure 24), Figure 35 (Figure 35), Figure 36 (Figure 36), Figure 37 (Figure 37), Figure 48 (Figure 48) and Figure 49 (Figure 49), it can be mentioned that flow distribution is strongly affected and depends on the stream condition. All cases are developed based on the same maximum discharge Q=240 m^3/s but, its dispersion is not the same for all of them, it differs.

Starting with Case 1, Figure 22 (Figure 22), Figure 23 (Figure 23) and Figure 24 (Figure 24), the primary water stream corresponding to segment 1 has a discharge of Q=240 m^3/s, maximum discharge. This segment is reconstructed with a rectangular cross section BXH=8x3m. From this segment the water flow is reorganized, in segment 2 and segment 3 where the flow distribution is Q=127.7m^3/s and Q=112.3m^3/s respectively. Even thought, segment 2 has the same cross section as segment 1 the flow will not be the same in both of them. Segment 3, where a culvert of dimensions BxH=5x3m, will provide a stream with optimal conditions for the water to flow there. In all three segments of case 1, the water flow does not overcome the limits of each segment.

Case 2, Figure 35 (Figure 35), Figure 36 (Figure 36) and Figure 37 (Figure 37), following the same logic as case 1, initial stream corresponding to segment 1, reconstructed with a rectangular cross section BXH=8x3m has a discharge of Q=240 m^3/s, maximum discharge. From this segment the water flow is rearranged, in segment 2 and segment 3 where the flow distribution is Q=58.6m^3/s and Q=181.6 m^3/s respectively. In this case the flow of water in segment 2 is smaller compared to the same segment in case one because in this case a trapezoidal channel is constructed. Its flow capacity is considerably smaller than the rectangular cross section of case 1. On the other hand, in segment 3 the flow capacity is increased compared to the same segment on case 1, because an addition culvert is constructed near the existing one. In all three segments of case 2, the water flow does not overcome the limits of each segment.

Case 3, Figure 48 (Figure 48) and Figure 49 (Figure 49), segment 1 and 3 have the same water flow Q=240 m^3/s, these two segments are constructed in the same rectangular cross section as in segment 1 of case 1.While the flow in segment 2 is equal to zero, because a wall is constructed to prevent the flow of water from segment 1 to segment 2. In two segments of case four, the flow of water does not overcome the limits so, the areas nearby do not flood.

Furthermore, taking into consideration the Water Surface Elevation, Figure 25 (Figure 25), Figure 26 (Figure 26), Figure 27 (Figure 27), Figure 38 (Figure 38), Figure 39 (Figure 39), Figure 40 (Figure 40), Figure 50 (Figure 50) and Figure 51 (Figure 51), it is important to point out that, in all cases, in all segments of the respective cases, the water level does not overcome the banks of the stream. This means that, under the boundary conditions of the maximum flood taken into consideration in this study, the area around Farka stream does not experience flooding.

5.2.2 Velocity Against Terrain

Stream velocity, water speed on a stream measured in distance per time, has a huge impact on the bed stream conditions. In optimal conditions, water velocity on a stream is higher in the center, near the surface and it reduces near the stream banks and bed due to friction forces action on water particles. Velocity fluctuation, increase or decrease, may cause erosion or soil deposition on the stream. Both of these natural phenomena, under uncontrolled conditions, may negatively affect the stream by causing damages that may assist the progress of flooding.

By interpreting Velocity Against Terrain, Figure 31 (Figure 31), Figure 33 (Figure 33), Figure 44 (Figure 44), Figure 46 (Figure 46), Figure 54 (Figure 54) and Figure 55 (Figure 55), it can be mentioned that for all cases, in their dominant respective segment, the velocity tends to have a higher value near the midstream and the velocity is reduced near stream banks. According to graphs, streams banks on the corresponding segments seems not to suffer from erosion, but stream bad in favorable conditions may experience erosion, due to the higher values of velocity.

On the other hand, considering Velocity Against Terrain Graphs, Figure 32 (Figure 32) and Figure 45 (Figure 45), it can be pointed out that in all directions, stream center, surface, stream bed and banks, velocity is characterized by normal to low values. On these segments, there is no possibilities for erosion to occur, but on favorable condition soil deposition may take place.

5.2.3 Water Depth Planimetry and Flow Hydrograph 1-dimensional model of variant 1

As is was mentioned above in presented thesis, 1-dimensional model was set up only for variant one of stream rehabilitation. The idea behind this remodeling was, to interpret water distribution along stream for both models 1 and 2-dimensional.

Frist of all, water depth planimetry, Figure 56 (Figure 56), shows that, variant 1 of rehabilitation provides optimal conditions for water to flow on the stream without causing flooding of the area. The result generated from 1-dimensional model, Figure 56 (Figure 56), is similar to water depth planimetry received from 2-dimensional model, Figure 21 (Figure 21). In both cases, the area, under the specified conditions is not inundated.

Continuing with, Flow Hydrograph, Figure 59 (Figure 59), Figure 60 (Figure 60), Figure 61 (Figure 61) and Figure 62 (Figure 62), the primary water stream known as ‘Reach1’, Figure 59 (Figure 59), corresponding to segment 1 has a discharge of Q=240 m^3/s, maximum discharge. This segment is reconstructed with a rectangular cross section BXH=8x3m. This segment ends into a split junction that reorganizes water flow into, ‘Reach 2’ corresponding to segment 2, Figure 61 (Figure 61), and ‘Reach 1-Lower’corresponding to segment 3, Figure 60 (Figure 60), where the flow distribution is Q=90.91m^3/s and Q=149.09m^3/s respectively. Even thought, segment 2 has the same cross section as segment 1 the flow will not be the same in both of them. Segment 3, where a culvert of dimensions BxH=5x3m, will provide a stream with optimal conditions for the water to flow there. Segment 2 and 3 will ends into a combined junction which their flow into segment four denoted as ‘Reach1-Lower-Lo’. This segment, Figure 62 (Figure 62), has a discharge of Q=240 m^3/s, maximum discharge.

In this model, water flow distribution, Figure 59 (Figure 59), Figure 60 (Figure 60), Figure 61 (Figure 61) and Figure 62 (Figure 62),, is not as consistent as in 2-dimensional model, Figure 22 (Figure 22), Figure 23 (Figure 23) and Figure 24 (Figure 24). Comparing both models, segment 2 and 3 differs with ± 21.39 m^3/s flow capacity, Table1 (Table 1).

CHAPTER 6

CONCLUSIONS

6.1 Conclusions

In the presented thesis, hydraulic analysis is provided to propose a solution for Farka Stream rehabilitation in order to prevent flooding of the area also, hydraulic analysis is used as base for comparison of 1-dimensional and 2-dimensional models. Three 2-dimensional HEC RAS model have been established in order to simulate unsteady flow analysis, to define water distribution along the stream on specific respective rehabilitation options. Furthermore, 1-dimensional model has been developed, under the same boundary conditions as 2-dimensional model, to simulate unsteady flow analysis. These two models are compared to each other, in terms of water distribution along stream.

The results obtained from, three 2-dimensional proposed cases of rehabilitation, suggests that, all cases protect the area from flooding and improves the flow of water into Farka stream. Based on performed hydraulic analysis, all proposed cases are valid for application. They are some other factors, important ones that defines the selection of the most convenient scenario. These factors include, rehabilitation period, available resources and economic condition.

Moreover, results obtained from 1-dimensional model of case 1 of rehabilitation, does not align with results obtained from 2-dimensional model of the same scenario. Two modeling approaches show that, under the same boundary conditions, the proposed rehabilitation case offers valid conditions to prevent flooding of the area around Farka stream. But, on the other hand, the flow distribution along streams changes for both models.

1-Dimensoional and 2-dimensional HEC-RAS models, can both be efficiently used for flood mitigation. However, selection of appropriate model strongly depends on project aim. Further studies are required to be conducted in order to clearly define project characteristic linking it to the most realistic modeling approach.

6.2 Recommendations

The following highlighted components, may markedly boost the accuracy of presented thesis, serving as strong foundation for potential researches:

1. Intense topographical data: Topographical data of the region are the bases of model set up. The higher the accuracy of collected data the higher will be the validation of results obtained from simulation. It is crucial to perform a concentrated topographical investigation, before modeling for better model selection and more realistic results.
2. Coupled 1D-2D model. Different locations of the stream, provides different conditions, related to topographical data, composed earthing materials etc. It is important to verify each section of the river and to select the appropriate model for that section. A combination of 1D-2D HEC-RAS model could be a valuable approach, while considering flood modeling, in order to interpret results authenticity.

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