Development of a study area

Case study: Day River basin

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By

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Summary

This thesis is about the development of a study area for the Hanoi University of Natural Resources and Environment (HUNRE). This university has chosen the Day river basin (next to Hanoi) to use as a study area for Integrated Water Resources Management (IWRM) education. This thesis will focus on two courses of the bachelor program of HUNRE: Water Resources Monitoring (WRM and Water Resources Systems Modelling (WRSM).
The first objective of this thesis is to explore the study area. The data and information which will be collected during fieldwork, a literature study and analysing the available data will be collected in a database. This data will be the input data for the models of the course WRSM. The second objective is to develop a practical site for the course WRM. At this practical site students will measure the cross section (water depths) and flow velocity. With the flow measurements the students can calculate the discharge. With the information/data from the first objective it will be possible to select a measurement location, measurement methods and equipment. After some trial measurements a guideline will be written, so the students can follow this guideline during the practical.

The study area exists of two tributaries of the Red River; the Tich River and the Day river. The characteristics of these rivers are different. The Tich River is a natural river, with its origin in the Ba Vi mountain range. The Day river is now a ''dead'' river. This is caused by the two control structures (Day dam and the Van Coc sluice) upstream. This results in a flow velocity of nearly zero. This is also the reason why the Day river is much more polluted than the Tich River. At the moment the government is constructing a new channel from Cam Dinh to the Day River which will supply fresh water to the Day River.

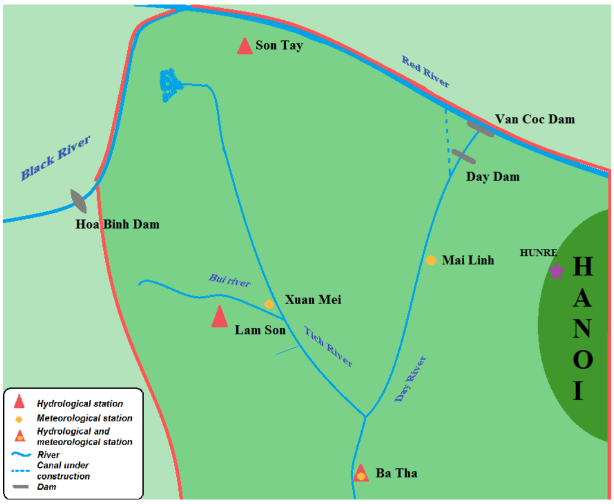

Figure 1 Schematization of study area

After some fieldtrips a measurement location at the Tich River is chosen which met all requirements to function as practical site for students. At this location an irrigation company has built a stair from the dike until the water surface. With this stair the river is easily accessible and this stair can be used as a reference for reading the water level.

The next step was to select measuring methods for this location and select equipment to for these methods. A staff gauge is chosen to measure the water depth. The velocity area method is chosen to measure the discharge at the measurement location. The flow velocity which is needed for this method is measured by a propeller current meter.

The last phase of the fieldwork existed of trial measurements at the measurement location. At the moment of the trial measurements it was dry season, this means a low water depth and a low discharge.

After the trial measurement a guideline for the course Water Resources Monitoring is written. This guideline contains background information about the study area, explanation why this location is chose to measure, an description of the methods and equipment, a step for step guideline to measure the water depth and flow velocity and some questions about the practical and theory behind the measurements.

The final recommendations for the total study area are:

- Monitor the influence of the new Cam Dinh channel. This channel can alter the characteristics of the study area drastically.
- Keep the database up to date

The final recommendations for the measurement location are:

- Collect more information about the measurement location from the Day irrigation company, they have precise information about the location of the reference level
- In the future it is useful to develop a second measurement location.
- The practical site can be used for more measurements of other courses, for example water quality measurements or meteorological measurements.
- Monitor the water level with a continuous water level recording device like a diver

The final recommendation for the course WRM and WRSM are:

- Collect missing input data for the models of WRSM
- Improve the guideline after the first students are finished with the practical

Preface

This case study is about the Day River Basin, west of Hanoi, the capital of Vietnam. Hugo is doing this case study for his Bachelor thesis. Lennart is doing this case study as part of his minor. Together we went to Vietnam at the beginning of November, 2014. We are working together with students from the Hanoi University for Natural Resources and Environment (HUNRE).

Before we left, we have made a research proposal. We have made this research proposal based on the information which was available. The information was collected via mail contact with Vietnamese students from HUNRE, using Google Maps and meetings with Maurits Ertsen and Wim Luxemburg from the TU Delft. This proposal was rough, because it was difficult to get an image of the situation in Vietnam. The main goal of these preparations was to create an idea for ourselves about what we could do if we arrived. This research proposal is available in appendix A.

When we arrived, we first met many people who are involved in the project and discussed with the Vietnamese students to make a clear plan for the period we would be at HUNRE. The results of this discussion and everything else what we have done are presented in this report.

Acknowledgements

Our deepest gratitude goes to the following persons who helped and supported us with this case study in Hanoi, Vietnam.

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H.P. Hagedooren
L.M. Keyzer
Hanoi, January 2015

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List of abbreviations

HUNRE	-	Hanoi University for Natural Resources and Environment
ICEM	-	International Center for Environmental Management
IWRM	-	Integrated Water Resources Management
MARD	-	Ministry of Agriculture and Rural Development
MONRE	-	Ministry Of Natural Resources and Environment
WRM	-	Water Resources Monitoring
WRSM	-	Water Resources System Modelling

1. Introduction

This report is about a case study for the Hanoi University of Natural Resources and Environment (HUNRE), which is part of the Ministry of Natural Resources and Environment (MONRE). A few years ago HUNRE is upgraded from a college to a university. They are still developing their curriculum. At the moment it is only possible to follow a bachelor program at HUNRE, but in the near future they will also start a master program. For the bachelor program, they need a study area which can be used for making models and teaching how to do measurements. In this project the study area will be explored, a measurement location will be selected and some trial measurements will be conducted at this location. This will result in a practical site where the students can do fieldwork. Before the start of the work in Vietnam a research proposal has been written. This can be found in appendix A.

The study area contains the Day River basin which is marked with the red-dotted line in figure 2. The Day river basin is an important distributer of the Red river system. It also fulfils an important task as supplier of water for the irrigation system for the metropolitan area of Hanoi and other provinces. The interaction between the dynamic river and the urban development in the area create complex and multidisciplinary challenges. Important themes are flood safety, irrigation, water pollution and hydrology. As study area it is therefore very interesting.

The study area will be used to do fieldwork for different kinds of courses at HUNRE. The scope of this project is to select a measurement location and prepare guideline for the course Water Resources Monitoring (WRM) and collect data about the study area for the course Water Resources System Modelling (WRSM).

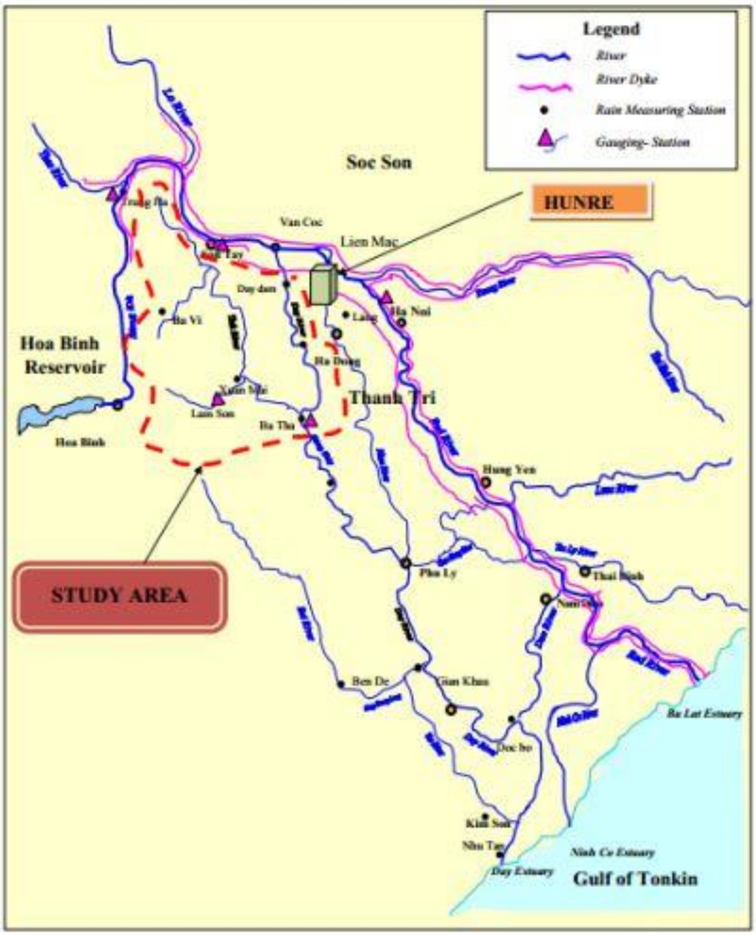


Figure 2 Study area in Day River basin[1]

[1] (Hanoi University for Natural Resources and Environment, 2014)

1.1 The study program at HUNRE

This research is mainly focussed on the two subjects below. The lectures for these courses will start in January.

Water Resources Monitoring
Teacher: Thi Van Lê Khoa
Year: 4th year (final year of bachelor), last semester
Credits: 3 = 15 classes of 45-50 minutes (this is without self-study)
Duration: ±15 weeks
Study material: book + reference material (mainly Vietnamese and partly in English)
Lectures will be given in Vietnamese.
Content:

1. Water level measurements
2. Discharge measurements
3. Sediment/water quality measurements
4. Errors/uncertainties in the measurements

2 to 3 days practical; in this practical student will do water level and discharge measurements.
Deliverables: write a report about the practical, midterm exam and final exam about the theory.
HUNRE expects that a group of 30 students will participate in the practical of this subject

Water Resources System Modelling
Teacher: Trần Ngọc Huân
Year: 4th year (final year of bachelor), last semester
Credits: 3 = 15 classes of 45-50 minutes (this is without self-study)
Duration: ±15 weeks
Study material: book + reference material
Lectures will be given in Vietnamese.
Content:

1. Rainfall-runoff model
2. Hydraulic model
3. Water resources allocation model

Required input: rainfall data, evaporation data, cross sections and topography.
Output: $Q_{simulation}$. $Q_{simulation}$ can be compared with the discharge measured during the practical of WRM.
Deliverables: make some assignment and present the results of these assignments (in a group). At the end of the period the students have to do a final exam (individual).

1.2 Objectives of this case study

The goals which are mentioned in the research proposal need to be adjusted to the scope of our project.

In the research proposal (see appendix A) two main objectives are defined:

1. The first objective is to define the dominant hydrological processes in the study area and describe why they are important on the topic of flood assessment.
2. The second goal is to collect data, analyse data and set up a beginning for a database on the topic of flood assessment. A guideline needs to be made, so that students can do the same measurements in the future to complete the database. With a complete database it is possible to make a complete, numerical model of the entire Day River Basin. This can be done when there is enough data. During this research project this will be impossible, because two months is a too short time to collect enough data. Making the numerical model is a goal for in the future.

Taking the study program of this faculty of HUNRE into account, the main focus will be on the hydrological parameters: water level and discharge. Measuring meteorological parameters has no priority in this thesis because this data is already measured by another department. So, adapting the main objectives of the research proposal to the two courses gives the following objectives for the case study:

1. **Explore the study area to make an overview of the study area.**
   This will be done by fieldtrips, a literature study and analysing available data. The results will be used as input data for the models of Water Resources System Modelling, for other research projects and for the second objective. A database needs to be set up so it is clear which data is available.
2. **Develop a practical site for Water Resources Monitoring.**
   With the gained knowledge of the first objective, a measurement location can be selected. The next step are choosing the measurement methods, equipment and conduct some first measurements. The final product for this objective will be a guideline for the students of Water Resources Monitoring to do practical their self.

1.3 Structure of report

In this chapter the introduction of this report is given and the objectives and scope of this case study is presented. In chapter two a first impression of the study area can be found. This overview is made after doing literature study, fieldtrips and analyses on available data. The next chapter is about the selection criteria for the measurement location. A suitable measurement location should meet all the requirements. At the end, after some fieldtrips, one location is chosen. For the practical of WRM it is necessary to select measurement methods and related equipment. The process of selecting this can be found in chapter 4. The final conclusion is presented in chapter 5. In the last chapter recommendations and topics for further research are explained. At the end of the report there are some appendices. In the chapters before are some references made to additional information. This additional information can be found here.

2. General information about the study area

2.1 The study area

The case study area is a part of the Day River basin, which is a part of the Red River Basin. The area is located in the province Ha Noi, west of HUNRE. The main river in the basin is the Day River. The total length of the Day River is 240 km. But the case study area covers just a small part of the total river basin. The distance from the mouth in the Red River till the confluence with the Tich River near Ba Tha is 71 km. But this part of the river is considered as a dead river. This is because there is a dam, the Day Dam, upstream in the Day River. This dam prevents water flowing into Day River. Only when Hanoi is threatened by flooding, the dam will be opened. In the case study area there is one, big tributary, the Tich River. This tributary originates in Ba Vi mountain range in the northwest of the Day River catchment. The total length is 91 km and flows into the Day River near Ba Tha. The catchment area of the Tich River is 1330 km^2. A map of the area is presented in figure 3.[2]

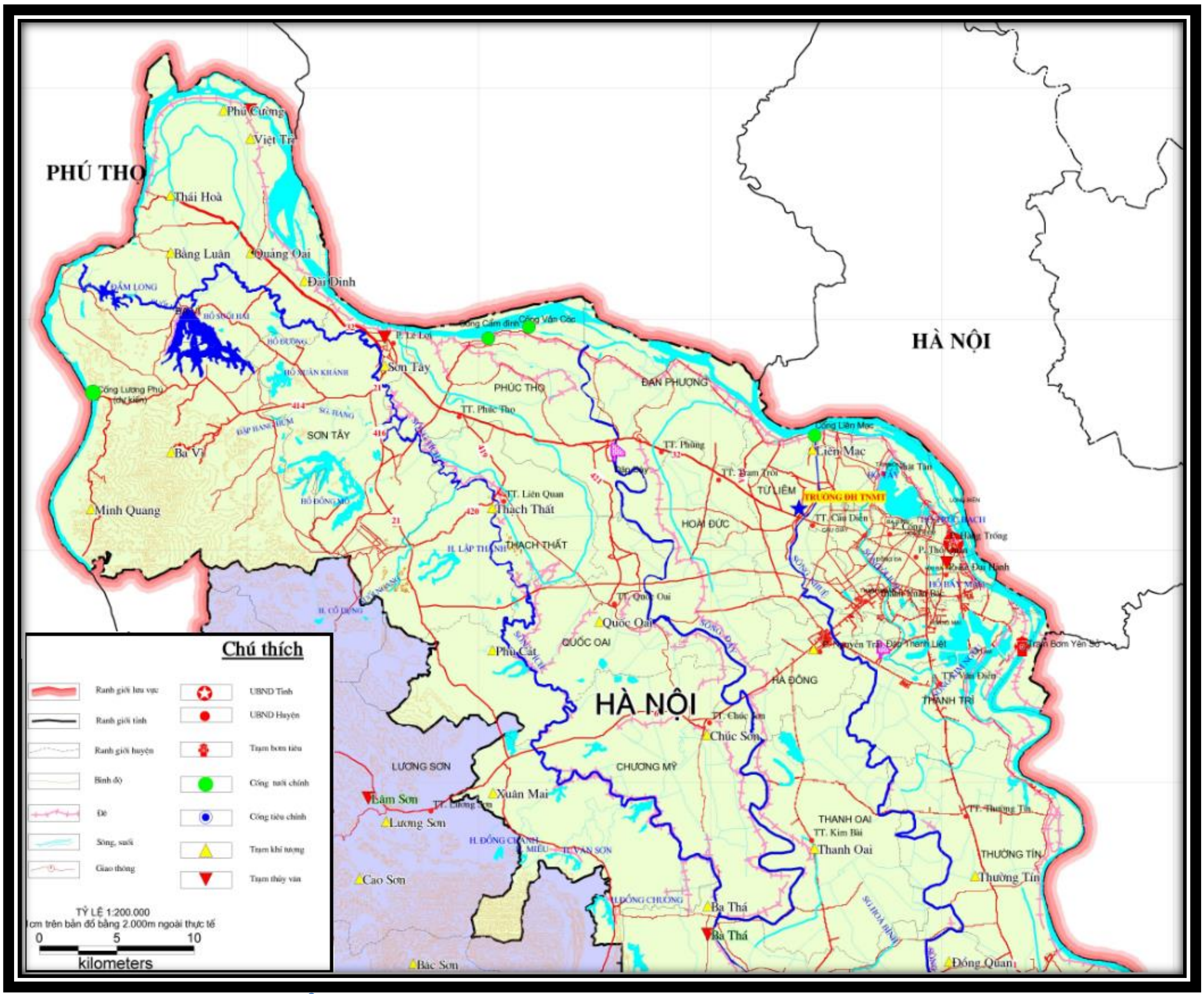


Figure 3 Map of case study area[3]

[2] (International Centre for Evnironmental Management, 2007)
[3] (Ha, 2014)

Meteorological and hydrological characteristics
There is a tropical-monsoon climate in this area with dry-cold winters and rainy-hot summers. The annual average temperature is in the range 24-27°C. The annual average rainfall is between the 1500 and 2200 m. The most rain falls in the Ba Vi mountain range in the northwest of the catchment area.[4,5]

Due to the climate, the rainy season (June to October) contributes 80% of the total annual flow. Near Ba Tha the annual average flow is about $1,35*10^9$ m^3. The annual average flow rate is about 42,8 m^3/s. During the dry months just an average volume of $0,27*10^9$ m^3 passes Ba Tha.[6]

To give a clear overview of the case study area, all important locations, hydrological stations and meteorological stations are presented in a schematization of the study area below.

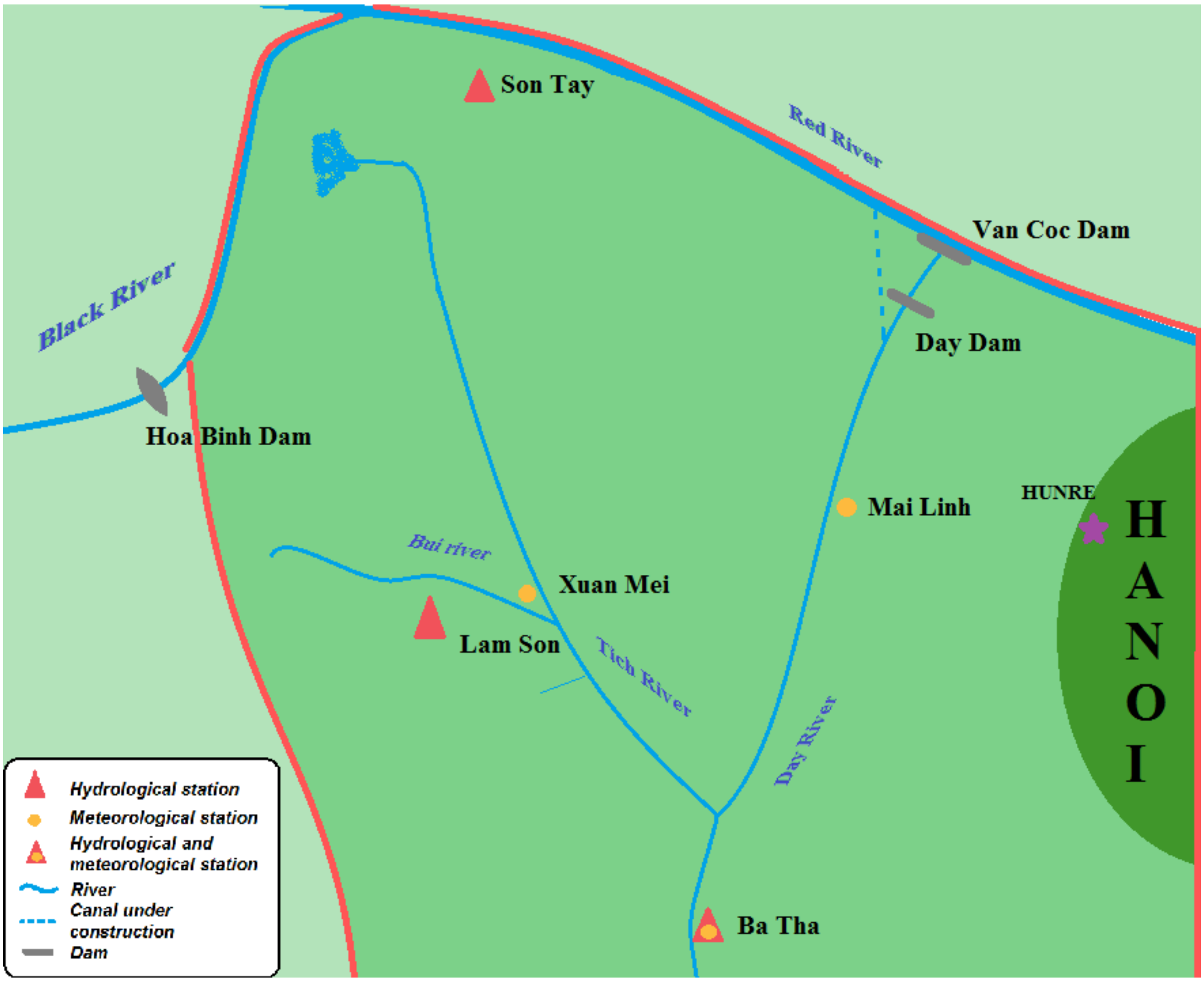


Figure 4 Schematization of the study area

To explore this area, some field trips have been done. The Day Dam is visited and some locations are visited by motorbike. The section from Ba Tha to the confluence of the Bui River and the Tich River is explored by boat. Pictures made during these trips can be found in appendix B.

[4] (The Embassy of Vietnam, 2007)
[5] (International Centre for Evnironmental Management, 2007)
[6] (International Centre for Evnironmental Management, 2007)

Van Coc sluice and Day Dam

The first trip was to the Day Dam. If you look at figure 4, you'll see that the Day Dam is located in the upstream section of the Day River. The main purpose of the day dam is to protect the city of Hanoi against flooding in case of high water in the Red river. The other task is preventing the downstream area (in- and outside the dikes) from flooding. The dam was built in 1937 by the French. The design flow is 5000 m^3/s. The dam exists of 6 gate doors. Each gate is 33,75 meter wide. The crest height is 4.9 meter.[7] In normal conditions the Day dam is closed. But one gate of the dam is broken, so there is a little flow through the dam.[8] However, this flow is that small that it is almost negligible. During the visit to the Day dam (19th November 2014) the water level on both sides was around 0.5 to 1 meter and there was hardly any water flow. This flow is so small because upstream of the Day Dam the Van Coc sluice is built. This sluice exists of 26 gates, each 8 meter wide. Between the Day Dam and the Van Coc sluice there is a reservoir. When Hanoi is threatened by a flood, first the Van Coc sluice will be opened and then the reservoir will be filled. If the water level in the Red River at Hanoi is more than 12.7 meter the Van Coc sluice will be opened. If this is not sufficient to protect Hanoi, the Day Dam will be opened. This will happen at a water level of 13.6 meter.[9] If the Day Dam is opened a part of the flood is diverted to the Day River basin. This will cause floods in the study area but this will save Hanoi from floods.[10] The Day Dam will be closed again when the water level at Hanoi is lower than 13 meter.[11] The last time the dam was opened was in 1971. [12]

The process of opening the dam and sluice seems to be a bit complicated. In Vietnam there are two ministries involved with water resources, namely the Ministry Of Natural Resources and Environment (MONRE) and the Ministry of Agriculture and Rural Development (MARD). All the hydrological stations in the study area are managed by MONRE, so MONRE has the task to monitor the river basin. The tasks of MARD consist of managing the existing hydrological structures (the Day Dam, Van Coc sluice and dikes) and making plans to build new structures if necessary.[13] So if the water level rises near Son Tay in the Red River, MONRE will report this to MARD. Then MARD needs to decide whether they open the Day Dam or not. The process looks a bit cumbersome. To prevent problems, it is really important that in the case of a flood event the two ministries work closely together.

A possible reason that the dam remained closed for the last years can be the construction of some dams in the main tributaries of the Red river, the Black River and the Lo River. Due to the dams big reservoirs arise in the tributaries. The dams are used for generating electricity, irrigation purposes and flood protection. In the Black River Hoa Binh Dam was finished in April 1994 and on 20th December 2012 the Son La Dam was finished. More upstream in China, there are 6 more dams (Yayangshan Dam (2004), Shimenkan Dam (2010), Longma Dam (20 July 2005), Jufudu Dam (December 2008), Gelantan Dam (2006), and Tukahe Dam (2008). Also in the Lo River are two dams constructed, the Tuyen Quang Dam and the Thac Ba Dam. The Thac Ba Dam was finished in

[7] (Đại học thủy lợi , 2012)
[8] (IMRR)
[9] (IMRR)
[10] (Ve, 2014)
[11] (IMRR)
[12] (Staff of the Day Dam, 2014)
[13] (Ministry of Argiculture and Rural Development (MARD))

August 1964 and the Tuyen Quang Dam was finished in 2008. [14,15,16] At the moment a third dam in the Black River is under construction, the Lai Chau Dam. But this dam will only be used for generating electricity, not for flood protection. [17]

Figure 5 Locations of dams in Vietnam[18]

In figure 6 the discharge is plotted from 1990 till 2010. With red, vertical lines the date is marked when a dam upstream in the Black River is completed. The green, vertical line stands for the Tuyen Quang Dam in the Lo River. From 2004, when the first dam upstream in the Black River was finished, it looks like the peaks in discharge are lower than before 2004.

[14] (Anh, 2006)
[15] (Huyen)
[16] (International rivers network, 2001)
[17] (IMRR)
[18] (Greater Mekong Subregion Core Environment Program)

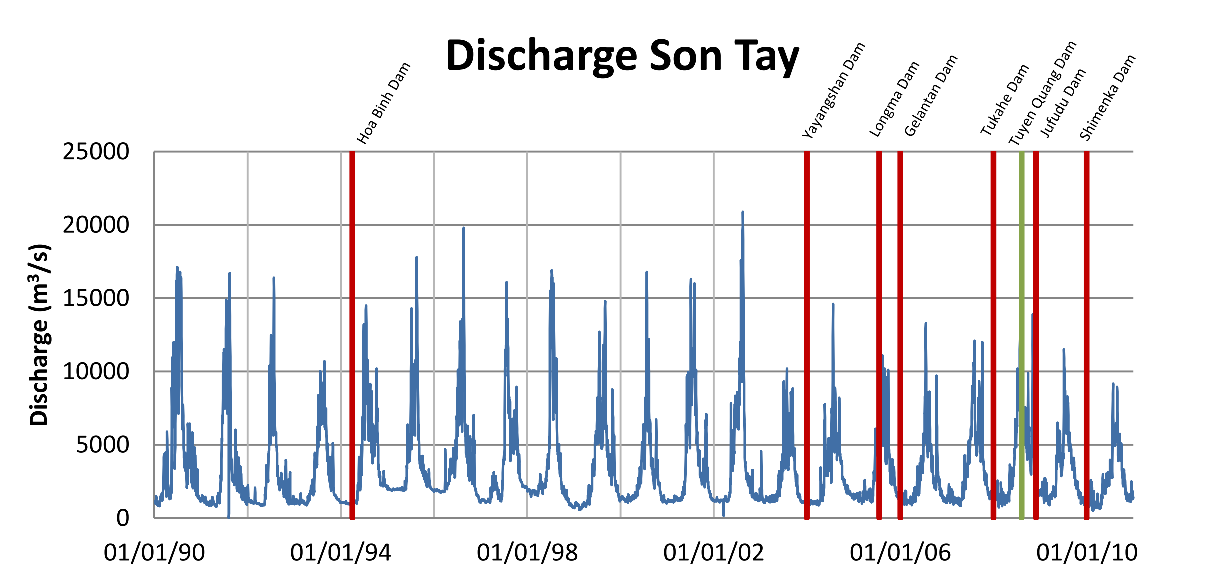


Figure 6 Discharge near Son Tay and dates of completion of dams[19]

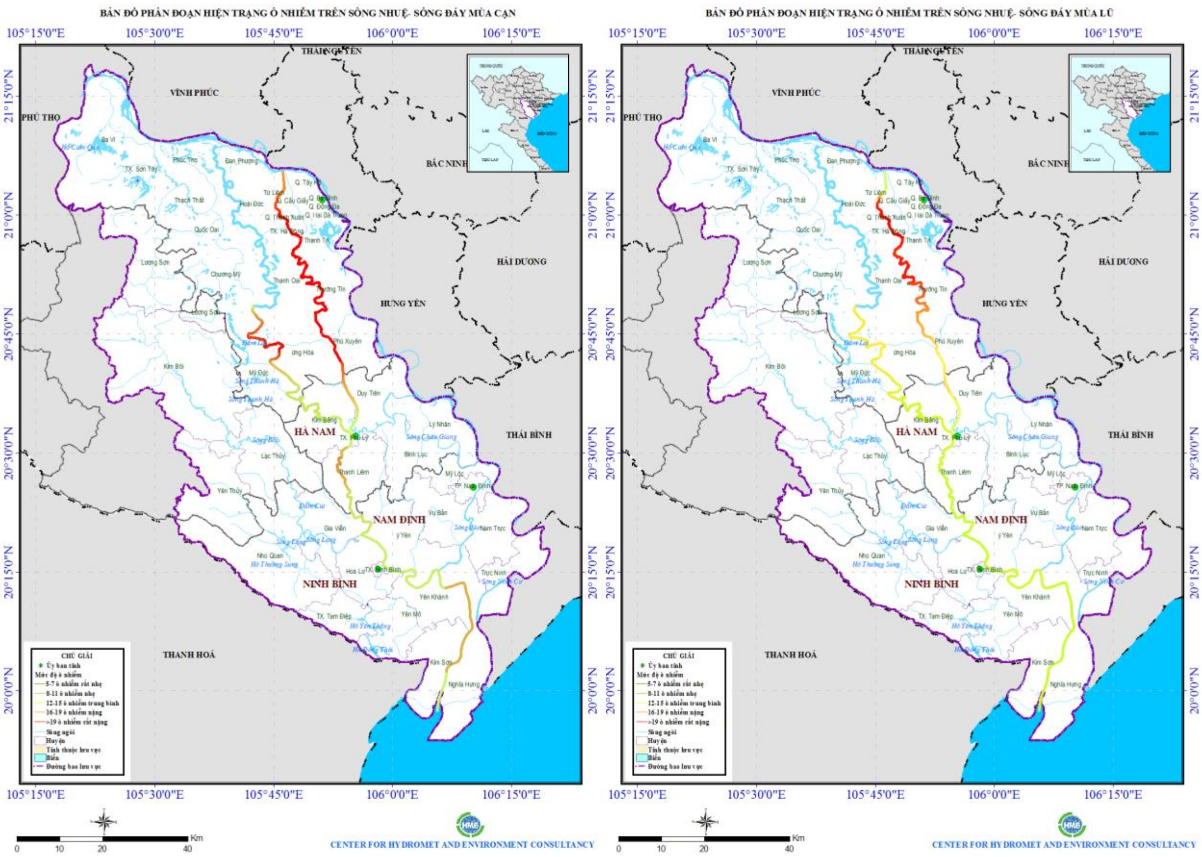
At the moment there is a new channel under construction. This channel will flow from Cam Dinh near the Red River to the downstream part of the Day Dam in the Day River (the dotted line in figure 3). Near Cam Dinh a sluice is already constructed. The channel will be finished in 4 to 5 years. The design capacity of the channel will be 2500 m^3/s. The water will mainly be used for irrigation. In the new situation the water quality will improve because the discharge will increase in the Day River.[20]

Water quality

A big issue in the Day river basin is the water quality. In the study area there are many industries and households who dump waste water in the river basin. On the same moment the population depends on this same river basin for irrigation and drinking water. Thinking about a solution for this issue can be a interesting subject for students of HUNRE. In this thesis a brief description of the water quality problems in the area will be given. Therefore the water quality will only be described qualitative. For a quantitative description you can take a look in the report "Day/Nhue River basin pollution sources" study by International Center for Environmental Management (ICEM).

The part of the Day River from the mouth at the red river until the confluence at Ba Tha is a dead river. This means that there is almost no flow and this tributary is not supplied with fresh water from the Red river. The cause of this problem is discussed in the paragraph about the Day dam. This in combination with the industries and households which dump waste water in the river, are the main reason why the water quality in this part of the river basin is really bad. During the field trips it was easy to notice the bad water quality by the amount of garbage in and around the river and the disgusting odour. These observations are confirmed in the report "Day/Nhue River basin pollution sources" about pollution in the Day river basin[21] and by figure 7.

[19] (Vietnam Hydrometeorological Data and Information Center, 2014)
[20] (Ha, 2014)
[21] (International Centre for Evnironmental Management, 2007)



a) Water quality in dry season   b) Water quality in wet season

Figure 7 Water quality in Day/Nhue River basin[22]

On 30/12/2014 also some water quality parameters are measured at the measurement location, these are presented in table 1. The water is clearly fresh water because the conductivity is below the 1000 ppm[23]. To draw conclusions, more measurements are needed.

Water quality	Value	Unit
Temperature	19.1	°C
Conductivity	100	ppm
Sediment transport	29	mg/L

Table 1 Measured water quality parameters

As already mentioned before, there is a new channel under construction which will supply fresh water from the Red River to the Day River. This will improve the water quality.

In the Tich tributary the water quality is noticeable better. This is caused by the natural supply of fresh water from the origin of the Tich River in the Ba Vi mountain range. The flow velocity in the Tich River is also much higher. But the households along the Tich River also dump wastewater and garbage in the river.

Land use and population

The catchment of the part of the Day River of the study area covers large parts of the province of Ha Noi. In 2010 4,972,800 people lived here.[24] Due to quick urbanization and

[22] (Rutten, 2014)
[23] (USGS, 2014)

industrialization the population is growing very fast. The growing population and the changes in land use influence the water balances in the area. Much more waste water is produced and is all discharged (in)directly in the Day River. Also the use of water resources is changed. Those facts needs to be taken into account when making models of the case study area, making plans to build dams, to improve the water quality or protect the environment..

2.2 Available data

There is already some data available about the study area, because there are several hydrological and meteorological stations (see figure 4). Table 2 gives an overview of the available data.

Overview available data			
Type		**Station**	**Period**
Rainfall	**Daily**	Ba Tha	1961-2010
		Son Tay	1960-2010
		Lam Son	1960-2010
		Phu Cat	1979-2010
		Hadong	1960-1972, 1974-2010
		Ba Vi	1971-2010
		Dap Day	1969-2010
		Thuong Tin	1963-2010
		Thach That	1963-2010
		Xuan Mai	1966-2010
		Chuc Son	1977-2010
Water level	**Daily maximum**	Ba Tha	1966-2012
		Lam Son	1967-2010
		Thuong Cat	1961-2010
		Ha Noi	1961-2010
Discharge	**Daily maximum**	Ha Noi	1956-2010
		Son Tay	1956-2010
		Thuong Cat	1957-2010
Cross Sections	**Red River**	From confluence with Black River till Hanoi	
	Tich River	From confluence with Bui River till Ba Tha	
	Day River	From Day Dam till Ba Tha	
Evaporation	**Monthly**	Son Tay	Unknown measurement period
		Hanoi	
		Ba Vi	

Table 2 Overview of available data[25, 26]

The meteorological data which is needed for WRSM is already available. Although the evaporation data is measured over an unknown period, there is no need to focus on measuring evaporation according to Mr Huan. So the focus will be on measuring water levels and

[24] (Ministry of Natural Resources and Environment, 2013)
[25] (Vietnam Hydrometeorological Data and Information Center, 2014)
[26] (Central committee for flood and storm control, 2014)

discharge, because as upstream boundary condition is discharge data needed. This is not available yet. Also the course WRM is only about the hydrological processes.

In figure 8 the daily rainfall and the daily water level at Ba Tha are plotted. This figure shows a clear relation between the rainfall and discharge at Ba Tha. After heavy rainfall you can see a peak in the discharge.

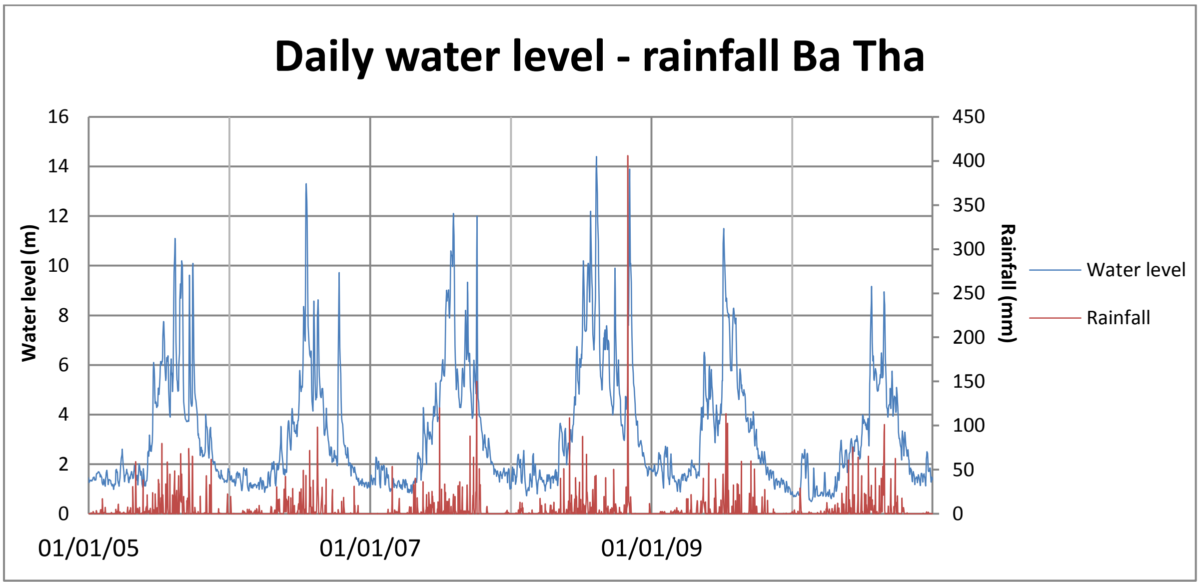


Figure 8 Daily water level - daily rainfall near Ba Tha[27]

2.3 Analysing data

Some data about the study area is not available yet. It was not possible to find discharge data at Ba Tha, reliable evaporation data and any land use data. Something else that can be done with the available data is make a prediction of the return period of opening the Day Dam. This is interesting for the population of the Day river basin, because if the Day Dam opens it will mean that their land will flood. A predication can be made with the use of the Gumbel-distribution in combination of a Q-H relation.

With the Gumbel-distribution it is possible to define the probability of exceeding a certain discharge.[28] In the Red River near Son Tay data about water level and discharge is available. So first a Q-H relationship can be computed. After this the probability of exceeding a discharge, that corresponds to a water level of 12 m (If the water level is higher than 12 m, the Day Dam will be opened. See paragraph 2.1), can be computed with the use of a Gumbel-distribution.

The Q-H relation

The Q-H relation is made with the available data from Son Tay. With the data of daily discharges and water levels in 2008 and data about historical floods from 1967 until 2009 it is possible to make a Q-H relation. The year 2008 is chosen because this seemed to be an average year and still quite recent. Figure 9 shows the Q-H relation at Son Tay. In the graph there is an inflection point around 12 meter. This means that the river floods if the water level is more than 12 meter. This inflection point corresponds with the height of the river bank at

[27] (Vietnam Hydrometeorological Data and Information Center, 2014)
[28] (Savenije, 2014)

this location, the cross section of Son Tay in 2008 is known. The data and method which are used to make this relation can be found in appendix C.

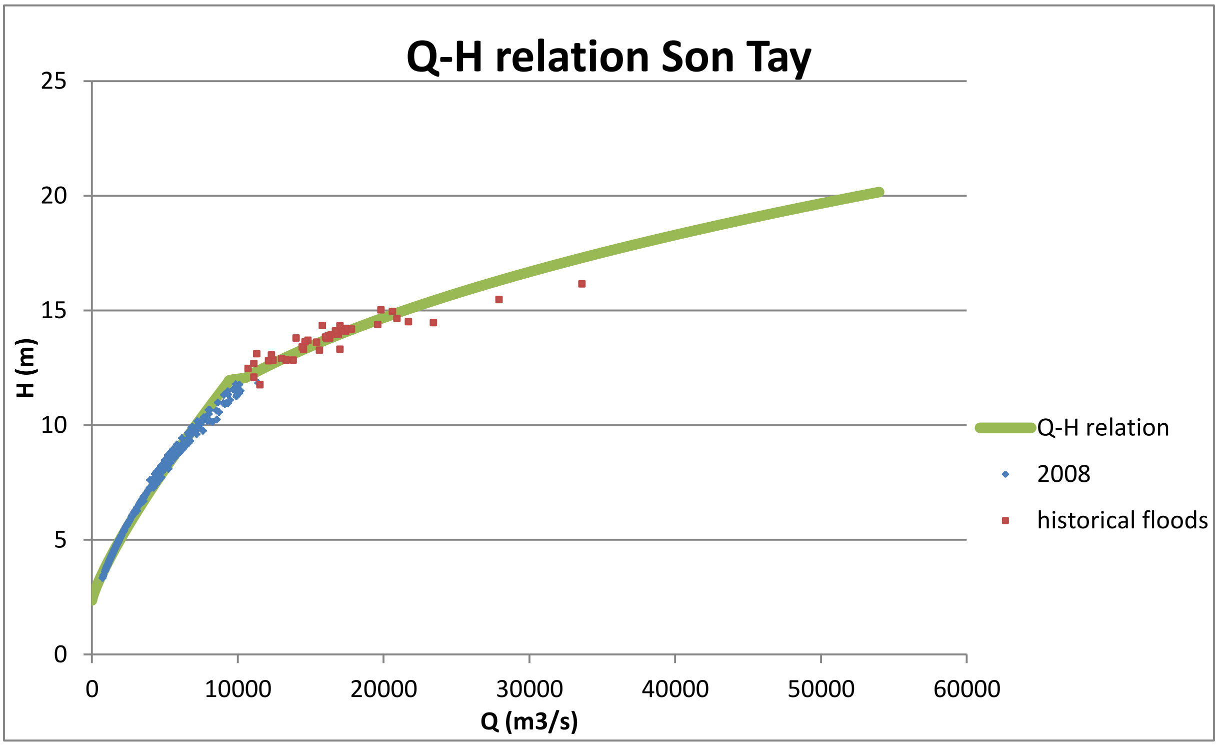


Figure 9 Q-H relation at Son Tay

The relation can also be described with a formula. The corresponding formula is:

$$Q = \begin{cases} 0, & H < 2.36 \text{ m } (H_0) \\ 583.4451*(H-2.36)^{1.2315}, & 2.36 \text{ m} < H < 12 \text{ m} \\ 22.76145*(H-2.36)^{2.6992}, & H > 12 \text{ m} \end{cases}$$

Discussion use Q-H and Gumbel

If the flow regime of the river changes significantly by human interventions, the Q-H relation and Gumbel relation change. It is possible that this took place in the Red River as a result of the construction of dams in the tributaries of the Red River in Vietnam and China (see previous paragraph). It is hard to say which data is still usable for the current situation. Like you could see in the previous paragraph, due to the constructions of dams upstream in tributaries of the Red River the peaks in discharge are lowered. The four most extreme floods are in 1968, 1969, 1970 and the biggest in 1971 (see data appendix C). The chance that floods like this will return is strongly decreased. So making a Gumbel analysis based on floods in the past cannot be used anymore. The Gumbel analysis that was made can be found in appendix C.

About the changes in cross section is no data available. So, it is hard to say if the cross section is such changed that the Q-H relation is not relevant or if it still is. The upper part of the Q-H relation can change if it seems that the most extreme floods may not be used anymore.

It will be interesting to research the influence of the dams on the Q-H relation and the Gumbel analysis, but this is too complex and off topic for this thesis

3. Exploring study area and selecting measurement location

3.1 Preparations

A measurement location must meet some certain requirements. The measurement location will be a practical site, so this leads to some specific requirements. Also the kind of measurements you conduct will result in specific requirements. In the end, the most suitable location should be chosen. To compare the different locations easily and check if they meet the requirements, some criteria are composed.

Criteria with regards to the practical site:

- Accessibility; the students need to do measurements, so the travel time may not be too long and river needs to be easy to access.
- Water depth: it must be safe for the students, so shallow water is preferred. So the risk of drowning is as low as possible.

Criteria with regards to the kind of measurements[29]:

- The river has to be straight for at least 100 meter upstream and downstream from the measurement location
- Regular velocity distribution, the flow has to be more or less uniform
- No flooding when high water occurs
- No backwater curves caused by structures, diversions or confluences
- Measurement location where it is possible to measure discharge and water level
- No big changes in resistance
- Width of the river: if you look at a Q-h relation, the differences in Q are bigger if h changes if the river is narrow at that point. So your measurements can be more precise.
- Shape of the cross section

Before going into the field, some research with the use of maps from Google Earth and Google Maps of the study is done. At the maps is searched for straight sections of the rivers with as little as possible disturbances in the river and close to the roads. So it could be that some locations are chosen because they were easy to reach by motorbike, but it is not a suitable measurement location. This helps to get a first impression of the flow in the river in that section. The confluence near Ba Tha is visited, because it is an important location in the study area, but it is not suitable as a measurement location, because it is near a confluence. This results in the following list of locations:

[29] (Luxemburg & Coenders, 2014)

	River	Name location	Commune	Coordinates	
				N	**E**
1	Day	Day Dam	Hiep Thuan	21° 4'55.28"	105°38'44.01"
2	Day	Near Highway Thang Long	Van Con	20°59'34.16"	105°40'3.27"
3	Tich	Near Highway Thang Long	Ngoc Liep	20°59'32.73"	105°35'36.65"
4	Tich	Bridge near Xom Trai	Liep Tuyet	20°59'6.58"	105°35'36.08"
5	Tich	Bridge near Phu Cat	Phu Cat	20°58'17.50"	105°34'35.34"
6	Tich	Near Doi Phu		20°57'6.51"	105°35'43.89"
7	Tich	Near QL6	Xuan Mei	20°54'2.74"	105°35'56.21"
8	Tich	Bridge near Hong Phong	Hong Phong	20°50'27.78"	105°42'16.81"
9	Day	Confluence Ba Tha	Phu Nam An	20°48'34.92"	105°42'33.85"
10	Day	Near bridge	Phu Nam An	20°48'46.00"	105°45'13.37"
11	Day	Near bridge	Van Vo	20°49'49.92"	105°45'27.22"
12	Day	Near Coc Thuong	Thuong Vuc	20°51'45.99"	105°44'11.29"
13	Day	Near Dai Tu	Lam Dien	20°53'11.08"	105°44'21.41"
14	Day	Near Bieng Giang		20°55'50.34"	105°43'47.57"

Table 3 List of visited (possible measurement) locations

3.2 Results after exploring the study area

During field trips most of the locations are visited. Below a list is shown of the observations per location. Each number corresponds to the same number in table 3. A total overview of all locations can be found in figure 10.

1. As mentioned in the previous chapter, the Day Dam is closed for most of the time. So just downstream of the Day Dam, there is almost no flow. So this location is not suitable.
2. The second place in the Day River that is visited is where the Thang Long Highway crosses the Day River. It is easy to access the river here and in the river is a small flow, but this is all waste water. The water quality is very bad and there is a disgusting odour. This is not a suitable location for students to conduct measurements.
3. 7 kilometres west of location 2, the Thang Long Highway crosses the Tich River. The river contains a lot of bends here, so this is not a suitable location for our purposes, but the water quality is much better and there is a significant flow.
4. After the boat trip it is decided that this location is too far upstream from Ba Tha.
5. There is a significant flow, so the Tich River is a suitable river to do measurements. But at this location there are too many bends.
6. *Impossible to reach this location.*
7. This is a possible measurement location. It is a straight part in the river and the accessibility at this location looks good. It looks like the cross section is suitable for the purposes of the case study. The stairs are used by an irrigation company to do water level measurements.
8. This is also a possible measurement location. It is a straight part in the river and the accessibility at this location looks good. It looks like the cross section is suitable for the purposes of the case study. The difference with location 7 is that this point is located more downstream. So it is easier to combine this with a visit of the hydrological station near Ba Tha.
9. This location is not selected for measurements because the Ba Tha station is just downstream from this point. But it is an important location in the study area.

10. Hard to see if there is any flow, but the cross section looks good, the location is easy accessible and the river is straight. Maybe only suitable for water level measurement.
11. *After visiting point 2 is the measurement location must be located in Tich River.*
12. *After visiting point 2 is the measurement location must be located in Tich River.*
13. *After visiting point 2 is the measurement location must be located in Tich River.*
14. *After visiting point 2 is the measurement location must be located in Tich River.*

Figure 10 Overview of possible measurement locations

After reviewing the field trips, a choice needs to be made between 2 locations, point 7 and point 8. In table 3 the two options are compared. In the future HUNRE can develop a second practical site if needed, but first will the focus be on just one practical site.

Point 7	Point 8
shallow water	Easy to combine WRM and WRSM
Higher flow velocity	Locations close to each other
Bigger distance between boundaries	Deep water

Table 4 Comparison between point 7 and 8

Finally, the following decisions were made:

1. For the course WRSM the students will make a model of a large part of the study area. The model area will have the following boundaries:
    - The Day dam (upper boundary Day River): in the current situation Q=0 at this point. The students can also model scenario's in which $Q \neq 0$
    - The measurement location (upper boundary Tich River): at the moment there is no dataset available at this location but it is maybe possible to get some data from the irrigation company. Otherwise a fabricated dataset will be used. The

students will not have enough time to collect data over a long time period. Data from the irrigation

- Ba Tha hydrological station (downstream boundary): HUNRE has access to the dataset of NAWAPI, which manages this station. Daily rainfall and daily water level data are available.

2. The measurement location which is used for WRM will be more upstream, so near point 7. If you only take into account the requirements for the course WRM, this location is preferable, because the travel time is shorter, the water depth is smaller and the flow velocity is higher. For the students it will be easier to understand what they are doing, if they measure significant differences in water depth and velocity over the cross section. This location is also preferable because of the safety.

In figure 11 a complete overview of important locations for WRM and WRSM is given. Photos of the measurement location can be found in appendix D.

Figure 11 Overview study area with model boundaries and measurement location

Structures in Tich River

During a boat trip, the section of the Tich River between the confluence with the Bui River and Ba Tha is explored. It was impossible to move further upstream in the Tich tributary because of an old bridge/weir upstream of the junction with Bui River. While travelling on the river, all locations that could be important for the case study, like pumping stations, small tributaries and irrigation canals are mapped. Figure 12 shows an overview of all the structures in the section of the Tich River (the blue line). The exact locations (the GPS coordinates) can be found in appendix E. There are a lot of pumping stations along the Tich River, which are mainly used for irrigation purpose. There is also a lot of wastewater flowing in the Tich River from households and industries along the river. In the course WRSM this information can be used as input data for the water allocating model.

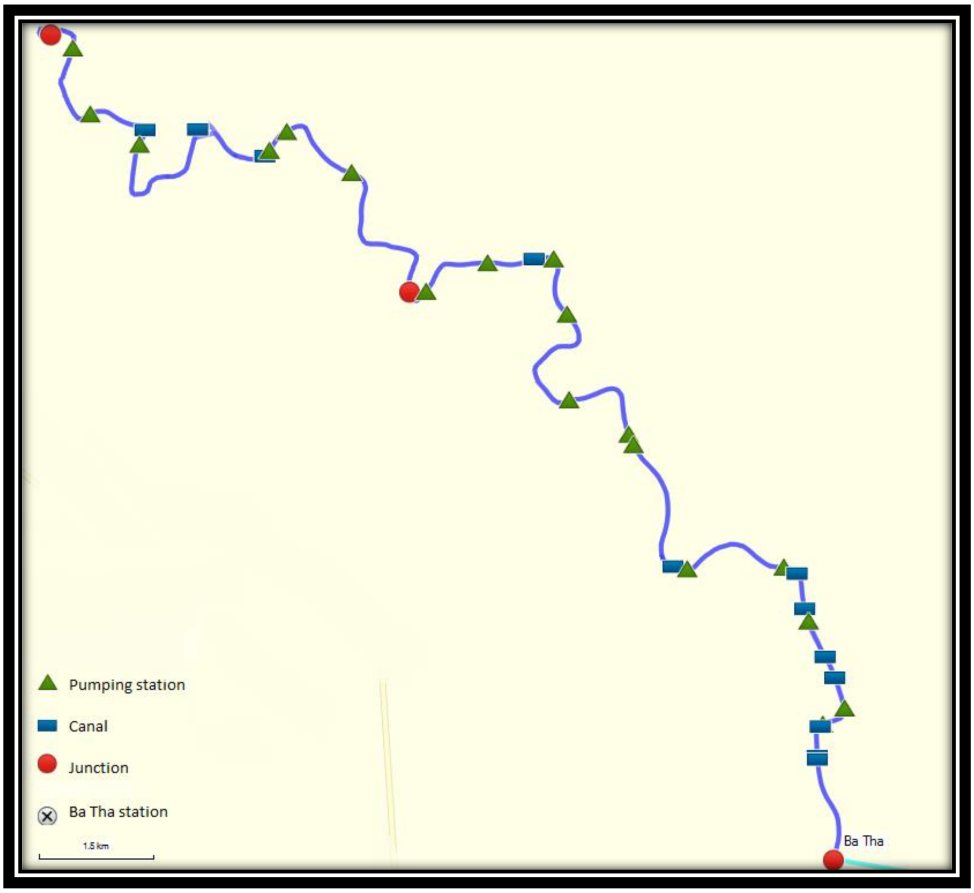


Figure 12 Structures in the Tich River

4. Selecting measurement methods and equipment

In the previous chapters the measurement location is chosen and earlier in the report the parameters are defined which will be measured at the practical site. The measurement location will be in the Tich River. At this location the students will measure discharge and water level. This practical site will be designed for educational purpose. This will mean that education is the first priority, the accuracy of the measurements are second. The same priorities will be set when choosing the measurement methods and equipment. This will result in a practical site where students will understand what they are measuring and which errors they make during the measurements. Because the students will not measure continuous or with constant frequency, the results will not be very useful for other studies.

4.1 Measurement methods

In appendix F you can find a description of some different measurement methods and related equipment. In table 5 can be found which methods are suitable for the practical site.

Method	Parameter	Equipment	Equipment available at HUNRE	Suitable for Tich River
Staff gauge/ portable depth sounder	Water level above reference level, not continuous	Staff gauge/ portable depth sounder	Yes (both)	Yes
Float + well	Water level above reference level, continuous	Structure	Have to build one	Yes
Water pressure	Water level, continuous	Divers	No	Yes
Velocity area method	Flow velocity	Current meter or floats + staff gauge +	Yes	Yes
Dilution gauging	Flow velocity	EC meter + salt	No	No, cross section is too big
Moving boat technique	Flow velocity	Boat with current meter	No	No, water is too shallow in dry season
Slope area technique	Flow velocity		Yes	Yes
Rising bubble technique	Flow velocity		No	-
Weir/structure	Flow velocity	Construct weir or measure dimensions of an existing weir	There is one weir upstream of measurement location, but this is	First a structure needs to be build

			upstream of confluence.	
ADCP	Cross section, discharge, water level	ADCP	Not yet	Depends on the water level

Table 5 Overview methods and equipment

From table 5 it follows that the method with the staff gauge is the only available method to measure water level in this study area. Using the divers is essential if you want continuous series of water level measurements. But they are not available. For measuring the discharge in the day river basin the velocity area method, weir or slope area method is suitable. Upstream of the measurement location there is already a structure that maybe can be used, but this structure is hard to access. For educational purpose the velocity area method is more suitable. By this method it is easy to visualise for the students what they are measuring and how the discharge follows from the measurements. For the velocity area method the students need to know the cross section. The cross section can be measured with the ADCP (if the water depth is sufficient) or with staff gauge/ portable depth sounder. Then the students can divide the cross section into smaller sections. If they measure the velocity in each cross section the students will be able to calculate the discharge with the following formula; $Q_i = \sum A_i V_i$.

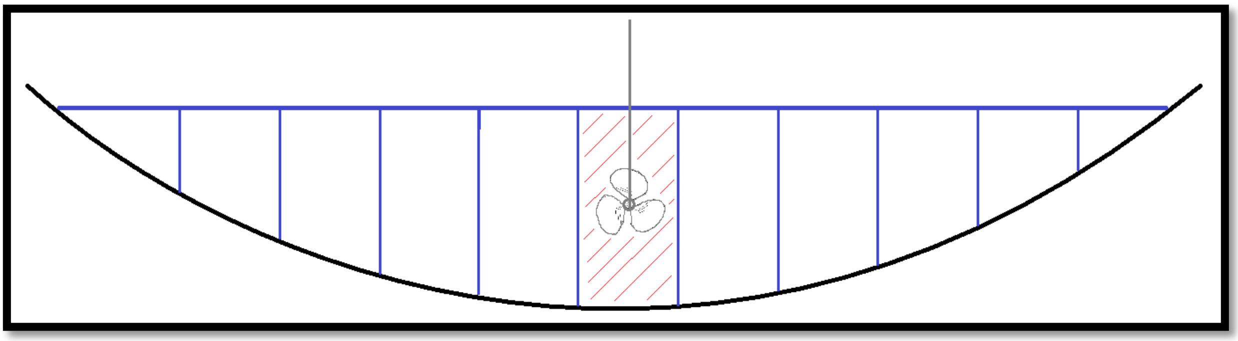


Figure 13 Velocity area method

To calculate the velocity at multiple points in the cross section the students will need to use a boat or high boots. The measurements can be checked by a measurement with the ADCP (if the water depth is sufficient). This measurement should be conducted by a supervisor (teacher of HUNRE). After the measurement with the ADCP the accuracy of the velocity area method is known. The students can explain the possible errors in the measuring method.

4.2 Equipment

For the measurement methods which are chosen in the previous paragraph the following equipment is needed:

- Water level gauge/ portable depth sounder to measure the water depth and cross section
- Propeller current meter to measure the flow velocity in each section
- Measuring tape to measure the width of the river and set up the sections
- Elevation meter to define the reference level.

The ADCP described in paragraph 4.1 is not yet available, but this does not make any difference for the practical, because this is only to check the measurements if the water depth is sufficient. The students can still say something about the accuracy of their measurements.

5. First results & conclusion

After selecting the measurement location, methods and instruments one good series of measurements is collected. The cross section, water depth and the discharge were measured with a staff gauge, propeller current meter and measuring tape. It was impossible to conduct more measurements because of a lack of time. During the final measurements all equipment was available and calibrated. The complete measurement series can be found in appendix G. Figure 14 shows the water depths which are measured. The total cross section is presented in figure 15. The water surface level is used as reference level, because the needed information about the official reference level is still missing. To measure the discharge with the velocity area method the cross section is divided into smaller segments. The red vertical lines in figure 14 are boundaries of the smaller segments. The green points are the locations where the velocity is measured. Using this method resulted in a discharge of 7,28 m^3/s.

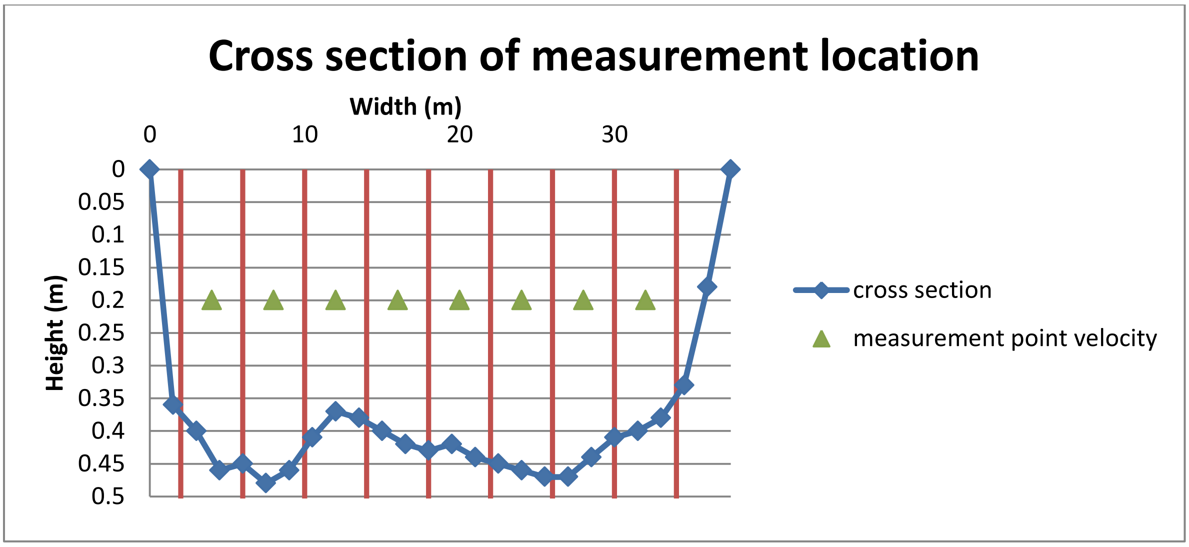


Figure 14 Cross section below water level of measurement location and measurement points

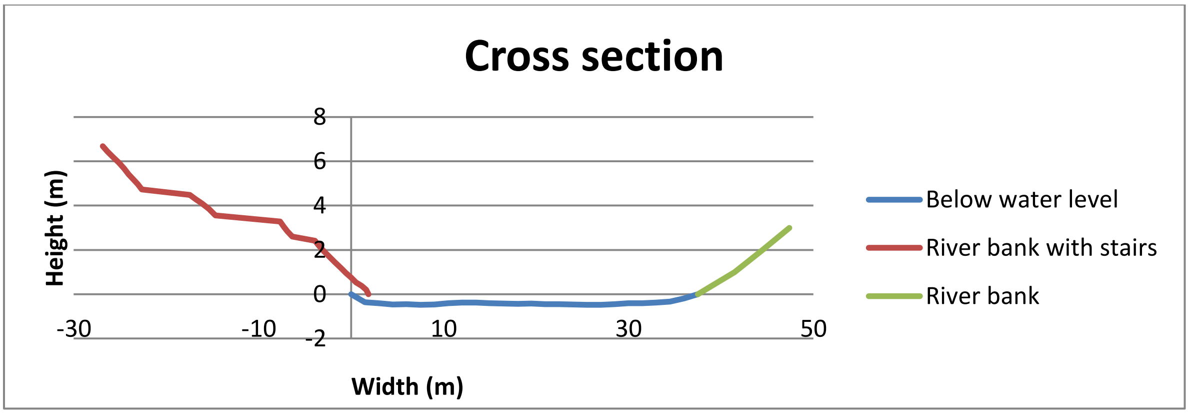


Figure 15 Total cross section

This location is also used by an irrigation company to measure the daily water level. They have given this data of the last 5 years. Figure 16 shows the daily water level from 2009 until 2014 at the measurement location.

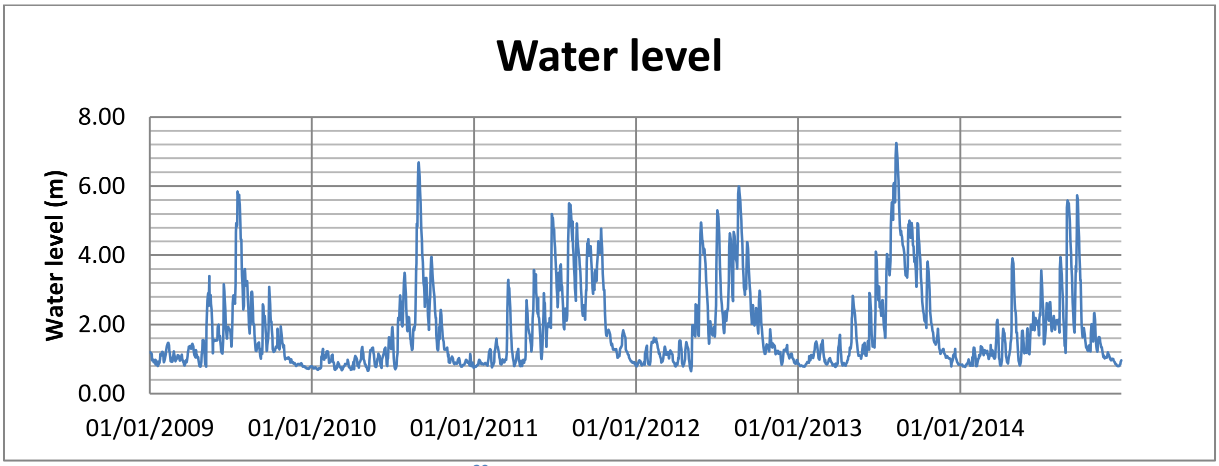


Figure 16 Water level at measurement location[30]

From our measurements and the historical data can be concluded that the reference level is somewhere between 0,3 and 0,5 m below the river bed. The local irrigation company has the exact elevation of the reference level, but they would not share it for this case study.

A practical guideline is made, so students can do exactly the same as practical for the course WRM. This guideline can be found in appendix G. Actually, hereby is the second objective of this case study completed.

The first objective was about exploring the study area by fieldtrips, a literature study and an analysis of existing data. To pass all the data and information to the faculty Water Resources of HUNRE a database is set up. The database is organized as presented in figure 17. For the course WRSM the database can be used as source for a lot of input data. The database can also be used when data is needed during further research.

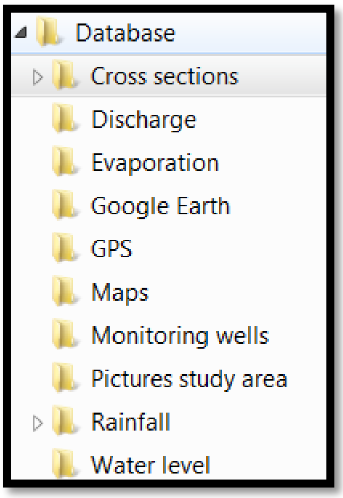


Figure 17 Structure of database

[30] (Công ty Đầu tư phát triển thủy lợi Sông Đáy, 2014)

6. Recommendations

After finishing this report, the project is not finished. Other institutes have a lot information and data about the study area, but at the moment HUNRE does not have access to it. Below recommendations can be found about the total study area, the measurement location, WRM, WRSM and about topics for further research to extend the amount of available data and knowledge about the study area. The more information is collected, the more useful the study area is for HUNRE.

6.1 Study area

Recommendations for the total study area:

- The study area will change significantly if the Cam Dinh channel is ready. The Day River shall no longer be a dead river. This will influent the hydrodynamics of the area, but also the water use will change. Those changes need to be monitored.
- At this moment it is not always clear if data is available or not. Some problems were caused by the differences in language and culture. Maybe a Vietnamese student can complete our overview of available data in the study area. There is still a lot of data available, where HUNRE has no access to.
- Add all data that will be collected in the future to the database. Keep it up to date
- Make the database easy accessible for the students, for example a website.

6.2 Measurement location

Recommendations for measurements in the study area:

- Collect more information from the Day irrigation company. Data about daily water level from 2009 until 2014 is already available, but they also know the precise elevation of the reference level at the measurement location and the complete cross section.
- It is not possible to monitor the water level daily because the water level will only be measured on a couple of practical days each year. And in the rainy season the students will only be able to read the water level by looking at the water elevation in relation to the steps of the stair. So if HUNRE would like a continuous data series they should buy a continuous water level recording device like a diver. A diver is an instrument which measures the water pressure in the river continuously.
- The measurement location can also be used for other courses from different faculties. For example they can measure water quality parameters or meteorological parameters.
- In the future a second practical site can be developed. If the Cam Dinh channel is finished, the Day River will no longer be a dead river. So then a second location can be chosen in the Day River. Also in the Tich River more downstream is a suitable location, near point 8 (see paragraph 3.2).

6.3 Water Resources Monitoring

Recommendations for the course Water Resources Monitoring

- If the students face any problems during the measurements, the lecturer should adapt the guideline so students understand the guideline.
- Students can also measure the water level, discharge and flow velocity with alternative methods. An alternative method to measure the discharge is the slope area method. The water level can also be measured with a diver. The flow velocity can also be measured with floats.

6.4 Water Resources System Modelling

For the course WRSM the students will be asked to make three different models; a rainfall-runoff model, a hydraulic model and a water allocating model. In the study area many aspects of integrated water resources management can be found. During this research there is also a lot of information and data collected, so the students will be able to make different kind of models with different scenarios.

Table 6 gives an overview of the input data which is needed for each model and if this data is available or not.

Kind of model	Input data	Location	Available (period)
Rainfall-Runoff model	**Rainfall**	Ba Tha	1961-2010
		Son Tay	1960-2010
		Lam Son	1960-2010
		Phu Cat	1979-2010
		Hadong	1960-1972, 1974-2010
		Ba Vi	1971-2010
		Dap Day	1969-2010
		Thuong Tin	1963-2010
		Thach That	1963-2010
		Xuan Mai	1966-2010
		Chuc Son	1977-2010
	Evaporation	-	Not yet available
	Discharge	-	Not available
Hydraulic model	**Discharge**	Day Dam	No flow
		Measurement location	Not available
	Water level	Ba Tha	1966-2012
	Cross sections	Along the rivers in the entire, recommended model area	Available
	River network	Entire model area	Maps are available
Water allocating model	**Water supply**	Entire model area	Not available
	Water demands	Entire model area	Not available

Table 6 Available input data

Some data is not (yet) available. Instead of real data, some synthetic data can be used. For the purpose of education this doesn't make any difference. Or HUNRE has to collect the data from institutes like MONRE, MARD, NAWAPI or IRWP. For the water demands, a map of structures is available for the Tich River (see figure 10). These structures are mainly irrigation canals and pumping stations. So this can be used as input data for the water allocating model. The lecturer will inspect the available data and provide suitable data sets to the students.

In the study area there are some interesting scenarios for modelling. Below some of those issues are mentioned briefly and the way how students can investigate the issues.

- In the study area fast urbanization takes place. This results in changing land use. The changes in land use influence the models the students have to make. If the students take this into account in their models, they can say something about the effects of the changes in land use on the runoff and water resources.
- At the moment a channel from the Red River to just downstream of the Day Dam in the Day River is under construction to supply the Day River with water. Students can change the boundary condition near the Day Dam. They can do research on what the influence is on the hydraulic model and what it means for the water allocating model. A possible question can be how much water is needed to meet all water demands in the downstream area. Another question can be how much water can flow through the canal without risking floods in the downstream area.

6.5 Further research

The Day river basin is an interesting study area because it is possible to investigate many different aspects of IWRM in this area. This paragraph will discuss some research topics which students of HUNRE can investigate in the future:

1. **Water quality**

In this thesis the problem about water quality is mentioned shortly. It is a big problem in the Day River basin. Examples of suitable topics for research that can be done by students of HUNRE are:

I. Monitor the water quality in the study area
II. Sources of pollution in the Day river basin
III. Effect of urbanization (and change in land use) on the water quality in the Day river basin
IV. Solutions to prevent that Hanoi's polluted waste water flows into the Day River basin

2. **Water resources**

The Day River and Tich River are used for several purposes. Each purpose has its own demands about water quantity and water quality. Earlier in this thesis a map can be found with all structures in the Tich River. Many of the structures are pumping stations used for irrigation. Students can use this and complete the overview of all water demands and water sources in the study area. Examples for possible research projects for students are:

I. Map all demands and sources of water in the study area
II. Make a water resources allocating model
III. Model the effects of urbanization and changes in land use on the water resources
IV. Make stakeholders analysis of the study area. Which institutes are responsible for managing the water resources in this area? What kind of arrangements are there? What is the role of industries, farmers and local population in managing the water resources in the study area?

3. **Flood risk**

In the study area the water levels and discharge varies over the year. In the rain season floods can occur. This thesis analysis some historical data about flooding but the measurements of this project are all in the dry season. Students can conduct more research on the following subtopics:

I. Analyse and collect data of historical flood events. There are a lot of flood marks in the areas which can be mapped and the students can interview the population of the study area.
II. Vulnerability study; what will be the impact of a flood event?
III. Flood control measures; what kind of measures can prevent flooding?
IV. What are the influences of the construction of the dams upstream in Black and Lo River on the flow regime of the Red River near Son Tay and Hanoi and on the flood risk of the study area?

4. Hydrology

In this thesis a description is given of the main hydrological processes in the study area. Because of the limited time during this project only a part of the Tich river is mapped and investigated closely in the dry season. Students can conduct more research on the following subtopics:

I. Collect hydrological data in the rain season and in other parts of the study area.
II. Map all water bodies in the study area. Make a map of all rivers, lakes and reservoirs in the study area.

5. Day dam

The Day Dam was opened for the last time in 1971. Due to the construction of dams upstream it looks like the dam lost his function. The history and future of this dam are described briefly. Also the problems caused by the Day Dam are mentioned. Students can do more research on:

I. Operation and purpose Day dam
II. Consequences of the new channel that will supply water from the Red River to the Day River.
    - Sediment transport
    - Water quality
    - Needed volume of water for irrigation

6. Groundwater

Another interesting topic which is not mentioned in this report is groundwater. Of course, the rivers, irrigation and the urbanization influence the groundwater. Possible topics for research can be:

I. Mapping all wells
II. Monitor the groundwater levels
III. Model the groundwater flows
IV. Interaction between ground water and surface water/ land use

Bibliography

Anh, A. (2006, September). *Major River Basins & Dam Overview in Vietnam.* Retrieved December 1, 2014, from Vietnam National Committee on Large Dams and Water Resources Development: http://www.vncold.vn/English/Posted/Basins_DamOverview.pdf

Central committee for flood and storm control. (2014). [Cross sections] Unpublished raw data. Hanoi.

Công ty Đầu tư phát triển thủy lợi Sông Đáy. (2014). [Water level] Unpublished raw data. Hanoi.

Đại học thủy lợi . (2012). *Báo cáo tổng hợp cua Day.*

Delft University of Technology. (2014). *CIE5471 - Hydrological and ecological fieldwork in riversystems.* Delft: Delft University of Technology.

Greater Mekong Subregion Core Environment Program. (n.d.). *Greater Mekong Subregion Core Environment Program*. Retrieved November 28, 2014, from map of Red river basin: http://www.gms-eoc.org/uploads/map/archives/map/GMS-Basin-Red_14.jpg

Ha, T. (2014, December 26). Interview at IWRP. (H. Hagedooren, & L. Keyzer, Interviewers)

Hanoi University for Natural Resources and Environment. (2014). *Building practical site for training, scientific research specialized in integrated water resources management.* Hanoi.

Huyen, T. (n.d.). *Thac Ba Hydropower Plant*. Retrieved December 29, 2014, from VNCOLD: http://www.vncold.vn/En/Web/Content.aspx?distid=333

IMRR. (sd). *System Characterization.*

International Centre for Evnironmental Management. (2007). *Day/Nhue river basin pollution sources study.* Minsistry of National Resources and Environment, Water Resources Management.

International rivers network. (2001, july 1). *Planned dams in Vietnam*. Retrieved November 28, 2014, from International rivers: http://www.internationalrivers.org/de/resources/planned-dams-in-vietnam-4079

Luxemburg, W., & Coenders, A. (2014). *CIE4440 - Hydrological processes and measurements.* Delft: Delft University of Technology.

Ministry of Argiculture and Rural Development (MARD). (n.d.). *mandate*. Retrieved November 19, 2014, from Ministry of Argiculture and Rural Development (MARD): http://www.mard.gov.vn/en/Pages/mandate.aspx?TabId=AboutMARD

Ministry of Natural Resources and Environment. (2013). *Planning on environmental protection in Day/Nhue river basin to 2020.*

Rutten, M. M. (2014). *Day basin description.* Delft.

Savenije, H. (2014). *Hydrology.* Delft: Delft University of Technology.

Staff of the Day Dam. (2014, November 18). Visit to the Day dam. (H. Hagedooren, & L. Keyzer, Interviewers)

The Embassy of Vietnam. (2007). *The climate of Vietnam*. Retrieved november 28, 2014, from Embassy of Vietnam: http://www.vietnamembassy.org.uk/climate.html

Ve. (2014, November 20). Interview with expert from NAWAPI. (H. Hagedooren, & L. Keyzer, Interviewers)

Vietnam Hydrometeorological Data and Information Center. (2014). [Discharge data near Son Tay]. Unpublished raw data.

Appendix A Research proposal

Preface

First of all we would like to introduce ourselves. We are Hugo Hagedooren and Lennart Keyzer, two bachelor students Civil Engineering of the Delft University of Technology.

For our bachelor thesis we are planning to do research at the Hanoi University of Natural Resources and Environment during the months November and December 2014 (8 weeks).

Introduction

The study area contains the Day-river basin which is marked with the red dotted-line in figure 18. The Day river basin is an important distributer of the Red river system. It also fulfils an important task as supplier of water for the irrigation system for the metropolitan area of Hanoi and other provinces. The interaction between the dynamic river and the urban development in the area create complex and multidisciplinary challenges. Important themes are flood safety, irrigation, water pollution and hydrology. As study area it is therefore very interesting.

At the moment there is few hydrological data available of the Day river basin. Therefore the HUNRE has set up a study area to understand and predict the behaviour of this river basin. The study area is near HUNRE and is therefore suitable as case-study area for students, in which they can conduct field work.

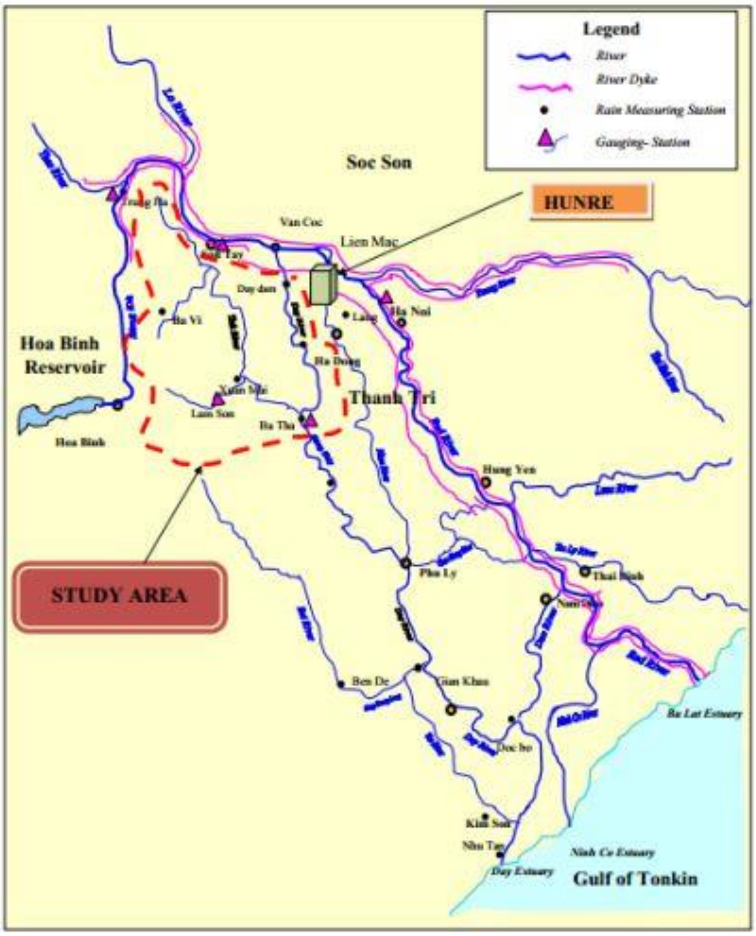


Figure 18 Day river basin (study area)

Objective

1. Our first goal is to define the dominant hydrological processes in the study area and describe why they are important on the topic of flood assessment.
2. The second goal is to collect data, analyse data and set up a beginning for a database on the topic of flood assessment. We want also to make a guideline of what we did, so that students can do the same measurements in the future to complete the database. With a complete database it is possible to make a complete, numerical model of the entire Day River Basin. This can be done when there is enough data. We are unable to do this, because in two months we won't be able to collect enough data. Making the numerical model is a goal for in the future.

Research questions

1. What are the dominant hydrological processes in the study area and why are they important to describe on the topic of flood assessment?
2. How can we set up a database and make a guideline, so the HUNRE students can finish the measurements that are needed to make a numerical model of the Day River Basin?

Methodology

The water balance

We want to set up a water balance. A water balance will look like the figure below.

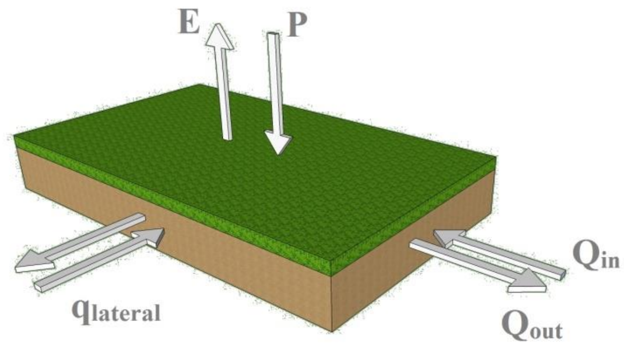


Figure 19 Water balance

For a defined area the following formula can applied. It says something about how much water is stored in the system. A water balance contains all hydrological processes.

$$\frac{dS}{dt} = P * A - E * A + Q$$

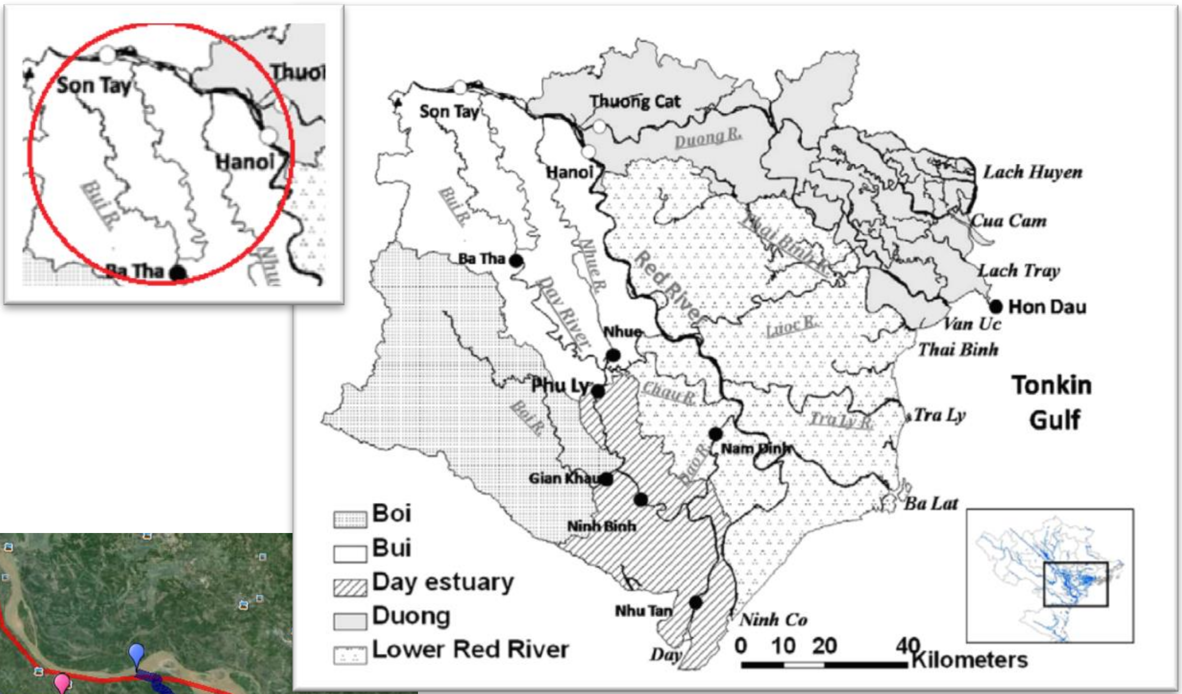
With:

dS/dt = change of water storage in system
P = rainfall
A = area of study area
E = evaporation
Q = sum of Q_{in}, Q_{out} and $Q_{lateral}$

In this water balance the parts infiltration and seepage/ groundwater flow are not presented, because we think it would be too difficult for us to measure in our available time. But if we know all other parameters, we know what the value for the difference between these two should be. If this equation can be filled in completely, there is a lot known about the water fluxes in the study area. When all water flows in the system are known, it is possible to take measures for preventing flooding.

Defining the study area

For a water balance we first have to explore and define our study area. We did some research with the help of Google Earth and Google Maps. We zoomed in into the Day River Bassin and decided that we are going to concentrate on the following area:



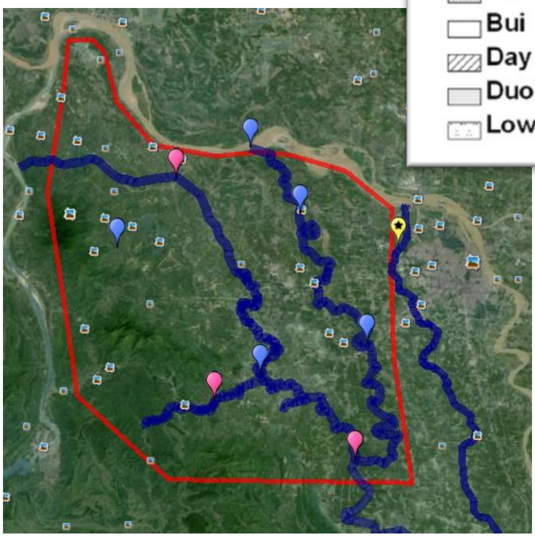


Figure 20 Study area

The yellow point in figure 20 is the location of HUNRE.

Collecting data

On the maps in 18 we found already some measuring stations. The blue points are rain measuring stations and the pink points are gauging stations. The names of these stations are:

- Van Coc (upper, blue)
- Son Tay (upper, pink)
- Ba Vi (left, blue)
- Day Dam (upper right, blue)
- Ha Dong (lower right, blue)
- Xuan Mai (lower, blue)
- Ba Tha (lower, pink)
- Lam Son (left, pink)

We will need to collect the data from these measuring stations.

We heard that the following data is available:
- Rainfall
- Discharge at Lam Son
- Water level at Ba Tha

We also looked for data in literature. We found the following articles:
- Hydrological regime and water budget of the Red River Delta (Northern Vietnam), Luu Thi Nguyet Minh, et al., (2009)
- River Basins in Vietnam

These articles contain general information and data about the region.
We think there should be data available at the Day Dam.

Location of measurements

We propose to do the following measurements:

Location	Water Level	Discharge	Evaporation	Description
Van Coc				
Son Tay			x	
Ba Vi				
Day Dam	x	x	x	Dam in the river,
Ha Dong				
Xuan Mai	x	x		Confluence of two rivers
Ba Tha		x	x	Confluence of two rivers
Lam Son			x	

Near these points we have to look for suitable locations if we are in Vietnam, for example bridges and narrow cross sections.
If this data is available, we should be able to compute the discharges and water levels over the rivers with the use of backwater curves and mass balances. How we are going to measure this is presented below and in the appendix.

Measure methods

It is possible to measure evaporation, discharge and water levels with the following methods:

- Discharge
  - Velocity area method
  - Salt dilution gauging
  - Moving boat technique
  - Rising bubble technique
  - Weir
  - Slope area method
- Water level
  - Manual
  - Divers
- Evaporation (open water)
  - Pennan
  - Evaporation pan

These methods are explained in appendix F.

Equipment

To conduct all measurements which are described in appendix F, we will need the following equipment:

- Current meter (propeller or float)
- EC meter + salt
- Boat with current meter
- Yardstick for water levels
- Divers
- Evaporation pan (class A)
- Rain gauge
- GPS

Setting up the database and making the guideline

In the guideline we will describe step by step how to measure, analyse the data and how to save the data in a database.

We think we should start with a simple database. This can be made for example in Excel. Every location and every physical quantity gets their own excel file and then the following columns have to be made:

- Date + time
- Value
- Unit

This needs to be updated by the students when they have done new measurements. After a year a new file should started to keep the database clear. In the future it is possible to set up a database with special software. This is not necessary in this phase of the project.

When we are in Vietnam

If we are arrived in Vietnam, we have planned the following activities:

1. *Explore the study area and choose measurement locations.*
2. *Set up the instruments and start the measurements.*
3. *Control the instruments and results, adjust if necessary.*
4. *Set up database*
5. *Analyse data*
6. *Write final report and guideline.*

Planning

Activity	Preparation	Week 1: 10/11-16/11	Week 2: 17/11-23/11	Week 3: 24/11-30/11	Week 4: 1/12-7/12	Week 5: 8/12-14/12	Week 6:* 15/12-21/12	Week 7: 22/12-28/12	Week 8: 29/12-4/1
Collect existing data, literature study measurement methods	X								
Explore study area: Trial measurement		X	X						
Select sites for data collection			X						
Choose methods and set up instruments			X	x					
Collect data				X	X	X	X		
Analyse data				X	X	X	X		
Evaluate method/instruments				X	X	X	X		
Final report and guideline								X	X

Table 7:Draft planning

*Maurtis Ertsen is in Vietnam (15th, 16th and 17th of December). A intermediate report with our findings and results obtained in the first 5 weeks has to be finished, so we can discuss in week 6.

Appendix B Pictures of study area

Figure 22 Day Dam

Figure 21 Pollution in Day River

Figure 23 Confluence between Day and Tich River near Ba Tha

Figure 24 Hydrological station Ba Tha

Figure 25 Domestic pollution in Tich River

Figure 26 Pumping station along Tich River

Appendix C Determining the return period of opening the Day Dam

Q-h relation

The Q-H relation is composed of two different datasets: a dataset of daily discharge and daily water levels in 2008 and a dataset of historical floods from 1967 until 2008. To make a Q-H relationship it is necessary to determine the h0. This is the water level at which there is no flow. This water level can be obtained by plotting the values of the lower discharges against the related water levels. In this case the first 100 points with the lowest discharge in the database of 2008 are used to determine h0. This will result in the graph of the figure below. From the equation of the linear regression line it follows that h0 is equal to 2.36 meter.

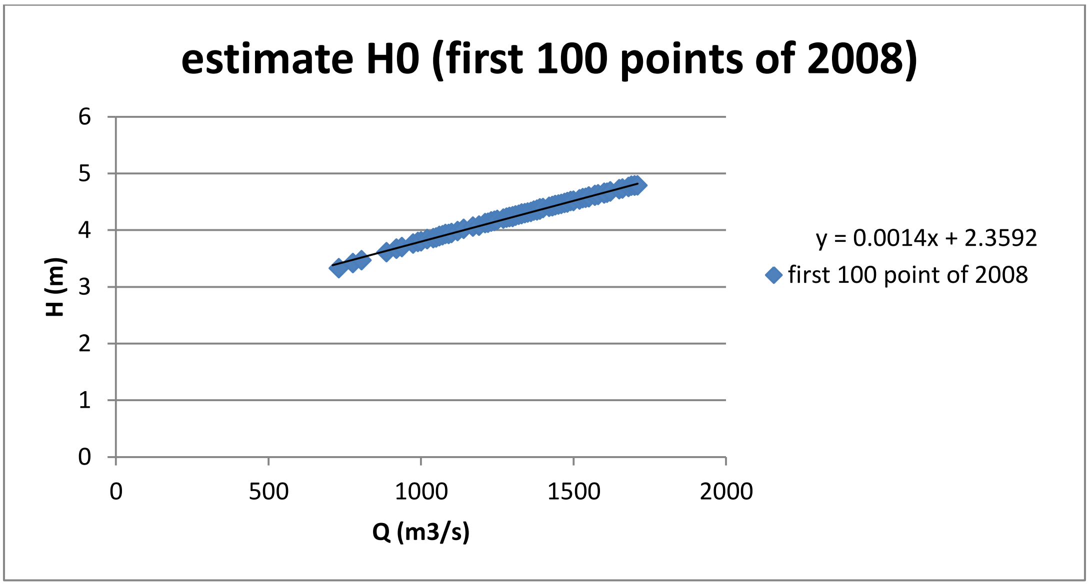


Figure 27 Estimate h0

The different Q-H relations during normal flow and during a flood can be seen in the next figure. In this figure log (Q) is plotted against log (h-h0) of the two datasets, the dataset of 2008 in blue and the dataset of historic floods in red. This result in two linear lines, each line represents a different situation and shows that the two different situations also have different Q-H relations.

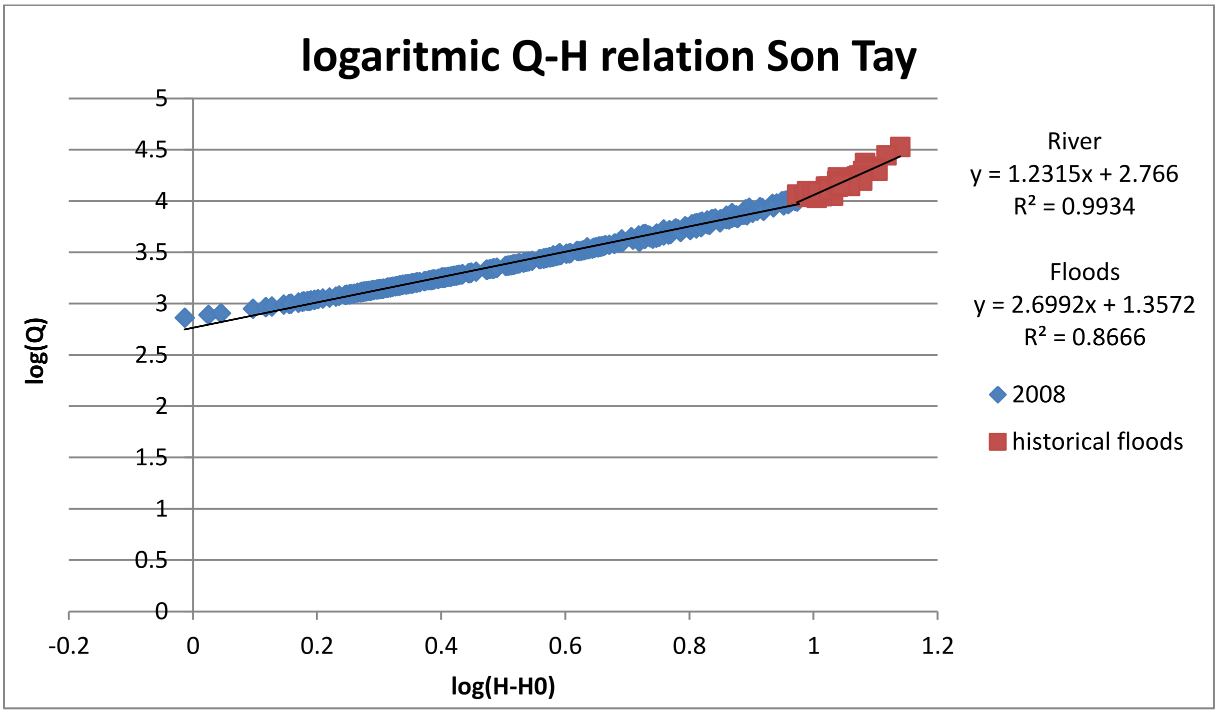


Figure 28 Logarithmic Q-H relation

The formula's for these two lines are:

Normal river bed: log(Q) =1.2315*log(h-h0)+log(2.766)

Floodplain: log(Q) =2.6992*log(h-h0)+log(1.3572)

Rewriting these formulas gives the Q-H relation:

$$Q = \begin{cases} 0, & H < 2.36 \text{ m } (H_0) \\ 583.4451*(H-2.36)^{1.2315}, & 2.36 \text{ m} < H < 12 \text{ m} \\ 22.76145*(H-2.36)^{2.6992}, & H > 12 \text{ m} \end{cases}$$

The following graph can be found in figure 15.

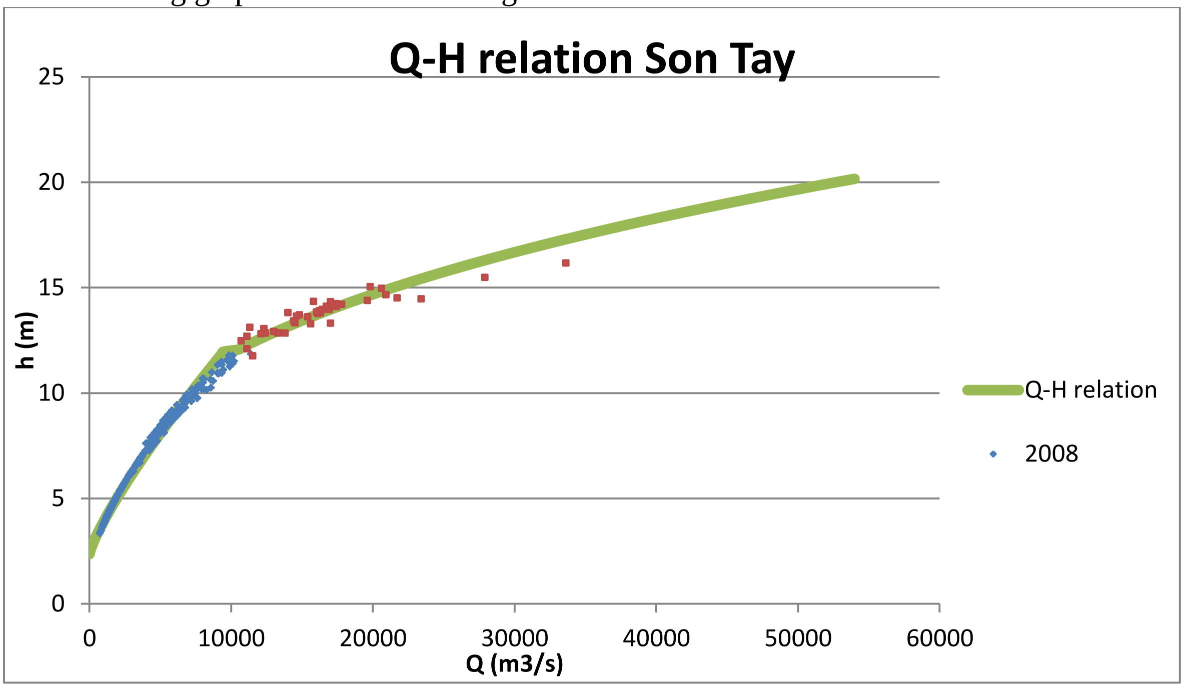


Figure 29 Q-h relation

Data 2008:

Year 2008		
Date	h (m)	Q
01/01/2008	3.93	1080
02/01/2008	3.84	1020
03/01/2008	4.23	1290
04/01/2008	4.39	1400
05/01/2008	4.65	1600
06/01/2008	5.02	1880
07/01/2008	4.23	1300
08/01/2008	4.66	1610
09/01/2008	4.89	1780
10/01/2008	4.93	1810
11/01/2008	4.62	1580
12/01/2008	4.63	1580
13/01/2008	4.57	1540
14/01/2008	4.08	1190
15/01/2008	4.26	1310
16/01/2008	4.51	1490
17/01/2008	4.49	1480
18/01/2008	4.88	1780
19/01/2008	5.33	2140
20/01/2008	5.62	2380
21/01/2008	5.65	2400
22/01/2008	5.45	2230
23/01/2008	5.37	2170
24/01/2008	5.15	1980
25/01/2008	4.99	1860
26/01/2008	5.22	2040
27/01/2008	5.42	2200
28/01/2008	4.85	1750
29/01/2008	4.25	1310
30/01/2008	4.15	1230
31/01/2008	4.44	1440
01/02/2008	4.68	1620
02/02/2008	5.04	1900
03/02/2008	5.41	2200
04/02/2008	5.81	2550
05/02/2008	5.41	2200
06/02/2008	4.91	1790
07/02/2008	4.59	1550
08/02/2008	4.23	1290
09/02/2008	3.86	1040
10/02/2008	3.67	919
11/02/2008	3.42	777
12/02/2008	3.33	730
13/02/2008	3.61	887
14/02/2008	3.76	974
15/02/2008	3.79	990
16/02/2008	3.87	1050
17/02/2008	3.9	1060
18/02/2008	3.7	937
19/02/2008	4.08	1190
20/02/2008	4.51	1500
21/02/2008	4.68	1620
22/02/2008	4.49	1480
23/02/2008	4.34	1370
24/02/2008	4.2	1270
25/02/2008	3.91	1070
26/02/2008	4.16	1240
27/02/2008	4.73	1660
28/02/2008	5.55	2320
29/02/2008	5.67	2420
01/03/2008	5.03	1890
02/03/2008	4.58	1550
03/03/2008	4.78	1690
04/03/2008	5.02	1880
05/03/2008	5.17	2000
06/03/2008	4.84	1740
07/03/2008	4.44	1440
08/03/2008	4.24	1300
09/03/2008	3.89	1060
10/03/2008	3.47	805
11/03/2008	3.8	1000
12/03/2008	4.13	1220
13/03/2008	4.3	1340
14/03/2008	4.38	1390
15/03/2008	4.49	1480
16/03/2008	4.79	1700
17/03/2008	4.87	1770
18/03/2008	4.72	1650
19/03/2008	4.36	1380
20/03/2008	4.35	1380
21/03/2008	4.48	1470
22/03/2008	4.45	1450
23/03/2008	4.35	1380
24/03/2008	4.22	1280
25/03/2008	4.27	1320
26/03/2008	4.28	1330
27/03/2008	4.32	1360
28/03/2008	4.15	1230
29/03/2008	3.98	1120
30/03/2008	3.95	1100
31/03/2008	3.67	919
01/04/2008	3.93	1090
02/04/2008	4.06	1170
03/04/2008	4.12	1210
04/04/2008	4.41	1420
05/04/2008	4.61	1570
06/04/2008	4.59	1550
07/04/2008	4.24	1300
08/04/2008	4.42	1430
09/04/2008	4.62	1570
10/04/2008	4.61	1570
11/04/2008	4.58	1550
12/04/2008	4.37	1390
13/04/2008	4.18	1250
14/04/2008	3.84	1020
15/04/2008	4.42	1430
16/04/2008	4.49	1480
17/04/2008	4.44	1440
18/04/2008	4.42	1430
19/04/2008	4.54	1520
20/04/2008	4.46	1460
21/04/2008	4.16	1240
22/04/2008	4.49	1480
23/04/2008	4.56	1530
24/04/2008	4.42	1430
25/04/2008	4.58	1550
26/04/2008	4.81	1720
27/04/2008	4.89	1780
28/04/2008	4.31	1350
29/04/2008	4.66	1600
30/04/2008	4.76	1680

01/05/2008	4.36	1390
02/05/2008	4.02	1140
03/05/2008	4.29	1330
04/05/2008	4.52	1500
05/05/2008	4.79	1710
06/05/2008	6.16	2870
07/05/2008	6.59	3270
08/05/2008	6.92	3600
09/05/2008	6.96	3650
10/05/2008	6.86	3540
11/05/2008	6.86	3540
12/05/2008	6.65	3330
13/05/2008	6.62	3300
14/05/2008	6.55	3230
15/05/2008	6.11	2820
16/05/2008	5.84	2570
17/05/2008	5.7	2450
18/05/2008	5.64	2390
19/05/2008	5.58	2340
20/05/2008	6.12	2830
21/05/2008	6.63	3320
22/05/2008	6.76	3440
23/05/2008	6.4	3090
24/05/2008	5.98	2700
25/05/2008	5.61	2370
26/05/2008	5.14	1980
27/05/2008	5.65	2400
28/05/2008	5.88	2610
29/05/2008	5.99	2710
30/05/2008	6.15	2850
31/05/2008	6.13	2830
01/06/2008	5.77	2510
02/06/2008	5.4	2190
03/06/2008	5.79	2530
04/06/2008	6.68	3370
05/06/2008	6.71	3390
06/06/2008	6.42	3110
07/06/2008	6.28	2970
08/06/2008	6.28	2970
09/06/2008	6.19	2890
10/06/2008	6.8	3480
11/06/2008	6.89	3570
12/06/2008	6.92	3600
13/06/2008	7.15	3840
14/06/2008	7.48	4200
15/06/2008	7.94	4720
16/06/2008	7.8	4550
17/06/2008	7.65	4390
18/06/2008	7.78	4590
19/06/2008	8.57	5680
20/06/2008	9.23	6630
21/06/2008	9.31	6750
22/06/2008	9.22	6620
23/06/2008	8.81	6020
24/06/2008	8.36	5380
25/06/2008	8.22	5200
26/06/2008	8.08	5000
27/06/2008	7.95	4820
28/06/2008	8.34	5350
29/06/2008	8.98	6260
30/06/2008	8.93	6190
01/07/2008	8.73	5900
02/07/2008	8.86	6080
03/07/2008	9.1	6440
04/07/2008	8.97	6250
05/07/2008	9.6	7180
06/07/2008	10.18	8080
07/07/2008	10.95	9340
08/07/2008	11.5	10200
09/07/2008	11.52	9890
10/07/2008	10.98	8640
11/07/2008	10.34	7660
12/07/2008	10.13	7390
13/07/2008	10.1	7370
14/07/2008	10.08	7350
15/07/2008	10.05	7370
16/07/2008	10.04	7440
17/07/2008	10.28	7920
18/07/2008	10.91	9110
19/07/2008	11.33	9960
20/07/2008	11.39	10100
21/07/2008	11.4	10100
22/07/2008	11.36	10000
23/07/2008	10.97	9230
24/07/2008	10.63	8540
25/07/2008	11.09	9460
26/07/2008	12.03	11500
27/07/2008	12.54	12200
28/07/2008	12.37	11200
29/07/2008	11.78	9860
30/07/2008	11.47	9320
31/07/2008	11.32	9050
01/08/2008	10.67	7990
02/08/2008	10.17	7230
03/08/2008	9.89	6820
04/08/2008	9.67	6600
05/08/2008	9.7	6870
06/08/2008	9.81	7120
07/08/2008	10.19	7910
08/08/2008	10.56	8720
09/08/2008	11.84	11400
10/08/2008	12.94	13700
11/08/2008	13.41	14400
12/08/2008	13.31	13800
13/08/2008	12.96	12900
14/08/2008	12.5	11800
15/08/2008	12.31	11400
16/08/2008	12.13	11000
17/08/2008	11.55	9690
18/08/2008	10.67	8080
19/08/2008	9.93	6900
20/08/2008	9.43	6180
21/08/2008	9.16	5820
22/08/2008	8.95	5550
23/08/2008	8.84	5400
24/08/2008	8.69	5210
25/08/2008	8.47	4990
26/08/2008	8.46	5010
27/08/2008	8.77	5580
28/08/2008	9.2	6250
29/08/2008	9.56	6800
30/08/2008	9.75	7090
31/08/2008	9.44	6620
01/09/2008	9.87	7260
02/09/2008	10.07	7410
03/09/2008	9.6	6620
04/09/2008	9.64	6690
05/09/2008	10.01	7290
06/09/2008	10.16	7580

07/09/2008	10.06	7380
08/09/2008	9.73	6810
09/09/2008	9.6	6620
10/09/2008	9.84	7000
11/09/2008	9.82	6960
12/09/2008	9.75	6850
13/09/2008	9.1	5910
14/09/2008	8.7	5360
15/09/2008	8.47	5060
16/09/2008	8.25	4780
17/09/2008	8.2	4720
18/09/2008	8.1	4600
19/09/2008	8	4470
20/09/2008	7.94	4390
21/09/2008	7.87	4300
22/09/2008	7.6	3980
23/09/2008	7.61	4110
24/09/2008	7.71	4260
25/09/2008	7.81	4410
26/09/2008	8.8	6020
27/09/2008	10.24	8570
28/09/2008	11.25	9900
29/09/2008	10.95	9010
30/09/2008	10.02	7430
01/10/2008	9.25	6310
02/10/2008	8.83	5780
03/10/2008	8.57	5460
04/10/2008	8.31	5160
05/10/2008	8.31	5160
06/10/2008	8.87	5830
07/10/2008	9.17	6200
08/10/2008	8.65	5560
09/10/2008	8.24	5070
10/10/2008	8.06	4860
11/10/2008	7.93	4710
12/10/2008	7.81	4580
13/10/2008	7.22	3950
14/10/2008	6.98	3700
15/10/2008	6.83	3550
16/10/2008	6.87	3590
17/10/2008	6.87	3590
18/10/2008	6.79	3510
19/10/2008	6.52	3260

20/10/2008	6.23	3000
21/10/2008	6.23	2990
22/10/2008	6.17	2960
23/10/2008	6.26	3100
24/10/2008	6.68	3540
25/10/2008	7.69	4730
26/10/2008	7.59	4600
27/10/2008	7.27	4220
28/10/2008	7.45	4430
29/10/2008	7.67	4700
30/10/2008	7.72	4760
31/10/2008	8.1	5260
01/11/2008	9.76	7620
02/11/2008	9.75	7600
03/11/2008	10.14	8280
04/11/2008	12.13	12500
05/11/2008	12.94	13900
06/11/2008	12.4	11800
07/11/2008	11.7	9990
08/11/2008	11.76	10100
09/11/2008	11.34	9340
10/11/2008	10.48	8020
11/11/2008	9.87	7190
12/11/2008	9.45	6640
13/11/2008	9.04	6090
14/11/2008	8.72	5670
15/11/2008	8.41	5280
16/11/2008	8.32	5160
17/11/2008	8.25	5080
18/11/2008	8.05	4850
19/11/2008	7.69	4430
20/11/2008	7.29	3990
21/11/2008	7.24	3940
22/11/2008	7.13	3820
23/11/2008	6.89	3570
24/11/2008	6.92	3600
25/11/2008	7.05	3740
26/11/2008	6.89	3570
27/11/2008	6.36	3050
28/11/2008	6.06	2770
29/11/2008	5.98	2700
30/11/2008	6.04	2750
01/12/2008	6.08	2790

02/12/2008	6.13	2830
03/12/2008	6.22	2910
04/12/2008	6.25	2950
05/12/2008	6.17	2870
06/12/2008	6.07	2780
07/12/2008	6.03	2740
08/12/2008	5.59	2350
09/12/2008	5.56	2320
10/12/2008	5.64	2390
11/12/2008	5.72	2470
12/12/2008	5.62	2370
13/12/2008	5.45	2230
14/12/2008	5.34	2140
15/12/2008	5.15	1990
16/12/2008	5.08	1930
17/12/2008	5.07	1920
18/12/2008	4.97	1840
19/12/2008	5	1870
20/12/2008	4.96	1830
21/12/2008	4.8	1710
22/12/2008	4.54	1520
23/12/2008	4.65	1600
24/12/2008	4.78	1700
25/12/2008	5.05	1910
26/12/2008	4.94	1820
27/12/2008	4.9	1780
28/12/2008	4.96	1830
29/12/2008	4.91	1790
30/12/2008	4.91	1800
31/12/2008	4.88	1800

Table 8 Water levels and discharge of 2008[31]

[31] (Vietnam Hydrometeorological Data and Information Center, 2014)

Gumbel analysis
Now the Gumbel-distribution needs to be made. The first step is to collect the annual maximum discharges. The data for 55 years is available. All yearly maximum discharges are picked out. The next step is to compute the return period T. This can be done with the following formula:
$T_i = \frac{N+1}{i}$ with N = number of measured years.
If T is computed, the reduced variable y can be calculated too.
$y = -\ln(-\ln\left(1 - \frac{1}{T}\right))$
The intermediate results can be find in appendix B. After this is done for all data points, the next step is plotting y against the discharge. This results in the following graph.

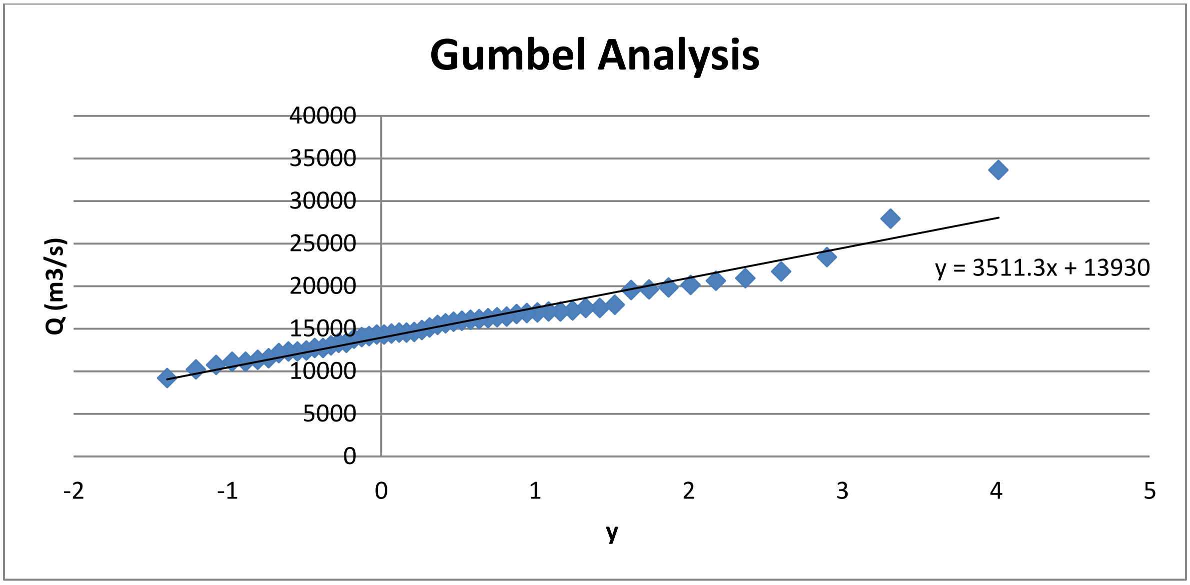


Figure 30 Gumbel analysis

The formula of the relation between Q and y is: $Q = 3511.3y + 13930$
Rewriting gives: $y = \frac{Q-13930}{3511.3}$
A flooding will occur when the water level reaches 12 m. According to the Q-h relation, this correspondent with a discharge of 11.500 m^3/s. This gives a value of -0,69 for y. Then the formula $y = -\ln(-\ln\left(1 - \frac{1}{T}\right))$ needs to be rewritten into $T = 1 - \frac{1}{-e^{-e^{y}}}$.
Filling in y, will result in the return period of 2,65 years.[32]

This value is not realistic. Making the decision to open the Day Dam seems to be a more complicated than just look at the water levels. Because if they only take the water levels into account, the Day Dam should be opened at least every three year. The last time the Day Dam was opened is more than 40 years ago.

The intermediate results of the Gumbel analysis are presented in the table below.

i	Date	Q (m3/s)	T	y
1	21-8-1971	33600	56	4,016356

[32] (Savenije, 2014)

2	18-8-1969	27900	28	3,314076
3	15-8-1968	23400	18,66667	2,899336
4	28-7-1970	21700	14	2,602232
5	18-8-2002	20900	11,2	2,369515
6	28-7-1986	20600	9,333333	2,177463
7	8-7-1964	20100	8	2,013419
8	21-8-1996	19800	7	1,869825
9	25-7-1980	19600	6,222222	1,741804
10	30-7-1966	19500	5,6	1,626023
11	18-8-1995	17800	5,090909	1,520104
12	11-9-1978	17400	4,666667	1,422286
13	4-8-1983	17400	4,307692	1,331232
14	30-6-1990	17100	4	1,245899
15	21-8-1967	17000	3,733333	1,165459
16	12-9-1979	17000	3,5	1,08924
17	13-7-1998	16900	3,294118	1,016691
18	26-7-2000	16800	3,111111	0,947354
19	15-8-1991	16700	2,947368	0,880842
20	27-7-1992	16400	2,8	0,816824
21	6-7-2001	16300	2,666667	0,755015
22	31-7-1977	16200	2,545455	0,695167
23	23-7-1997	16100	2,434783	0,637062
24	5-9-1973	16000	2,333333	0,580505
25	23-7-1957	15900	2,24	0,525323
26	12-9-1985	15800	2,153846	0,471358
27	31-7-1981	15600	2,074074	0,418465
28	17-8-1976	15400	2	0,366513
29	9-8-1961	15100	1,931034	0,315376
30	3-9-1999	14800	1,866667	0,264936
31	24-7-2004	14600	1,806452	0,215081
32	23-8-1956	14500	1,75	0,165703
33	18-7-1994	14500	1,69697	0,116694
34	11-8-2008	14400	1,647059	0,067948
35	3-8-1959	14300	1,6	0,019357
36	16-8-1960	14300	1,555556	-0,02919
37	19-8-1958	14100	1,513514	-0,07781
38	22-8-1982	14000	1,473684	-0,12661
39	29-7-1972	13800	1,435897	-0,17575
40	24-8-1987	13300	1,4	-0,22535
41	20-7-2006	13300	1,365854	-0,27559
42	2-9-1975	13000	1,333333	-0,32663
43	4-8-1963	12700	1,302326	-0,37871
44	28-10-1965	12700	1,272727	-0,43207
45	8-8-1974	12400	1,244444	-0,48702
46	6-7-1962	12300	1,217391	-0,54393
47	14-6-1989	12300	1,191489	-0,60329
48	6-8-2007	12100	1,166667	-0,66573
49	7-7-2009	11500	1,142857	-0,7321
50	28-8-1984	11300	1,12	-0,80361
51	28-8-1988	11100	1,098039	-0,88208
52	13-8-2005	11100	1,076923	-0,97042

53	26-8-1993	10700	1,056604	-1,07389
54	28-7-2003	10200	1,037037	-1,20363
55	26-7-2010	9170	1,018182	-1,39261

Table 9 Intermediate results of the Gumbel analysis

Appendix D Measurement location

Figure 31 Measurement location; downstream direction

Figure 32 Measurement location; upstream direction

Figure 33 Measurement location; stairs in the river

Figure 34 Measurement location; upper part of the stairs

Appendix E Exact locations structures in Tich River

Data collected during boat trip on 29-11-2014.

Name	Longitude (E)	Latitude (N)
temporary bridge	105,679809	20,859801
church+bridge	105,668576	20,864077
junction	105,648713	20,876039
confluence Bui and Tich River	20,90485903	105,60081
pumping station + bridge	20,89881501	105,599831
Stairs in river (Huan)	20,89682104	105,603324
pumping station	20,894987	105,611118
small canal (dry)	20,89328103	105,610344
pumping station	20,88876796	105,609312
canal	20,89257301	105,628843
pumping station	20,89477099	105,631319
pumping station	20,88998199	105,640541
pumping station	20,876004	105,648796
junction	20,87612302	105,651157
pumping station + ferry	20,87944401	105,659913
pumping station	20,87991097	105,666519
sluice	20,87990896	105,669318
pumping station	20,87345297	105,671223
bridge+pumping station (with floodmark) +canal	20,86525002	105,66746
bridge	20,86345503	105,671517
pumping station	20,85943398	105,680008
pumping station	20,85822104	105,680698
pumping station	20,844021	105,686306
canal	20,84371003	105,688338
pumping station+ferry	20,84392	105,702091
pumping station	20,84320301	105,703982
2 canal (one dry, one with sluice)	20,84023196	105,704826
bridge (point 8)	20,839073	105,705078
small canal	20,83761496	105,705626
pumping station	20,83347699	105,707969
small canal	20,83103199	105,709355
small canal	20,827468	105,710751
pumping station	20,82558098	105,707652
small canal+pumping station	20,82186998	105,706835
small canal	20,82150503	105,70687
pumping station	20,80966299	105,709161
Ba tha	20,80628903	105,707777
Ba Tha station	20,91355098	105,70044

Table 10 Coordinates of locations

Appendix F Measurement methods and equipment

In this appendix the different measurement methods and equipment are explained which can be used for determining the water level, cross section and flow velocity (discharge).

Measurement Methods

Discharge[33]

To determine the discharge there are different methods available. Probably not every method is suitable for the Day river. So therefore we mention some different methods with different approaches:

- Velocity area method

With this method a cross-section of the river is divided into segments. The number of segments depends on the width of the river and the required accuracy of the measurement. The area of each segment should be measured and the flow velocity in each segment should be measured. By taking the sum of all segments the average discharge of the entire cross-section can be calculated.

$$Q = \int^{A} u \, dA \approx \sum^{n} u_i * \Delta A_i$$

The velocity in each segment can be measured with two different methods:

  - Propeller type current meter
  - Floats
  - Acoustic Doppler Current Profiler (ADCP)

- Salt dilution gauging

By this method a volume of water with a known salt concentration is added upstream. By measuring the change of salt concentration downstream with an EC-meter it is possible to calculate the discharge. This method isn't feasible for high discharges, so we will not use this method in the main river.

[33] (Delft University of Technology, 2014)

- Moving boat technique[34]

The moving boat technique is based on the area velocity method of determining discharges. For this method the cross-section of the river is also divided into sub-areas for which a representative velocity is measured. The moving boat technique measures the direction of the current by a current meter at a constant depth while the boat crosses the river cross section. As result we know the direction of the current in relation to the movement of the boat. If the velocity of the boat is know we can calculate the flow velocity via the vector diagram.

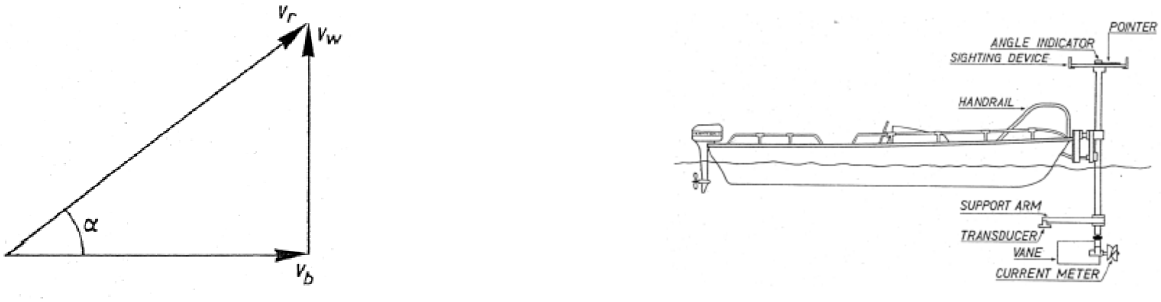


Figure 35 Moving boat technique

- Rising bubble technique

For this method a device which releases air bubbles is placed at the bottom of the river. While the bubbles rise to the surface they are dragged along the river by the current. If you measure the displacement (L) of the bubbles and combines this with the rising velocity of the bubbles the discharge of the river can be calculated.

- Weir (Bernouilli -> based on energy and impulse balance)

If the dimensions of a structure such as a weir or dam and water levels are known it is possible to calculate the discharge with an energy- and impuls-balans. Maybe this is possible in a small tributary. But it will be expensive and takes a long time to construct.

- Slope area method

This method is less accurate than the other methods and should only be used if other methods aren't feasible. For this method the cross-sectional area(A), hydraulic radius(R) and water slope(i) are required. The formula for the discharge is: $Q = i^{1/2} * \sum^{j} C_j * A_j * R_j^{1/2}$
It is hard to determine the roughness/chézy coefficient (C) in this formula.

[34] (Luxemburg & Coenders, 2014)

Water level
The following methods are available to measure water levels in the study area:

- Manual measurements

A person reads the water level from a measuring device such as a staff gauge at regular intervals.

- Divers

A Diver is a device which constantly measures the pressure on the bottom of the river. This device gives a constant measurement of the water level. With this method it is also necessary to install one diver next to the river which measures the atmospheric pressure. The water pressure is the pressure on the bottom minus the atmospheric pressure. From the water pressure the water level can be calculated easily.

In the research proposal it is proposed to measure the evaporation and precipitation. Eventually these parameters are not measured because this data is mainly available and these measurements are conducted by another department.

Evaporation
Evaporation will not be measured, because there is already a dataset available. But it is unknown over which period, with which method and where this data is measured. So if it is neceassry in the future, you can use the following methods. With those methods you measure the open water evaporation.

The two methods to measure open water evaporation are

- Theoretical (Pennan)

This is a good method to estimate the open water evaporation(E_0) is the Pennan formula. The method only needs five meteorological parameters:

- Hours of sunshine
- Wind velocity
- Relative humidity
- Air temperature
- Netto radiation

If we can find the parameters for the Pennan formula in literature or from weather stations, the Pennan formula will provide a good first estimate of the evaporation in the study area.

Formula of Pennan: $E_0 = \dfrac{\frac{sR_N}{\rho\lambda} + \frac{c_p\rho_a}{\rho\lambda} * \frac{(e_s - e_a)}{r_a}}{s+\gamma}$

- Evaporation pan (class A)

We can also measure the evaporation in the study area with a evaporation pan. By measuring the change in water level in this pan it is possible to calculate the evaporation. This pan should be combined with a rainfall gauge to correct for increase of water level due rainfall.

Precipitation
There is daily rainfall data available over the period 1970-2010 for the following stations: Xuan Mai, Ba Vi, Ha Dong, Ba Tha, Day Dam, Ha Dong and Son Tay. This will be enough data for the water balance. Besides it is hard to measure precipitation in November, December and January because it hardly rains in this period of the year.

Equipment

The following equipment is available at HUNRE:

- Propeller current meter
  Measure flow velocity at a certain point in the river
  Model LS25-1A
  Company name: Chongqing Huazheng Hydrometric instrument LTD. (Chinese)
- Staff gauges of 1 or 3 meter
- GPS Garmin eTrex 10
- Land meters
  Determine elevation from reference level (national level)
  Equipment to determine elevation NIKON (AC-2s) automatic level 360 model 677524
  Another elevation instrument
  DT510s (Japan)
  Digital/electrical theodolite
  Model 100334
- Portable depth sounder
  HONDEX PS-7 (Japan)
  Depth range: 0.6 to 80 m
  Frequency 200 kHz

The following equipment has not arrived yetat HUNRE:

- ADCP

Some equipment is described here and the accuracy and limitations of these instruments are discussed.

Portable depth sounder
The portable depth sounder which determines the water depth by transmitting sound with a frequency of 200 kHz and measure the echoes of the returning sound. This instrument is designed to use for fishing or diving (leisure). So it is not sure if this instrument is also suitable for hydrological purpose. This instrument did not work at the measurement location because the water was too shallow

Propeller current meter
The students of the course Water Resources Monitoring will use a Propeller current meter to determine the velocity at multiple point in the cross section of the river. They can use the results to calculate the discharge with the velocity area method. The propeller current meter and the manual which is available at HUNRE is in Chinese. We have made a English manual which describes how to use the current meter and how to set the right calibration coefficients.

Acoustic Dopler Current Profiler (ADCP)
HUNRE has ordered a ADCP. This instrument measures the flow velocity by using the Doppler effect. This instrument transmits sound at a fixed frequency and is listening to echoes returning from sound scatters in the water. With the ADCP it is possible to make a continuous velocity profile. This will give the discharge, water level and a part of the cross section of the river. In shallow water the errors in the ADCP measurements will be bigger, this can be a problem in the Day river basin.[35] This instrument can be used to calculate the discharge with

[35] (Luxemburg & Coenders, 2014)

the velocity area method. The students of the course Water Resources Monitoring will not use the ADCP. Because it is less useful for educational purpose and the equipment is more complex and expensive than a propeller current meter. The ADCP can be used to check the measurements of the students.

Land meters

The land meters are not used during this project. It was not useful to use this meters because it was not possible to get information about the reference level.

Appendix G Measurement results

In this appendix the measured data from the final measurement series can be found. This data is measured on 30/12/2014. Table 11 shows the measured water depths.

x	Water depth
0	0
1.5	0.36
3	0.4
4.5	0.46
6	0.45
7.5	0.48
9	0.46
10.5	0.41
12	0.37
13.5	0.38
15	0.4
16.5	0.42
18	0.43
19.5	0.42
21	0.44
22.5	0.45
24	0.46
25.5	0.47
27	0.47
28.5	0.44
30	0.41
31.5	0.4
33	0.38
34.5	0.33
36	0.18
37.5	0

Table 11 Water depth

At the measurement location is a stairs. This stairs is measured (red line in figure 38) to make an estimate of the complete cross section. At the other side of the river the estimate of the cross section (green line) is based on three rough measurements where the slope is measured. The reference level is taken at the water surface level.

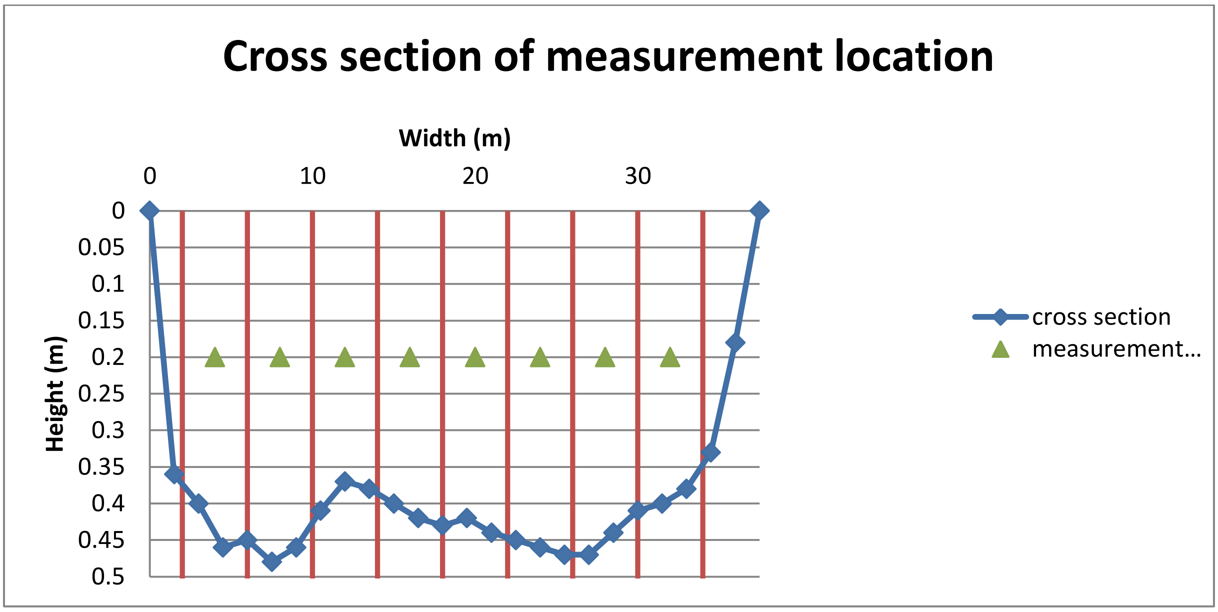


Figure 36 Water depth and measurement points

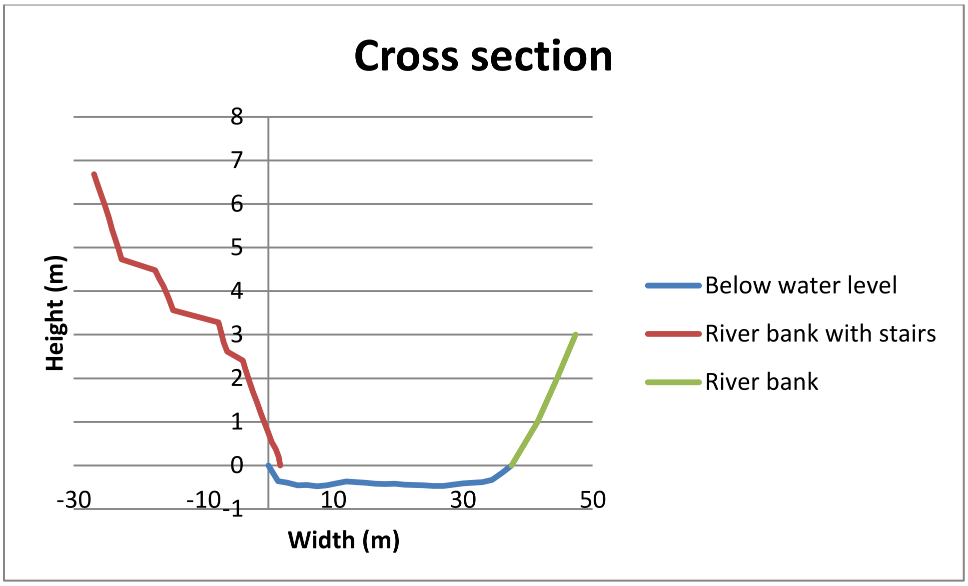


Figure 37 Total cross section

steps	y	x
water level	0	1.87
1	0.2	1.62
2	0.37	1.15
3	0.54	0.54
4	0.76	-0.01
5	0.95	-0.54
6	1.18	-1.09
7	1.45	-1.76
8	1.68	-2.32
9	1.94	-2.95
10	2.21	-3.53
11	2.41	-3.9
12	2.61	-6.35
13	2.83	-6.88
14	3.03	-7.25
15	3.28	-7.68
16	3.56	-14.68
17	3.84	-15.37
18	4.11	-16.15
19	4.28	-16.8
20	4.48	-17.43
21	4.73	-22.63
22	4.98	-23.1
23	5.2	-23.61
24	5.42	-24.08
25	5.67	-24.54
26	5.94	-25.14
27	6.19	-25.74
28	6.44	-26.34
29	6.68	-26.86

Table 12 Dimensions of the stairs on the river bank

estimate slope other side	
x	y
4	1
3	1
2.9	1

Table 13 Slope of the other riverbank

The exact elevation of the reference level is not shared by the Day irrigation company. But some data about water levels of the last 5 years is available (figure 39). If you compare the water depths with the water levels in the past at the same time of the year, you can conclude that the reference level must be 30 to 50 cm lower than the river bed.

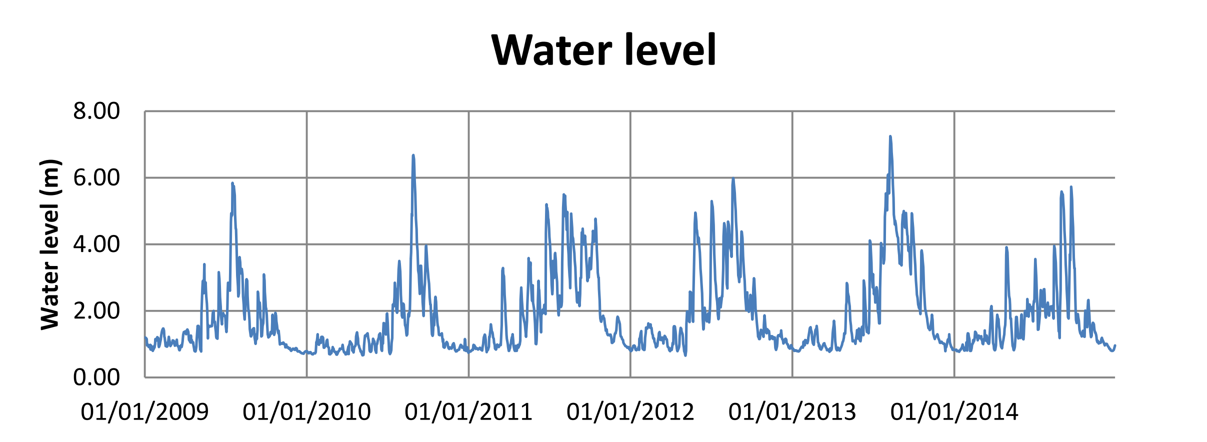


Figure 38 Water level at measurement location

The results of the discharge measurements can be found below.

X	N	T	V
4	34	20	0.54
4	41	20.4	0.52
8	43	20.2	0.55
8	42	20.1	0.54
12	42	20.1	0.54
12	43	20.1	0.55
16	42	20.3	0.53
16	42	20	0.54
20	41	20.2	0.52
20	42	20	0.54
24	46	20.1	0.59
24	46	20.2	0.58
28	45	20.2	0.57
28	43	20.2	0.55
32	33	20	0.43
32	32	20.4	0.41

Table 14 Results propeller current meter

section	A	Vaverage	Q
1			0
2	1.646667	0.53	0.872733333
3	1.786667	0.545	0.973733333
4	1.66	0.545	0.9047
5	1.633333	0.535	0.873833333
6	1.766667	0.53	0.936333333
7	1.846667	0.585	1.0803
8	1.76	0.56	0.9856
9	1.546667	0.42	0.6496
10			0
total			7.276833333

Table 15 Calculation of the discharge

Appendix H Practical guideline WRM

HANOI UNIVERITY OF NATURAL RESOURCES AND ENVIRONMENT

Water Resources Monitoring

Pracitcal Guideline

Mr. Thi Van Le Khoa

1/6/2015

Introduction

For the course Water Resources Monitoring, you all have to complete the practical. But where is this practical about?

This practicum has four main goals:

1. Teaching you how to measure water level and discharge in a river.
2. Show what important is for a suitable measurement location.
3. Explain why certain measurement methods are more suitable than others.
4. Give you a better understanding of the errors that could be made during measurements.

To achieve those goals, there are four steps you have to do:

1. Read the entire practical guideline.
2. Go into the field and conduct the measurements.
3. Answer the questions.
4. Write a short report.

The practical site

The practical site is located in the Tich River, in the Day River basin. The origin of this river is located in the Ba Vi mountain range (more upstream from the measurement location). Finally the river will flow into the Day river at Ba Tha (more downstream of the measurement location). In the Day River Basin, where the Tich River is part of, are a lot of problems with integrated water resources management. To solve these problems, data is needed. You will make a first start with collecting data.

On the maps below you can see where the practical site is located. With motorbike the travel time is about one and a half hour.

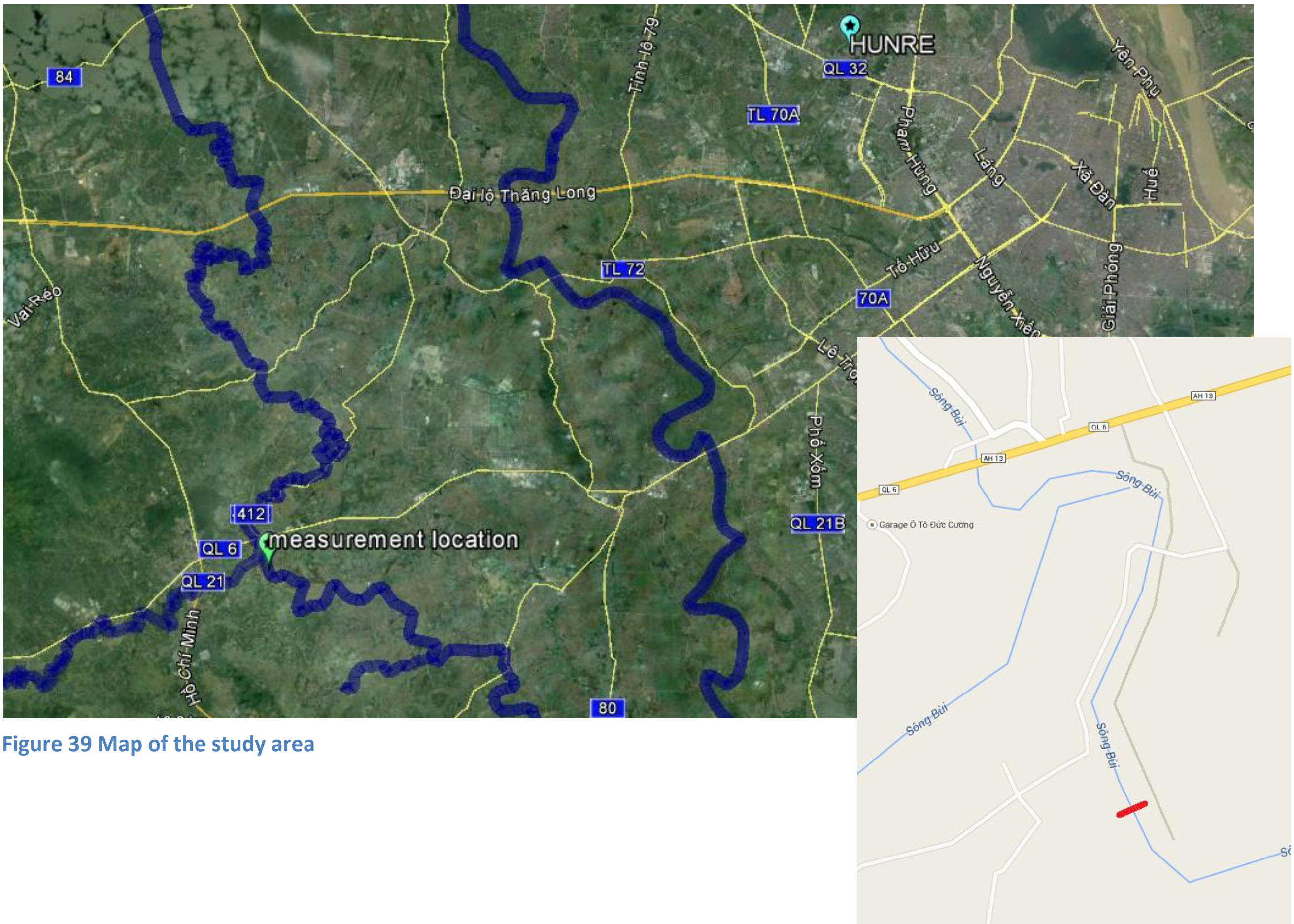


Figure 39 Map of the study area

Methods

To measure the water level and cross section you are going to use a staff gauge. This is not the most accurate equipment that is available, but using the staff gauge is the easiest way to visualize your results.

For the discharge, the measurement method you are going to use is the velocity-area method. If you use this method, you have to divide the river into segments. The number of segments depends on the width of the river, the cross section and the required accuracy of the measurement. The area of each segment should be measured and the flow velocity in each segment should be measured. The flow velocity can be measured with a current meter. Now the discharge of one segment can be calculated. If you take the sum of all segments, you can compute the discharge of the total cross section.

$$Q = \int^{A} u \, dA \approx \sum^{n} u_i * \Delta A_i$$

Figure 40 Velocity area method at measurement location

Equipment

To do the measurements, you'll need the following equipment. Everything will be provided by HUNRE. You only have to bring your own pen and paper to make notes.

- Propeller current meter (provided by HUNRE)
- Staff gauge (provided by HUNRE)
- High boots (provided by HUNRE)
- A 40 m tape (provided by HUNRE)
- Paper and pencil

Conducting the measurements

You'll do the practical in groups of 4/5 students. When you arrive at the practical site, start with reading the questions on the next page. Secondly, read the description about using the propeller current meter. After that, you can immediately start with the practical by following the steps on the next page.

WRITE DOWN EVERYTHING YOU DO STRICTLY AND NOTE ALL YOUR RESULTS CAREFULLY. YOU'LL NEED THEM LATER!

Using the propeller current meter

The propeller current meter is used for measuring the flow velocity. The meter you'll get is already calibrated, so it is not necessary to do that yourself. But you have to assemble the current meter before you can use it. Do this together with a supervisor or lecturer. Ask the supervisor if the right values of K,C, A and T are set. (The supervisor has a manual to set the right values)

If this is done, you can start to measure. Below, step by step is described how you should use the propeller current meter.

1. One student takes care of the propeller and one student takes care of the control panel, these two students will wear high boots. The other students write down the (intermediate) results and use the measuring tape to make sure you measure at the right locations.
2. Turn the meter on by pushing the left red button (nr. 1).
3. Press the most right button (nr. 6).
4. The student with the propeller puts it into the water. Pay attention that you stand downstream of the propeller and keep some distance from the propeller; otherwise you will influence the measurement.
5. If the propeller turns at a constant speed, the measurement can be started. You can start the measurement by pushing the most right button again (nr. 6).
6. After 20 seconds, the measurement will stop automatically.

   20 seconds is the time that is set. You can also set the time to 50, 100, 200 seconds. This will reduce the error in your measurement, but also costs a lot of time. For the practical is 20 seconds sufficient.
7. Write down the number of rotations (N), the time (T) and the velocity which will be automatically showed after N and T.

   *The velocity follows from the equation V=K*n+C. K and C are parameters that are already defined by the manufacturer. n is the number of rotations per unit of time.*
8. To do a second measurement, start at step 4.

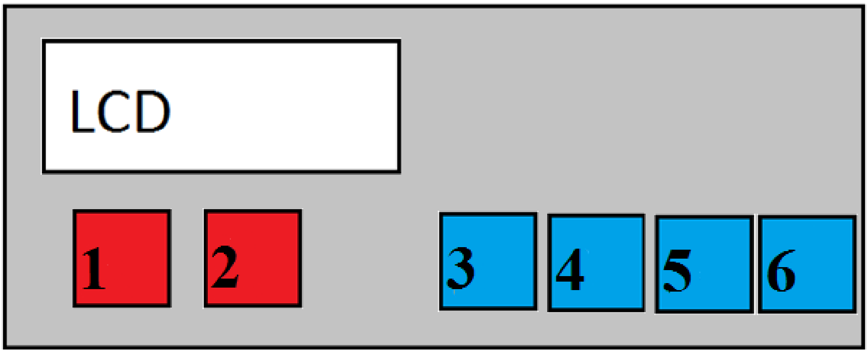


Figure 41 Control panel of propeller current meter

Figure 42 Use the propeller current meter[36]

Now you know how to use the equipment, you can start conducting the measurements. Below is described how to conduct the measurements, step by step.

1. **Measuring the cross section**
    I. First measure the width of the river.
    II. Divide the cross section into smaller sections.
    When you divide the cross section into smaller sections, you have to think about the width of each section. The width of the section depends on the shape of the cross section and the needed accuracy of your measurements. If the river bed is very irregular, you need a smaller width to reduce the errors in your measurements. The wider your section is, the bigger your errors will be.
    III. Measure in the middle of each section the water depth.
    IV. Now you have the cross section of the river.

2. **Measuring the discharge**
    I. You already measured the width of the river. Divide the cross section again into smaller sections.
    II. Measure in the middle of each section the water depth.
    III. Measure in the middle of each section twice the flow velocity.
    You would like to measure the average flow velocity in the section. Close to the river bed the flow will be influenced by irregularities of the bottom. So measure in the middle, then you can make the best approximation to the average flow velocity in the section.
    You do two measurements, to reduce the errors.

Now you finished the measurements. Check if you'll be able to answer all questions. At home you have to answer some questions and write a short report about your results.

[36] Lecture note: ''CIE4440 – Hydrological processes and measurements'' by ir. W.M.J. Luxemburg and dr. ir. A.M.J. Coenders of the Delft University of Technology, 14 August 2014

Questions

1. Why is this measurement location suitable to do accurate measurements?
2. Show the measured cross section (present also the values). Change the water depth into water level.
3. What is the maximum water depth?
4. Calculate the discharge.
5. What is the difference between the dry and rainy season in terms of water level, discharge and cross section? Do you see any indications of the difference between these two seasons at the measurement location?
6. Which errors do you have possibly made? How can you prevent this?
7. Which other methods are suitable to measure discharge and/or water level at this location?
8. What kind of human activities can you see around the river?
9. Can you give an estimate of the roughness of the river bed (Manning)? Show your assumptions and calculations. Use length of the river (L) = 25,8 km and difference in elevation = 0,8 m (between measurement location and Ba Tha).

Report

Write together with your group a short report in which you:

- Describe what you have done
- Present your results
- Answer all the questions (*show the calculations)*

From here only for the lecturer/supervisor!!!

Answers

1. The research location is suitable because it meets the following criteria:
    - More or less uniform flow because it is a straight segment without any structures. So there are no big disturbances.
    - Easy accessible. It is located near the main road and has a stairs to enter the river.
    - It is already used as measurement location by an irrigation company. So we can use their data and the stairs which they have built.
    - Flow is high enough to measure the discharge at this location
    - Shallow water so it is safe for the students to measure at this location
2. During the practical the students will measure the cross section. The students can set this data in an excel table and plot it in a graph. In this graph they can also show the chosen subsections for the velocity area method. The reference level is about 30 to 40 cm under the river bed. This will look like this:

x	Water depth
0	0
1.5	0.36
3	0.4
4.5	0.46
6	0.45
7.5	0.48
9	0.46
10.5	0.41
12	0.37
13.5	0.38
15	0.4
16.5	0.42
18	0.43
19.5	0.42
21	0.44
22.5	0.45
24	0.46
25.5	0.47
27	0.47
28.5	0.44
30	0.41
31.5	0.4
33	0.38
34.5	0.33
36	0.18
37.5	0

Table 16 Measured water depth

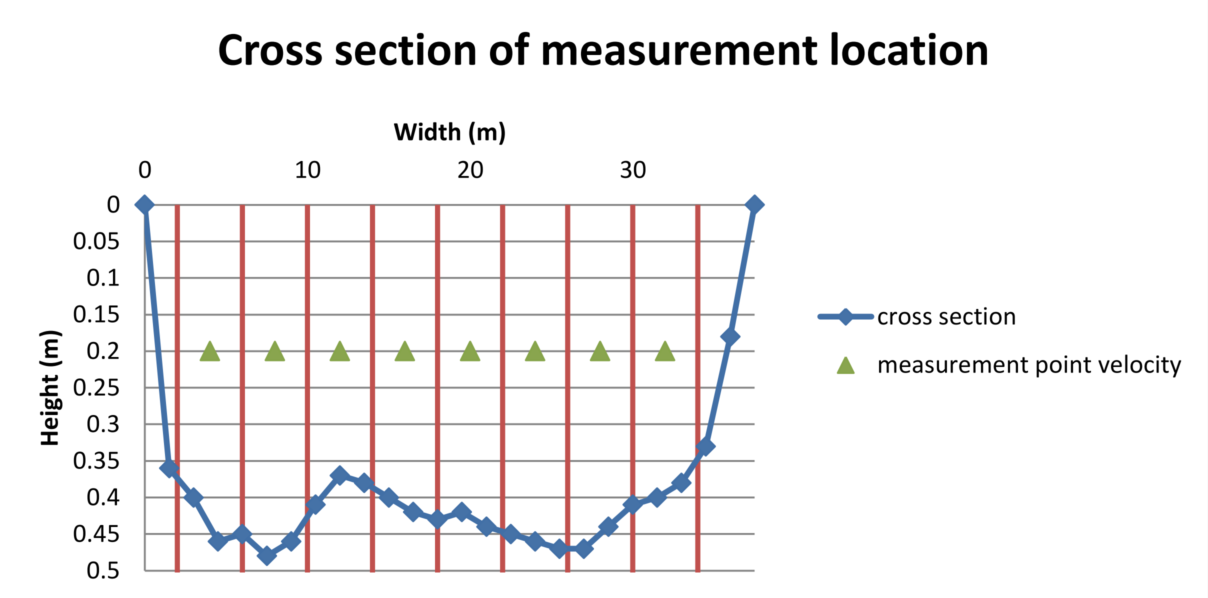


Figure 43 Cross section of measurement location and measurement points

3. On 30th December of 2014 the maximum water depth was 0.48 meter. You can compare your measurements with the historical water level data of the irrigation company (see database)
4. To calculate the discharge first the area of each subsection has to be calculated. This can be done whit the measured data about the cross section (see the answer of question 2). Then you can calculate the Q of each subsection by multiplying this area by the measured velocity in each subsection. The sum of all these discharges is the total discharge of the river. The area near the river banks can be neglected, in our example it will be an area of 2 meters out of the river bank.
   The following table shows the discharge which is calculated with our measurements on 30/12/2014:

X	N	T	V
4	34	20	0.54
4	41	20.4	0.52
8	43	20.2	0.55
8	42	20.1	0.54
12	42	20.1	0.54
12	43	20.1	0.55
16	42	20.3	0.53
16	42	20	0.54
20	41	20.2	0.52
20	42	20	0.54
24	46	20.1	0.59
24	46	20.2	0.58
28	45	20.2	0.57
28	43	20.2	0.55
32	33	20	0.43
32	32	20.4	0.41

Table 17 Results propeller flow meter

section	A	Vaverage	Q
1			0
2	1.646667	0.53	0.872733333
3	1.786667	0.545	0.973733333
4	1.66	0.545	0.9047
5	1.633333	0.535	0.873833333
6	1.766667	0.53	0.936333333
7	1.846667	0.585	1.0803
8	1.76	0.56	0.9856
9	1.546667	0.42	0.6496
10			0
total			7.276833333

Table 18 Calculation of the discharge

5. The difference are:
    - Water level:
    - Discharge:
    - Cross section:

    Indicators at location:
    - A high dike. This means this should be necessary to protect the village from a higher water level in the rain season.
    - Erosion of the river banks. This is an indication for a higher water level and discharge in the rain season.
6. Possible errors are:
    - Current meter is not calibrated correctly
    - Divided the cross section in too big sections. So the flow velocity varies too much within the sections. So the student has chosen not enough measurement points in vertical or/and in horizontal direction
    - Errors made in determining cross section
    - Errors in measuring water level
    - Errors in measuring flow velocity
    - Local disturbances/turbulence which influence the measurement
    - ……
7. Other suitable methods would be:
    - Discharge:
        i. Slope area method
        ii. ….
    - Flow velocity
        i. floats
    - Water level
        i. Install a well and floater
        ii. Install diver
    - Not suitable
        i. Salt dilution method: river is too big
        ii. ADCP in the dry season: the water depth is too small for an ADCP. In the rain season it is maybe possible to use an ADCP, but you still have to notice that the errors of the ADCP are bigger with low water levels.

8. Human activities around the river:
   - Duck farm
   - Irrigation
   - Fishing
9. The formula of Manning is $U = \frac{1}{n} R^{2/3} \sqrt{i} \rightarrow n = \frac{1}{U} R^{2/3} \sqrt{i}$. The students have to calculate the manning coefficient n. The flow velocity U is measured by the students during the practical with the propeller flow meter. The students can take an average value of the measured flow velocities for U. The students can calculate the slope i by dividing dz/L =0.8/25800=$3.1*10^{-5}$. Dz is the difference in elevation between the practical site and Ba Tha and L is the length of this segment of the river. With these two parameters and the manning formula it is easy to calculate n. With our measurement of $U_{average}$ = 0.53 m/s and R = 0,39 m, the answer in this case is: n= 0.005495393 [-].
   This is very small. This is most probably caused by using a wrong value for the slope. The used value is the average slope between the measurement location and Ba Tha. But it looks like near the measurement location the slope is steeper. n should be around 0.03 (natural stream). Maybe this can be another question for the students (depends on their knowledge about this).

Manual propeller current meter (LS25-1A)

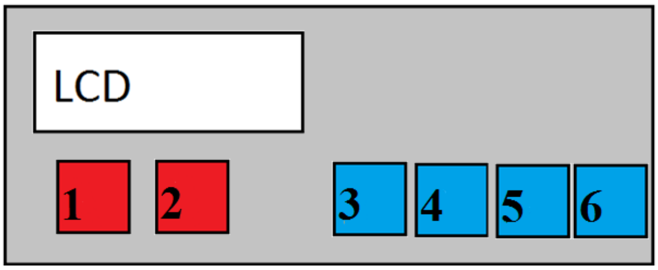


Figure 44 Control panel of the propeller current meter

Buttons

1. On/Off
2. Reset/set up K,C,T
3. For change the value/get the data
4. Change value K,C,T
5. Save the measurement data→and ready for next measurement
6. Wait for measurement →without saving

Step 1: set up K,C,A,T

1. First we have to set up K,C,T
2. First K:

Press on 4→ press 4 again→LCD shows: [K000] → select value/digit of K with 3 → change the value with 5 → set K=0.2529

3. Set up C:

Press 4 to set up C after K → repeat the same procedure →set C=0.0097

4. We have to up a specific rotation which is related to this model

After set up K press 4 → LCD shows A→ set A =1

5. Set up measurement time

Press 4 → Choose between T = 200,100,50,20

Step 2:

After finishing set up K,C,T the LCD shows: [---] it means that the current meter has already saved our set up

Step 3:

After finish step 1 and 2: press 6 → LCD shows: [0000] this means the meter is ready to measure

To save the measurement press 5 after every measurement, press 6 if you don't want to save it

Step 4: get the saved data

After finish measurement → you have to turn off the meter with 1 to save everything → then turn on and press 4 → LCD shows: [---] → then press 3 to view the saved data

Calibration LS25-1A

V=K*n+C with n=N/T

b (m) = K	a (m/s) = C	m (%) = accuracy	Vk (m/s)	Range (m^2/s)
0.2529	0.0097	0.59	0.1200	0.0400-3.5000