Appendices thesis Bob Dubbel

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APPENDIX A: GENERAL ANALYSIS BAGO REGION

GENERAL INFORMATION ON THE BAGO REGION

Version	1.0
Date	14-03-2017
Location	Bago
Authors	Bob Dubbel

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ABSTRACT

During the research conducted by Bob Dubbel, Dennis Neleman and Leon Brok in Myanmar, different sources have been used to retrieve general data on the Bago region. The gathering of information has brought clarity in the main problems the region is facing. Allegations made in the final documents are based on conclusion written in the document. All figures, values, and facts in this document are legitimately based on sources which are included in the report.

CONTENTS

1. BAGO REGION IN GENERAL

1.1 GEOGRAPHICAL BOUNDARY DETERMINATION

The research has been conducted in the Bago region, Myanmar. The Bago region is one of the 15 states in which Myanmar is divided in. The research is conducted in Bago, the capital of Bago region. Since data is lacking in general in Myanmar and the interchange of data between different state authorities happens rarely, the research focusses solely on the Bago Region itself. The ITC (Irrigation Technology Center) collects al available data throughout the region and works as a basepoint for the research. Therefore, most of the data that is available inside of the Bago region is reachable.

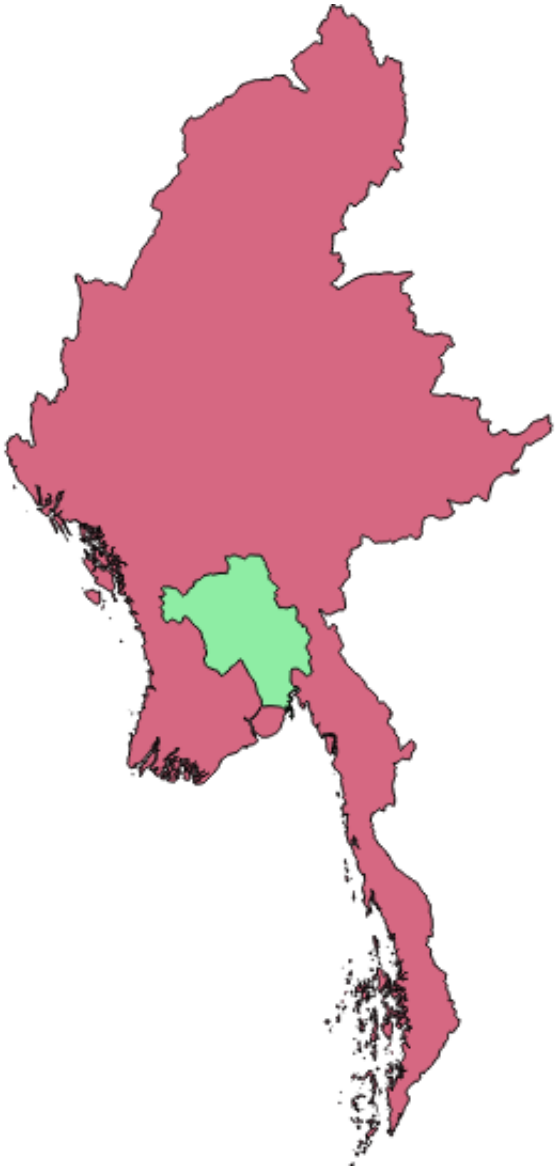

Figure 1: Bago Region projected on the map of Myanmar

1.2 LOCATION

On global scale, the Bago region is geographically located between 9˚ 32' and 28˚ 31' north latitude and 92˚ 10' and 101˚ 10' east longitude. In GIS, 46N or 47N should be used for the CRS. It is characterized by mountain ranges in the north, east and west and a long coastal strip in the south. Lengthwise, it stretches about 400km north to south and approximately 220km east to west. Area wise, the region covers about 39,400 km^2.

Bago Region is located central in Myanmar. The surrounding states are Mandalay Region, Kayin state, Mon state, Yangon Region, Ayeyawaddy Region, Rakhine state and Mangway Region. These 8 regions make up for about $1/4^{th}$ of Myanmar in surface, but inhabit 65% of the total population of Myanmar.

1.3 DISTRICTS

14 townships are located in Bago region, with a total population of 3.67 million people. These townships are divided over the 4 districts Bago Region consists of: Bago District, Taungoo District, Tharyarwaddy District and Pyay District.

1.4 CLIMATE

Myanmar has three distinct seasons± The dry, the wet and the cold seasons. In general, summer emerges from March to May, the rainy season emerges from May to October and the cold season from November to the end of February.

1.5 FLOOD RELATED INFRA WORKS

A total of 65 irrigation works are located in the region. This includes weirs, dams, sluices, sluice gates and lock gates. These 65 irrigation works together store, protect or irrigate the following amounts of land and water use in the region:

Full storage capacity	**6,935,000,000**	**m^3**
Beneficial irrigated area	**190,428**	**ha**
Beneficial flood protected area	**71,523**	**ha**

Table 1: Irrigational works (SOURCE: Bago region agriculture, Livestock & irrigation in brief)

1.6 HYDRO POWER WORKS

Name of work	Township	Extend of hydropower (MW)	Completed year
Phy Chaun Dam	Phyu	40	2016
Kapaung Dam	Oktwin	30	2008
Yenwe Dam	Kyauktaga	25	1987
Pathi Dam	Taungoo	2.2	1997
Schwelaung Dam	Bago	0.1	2012
Total:		97.3	

Table 2: Hydro power works(SOURCE: Bago region agriculture, Livestock & irrigation in brief)

2. POPULATION AND SOCIO-ECONOMICS

2.1 Ministries

For inclusive development of Myanmar, agricultural growth is critical to ensure that food security is achieved throughout the country. Currently Myanmar's population reaches 54 million but is expected to grow over the 80 million by 2025. Government and Ministry of Agriculture, Livestock and Irrigation are responsible for sustaining the rising demands for food in the future. Developping strategies that improve the welfare and income of farmers and their dependent families is the prime objective of the ministry. The Irrigation and Water Utilization Management Department (IWUMD) takes responsibility for the provision of irrigation water demands and flood protection works to achieve agriculture's objectives.

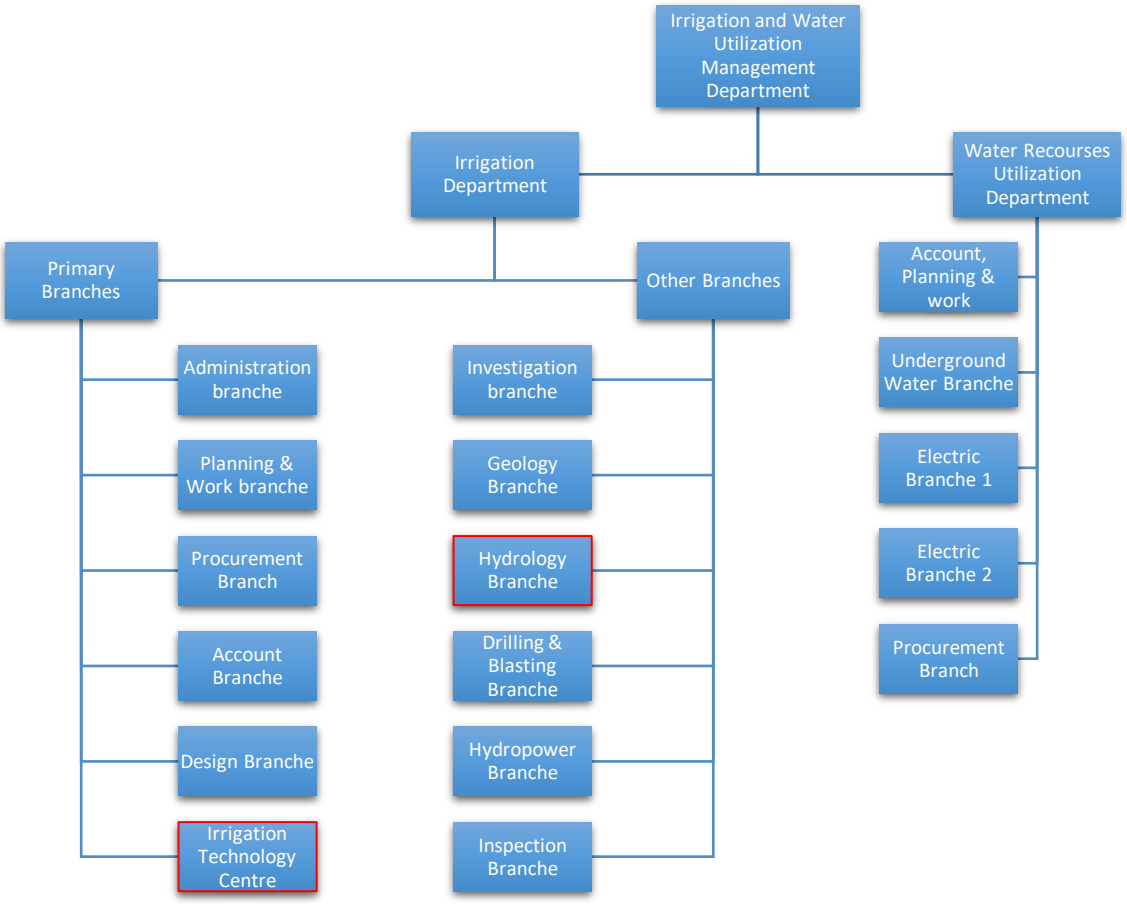

Figure 2: Organigram

The organization chart above shows the different branches the IWUMD consist of. The branches indicated with a red box are branches where close collaboration has been maintained with during the research.

2.1 Population

Numbers of Bago Region

Urban population:	1.18 million
Rural population:	3.76 million
Population density:	125.5 per square kilometre

Table 3: Population figures

Social Indicators

Under 1 mortality rate:	12.7%
Under 5 mortality rate:	13.5%
Adult literacy rate:	99.3%
Birth rate:	14.4%

Table 4: Social Indicators

2.1 Economy

With a gross domestic product of 38.614 billion Kyats and a population of almost 5 million, the GDP per capita in the region is 7.72 million kyats, what roughly translates to $5.720 US annually. Compared to the world scale, the Bago region is compatible to countries as Honduras and Laos. On national scale, Bago region is doing slightly better than the country's average.[1]

Economic sectors

Product	Part of GDP
Goods	60.3%
Agriculture	24.3%
Livestock and Fishery	10.7%
Forestry	0.2%
Energy	0.001%
Mining	0.3%
Processing and manufacturing	19.6%
Electric power	0.8%
Construction	4.5%
Services	22.8%
Trade	16.9%

Table 5: Economic sectors Bago Region (SOURCE: Bago region agriculture, Livestock & irrigation in brief)

2.1 Land use

As can be concluded from the table above, agriculture is the biggest economic sector in The Bago region. The Economic sectors are divided in Goods, Services and Trades, of which Goods make up for the biggest part of the whole GDP. Bago Region has a massive food security (e.g. rice 2015: 272%), meaning that 2,7 times more rice is produced than is used in the region. Therefore, it can be assumed that the biggest part of Trades (16,9% of GDP) is also depended on the production of goods. The table on the next page shows the utilization of land per specific good in the region.

[1] Source : Bago region: Agriculture, livestock and irrigation in brief

Utilization	Sown Area (*1000 Ha)	Harvest Area (*1000Ha)	Yield (MT/Ha)	Production (*1000MT)
Paddy	1206.56	1188.73	4.06	4824.85
Maize	3.47	3.47	4.95	17.17
Pulses	835.83	835.83	1.60	1338.79
Oilseeds	154.51	151.60	0.322	48.878
Ground nut	79.54	78.25	1.76	137.72
Sesames	72.10	71.94	0.64	46.19
Cassava	0.056	0.056	25.3	1.432
Banana	14847	14847	1.64	24464
Watermelon	6.160	6.160	2.094	43.991
Sugar cane	22.10	22.10	59.52	1309.36
Long staple cotton	0.70	0.70	1.70	1.19
Short staple cotton	6.44	6.44	0.43	2.76
Jute	0.006	0.006	1.04	0.006
Kenaf	0.088	0.088	1.25	0.110
Rubber	47.22	19.82	0.75	14.91
Total:	21007	21007	2094	118765

Table 6: Land utilization Bago Region (SOURCE: Bago region agriculture, Livestock & irrigation in brief)

3. GEO-HYDROLOGICAL ANALYSIS

The Bago region is home to some of the biggest rivers in the country. Water flowing from the mountains in the north, combined with rainwater throughout the country comes together in this region. Here, the mighty Bago and Sittaung river are at their greatest with the highest discharges over their total length. This leads into an extreme dynamic landscape that is changing very rapidly. In this chapter the geographical and hydrological aspects that could be relevant to the research are analyzed.

3.1 Elevation in the Bago area

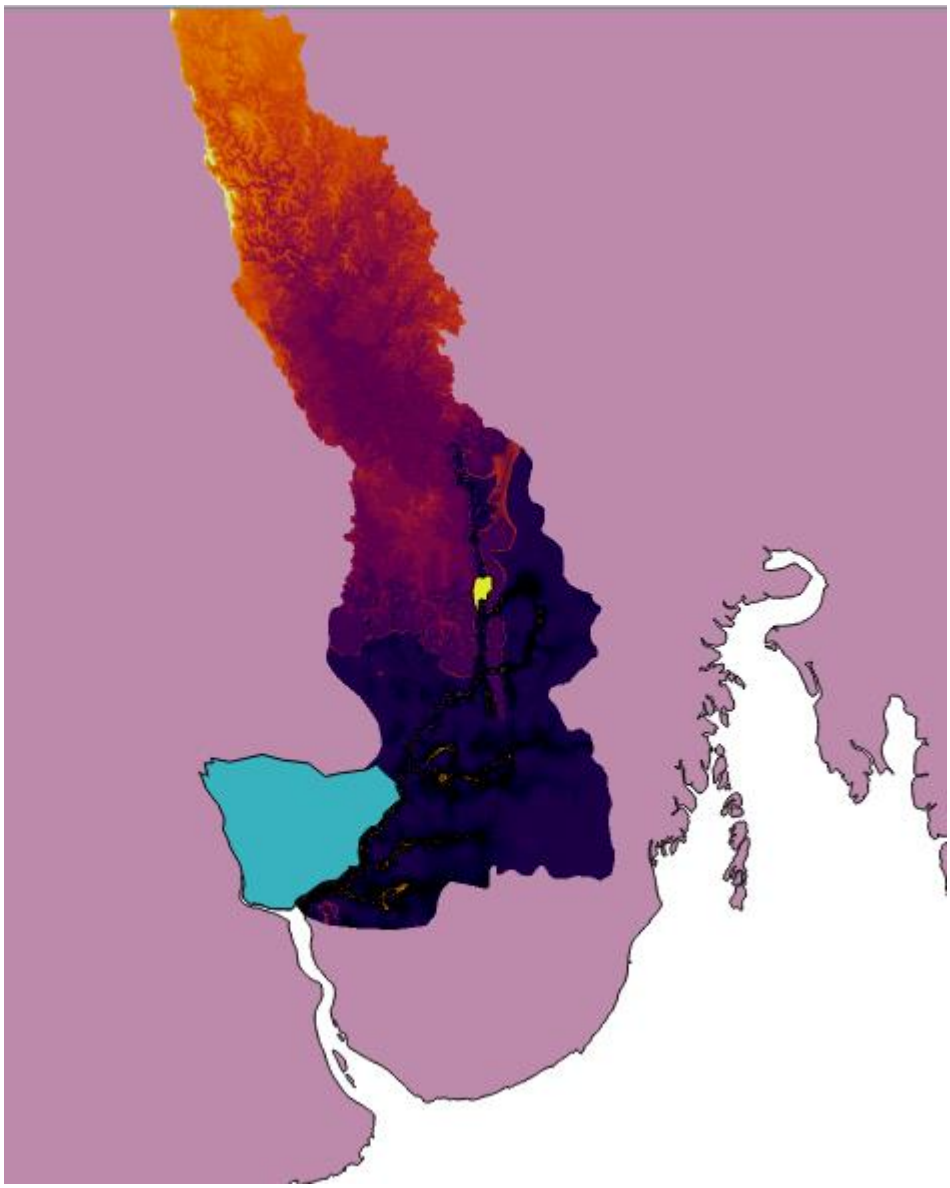

Figure 3: Elevation around the Bago River

Elevation in the Bago region defers from 448m at highest, to just above mean sea level at most of the south part of the region. Here, landscape consists out of flat land where elevation is slim. This leads to great flood planes in case of an inundation. The northern part of the region consists out of outstretched mountain ranges with average heights of 122m. In this part of Bago rivers many tributaries are present, due to elevation in the area.

3.2 Rivers

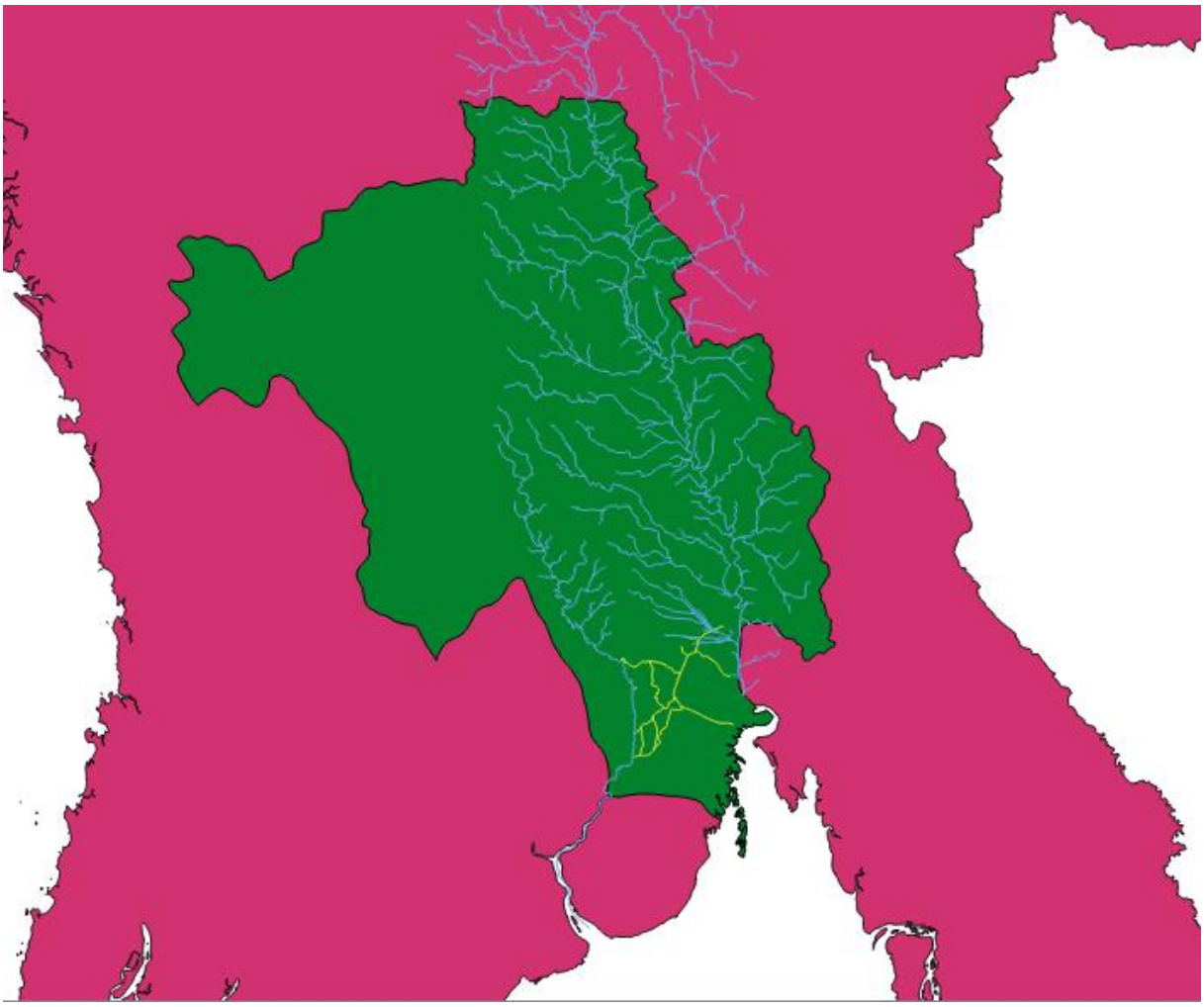

Figure 4: Rivers in Bago region

The Sittaung river and the Bago river (both in blue), flow through the region. The Bago-Sittaung canal (yellow) forms a connection between the two rivers. On the other side of the channel, several drainage and irrigation canals are attached to the channel.

4.3 Erosion sedimentation

Sedimentation causes problems mainly in the Bago river and in many of the reservoirs in the region. In 2013 a big renovation project in the Bago-Sittaung cannel has resulted in the enforcement of many of the embankments next to the channel. This has most like led into a decrease of erosion at the bottom of the dikes and into a decrease of sedimentation downstream. However, since decent measurement equipment is lacking throughout the region, no data on the sedimentation and erosion occurring in the canal is present yet.

4. CLIMATE

Myanmar knows three different seasons:

November-Februari
Cool season Precipitation occurs very rarely during this period.

March-May
Dry season During this period, no precipitation occurs at all in the whole Bago region.

June-October
Rainy season A heavy monsoon rushes over the region, bringing over 2000mm of precipitation down on the region.

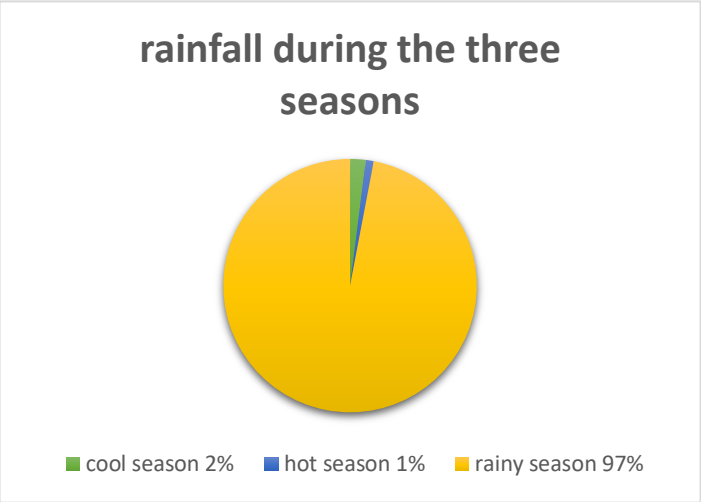

Figure 5: Rainfall diagram

A better image of the extreme differences in precipitation between the seasons can be given by the table provided below:

Precipitation (inch) in Bago region												
	2012		2013		2014		2015		2016		Average	
month	mm	days	mm	days	mm	days	mm	days	mm	days	mm	days
Jan	2	0,75	3	0,50	0	0,00	1	0,30	16	1,30	5	0,57
Feb	0	0,00	3	0,30	0	0,00	0	0,00	1	0,00	1	0,10
Mrt	2	0,25	1	0,30	0	0,00	0	0,00	0	0,00	1	0,11
Apr	23	2,25	4	1,30	1	0,50	24	2,30	2	0,30	11	1,33
Mei	127	0,09	202	12,50	124	8,30	193	7,80	227	9,00	180	9,32
Jun	467	22,50	445	20,50	427	21,00	415	18,50	479	22,30	444	20,96
Jul	563	24,75	338	25,50	610	25,00	611	23,80	509	23,30	556	24,47
Aug	669	24,50	535	22,80	512	22,30	389	22,00	354	21,80	492	22,68
Sep	299	17,50	4	21,50	254	15,00	310	17,30	319	19,00	396	18,06
Okt	95	7,75	341	13,30	44	5,00	208	12,50	210	13,50	197	10,41
Nov	17	2,50	10	1,30	142	3,80	7	1,30	48	3,30	45	2,44
Dec	2	0,25	13	0,80	0	0,00	5	0,50	0	0,00	4	0,31
Tot	2265	103,09	1900	120,60	2114	100,90	2163	106,30	2164	113,80	2330	110,76

Table 7: Annual rainfall Bago Region (SOURCE: Bago region agriculture, Livestock & irrigation in brief)

Bago region is separated into 4 districts. Precipitation data is measured in all 4 regions separately (table 8), this table makes clear that precipitation is equally divided over the region throughout the years. The table also shows that there is no clear trend in increases/decreases in precipitation visible over the last 4 years.

rainfall (inch) and rainy days (n) per district										
	2012		2013		2014		2015		2016	
district	mm	day	mm	day	mm	day	mm	day	mm	day
Bago	559	28	718	35	528	30	591	31	618	33
Toungoo	584	30	568	30	526	22	491	19	546	27
Pyay	559	27	616	22	493	24	555	26	464	25
Tharyarwaddy	563	27	563	33	566	25	522	30	531	28
Bago region	2265	112	2464	120	2113	101	2159	106	2159	113

Table 8: Precipitation data in the 4 districts of Bago Region (SOURCE: Bago region agriculture, Livestock & irrigation in brief)

The 3 seasons in Myanmar are not only distinguished by rainfall, but also the temperatures differ throughout the year. In table 3 the minimum and maximum temperatures of every month of the year 2010-2016 are given.

Temperature (°C) in Bago region										
	2012		2013		2014		2015		2016	
month	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Jan	34,5	10,3	34,3	10,8	34,1	12,5	34,3	12,2	34,6	12,4
Feb	38,6	13,5	39,8	14,5	36,6	13,5	37,1	14,0	37,8	13,9
Mrt	40,5	15,6	40,5	17,0	40,3	16,2	40,5	15,8	40,1	19,3
Apr	41,1	20,5	41,7	21,3	41,4	20,4	41,3	20,5	42,3	21,7
Mei	40,5	20,7	40,3	22,2	40,2	22,0	40,8	23,0	42,7	22,9
Jun	35,2	21,4	36,4	22,0	36,6	22,4	35,6	22,8	34,9	23,0
Jul	33,9	22,0	33,8	21,9	33,5	21,3	34,5	21,3	34,1	23,4
Aug	33,1	22,0	33,7	21,7	33,7	21,7	33,0	23,0	33,8	23,2
Sep	34,6	22,1	34,2	21,0	35,1	21,7	34,5	22,8	34,1	23,1
Okt	35,3	21,4	35,2	20,6	34,9	20,1	35,1	21,6	35,0	22,6
Nov	35,3	20,1	34,7	19,2	34,8	15,6	35,2	18,1	34,5	16,5
Dec	34,5	12,0	33,1	11,0	33,9	14,9	34,6	15,2	34,0	16,8

Table 9: Temperatures throughout the years 2010-2016 Bago Region (SOURCE: Bago region agriculture, Livestock & irrigation in brief)

Unlike precipitation and temperatures, wind speeds are stable all year long. In table X the wind speeds between 2012 and 2016 are shown.

Wind speed (mph) in Bago region					
month	2012	2013	2014	2015	2016
jan	1,47	1,1	1,13	1,45	1,35
feb	1,24	1,18	0,67	1,05	1,07
mrt	1,13	1,13	1,16	1,05	0,68
apr	1,28	1,36	1,48	1,21	1,27
mei	1,25	1,35	1,65	1,18	1,08
jun	1,38	1,23	1,24	1,27	1,17
jul	1,15	1,25	1,1	1,38	0,76
aug	1,25	1,22	1,05	1,25	0,99
sep	1,25	1,02	0,95	1,2	0,91
okt	1,18	0,92	1,24	1,21	1,01
nov	1,38	1,31	1,23	1,82	1,38
dec	1,53	1,3	1,76	1,48	1,2

Table 10: Wind speeds throughout the years 2012-2016 in Bago Region (SOURCE: Bago region agriculture, Livestock & irrigation in brief)

5. FUTURE EXPECTATION

Climate change

According to many scientist, the the south-east Asia region is one of the most vulnerable regions in the world to climate change. This is mainly due to the combination of poor water protection infrastructure and a heavy monsoon climate. A recently conducted research executed by the SPARRSO, in Bangladesh, has concluded that the yearly occurring tropical storms in South-East Asia are most likely to increase drastically in the event of a global temperature rise. According to the research, an increase in the amount of tropical storms and rainfall in the monsoon season, will undeniably result in warmer, longer and dryer periods of drought in the dry seasons. For what it's worth, Myanmar is very likely to experience a significant change in the near future. A temperature rise of 2˚C will already have a huge impact on the country's climate.[2]

Economy

Since former Myanmar president, Thein Sein, opened the borders of Myanmar and ended all tax exemptions and their import monopolies on many goods, he welcomed foreign competitors to some of their businesses. Now, 6 years later, many internationals have find their way into the country and although at the time of writing, no single MacDonald's restaurant is present in the country yet, it is expected that more and more international businesses will start trading with the country in the near future.

Population

Although Myanmar has experienced a decreasing population since the last military coup in 1962, the population has slightly been growing since the year 2010. It is expected that the population will keep expanding for the next coming years.

[2] http://www.int-res.com/abstracts/cr/v12/n2-3/p109-116

6. RESERVOIRS

To minimize the problems occurring due to the heavy rainfall during the monsoon season, and the extreme water shortages in the dry seasons, several dams have been constructed in the region. These dams create reservoirs which store water abundances in the rainy season and release the water in periods of drought, mainly for irrigation and urban usage purposes. In the map below, the 12 biggest reservoirs that are located in the region are shown.

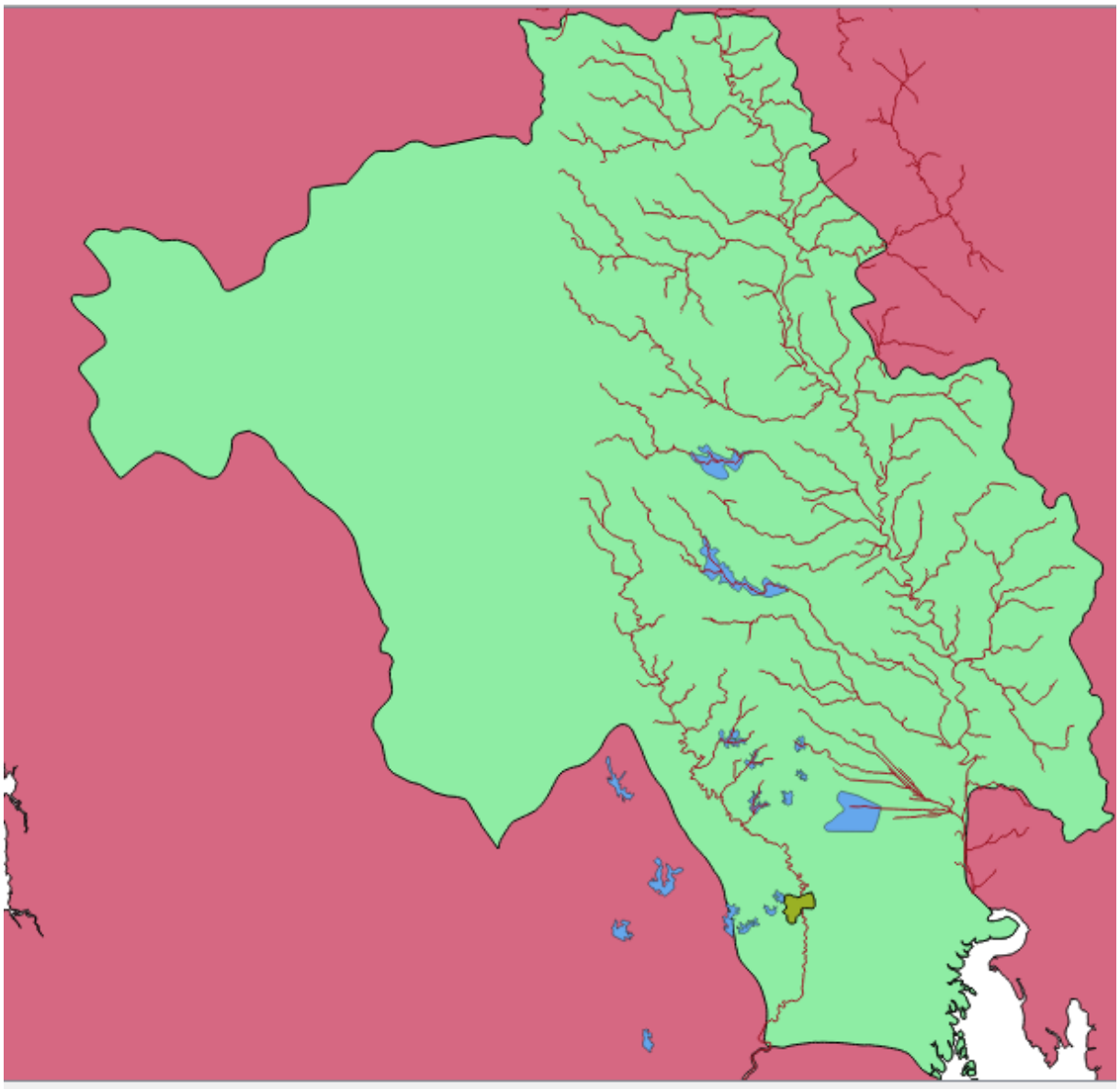

Figure 11: Reservoirs in Bago Region

These reservoirs combined, can store up to 5,798,000*$10^3 m^3$ of water. On the next page, a table is listed containing information on 12 of the biggest reservoirs in the region.

Dam	Township	Length (m)	Height (m)	Storage capacity (*10^3 m^3)	Beneficial area (ha)
Bainge Dam	Daik-U	426	34	461,199	10,014
Kawliya Dam	Daik-U	274	39	203,416	2,711
Kodukwe Dam	Bago	356	27	266,432	-
Yenwe Dam	Kyauktaga	320	76	1,149,359	-
Kapaung Dam	Oktwin	280	61	1,083,700	21,564
Phyu Chaung Dam	Phyu	310	74	780,214	-
Swar Chaung Dam	Yedashe	2011	30	281,234	9,358
Mazin dam	Bago	1249	18	35,524	257
Nawin Dam	Pyay	5082	43	713,754	16,390
Wegyi	Paukkhaung	1271	35	310,837	23,171
Taungnyo Dam	Paungde	1036	33	259,031	13,373
Thonese Dam	Tharrawaddy	402	8	292,952	16,998

Table 12: Biggest reservoirs in Bago Region (SOURCE: Bago region agriculture, Livestock & irrigation in brief)

In the dry season, when no rain is present at all throughout the region, cities and farmers are completely dependent on either natural rivers or the water reserves stored in these reservoirs. The Water Utilization Management Department, where the ITC is part of, is responsible for the amount of water let out of the reservoirs at all times. Unfortunately, despite all efforts, the water reserves run out completely each year, resulting in a certain number of crops dying annually. In some cases, farmers have grown crops for almost a whole season but are not able to harvest them due to the water running out. Besides that, many of the farmers in the Bago region switch to growing a less-profitable crop which needs less water during the dry season to still. A better regulation of the water reserves could therefore increase the production in the region significantly.

Not all reservoirs are dam-made and of this size. Small reservoirs play an important for many people throughout the country. These smaller reservoirs are excavated in the ground and are roughly the size not bigger than a football field. They are mostly found within small townships and are primarily used for urban water purposes. More information on these reservoirs can be found in appendix E.

APPENDIX B: SOFTWARE ANALYSIS

ANALYSIS OF AVAILABLE SOFTWARE FOR CREATING DEM'S BASED ON DRONE IMAGERY

Version	1.1
Date	28-03-2017
Location	Bago
Author	Bob Dubbel

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ABSTRACT

Upon arrival in Myanmar, little was known about the possible usages of drone technology. Lots of research had to be done into the possible applicability of the drone and the existing methods and programs available for drone research. In this document, the outcomes of the software analysis executed in name of the TU Delft and the ITC are summarized. The report is divided into an analysis of an existing report on available drone software, carried out by one of the partners of VPDelta and a self-executed research on the available mapping software, purely focussed on the ability of obtaining DEM's, carried out to the person in charge of the ITC.

Partly by this document, the TU Delft has decided on purchasing a standalone license of Pix4D, used in this thesis. The ITC is now able to use the software on 25 computers simultaneously for the next coming years. This greatly increases the value of the research outcomes.

CONTENTS

1 PREVIOUS SOFTWARE ANALYSIS

In March 2015, Sam van Til set up a document, researching several different mosaic software, in name of Future water. In his study, Sam is comparing the advantages and disadvantages of 13 different types of software. The software are all used for stitching together aerial photographs made by drones, kites and other equipment. In this document, the most important conclusions from the report are summarized. Sam's findings and opinions on the researched software are taken into account when choosing what software to use for the ITC.

1.1 SOFTWARE TESTED

The following software have been compared to each other in the document:

-	Dronemapper.com	-	Agisoft Photoscan standard
-	Aerogis.de	-	Microsoft ICE
-	Agrolytic.com	-	VisualSFM
-	Photosynth.net	-	HuFree
-	Autopano Pro	-	AutostitchFree
-	Pix4D Discovery	-	Autopiano Giga
-	Simacti V	-	Airphoto
-	MicMac	-	Photomodeler scanner

1.2 ASSESMENT PROCEDURE

The research makes use of 6 different datasets, each with different specifications. The datasets are described as followed:

Dataset 1: Swifterbant.
The first dataset, of location Swifterbant, is used as an example of a real flight.
Flight height: 100m
camera details: 16MP, 1/100sec.-1/400sec., f/2.4, ISO100,)(image quality: some slightly blurred)

Dataset 2: Mozambique
The second dataset was acquired by a kite-flight. This set is used to see how the software handles the partic- ular features of the Mozambiquan landscape.
Flight height: 50m
camera details: 16MP, 1/400sec.-1/500sec., f/2.4, ISO100 (image quality: great, but slightly blurry in the corners)

Dataset 3: Dintelse Gorzen
The third dataset, of location Dintelse Gorzen, is used to see how the software will cope with a bigger, more difficult, dataset. This dataset consists of 174 images taken at a height of 100m. This dataset will be harder to process, not only because of its size but also because some images are slightly blurry and others contain a lot of water. The features in the landscape are quite monotone. this dataset will test the limits of the software capabilities.
Flight height: 100m
camera details: 16MP, 1/60sec.-1/125sec., f/2.4, ISO100 (image quality: great, but slightly blurry)

Dataset 4: De Groote Peel
The fourth dataset, De Groote Peel, is also a large dataset. It consists of 184 images. As with dataset 3 this set is used to see how well the software copes with a large dataset. In this set however the features are clearer and there is no water.
Flight height: 100m
camera details: 16MP, 1/500sec.-1/800sec., f/2.7, ISO100 (image quality: great)

Dataset 5: Voorne
This dataset is taken at Voorne. This set is chosen because the features in the landscape are easier to distinguish, so it is easier to detect possible errors in the resulting stitches.
Flight height: 70m
camera details: 16MP, 1/500sec.-1/1000sec., f/2.7, ISO100 (image quality: great)

1.3 ASSESMENT CRITERIA

The different datasets are used to test the efficiency of the software for different purposes. The software is tested on the following criteria:

- General criteria
- Price
- Stitching quality
- Processing time
- Geotagging
- Consistency
- Ease of use

One should note that the research only compares these aspects of the software. The gaining of DEM's, DSM's, DTM's and volume calculations are not considered.

1.4 REJECTED SOFTWARE

general malfunctions

The following software are rejected from the research because they contain online software solutions. In the report this is a reason for rejecting the software because the foresighted activities are to be executed in field, with limited access to high internet speeds. Since good internet connection is not available at the ITC, these software are rejected from this research as well.

- Dronemapper.com
- Aerogis.de
- Agrolytic.com
- Photosynth.net

Other software is cancelled out because of the following reasons:

- Autopan Pro: Does not allow multiple viewpoints
- Pix4D Discovery: Has no stitch output
- Simacti V: Hardware requirements are too high
- MicMac: Website is offline

Price

Following software is considered too expensive and are therefore rejected:

- Agisoft Photoscan Pro: $3499,- USD
- PIX4D pro: $8500,-USD
- Photomodeler Scanner: $2500,-USD

The prices of the resulting software are as follows:

-Agisoft Photoscan Standard Edition	179,- USD
-Microsoft ICE	Free
-VisualSFM + CM	free
-VisualSFM + CloudCompare +MicrosoftICE	Free
- Hu Free	Free
-Autostitch 64	Free
-Autopano Giga	199,- EUR
-Airphoto	Free
-Photomod free	Free, full version +-20.000,- USD
-EnsoMOSAIC	max 100 images 700,- EUR

1.5 STITCHING QUALITY

Most of the software were rejected from the research for numerous reasons concerning unsatisfactory stitching results. Mostly when tested on the bigger datasets.

-Pix4D Discovery
-PanoramaPlus
-AirphotoSE
-Photomodeler scanner
-EnsoMOSAIC

1.6 CONCLUSION

only four different software were considered pleasant enough to work with:

- Agisoft Photoscam
- Autopano Giga
- Autostitch-64
- MicrosoftICE

The final conclusion of the research is stated as follows:

''A grounded conclusion can be drawn by combining the evaluations from all of the criteria. On the criteria 'processing time', 'ease of use' and 'NDVI' not much difference was observed between the four software solutions. On all other criteria except 'price' Agisoft Photoscan was clearly performing much better. Although Agisoft Photoscan comes at a slightly higher cost its consistency and stitching quality are far superior to the other competing software solutions making Agisoft Photoscan the best software in those conditions''

2 OWN SOFTWARE RESEARCH

2.1 EXAMINED CRETERIA

3D Survey

Price:	Monthly subscription	$300,00	
	Student license	$0,00	(includes all option except support and upgrades)
	Free trial	2 weeks	

http://www.3dsurvey.si/

numerous video tutorials available: http://www.3dsurvey.si/tutorials/how-to-start-using-3dsurvey-computer-settings

Agisoft photoscan

Price:	professional license	$3499,00	
	Standard license	$179,00	(DEM option included)
	Free trial	30 days	

http://www.agisoft.com/

tutorial: http://www.agisoft.com/pdf/PS_1.2%20-Tutorial%20(BL)%20%20Orthophoto,%20DEM%20(without%20GCPs).pdf

The license is permanent, but only available at 1 pc. Meaning that if I buy the license on my laptop, the TU is not able to use it. I can work with the 30 day trial version on my laptop and a laptop of one of my collegues during my time here. VPDelta (or the TU) can buy a license on an own pc which I can use for my final months in the NL)

drone deploy

price:	business license	$299,00 p/month	
	pro license	$99,00 p/month	(DEM option included)
	free trial	30 days	

Erdas Hexogon geospacial		**online tool**
Price:	10GB storage	$10,00 p/month
	100GB storage	$70,00 p/month
	500GB storage	$300,00 p/month
	2GB storage	$0,00 p/month

https://store.hexagongeospatial.com/apps/40785#!overview

The website of Edras Hexogon promises to contain the necessary software for the forethought purposes against the prices given above. However, so far I have not been able yet to register at the website due to several errors that keep occurring. Erdas HExogon does provide the software for a very reasonable price. New attempts to download the software will be made on short notice.

Precision mapper		**online tool**
Price:	50GB storage	$50,-/month
	150GB storage	$95,0/month
	DEM add on	$5-$15/month

2.2 FREE SOFTWARE

Drone to map

Drone to map provides software for creating DEM's out of drone imagery, which can be inserted into GIS. To download the software, Ubuntu operating system is required. An emulator can be downloaded on a windows system.

http://www.esri.com/products/drone2map

http://opendronemap.github.io/odm/pages/about.html#

2.3 CONCLUSION

Software	**Free trial**	**Monthly price**	**One time purchase**	**remarks**
3D Survey	2 weeks	$300.00	N/A	Student license available
Agisoft Photoscan	30 days	$179.00	$3,499	Cheaper license available
Drone Deploy	30 days	$299.00	N/A	-
Pix4D	2 weeks	N/A	$8,500	Student license available
Erdas Hexagon	max 2GB	$70.00	N/A	Online tool

Since the Pix4D software provides a student license on which 25 computers can work simultaneously, on a one-time purchase, the ITC, TU delft and my direct supervisors have jointly decided on purchasing this software. This thesis is the very first of many which will use Pix4D in the name of the ITC.

APPENDIX C: QGIS MANUAL

GUIDE – DATA PROCESSING IN QGIS

Version	1.0
Date	12-6-2017
Location	Bago
Author	Bob Dubbel
	Leon Brok
	Dennis Neleman

CLIENTS:

- Mr. Myin Soe, Bago regional office (MOALI)

INTRODUCTION

Data processing and storage systems in Myanmar are currently under rapid development. However, hydrological data and information about infrastructure are often still stored on paper. This guide describes the global steps needed to store infrastructural data in the program QGIS. Using GIS programs to store data in is of great value for future researchers who use computer models in order to predict floods and understand the system, such as mr. Nay Myo Lin.

The described method is used by Dennis Neleman, Leon Brok and Bob Dubbel to store data of flood-related infrastructure in the Bago-Sittaung basin during the period of February – May 2017.

QGIS is a Geographical Information System (GIS) program. GIS programs can be used to store different types of datasets in. Geographical data as well as numeric data can be stored in QGIS. This guide only describes the method of inserting data of flood-related infrastructure. Other functionalities of QGIS are freely available in the official QGIS manual, which can be downloaded at:

https://docs.qgis.org/2.8/en/docs/user_manual/index.html

Together with this guide, a base map made by Leon, Bob and Dennis is provided. This base map consists out of qgis compatible files that contains all the data of the Bago-Sittaung basin that was collected and stored. At the end of the manual, the contents of the base map are described.

Storing and handling infrastructural data in QGIS is described with three main steps:

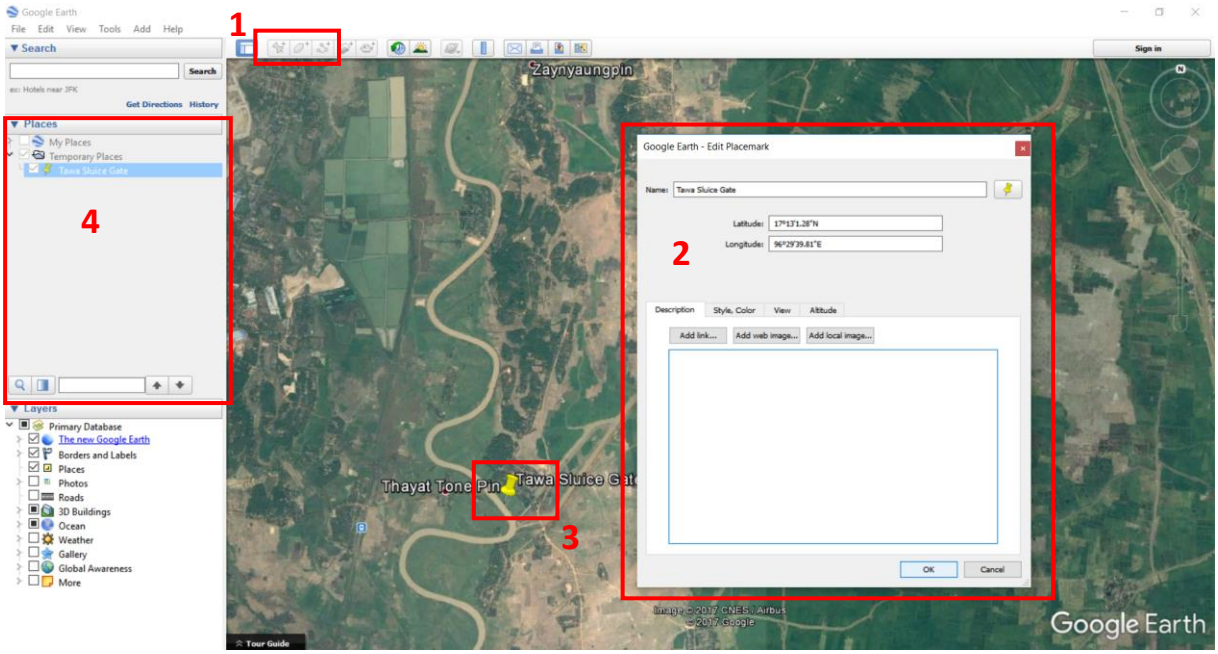
1. Locating geographical data with Google Earth
2. Inserting geographical data from Google Earth to QGIS
3. Inserting numeric data from Microsoft Excel to QGIS
4. Combining numeric and geographical data

1. LOCATING GEOGRAPHICAL DATA WITH GOOGLE EARTH

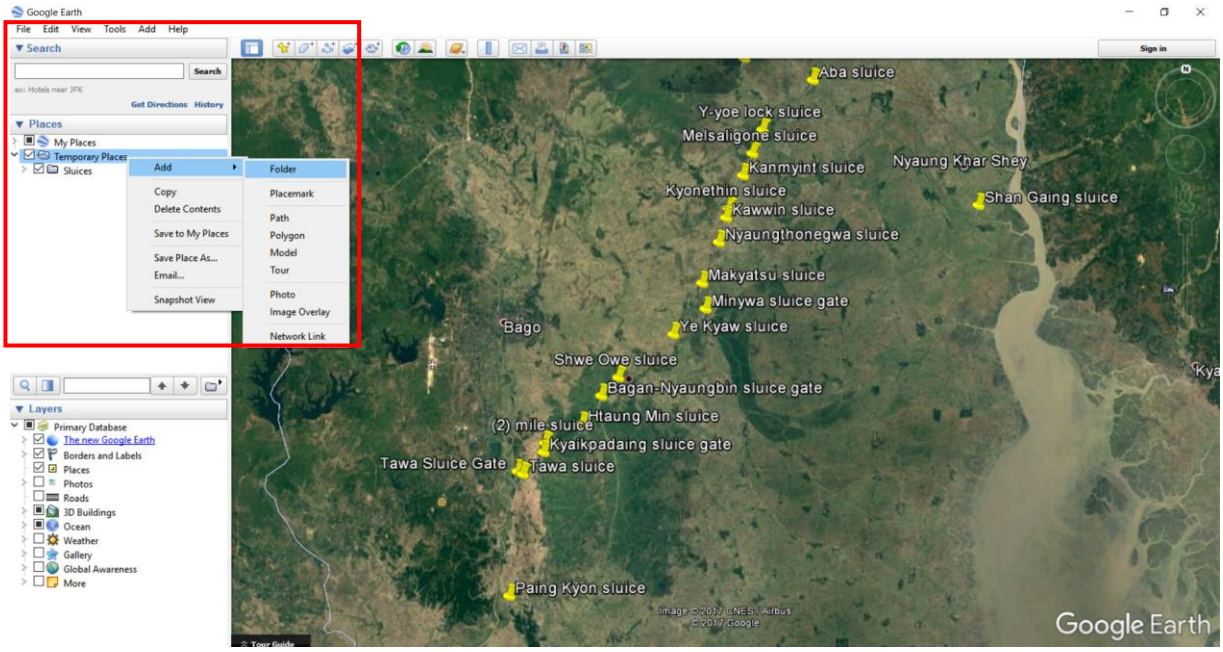
Google Earth is an online application that contains satellite imagery of the whole world. It is freely available at https://www.google.com/earth/download/ge/agree.html.

Google Earth can be used to locate real life objects on the map. The user can do this by adding a placemark, path or polygon to the map.

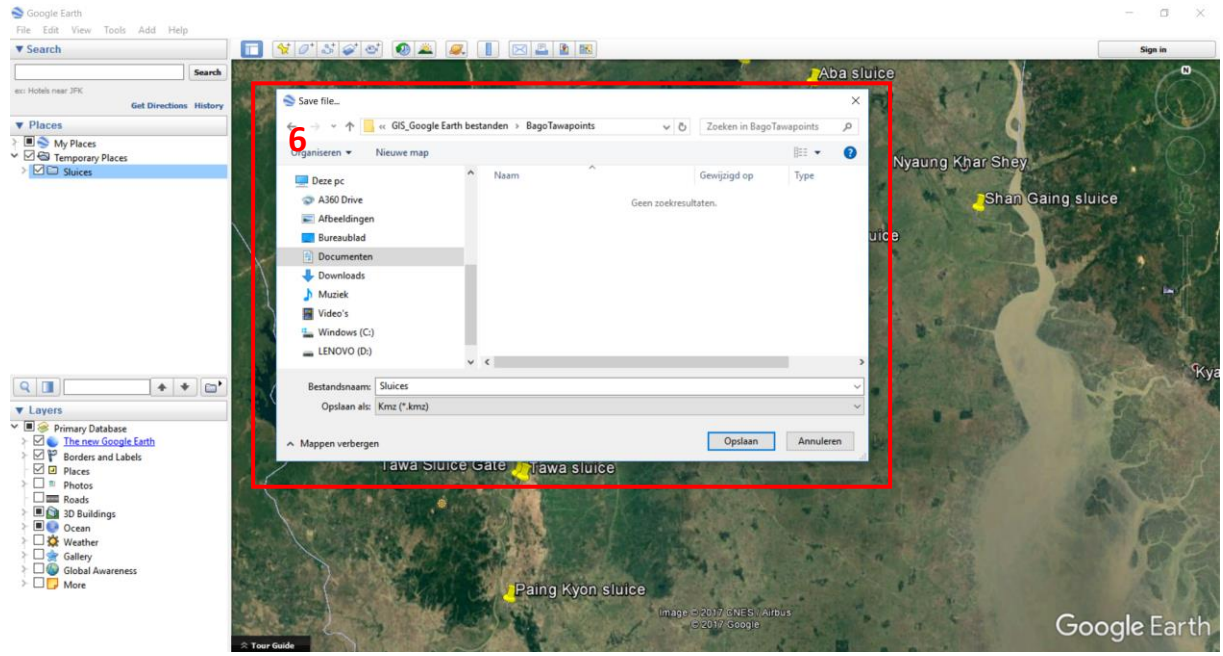
- Placemark: A placemark gives information of one specific location. Placemarks can be used to locate sluices, bridges, lock gates etc.
- Path: A path gives information of a stretched object. A path can be used to locate embankments, canals, rivers etc.
- Polygon: A polygon gives information of an object with a certain area. Polygons can be used to locate reservoirs, lakes, paddy fields etc.



1. To insert a placemark, path or polygon, click one of the three buttons at the top of the screen.
2. A screen appears in which the name of the object can be filled in. In this screen, other properties of the object can be adjusted.
3. In this guide, placemarks will be used to locate sluice gates. After clicking on 'add placemark' (step 1), the placemark appears on the map, and its location can be determined by dragging the placemark with the computer mouse.
4. After clicking OK, the name of the sluice gate will appear in the list of places left on the screen.



5. If the users wishes to arrange objects in the 'Places' list, go to **'My Places' > Right click > Add > Folder**. In the picture above, the folder 'Sluices' was made to store all the placemarks of sluice locations.
6. For the next step, transferring data to QGIS, locations in the 'Places' list in Google Earth must be saved. To save a location, or a folder containing multiple locations, **Right click > Save place as.** Give the file a name and save the file with a .kmz or .kml extension



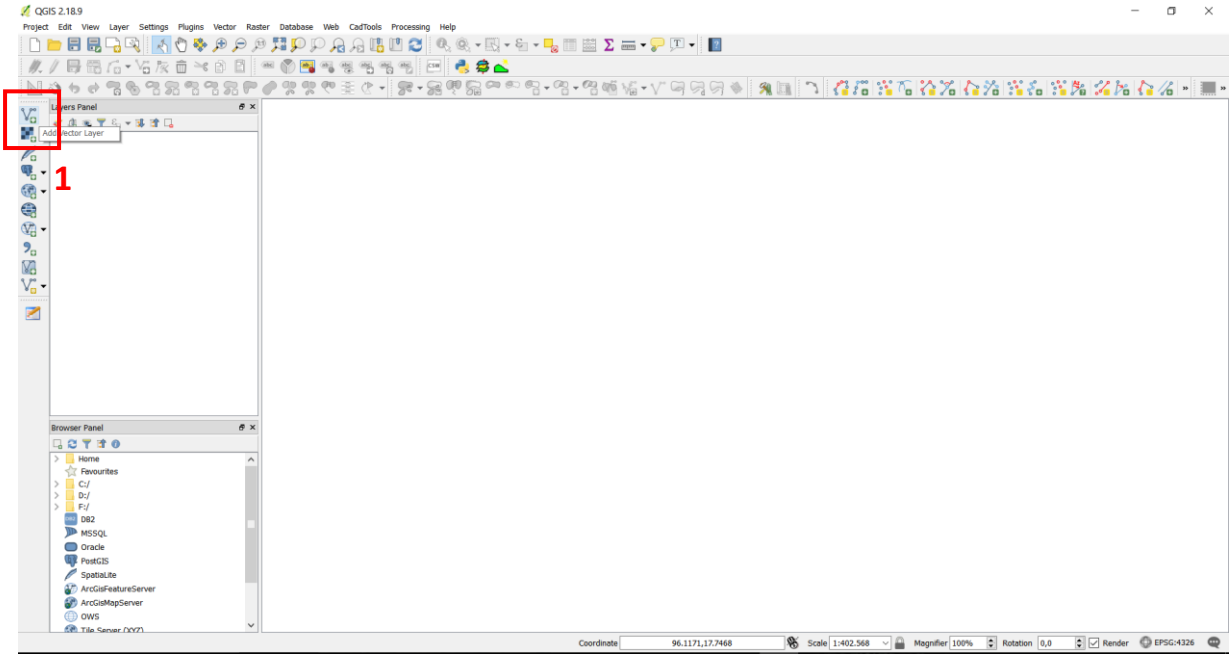
2. INSERTING GEOGRAPHICAL DATA FROM GOOGLE EARTH TO QGIS

For the next steps, QGIS software is needed. This is freely available at http://www.qgis.org/en/site/forusers/download.html.

A GIS application, such as QGIS, can be seen as an empty world map, in which the user can insert layers and data. Two types of data can be inserted:

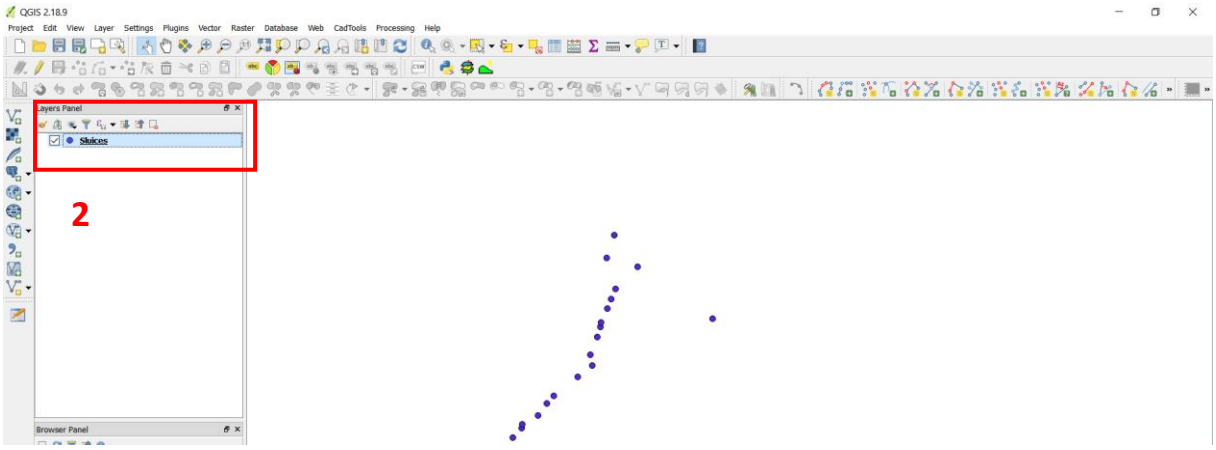
- Raster data
- Vector data 
  In this guide, only vector data will be used. Vector data can represent a location or area on the world map, comparable to a 'Placemark', 'path' or 'polygon' in Google Maps. In QGIS, the types are 'point', 'line' and 'polygon'.

After opening QGIS, the following white screen will appear.



1. To insert the places saved in Google Maps, click **add vector layer** and select the saved .kmz or .kml file(s) from your computer.

2. The locations of the sluices gates are now inserted in the model as point vector data. The layer ‘sluices’ is added to the ‘Layer Panel’ on the left of the screen.

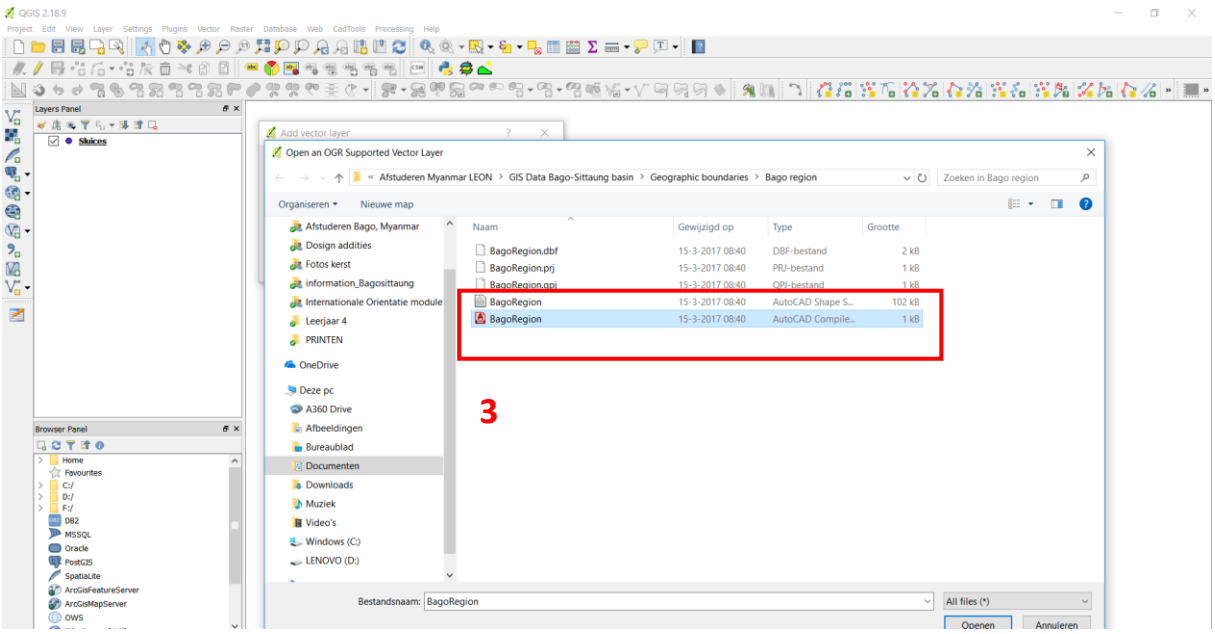


Vector layers can be downloaded on the internet. Country boundaries are widely available on websites such as:

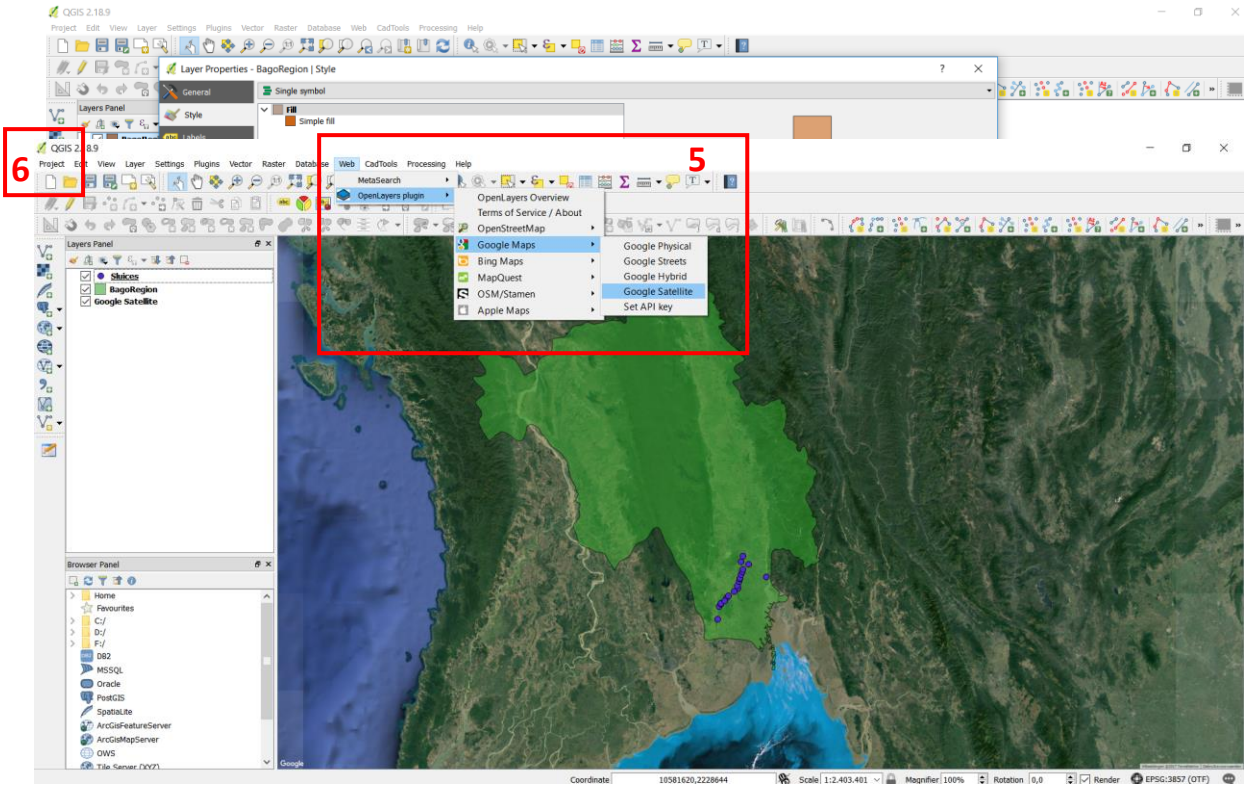
http://www.diva-gis.org/gData

http://www.gadm.org/country

3. To import a downloaded vector layer, click **add vector layer** and select the file on your computer. Always select the **shapefile** (.shp extension). In the picture below, the Bago Region boundaries are inserted.



4. To change the colour, transparency or other characteristics of a layer, **right click** on the layer in the 'Layer Panel', choose **properties.** A window will appear in which several layer settings can be adjusted. In the picture below, the colour and transparency will be adjusted.



5. Instead of using vector layers of country boundaries, it is also possible to insert Google Maps satellite imagery to your GIS file. To do this, click **web > Open Layers Plugin > Google Maps > Google Satellite**. This will add a 'Google Sattelite' layer to your Layer Panel on the left of the screen.

Important:

When working with QGIS, be sure to use the right CRS (Coordinate Reference System) for your project and layers.

6. Your **Project CRS** must be set at **WGS 84.** To change this, click on **Project > Project properties > CRS**
7. Your **layer CRS** must be set at **WGS 84, WGS 84 46N** or **WGS 84 47N**, to change this, right click on a layer in the Layer Panel, click **properties > CRS.**

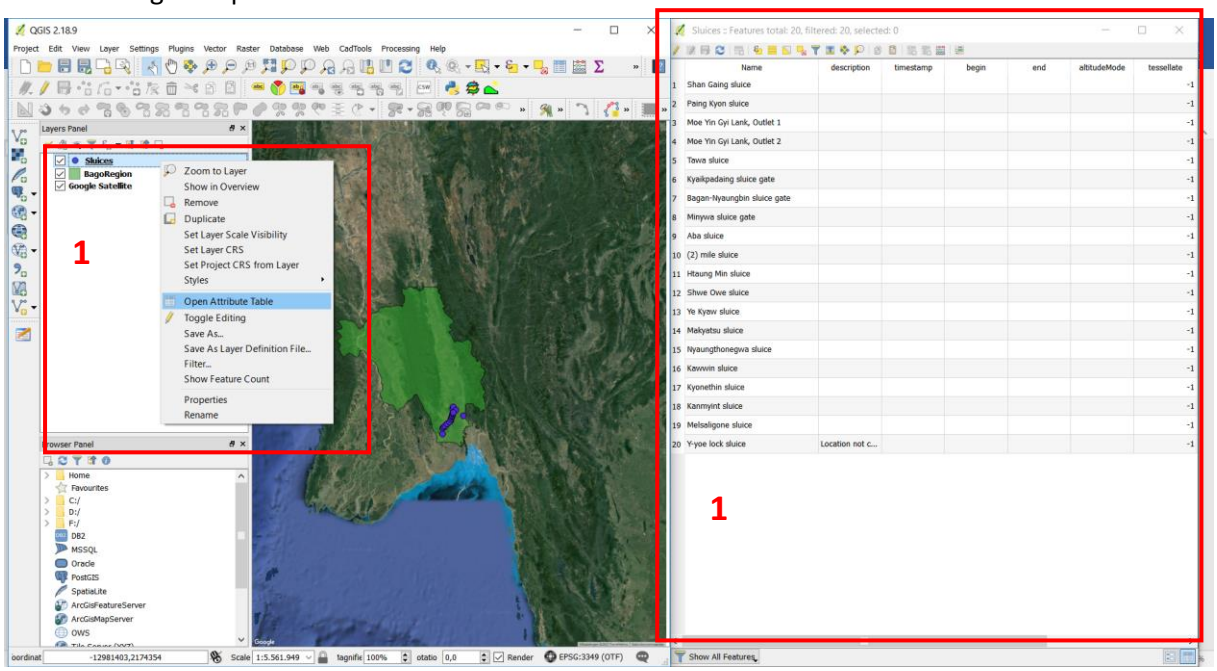
Coordinate Reference Systems:

http://docs.qgis.org/2.0/nl/docs/gentle_gis_introduction/coordinate_reference_systems.html

3. INSERTING NUMERIC DATA FROM MICROSOFT EXCEL TO QGIS

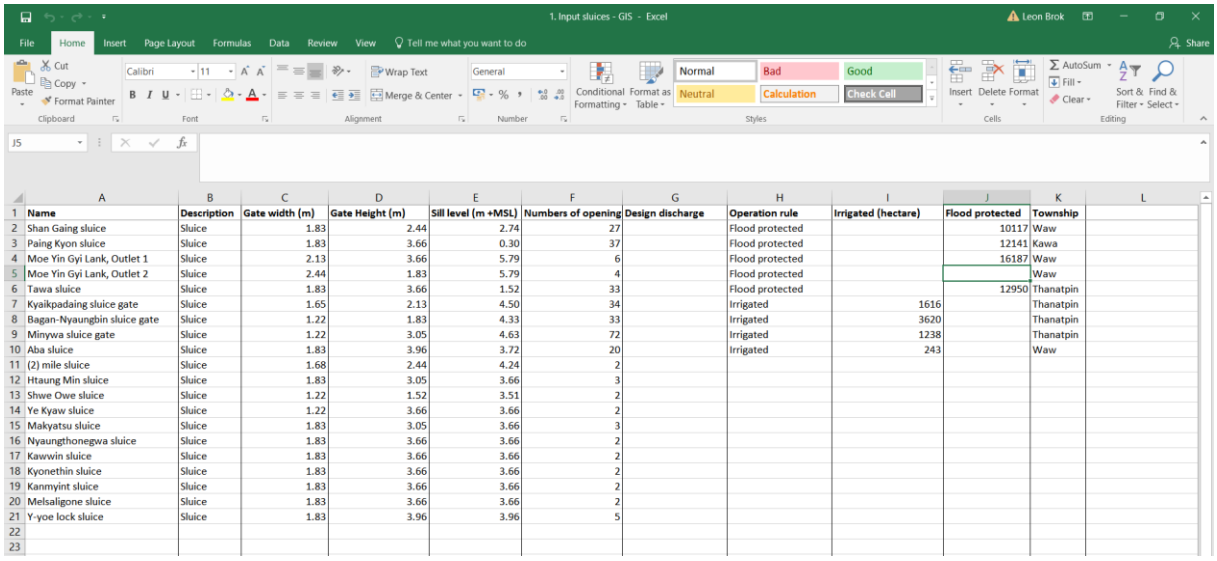
We now have a QGIS file with the Bao Region and the locations of several sluices. It might be important to insert characteristics of the sluices into GIS. These characteristics are stored in a layer's **attribute table.**

1. To view a layer's attribute table, right click on the layer > **open attribute table.** The attribute table will appear, with all the names of the objects (in this manual sluices) the user made in Google Maps.



Right now, there is no data in the attribute table, except for some useless data that automatically appear when inserting .kmz or .kml files from Google Earth. To insert useful data in the model, follow the next steps:

2. Use Microsoft Excel to first order the data. In this manual, several characteristics (such as gate size, sill level) of the sluice gates will be inserted.



	A	B	C	D	E	F	G	H	I	J	K	L
1	Name	Description	Gate width (m)	Gate Height (m)	Sill level (m +MSL)	Numbers of opening	Design discharge	Operation rule	Irrigated (hectare)	Flood protected	Township	
2	Shan Gaing sluice	Sluice	1.83	2.44	2.74	27		Flood protected		10117	Waw	
3	Paing Kyon sluice	Sluice	1.83	3.66	0.30	37		Flood protected		12141	Kawa	
4	Moe Yin Gyi Lank, Outlet 1	Sluice	2.13	3.66	5.79	6		Flood protected		16187	Waw	
5	Moe Yin Gyi Lank, Outlet 2	Sluice	2.44	1.83	5.79	4		Flood protected			Waw	
6	Tawa sluice	Sluice	1.83	3.66	1.52	33		Flood protected		12950	Thanatpin	
7	Kyaikpadaing sluice gate	Sluice	1.65	2.13	4.50	34		Irrigated	1616		Thanatpin	
8	Bagan-Nyaungbin sluice gate	Sluice	1.22	1.83	4.33	33		Irrigated	3620		Thanatpin	
9	Minywa sluice gate	Sluice	1.22	3.05	4.63	72		Irrigated	1238		Thanatpin	
10	Aba sluice	Sluice	1.83	3.96	3.72	20		Irrigated	243		Waw	
11	(2) mile sluice	Sluice	1.68	2.44	4.24	2						
12	Htaung Min sluice	Sluice	1.83	3.05	3.66	3						
13	Shwe Owe sluice	Sluice	1.22	1.52	3.51	2						
14	Ye Kyaw sluice	Sluice	1.22	3.66	3.66	2						
15	Makyatsu sluice	Sluice	1.83	3.05	3.66	3						
16	Nyaungthonegwa sluice	Sluice	1.83	3.66	3.66	2						
17	Kawwin sluice	Sluice	1.83	3.66	3.66	2						
18	Kyonethin sluice	Sluice	1.83	3.66	3.66	2						
19	Kanmyint sluice	Sluice	1.83	3.66	3.66	2						
20	Melsaligone sluice	Sluice	1.83	3.66	3.66	2						
21	Y-yoe lock sluice	Sluice	1.83	3.96	3.96	5						
22												
23												

Important:

To successfully insert the Excel data in QGIS, be sure to give that one column in the Excel file and the attribute table of the layer are identical. When inserting data to sluice gates, the column with the names of the sluice gates must be identical, as shown on the picture below. The title of the column ('Name') must also be the same in Excel and QGIS. The names have to be **exactly** the same. Be sure to check punctuation marks, capital letters and spaces.

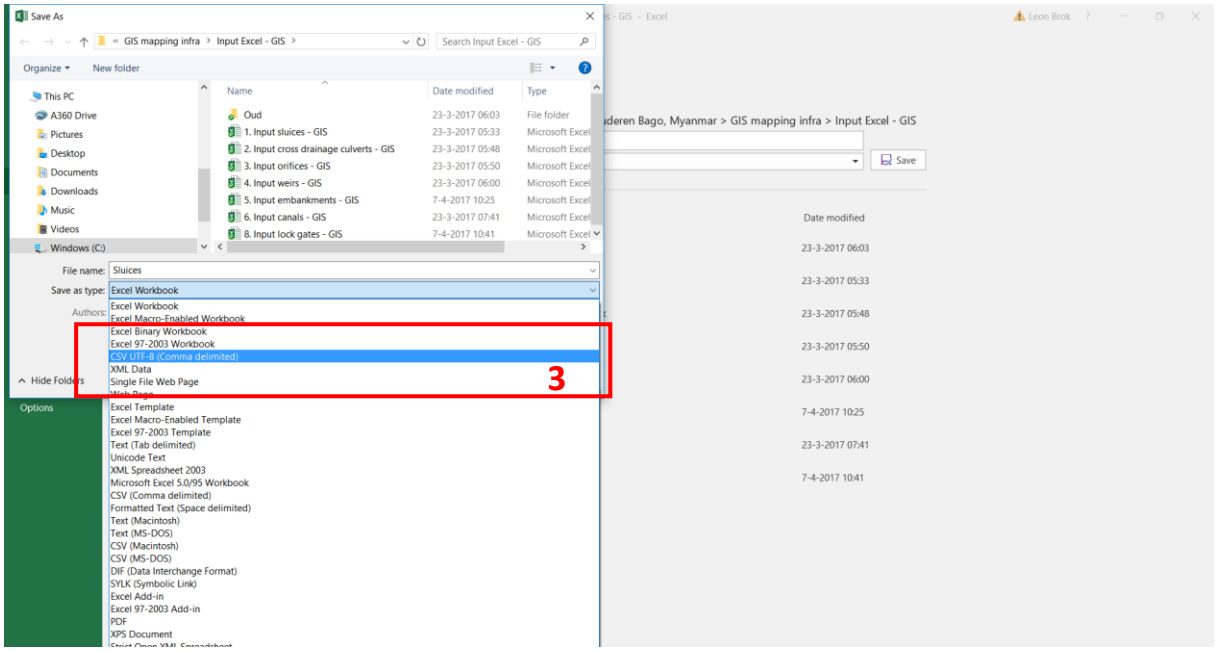
	Name
2	Shan Gaing sluice
3	Paing Kyon sluice
4	Moe Yin Gyi Lank, Outlet 1
5	Moe Yin Gyi Lank, Outlet 2
6	Tawa sluice
7	Kyaikpadaing sluice gate
8	Bagan-Nyaungbin sluice gate
9	Minywa sluice gate
10	Aba sluice
11	(2) mile sluice
12	Htaung Min sluice
13	Shwe Owe sluice
14	Ye Kyaw sluice
15	Makyatsu sluice
16	Nyaungthonegwa sluice
17	Kawwin sluice
18	Kyonethin sluice
19	Kanmyint sluice
20	Melsaligone sluice

SLUICE NAMES IN EXCEL

	Name
1	Shan Gaing sluice
2	Paing Kyon sluice
3	Moe Yin Gyi Lank, Outlet 1
4	Moe Yin Gyi Lank, Outlet 2
5	Tawa sluice
6	Kyaikpadaing sluice gate
7	Bagan-Nyaungbin sluice gate
8	Minywa sluice gate
9	Aba sluice
10	(2) mile sluice
11	Htaung Min sluice
12	Shwe Owe sluice
13	Ye Kyaw sluice
14	Makyatsu sluice
15	Nyaungthonegwa sluice
16	Kawwin sluice
17	Kyonethin sluice
18	Kanmyint sluice
19	Melsaligone sluice
20	Y-yoe lock sluice

SLUICE NAMES IN THE ATTRIBUTE TABLE OF THE LAYER 'SLUICES' IN QGIS

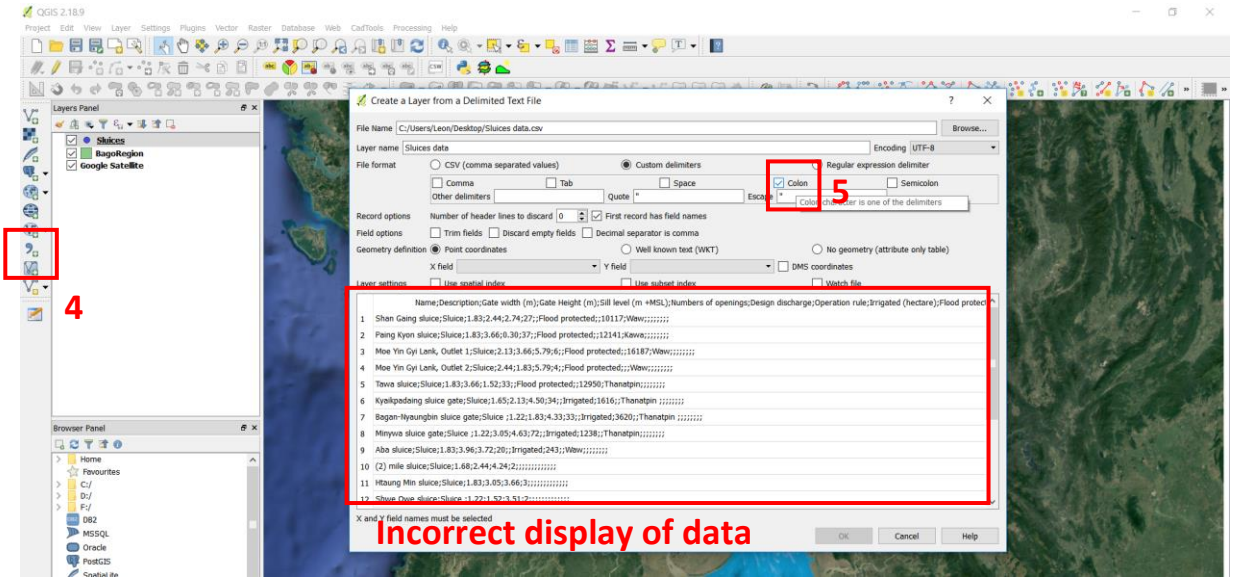
3. Save the Excel file with the data as a .CSV file



CSV stands for Comma Seperated Value. In this format, the separation between columns in Excel are changed into comma's, or another punctuation mark, for example:

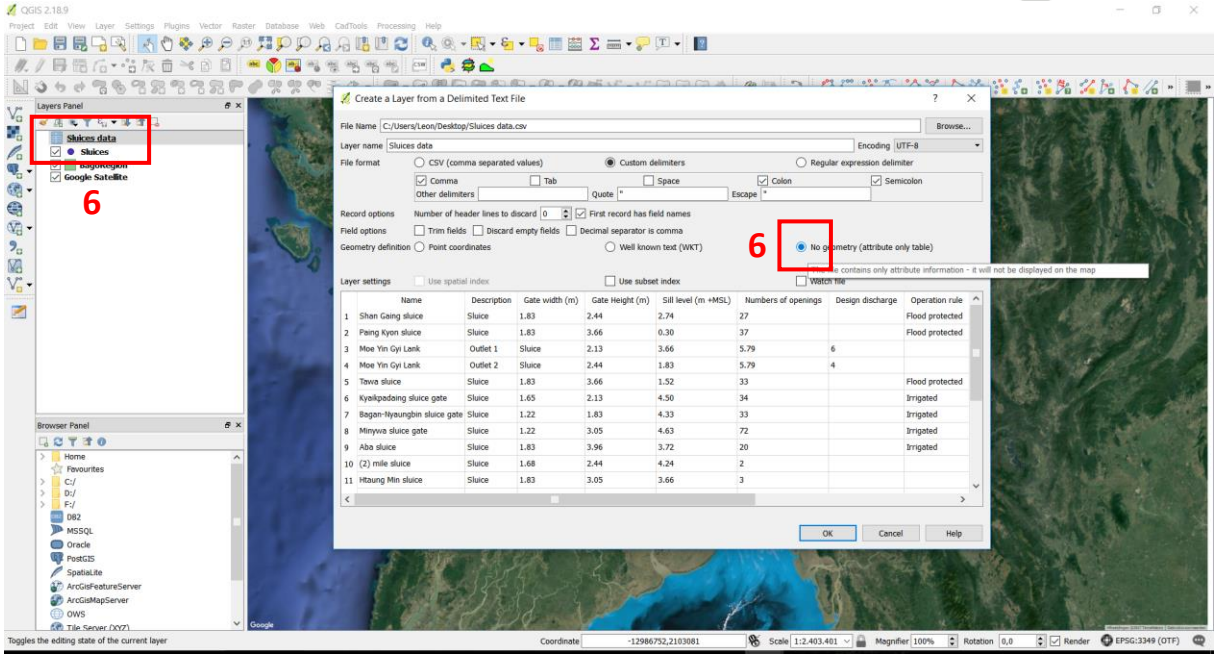
A	50	One	Will become	A,50,One
B	100	Two		B,100,Two
C	550	Three		C,550,Three

4. Insert the .CSV file in the QGIS file by clicking **add delimited text layer**
5. In the window that opens, the user can choose which punctuation marks stand for colomn seperations. In the screen below, the **colon (:)** is selected as separation mark. However, the **comma** is used in the .CSV file. Therefore, the data is not displayed correctly. Change the settings and select the comma as separation mark.



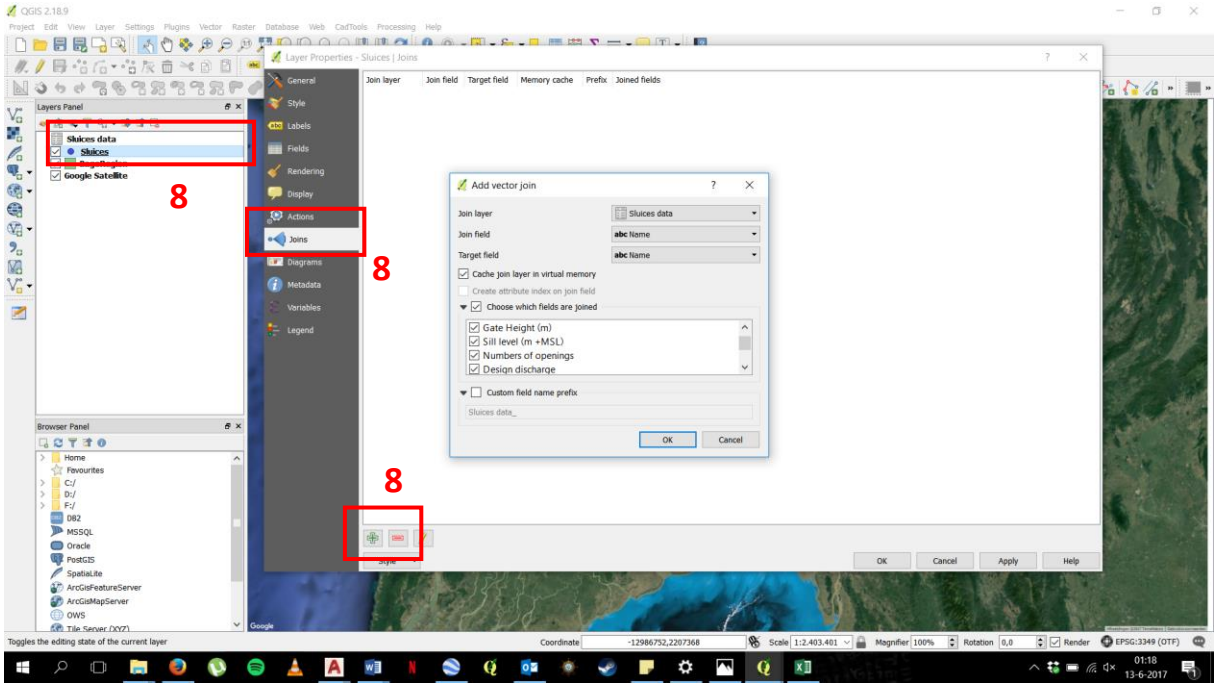
If step 5 does not work, Excel might be using other symbols than comma's to separate the values. Try out different options in the 'add delimited text layer' window.

6. When the data is displayed correctly, tick the 'No geometry' box, as the data has no location (yet). After clicking OK, the data will be added to the Layer Panel with a symbol.

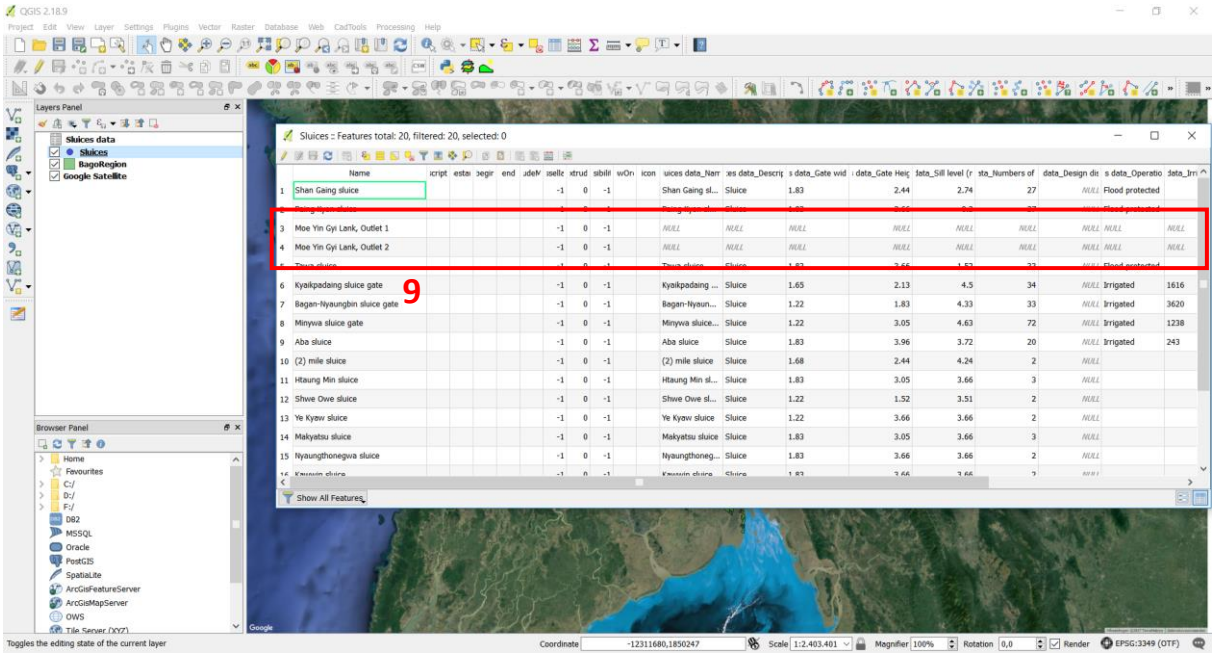


To link the data to the location layer of the sluices:

7. Right click on the vector layer **sluices > properties > Joins >** +
8. In the drop-down menus, choose which layer you want to join the sluice locations with (Sluice data) and choose the matching columns (name). Choose the attributes that you want to be joined by ticking the boxes. Click OK



Now the two layers have merged, and there is now one layer that contains both the location, as the numeric data of the sluices. View the data by right clicking on **sluices > Open attribute table.**



9. Whenever the names of the sluices (or other objects) in the attribute table did not perfectly match the names in the Excel File, all values for that sluice (or other object) will be *NULL.* On the picture above, this happened with the Moe Yi Gyin Lank outlets 1 and 2.

   The layer can be saved by right clicking on the layer in the layer panel **> Save as.** Save the layer as an ESRI shapefile, this way it can be used again in other QGIS models.

The described method can be used to save all sorts of data in QGIS. A base map of hydrological infrastructure in the Bago-Sittaung basin was made by the authors of this guide. Contents of the base map are

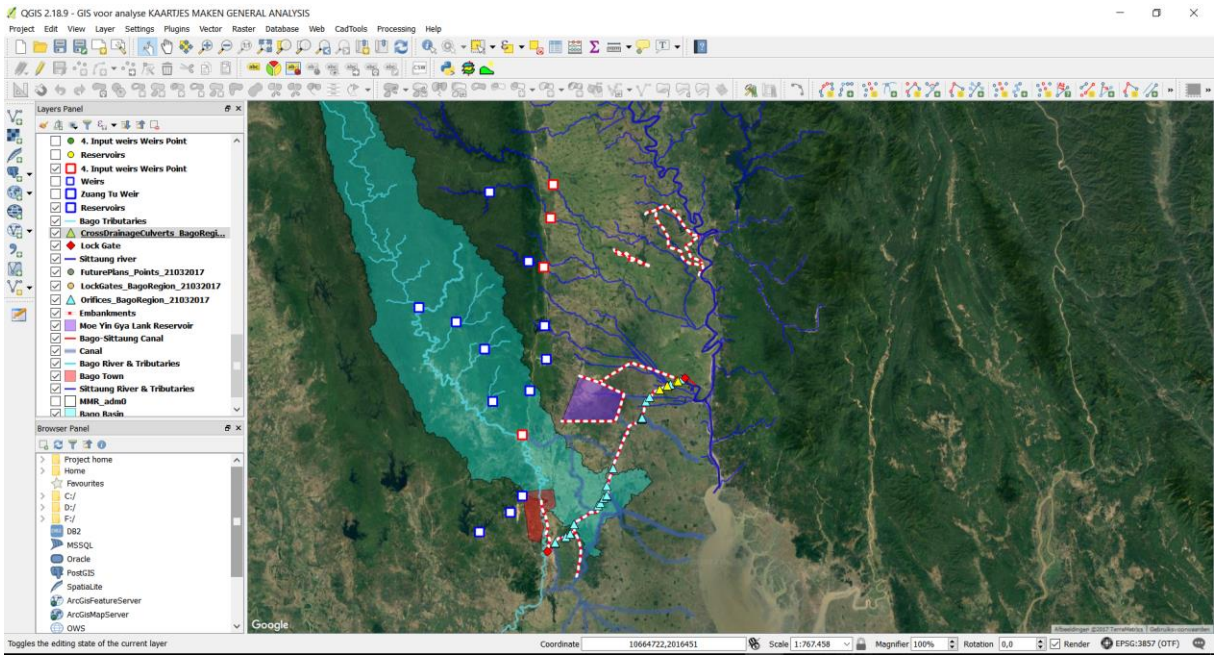
Complete project	12-6-2017 22:23	Bestandsmap
Excel	12-6-2017 22:23	Bestandsmap
Geographic boundaries	12-6-2017 22:21	Bestandsmap
Google Maps (KMZ)	12-6-2017 22:23	Bestandsmap
Shapefile	12-6-2017 22:23	Bestandsmap
SpatialLite	12-6-2017 22:23	Bestandsmap

Excel:	All numeric data of sluices, lock gates, drainage channels, orifices, embankments, weirs etc. in Excel
Geographic boundaries:	Shapefiles of the boundaries of the Bago basin, Sittaung basin and multiple countries including Myanmar
Google maps (KMZ)	KMZ files created in Myanmar of the named infrastructure
Shapefile/Spatiallite	Vector layers, including data and locations of the named infrastructure
Complete project:	All files in the folders uabove

The following types of infrastructure around the Bago-Sittaung Canal are available in the base map:

1. Sluices
2. Cross drainage culverts
3. Orifices
4. Weirs
5. Embankments
6. Canals
7. Future plans
8. Lock gates

The base map looks something like this:



APPENDIX D: FIELD REPORT BAGO-SITTAUNG CANAL

PROBLEM ANALYSIS & FIELD TRIP REPORT ON 07-03-2017

Version	1.1
Date	08-03-2017
Location	Bago

Authors	Leon Brok, bob dubbel, Dennis Neleman

CLIENTS:

TU Delft

- Dr. Ir. Martine Rutten
  Assistant Professor Water Management
- Ir. Marjan Kreijns
  Head of Project Management Department at Valorisation Centre

Rotterdam University of Applied sciences

- Ir. E. Schaap
- Ir. W. Kuppen

1 CONTENTS

2 INTRODUCTION

The area around the Bago-Sittaung canal in the Bago region is an area where many flood related problems occur on an annual basis. The Bago-Sittaung canal connects the Sittaung river with the Bago river and has a length of 61 km. The canal is an important water supplier for agriculture in the area. The canal was renovated in 2014 and plays an important role in protecting villages from inundations in the rainy seasons, as it provides great capacity for excess rain water stored in upstream reservoirs, and its many flood related infrastructure control the water levels in the area. The dike on the south side of the canal physically protects many villages from flooding in the rainy season.

On 08-03-2017 a field trip was organized by the Irrigation Technology Center (ITC) in Bago. All the important bottlenecks and infrastructure in and around the canal were visited.

Date:	*07-03-2017*	
Participators:	*mr. Zaw Min Htut*	*Director of ITC Bago*
	mr. Ye Htut Aung	*Staff Officer Water Management Section ITC Bago*
	Tara van Iersel	*TU Delft Master of Science student*
	Dennis Neleman	*Rotterdam University Bachelor graduation student*
	Bob Dubbel	*Rotterdam University Bachelor graduation student*
	Leon Brok	*Rotterdam University Bachelor graduation student*

Staff of multiple local offices of the Ministry of Agriculture, Livestock and Irrigation and operational staff of sluice (gates).

I. PROBLEM DESCRIPTION

The fieldtrip made clear that the problems occurring around and inside of the canal, are mainly on a broad scale. In 2013 the canal and infra around it was amended and reconstructed in a huge project. This levee is supposed to protect the area behind it from flooding at all.

On the north side of the canal, lots of paddy fields are protected by a small levee. Thanks to all the sluices and water gates around the canal, the water level is good controllable. The rice fields on the north side of the canal can therefore be flooded intentionally. This has a great advantage because flooding these field enables the farmers to grow rice all year long, instead of switching from rice to bean production between the rainy and the dry season. Rice is more profitable than beans are.

Despite good control of the water levels, discharges and inlet in the canal and the side canals, problems still occur annually; the levee on the south side of the canal still floods on average 3 times a year and for the farmers on the north side of the canal it is still not possible to grow rice all year long. This is due to problems with controlling the water level in the Bago river.

In order to control the water level in the canal, the Tawka lock gate, which connects the canal to the much bigger Bago river, must be able to discharge the water. The problems occur during the rainy season, when the water levels in the Bago river increase. These water levels tend to get so high, that opening the Tawka lock gate would result in a water flow towards the canal: the canal is not able to discharge water, the water level in the canal rises and the levee floods.

The main problem lies within the Bago river system. It is possible that smaller problems and inconveniences are occurring in the canal which can be solved. During the field trip, almost the entire length of the levee has been visited, as well as most of the infrastructure within it.

https://sites.google.com/site/bagosittaungriverbasinanalysis/system-discription/a-phy/vi-infrastructures

2. FIELD REPORT

What follows is a description of the places visited during the field trip, supported with pictures taken on spot and geographical imagery.

2.1 TAWA LOCK GATE/SLUICE GATE

The Tawa sluice gate is the connection between the Bago river and the Bago-Sittaung canal. The most southern point of the canal is at the lock gate. A major problem in the area starts at the location of the lock gate. During the rainy season, the water level in the Bago River is higher than the intended water level in the canal. Therefore, the Tawa lock gate has to close, stopping excess (rain)water in the canal to flow out and raising the water level in the canal, possibly causing floods in the area north of the lock gate.

FIGURE 1: TAWA LOCK GATE

Inside the operational building of the lock, a clear map of the area surrounding the canal was displayed. On this map, the whole canal with all locks, sluices and sluice gates within it are displayed. Also all side canals, which drain water from the canal to irrigate downstream rice field are displayed. Next to this overall map, another map showing the results of a bathymetry research done in 2014 (after the rehabilitation project) was displayed. On this map the proposed cross section as well as the current cross section were clearly visible. The chart showed that a lot of sedimentation has been taking place inside the canal, decreasing the maximum discharge and storage capacity significantly over the total length of the canal. Dredging activities in 2013 solved a part of the problem, but sedimentation still occurs at some parts of the canal.

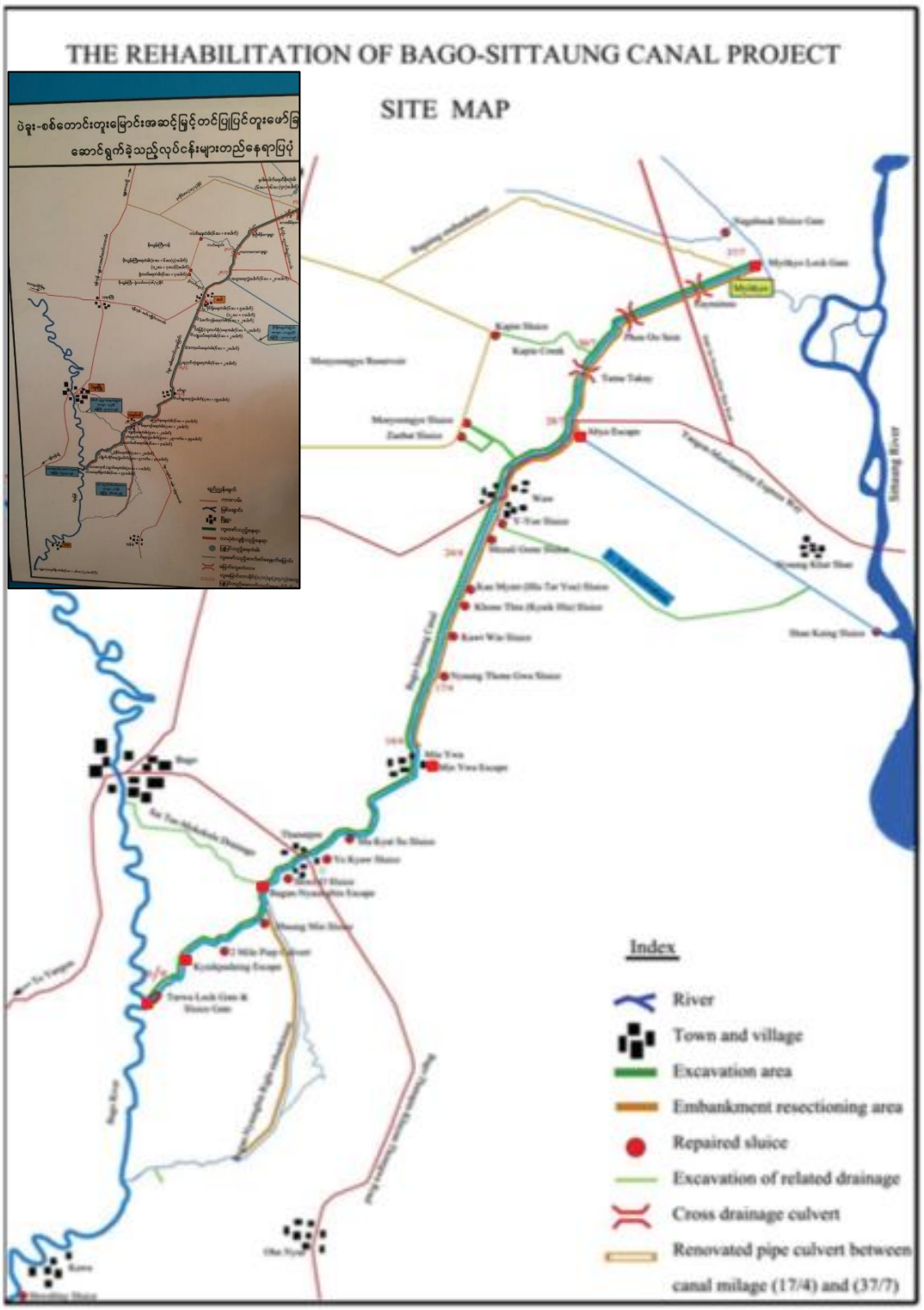


FIGURE 2: RECONSTRUCTION OF THE BAGO - SITTAUNG CANAL

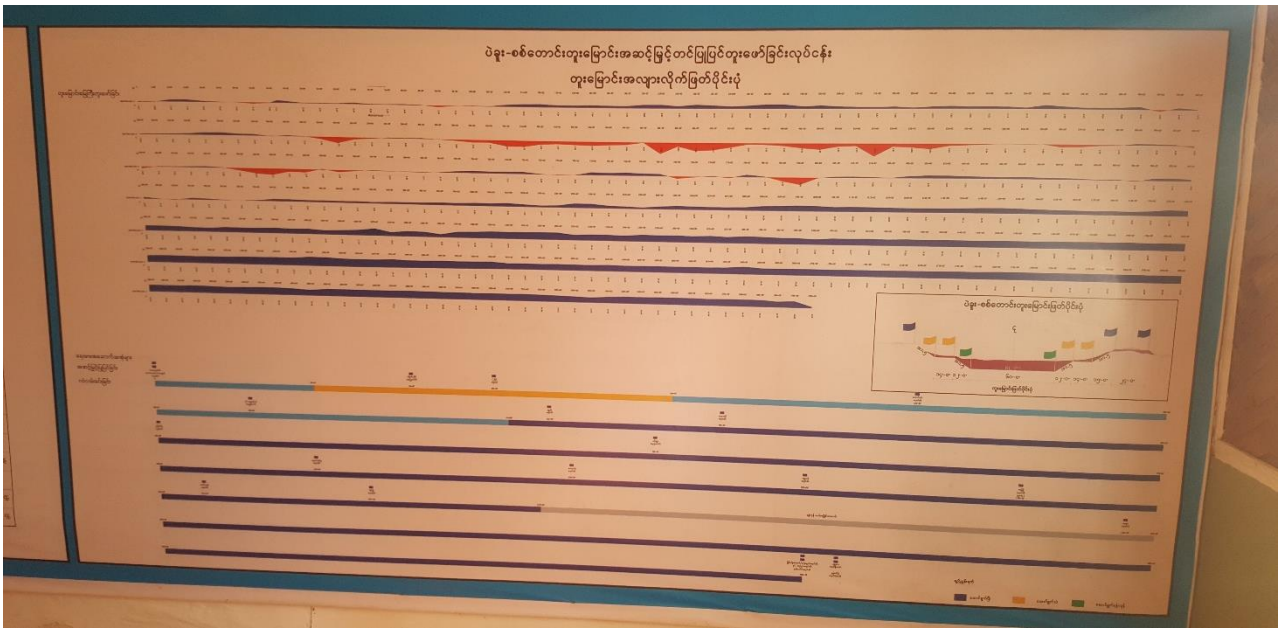


FIGURE 3: LENGTH SECTIONS FROM BATHYMETRY MEASUREMENTS AFTER THE REHABILITATION PROJECT

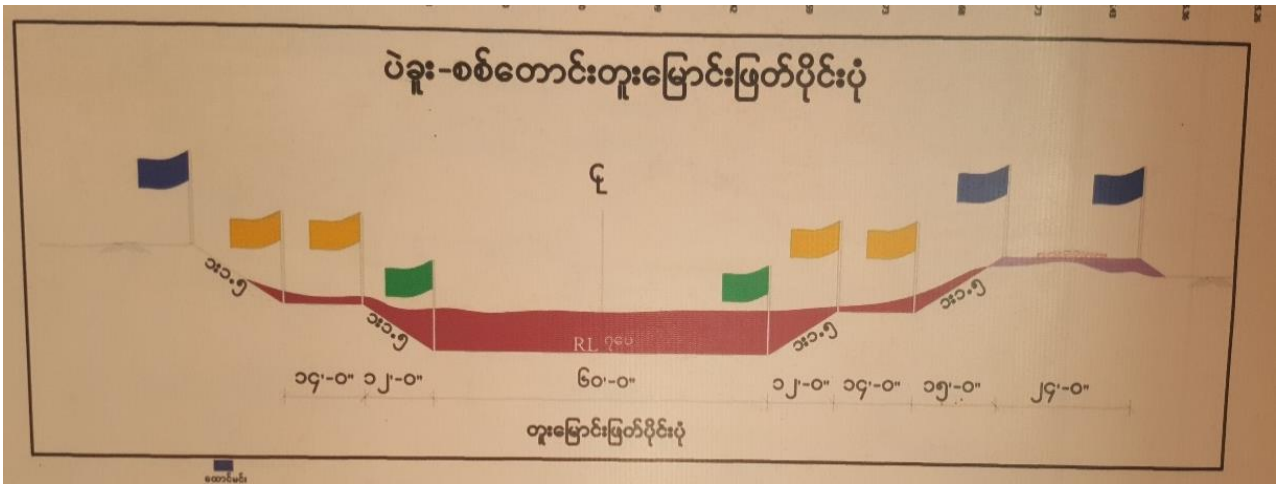


FIGURE 4: CROSS SECTION FROM BATHYMETRY MEASUREMENTS AFTER THE REHABILITATION PROJECT. RED=SEDIMENTATION

FIGURE 5: SILT CLEARLY VISIBLE ON THE BAGO-RIVER SIDE OF THE SLUICE

The Tawa sluice gate is a structure controlling the water level in the most southern part of the Bago-Sittaung canal. It is situated just several meters from the Tawa lock gate, the purpose of the extra canal of which the Tawa sluice gate is the end is to enlarge the maximum capacity of water flowing from the canal into the Bago river. Silt was clearly abundant at the sea side of the sluice, tidal waves flowing in cause this.

FIGURE 5: THE TAWA SLUICE GATE, SEDIMENTATION DIRECTED FROM THE OCEAN IS CLEARLY VISIBLE A METER FROM THE GATES

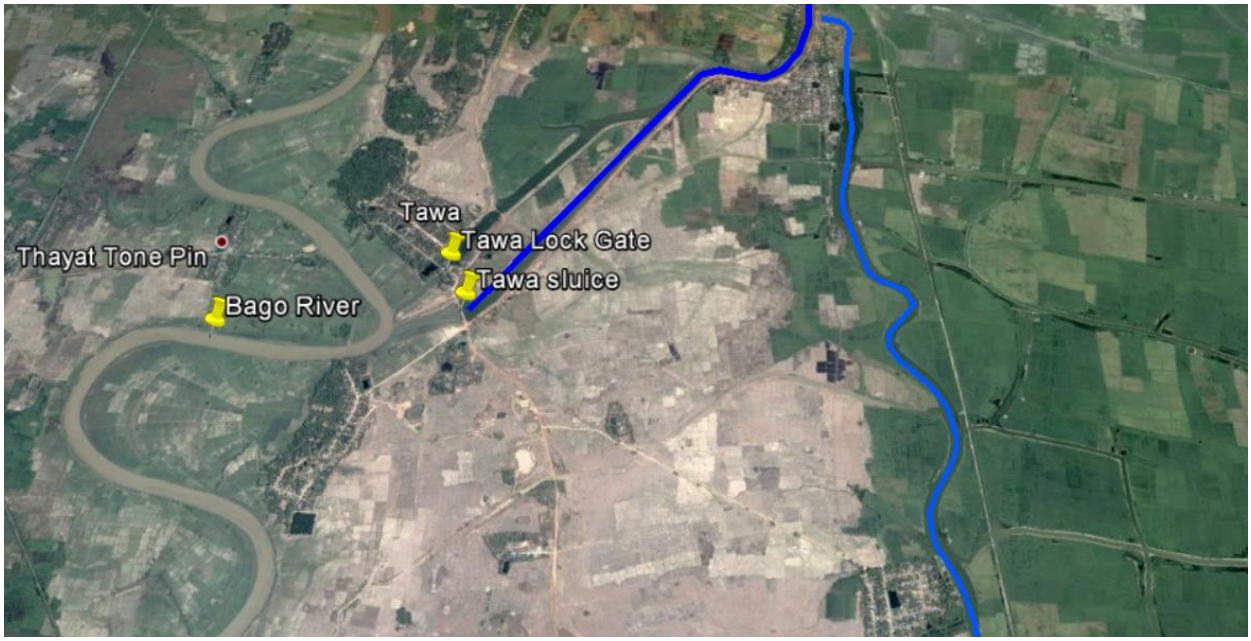


FIGURE 6: LOCATION OF THE TAWA LOCK GATE AND SLUICE GATE (GOOGLE EARTH)

2.2 KYAIKPADAING SLUICE GATE

The Bagan-Nyaungbin sluice gate connects the Bago-Sittaung canal with a small drainage canal. The drainage canal is used to transport excess rain water from the canal to the Bago river in the rainy season and supply an agricultural area with water in the dry season. The sluice irrigates an area of 1616 ha. The condition of the surrounding objects and the sluice gate itself seem to be good. Water levels are measured daily at both sides of the sluice gate.

FIGURE 6: KYAIKPADAING SLUICE GATE

FIGURE 7: WATER LEVEL MEASURING AT THE DRAINAGE CANAL SIDE OF THE SLUICE GATE

FIGURE 8: LOCATION OF THE KYAIKPADAING SLUICE GATE (GOOGLE EARTH)

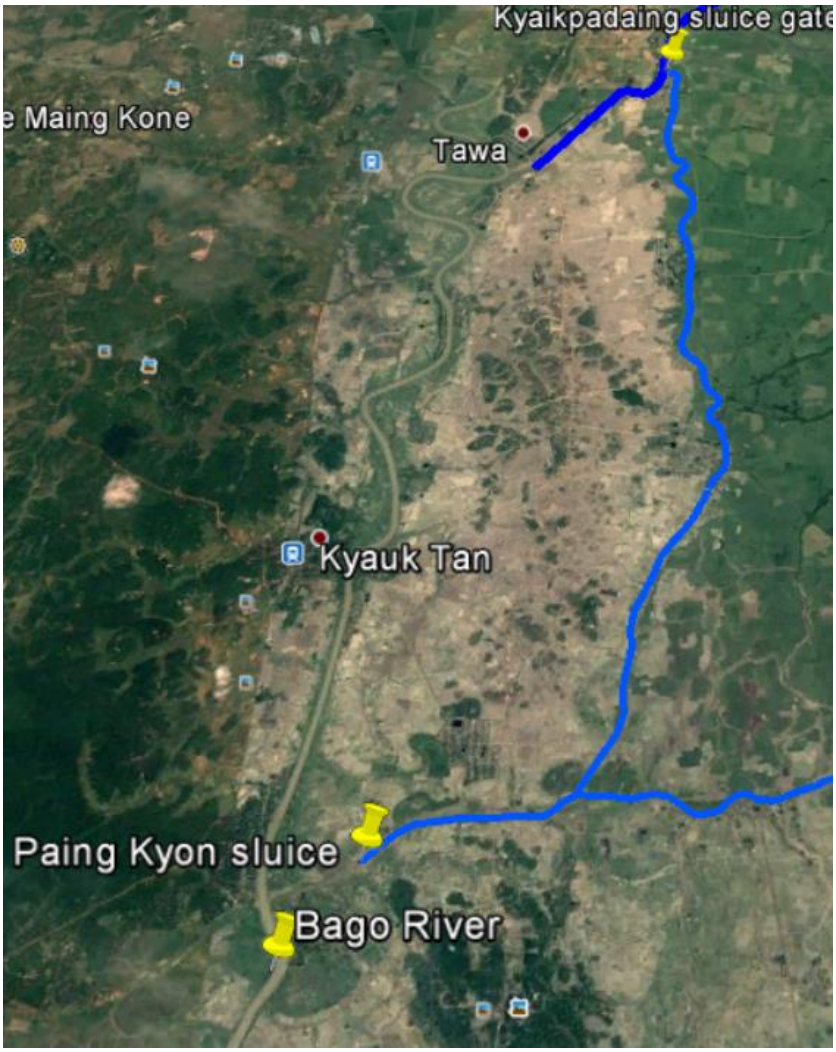


FIGURE 9: LOCATION OF THE KYAIKPADAING SLUICE GATE AND ITS DRAINAGE CANAL (GOOGLE EARTH)

2.3 BAGAN – NYAUNGBIN SLUICE GATE

The Bagan – Nyaungbin sluice gate is a gate similar in size as the Kyaikpadaing sluice gate, but the drainage canal it connects to the Bago-Sittaung canal (the Maungma canal) has influence on a much greater area as the Kyaikpadaing drainage canal 3620 ha. Vs. 1616 ha.). The Maungma canal goes south until it joints the Kawet C (drainage) canal which almost immediately merges with the Bago river near Yangon City. Water levels are measured daily at both sides of the sluice gate.

FIGURE 10: BAGAN-NYAUNGBIN SLUICE GATE, MAUNGMA CANAL SIDE

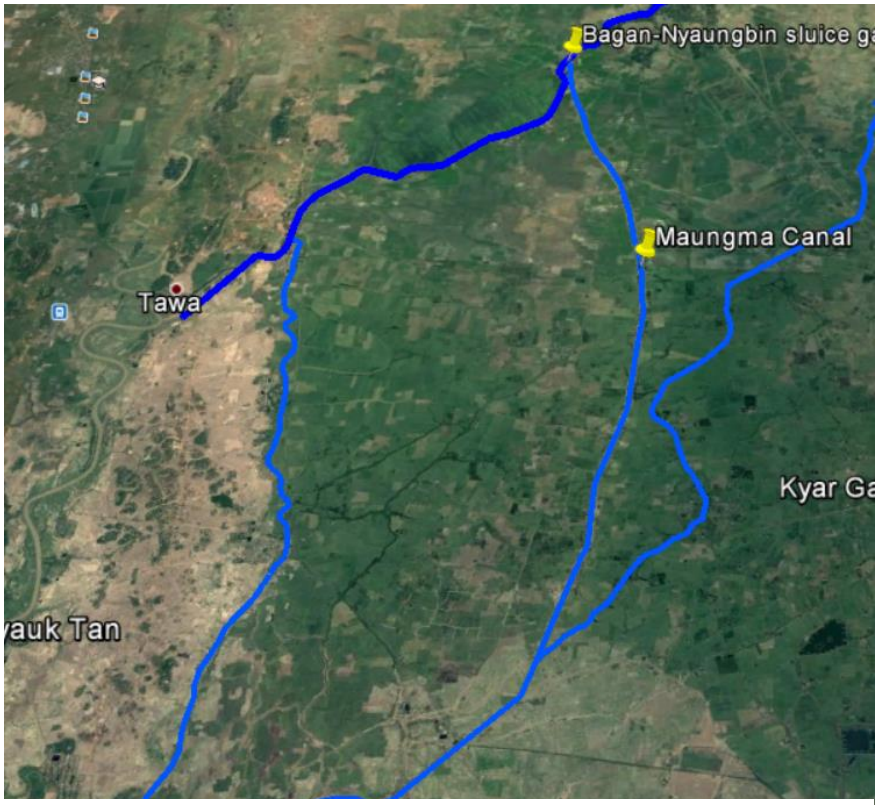


FIGURE 11: LOCATION OF THE BAGAN-NYAUNGBIN SLUICE GATE AND THE MAUNGMA CANAL (GOOGLE EARTH)

2.4 MINYWA SLUICE GATE

The Minywa sluice gate, located in the middle of Minywa town, connects two important draingage canals to the Bago-Sittaung canal. The Min Ywa – Kok Ko drainage will lead irrigation and excess rain water to the south east into the delta area of the Sittaung river. The Min Ywa – Paing Kyone drainage canal will go south west and merge with the Bago River. The two drainage canals are busy routes as man boats pass through the sluice gates. In the rainy season, the water level in the Sittaung River is too high to let the Minywa sluice drain enough water to the Sittaung river. Together the drainage canals irrigate an area of 1218 ha. Water levels are measured daily at both sides of the sluice gate.

FIGURE 12: MINYWA SLUICE GATE, DRAINAGE CANAL SIDE

FIGURE 13: MYNIWA SLUICE GATE, BAGO-SITTAUNG CANAL SIDE

The dikes around the Minywa sluice gate and town were in bad condition. On many places, bad erosion had occurred, worsened by the loads of thrash on the dikes. Some places on the dike near the sluice gate were strengthened with concrete, but next to these places the dike was in bad condition instantly.

FIGURE 14: EROSION ON THE BAGO-SITTAUNG CANAL DIKE NEAR THE MINYWA SLUICE GATE

FIGURE 15: EROSION ON THE DRAINAGE CANAL DIKE NEAR THE MINYWA SLUICE GATE

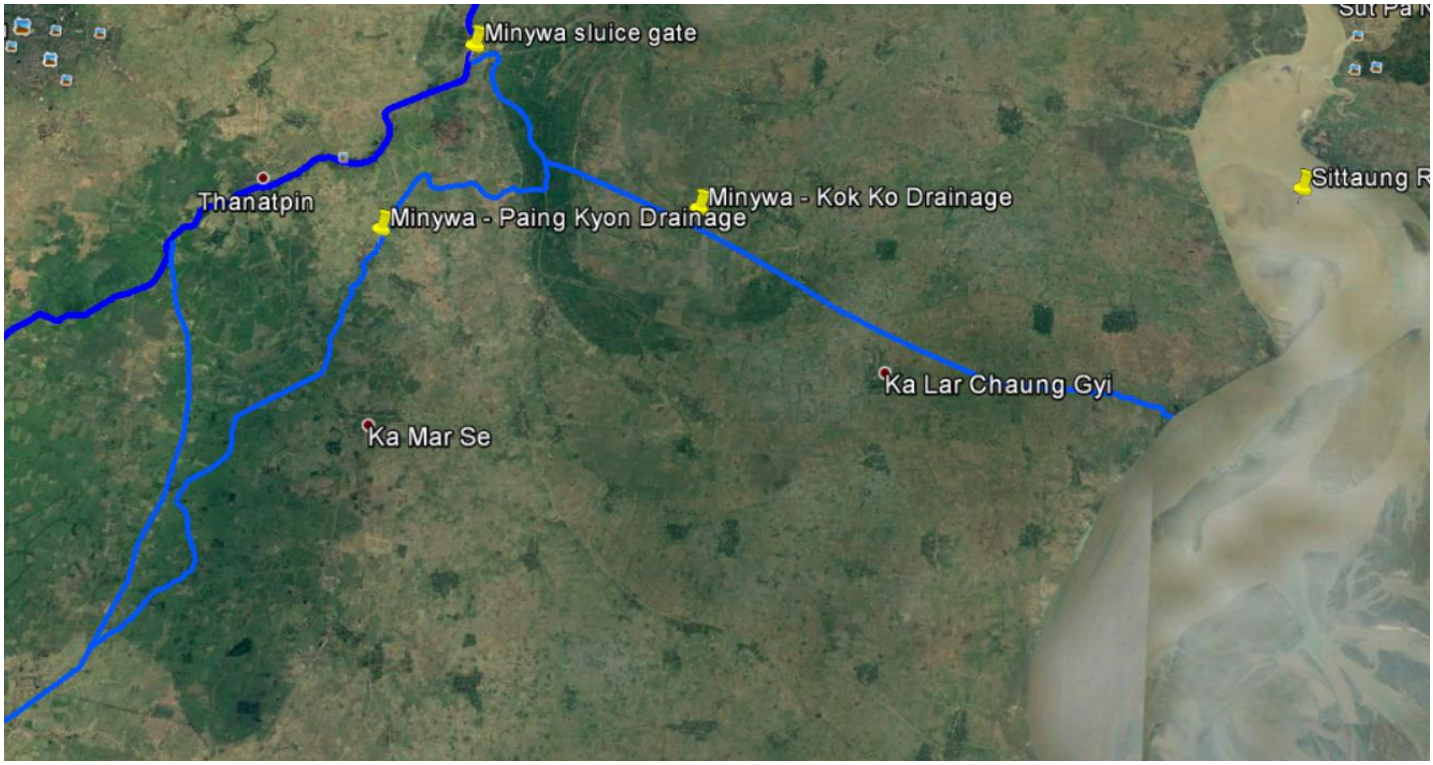


FIGURE 16: LOCATION OF THE MINYWA SLUICE GATE AND THE TWO CONNECTED DRAINAGE CANALS (GOOGLE EARTH)

2.5 MOE YIN GYI LANK RESERVOIR

The Moe Yin Gyi Lank reservoir is an enormous reservoir with an area of 12000 ha. The area is used for agricultural purposes, at the time of visiting there were many paddy fields in the area in full operation. The Moe Yin Gyi Lank reservoir has two inlets from the Pyin Bon reservoir and the Wa Ga Dok reservoir upstream. When these reservoirs reach full capacity in the rainy season, water is drained from the reservoirs to Moe Yin Gyi Lank. Because of the huge surface, it can hold much water. During the rainy season however, it is not enough, and the two outlets of the Moe Yin Gyi Lank reservoir are completely open for a long time as the Moe Yin Gyi Lank reservoir is at full capacity, raising the water level in the Bago-Sittaung canal through two connections between Moe Yin Gyi and the canal. .

FIGURE 17: ONE OF THE TWO OUTLETS OF THE MOE YIN GYI LANK RESERVOIR, THE MOEYINGI SLUICE GATE

FIGURE 18: ONE OF THE TWO OUTLETS OF THE MOE YIN GYI LANK RESERVOIR, THE MOEYINGI SLUICE GATE

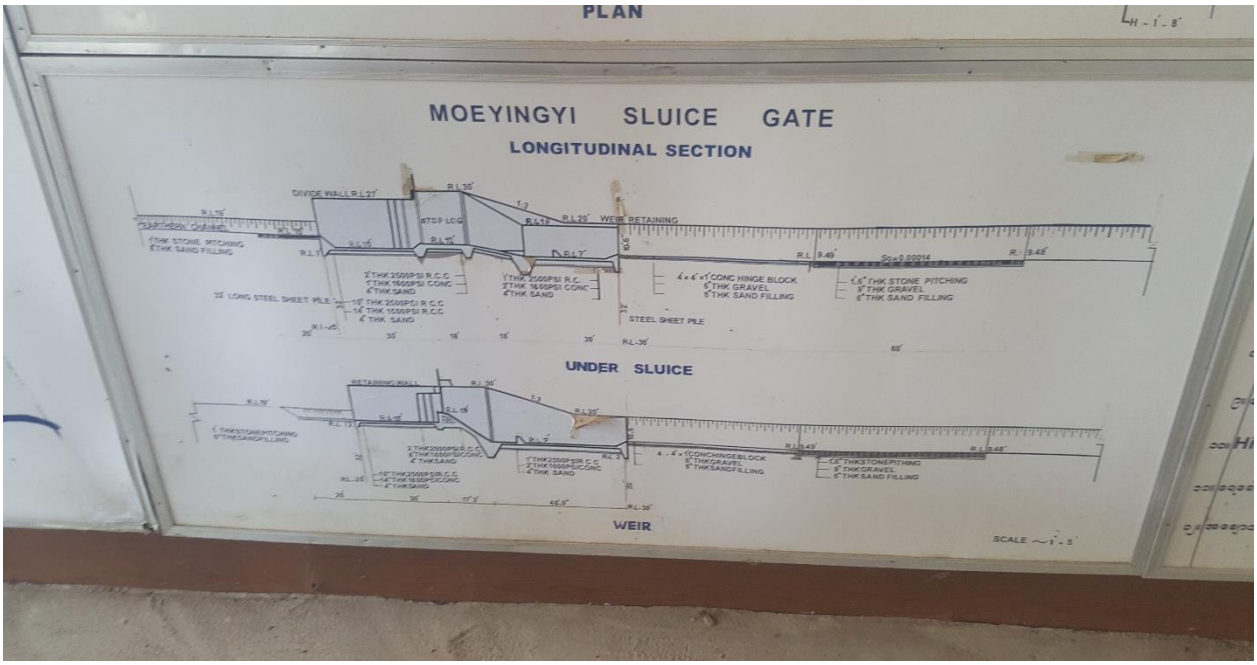


FIGURE 19: EXPOSITION OF THE SLUICE GATE CONSTRUCTIONS INSIDE THE OPERATIONAL OFFICES NEAR MOE YIN GYI LANK

FIGURE 20: LOCATION OF THE MOE YIN GYIN LANK RESERVOIR, AND ALL INLETS AND OUTLETS (GOOGLE EARTH)

2.6 SITTAUNG BRIDGE

The Sittaung bridge is a steel bridge spanning the Sittaung River and is the border between Waw region and Bago region. It is one of the two bridges across the Sittaung river. The stop at the bridge was to get an idea of the size and characteristics of the Sittaung river.

FIGURE 21: SITTAUNG BRIDGE

FIGURE 22: VISITING THE STTAUNG BRIDGE, WITH THE CONSTRUCTION OF THE OLD BRIDGE IN THE BACKGROUND

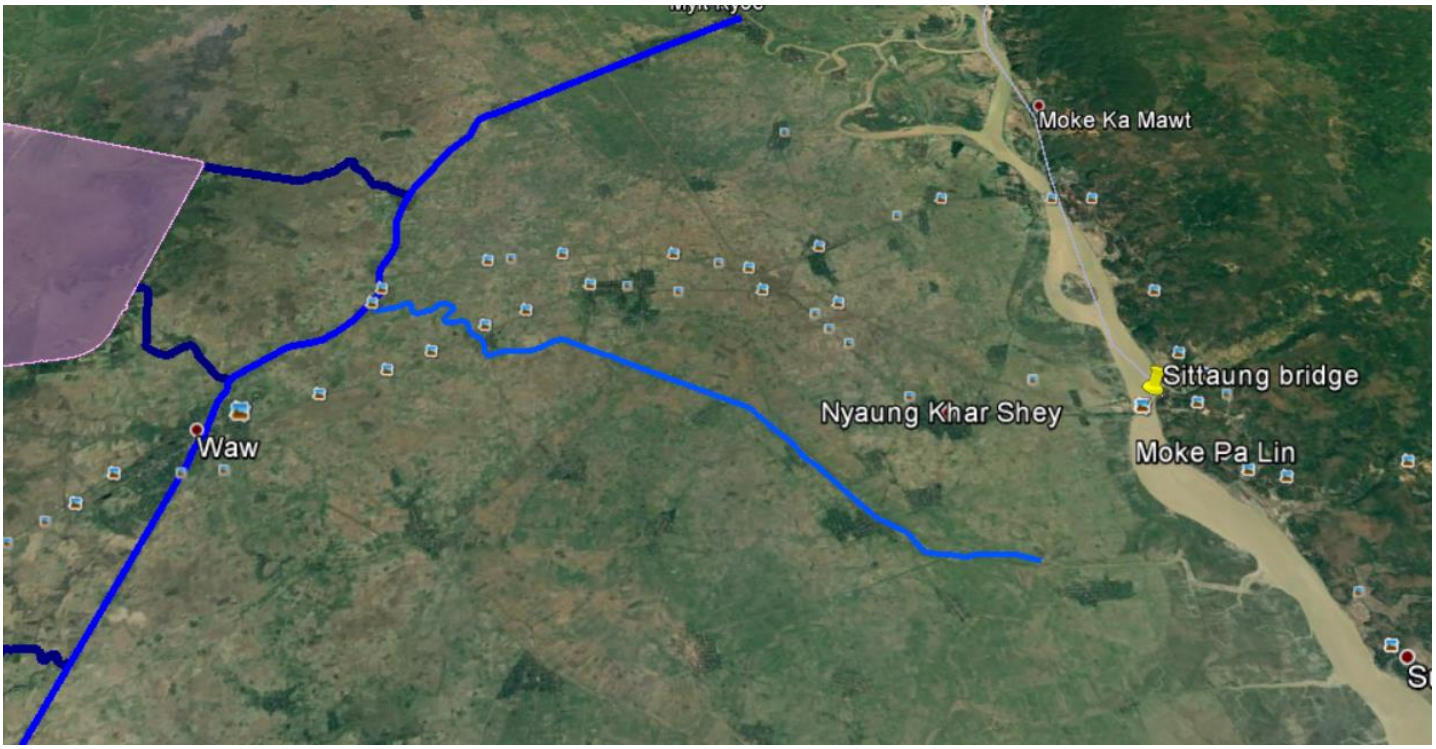


FIGURE 23: SITTAUNG BRIDGE LOCATION (GOOGLE EARTH)

I. MYITKYO LOCK GATE

The Myitkyo lock gate is the final piece of infrastructure visited, and it forms the connection between a tributary of the Sittaung river and the Bago-Sittaung canal. The Sittaung river is one of the two big suppliers of water of the canal, next to the Moe Yin Gyi Lank reservoir. The canal water level was higher than the river water level at the time of visiting. The lock gates were closed to hold the water in the canal to use for irrigation. In the rainy season the lock gates will be closed most of the time as well, to keep salt intrusion at a minimal level and to not let too much water in the canal, as the reservoir already lets in abundant water quantities.

FIGURE 24: MYITKYO LOCK GATE

FIGURE 25: SITTAUNG RIVER SIDE OF THE LOCK GATE

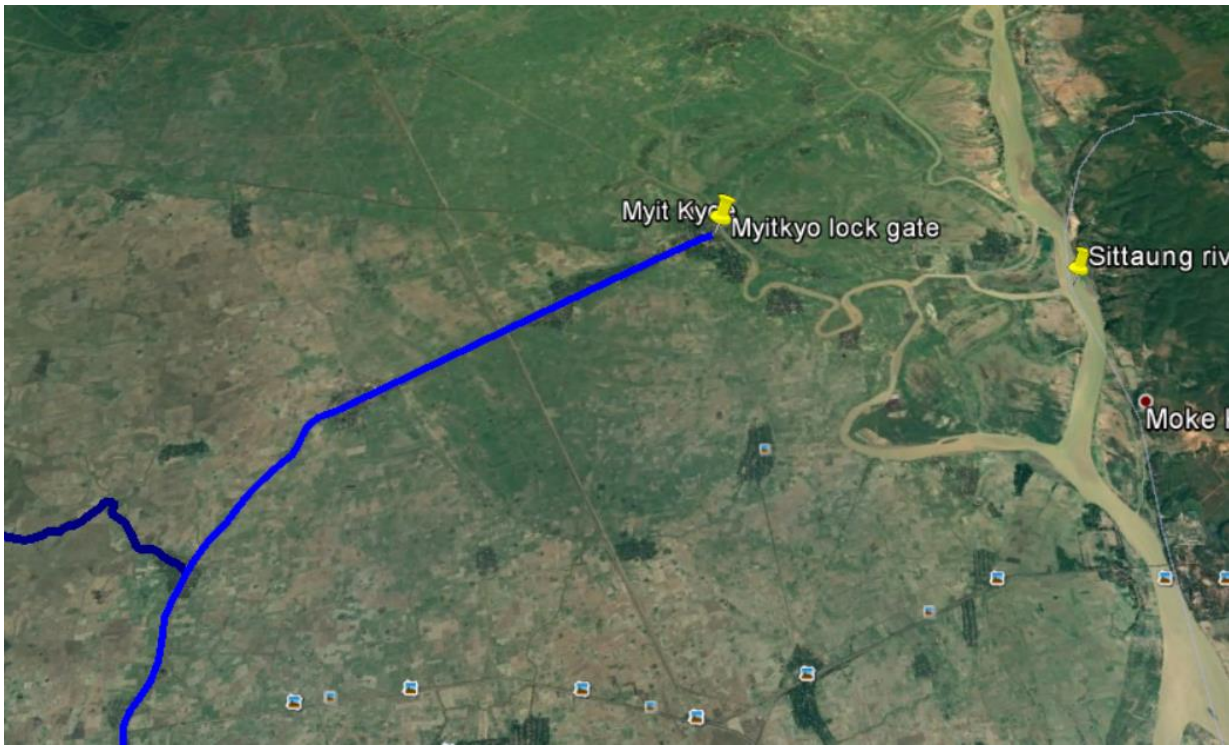


FIGURE 26: LOCATION OF THE MYITKOYO LOCK GATE (GOOGLE EARTH)

FIGURE 27: ALL VISITED LOCATIONS AND RELATED INFRASTRUCTURE

Visit Bago – Sittaung Canal & Moe Yin Gyi Lank reservoir

7-3-2017

1. Flood inundation areas around the canal
    a. Track by GPS (smartphone)
        Done
    b. Track by drawing on map provided
        Done
    c. Timing and duration of the floods
        2 a 3 times a year, for 1-3 weeks every time, parts north of the canal flood

2. Embankment on the south side of the canal
    a. Ask for weak points
        According to local employees the dike does its job well, no major problems are caused by weaknesses in the dike
    b. Look for weak points
        Some weak points caused by garbage/erosion were found, see report.
    c. Clearly define function of the dike
        Protecting southern farmlands from floods

3. Infrastructure in/around the canal
    a. Map all infrastructure and check if our available maps are correct
        Done
    b. **Yenwe**, **Baingda**, **Kawliya** and **Zaungtu** weirs: In the canal or elsewhere? ASK!
        Elsewhere, most are west of the canal

4. Moe Yin Gyi Lank reservoir
    a. Dike – weak points
        None known
    b. Heights, depths
        i. Fluctuation between wet and dry season about 2 – 2.5 meters
    c. When does this area flood? Connection with what reservoir? How often? Etc
        i. While in most parts of the year the area serves as a paddy field, in the rainy season the reservoir will reach its full capacity and excess water is drained to the Bago-Sittaung canal
    d. Erosion/sedimentation upstream/downstream of the dam
        i. As the inlets were off route, we did not visit them. The local experts said there were no problems concerning sediment at the inlets.

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Naing, W. (2009, July 29). Sittaung Bridge (Motpalin), Gateway to Mon State. *The new ligth of Myanmar*.

Information gathered during the trip from local offices of the Ministery of Livestock, Irrigation and Agriculture and employees of the operational offices of the sluices (gates)

APPENDIX E: RESERVOIRS AROUND BAGO

OVERALL DOCUMENT CONTAINING ALL FIELD REPORTS OF RESERVOIR ANALYSIS

Version	1.0
Date	30-03-2017
Location	Bago
Author	Bob Dubbel

Adjustments from previous version(s):

- ...

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ABSTRACT

The reservoirs within the Bago region, can easily be distinguished into those that are created by dams, and those that are excavated. Several visits have been paid to both the categories. The smallest, dam/made reservoir in the Bago region has an area of 2,08km^2. The ITC ´s drone, the Phantom 4, has two sets of batteries, both capable of flying 16 minutes. In order to map an area for DEM purposes, two flights must be executed, taking aerial pics of the landscape. The most common flight heights are 60m and 80m. With the pix4d application, which is used to set up flight plans for the drone, flight routes can be modelled. The drone takes into account the drone´s maximum velocity, battery power and area to map. Taking all these aspects into account, the app has calculated that an area of roughly 100.000m^2 can be mapped at once.

Since at the time of executing the case study only limited time is left in Myanmar, it is not practical to visit one reservoir twice just for mapping it. Therefore, the maximum area surface of the reservoirs for this study are limited to 100.000m^2.

Shape of the reservoirs
Several field trips have been executed, analyzing the different reservoirs around Bago. It stood out that there are two very clear different types of reservoirs when looking at the shape. Some of the reservoirs are characteristic for their perfectly rectangular shape. The edges of these reservoirs are smooth, angular slopes. Other reservoirs are distinguished by a rather random shape with very bumpy edges and different elevations on the slopes. It is expected that the calculation process with the software will differ strongly between these two reservoirs.

Water in the reservoirs
Drone DEM modelling techniques will not be able to penetrate through the water when a reservoir is not completely empty. It is not sure how the software will react on- and if it will be able to distinguish water from land when processing elevation lines. This is an important aspect to research since all the bigger, dam-made reservoirs contain water all year around.

For these reasons, drone techniques will be implemented on the following reservoirs:

- A rectangular, sharp-edged, excavated reservoir containing water
- A rectangular reservoir with concrete edges containing water
- A ‘messy, bumpy-edged’ reservoir containing water
- A dry ‘messy, bumpy-edged’reservoir
- The foreseen reservoirs are described on the pages below

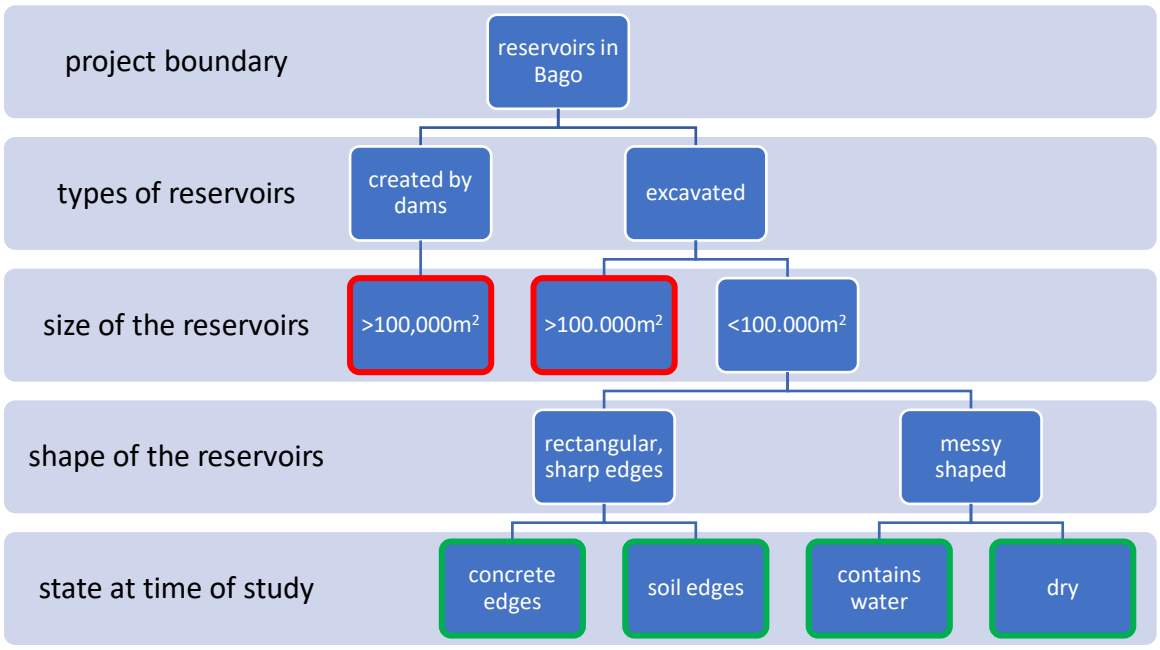

FIGURE 1: FORESEEN RESRVOIRS

CONTENTS

1. MAZIN RESERVOIR

Date	16-03-2017
Location	West of Bago
Characteristics	Dam-made reservoir
Executed by	Bob Dubbel

On the 16th of March, Mr. Zaw Min Htut, director of the ITC, organized a field trip to the Mazin reservoir, 15 minutes from the ITC. At location, a presentation was given inside an office next to the reservoir.

LOCATION

The reservoir is located to the West of Bago and can be reached with a fifteen-minute drive from the ITC.

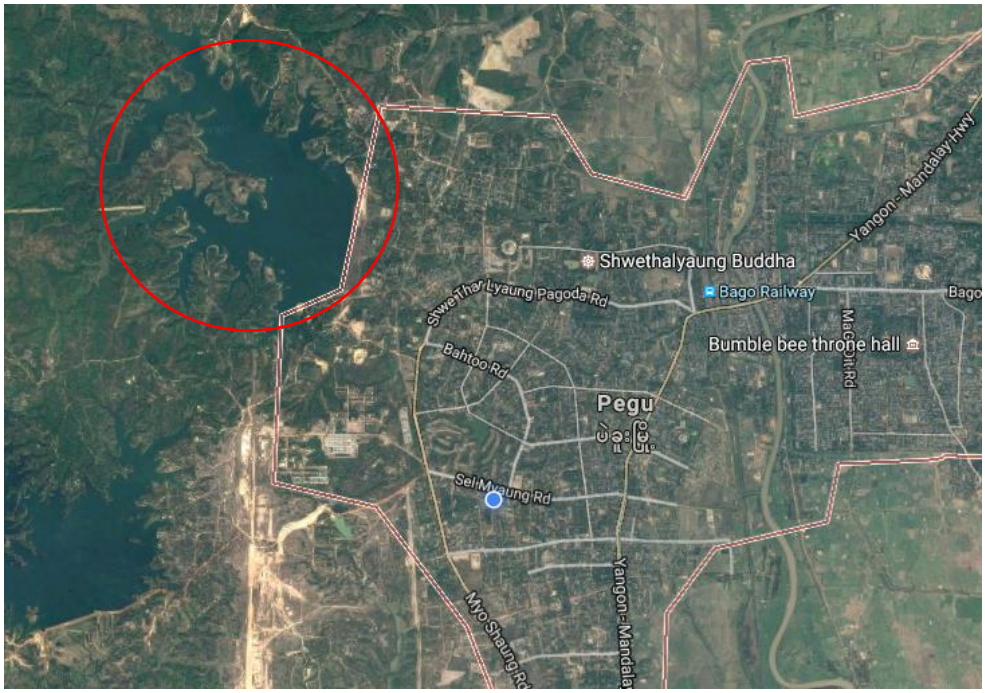

FIGURE 2: LOCATION MAZIN RESERVOIR

FINDINGS

The reservoir forms the main water source for Bago city and the surrounding paddy fields. The Mazin dam, with a length of 1.2km and a height of 18m, creates a reservoir with a surface of 4.81km^2. When completely full, the Mazin reservoir stores around 35.5*10^{6}m^3 of water. Enough to irrigate an area of 257ha.[1]

In the office, a brief presentation was given about the reservoir. The advantage of this reservoir is clear: The storage of water during the rainy season to supply irrigation water to mainly paddy fields during the dry seasons. This reservoir does however not play a role in flood protection, unlike most of the other reservoirs of this kind.

[1] Source: Outline of Irrigation and Water Utilization Managemaent Department

FIGURE 3: MAZIN DAM

FIGURE 4: ONE OF THE OUTLETS

FIGURE 5: PRESENTATION AT THE LOCAL OFFICE

Characteristics

The reservoir's edges defer strongly among each other. On the east side, there is the Mazin dam that is coated with lava stone. The South border of the reservoir consist out of a sandy, beach-like shore with a very slim slope. At the Northern border of the lake many trees and some sandbanks are present.

FIGURE 7: THE MAZIN DAM IS COATAD WITH LAVA STONE

FIGURE 6: WEST BORDER OF THE MAZIN RESERVOIR

PROBLEM DEFINITION

At location, Mr. Zaw Min Htut explained that the reservoir is under control of the ITC. The ITC regulates the amount of water that is let through the outlets at all times. There are lots of different farmers, crops and townships that are all depending on the water out of this reservoir. Shortages occur every year, so an efficient regulation of the water is crucial for the region. In an ideal season, the water reserves should be completely used just before the rainy season sets in. therefore it is crucial for the ITC to know exactly how much water is inside of the reservoirs.

Due to sedimentation inside the reservoirs, no clear idea of the total storage capacity is present at this time. Traditional methods of measuring the bathymetry are either done by hand or with the use of an ADCP (Acoustic Doppler Current Profiler), both either very expensive or highly time consuming. For this reason, volume calculations are executed very rarely. A new method for volume calculations would be of huge value to the ITC. Perhaps that the ITC drone can form a solution.

DRONE LIMITIATIONS

To map a certain area with the Phantom 4 drone, the Pix4D application needs to be used. This application helps creating a flight plan and sends the information to the drone, so that the drone does not have to be controlled manually. More information on the drone and the software can be found in appendix B: Software analysis.

Because of the enormous size of the reservoir, it will take the drone 160minutes to map the area at minimum. The maximum flight Height of 150m is then used, what is too high to make an accurate volume calculation. The Phantom 4 has a maximum battery life of 18 minutes, what means that at least 8 visits must be paid to the reservoir. Besides that, the dataset to process will be enormous.

For these reasons, the reservoir is considered too big for the case study. A research method will be set up using smaller reservoirs to calculate. The used methodology on these smaller reservoirs could be applied to the Mazin reservoir as well, but will take much more time. To make sure that the used methodology in the small reservoirs is applicable to the Mazin reservoir as well, reservoirs will be chosen with the same characteristics.

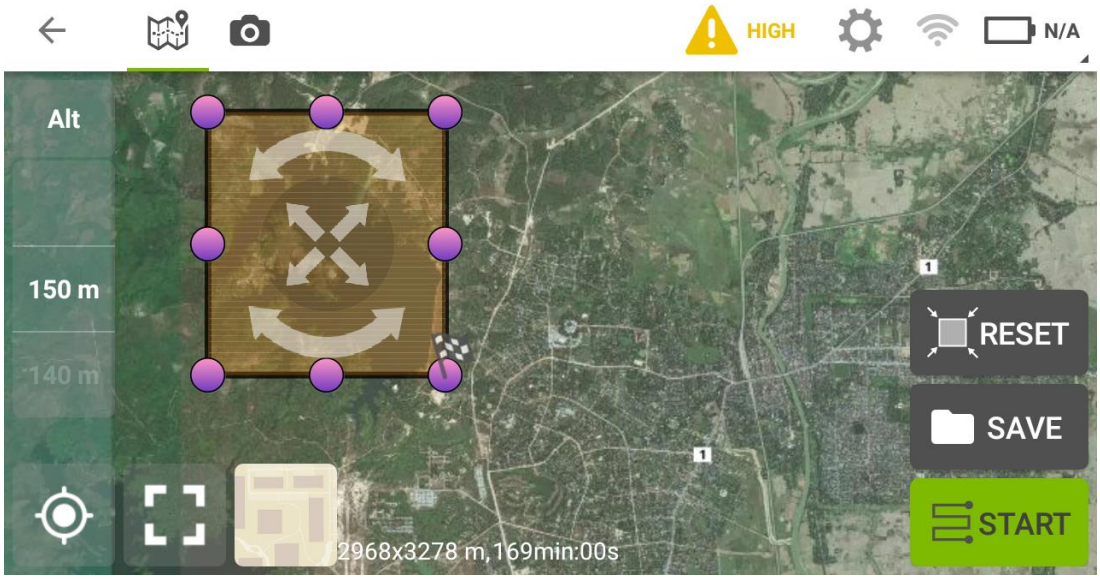

FIGURE 8 : PIX4D APP ABOVE THE MAZIN RESERVOIR

2. ITC RESERVOIR

Date	30-03-2017
Location	Bago, ITC
Characteristics	Messy, round-edged reservoir containing no water.
Executed by	Bob Dubbel

The ITC features an own reservoir, just behind the institute. The water is mainly used for watering the grass and bushes around the ITC. At the time of arrival at the ITC, on the 22th of February, there was still water present in the reservoir. Due to the drainage of water for watering the ITC and evaporation occurring inside of the reservoir, the water level lowered visibly each week. At the 20th of march. There was no water present in the reservoir at all anymore.

LOCATION

The reservoir is located just behind the institute building. The blue dot on image 9 indicates the location where this report is written.

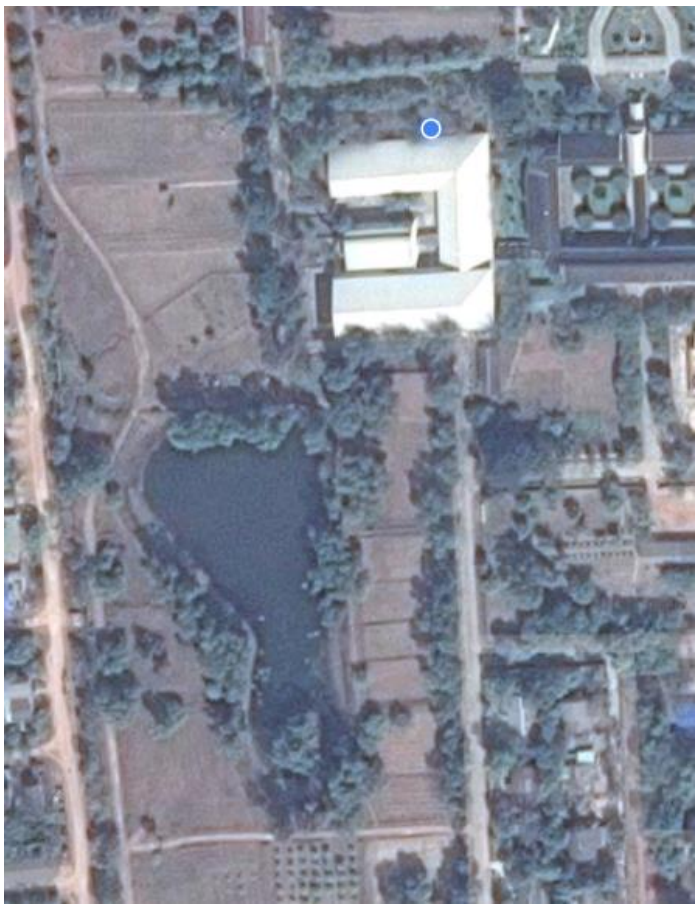

FIGURE 9: THE ITC RESERVOIR

FINDINGS

Characteristics

The reservoir is curvy shaped with a depth of 6m. the edges are made out of soil and contain lots of bumps and ridges. Inside of the reservoir there is an island present. Several spill ways are visible around and inside the reservoir.

FIGURE 10: EDGE OF THE RESERVOIR

FIGURE 11: ITC RESERVOIR

Precence of water

at the time of the visit at the 30th of march, no water was present at all inside the reservoirs

Accessibility

The Reservoir can be reached by foot and by car.

FIGURE 12: ISLAND INSIDE THE RESERVOIR

ADVANTAGE OF THIS RESERVOIR

Most of the reservoirs around Bago dry completely during the dry seasons. At this time, the drone can be used for the volume calculations. A model can be set up determining the amount of water inside the reservoir at a certain water height, which can be measured simply with gauges. The sloppy edges and ridged shapes of the reservoir will increase the complexity of the volume calculations, which makes the reservoir a challenging choice and a good challenge for the software.

3. FISH POND

Date	22-03-2017
Location	15km South of Bago
Characteristics	Rectangular reservoir with sharp edges filled with water
Executed by	Bob Dubbel

The ponds were located on google earth. To determine if there was still water present at the time of the research, a visit needed to be paid to the location. By motorbike it took around 15 minutes to get on location.

LOCATION

The fishponds are located 15km South of Bago, sandwiched between the Yangon-Mandalay highway in the West, and the Bago river in the East. Therefore, the ponds can be easily reached by car or motorbike over the highway, or by boat over the Bago river.

FIGURE 13: LOCATION B, FISHPONDS

FINDINGS

Characteristics

The ponds have rectangular shapes with sharp edges, which is a very common shape for reservoirs in the Bago region. The edges of the ponds consisted out of soil with small vegetation.There are around 30 different ponds, some connected to the others, some completely isolated. Sizes variating from 20.000m^2 to 90.000m^2.

Presence of water

The field trip made clear that there is plenty of water present. All the ponds were filled almost completely at the time of visit. This is due to the constant drainage of water out of the Bago river, into the ponds.

FIGURE 14: FISHPOND

Accessibility

A good quality dirt road leads from the highway, right through the ponds. It would be certainly possible to drive a car and evan a big truck, containing a small boat, to the location. On the East side of the pond, the Bago river floats just 200m next to the nearest pond. This opens opportunities of dragging a small boat out of the river and carrying it to the ponds by manpower.

FIGURE 15: ROAD TO LOCATION

ADVANTAGE OF THIS RESERVOIR

The rectangular shape and vegetated soil edges of the ponds, are characteristic for most of the excavated reservoirs around Bago. The big advantage of these ponds, is that, unlike most of the similar reservoirs, the ponds still contain water due to the draining of the Bago river. A rough estimation at location estimates the water level at least 2m in the pond, what is enough for the Fishfinder.

4. OKTHOA GOLF CLUB RESERVOIR

Date	28-03-2017
Location	Bago, 500m North of the ITC
Characteristics	Highly vegetated reservoir with ridged edges containing water
Executed by	Bob Dubbel

The reservoir was found by looking at Bago on google maps. The satellite photos showed a reservoir with some small sandy obstacles in it. A visit was paid to the reservoir by foot to determine if there was water present at the time of the case study.

LOCATION

The reservoir is located in the middle of the golf course, 500m away from the ITC and can be reached easily by foot.

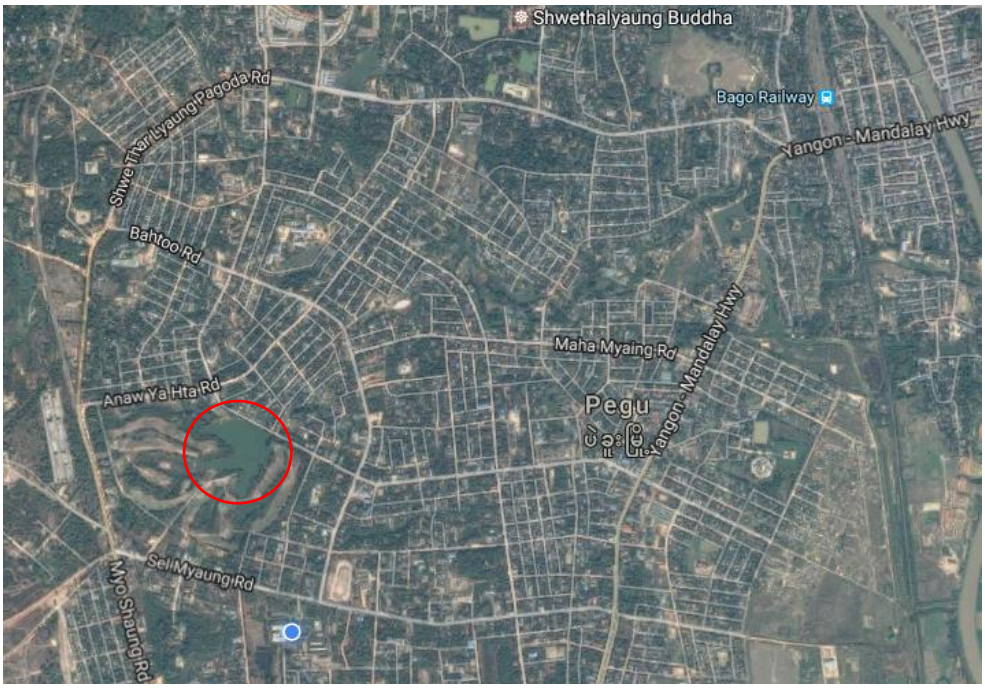

FIGURE 16: LOCATION C: OKTHOA GOLF CLUB RESERVOIR

FINDINGS

Characteristics

The reservoir is surrounded by trees and other vegetation. At different locations inside the reservoir, vegetated sandbanks rise above the water surface. The edges of the reservoir consist out of sandy sloped full of riches and different elevations. Vegetation is present on the slopes although most of the edges are free of plants. The reservoir looks very similar to what the bigger dam-made reservoirs look like, but smaller.

FIGURE 17: EDGES OF THE OKTHA GOLF CLUB RESERVOIR

FIGURE 18: SANDBANKS INSIDE THE RESERVOIR

Presence of water

Although it is clear that the reservoir is far from full, lots of water is still present. At location it was hard to estimate the average water depth of the reservoir, because the shore leads into the water at a very small angle.

FIGURE 19: AMOUNT OF WATER PRESENT

Accessibility
The reservoir can easily be reached by foot, but not by car.

advantage of this reservoir
The advantage of this reservoir, is that it looks very similar to the dam-made reservoirs common in the region. Calculating the storage capacity in this reservoir, will be a much harder task then any of the other foreseen reservoirs. The different elevations of the slopes, presence of vegetation, sandbanks in the middle and the presence of water will all influence the calculation process drastically. Yet, these calculations will give the most accurate method that needs to be used for calculating bigger reservoirs in the future.

5. YAUNG SAY KYUM PAGODA RESERVOIR

Date	30-03-2017
Location	Bago center, next to highway
Characteristics	Reservoir with stone edges containing water
Executed by	Bob Dubbel

LOCATION

The reservoir is located in the center of Bago, next to the highway.

FIGURE 20: LOCATION OF THE PAGODA RESERVOIR

FINDINGS

The reservoir surrounds a pagoda and appears to be very deep. There are two clear levels of elevation visible, with the second level being covered in stone.

FIGURES 21 & 22: EDGES OF THE RESERVOIR

As can be seen in image 22, a bridge crosses the reservoir to connect the pagoda with the mainland. This will make it harder to perform volume calculations.

FIGURE 22: BRIDGE OVER THE RESERVOIR

The reservoir was chosen for the fact that edges are made from rock material, similar to the Ma Zin dam. The reservoir could figure as a test to determine how the software will react to the border between water and stone in a sharp edge. Unfortunately, at the time of the visit, the water level was so low that the there was no connection between the water surface and the stone embankment and the under laying soil-made embankment was visible. Together with the bridge blocking the aerial view of the drone and a big outlet in the corner of the reservoir which would Make it impossible for the program to calculate the volume, the decision has been made that this reservoir will not be included in the research.

APPENDIX F: DATA COLLECTION

DOCUMENT CONTAINING ALL PRACTICAL STEPS AND ACTIONS IN THE PROCESS OF DATA RETRIEVAL

Version	3.2
Date	04-04-2017
Location	Bago

Author	Bob Dubbel
In cooperation with	Sai Wunna, Ye Pyae Tun, Lin Lin

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ABSTRACT

In this appendix, all the practical measures taken in the process of obtaining data of the 3 reservoirs are described. It contains 3 field trips and an explanation of the preparational steps that had to be taken in order to use both the drone and the Fishfinder.

CONTENTS

1. PREPARATIONAL STEPS

Date	04-04-2017
Location	ITC
Product	Ground Coordinate points
Executed by	Bob Dubbel and Sai Wunna.

When mapping an area, drones use a georeferenced tag on the images. The location of where the drone has taken a specific image, helps the software to model the area and makes the creation of dense point clouds possible. However, in order to make a map detailed enough to perform volume calculations, GCP's or Ground Coordinate Points need to be added to the model.

A GCP is a location on ground of which the exact GPS location has been determined. This location is then clearly marked with a sign or physical designation, which can be photographed by the drone. When importing the images in the software program, the GCP's need to be marked and the determined GPS location of the marked locations is filled in into the program. Using at least 5 GCP's will increase the accuracy of the dense point cloud extremely and is therefore highly recommended.

2.1 CREATING THE GCP'S

The GCP's used by the ITC for the GIS course are unfortunately too damaged to be used again. Luckily, the ITC employees have learned how to craft them by hand. Everything can be used as a GCP, as long as the used object is clearly visible from the air and contains a point which can easily be pointed out with the accuracy of just centimeters.

For the mapping of the reservoirs, the ITC decided to use cardboards of high quality that could be used for future projects and are easy to relocate. The pictures below give a good impression of the process.

Figures 1 & 2: Process of crafting the GCP's

2.1 PLACING THE GCP'S

A minimum of three, but favourably 5 to 8 GCP'S are needed in every project to make the Dense Point Cloud reliable enough for volume calculations. Since the reservoirs are relatively small projects, compared to the brought possible usages of drone mapping, 5 would be enough for the proposed mappings. The best way to place them can be compared with installing legs underneath a table. The area to map is the table surface and the GCP's should make the table as stable as possible. One GCP should favourably be placed in the middle.

2.3 DETERMINING GPS LOCATIONS

Once the GCP's were installed, a Differential GPS device was used to determine their exact locations. There is one determined GPS location point in Bago, at the ministery of forestry, 4 km away from the ITC. Luckily, as part of the GIS courses, the employees of the ITC have crafted a new point inside the ITC. This location can be used as a starting point for locating the exact GPS locations of the GCP's.

Figures 3 & 4: Known GPS location point

From this point, the GPS location of the next point can be determined. The maximum distance on which the device can measure accurately enough is 6km. For the ITC reservoir and the Golf Course Reservoir this is enough to locate the locations of all GCP's at once. For the Fish pond several waypoints need to be added.

2.4 DETERMINING GPS LOCATIONS

The Pix4D application is used to set up the flight plans for the drone. In this application, the chosen flight speed, altitude, camera focal length, shutter speed and other specifications that are relevant for the final result can be inserted. The Pix4D application provides a 'double grid mission' option that is highly useful for obtaining DEM's.

2.4 GRID OPTIONS IN PIX4D

Although for the thesis only 3D map models will be obtained, Pix4D features many different options. Image 4 is taken from the start screen of Pix4D when opening a nem project:

Figure 4: Options in Pix4D

Depending on the required model, a flight plan is chosen, the Pix4D capture application feasutures the following flight option:

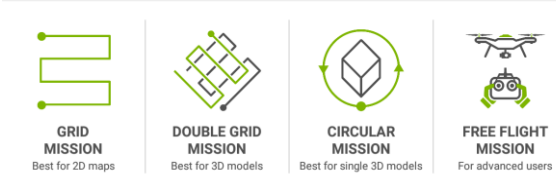

Figure 5: Different mission options in Pix4D

As shown in the image, double grid missions are best for 3D models. The difference between a single grid and a double grid is demonstrated below:

The top image shows the maximum area of a single grid mission, on a flight height of 100m with a flight time of 17 minutes. This grid covers an area of 729m x 501m and consists of 182 photo's.

The image below shows the maximum area of a double grid mission, also with a height of 100m and a flight time of 17 minutes. This grid covers 416m x 420m and consists 418 photo's.

Figure 6 & 7: Single and double grid mission above the ITC

2. ITC RESERVOIR

Date	05-04-2017
Location	Bago, ITC
Product	DSM of the ITC reservoir
Executed by	Bob Dubbel, Sai wunna, Ye Pyae Tun, Lin Lin

3.1 FLIGHT PLAN

Figure 8: Flight plan ITC reservoir

Mission type: Double grid mission
Altitude: 50m
Flight time 14:00 minutes
F-stop: f/2.8

3.2 LOCATION GCP'S

Since the reservoir was empty, one GCP could be placed in the middle of the project. The other 4 GCP's were placed around the reservoir.

Figure 9: Locations of the 5 GCP's

Figures 10 & 8: Placing the GCP's around the reservoir

3.3 FINDINGS

The first steps of processing the datasets are executed to validate if the dataset contains no errors. A description of the process is given in the manual, which is one of the final products of the thesis. For now, the conclusion can be drawn that there are no malfunctions in the dataset and that DSM's and volume calculations can be obtained.

After processing the images into a first, raw DSM model, the model can be processed again in higher detail by adding the GCP's. The act of inserting the GCP's in the model is difficult and time consuming and shall therefore only be done for this first model. Image 14 shows the model after the first time processing. The image on the next page shows the result after adding the GCP's. It is clear that the model is much more detailed after the second time processing.

Figure 13: First step of processing images

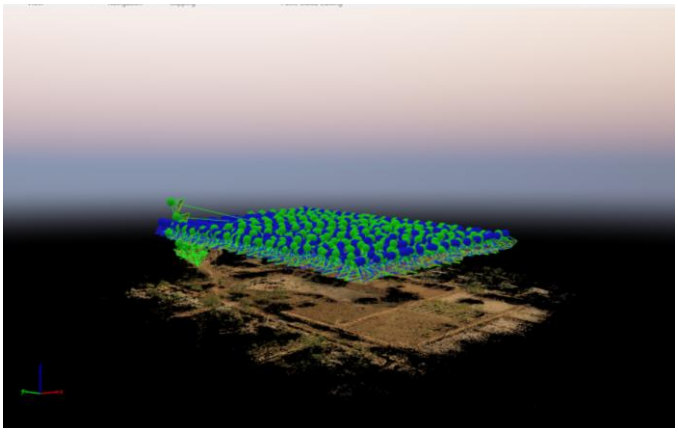

Figure 14: First DSM result

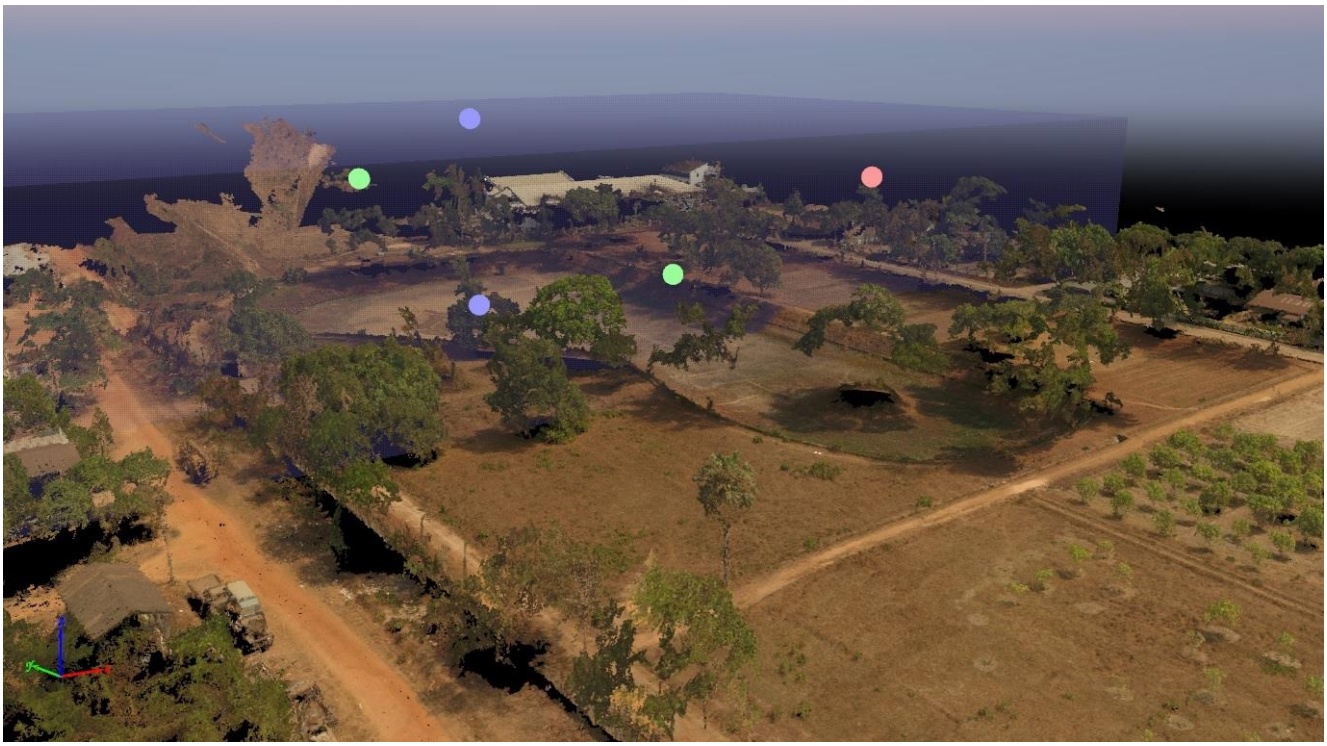

Figure 15: Finalized 3D model

3. OAKTHA GOLF CLUB RESERVOIR

Date	06-04-2017
Location	Bago, Oaktha Golf Club
Product	DSM of the ITC reservoir
Executed by	Bob Dubbel, Sai wunna, Ye Pyae Tun, Lin Lin

4.1 FLIGHT PLAN

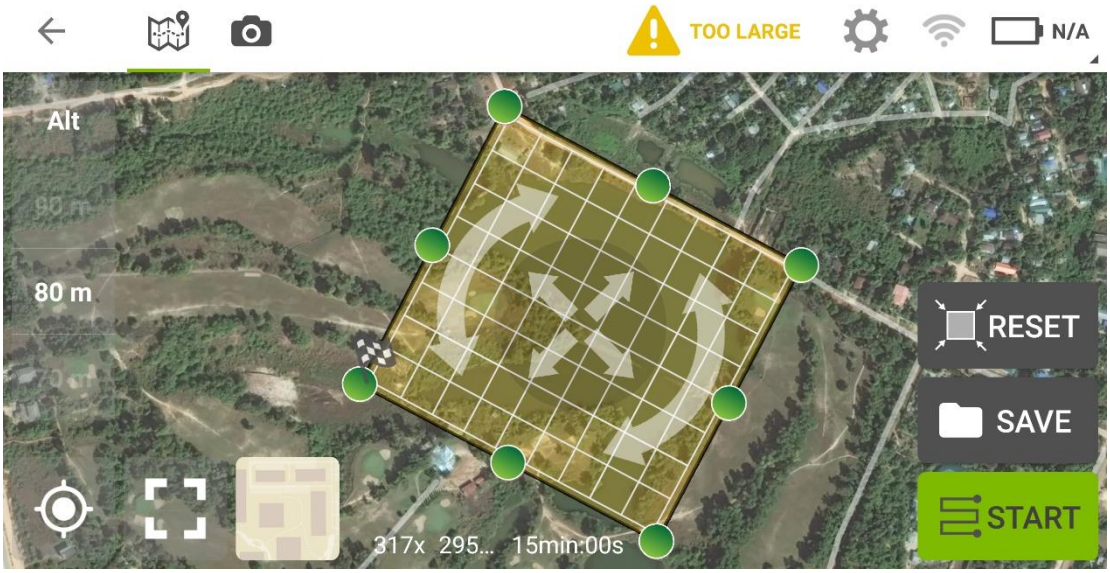

Figure 16: Flight plan Oaktha Golf Club reservoir

Mission type: Double grid mission
Altitude: 80m
Flight time 15:00 minutes
F-stop: f/2.8

4.2 LOCATION GCP'S

4 GCP's were placed around the reservoirs. Since the battery of the drone allows the grid to be just big enough to cover the entire reservoir, the GCP's were placed as close to the water surface as possible. The flight altitude had to be increased to 80m to be able to map all the corners of the reservoir. The 5th GCP was placed on the embankment, exactly in the middle of the reservoir.

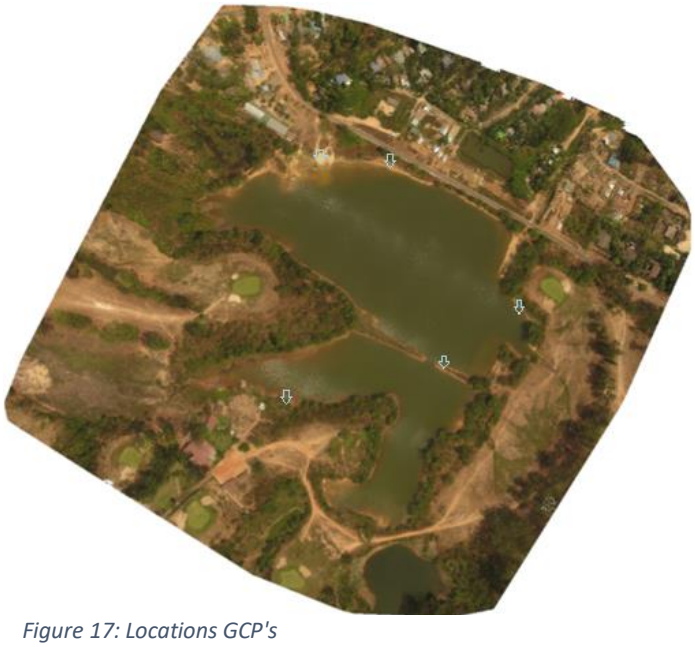

Figure 17: Locations GCP's

Figures 18 & 16: Placing GCP's

4.3 FINDINGS

The larger area of the reservoir results in a much larger dataset. Even though the flight height has been increased, the dataset still contains 416 images, which is 120 images more than the first data set. The total area of the grid is 0,1km^2 or 10ha. With this flight height, this is the maximum area that could be mapped in one flight with the drone due to the maximum range of the remote control.

A first DSM has been obtained, the quality of the DSM will increase after adding the GCP's but the first results determine that the dataset is usable and no malfunctions are present.

Figure 20: Processing images.

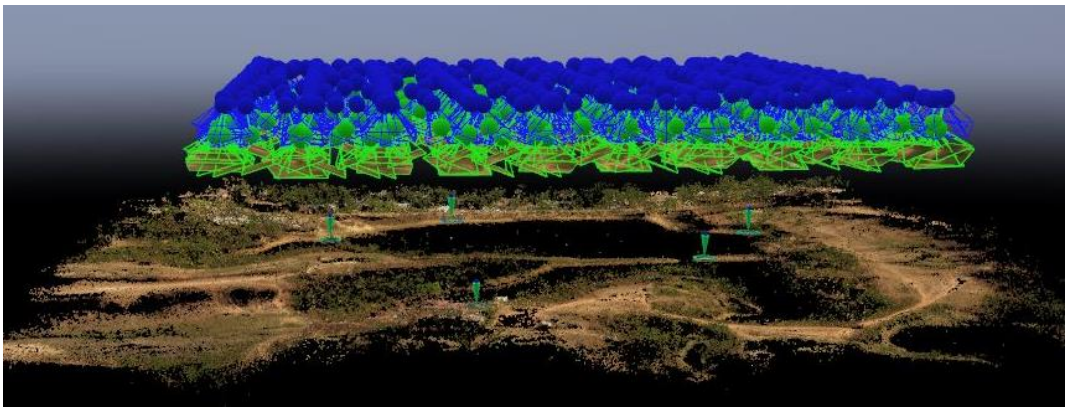

Figure 21: First DSM results

4. FISH POND

Date	25-04-2017
Location	Bago, Bago Fish nursery
Product	Datasets for several reservoirs & Fishfinder dataset
Executed by	Bob Dubbel, Sai wunna, Leon Brok

5.1 FLIGHT PLAN

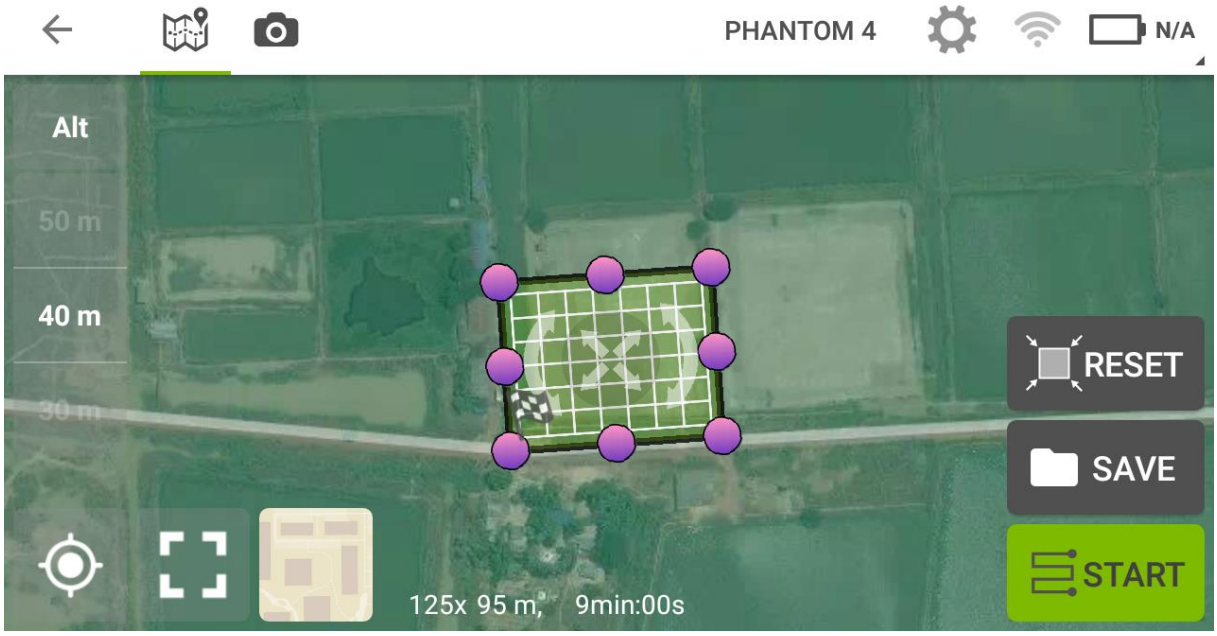

Figure 22: Flight plan 1

Figure 23: Flight plan 2

Two flights have been executed at the Bago fish nursery. The first flight focussed solely on the fish pond where the Fishfinder has been used that same day. The limited area of the pond allows the drone to flight at an altitude of only 40m and still be capable to make a full double grid, resulting in a very detailed dataset. The 5 GCP's have been placed around this pond in order to make a model as detailed as possible.

Mission type:	Double grid mission
Altitude:	40m
Flight time	9:00 minutes
F-stop:	f/2.8

The second drone flight covers a large area, containing 3 fishponds with different characteristics, including the first fishpond as well. The second flight has been executed for various reasons: First of all, the act of determining the specific locations of the GCP's is by far the most time-consuming part of the act of obtaining datasets. No GCP's have been placed around the ponds, which theoretically should make it possible to create DSM's but with a lower accuracy. The dataset will be used as a test model to determine whether or not accurate volume calculations can be obtained without the use of GCP's.

Mission type:	Double grid mission
Altitude:	70m
Flight time	15:00 minutes
F-stop:	f/2.8

5.3 LOCATION GCP'S

At the time of the measurement, unfortunately the Differential GPS device was in use by a different department of the ministry of irrigation. The GCP´s have been placed prior to flying the drone, but the locations have been determined 4 days later by the ITC staff itself.

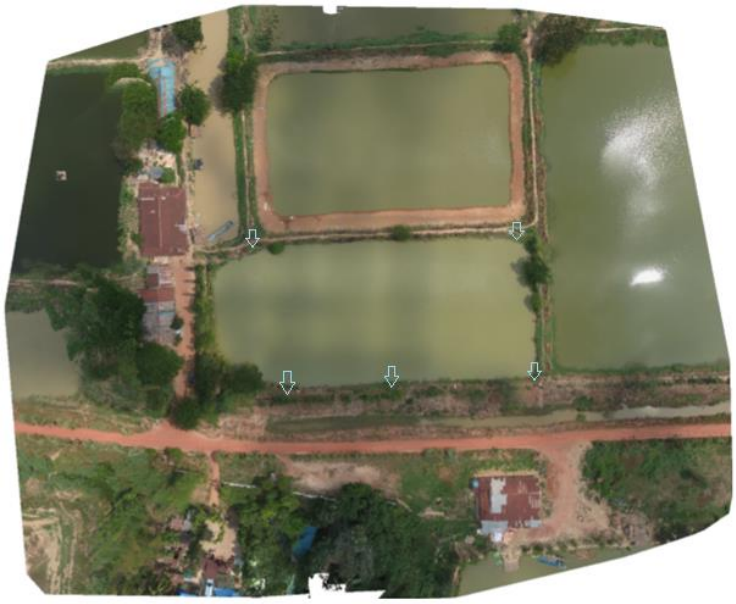

Figure 24: Locations of the GCP's

Figures 26 & 23: Placing GCP's

5. USING THE FISHFINDER

Date	13-04-2017 & 25-04-2017
Location	ITC & Bago Fish Nursery
Product	Fishfinder dataset
Executed by	Bob Dubbel and Leon Brok

By using the Fishfinder in one of the reservoirs that is also mapped with the drone, a complete model showing the total storage capacity in the reservoir could be created. This could be the solution for measuring storage capacities of reservoirs that contain water all year around for the ITC.

6.1 CRAFTING THE FRAME

In order to use the Fishfinder, first a frame had to be crafted. This frame has to be attachable to several types of boats, since at the time of crafting it was uncertain what kind of boat would be used at the fishponds. Ideally, the sonar device should be placed around 30cm under the water surface. In previous testing done with the FIshfinder in Ghana, a modified pallet was used. The design of this frame is used as an example.

Figure 27: process of crafting frame

6.2 GAINING DATA

At location, a boat and a boatman have been arranged and the sonar device was attached to the frame on the desired height. The Garmin device was set on obtaining both sonar images as depth point measurements, gaining data every second. A square spiral was chosen as ideal sailing plan to craft a grid of data, rather than sailing in a grid due to the length of the boat.

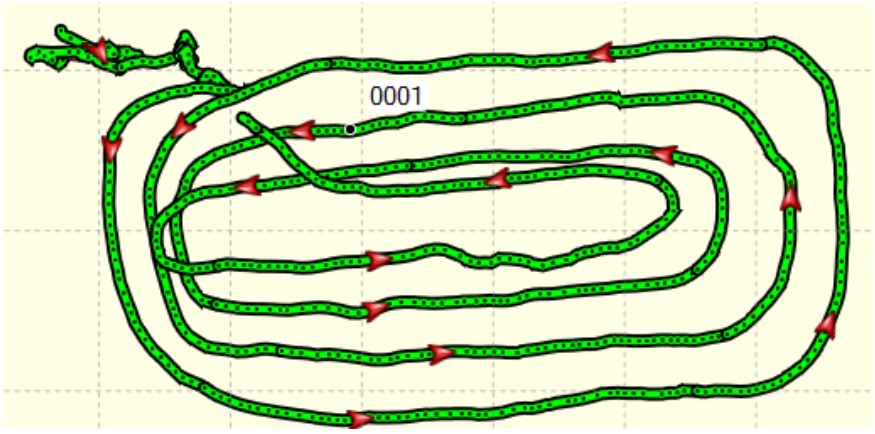

Figure 28: Dataset Fishfinder

Since the measurement was executed in a fishpond, the depth measurements could have been wrongfully influenced due to fish swimming underneath the sonar device. Therefore, the Garmin was set on taking a measurement every second so that flawed data could be easily detected and removed from the grid. This has resulted into an immense amount of measurement points. Most of the points will be deleted in Homeport (next page), prior to exporting the dataset to a different software. This way a clear grid can be generated of only the necessary points. Since the transducer was positioned underneath the water surface, 34cm had to be added to every measurement in Excel.

Figure 30: Example of Frame used in Ghana

Figure 29: Frame used in Myanmar

Figures 32 & 29: Using Fishfinder at the Bago Fish Nursery

6.3 PROCESSING DATA

This paragraph does not contain information on the act of data collection, but is written as a brief manual on how the obtained data from the Fishfinder is processed in the research. The results are written in the chapter ´results´ of the main document.

Homeport
In order to view the obtained data, the free-to-download software program homeport needs to be installed on a computer. With the MicroSD card , the data can then be transferred into the program, which allows the user to view and process the results. The following instructions are given by HKV:

The program Homeport is used to view the saved data from the Garmin.

It is a free software that can be downloaded via the link below:
http://www8.garmin.com/support/download_details.jsp?id=7263

After gaining the data, the user has to save all data from the Garmin on the SDCard. The Garmin creates two foldersd: ÚserData' and 'Son ar Recordings'. In the folder ÚserData',, ADM files are stored. The ADM file with the highest value is the most recently saved file.

>Download the program Homeport
>Open Homeport
>Go to *File* > *New* > *List folder*. To create a new map
>Select the folder you wish to placet he data into
>Go to *File* > *Import into* 'name folder'…
>Select the most recent .ADM file
>Scroll down in the colom left at the bottom fort he most recent log
>Double click to view data
>Select the log you want to export
>Go to *File* > *Export* > *Export Selection…*
>Save the file as .csv or .txt in order to work with it in Excel or QGIS.

The data can either be transferred to an Excel file and then to QGIS, or be transferred to QGIS directly. Since the dataset needs to be checked and adapted, Excel needs to be used.

G4

	A	B	C	D	E
1	ID	trksegID	lat	lon	depth
2	535	1	17''246870510280 13	96''476217890158 29	0.806474685668945
3	536	1	17''246869252994 65	96''476220404729 24	0.853914260864258
4	537	1	17''246868414804 33	96''476221913471 81	0.782754898071289
5	538	1	17''246868414804 33	96''476221913471 81	0.806474685668945
6	539	1	17''246867408975 95	96''476223841309 54	0.877634048461914
7	540	1	17''246867073699 83	96''476225098595 02	0.90135383605957
8	541	1	17''246866654604 67	96''476226355880 49	0.948793411254883
9	542	1	17''246865984052 42	96''476227696985 00	0.925073623657227
10	543	1	17''246865062043 07	96''476228954270 48	0.972515106201172

Figure 33: Data in Excel

The data is checked and flaw data has been removed. The following errors can occur in the dataset:

- Depth point measurements (DPM's) do not contain a depth value. This occurs when the device has started taking measurements, whilst the transducer has not been placed underneath the water surface yet, since sonar waves cannot be transmitted through air.

- DPM's are unreliable since the measurement has been taken at the time that people were still entering the boat, causing the boat to swing.

- DPS's are influenced by fish swimming underneath the boat, giving a significantly lower value than the DPM's taken directly before or after.

After removing all the flaw measurements from the dataset, the number of DPM's decreased significantly, as can be seen on the images below.

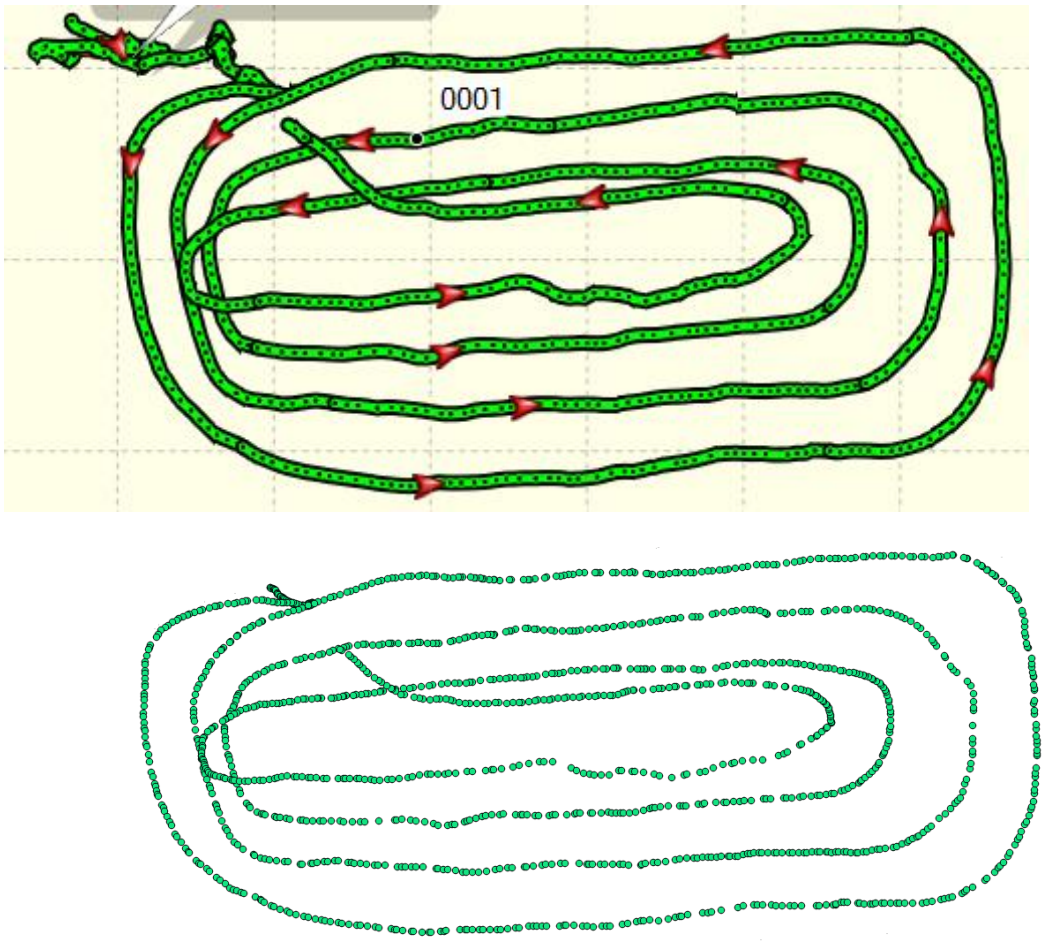

Figure 35 & 35: DPM's in Homeport and QGIS

QGIS

After saving the Excel file, the dataset can be inserted into QGIS by clicking *insert text delimited layer*

With the function *zonal statistics*, the average value of every pixel in the interpolated grid can be found. To do this, first a polygon has to be drawn around the layer. Then, by clicking *raster > zonal statistics* the interpolated raster layer and the drawn vector layer can be chosen from the menu. In the tab *statistics to be calculated*, all the values that need to be calculated can be checked. After clicking the *OK* button, the program calculates all the selected values.

APPENDIX G: MAPPING THE MA ZIN RESERVOIR

DOCUMENT CONTAINING ALL PRACTICAL STEPS AND ACTIONS IN THE PROCESS OF DATA RETRIEVAL

Version	2.1
Date	04-04-2017
Location	Bago
Author	Bob Dubbel

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1. ABSTRACT

None of the outcomes of the research state that mapping the Ma Zin Reservoir would not be possible. Yet, there are some uncertainties which can only be tackled by testing it in the field. Therefore, the Ma Zin Reservoir was chosen as test pilot. The reservoir lays very close to the ITC so visits to the reservoir would take a maximum travel time of just 15 minutes. This appendix contains instructions which are carried out to the ITC for how the volume calculation best could be done, if decided to do so in the future. Three methods are described: Using only the drone, using only the Fishfinder and using both drone and Fishfinder. The pros and cons of each of these methods are described as well.

2. USING ONLY THE DRONE

Even without using the Fishfinder, mapping the reservoir solely by drone could still be beneficial for the ITC. When the reservoir is mapped on the very end of the dry season, when the water inside the reservoir reaches its lowest possible point, the amount of water stored on top of that can be calculated by the drone. Since the outlet of the reservoir is positioned above the reservoir's bed, the amount of water underneath this water level is irrelevant.

Since the Pix4D program is able to calculate the volumes of the reservoirs without pixels being present on the water surface, the volume calculation should be possible when mapping just the edges of the reservoir. This greatly reduces the necessary amount of drone flights and thus the time needed for mapping the reservoir. It also tackles the connectivity problems which might occur when flying the drone in the middle of the reservoir. The different datasets can be collected one at the time and later be inserted as one project into Pix4D.

With the Pix4D capture application, several flight plans have been modelled to determine the necessary amount of flights. On the figures that can be found on the next page, the flight plans can be seen.

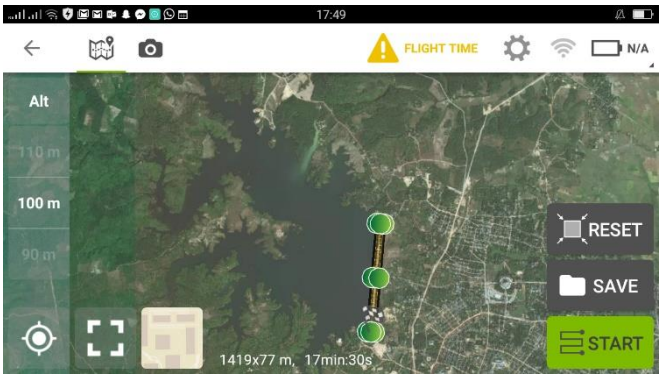
2.1 FLIGHT PLANS

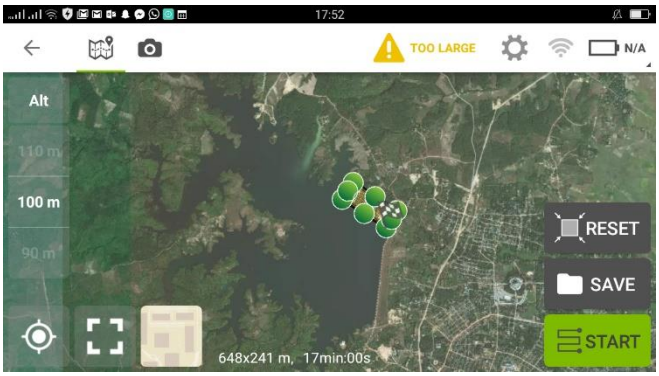
Double grid mission
A total amount of 16 flights should be sufficient to map the edges of the reservoir, a maximum flight time of 17 minutes is then maintained at all time. Some flights will however take slightly shorter. Given the fact that the ITC possesses two batteries, two flights can be executed per visit; meaning that 8 visits must be paid to the Ma Zin Reservoir. All flights need to be executed at the same flight height, if done so, all the figures can be collected on a computer and then be imported into the program at once. A flight height of 100m is maintained at all flights, as this is low enough to perform volume calculation s with the shortest necessary flight time. Specifications of the flight plans can be found on the next two pages.

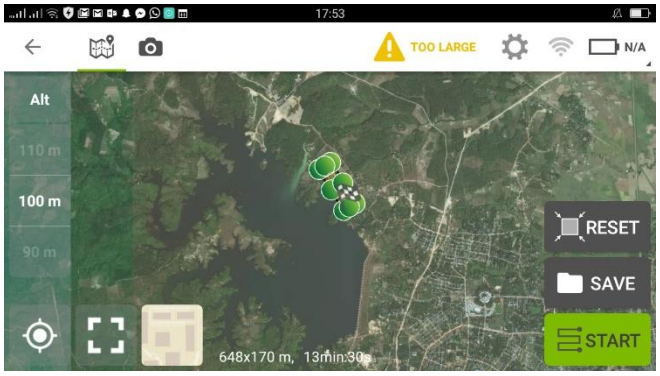
Notes
The maximum flight time of the battery is taken into account. However, the maximum area of the grid is also limited by the maximum possible distance between drone and remote control whilst maintaining a connection. Therefore, at all times, a strategic location for the person controlling the drone need to be chosen. Favorably, in the middle of the grid. Also, the water level inside the reservoir may not change between the gaining of different datasets.

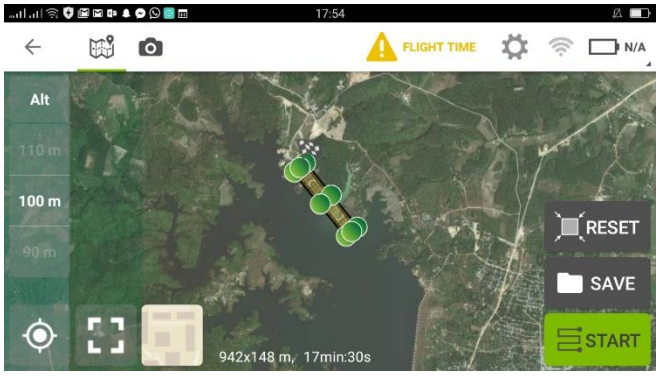
Even when the program will react to the reservoir exactly like it did to the test reservoirs and when no problems are occurring considering the fact that only the edges of the reservoirs are mapped, the act of deleting all flaw pixels will take lots of time. According to the necessary time for deleting flaw data on the test pilots, the estimated amount of time needed for cleaning the whole project would take around 5 hours. No indication could be given on the necessary amount of time for processing the vast dataset, but it should be clear that it will rather be a matter of days than hours.

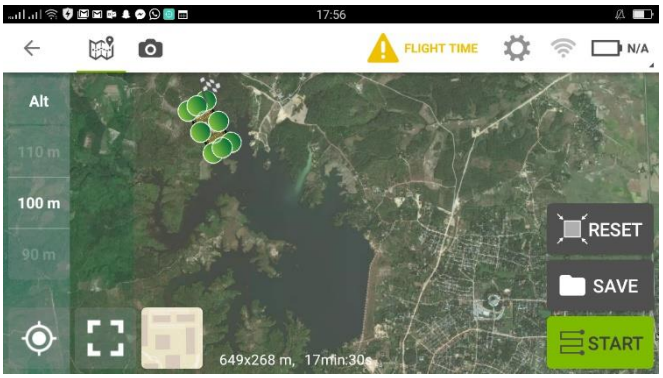
The polygon for the volume calculation needs to be drawn by hand. It should be clear that drawing a polygon around the edges of the entire reservoir, will not only be time consuming (estimated 3 hours), but also needs to be done very precisely. Clicking a point slightly higher or lower will have a huge effect on the calculated volume and two separately drawn polygons are very unlikely to calculate the exact same value. This is demonstrated in figure 2.

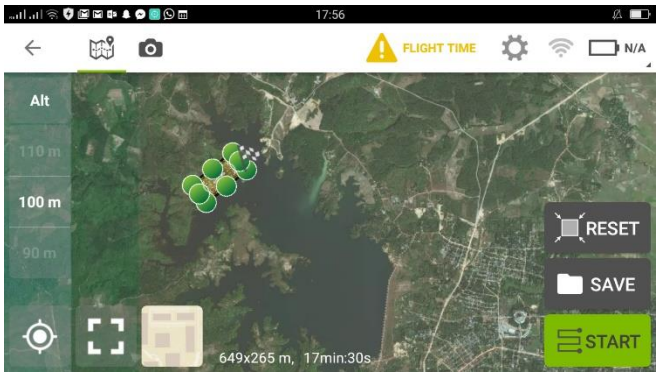

17:49
FLIGHT TIME
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
1419x77 m, 17min:30s


17:52
TOO LARGE
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
648x241 m, 17min:00s


17:53
TOO LARGE
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
648x170 m, 13min:30s


17:54
FLIGHT TIME
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
942x148 m, 17min:30s


17:56
FLIGHT TIME
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
649x268 m, 17min:30s


17:56
FLIGHT TIME
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
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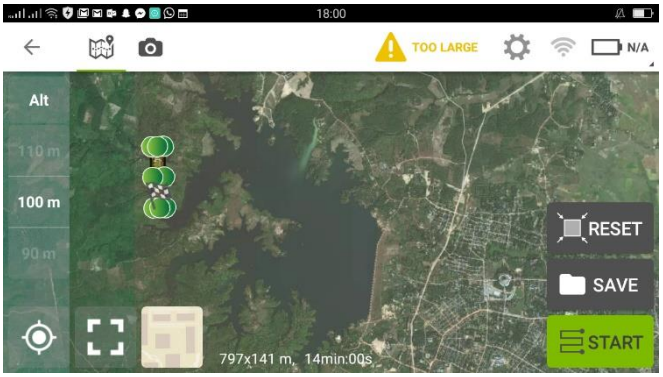
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N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
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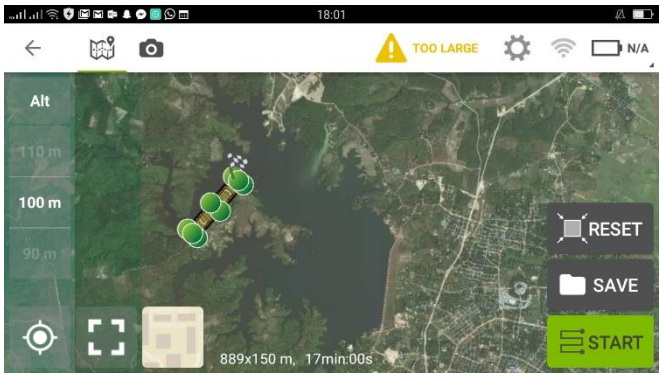
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TOO LARGE
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
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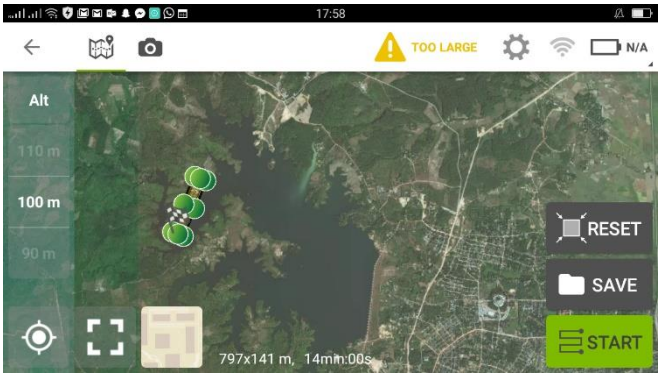
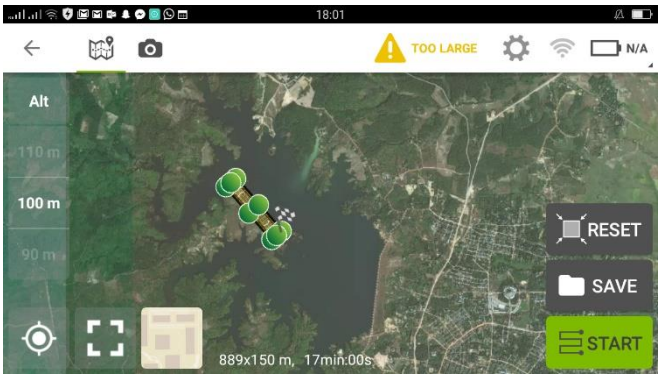
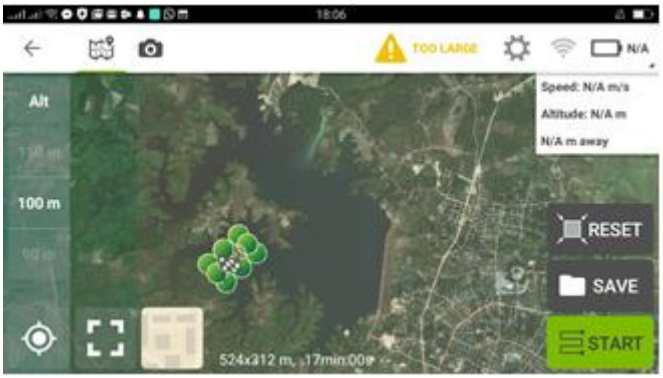
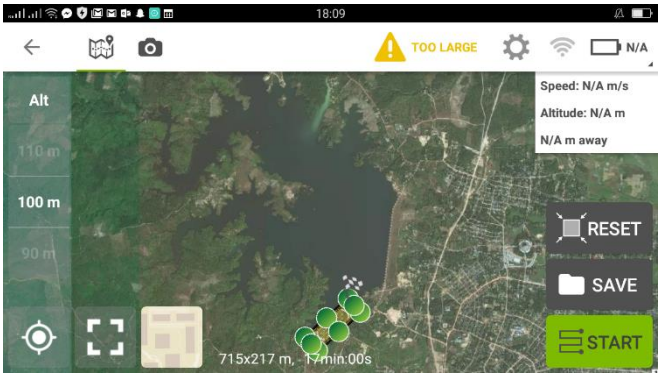
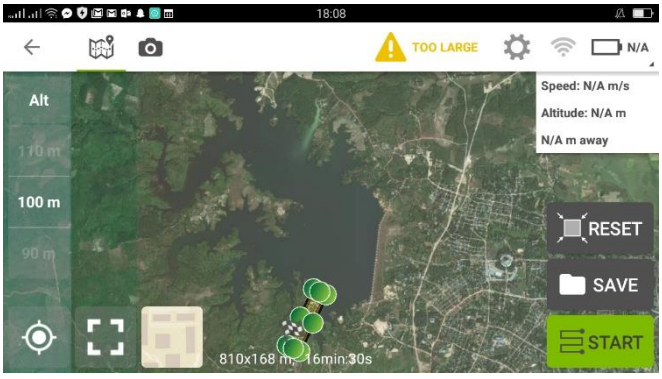
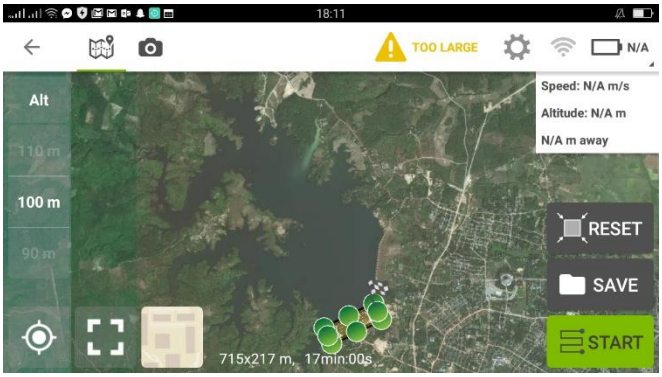












The images above represent the chosen flight plan made with the Pix4D capture application as is described in more detail in appendix F: Data collection. These grids combined, cover the entire border of the Ma Zin reservoir.

Single grid mission

In chapter 6.3: 'Further studies', the advantages of testing the accuracy of the volume calculation when flying a single grid mission, instead of a double grid, are described. Now, only 10 flights need to be executed, which could be done in 5 visits instead of the 8 visits necessary with the double grid mission.

This is not a huge reduction in the necessary visits. However, the number of figures that needs to be uploaded into Pix4D decreases drastically. It is estimated that a total number of 800 figures (10 flights * 40 corners * two sides of the grids) is enough to create a model in single grid mission. In comparison, a single double grid dataset, obtained above the ITC reservoir contained already 382 figures.

On the next page, the 10 necessary flight plans are shown, again maintaining a maximum flight time of 17 minutes and a flight height of 100m.

Estimated necessary time for this method:

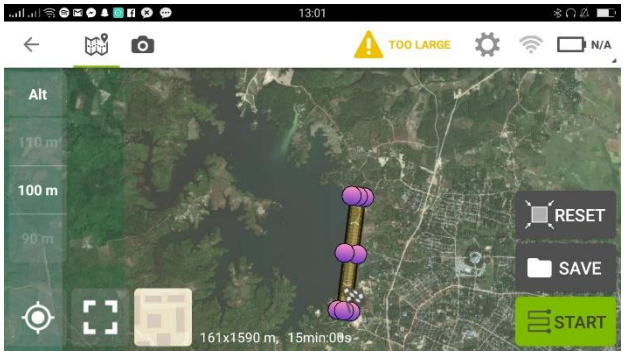
Table 1:Necessary time method 1

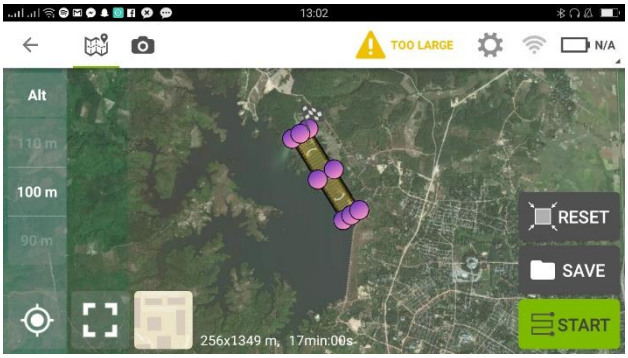
Method	**Time in field**				**Processing time (estimated)**		
Grid type	Visits to reservoir	Time per visit	Placing GCP's	Time in field	Processing time 3 steps	Deleting flaw pixels	Drawing polygon
Double	8	80 min	5	±16hrs	6 days	5 hrs	3 hrs
Single	5	80 min	5	±12hrs	2 days	5 hrs	3 hrs

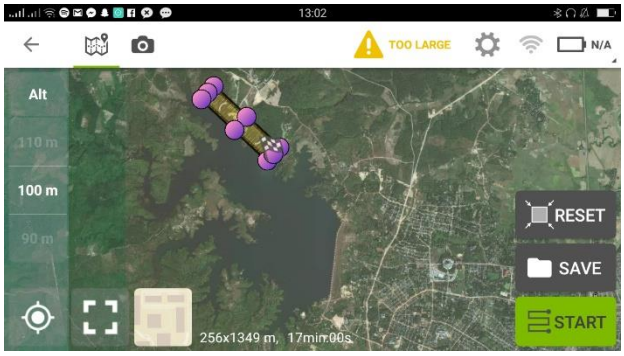
$$\text{Time per visit} = (2 \text{ x att}) + (2 \text{ x ft})$$
$$\text{att} = \text{avarage travel time to grid location}$$
$$\text{ft} = \text{flight time}$$

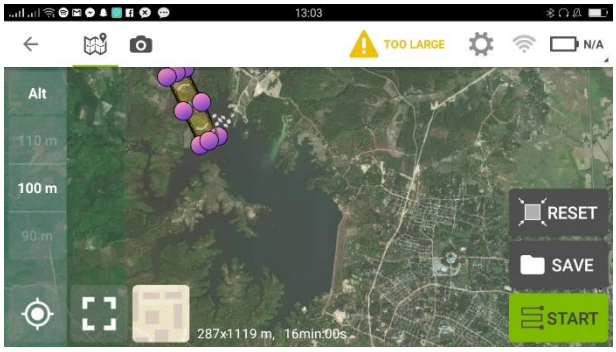
The average travel time from the ITC to the center of the grid, is estimated on 25minutes on average.
The methods consider 10 GCP's being placed around the whole reservoir and is estimated to take 5 hours. Not every dataset needs to contain a GCP since the figures are added together. The flight time of every grid is 17 minutes at maximum, some a little bit shorter. 15 minutes are considered in the equation.

The processing times in the table are roughly estimated and cannot be considered reliable by the ITC. The table should only be used as an indication for the necessary time for all the different steps in the process. No total necessary time is given, since it is up to the employees of the ITC themselves to decide how tight they want the schedule to be. The necessary total time strongly depends on the amount of visits the staff pays to the reservoir per day, this can be on, two or three.


13:01
TOO LARGE
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
161x1590 m, 15min:00s


13:02
TOO LARGE
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
256x1349 m, 17min:00s


13:02
TOO LARGE
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
256x1349 m, 17min:00s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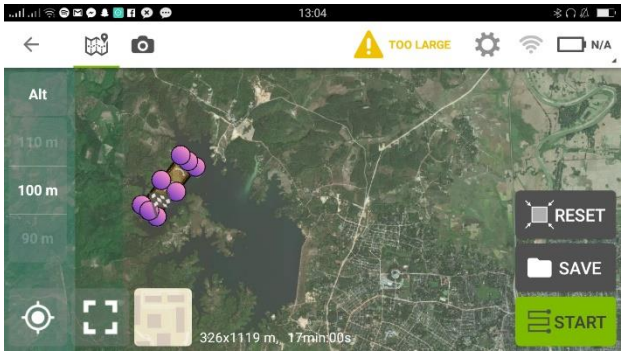
TOO LARGE
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
287x1119 m, 16min:00s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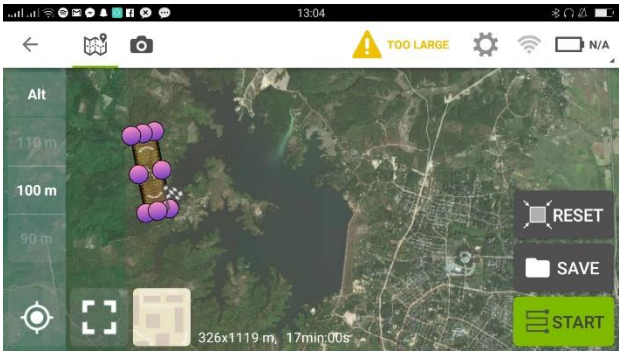
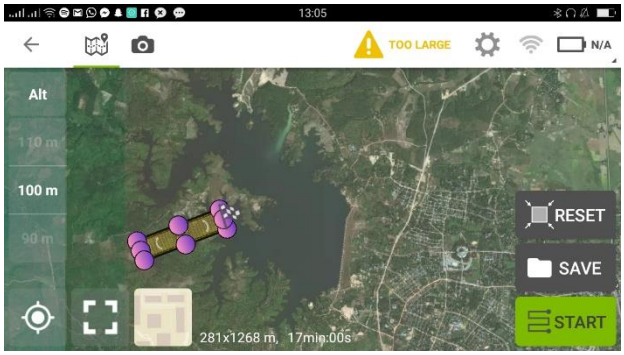
TOO LARGE
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
326x1119 m, 17min:00s


13:04
TOO LARGE
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
326x1119 m, 17min:00s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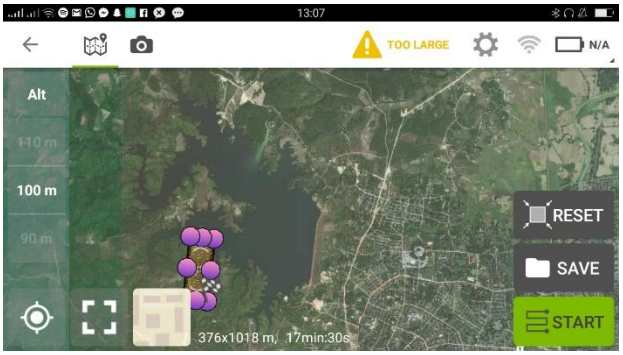
TOO LARGE
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
281x1268 m, 17min:00s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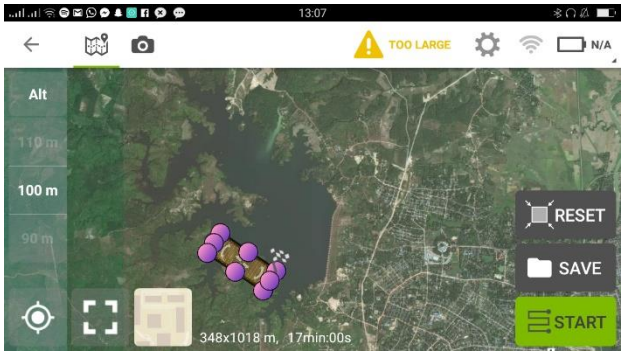
TOO LARGE
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
376x1018 m, 17min:30s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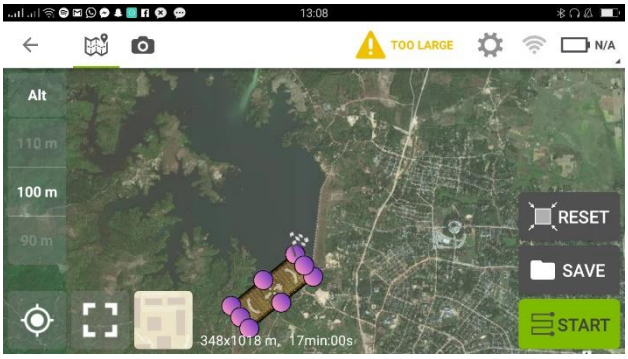
TOO LARGE
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
348x1018 m, 17min:00s


13:08
TOO LARGE
N/A
Alt
110 m
100 m
90 m
RESET
SAVE
START
348x1018 m, 17min:00s

3. USING ONLY THE FISHFINDER

Instead of mapping the Ma Zin reservoir when the water level reaches its lowest, the Fishfinder can be used to calculate the volume when the water level reaches its highest point. Depending on how accurate the ITC wants the volume calculation to be, the staff can choose a sailing route with a very dense or a less dense grid. Figure 1 shows the minimal accuracy of a grid. The total length of this proposed grid is 41km, sailing this grid is expected to take roughly 7 hours. Table 2 shows that all the processes required for determining the water volume with this grid, can be executed in just one day of work.

This grid will interpolate depth point measurements over a maximum distance of 100m. If sedimentation occurs equally over the reservoir bed, this should give a good estimation. If silt particles tend to cluster or sink at specific places in the reservoir, a more detailed grid is necessary. Since all measurements are geotagged, as many trips can be made to the reservoir as the ITC ought to be necessary. This can be spread over separated days, given that the water level does not change.

The biggest disadvantage of this method, is that it will be very difficult to sail the boat close to the border of the reservoir. In the fishpond, depth points with a value of 0m were manually added to the model on the edges of the reservoir in QGIS. This will be much more complicated on the Ma Zin reservoir. These points can be added by placing the depth point measurements over a Google earth figure, but an orthomosaic of the reservoir will give more accurate results. Besides that, the program will interpolate a straight line between the manually added 0-points and the most nearby measurement from the Fishfinder from those points, making it an imprecise calculation. This is demonstrated in figure 3.

Table 2: Necessary time method 2

Method	**Time in field**			**Processing time (estimated)**		
Grid type	Visits to reservoir	Time per visit	Time in field	Homeport & excel	QGIS	calculation
Single	1	7 hrs	8 hrs	2 hrs	2 hr	1 hr
Double	2	7 hrs	16 hrs	3 hrs	2 hr	1 hr

On the figure below, a proposed route to sail the boat is drawn. With an average velocity of 5km/h, it will take roughly 7 hours to map the reservoir this way. The edges of the reservoir need to be filled in with a depth of 0m in QGIS. This grid covers 90% of the total area of the Ma Zin reservoir, if assumed that the sedimentation inside the reservoir takes place gradually over the reservoir bed, this grid should give a volume with an accuracy of about 80%.

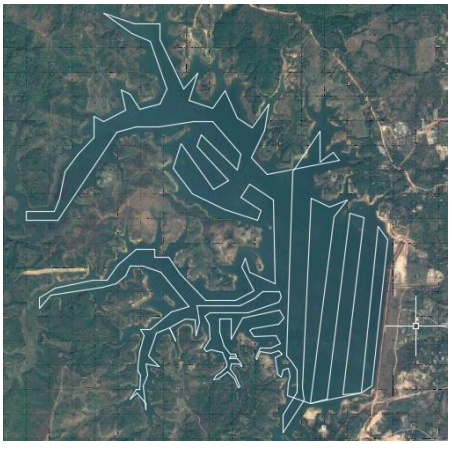


Figure 1: Sail route proposal for a minimum detailed grid

4. USING BOTH DRONE AND FISHFINDER

This method is most likely to give the most accurate results as is demonstrated on figures 2, 3 and 4. This is also the only method that gives a value of the full storage capacity of the reservoir.

If the water level reaches its lowest point, the total surface area of the reservoir is at its smallest. This decreases the necessary time to sail a dense grid. As can be seen on figure 1, the shape of the reservoir makes it difficult to sail around the entire edges. When the water is at its lowest, the reservoir is likely to have a more circular shape. The best sailing route is to sail a full circle as close to the edge of the reservoir as possible and then sail in a grid over the total surface. Placing this grid on top of the orthomosaic in QGIS, will show a clear border between water and land.

The absolute maximum storage capacity could thus be calculated. If the water level reaches below the outlet, the model can be used to calculate the effects of lowering the outlet. On the other hand, with the QGIS model, the effects, of lifting the overflow can be calculated.

Another advantage of this method, above just using the drone, is that it can be calculated how much water needs to be filled inside of the reservoir before the water level reaches the lowest outlet.

Table 3 & 4: necessary time method 3

Time in field			**Processing time (estimated)**		
Visits to reservoir	Time per visit	Time in field	Homeport & excel	QGIS	calculation
1	7 hrs	8 hrs	2 hrs	2 hr	1 hr

Time in field				**Processing time (estimated)**		
Visits to reservoir	Time per visit	Placing GCP's	Time in field	Processing time 3 steps	Deleting flaw pixels	Drawing polygon
5	80 min	5	±12hrs	2 days	5 hrs	3 hrs

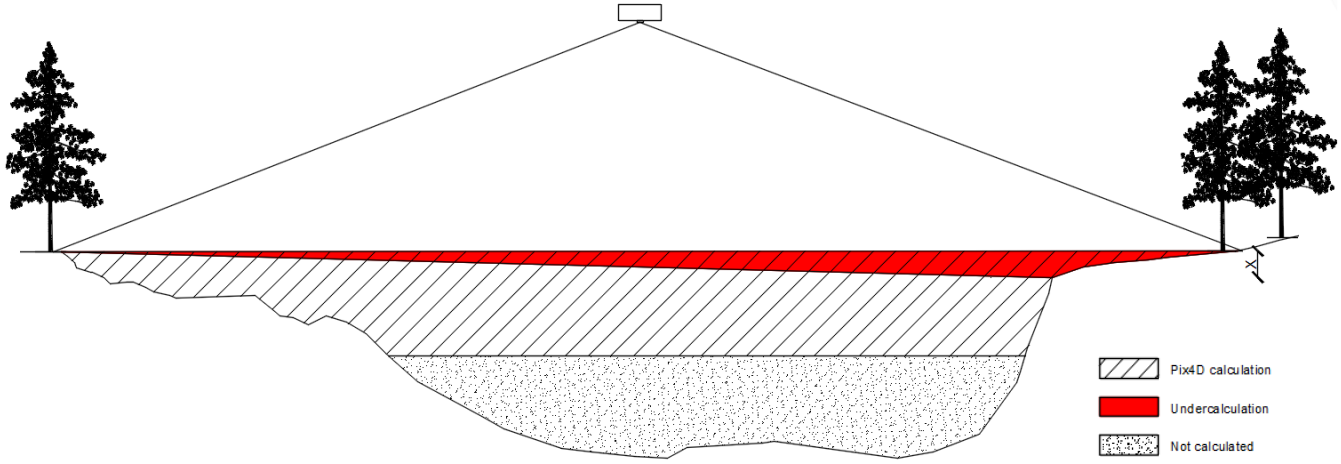


Figure 2: Impression of the accuracy of the first method

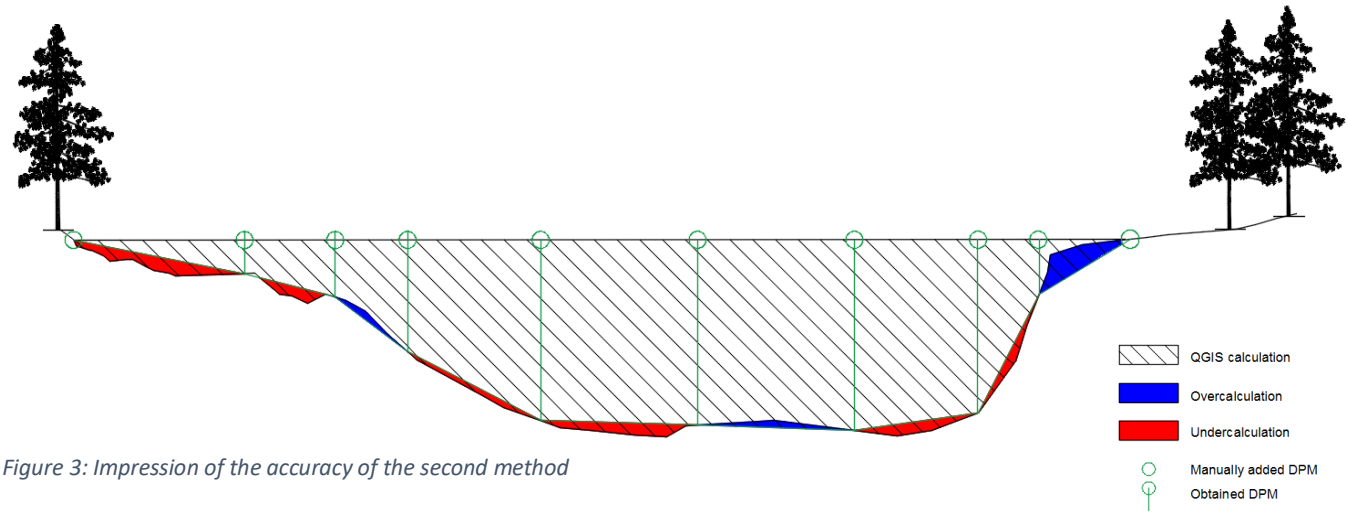


Figure 3: Impression of the accuracy of the second method

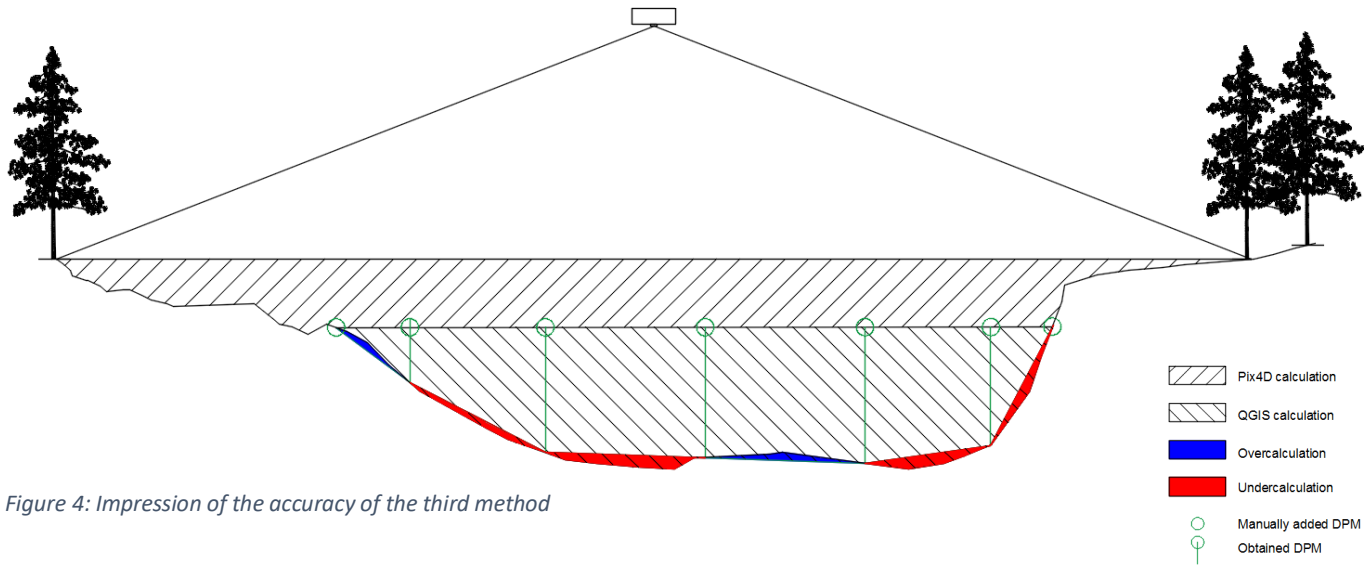


Figure 4: Impression of the accuracy of the third method

APPENDIX H: MEASURING THE BAGO RIVER BATHYMETRY

FIELD TRIP REPORT - 28-04-2017

Version	1.1
Date	01-05-2017
Location	Bago, Myanmar
Author	Leon Brok

Adjustments from previous version(s):

- …
- …

CLIENTS:

TU Delft

- Dr. Ir. Martine Rutten
  Assistant Professor Water Management
- Ir. Marjan Kreijns
  Head of Project Management Department at Valorisation Centre

Rotterdam University of Applied sciences

- Ir. E. Schaap
- Ir. W. Kuppen

VP Delta SME's and start-ups

CONTENTS

1. INTRODUCTION

This field report describes the activities carried out on 28-4-2017 concerning taking depth measurements of the Bago River. The core purpose of these activities are to retrieve data gathered by the Fish Finder by HKV Lijn In Water and compare the results with those of conventional techniques used for depth and bathymetry measurements in Myanmar. A secondary, more global goal of the field trip was to gather some additional knowledge of the Bago River in general. Retrieving information about the Bago River could contribute to understanding and solving the sedimentation related problems in the river.

The measurements were carried out at two different locations in the Bago River. Staff from the Hydrology Branch of the Ministry Of Agriculture, Livestock and Irrigation (MOALI) were present.

Date:	*28-04-2017*	
Participators:	*Ms. Khin Si Si Hlaing*	*Engineer Hydrology Branch, MOALI*
	Mr. Nyein Chan Aung	*Engineer Hydrology Branch, MOALI*
	Aung Myat Lin	*Engineer Hydrology Branch, MOALI*
	Bob Dubbel	*Rotterdam University Bachelor graduation student*
	Leon Brok	*Rotterdam University Bachelor graduation student*

Three other staff members of the Hydrology Branch were present at testing the equipment of both locations. Two boat drivers were also present, one at each location where the measurements took place.

IMAGE 1: PARTICIPANTS OF THE FIELD TRIP, EXCLUDING 2 MORE HYDROLOGY BRANCH STAFF MEMBERS

2. LOCATIONS

This chapter described the two location at which the bathymetry of the river was measured during the field trip.

LOCATION A: BAGO TOWN – WOODEN BRIDGE

The first location where the bathymetry of the Bago River has been measured is in the centre of Bago Town. It is located next to the old wooden bridge, which is used for pedestrians and light traffic to cross the Bago River. The MOALI Hydrology Branch has already been measuring the bathymetry, flow discharges, flow distribution and more important hydraulic parameters of the Bago River at this location for years.

GPS coordinates: *Latitude:* *17.3354*
Longitude: *96.4785*

IMAGE 3: LOCATION A - THE WOODEN BRIDGE IN BAGO TOWN.

IMAGE 2: LOCATION A (BLUE LINE) WITH THE YANGON-MANDALAY HIGHWAY CROSSING THE BAGO RIVER 200 METRES TO THE SOUTH

LOCATION B: TAWA SLUICE GATE

The second location (location B) lies 15 kilometres south of the first location and is located downstream from location A. The Tawa sluice and lock gate, which connect the Bago River with the Bago-Sittaung canal, are located a few hundred metres from location B. **More recently than at location A, the Hydrology branch has been measuring depths, flow discharge and flow distribution at Location B.**

GPS coordinates: *Latitude:* *17.3354*
Longitude: *96.4785*

IMAGE 5: LOCATION B

IMAGE 4: LOCATION B (BLUE LINE) WITH THE TAWA SLUICE AND LOCK GATES SITUATED TO THE EAST AND NORTH

3. MATERIAL

All material used during the field trip are described in the following chapter. The name and the purpose of the material is described, if needed supported by images.

MEASURING EQUIPMENT

Sontek M9 RiverSurveyor

The Sontek M9 RiverSurveyor is, together with the Sontek S5, the instrument with which the Hydrology branch measures important hydraulic parameters with in Myanmar. The M9 is a very accurate and valuable piece of equipment. The M9 measures the following hydraulic parameters:

- Depth
  The Sontek M9 automatically generates cross sections of the river's profile from depth measurements.
- Flow discharge/velocity
- Flow distribution
- Water temperature
- Exact location using GPS

The M9 is used by putting it on a hard plastic floating unit, and pushing or towing it with a boat. The M9 needs several times up and down the width of the river to generate an accurate image of the measured parameters.

IMAGE 6: USING THE SONTEK M9 AT LOCATION B

IMAGE 7: THE SONTEK M9 AND ITS FLOATING CONSTRUCTION

Hondex PS-7 LCD Digital Sounder

The Hondex PS-7 is a simple so called echo-sounder, used for measuring depths at single-point locations. It has a simple manual: the PS-7 must be put slightly under water, after this a button is pressed. The PS-7 sends out a single echo signal, and the depth of that location is displayed on the small LCD display. When a new measurement is carried out, there is no data whatsoever being saved on the device. The Hondex PS-7 was provided by the Hydrology Branch.

IMAGE 8: THE HONDEX PS-7 LCD DIGITAL SOUNDER

Garmin ECHOmap 42DV Fishfinder

The Garmin Fishfinder is a device originally used for detecting fish under water. It can also be used to measure depths (point measurements) and translate these depths to (river) cross sections. The Fishfinder also has an echo function, which gives a detailed image of how the river bedding (and other solid objects reflecting the echo, like fish or garbage) looks. The Garmin ECHOmap 42DV Fishfinder measures the following (hydraulic) parameters:

- Water depth
  Measured at a set frequency, max 1 Hz.
- Water temperature
- Exact location using GPS
- Echo imagery of the river bedding

The point depth measurements of the Fishfinder have to be manually translated to cross sections using a GIS programme.

The Fishfinder exists of a chartplotter and a transducer, which are connected with a cable. The transducer measures the actual parameters, while the chartplotter processes, displays and saves the results. The chartplotters' LCD display can be used to change various settings. A battery is needed to power the chartplotter, without it the chartplotter will not work.

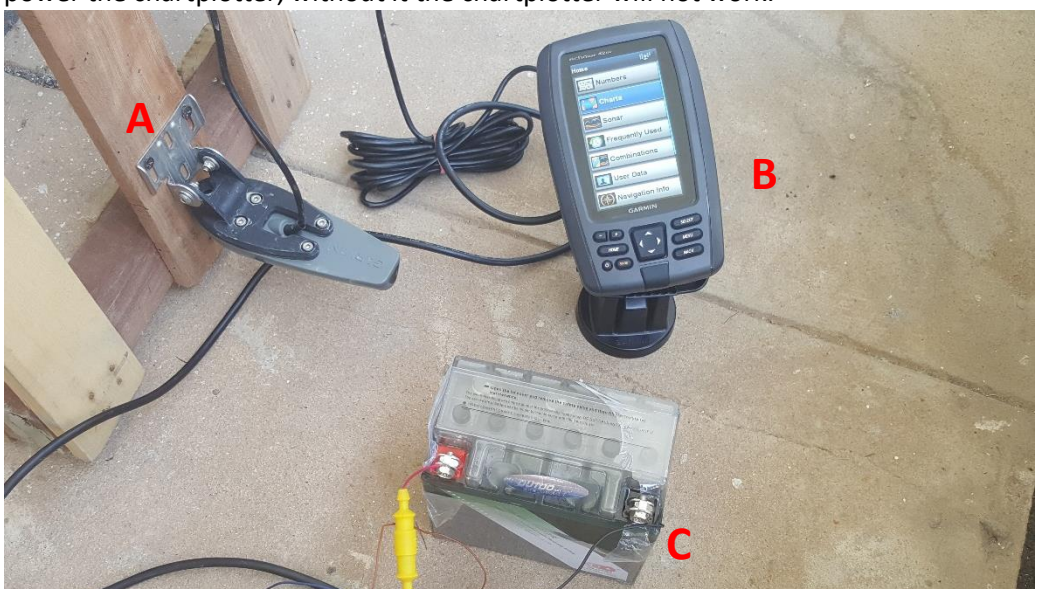


IMAGE 9: THE FISHFINDER'S TRANSDUCER (A), CHARTPLOTTER (B) AND BATTERY (C, NOT INCLUDED)

SJCAM SJ4000

The SJCAM SJ4000 is a small HD camera that is generally supplied with a shock- and waterfree plastic case. During the 28-4 field trip, the SJCAM was used to get an idea of the bed shape of the Bago River. The SJCAM was attached to the end of a long stick, which was brought to the bedding of the river several times in order to catch a glimpse of the shape of the bedding. The case of the SJCAM was attached to the stick by tie-wraps

The SJCAM films in HD (1080p) and a memory card must be inserted in order to save the videos and fotos made.

IMAGE 12: SJCAM SJ4000 IN THE WATER- AND SHOCK FREE CASE, ATTACHED TO THE STICK

OTHER

Boat

A boat being capable of holding at least 3 full-grown people at the same time is needed to use all previously described measuring equipment. The boat's maximum distance between the water level and boat side may nog exceed 1 meter, at greater distances manually handling the measuring equipment becomes hard or impossible.

IMAGE 10: THE BOAT USED AT LOCATION A

IMAGE 11: THE BOAT USED AT LOCATION B

Car

A car was provided by the Hydrology Branch to transport all personnel and equipment. Especially the Sontek equipment could not be transported by hand, as it is kept in a large suitcase.

Wooden pallet

A modified wooden pallet was used to attach the Fishfinder's transducer to. It was important that the pallet had some weight in order to keep the transducer stable during measuring. The pallet had a wooden bar sticking out in order to let the pallet rest on the boat's side. The draught of the pallet (distance between water line and transducer) must be noted and measured after using it.

IMAGE 13: USING THE FISHFINDER AT THE MODIFIED PALLET AT LOCATION A

Wooden stick

A wooden stick was used to attach the SJCAM to. The stick was about 1.80 meters long and attached to the camera's case with tie-wraps

Laptop

A laptop is needed at the location during measuring to fully complete the settings and calibrating the Sontek M9 equipment. The laptop is connected with the Sontek M9 via a Bluetooth connection.

IMAGE 14: THE MODIFIED PALLET WITH THE FISHFINDER'S TRANSDUCER ATTACHED

Battery

As described before, a battery is needed to provide power for the Garmin Fishfinder. The battery used during the field trip is a 12V9Ah/10Hour rechargeable motorcycle sealed lead battery.

Memory card

Micro-SD memory cards are used to save and transfer data from both the Fishfinder as the SJCAM.

Plastic bags

Two plastic bags were used to take and transport soil samples of both location A and B.

4. ACTIVITIES

This chapter describes the activities carried out on the field trip at both locations. All important aspects of using, handling and processing results **at the site** are described. The different measuring equipment have different needed activities, so the activities are step by step described, structured per measuring technique.

Sontek M9 RiverSurveyor

- Unpacking and setting up the measuring device with the floating unit
- Preparing the program on the laptop. Calibrating the device with the program.
- Move up and down the river 4 times with the device floating next to the boat, being held manually by staff. The device could also be attached to the boat.
- Instantly checking results on laptop and saving them.
- Dismantling and repacking the equipment

Garmin ECHOmap 42DV Fishfinder

- Connecting the battery to the chartplotter and the chartplotter to the transducer. Protect the battery against water by putting it in a closed plastic bag.
- Rest the modified pallet on the side of the boat and hold the pallet stable. This is done by one person (Bob). The other person (Leon) holds the chartplotter and battery, and takes care of the settings of the chart plotter.
- Move up and down the width of the river 2 times. The Fishfinder is constantly measuring and saving the depth of the river and location of the measuring point, as well as the echo visuals.
- After leaving the boat, measure the distance between the water line (visible on the wet wooden pallet) and the transducer.
- Transfer all data from the chartplotter's memory to the SD-card.
- Disconnecting the battery, chartplotter and transducer.

Hondex PS-7 LCD Digital Sounder

- While measuring with the Fishfinder, measure the depth using the Hondex PS-7 and noting it down on paper, while at the same time noting down the depth displayed on the Fishfinder's chartplotter.

SJCAM SJ4000

- While measuring with the Fishfinder or Sontek M9 and sailing through shallow waters (less than the length of the stick the SJCAM is attached to), put the stick in the water until the side with the camera attached to it reaches the river bedding.

APPENDIX I: ANALYSIS GHANA REPORT

DOCUMENT CONTAINING THE MOST IMPORTANT CONCLUSIONS FROM THE 2015 GHANA REPORT ON THE FISHFINDER

Version	1.0
Date	30-03-2017
Location	Bago
Author	Bob Dubbel

CLIENTS:

TU Delft

- Dr. Ir. Martine Rutten
  Assistant Professor Water Management
- Ir. Marjan Kreijns
  Head of Project Management Department at Valorisation Centre

Rotterdam University of Applied sciences

- Ir. E. Schaap
- Ir. W. Kuppen

ABSTRACT

In October 2015, students Tom Arnold Bik and Jesse van der Heide from the Rotterdam university of applied sciences, tested the Fishfinder for their internship in name of HKV Lijn in water in Ghana. These were the first tests done with the Fishfinder out of the Netherlands. The conclusions from this research are of great value of the thesis. The students carried out an advice to HKV on the best way of using the Fishfinder based on tests in the field.

The report of the research has been requested for at HKV and has been analyst thoroughly. The conclusions from this report were considered when using the Fishfinder in the field. A brief summary of the outcomes of this research is given in this document.

CONTENTS

1. RESEARCH

In Ghana, the students have conducted different experiments with the Fishfinder. The main goal was to determine the best way for using the device and test the accuracy of the measurements.

1.1 RESEARCHED ASPECTS

The following aspects to the Fishfinder have been tested:

- Accuracy when attached next to the boat
- Accuracy when toad on a raft behind the boat
- Effect of a small gradient in the boat
- Effect of turbulence and sail velocity
- Accuracy of the GPS

1.2 RESEARCH METHOD

Accuracy next to the boat:
For this first test, a frame was crafted from a wooden pallet. This frame was attached to the side of the boat with the transducer attached underneath it. Several measurements were taken at different water depths, both stationary and in movement. The measurements were compared and an accuracy graph was created.

Accuracy when toad behind a raft:
The transducer was now attached behind the boat on a raft made from two jerrycans.

Effect of a small gradient in the boat:
When attached to the side of the boat, a small angle between the Fishfinder and the bed level could influence the measurements. Several measurements were taken to determine the effect of a small, a bigger and a very big angle between the boat and the water surface. The angles were created by moving the boat with their body weight.

Effect of turbulence and sail velocity:
Water turbulence around the transducer created by the water current or the sail velocity could influence the measurements. In this experiment the fishfinder was tested in a river with a flow velocity of 2m/s and with a sail velocity of 5km/h.

Accuracy of the GPS:
The river was mapped with a DJI Phantom 3 drone and a mosaic stitched model was created based on this imagery. The boat with the Fishfinder attached to it then sailed as close to the sore as possible. The GPS route of the depth point measurements was then placed on top of the drone imagery model to determine the accuracy.

1.3 RESEARCH CONCLUSIONS

Accuracy when attached next to the boat

TEST NR.	*MEASUREMENT STICK (M)*	*FISH FINDER((M)*	*ACCURACY (M)*
1	2.10	2.14	0.04
2	0.93	0.91	0.02
3	1.23	1.23	0.00
4	2.41	2.36	0.05
5	2.22	2.20	0.02
6	2.01	2.05	0.04
7	0.77	0.79	0.02
8	0.61	0.61	0.00
9	1.05	1.08	0.03
10	3.03	3.07	0.04
11	2.86	2.89	0.03
12	2.15	2.17	0.02
13	0.86	0.86	0.00
14	0.54	0.56	0.02
15	0.91	0.92	0.01

These tests give the EchoMAP™ 42dv an accuracy value of:

- $0.34 \div 15 = 0.023\ meters\ accurate.$

Accuracy when toad on a raft behind the boat

TEST NR.	*BOAT (M)*	*RAFT (M)*	*ACCURACY (M)*
1	2.10	2.02	0.08
2	3.12	3.14	0.02
3	1.06	1.14	0.08
4	0.92	1.01	0.09
5	1.77	1.86	0.09
6	1.82	1.93	0.11
7	1.32	1.39	0.07
8	1.19	1.23	0.12

These outcomes give the EchoMAP™ 42dv in this test an accuracy of:

- $0.66 \div 8 = 0.083\ meters\ accurate.$

Effect of a small gradient in the boat

TEST NR.	*ANGLE (BIG/SMALL)*	*VERTICAL (M)*	*IN ANGLE (M)*	*ACCURACY (M)*
1	Small	1.68	1.79	0.11
2	Small	1.53	1.61	0.18
3	Small	1.94	2.08	0.14
4	Small	1.78	1.86	0.12
5	Big	1.22	1.41	0.19
6	Big	1.35	1.56	0.21
7	Big	1.66	No data	X
8	Big	1.75	1.98	0.23
9	Big	1.64	1.83	0.19

These outcomes make it very clear that stability of the boat is a really important matter when a reading is taken. The accuracy is very low as shown below:

- Small: $0.55 \div 4 = 0.138\ meters\ accurate.$
- Big: $0.82 \div 4 = 0.205\ meters\ accurate.$

Effect of turbulence and sail velocity

TEST NR.	*MEASUREMENT STICK (M)*	*FISH FINDER (M)*	*ACCURACY (M)*
1	4.22	4.28	0.06
2	3.98	4.02	0.04
3	3.51	3.47	0.04
4	3.67	3.70	0.03
5	3.24	3.20	0.04
6	4.06	4.09	0.03
7	2.93	1.91	0.02
8	3.09	3.14	0.05

According to these results the conclusion can be made that turbulence up till 1.2m/s does not have too much effect on the data. Garmin ensures that the EchoMAP™ 42dv keeps working properly up to a speed of 6.7m/s. This couldn't be tested because of the strength of the construction.
The average accuracy at 1.2m/s is:

- $0.31 \div 8 = 0.039\ meters\ accurate.$

Accuracy of the GPS

´´The conclusion can be made that the Gps of the EchoMAP™ 42dv is accurate enough when both the Gps of the EchoMAP™ 42dv and the Gps of the DJI phantom 3 are compared. Eventually, they may not give the exact location on the earth, but for intern research that doesn't matter. ´´

1.4 CONCLUSIONS FOR OWN RESEARCH

When applying the Fishfinder, a similar frame will be used as the pallet frame used in Ghana. Not too much attention will be payed to the sail velocity of the boat, but lots of effort will be put into keeping the boat as stable as possible.

APPENDIX J: INTERVIEWS HELD RELEVANT FOR THE THESIS

DOCUMENT CONTAINING ALL INTERVIEWS WHICH HAVE RESULTED IN- OR CONTRIBUTED TO THE RESEARCH QUESTIONS, METHODS AND OUTCOMES

Version	1.0
Date	04-04-2017
Location	Bago
Author	Bob Dubbel

CLIENTS:

TU Delft

- Dr. Ir. Martine Rutten
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Rotterdam University of Applied sciences

- Ir. E. Schaap
- Ir. W. Kuppen

CONTENTS

INTERVIEW REPORT 1

Interviewee:	Myint Soe
Company:	Ministry of Agriculture Livestock and Irrigation
Function:	Assistant Director
Interviewers:	Bob Dubbel Dennis Neleman Leon Brok
Others present:	Ye Htut Min
Date:	28/02/2017
Location:	Ministry of Agriculture Livestock and Irrigation, Bago region
Subject:	Data collection of the Bago-Sittaung basin

1.	Question by interviewers:	Is there a more recent version of the annual flood map and is it possible to receive this one? The map we received from Nay Myo lin is outdated and he requested a newer version.
	Response by Interviewee:	Mr Myint Soe does not have the most recent map. It may be available at the Meteorological Department.
	Action by:	Interviewers
	Action:	Get contact information of the Meteorological Department and ask them.
	Result:	Went to mr. Sai to ask for the contact information. In Myanmar it is not usual to e-mail about information, this has to be done by an official request by letter. We agreed it would be better if Nay Myolin
2.	Question by interviewers:	We have heard about Japanese students conducting a similar research in the area. What do you know about this?
	Response by Interviewee:	There are Japanese students from the YTU True. Japanese students from the YTU (Yangon Technical University) are making a model of the Bago Basin.
	Action by:	
	Action:	

INTERVIEW REPORT 2

Interviewee:	Martine Rutten
Company:	TU Delft
Function:	Assistant Professor
Interviewers:	Bob Dubbel Dennis Neleman Leon Brok
Others present:	Tara van Iersel
Date:	01/03/17
Location:	Irrigation Technology Center, Bago
Subject:	1. Data collection 2. Most recent flood map 3. Case possibilities 4. Project proposal 5. Remaining

1.1	By interviewers:	Description about the actions taken so far (interview local office 28/02/17 Myint soe), uncertainties (known information vs required information) and the further approach of creating a kind of pilot map with the sluice gates to show the offices our intentions.
	By Interviewee:	Requested information about (some) reservoirs might be unnecessary, duplication has to be avoided. Suggested to create a table of the structures on the "Flood protection works in Bago, Waw, Thanatpinnkawa townships" and their specifications. Notify what information already can be found in the TU-Database and what cannot, so Nay Myolin can point to which specific data he needs from which specific structure. Creating a pilot map is a good thing to do.
	Action by:	Interviewers
	Action:	Map sluice gates as review, create a table as stated above, E-mail Nay Myolin with the table and request information at Myint Soe, local office Bago.
	Result:	

2.1	By interviewers:	Most recent flood map was not available, how to deal with this?
	By Interviewee:	In 2015 a flood occurred, SARvision made a flood map based on satellite images. It is not possible to see what areas flooded on purpose or by accident. Go to the local office with this map to ask them to draw the flooded areas by hand as well as possible. This map has been created by Shelly Win, a master student from the Yangon University. There are several possible ways and existing techniques that could be used to determine a flood map using remote sensing. Aqua Monitoring: A remote sensing technique developed by Deltares which uses satellite images and a set of mathematical equations to provide information on land use with an accuracy of 30m x30m. the aqua monitoring engine is free to use. This technique can be used to map morphological changes, not floods. Landsat technologies is the longest running satellite photography program in the world. The satellite takes images of landscapes with high frequency on which changes in landscape can be detected. The images are not able to penetrate through clouds, which are abundant in the rainy season. To cover this up, the software of Landsat uses different parts of different images to create one clear map. Sentinel is a different kind of satellite technology in which radar waves are used to scan the landscape. Therefore, clouds are not visible on the images. SARvision has created a flood map based on these images which could contribute to the research.
	Action by:	Interviewee and Interviewers
	Action:	Interviewee: Requesting/sending the flood map of SARvision/Shelly Win. Interviewers: Visiting the local office to lie down the question if they can draw the flooded areas on a map. When the SARvision map is for hand, both maps will be compared with each other in order to find out which areas are flooded on purpose and to update the flood map. Look into the possibilities for using aqua monitoring within the research.
	Result:	
3.1	By interviewers:	A case possibility discussed in an interview with Mr. Myint Soe at 28/02/2017 is the salt intrusion. The government is planning to create embankment with sluice gates to prevent sea water intrusion in the dry seasons.
	By interviewee:	Due this measure the fresh/salt grade changes drastically, which could lead to lumps of clay following into sedimentation and dredging cost. Subsidence could be an issue here as well, the land gets drained but

		not flooded with sediment regularly. Perhaps that the research of Teije van der Horst could contribute to examine and monitor this. How is the salt intrusion measured at this moment and how to react to this new problem could be one of the cases. Menno de Ridder did a research to this area which could be helpful if there will be focussed on this case. Another case could be to set up a system to measure the water depths of inundated areas. This is requested by the director of the ITC, Mr. Zaw Min Htut, personally. A combination of the fish-finder, remote sensing (by the drone of the ITC) and the equipment of Tara van Iersel could contribute to this case. Ways of how using the technology of SHORE and mobile water management could contribute within this case should be examined A third case could be the mapping of the bathymetry of a reservoir with sedimentation problems. In this case the fish-finder might be useful. A case study could focus on the differences in results between the fishfinder and current method. This option has to be discussed with the Taungo office.
	Action by:	-
	Result:	Possible cases

4.1	By interviewee:	Reviewed the project proposal so far, suggested to add more about the backgrounds, previous researches and refer to those. Explain what already has been done and what is still missing. Explain the relevance to the community and the professional branch. Based on this a goal can be formed, which leads to questions, activities and products.
	Action by:	Interviewers
	Action:	Edit project proposal, based on the above
	Result:	

5.1	**Discussion/ideas:**	Try to transit knowledge and working methods to staff of the local offices, so they can reproduce/continue this working method once this research ends. Visit the Taungo office as well, once it is more clear what Nay Myolin exactly needs. Use the same approach/list of questions. If changed, document what changed and why, to make the research imitable.

INTERVIEW REPORT 3

Interviewee:	Mr. Zaw Min Htut
Company:	ITC
Function:	Director
Interviewer:	Bob Dubbel
Others present:	Sai Wunna Ye Htut Min (staff officer)
Date:	20/03/2017
Location:	ITC director's office
Subject:	Using drone for creating DEM's

1. Meeting dialog

Bob	I want to fly the drone over a reservoir, then I want to use software to make a DEM and calculate the amount of water that could be stored on top of the available water surface. Would this kind of data be valuable to the ITC?
Zaw:	The ITC regulates the amount of water that is released out of the reservoirs constantly during the dry seasons. To know how much water is exactly stored inside of the reservoir would be very useful in order to give regulate the water as efficient as possible.
Bob	The advantage that I have, is that I will be in Myanmar the entire dry season, when the water in the reservoirs reaches its lowest level. A DEM could be created in which the storage capacity on top of that could be calculated. Then in the rainy season, you would know how much water has been stored on top of that. The drone can however not determine bathometry under water.
Zaw:	This would already be valuable to the ITC, still it would be preferable to obtain a full model of the reservoir.
Bob	Why?
Zaw:	Due to sedimentation occurring in the reservoirs, we are not sure how deep the reservoirs are. Right now, when regulating the water, we have to take uncertainties into account. Exact knowledge on the amount of water in the reservoirs would allow us to optimize the efficiency of our drainage activities.

	Bob	What have the employees of the ITC learned so far about drone techniques?
	Sai:	Today the GIS course has come to an end. The last 20 days we have learned to process drone imagery and make a map of the ITC.
	Bob	I have done research into the different available software to retrieve DEM's using drone imagery. It appears that there are many different companies. Which software have you learned during the course?
	Sai:	We have learned to work with PIX4D, during the course, also Arc GIS and Agisoft fotoscan have been used.
	Zaw:	The course lecturer has given me a list in which he compared the PIX4D software with Agisoft. Althoug PIX 4D is twice as expensive as Agisoft, the advantages of PIX4D seem to way up to those of AGIsoft. The ITC is thinking about purchasing the software.
	Bob	think that there is a lot of software available which can be used for the same purposes, but are much cheaper. If I could show other software to be working, which are much cheaper than PIX4D, could I change your mind?
	Zaw:	My employees have already learned to work with PIX4D, the PIX4D is a onetime purchase which is expensive, but the ITC can make this purchase. We are still curious to other programs if you can show that they work for the foreseen cause.
	Sai:	This afternoon we can fly the drone together over the ITC and I can show you how to gain imagery.
4.	Actions:	
	Bob and Sai:	Fly the drone together for first testing.
	Bob:	Analyse different types of software.
		Analyse opportunities for measuring the reservoirs under water.

INTERVIEW REPORT 4

Interviewee:	Mr. Zaw Min Htut
Company:	ITC
Function:	Director
Interviewer:	Bob Dubbel
Others present:	-
Date:	22/03/2017
Location:	ITC director's office
Subject:	Using drone for creating DEM's

1. Meeting dialog

Bob:	I've thought about a plan for modelling the reservoirs, both above and underneath the water surface. I want to test if it is possible and if so, describe the methodology and write a manual for the ITC employees which they could use for determining storage capacities of reservoirs in the future. *hands over brief plan description*
Zaw:	I don't think you can use the Leikpaya reservoir. The water in the reservoir is used as drinking water for the Bago city residents. To sail a small boat inside of the reservoir, first permission from the Bago council needs to be obtained. I don't think I can help you with gaining this permission.
Bob:	Do you know another reservoir close to Bago which is not too big to use as a pilot, but also still contains enough water in it?
Zaw:	15km down the Yangon-Mandalay highway there is the Shwefyi reservoir. It is a small reservoir which contains water. You could fly the drone from a nearby bridge.
Bob:	If I find a different reservoir which meets the dements of this study, do you think it would be valuable for the ITC in the future? Do you have any tips or recommendations for executing this pilot?
Zaw:	It will be very useful for the ITC. You can ask Sai and other employees within the ITC for assistant. The PIX4D software

2. Actions

Bob:	Investigate the possibilities for using a different reservoir.

INTERVIEW REPORT 5

Interviewee:	Ir. Khon Ra Dr. Ir. Aung Than Oo
Institution	Ministry of Agriculture, Livestock and Irrigation Hydrology Branch
Function:	Director Assistant Director
Interviewers:	Dennis Neleman Leon Brok Bob Dubbel Tara van Iersel
Others present:	Multiple staff members of the hydrology branch
Date:	24-03-201
Location:	Ministry of Agriculture Livestock and Irrigation, Hydrology Branch office in Yangon. Thitsar Road, Kanbe
Subject:	Data retrieval Monitoring information

1.1	By interviewers:	General explanation of goals here in Myanmar. Explain shared stakes in data retrieval for Ir. Nay Myo Lin. In what way could the Hydrology Branch help us with the following: Recent flood inundation map (DEM map would also be useful to combine with existing flood danger maps from MIMU), more data about existing flood related infrastructure (Canal sections, river sections).
	By interviewee:	The Hydrology branch could help with data concerning river sections, as they measure this multiple times a year. Canal sections are available at regional offices. A flood inundation map was made by Dr. Aung Than Oo but this map has to be validated. Bob, Leon and Dennis could play a role in validation and verification of this map by interviewing local experts in Bago and at the ITC. Ir. Kohn Ra also insisted on narrowing our project boundaries down to a smaller area, so the area on the *'Flood Protection Works in Bago, Waw, Thanatpin and Kawa Townships'* map was presented as our boundaries, instead of the entire Bago-Sittaung river basin.
	Action by:	Hydrology Branch
	Action:	Provide river cross sections Provide flood inundation map for validation
	Result:	

2.1	By interviewers:	Explanation of Leon's plan for a case study. Using the Fishfinder to measure the bathymetry of the Bago river and comparing the results with results from existing measuring techniques. Leon would like as much existing information and data from current techniques and measurements: Current monitoring techniques, frequencies, locations, proposed measuring locations. Also Leon would like to learn more about the sedimentation problem, where it is occurring and if it could be combined with the Fishfinder case study. Thirdly, does the Hydrology Branch have a recommendation of a location in the Bago River where the depth exceeds 10 meter (in the dry season) for testing out the Fishfinder in large depths?
	By interviewee:	This idea goes well with the needs of the Hydrology Branch. Multiple times a year (sometimes 10+, depending on the available budget) the bathymetry of the Bago river is measured at only one location, but there is no standardized system of measuring moments as the equipment used is often needed at other locations. Dr. Aung Too is interested in testing out the Fishfinder. Existing data and information about the current monitoring system will be shared. The sedimentation problem is a problem of which little is known about. It is recommended that the testing of the Fishfinder goes first, and optionally a study about the sedimentation problem can be carried out. There are no places in the Bago River where the water depth exceeds 10 meter. There could be a reservoir with depths higher than 10 meter: Nga Moe Yeik Reservoir. The Fishfinder could be tested here, while using a depth sounder to verify results of the Fishfinder. Specifications of the reservoir could be retrieved at the ITC or at the Bago Regional Office. There could be water depths exceeding 10 meter in the Sittaung river as well.
	Action by:	Hydrology Branch
	Action:	Provide data and info of monitoring of the Bago River and Sittaung river.
	Action by:	Leon, Bob and Dennis.
	Action:	Get to know more about the Nga Moe Yeik reservoir.
	Result:	
3.1	By interviewers:	Explanation of Bob's idea of his case study. The goal of this study is to gain data on storage capacities in reservoirs. For the ITC, it is of great value to know exactly how much water is stored inside of the reservoirs. Due to sedimentation, only rough estimations can be made on the total volume of water. Then ITC is now not capable of regulating the water very efficiently. Making use of drone techniques and the Fishfinder, for this study we want to set up a methodology for mapping the reservoirs in the future. A pilot reservoir is needed to

		test the techniques. This reservoir has to meet the following demands: - The reservoir may not be too big (about the size of a football field). - There needs to be at least 1,5m water inside of the reservoir. - It must be possible to sail a small boat inside the reservoir. In the Bago area several reservoirs have already been analysed, but unfortunately, none of them meets all these requirements. Our question is if you know of a reservoir in the Yangon region which would meet these demands?
	By interviewee:	In the North of Yangon, just above the airport, there is a series of small reservoirs which might still contain water. (reservoirs are shown on google maps)
	Action by:	Bob
	Action:	Find out if the reservoirs contain the required amount of water and if it is possible to bring a boat to the area.
	Result:	
4.1	By interviewers:	Explanation of Dennis' idea of his case study to try and find a solution to open the Tawa Lock Gate during the wet season. Asked to the availability of information about; - Water levels in the Bago-Sittaung Canal, Bago River and Irrawady River. - Discharge of the dams upstream - DEM map of the area - Rainfall information
	By interviewee:	Interesting and important topic. Information available: - Water levels are available at local offices and can be requested and sent to the hydrology branch. - Monthly inflow and discharge of the dams is known and easily available. Suggested to work with daily information for this topic, this information has to be requested and sent to the hydrology branch. - DEM map should be findable at the internet. - Inflow of the dams is known.
	Action by:	Dennis
	Action:	Orientate about the problem and make a list of needed information. Afterwards inform the branch and request data.
	Result:	
5.1	By interviewers	Explanation of Tara's plans of measuring water levels at multiple locations in the region. Does the hydrology branch know any

		locations that need live water level monitoring data? Tara explained how her technique works and her progress so far.
	By interviewee	Hydrology branch brought forward multiple locations for measuring water levels.
	Action by:	Specified by Tara van Iersel.
	Action:	Specified by Tara van Iersel.
	Result	

INTERVIEW REPORT 6

Interviewee:	Martine Rutten Edwin Schaap
Institution	TU Delft Rotterdam University of Applied Sciences
Function:	Company supervisor University supervisor
Interviewers:	Dennis Neleman Leon Brok Bob Dubbel
Others present:	-
Date:	28/03/2017
Location:	Irrigation Technology Centre, Bago / Rotterdam University of Applied Sciences, G.J. De Jonghweg 4-6, Rotterdam
Subject:	Skype meeting about general project progress

1.1	By interviewers:	All: General progress about project is going well. The data retrieval phase for Ir. Nay Myo Liwn is almost finished, some last details must be validated by Mr. Myint Soe (local office Bago). We still need a DEM map of our project area, to create a flood inundation map for Nay, this is the last main problem we have with the data retrieval for Nay. So far no DEM maps have been found at it is very hard looking for those on the internet since ITC Wifi is very slow.
	By Interviewee:	Martine: I will get in contact with Afia Dim, who is probably in possession of the needed DEM maps.
	Action by:	Martine
	Action:	Get in contact with Afia Dim about the DEM map
	Result:	The DEM maps have been successfully received on 29-3-2017
2.1	By interviewers:	-
	By Interviewee:	Edwin: Bob, I am curious to what your case is. As far as I know, you want to use the drone to measure flood plains?
	By Interviewers:	Bob: That is not completely right. What I want to do is measure storage capacities in reservoirs, using the drone. The director of the ITC has made clear that the ITC has no good understanding of the amount of water inside reservoirs, at this point. The ITC regulates all the water that is let out of the reservoirs during the dry seasons for irrigation purposes. A better understanding of the amount of stored water could increase the irrigation efficiency. What I want to do for my case, is to calculate the volumes of 4 different reservoirs in the Bago area. Then I want to set up a

		methodology and write a manual that the employees of the ITC can use in the future for reservoir calculations. Tomorrow I will have a meeting with the director, then I will propose 4 reservoirs to him that I want to calculate. Some reservoirs in Myanmar never dry completely and will always contain some water. It is impossible to use the drone for volume calculations under water. That is why I also want to use the Fishfinder in my research. In one reservoir, I want to use the drone and the Fishfinder together to set up a whole model to calculate the total volume. The problem is that I am not sure if I am allowed to sail a boat in the reservoir I want to map with the drone. For my research, would it be possible to use the Fishfinder at a different reservoir and then hypothetically state that if it works, it could be used for my foreseen purposes? HKV has requested us to test the Fishfinder with a water depth of more than ten meter, I could combine this solution with their request. Since the Fishfinder is still in a test phase, I am aware that the results might be too inaccurate to use. For Leon's research, he will test the Fishfinder very thoroughly, comparing it with different sonar techniques as well. In my research, I will consider his findings in my own results.
	By interviewee:	Edwin: It is definitely possible to use the Fishfinder at a different location, as long as you prove that it works. About your research; I prefer quality over quantity. I would rather see you modelling one reservoir very detailed than 4 very messy. I propose you reduce your activities to scanning just one reservoir. Martine: When using the Fishfinder, keep in mind that the results are strongly dependent on the type of soil at the bottom of the reservoir. Keep that in mind when comparing your results with those of Leon.
	Action by:	Bob
	Action:	- Reconsidering the research method. - Add a ground sample research to the project. - Send finalized plan of action by email within two days
	Result:	
3.1	By interviewers:	Leon: Explanation of the personal case study. "I will be testing the Fishfinder on the Bago River with staff from the Hydrology Branch, comparing the Fishfinder with locally used equipment may create enthusiasm for the Fishfinder with local authorities. Next to a comparison of different measurement techniques, I would like to analyse the sedimentation problem in the Bago River. For this I would have to collect relevant data to create a model with (Question: What

		data/parameters are important to put in a model?). This would probably be a SOBEK model and I would like to create more clearness about the sedimentation problem, the causes and possible solutions as very little is known about it.
	By Interviewee:	Martine: The most important parameters, and data to collect, for your model will be: Cross sections, flow discharges/velocities, bed shapes, soil information. Soil information you will probably have to take care of yourself, so take monsters of the soil and use ITC equipment to measure the parameters (sieving the sand). Concerning the Fishfinder case: It would make the case study more interesting the more different types of equipment you could compare, so try to gather as many types as possible. Edwin & Martine both emphasized that the analysis of the sedimentation problem will always be a model that could only resemble the true situation. So try not to get lost in gathering too much data.
	Action by:	
	Action:	
	Result:	

INTERVIEW REPORT 7

Interviewee:	Mr. Zaw Min Htut
Company:	ITC
Function:	Director
Interviewer:	Bob Dubbel
Others present:	Mr. Sai Wunna Leon Brok
Date:	30/03/2017
Location:	ITC director's office
Subject:	Proposed location for drone mapping

1. Reservoir proposals

Bob:	Two days ago, we had a skype conversation with Martine Rutten and our other supervisor. I explained them what my plan is: To test the software and the drone technology as thoroughly as possible, I want to calculate 4 reservoirs. All the reservoirs are completely different from each other, some contain water, others are completely empty. Today I want to propose the 4 reservoirs I have in mind to you. The first location I want to propose, is the Shwepyi reservoir, South of Bago. The reason I want to visit this specific reservoir, is because it has the right size, rectangular shape and sharp edges. Last Thursday I went to the location to see if there is still water in the reservoir. I found that there is plenty of water.
Zaw:	This location is not a reservoir, but is actually a fishpond. They bread fish there.
Bob:	That may be, but since all the real reservoirs like this are empty at this time of the year, this might be the only place where I can test the drone. The characteristics of the pond are exactly the same as those of a real reservoir. If it is privately owned, I can imagine that it is hard to gain permission for flying the drone there. DO you think it is possible?
Zaw:	The location is open area; it is no problem at all to fly the drone there.

Bob:	The second location I have in mind is the Leikpaya reservoir in the Bago center. The reason that I want to map this reservoir, is because it has edges made from stone. This is similar to what the drone will need to calculate when we will determine the storage capacities of big, man-made reservoirs in the future. Is it possible to fly this location?
Zaw:	Unfortunately, it is not possible to fly the drone here. The reservoir is located in the middle of the city. There are restrictions by law that prohibits the use of drone inside urban area's.
Bob:	Could you think of another reservoir like this, with concrete edges, near Bago, where I would be allowed to fly the drone?
Zaw:	Next to the highway, there is the Yaung Say Kyum pagoda. It is located in the middle of a reservoir. The edges are not concrete, but river stones. You are allowed to fly over that pagoda because it is just a small one and the ITC paid for the reservoir.
Bob:	The third reservoir I want to propose, is the reservoir at the Oktha golf club. This I a good location because it still contains water, is the right size and the edges are vull of ridges and trees, making it very similar to most of the borders of the big reservoirs. This location knows a lot of elevation and will be very hard to calculate. That is why I want to test the technology here also.
Zaw:	You will easily gain permission to fly there.
Bob:	The last location is the reservoir behind the ITC, it is a completely dry reservoir with a random shape and some obstacles in it. I want to test this location because it gives a very good representation of most of the empty reservoirs in the region right now.
Sai:	For the GIS course, we already flew the drone over this reservoir, you have the dataset already.

	Bob:	The dataset contains pictures of the reservoir, but also of the whole surrounding of the ITC. It will consume a lot of time to process all this data. It will be more efficient if I will just fly the drown again.
2.	Fishfinder proposal	
	Bob:	A part of the research, is combining the Fishfinder with the drone to create one whole model of a reservoir. Considering the location of all the reservoir, my idea was to load a small boat into the Shwepyi reservoir. Now that I know it is a fishpond, I can imagine that is not possible?
	Zaw:	It is possible, we will help you arranging a small boat for you and find a way to get it into the pond.
3.	actions	
	Bob and Sai:	Visit all the 4 location prior to mapping them. First the location needs to be examined and permission needs to be gained by the local authorities of the locations.
	Bob:	Send a planning proposal to Sai with the date for visiting all the locations and separate days for flying the drone over each location.

INTERVIEW REPORT 8

Interviewee:	Mr. Myint Soe
Company:	Ministry of Agriculture, Livestock and Irrigation
Function:	Assistant Director
Interviewers:	Dennis Neleman Leon Brok
Others present:	-
Date:	07/04/2017
Location:	Ministry of Agriculture Livestock and Irrigation, Bago region
Subject:	Data retrieval and individual cases

1	By interviewers:	By Leon, for mutual data collection and mapping project: 1. The location of the Minywa koko drainage canal is unclear? Which one of the 2 is it? 2. Is the dike at Ye Nwe creek single or double sided? 3. Is the unity of sill level in ft. +msl? 4. What names of the constructions are spelled correctly: Map names or table names correct? 5. Do you have more cross sections of canals for us?
	By Interviewee:	1. The south one. The north one is the Kalar Chaung Gyi - Kalatsu drainage canal 2. Double sided, plus it continues more to the east 3. Yes 4. Map names are correct 5. Yes we received the Kalar Chaung Gyi - Kalatsu drainage canal. Rest of the canals are so small and cross sections are not available. Another note by Myint Soe: "There are only 2 Lock gates: Tawa and Myitko. The Minywa lock gate (as displayed on our Google Maps file) is a sluice."
	Action by:	Interviewers
	Action:	Update Google Maps and QGIS database
	Result:	All data processed (7-4-2017)
2	By interviewers:	By Leon, for Bob's case: 1. "Do you know of any reservoirs in your area where sedimentation is a problem, for instance sedimentation causing the capacity of reservoirs to be dangerously lowered?"

		2. "We are conducting research about innovative and low-cost monitoring techniques, you may be interested in the outcome as you mentioned your need for equipment to measure bathymetries or depths of reservoirs. Bob is currently studying the possibility to use different equipment to measure (remaining) capacities of reservoirs. Where would measuring the capacity of a reservoir be needed?"
	By Interviewee:	1. "There are no reservoirs with known sedimentation problems in the area. This is because of the lack of knowledge: we do not have the measuring equipment to measure depths of the reservoirs. We do know there is too much sediment in some reservoirs, but we do not have a clear image of where the real and biggest problems occur." 2. "In Moe Yin Gyi Lake, the deeper parts are highlighted on the map."
	Action by:	
	Action:	
	Result:	
3	By interviewers:	Leon: "I am looking into the sedimentation problem at the Bago River. I am curious of the places that have been dredged, as those are places where much sedimentation would have occurred." River track: Bago town – Tawa sluice gate
	By Interviewee:	"I will send you a map that displays all 11 locations where dredging activities between Bago and Tawa were performed. The sedimentation problem is a problem that is most urgent in the river track you described: between Bago and Tawa." Myint Soe also mentioned that enlargening the capacity of the Bago River could be (part of the) solutions of frequently occurring floods in the area. Preventing sedimentation in the Bago River may thus have positive effects on the area and reduce floodings.
	Action by:	Myint Soe
	Action:	Send Leon the map of dredging locations
	Result:	Not yet received

APPENDIX K: POSSIBLE CASE STUDIES

JOINTLY COMPOSED DOCUMENT CONTAINING DESCRIPTIONS OF POSSIBLE CASE STUDIES WHICH WERE ANALYSED DURING THE FIRST PART OF THE RESEARCH

Version	1.3
Date	04-04-2017
Location	Bago

Authors	Bob Dubbel Dennis Neleman Leon Brok

CLIENTS:

TU Delft

- Dr. Ir. Martine Rutten
  Assistant Professor Water Management
- Ir. Marjan Kreijns
  Head of Project Management Department at Valorisation Centre

Rotterdam University of Applied sciences

- Ir. E. Schaap
- Ir. W. Kuppen

Mapping flood related infrastructure in the Bago-Sittaung basin in Myanmar

Case study descriptions

Final thesis

Bachelor of Science

University of Applied Sciences, School of Built Environment, Civil Engineering
CIVAFS40
Bago, 14 March 2017

By

Leon Brok
0880483

Bob Dubbel
0866549

Dennis Neleman
0876260

ABSTRACT

While the information about the project area is received and processed, bottlenecks come forward. In this document, possible cases are described. Their relevance will be argued and in the end one of the cases will be chosen. The case studies concerning the final theses of Bob Dubbel, Leon Brok and Dennis Neleman. This document has relevance to each of the students. The goal of the case and the relevance to the overall graduation is described in the research proposal.

Each case will be described with the following structure;

- Case description
- Goal of the case
- Possible measuring systems
- Risks

This is a dynamic document, which means it will be updated every time a new case arises from fresh required information.

CONTENTS

1 CASE – EMBANKMENT SOUTHERN MYANMAR

Suggested by:	Mr. Myint Soe
Case location:	Sittaung delta area, East Myanmar
Date:	28/02/17
Sources:	Interview Myint Soe 28-02-2017
	Meeting Martine Rutten 01-03-2017
	Sutherland, "Clay settling in fresh and salt water"
	Partners for Water project description

1.1 CASE DESCRIPTION

The government is planning to realize an embankment with sluice gates/lock gates to prevent sea water intrusion in the Sittaung river delta in the dry seasons and be able to discharge water from the Bago-Sittaung canal during the rainy season. Due to the sluice gates fresh/salt grades will change drastically, which could result to local lumps of clay, causing sedimentation and dredging costs. Placement of the embankment could also lead to subsidence when the ground gets less saturated and no new sedimentations will occur once floods are prevented.

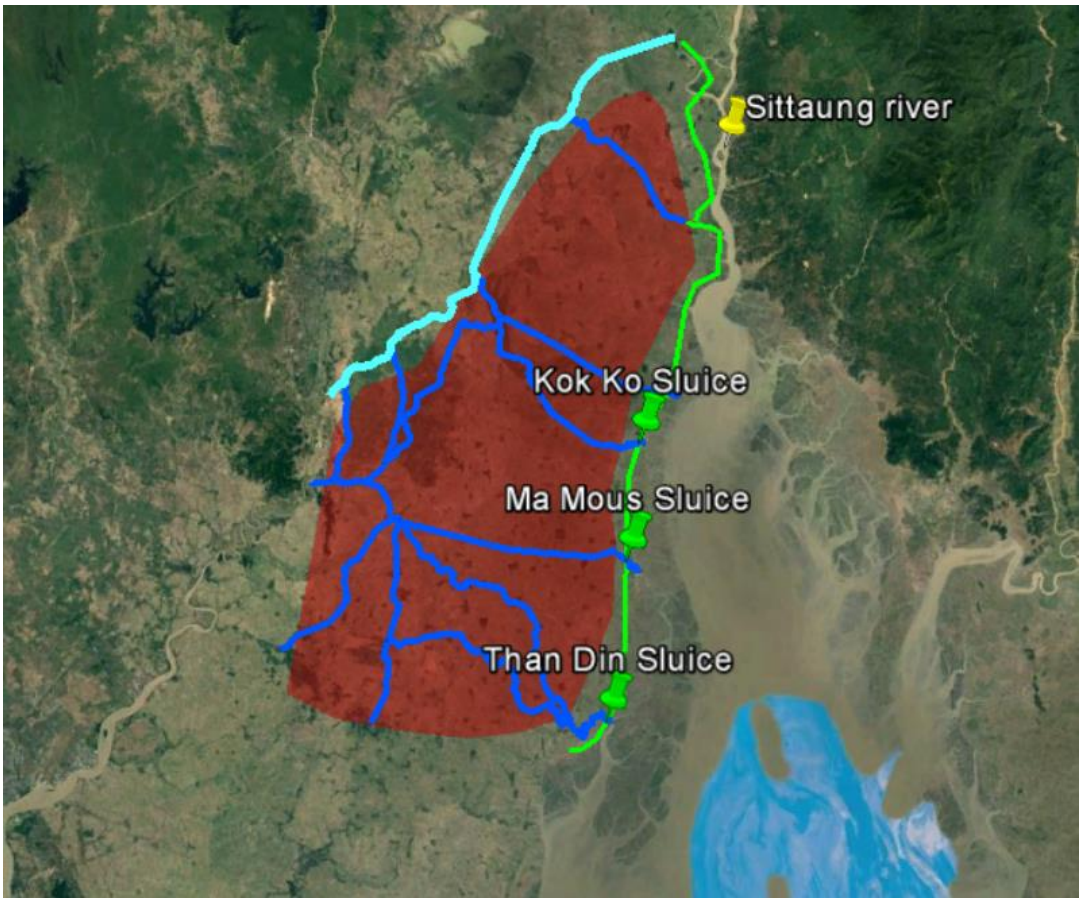


Image 1: Global overview of the plan. New embankment and sluices (green) must take care of salt intrusion problems in the danger area (red) and still make successful drainage of excess water from the Bago-Sittaung canal possible (Light blue). (Google Earth)

1.2 GOAL

Prevent or minimize future problems, which could occur after the creation of an embankment with sluices in the east of Myanmar. Either an advice of how to prevent clay clogging at the new sluices could be a study subject, or an advice of how to prevent subsidence in the area as much as possible.

1.3 POSSIBLE APPLICABILITY OF (MEASURING) TECHNIQUES

- Aqua monitoring tool from Deltares
- HKV remote sensing techniques
    - MijnOverstromingsrisicoProfiel
    - RainSat
    - SAT-Data
- SHORE monitoring
    - Aerial surveys by drone
- SOBEK
- QGIS

1.4 STEPS TO TAKE

- Retrieve information about the plans from the Ministry of Irrigation, Livestock and Irrigation, design branch.
    - What stage is the planning of the new embankment in?
    - What uncertainties are there in the plan that we could contribute to?
- Analyse existing reports concerning clay clogging and subsidence in delta areas.

1.5 RISKS

The case would be about future plans, which are still in the initiation phase of the authorities. This will lead to a very vague and theoretical case, with lots of uncertainties. If the plans will not be approved this case would be a waste.

The roads to the location are in a very bad condition. Even in the dry season it is sometimes unattainable, a visit to the site would not be possible.

2 CASE – FLOOD DEPTH AND SPEED

Suggested by:	Mr. Zaw Min Htut & Martine Rutten
Case location:	Bago region, emergency reservoirs
Date:	01/03/17
Sources:	Meeting Martine Rutten 01-03-2017
	Partners for Water project description
	Flood hazard maps Bago 2015, Sentinel Asia

2.1 CASE DESCRIPTION

Mr. Zaw Min Htut, director of the Irrigation Technology Center in Bago (ITC), requested for a way to measure water depths of flooded areas pace of the water rising. From results of the 2015 floods (Flood hazard maps Bago 2015, Sentinel Asia) and experiences of the local authorities, some areas can be marked as vulnerable to inundation. Within this area a testing ground could be set up, using different measuring systems to generate a general method for measuring inundation speed and depths.

2.2 GOAL

The development and implementation of a method for gaining information about the speed of which areas are flooding and the inundation depth, which is applicable in multiple regions and affordable by the authorities.

2.3 POSSIBLE APPLICABILITY OF (MEASURING) TECHNIQUES

For this case the following measuring systems could be tested effectively;

- Drone technology, owned by the ITC
- Water level monitoring with the use of a parking sensor (Tara van Iersel)
- The HKV Fishfinder
- Mobile Water Management application.

2.4 STEPS TO TAKE

- Analyse applicability of measuring techniques
- Analyse flood inundated areas, decide best testing grounds.

2.5 RISKS

Since the head of the ITC himself requested for this case, there can be no doubts on the value of this research. Furthermore, VPDelta equipment can be used and shown valuable to the local authorities.

A downside to this case is the start of the wet season. 22nd of May we leave the country, the wet seasons starts around this time so no actual data could be collected while present in the country. The measuring method could be set out, but not tested. Knowledge has to be transferred to the local staff and the would have to continue this case study themselves.

3 CASE – BATHYMETRY AND SEDIMENTATION IN RESERVOIRS

Suggested by:	Nay Myo Lin
Case location:	Reservoirs in Bago region and Mandalay region
Date:	01/03/17
Sources:	Reservoir data provided by Nay Myo Lin
	Google.sites - Bago-Sittaung river basin analysis

3.1 CASE DESCRIPTION

In order to control the floods and withhold water from the rainy season for irrigation purposes in the dry season, dams have been constructed upstream of the Bago River. At these dams and reservoirs trouble with sedimentation has been noticed.

The case and size of it are unclear, as is the need for a solution. In order to get the problem more clear a visit to the Bago regional office is needed. Known is that the local authorities measure the bathymetry by expensive sonar equipment once in a while. This case would study the usage of the Fishfinder for the monitoring of sedimentation within the reservoirs.

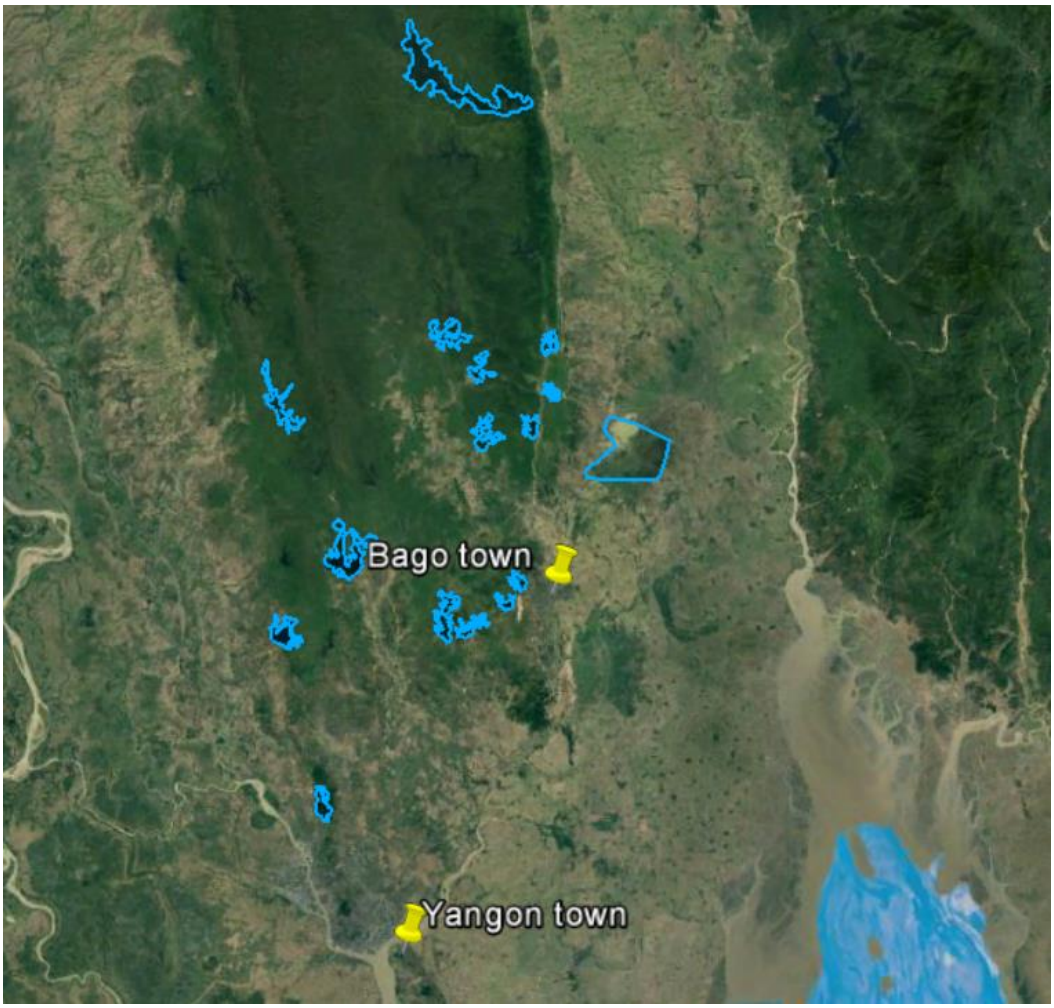


Image 2: Reservoirs, mostly constructed with the use of dams and weirs, in the Bago region (Google Earth)

3.2 GOAL

Determine the amount of sedimentation in the reservoirs using the Fishfinder, scale the problem and give advice about the monitoring methods. Determine problematic areas within the reservoirs and bring advice out on future monitoring methods, frequencies and locations.

3.3 POSSIBLE APPLICABILITY OF (MEASURING) TECHNIQUES

- The Fishfinder
- Traditional (echo-sounder) equipment

3.4 STEPS TO TAKE

- Analyse current monitoring methods, Bago regional office
    - Frequency
    - Equipment used
    - Processing data
- Analyse sedimentation related data, Bago regional office
- Plan on measuring (multiple) cross sections
    - With the Fishfinder
    - With other possible techniques
        - RTK GPS
        - Levelling
    - Define best locations for measurements
        - What does the ministry propose?
        - HKV is interested in information about depths over 10 meters
- Compare existing methods/results with the Fishfinder

3.5 RISKS

The Fishfinder might not be sufficient enough for the measurements. Data could have too many deviations to come to a reliable advice. The Fishfinder could be used in some other problem cases as well, there is only one Fishfinder available for the entire project.

If the Fishfinder is needed in multiple cases it has to be shared. Most reservoirs are located far away from the ITC, so the one studying this case would have to stay near the reservoirs for period of time for data collection which makes it hard to share the Fishfinder.

4 CASE – BATHYMETRY SITTAUNG RIVER

Suggested by:	Leon Brok
Case location:	Border of Bago region and Mon region, Sittaung River
Date:	06/03/17
Sources:	Google.sites - Bago-Sittaung river basin analysis
	Max van Rest – Monitoring of the Sittaung River - Bathymetry and Floodplains

4.1 CASE DESCRIPTION

Student Max van Rest from the technical university of Delft, has conducted a research into monitoring the water levels of the Sittaung river. A big part of his thesis is about researching the possibilities of using new measurement equipment tools from SHORE monitoring. The research comperes the new technologies with the current measurement methods. The conclusion of the research states that the new technologies cost more than the traditional methods and research into new methods could be very useful. Measuring the Sittaung River bathymetry using the Fishfinder could be a good sequel study.

Image 3: Sittaung River (green) (Google Earth)

4.2 GOAL

Using the Fishfinder to measure the Sittaung River's bathymetry could be a good opportunity to test the Fishfinder in other situations than it is tested in previously. Comparing the results of Fishfinder measurements to traditional or other innovative methods of bathymetry measuring could contribute to determining follow-up studies about the Fishfinder, or perhaps make local authorities in Myanmar enthusiastic about using the Fishfinder instead of their traditional, probably more expensive ways of measuring bathymetries.

Comparing historic measurement results of the Sittaung river to more recent results could also bring insight in the behaviour of the river system. Insight that could help Ir. Nay Myo Lin with his PHD research at TU Delft of modelling the entire Bago Region hydrological situation.

4.3 POSSIBLE APPLICABILITY OF (MEASURING) TECHNIQUES

- The Fishfinder
- Current local measuring equipment

4.4 STEPS TO TAKE

Information concerning monitoring of rivers can be retrieved from the Hydrology branch of the Ministry of Agriculture, Livestock and Irrigation.

- Retrieving existing data and information of the Sittaung River
    - Global analysis of the river system
    - Is there a current system of monitoring the river?
        - If so, when will be the next measuring moment?
        - What equipment is used?
    - Is there historic data of the Sittaung River bathymetry available?
        - Compare all existing data, including Max van Rest's data.
- Plan on measuring (multiple) cross sections
    - With the Fishfinder
    - With other techniques?
        - RTK GPS?
        - Levelling?
    - Define best locations for measurements
        - What does the ministry propose?
        - What does HKV propose?
            - Depths from 10 meter are proposed
        - Use (some of) Max van Rests cross sections? Good for comparison?

- Data analysis
    - Compare recent data from different techniques with each other
        - Fishfinder accuracy compared to other technique(s)
        - Fishfinder deviation compared to other technique(s)
        - Fishinder costs compared to other technique(s)
        - Fishfinder ease of use compared to other technique(s)
        - Fisfhinder cost of time compared to other technique(s)
        - Etc.
    - Compare recent data with historic data
        - Where does the river change bathymetry at a high rate?
        - What does this mean? Morphological explanation
            - Possible future problematic areas
            - Advice on where to monitor more often

4.5 RISKS

The case will stagnate completely if the Fishfinder is found to be useless for the proposed purposes. However, the conclusion that the Fishfinder is not a good alternative to current methods is also a conclusion to the research and can suffice as a useful result.

Other problems/risks are:

- A battery still needs be found and bought for the Fishfinder.
- The Sittaung river is located very far from Bago and is difficult to reach.
- The Sittaung river generally is a large river with high flow velocities, which could make measuring with the Fishfinder too hard or impossible.

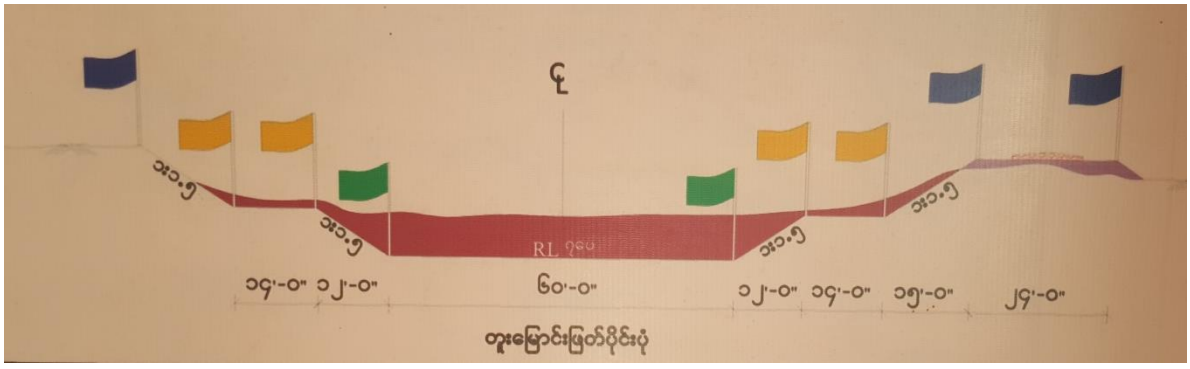
5 CASE - SEDIMENTATION OF THE BAGO-SITTAUNG CANAL

Suggested by: Dennis Neleman
Case area: Bago region, Bago-Sittaung Canal
Date: 06/03/17
Source: Field report
Mr. Zaw Min Htut

5.1 CASE DESCRIPTION

The director of the ITC organised an excursion along the Bago-Sittaung Canal. During this excursion multiple offices within the region has been visited and all structured related to the Canal where shown. The document "Field report Bago-Sittaung canal 8-3-2017 V1.1" contains a field report of this excursion.

At one of the visited offices a cross-section and a longitudinal cross-section of the entire canal was shown. The cross-section contained the design profile and a measured profile showing the sedimentation in the canal. A picture of the cross-section is shown below.



In 2013 major maintenance works have been executed. Local authorities dredged the Bago-Sittaung Canal using 200 excavators situated along the canal. Within this case a new longitudinal cross-section will be made and at critical points some additional cross-sections, using the fishfinder. An update of the map will be made using the results. Knowing the amount of sediment over time a prediction can be made about when the next maintenance works have to be planned and maybe some measures can be conceived to postpone these works.

5.2 GOAL

Postpone major maintenance works due sedimentation within the Bago-Sittaung Canal.

5.3 POSSIBLE MEASURING SYSTEMS

- Fishfinder

5.4 STEPS TO TAKE

- Map the canal with the fishfinder.
- Analyse the results and determine the sedimentation over time.
- Think about a measure to postpone major maintenance works due sedimentation.

5.5 RISKS

The water depths in the canal might not be sufficient enough for the fishfinder and it would have to be shared if it is needed in another case as well. The Canal might have changed so the centreline which will be measured might be differ of the previous measurements.

Measuring the complete canal and processing the data will take a lot of time, besides this measurement information about the flow velocities, accelerations, decelerations and bed shear stress is needed. Acquiring this information in a county like Myanmar will take a lot time, if it is even available.

A SOBEK model has to be created, currently no one at the ITC has SOBEK installed on his computer and obtaining this software is very hard with the local internet conditions. In addition there is insufficient experience of SOBEK so this would have to be obtained, which again will take a lot of time.

6 CASE - BAGO-SITTAUNG BOTTLENECK

Suggested by: Mr. Zaw Min Htut
Case area: Bago region, emergency reservoir
Date: 06/03/17
Sources: field report
Ir. Nay Myo Lin

6.1 CASE DESCRIPTION

This case is of a larger scale and focusses on the discharge of the Bago-Sittaung Canal during the rainy season. During the excursion along the canal the director of the ITC, Mr. Zaw Min Htut, told that the canal itself functions properly, but the main problem is with the Bago River.

During the wet season, the water level in the Bago River is higher than the intended water level in the canal. Therefore, the Tawa lock gate has to close, stopping excess (rain)water in the canal to flow out and raising the water level in the canal, possibly causing floods in the area north of the lock gate.

6.2 GOAL

Prevent floods around the Bago-Sittaung Canal during the wet season, especially at near the Tawa lock gate.

6.3 POSSIBLE MEASURING SYSTEMS

-

6.4 STEPS TO TAKE

- Find out what causes the floods
- What negative sides does the floods have
- What positive sides does the floods have
- What measures can be taken to take away all or most of the negative sides

6.5 RISKS

The scale of the project is quite big, requiring data could take too much time and the influence of a measure to the complete water system is hard to predict.

7 CASE - BATHYMETRY BAGO RIVER

Suggested by:	Mr. Zaw Min Htut
Case location:	Bago region
Date:	07/03/17
Sources:	Google.sites - Bago-Sittaung river basin analysis
	Max van Rest – Monitoring of the Sittaung River - Bathymetry and Floodplains

7.1 CASE DESCRIPTION

This case has arisen from case 4: Measuring the bathymetry of the Sittaung river. The global idea of the case is similar to case 4, instead of measuring the Sittaung River the Bago River will be used as a testing ground for the HKZ Fishfinder. The Bago river is a smaller river than the Sittaung river and thus easier to measure with small-scale equipment like the Fishfinder. The Bago river, according to Mr. Zaw Min Htut, has some locations near Kawa town where sedimentation is occurring, which could be explicitly interesting locations for the Fishfinder to be tested out.

7.2 GOAL

Compare all aspects of using the Fishfinder to measure the Bago river bathymetry with other/traditional methods. Map problematic areas in the Bago river and propose technical measure and/or future monitoring methods against sedimentation-vulnerable locations

7.3 POSSIBLE APPLICABILITY OF (MEASURING) TECHNIQUES

- The Fishfinder
- Current local measuring equipment

7.4 STEPS TO TAKE

- Retrieving existing data and information of the Bago River
    - Global analysis of the river system
    - Is there a current system of monitoring the river?
        - If so, when will be the next measuring moment?
        - What equipment is used?
    - Is there historic data of the Bago River bathymetry available?
        - Compare all existing data
        - Where do sedimentation problems occur?
- Plan on measuring multiple cross sections
    - With the Fishfinder
    - With other techniques?
        - RTK GPS?
        - Levelling?
    - Define best locations for measurements
        - What does the ministry propose?
            - Locations where sedimentation occurs rapidly?
        - What does HKV propose?
            - Depths from 10 meter are proposed
- Analysing testing results
    - Compare recent data from different techniques with each other
        - Fishfinder accuracy compared to other technique(s)
        - Fishfinder deviation compared to other technique(s)
        - Fishinder financial costs compared to other technique(s)
        - Fishfinder ease of use compared to other technique(s)
        - Fisfhinder cost of time compared to other technique(s)
        - Etc.
    - Compare recent data with historic data
        - Where does the river change bathymetry at a high rate?
        - What does this mean? Morphological explanation
            - Possible future problematic areas – propose measure?
            - Advice on where to monitor more often

7.5 RISKS

- The water depth must be at least 1 meter in order for the Fishfinder to measure
- The Fishfinder could break/lose its functionality otherwise
- An absence of existing cross sections

8 CASE – MODELLING STORAGE CAPACITIES OF RESERVOIRS

Suggested by: Zaw Min Htut
Case location: Leikpaya reservoir, Bago town
Date: 22/03/17
Sources:

8.1 CASE DESCRIPTION

Due to sedimentation occurring in the reservoirs, there are uncertainties on the current storage capacities. During the dry seasons, the ITC regulates the amount of water that is drained from the reservoirs to the paddy field for irrigation purposes. To distribute the remaining water as efficient as possible, it is important to know how much water is still left in the reservoirs.

Some of the reservoirs are completely empty at the end of the dry seasons, meaning that it is possible to model them by using only drone techniques. However, the bigger, more important reservoirs in the region will always contain some amount of water, meaning that the reservoir bed is never visible and cannot be scanned by a drone. This is where the Fishfinder can be used. By using drone imagery for modelling the storage capacity above the water surface and using the Fishfinder for modelling underneath the water surface, a complete model can be obtained which shows exactly how much water is stored in the reservoir.

Many of the ITC employees have just completed a GIS/PIX4D course in which they learned how to map surfaces in GIS with drone imagery. The director is considering purchasing the PIX4D software. The PIX4D software is one of the top priced drone software on the market right now ($8.500). If this case could prove a (much) cheaper software to be working, the ITC could save a lot of money. That is why different software will be used for modelling the reservoir.

8.2 GOAL

Executing a pilot project for setting up a methodology and writing a manual for determining the storage capacity of a reservoir using different types of software. By using different types of software, a recommendation can be given to the ITC for which software to purchase.

8.3 POSSIBLE APPLICABILITY OF (MEASURING) TECHNIQUES

- The Fishfinder
- The ITC drone

8.4 STEPS TO TAKE

To be able to test both the drone software and the Fishfinder, a reservoir needs to be found which contains at least 1 meter water in it. This excludes most of the smaller reservoirs in the region because they are completely dried up during this time of the year.

On the other hand, drone imagery data sets are enormous files which take very long to process. Since numerous different types of software will be used to map the reservoir, and the case is about setting up a methodology, it is favourable to use a small reservoir as a test pilot. That is why a reservoir needs to be found which is relatively small but still contains water.

The Leikpaya reservoir in Bago center meets both requirements. The following things need to be examined:

- Is the water level currently above 1 meter (3 feet)?
- Is it possible to get a small boat (canoe, small rowboat) inside of the reservoir?
- Could the ITC help with gaining permission from the Bago council authorities for doing this research?

8.5 RISKS

The Fishfinder is still in a testing phase and there are some uncertainties on the accuracy of the data.

Knowledge on 3D modelling using drone imagery is limited. However, the ITC has just completed a GIS course where the techniques have been thought to some of the students which are willing to assist during the process.

Most of the software can only be used after purchasing an (expensive) licence. Free trial versions are available but these trials may exclude the options for exporting the data set.

9 CHOOSING A CASE

In this chapter the selection criteria are stated, as well as the choice support of each of the students.

9.1 SELECTION CRITERIA

Given the project structure as described in the project proposal, the project contains of three phases. The first phase consists of data collection and processing. The second phase involves a problem analyses. The third and last phase of this thesis is to conduct research on a specific bottleneck in the Bago-Sittaung basin. Given the short presence in Myanmar, it is preferred that the problem case has some relation to the previous phases. If so, the data collection and processing have already been conducted for the topic.

The final case must have relevance to the competences belonging to the bachelor of Civil Engineering at the Rotterdam University of Applied Sciences. These competences can be found in the graduation guide, "IGO_Keyhc_CIVafs40_Afstudeerhandleiding CT voltijd en duaal_2013-2014 (1)" chapter 1.2.2. The final report includes 50% of the final mark and will be reviewed based on the "Rubric afstudeerrapport", other criteria will be the defence (20%), final presentation (10%) and contribution within the firm (20%).

Usage of VPDelta measuring equipment is preferred. VPDelta offers innovative measuring equipment. Using the equipment to retrieve data would test the innovation and local authorities will be introduced to the new techniques.

Due to the many (hydraulic) problems in Myanmar it is preferred to solve or contribute to a recent problem topic, taking account with future problems.

It is not handy to aim the case of a topic with a lot of unknown variables. There is not much hydrological data available in Myanmar and if so, it is mostly on paper and in Burmese. Missing data has to be determined by measurement. Data collection in any way is very time costly because of the many different involved departments, the hierarchic system and bad internet connectivity.

The last factor to decide what case will be focussed on is personal interest.

9.2 CASE DENNIS NELEMAN

Case chosen:	Sedimentation of the Bago-Sittaung Canal
Reasons:	Major maintenance works, like in 2013, seem to be very expensive. Being able to postpone or prevent this kind of works would drastically degrease the maintenance cost. Sedimentation is a huge problem at various locations in the Bago region. Using the fishfinder to determine the speed and amount of sedimentation in the Canal could be a pilot project for other locations. Occurrence of sedimentation has relevance to the hydrologic engineering part of the study Civil Engineering at the Rotterdam University of Applied Sciences. Usage of the fishfinder as a VPDelta technique. Information obtained could be useful for the PhD study of Ir. Nay Myo Lin.
Update:	Had e-mail contact with Nicole Jungermann, from HKV lijn in water, contact person about the fishfinder at 10 March 2017. She said this kind of measurement is hard to achieve with the fishfinder, given the fishfinder shows the waterdepth in the middle of the canal, where the highest velocities occur. This varies within the time, which is why centrelines are hard to compare. It is also unknown if the fishfinder is repayable enough at these water depths. Besides mapping the canal, lots of other information about the canal has to be obtained, like the flow velocities, accelerations, decelerations and soil shear stresses. Mapping the canal seemed to be the most clear and easy to do, obtaining the other parameters will be very time costly. Leon is also willing to use the fishfinder for his case. Mapping the Bago-Sittaung Canal would take a lot of time and the fishfinder would have to be shared. Because of these reasons the case " Sedimentation of the Bago-Sittaung Canal" will not be studied.
Case chosen:	Bago-Sittaung bottleneck
Reasons:	If the Tawa lock gate could be opened during the wet season, excess (rain) water from the canal could be discharged to the Bago River. This will fix a huge bottleneck to the complete downstream water system of the Bago area. It will reduce the floods around the Bago-Sittaung Canal and cause a continue discharge that could also be a solution to the sedimentation problems from the 'Sedimentation of the Bago-Sittaung Canal' case, although this effect will not be studied in this case. Water systems like canals with hydraulic structures and the influence of these structures to the system fit seamlessly in to the study program of the study Civil Engineering at the Rotterdam University of Applied Sciences This study has direct relevance to the PhD. research of mr. Ir. Nay Myo Lin, who is currently modelling the Bago-Sittaung basin at the TU-Delft. New information or conclusions obtained by this case study could be useful for his research.

9.3 CASE BOB DUBBEL

Case chosen:	Determining the storage capacity of reservoir using drone and sonar techniques.
Reasons:	A better understanding of the amount of water that is stored in reservoirs would increase the efficiency with which the ITC can regulate the water and will increase the crops production in the area. New, cheaper methods for determining the storage capacities are needed, since conventional, current methods are either too expensive or too time consuming. The applicability of the recently purchased Phantom 4 drone can be demonstrated. Testing and comparing different types of software can result in an advice for the ITC what software to buy.
Update:	The ITC has decided on purchasing a specific type of drone software, Pix4d, to use for the drone in the future. The comparison of different software will therefore be invaluable. Part of the thesis is writing a manual on how to calculate volumes with the drone, this manual will be only useful if the used software is Pix4d. Since the bigger reservoirs are much more significant for supplying water than the smaller once are, the case will focus on the possibilities of mapping these reservoirs in the future. For now it is not possible to map a big reservoir due to the lag of experience and time. The reservoirs that will be tested are chosen for their similarity with the big reservoirs. A meeting with the director of the ITC has determined that the foreseen location for using the Fishfinder can indeed be used. On this location both the Fishfinder and the drone will be applied to obtain a full model of the reservoir.
Case chosen:	Calculate the storage capacities of different reservoirs using the ITC drone and Fishfinder
Reasons:	Writing a manual for employees of the ITC to use for volume calculations in the future. Applying the Fishfinder for an important cause, as a (much) cheaper substitute for conventional methods.

9.4 CASE LEON BROK

Case chosen:	Bathymetry Sittaung River
Reasons:	Measuring the Bathymetry with the Fishfinder could perfectly sequal the previous study conducted by Max van Rest. Max researched the possibility of using multiple innovative monitoring techniques for measuring the bathymetry of the Sittaung river, and the Fishfinder fits perfectly in the list of techniques stated in his study. Max clearly stated more research using other techniques should be carried out in the future. The importance of the Sittaung river in both irrigation and drainage purposes is huge. This makes it even more important that hydraulic paramaters such as bathymetries are measured frequently. Frequency is currently what the monitoring system misses, as there is not enough material (Echo sounders) available in the country. The pace of which the Sittaung River varies in shape makes it an important factor in flood risks management. Frequent monitoring results could bring more understanding in how the river behaves. Usage of the Fishfinder as a VPDelta technique. Information obtained could be useful for the PhD study of Ir. Nay Myo Lin.
Update:	A visit to the Sittaung river during the Bago-Sittaung canal field trip let us see with our own eyes the enormous size of the Sittaung River. Smaller widths are many kilometres upstream, which is a long way traveling from our working place at the ITC in Bago. ITC Director Zaw Min Htut confirmed the expected difficulty of measuring (multiple) cross sections of the Sittaung River because of its size and strong currents. ITC Director Zaw Min Htut described a sedimentation problem in the Bago River near Tawa. The previously described reasons made the case location shift from the Sittaung River to the Bago River.
Case chosen:	Bathymetry Bago River
Reasons:	The Bago River is a smaller, less dynamic river where frequent bathymetry measurements are performed. The historic data of the Bago river can be used to determine the Fishfinder's qualities and perhaps convince local authorities to use the Fishfinder in their future research. The sedimentation problem is a problem that is now known much about now, and not much data has been gathered concerning the exact nature of the sedimentation problem. Aside testing the Fishfinder, a more theoretical study could be conducted about the sedimentation problem. Setting up a SOBEK model could help in determining what possible measures are applicable to the sedimentation problem. This study has direct relevance to the PhD. research of mr. Ir. Nay Myo Lin, who is currently modelling the Bago-Sittaung basin at the TU-Delft. New information or conclusions obtained by this case study could be useful for his research.

Appendix L: 3D models

TPRESENTATION OF ALL OBTAINED MODELS

Version	1.0
Date	09-06-2017
Location	Rotterdam
Author	Bob Dubbel

CLIENTS:

TU Delft

- Dr. Ir. Martine Rutten
  Assistant Professor Water Management
- Ir. Marjan Kreijns
  Head of Project Management Department at Valorisation Centre

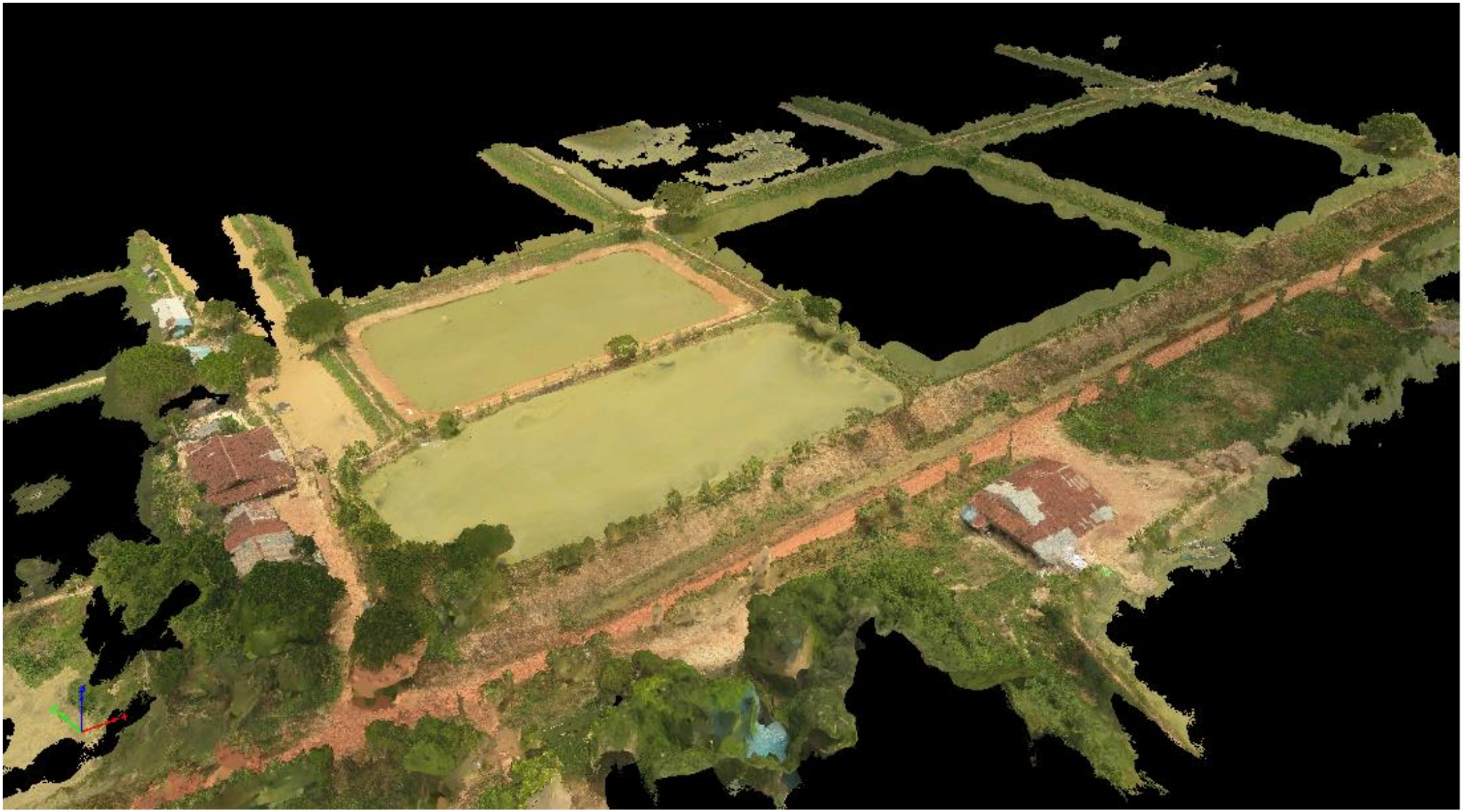
Rotterdam University of Applied sciences

- Ir. E. Schaap
- Ir. W. Kuppen

Dataset 1: ITC reservoir

Dataset 2: Okthoa Golf Course reservoir

Dataset 3: First fish pond



Dataset 4:three fish ponds

APPENDIX M: OUTCOMES SOIL TEST

RESULTS FROM THE SOIL SAMPLE TAKEN AT THE FISHPOND, TESTED BY THE ITC LAB.

Version	1.0
Date	04-05-2017
Location	Bago
Authors	Bob Dubbel

CLIENTS:

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Rotterdam University of Applied sciences
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- Ir. W. Kuppen

CONSTRUCTION MATERIAL TEST LABORATORY
(SOIL)

IRRIGATION TECHNOLOGY CENTER, BAGO
IRRIGATION DEPARTMENT

SUMMARY SOIL TEST RESULTS

PROJECT ..... ငါးကန် (FISH POND)

DATE ... 2.5.2017

Sr No.	SAMPLE NO.	GRAIN SIZE DISTRIBUTION				ATTERBERG'S LIMIT			SPECIFIC GRAVITY	MOISTURE & DENSITY		DIRECT SHEAR		Natural Moisture Content	DISPE-RSIVE	SOIL TYPE
		Clay (%)	Silt (%)	Sand Coarse / Fine (%)	Gravel (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)		Moisture Content W%	ρ_d lb/ft^3	Cohesion (Kg/cm^2) (C)	Angle of internal fraction ϕ	W %	Grade	
1	Sample	42.00	39.00	19.00	0.00	39.35	16.22	23.13	2.67							CL

Submitted By: (ဦးစီးအရာရှိ)

Checked By:

(Naw Zar Khin)
Staff Officer (Lab)
Water & Soil Mechanics Laboratory
Irrigation Technology Centre Bago

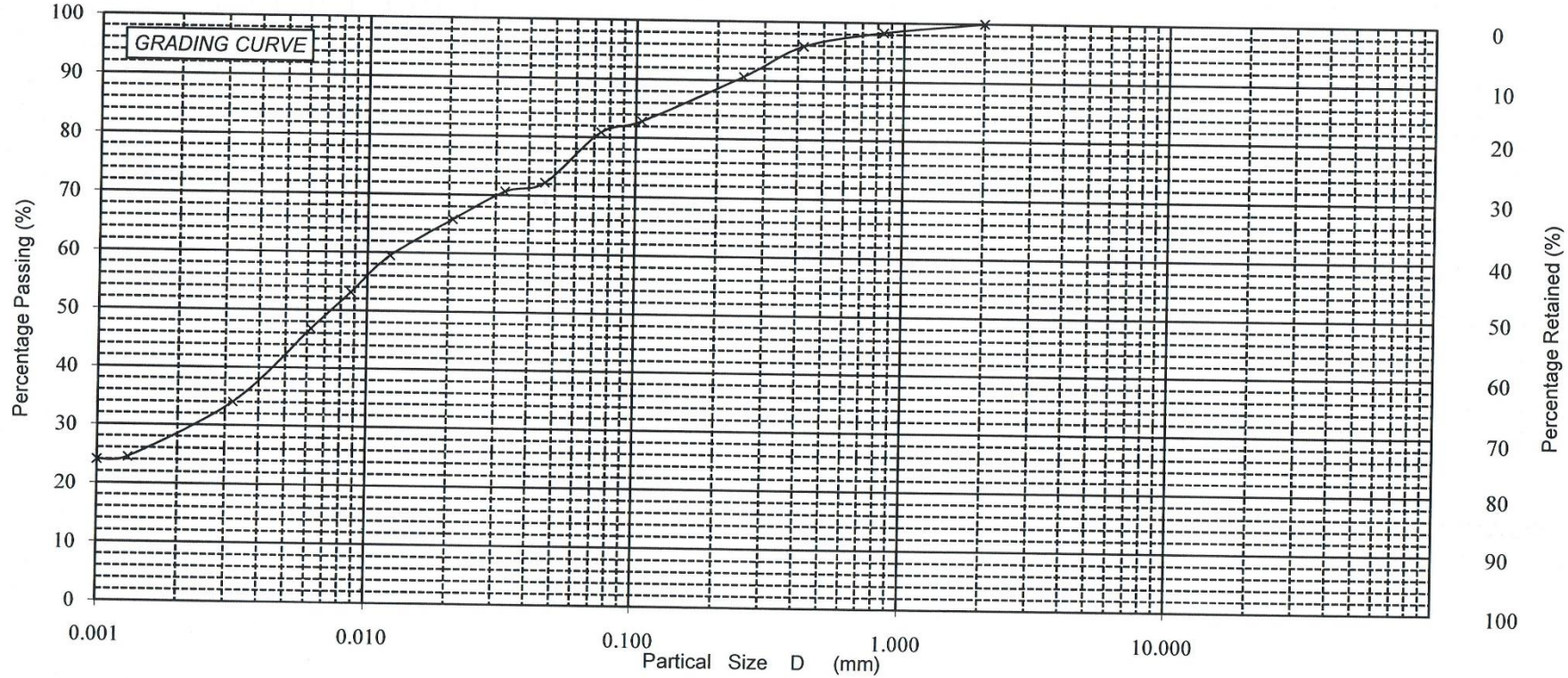
CONSTRUCTION MATERIAL
TEST LABORATORY
(SOIL)

IRRIGATION TECHNOLOGY CENTER, BAGO
IRRIGATION DEPARTMENT

PARTICAL SIZE ANALYSIS TEST

PROJECT: ငါးကန် (FISH POND) Date ... 2.5.2017

TEST NO: LOCATION :



Colloids	Clay	Silt	Fine Sand	Coarsed Sand	Fine Gravel	Gravel	Cobble
0.001mm	0.005mm	0.074mm	0.42mm	2.00mm	4.76mm	75.0mm	

Remarks:

Clay = 42.00% Silt = 39.00% Sand = 19.00 %

TESTED BY : Myo Thanda

CHECKED BY: Naw Zar Khin, S.O (Lab:)

Appendix N: Theory behind drone mapping

THE MATH BEHIND DRONE IMAGE STITCHING

Version	1.0
Date	01-06-2017
Location	Rotterdam
Author	Bob Dubbel

CLIENTS:

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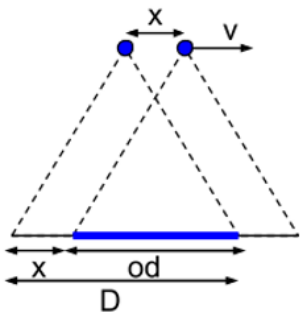
- Ir. E. Schaap
- Ir. W. Kuppen

ABSTRACT

The Pix4D application designs a grid and calculates the necessary amount of photo's, based on the predefined flight height and surface area inserted in the application. In this document the mathematical explanation behind this process is briefly explained.

The number of pictures taken by the drone, depends on the flight height, the overlap of the images, the distance covered on the ground by one image in the flight direction and of course the size of the grid. The image below give a representation of the theory.



D = distance covered on the ground by one image in the flight direction [m]

overlap = percentage of desired frontal overlap between two images

od = overlap between two images in the flight direction [m]

x = distance between two camera positions in the flight direction [m]

v = flight speed [m/s]

t = elapsed time between two images (image rate) [s]

From this image, the following equations can be obtained:

$od = overlap * D$ *(1)*

$x = D - od$ *(2)*

$t = x / v$ *(3)*

The standard value for the overlap when obtaining 3D models is 80%[1]. The images taken by the drone have a size of 4000 x 3000 pixels, with 3000 pixels in the flight direction. As can be seen on the images below, the distance covered on the ground by one image in flight direction, D, is 86m at a height of 50m.

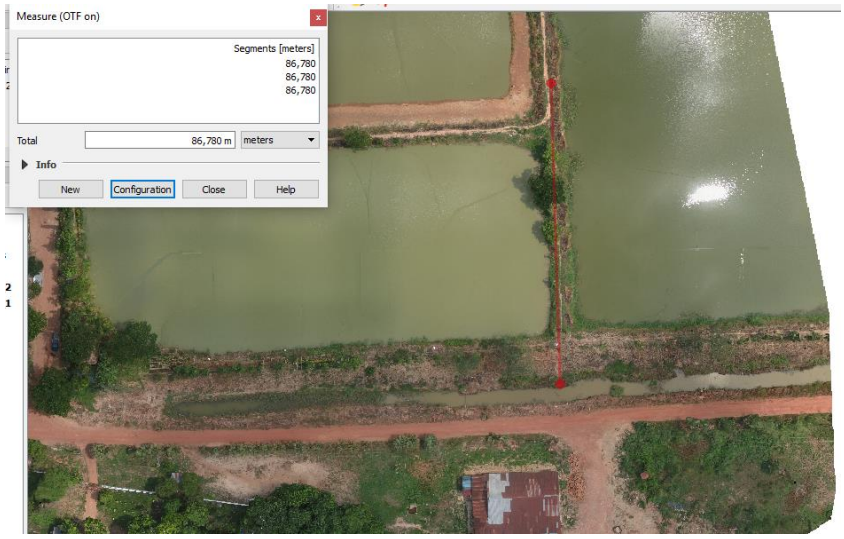
example: Fishpond
overlap = 80% (pix4d)

V= 18m/s

D=86m
od= overlap * D = 80% * 86m = 68.8m
x=D-od = 86m – 68.8m =17,2m
t= 17,2m / 18m/s = 0,95s

[1] www.pix4d.com

Figure 1: Foto taken by the drone above on of the Fishponds at a height of 50m.



Figuur 2: Calculated distance, D in orthomosaic