Protocol about delivered software tools

Assessment of Suitable Flood Mitigation Measures (based on Dukniskhevi River Extreme Flood Analysis) in Tbilisi, Georgia

CTCN REFERENCE NUMBER: 2016000043
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1. Introduction

The main objective of this consultancy is to improve the flood risk management in the Leghvtakhevi River basin in Tbilisi (Georgia). This will be accomplished through the implementation of a modelling framework, the inclusion of climate change impacts, the definition of flood maps and the designation of flood mitigation and adaptation measures. Capacity building and technological transfer activities will be undertaken too, and will be at the core of the project.

This consultancy started in August 2017 and it is due to finish in August 2018 (duration of 12 months). The contract between UNIDO and HYDROC was signed on the 14th of August 2017.

This technical assistance is managed by the CTC-N, the National Designated Entity is the Ministry of Environment and Natural Resources Protection of Georgia, while key stakeholders are the National Environmental Agency (request applicant), the Tbilisi Municipality and the Emergency Management Agency under the Ministry of Internal Affairs.

This report will describe all the software provided to the stakeholders during this assignment and also protocols about the use of this software.

2. Delivered Software Tools

Capacity building and knowledge transfer is a core component of the project “Assessment of Suitable Flood Mitigation Measures (based on Dukniskhevi River Extreme Flood Analysis) in Tbilisi, Georgia”. This includes the supply of and training on all software required to fulfil the project’s goals. All software has been handed over to the stakeholders during a two-week hydrological- and two-week hydraulic training. All attendees were thoroughly trained on the software, as presented in detail in the Training Report. The supplied software packages are listed in the following subchapters with their install file names, including information about what the software was used for throughout the project. All software is available free of charge and runs on Microsoft Windows operating systems.
2.1. Apache OpenOffice 4.1.5

The Apache OpenOffice program (https://www.openoffice.org/, file name: “Apache_OpenOffice_4.1.5_Win_x86_install_en-US.exe” in the supplied data (Annex)) was used to process and visualize tabular data of time series, spatial data, model results and to carry out gap-filling, replacing and correlation analysis (Figure 1). Similar software (LibreOffice (https://www.libreoffice.org/) or Microsoft Excel (https://www.office.com/) ) can also be used.

Data that can be used in Open Office includes all files with the extension .xlsx listed in the Annex. The software is operated on a user-friendly graphical user interface (GUI).

Figure 1. Correlation analysis carried out within OpenOffice 4.1.5
2.2. QGIS-OSGeo4W-3.0.2-1-Setup-x86_64.exe

The QGIS software (https://qgis.org/en/site/, File name: “” in the supplied data (Annex) QGIS-OSGeo4W-3.0.2-1-Setup-x86_64.exe) is an open source Geographical Information System that was used to prepare input data for HEC-HMS, visualize radar data, overlay model data with satellite images and extract spatial locations. QGIS can be extended through a variety of free extensions which cover a wide scope of spatial data analysis, visualization and modelling.

Supplied data that can be used in QGIS includes all files with the extension .tif, .shp, and .csv listed in the Annex (mostly within folder: “\Part_1\04_SpatialData_Processing”). The software is operated on a user-friendly GUI.

Figure 2. QGIS software with spatial data processed for the HEC-HMS model
2.3. ArcHydro

If users have the commercial ArcGIS software available, ArcHydro has been supplied to carry out hydrological analysis within the ArcGIS environment. (http://downloads.esri.com/archydro/archydro/Setup/10.3/10.3.0.168/ArcHydroTools10.3/, file name: “ArcHydroTools.msi” in the supplied data (Annex)).

The software must be installed and then activated under the ArcGIS “Customize – Toolbars” Menu (Figure 3). The ArcHydro tools include a rich set of functions for hydrological analysis based on Digital Elevation Models (DEM) to calculate hydrological characteristics like slopes, flow directions, flow accumulations, streams, subbasins, watersheds and related properties.

Supplied data that can be used in ArcHydro includes the DEM files with the extension .tif, in the folder “\Part_1\04_SpatialData_Processing“ listed in the Annex. The software is operated on a user-friendly GUI.

Figure 3. Arc Hydro Tools for hydrological analysis
2.4. HEC-GeoHMS

In order to prepare the HEC-HMS model data with ArcGIS, HEC-GeoHMS was supplied in two different versions for potential users of ArcGIS 10.2 and 10.3 versions (http://downloads.esri.com/archydro/HECGeoHMS/Setup10.3/10.3.0.6/, file name: “HEC-GeoHMS_10.2_Setup.msi and HECGeoHMS10.3.msi” in the supplied data (Annex)).

The software must be installed and then activated under the ArcGIS “Customize – Toolbars” Menu. The HEC-GeoHMS tools include the full set of functions to create a HEC-HMS model for the region of interest. The user has to operate subsequently through the shown menu options (Figure 4) and supply all relevant data and input decisions.

Supplied data that can be used in HEC-GeoHMS includes the grid and vector files with the extension .tif and .shp in the folder “\Part_1\04_SpatialData_Processing” listed in the Annex. The software is operated on a user-friendly GUI.

![Figure 4. HEC-GeoHMS GUI to prepare input data to HEC-HMS](image-url)
2.5. HEC-DSSVue

The US Army Corps of Engineers - Hydrologic Engineering Centre (USACE - HEC) has developed HEC-DSSVue (http://www.hec.usace.army.mil/software/hec-dssvue/, file name: “HEC-DSSVue_201_SelfExtracting.exe” in the supplied data (Annex)) for data storage, retrieval and exchange by HEC’s models and software. In the project, HEC-DSSVue was used to visualize, extract and store HEC-HMS model results. The software can be extended with scripting functions, defining spatial computation points where data is retrieved, summed, converted, visualized and exported. In addition, HEC-DSSVue is the connection software between HEC-HMS and HEC-RAS to access the .dss files.

The software must be installed and can then be used to open .dss files which are model output files of HEC-HMS (see .dss files in Annex) in a user-friendly GUI (Figure 5).

Figure 5. HEC-DSSVue main window and graphical editor to view and export time series data
2.6. HEC-HMS 4.2.1

The USACE’s major hydrologic modelling software is HEC-HMS (http://www.hec.usace.army.mil/software/hec-hms/, file name: “HEC-HMS_421_Setup.exe” in the supplied data (Annex)), of which version 4.2.1 was used in the project to simulate the runoff response to rainfall in the Leghvtakhevi and Vere catchments.

The model has a strong focus on flood modelling and engineering design (acknowledged by the Federal Emergency Management Agency, FEMA). It is a flexible software (multiple algorithms, continuous and event-based) and widely used due to constant development and excellent documentation and user groups (http://www.hec.usace.army.mil/software/hec-geohms, https://www.linkedin.com/groups/3863089, http://www.hec.usace.army.mil/software/hec-hms/documentation.aspx). It can be linked to other HEC models, e.g. HEC-RAS via the HEC-Data Storage System (DSS)

The software must be installed and can then be used to open supplied HEC-HMS models. These are .hms files, listed in the Annex, which are always part of multiple files contained in a folder. The whole folder that contains the .hms files needs to be copied and supplied in order to share the HEC-HMS model. The software is operated on a user-friendly GUI (Figure 6). Due to the complexity of the software, extensive experience and training is required for a successful application.
Figure 6. HEC-HMS with the Leghvtakhevi model
2.7. R

The statistical software R (https://www.r-project.org/, File name: “R-3.5.0-win.exe” in the supplied data (Annex)) is a powerful programming environment to carry out statistical computing and visualize data. In the project, it is used for the calculation of daily rainfall return periods. Similar to QGIS, the software can be extended by additional packages which greatly improves the capabilities of the software. Functionalities include the analysis of time series data, handling of large datasets for statistical computing as well as GIS-based functions to view and even modify spatial data.

The software must be installed, but is not user-friendly to operate without additional software, since it runs in a command-line style environment (Figure 7). Experienced users can use this environment to write commands to operate the software. However, the software is usually applied within an integrated development environment (IDE), such as R Studio.

![Figure 7. Run window of the software R](image-url)
2.8. RStudio

R Studio (https://www.rstudio.com/, File name: “RStudio-1.1.447.exe” in the supplied data (Annex)) is an integrated development environment (IDE) for R and is mainly used to write, run and debug R scripts in a user-friendly manner as well as to install additional R packages. The operation of R requires experience or training since all actions to be carried out by the software need to be defined in a scripting language. If an existing script is available, application is simpler, but requires knowledge of the statistical functions used.

The software needs to be installed together with R (Chapter 1.7) and supplied data that can be used in R Studio are .R files such as the script to calculate return period design events “\Part_1\02_Daily_PCP_Processing\ReturnPeriod.R”, listed in the Annex. The software is operated on a GUI which includes the main scripting window, the console that shows the direct R output (Figure 7), the variable types and values as well as a window where Plots, additional packages, help files and data viewer can be accessed (Figure 8).

Figure 8. Main window of the IDE R Studio for the statistical software R
2.9. Extract Radar Data Tool

This software tool was specifically developed by HYDROC for the project to read and convert the supplied Rainbow® radar data format to a precipitation time series to be used for HEC-HMS and to visualize every time step and vertical radar data slice in QGIS (file name: "extract_radar_rainbow_Compiled.exe" in the supplied data (Annex)). A script was developed in the Python programming language (https://www.python.org/) and compiled using PyInstaller (https://www.pyinstaller.org/). The script utilizes the additional Python software libraries Wradlib, an open source library to read weather radar data (https://wradlib.org/) and NumPy, the fundamental package to carry out scientific computing in Python (http://www.numpy.org/).

![Execution screen of the radar data extraction software](image)

Figure 9. Execution screen of the radar data extraction software
The software does not require installation and can be operated under Windows command line using keystroke inputs that need to be confirmed with “Return” (Figure 9).

The software requires a subfolder “RadarFiles” that contains the Rainbow® weather radar files with the extension .vol (see Annex, not all files are listed due to the large number of files).

The program can be run in two settings. First, to extract time series at a location. Therefore, a text file “ExtractionPointsRadar.txt” is required that contains latitude and longitude information of the locations where the data is to be extracted. The output is a time series that can be used in a spreadsheet software to disaggregate daily precipitation sums to sub-daily rainfall intensities (Figure 10):

![Figure 10. Five different radar disaggregation events read from the supplied radar data](image)

Second, the script can be run in a mode to extract the spatial distribution of the rainfall for each supplied radar file (=time step). The output is an ASCII file that can be plotted in standard GIS software (Figure 11):
Figure 11. Visualization of rainfall for one radar data time step, Leghvtakevi catchment in red
2.10. HEC-RAS 5.0.5.

The USACE’s major hydraulic modelling software package is HEC-HMS ("http://www.hec.usace.army.mil/software/hec-ras/downloads/HEC-RAS_505_Without_Examples_Setup.exe" in the supplied data (Annex)), of which version 5.0.5 was used in the project to route flows in the Lgehvtakhevi catchment.

The model has a strong focus on flood modelling and engineering design (acknowledged by Federal Emergency Management Agency, FEMA; and the Environment Agency of England and Wales). HEC-RAS is a 1D, 2D or 1D-2D hydraulic modelling software widely used and in constant development. There is an excellent documentation and several user groups for the software (http://www.hec.usace.army.mil/software/hec-ras/, http://hecrasmodel.blogspot.com/, http://www.hec.usace.army.mil/software/hec-ras/documentation.aspx, http://hec-ras-help.1091112.n5.nabble.com/, https://www.linkedin.com/groups/1908568/profile). It can be linked to other HEC models, e.g. HEC-HMS via the HEC-Data Storage System (DSS).

The software must be installed and can then be used to open supplied HEC-RAS models. These are HEC-RAS files (different file formats), listed in the Annex, which are always part of multiple files contained in a folder. The software is operated on a user-friendly GUI (Figure 6). Due to the complexity of the software, extensive experience and training is required for a successful application.

![Figure 12. HEC-RAS with the Lgehvtakhevi model](image-url)
2.11. DELFT-FEWS 2017.01

Delft-FEWS is being developed at Deltares, an independent Dutch institute for applied research in the field of water, subsurface and infrastructure, and it can be downloaded here (https://content.oss.deltares.nl/fews/executables/fews_basic_windows.zip). Delft-FEWS was used during training for forecasting purposes and it is used in NEA as a flood forecasting platform.

Delft-FEWS is an open data handling platform initially developed as a hydrological forecasting and warning system. Essentially it is a sophisticated collection of modules designed for building a hydrological forecasting system customised to the specific requirements of an individual organisation. Because of its unique characteristics concerning data importing and processing and model connections, Delft-FEWS has also been applied in a wide range of different operational situations. Examples are water quality forecasting, reservoir management, operational sewer management optimization, and even peat fire prediction.

Two times a year a new version of Delft-FEWS is released, containing new features and bug fixes. It has a forum and user group webpage (https://oss.deltares.nl/web/delft-fews/forum), and there is ample documentation available too (https://oss.deltares.nl/web/delft-fews/documents).

Delft-FEWS has a GUI (Figure 13) that is very friendly and were the data from the different linked stations and models can be analysed. Also, the information from the linked models results can be analysed.

Figure 13. Delft-FEWS interface
2.12. **HEC-HMS ADAPTER**

In order to be able to link HEC-HMS to Delft-FEWS, a software adapter is required. This adapter is not available in the web and it is not easy to acquire. It has to be specifically requested from Deltares. The HEC-HMS model adapter is a combination of Java and executable files required to link the forecasting system to the hydrological model. There is no GUI available for this and it has to be configured through Delft-FEWS.

There is very little documentation available for the implementation of the model adapter, but available information was provided to the trainees during the sessions. Also, it should be noted that examples of this implementation were provided too. All this documentation can be found in the provided material and in the provided software.

2.13. **HEC-RAS ADAPTER**

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3. Conclusions

Within this report, the software used during the implementation of the Leghvttakhevi flood risk modelling framework has been listed and explained. In addition, all the software tools used were already thoroughly described during the training sessions and were provided to the stakeholders together with recommendations and instructions regarding software and tool use.
4. Annex: File list of supplied software and data

- \HydrologicalModellingTraining_Handout.pdf
- \HydrologicalModellingTraining_Tbilisi_May2018.rar
- \Part_1
- \Part_2
- \Part_1\01_DecisionMaking_SoftwareSupply
- \Part_1\02_Daily_PCP_Processing
- \Part_1\03_SubDaily_PCP_Processing
- \Part_1\04_SpatialData_Processing
- \Part_1\05_Simplified_HEC-GeoHMS
- \Part_1\01_DecisionMaking_SoftwareSupply\180514_TbilisiTraining_01_DecisionMaking.pptx
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature
- \Part_1\01_DecisionMaking_SoftwareSupply\Software
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\Deliverable 4 - Hydrological Modelling Report.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\Deliverable 5 - Climate Change Modelling Report.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\GeorgiaHydroReports
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\HEC-HMS
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\Manuals
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\RelevantPapers
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\GeorgiaHydroReports\01_HydrologyRioni_150kmaway_Final_Hydrological_Modelling_report.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\GeorgiaHydroReports\02_Gldaniskhevi_15kmAway_Hydrological_report_SCSCNModelling_RPsDerived.docx
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\GeorgiaHydroReports\03_hydrological_report_of_Vere_river.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\HEC-HMS\HEC-HMS_KinematicWave_vs_SCS-UCH.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\HEC-HMS\HEC-HMS_LossMethods_SCSCN_InitialConst_GreenAmpt.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\HEC-HMS\HEC-HMS_ModClark_orSCSCNPaper.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\HEC-HMS\HEC-HMS_FluentlyBasedComponents_PriestleyTaylor_etc_4F_Scharffenberg_02_24_10.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\HEC-HMS\HEC-HMS_ReleaseNotes420_SMAandLinearReservoir.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\HEC-HMS\HEC-HMS_SetupExampleSingleBasin_Merwade.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\HEC-HMS\HEC-HMS_SetupExample_Merwade.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\HEC-HMS\HEC-HMS_SetupExample_SoilMoistureAccounting.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\HEC-HMS\HEC-HMS_StorageCoefficient_ModClark_Eqn10.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\Manuals\HEC-DSSVue_20_Users_Manual.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\Manuals\HEC-DSS_Excel_Data_Exchange_Add_In_For_Excel_2007-2010_v3.2.1.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\Manuals\HEC-GeoHMS_Users_Manual_10.1.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\Manuals\HEC-HMS_AppGuideMar2015.pdf
- \Part_1\01_DecisionMaking_SoftwareSupply\Literature\Manuals\HEC-HMS_QuickStartGuide42.pdf
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_0.dbf
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_0.prj
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_0.qml
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_0.qpj
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_0.shp
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_0.shx
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_4.cpg
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_4.dbf
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_4.prj
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_4.qpj
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_4.shp
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_4.shx
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\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_8.qpj
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_8.shp
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-12-17_slice_8.shx
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-18-27_slice_0.cpg
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-18-27_slice_0.dbf
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-18-27_slice_0.prj
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-18-27_slice_0.qpj
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-18-27_slice_0.shp
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-18-27_slice_0.shx
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-18-27_slice_9.cpg
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\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-18-27_slice_9.prj
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-18-27_slice_9.qpj
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-18-27_slice_9.shp
\Part_1\03_SubDaily_FCP_Processing\#Backup\GIS\2016-09-23_13-18-27_slice_9.shx

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