# Implementation of new data retrieval and handling technologies in Myanmar


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## TITELPAGE

Mapping the water related infrastructure in Bago and Sittaung Basin area, Myanmar.

Determining storage capacities in reservoirs using new technologies.

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Delft University of Technology
VPDelta
Irrigation Technology Centre

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# PREFACE

This research has been conducted in name of VPDelta, the Technical University of Delft and the University of Applied Sciences of Rotterdam. During a period of 10 weeks, I have analyzed and researched, but most of all experienced the hydrological, governmental and cultural aspects of Myanmar. The very pleasant time I have spent here with the ITC as my base point, has resulted into this report.

In advance of the report, a word of graditute is to be carried out to all those who have helped me during my time in this country and those who have contributed to the research and the report:

Leon Brok and Dennis Neleman, students at the Rotterdam University of Applied Sciences, for the fine collaboration during the preparational, executional and final phase of the thesis research. Important papers, part of this research, have been communally obtained and written in a very pleasant partnership. Everything written in this report, can therefore freely be used by both named students.

Mr. Zaw Min Htut, director of the ITC, for all the good cares and providing all the help one could wish for. His guidance, assistance and cares have greatly contributed to the quality and quantity of obtained reports for this research.

Mr. Sai Wunna, staff director of the ITC, for serving as a mentor for us at the ITC. His general guidance, translations, answers to questions and most of all, his assistance with collecting datasets, has been a great contribution to my research and the pleasantness of my stay in Myanmar.

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Ir. Edwin Schaap, for reviewing interim papers and grading my final report.

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## *List of acronyms*

| | |
|---|---|
| ITC | Irrigation Technology Centre |
| HB | Hydrology Branch |
| DPM | Depth Point Measurement |
| DEM | Digital Elevation Model |
| DSM | Digital Surface Model |
| MSL | Mean Sea Level |
| GCP | Ground Control Point |
| GIS | Geographic Information System |
| UAV | Unmanned Arial Vehicle |
| GPS | Global Positioning System |

# 1 BACKGROUNDS

## 1.1 *Backgounds of Myanmar*

Myanmar, former Burma, is a Southeast Asian country with a climate of heavy rain, interchanged with tropical temperatures and intense sun rays. A country with a very high potential, rich in culture and even richer in natural resources, but also a country that will face huge challenges in the near future. Already, the country is suffering from water related problems, with the need to identify solutions to inundations and water shortages. These problems are expected to get worse due to climate change.

In 1962, a military coup caused the abolishment of all democratic governances, resulting in 49 years of military regime reigning over the country. During this period, Myanmar developed as the second most closed country in the world, leading to a stagnating economy and an educational backlog. In 2011, a new constitution was implemented, announcing the end of the military regime. The country is completely open now, but is still recovering from almost 50 years of isolation. Protocols concerning geological and hydrological data collection are not implemented among government bodies yet, leading to an absence of clear data.

## 1.2 *Backgrounds of VPDelta*

The Myanmar and Dutch governments have agreed to cooperate on Integrated Water Resources Management (IWRM) through a Memorandum of Understanding (MoU) between the Myanmar Ministry of Transport and Dutch Ministry of Infrastructure and Environment. This is where TU Delft comes into the picture. TU students have previously done research in different places in Myanmar under this MoU, mostly analyzing flood risks, determining the applicability of new monitoring systems and designing plans or technical measures to protect the inhabitants from the floods.[1]

VPDelta forms a link between technical (start-up) companies and the Myanmar government by creating testing grounds for the testing of equipment, well collecting crucial geological and morphological data that can be used for problem solving. In the past 5 years, VPDelta has been testing new, innovative technologies in the Myanmar Delta. In 2017, funded by RvO partners voor water, 6 pilot projects will be done by VPDelta in Myanmar. The thesis is part of a group of pilot projects on the testing of new, innovative Dutch technologies concerning the improvements of Delta management. Altogether they form the showcase ''Smart Information Solutions'' where 6 informational product pilots are developed in Myanmar.

The thesis has been executed in collaboration with the Irrigation Technology centre (ITC) in Bago. This is a governmental institution of the Irrigation and Water Utilization Management Department (IWUMD)[2]. In a group of three students from the Rotterdam University of Applied Sciences, a joint assignment has been executed in name of the TU Delft. This has led to a better understanding of the hydrological challenges the country is facing today and in the future. The activities carried out for this research have led to a case study upon which this report is based.

[1] https://repository.tudelft.nl/islandora/search/myanmar?collection=research
[2] Appendix A, General analysis, chapter 2± Organigram.

## 1.3 *Backgrounds of the thesis*

The Bago region is suffering problems of water shortages in the dry season, and flooding during the rainy season. Storing the water abundances during the rainy season in order to replenish the water shortages during the dry season, will reduce these problems and increase life quality in the region. Numerous hydro dams have been installed in the catchment area of the region, creating several reservoirs to contain the water. These reservoirs play a very important role in both flood risk management as well as the prevention of water shortages in the region.

Ir. Nay Myo Lin, is currently conducting a PHD research in the Bago and Sittaung Basin area on the topic of ''Flood Risk Assessment and Management'' at the Delft University of Technology. The goal of this research is to improve the effective measures for preventing and managing floods in Myanmar. The research focusses on the optimization and simulation of multiple reservoirs in a river basin that can be used to reduce flooding in downstream areas.

In order to improve the water management in the area and to obtain a reliable water simulation model, hydrological and geological information is necessary. Lots of information about the region is available at governmental offices, but since the system has not digitalized or standardized the handling of this data, it cannot be used yet. In order for Ir. Nay Myo Lin to use this data, the information needs to be inserted into a GIS model. During the thesis, in a group of three students, the available data has been collected, handled and inserted into GIS. The act of collecting raw data from local offices and digitalizing it by inserting it in a QGIS model has drawn the interest of local authorities into one of the many methods for improving the conventional method for data collection and handling.

Not all necessary data for Ir. Nay Myo Lin's model is available yet and real time data is rare. The implementation of new measurement methods could lead to a significant increase of necessary data that will contribute to flood risk management projects now and in the future. The technologies of VPDelta can lead to a breakthrough. During the research 2, new technologies have been analyzed and tested in the field in order to examine the possible ways for implementing these new methods in the region. These new methods are compatible and can be combined with the newly introduced method for data handling using QGIS.

***Figure 1: Bago Region projected on the Map of Myanmar***

# 2 INTRODUCTION TO THE RESEARCH

## *2.1 Current challenges*

**Rainfall**
Myanmar knows three different seasons: A dry season with no rain at all present from March till May, a cool season with temperatures lower than during the dry season with rain occurring very rarely from November to February, and a rainy season present from June till October. In this period, a heavy monsoon rushes over the country. Over 4000mm of precipitation occurs in this season, compared to almost 0mm in the hot season. Figure 2 shows average amounts of annual rainfall for the Bago region.

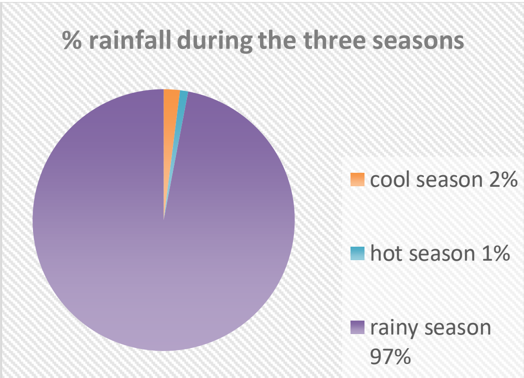



***Figure 2: Rainfall over the year in Bago region. (SOURCE: Bago Region: Agriculture, livestock and irrigation in brief)***

**Agriculture shortages**
During the rainy season, rainwater is captured and stored in reservoirs. This has two important advantages: At first, the unwanted water is captured, which leads to a decrease in the occurrence of floods downstream. Secondly, the vast water shortages that occur in the dry seasons can be covered up by releasing water from the reservoirs during the dry seasons.

The biggest part of these water reserves is destined for irrigation purposes. Agriculture is by far the biggest industry in the Bago region. For paddy, watermelon and banana production alone, over 32,000ha is used in the region.[3] During the dry seasons, many farmers in the region depend completely on the water reserves inside the reservoirs, since no rain is present. More information can be found in appendix E: Reservoirs around Bago.

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

**Sedimentation problems**
It is known that most of the reservoirs in the region suffer with sedimentation problems. Silt and clay particles that eroded in upstream parts of the river basin sink inside the reservoirs when the water velocities stagnate. With no dredging operations being performed, this has led to a certain increase of the bed level in the reservoirs, leading into a decrease of the reservoir´s storage capacity.

Currently, it is not clear how much sedimentation actually occurs in the reservoirs. This is due to the lack of measuring equipment in the country. Conventional methods for measuring the bathymetry are either too expensive or too time consuming to be executed regularly and on such a large scale. The lack of real time information makes the volume estimations for the available amount of water stored in the reservoirs rather unreliable.

The irrigation technology centre (ITC), where this research has been conducted from, is a governmental branch which regulates the outlet of water of some of the big reservoirs in the Bago region[4]. Due to the lack of knowledge on the total amount of water reserves, the ITC is currently not able to regulate the water efficiently. Water shortages are still occurring every year, leading to a certain number of crops drying out annually. A better understanding of the water capacity inside the reservoirs would enable the ITC to regulate the water reserves with a much higher efficiency and would eventually lead into an increase of the crop incomes of the Bago region.

## *2.2 implementing new technologies in Myanmar*

**Remote sensing**
New, innovative technologies could be the answer to the problem. The ITC is in the possession of an unmanned aerial vehicle (UAV), also called a drone. The sudden emergence of these vehicles has brought about a plethora of possible usages and applications with it, provided by many different types of software. Developing a method in which the drone could be used to determine the storage capacities in reservoirs could contribute to the solution of some of the problems concerning the irrigation shortages in Bago region, and perhaps the rest of Myanmar.

In order to calculate the storage capacity of a reservoir, a DSM (Digital Surface Model) of the reservoir and the surrounding area has to be obtained. In order to do so, a software program is required in which data from drone imagery can be converted to a 3D mesh model. There are several software available, all with different options and price tags ranging from a few hundred dollars to up in the thousands. For this thesis, a software analysis has been executed. The results and findings from this research can be found in appendix B, software analysis.

From this research, an advice has been carried out to the person in charge at the ITC and the supervisor of the thesis. The Technical University of Delft and the director of the ITC have commonly decided on purchasing the Pix4D software student license, on which 25 persons can work simultaneously. This purchase has greatly contributed to the added value of the outcomes of this research, since the necessary tools and software will be available for the ITC the next coming years.

[4] Appendix A: General analysis

**Ground observation**
Remote sensing techniques, such as the drone, can be used for gaining data above the water level of the reservoirs or on reservoirs that dry up completely during the dry season. Most of the big, dam-made reservoirs in the region will however contain water all year since the outlet is positioned above the bed level of the reservoir. The software is not capable of mapping underneath the water surface.

In order to gain full information on the storage capacity of a reservoir, ground observation tools need to be included to the research. As part of the thesis, HKV lijn in water, partner of VPDelta, has provided a sonar device to implement in Myanmar. The ''Garmin Echomapper 43'', trivially named 'the Fishfinder', is an under-water sonar device commonly used by fisherman to detect fish under a boat.

HKV sees opportunities in using the Fishfinder as a cheap replacement for conventional technologies for mapping the bathymetry of rivers and lakes. The Fishfinder has already successfully been tested in the Netherlands and Ghana. A successful test with the Fishfinder in Myanmar could lead to the attention of the Myanmar authorities and possibly result in a purchase of the device for future use in Myanmar.

**New ways for data handling**
As explained in the chapter 'backgrounds', digitalizing data is something that happens rarely in Myanmar. One of the main reasons for the necessary visit to Myanmar, was the need for collecting available data for Ir. Nay Myo Lin's model. The necessary data was available, but since it was written down in books, it was not reachable. This is but one of the many examples of how the lack of digitalized data in the country causes stagnations in progress on a regular basis. Transferring the data into QGIS will solve inconveniences like this. As part of the thesis, the advantages and methods of digitalized data handling protocols were shown and taught to the persons in charge of data handling within the ministry.[5]

## 2.3 Research question

´´Can drone techniques, sonar instruments and digitalized protocols for data collection, be used and implemented in Myanmar as a method for determining the storage capacity of reservoirs in the Bago region and thus increase the efficiency of the regulation of water recourses?''

**sub questions**
- Can drone DSM modelling be used to calculate the volume in an empty reservoir?
- How will the drone software react on water inside reservoirs when modelling DSM's?
- Could the Fishfinder be used to measure capacities under water, and be combined with the drone software to obtain one complete model of the reservoir?
- Can the software be used to calculate the volumes of all the differently shaped reservoirs?
- How can the local authorities be introduced to, and convinced of the benefits of digitalized data handling?

## 2.4 Research goal

The final goal of the research is to determine if the proposed method is applicable for mapping the Ma Zin Reservoir by the ITC in the future. A positive outcome will allow the ITC staff to (independently on foreign expertises) and with an affordable budget, gain better knowledge of the available water reserves in the region. This will hopefully result in a more efficient water management and an increase of the annually grown crops in the region.

[5] Appendix J, Interviews, interview hydrology branch 04-04

# 3 RESEARCH METHODS

The activities carried out in name of the thesis research can be distinguished into three different methods: The introduction of new data handling methods using digitalized protocols with QGIS, obtaining DSM's using the ITC Drone in order to perform volume calculations using Pix4D, and using the Fishfinder for calculating volumes underneath the water surface. The methods used for these three research goals are described below.

## *3.1 Implementation of digitalized data storing by QGIS*

**Current methods**

In Bago Region, on a daily base, hydrological data like water levels, flow velocities and rainfall, is read from gauges. The observed values are then written down on paper by the person responsible for reading the measurement. At the end of every week, a phone call is given to the Ministry of Agriculture Livestock and Irrigation, located behind the ITC. Here, verbally, the observed measurements are passed to one of the staff members at the ministry. Here, the values are written down in books, containing all the collected data of the region.

In 2013, a big project was carried out for the reconstruction of the Bago-Sittaung canal. Numerous embankments were reconstructed and 203 Excavators removed 2220,000m$^3$ of soil in a period of three months. The results of this huge project are displayed at small offices, next to were the activities took place. The data on the new infra structure was however, never digitalized. In order for Ir. Nay Myo Lin to finish his model, a visit had to be payed by three students to collect the necessary data of the water related infrastructure.

During the research, Ir. Nay Myo Lin requested for available data of water levels, measured in specified reservoirs in the region. The act of collecting all data and inserting it into an Excel file took roughly one week and occupied a full team for this period of time. Needless to say, there is room for improvement of this method. All hydrological data collected in Myanmar, is collected and written down by regional offices of the Ministry of Agriculture Livestock and Irrigation. Unfortunately, data is rarely interchanged between the different offices in the regions.

**Introduction to QGIS**

QGIS (Geographic Information System) is a digital software program which can be use for the viewing, editing, storing, analyzing and calculating of geospatial data. Data obtained in the field, can be inserted in the program in order to make a digital model of the real situation. The program distinguishes vector and raster data and orders the data in different layers. Geotagged data can therefore be inserted in different layer on the right geographic location. Using QGIS as a method for data handling, allows the user to have a clear view on the data and even makes it possible to perform calculations with the available data.

In order to get a good understanding of the area that needed to be mapped for IR. Nay Myo Lin's research, a field trip was executed to the Bago_sittaung canal.[6] Different methods were used for inserting data into the QGIS program, which are broughtly explained in appendix C, QGIS manual, The QGIS model was then shown to Mr. Myint Soe, director at the Ministry of Agriculture Livestock and Irrigation. On this meeting, Mr. Myint Soe was introduced to this way of data collection for the first time and showed great interest in the technique. On his request, a GIS manual[7] was written.

[6] Appendix D, Field excursion Bago-Sittaung canal

[7] Appendix C, GIS manual

## 3.2 Usage of the drone

**Introduction to Pix4D software**

Pix4D is a professional drone-based mapping software program which can be used to make 2D and 3D models based on drone imagery. The software transforms data from several images into one model.

Stitching together the images into one model, requires accurate georeferenced information and a high quality of the pictures. That is why most commonly drones are used, although theoretically the program would also work with pictures taken by a normal camera.

In order to map a specific area, the drone needs to fly a grid on a predefined height. Every few seconds, the drone takes a picture in a specified angle. The predefined height has to be maintained at all times and the grid has to be flown as effective as possible in order to take enough pictures in the available flight time, limited by the drone's battery. That is why it is almost impossible to fly the drone manually, when obtaining datasets. Pix4D comes with an application that can be installed on any smartphone. This application allows the user to predefine a flight route and set all the necessary settings.[8]

Thanks to the drone's GPS geotag, the precise geographic location of where the images have been taken is attached as data to the pictures. This allows the software program to locate all images and stitch them in a georeferenced model. With an accuracy of 0,5m vertically and 1,5m horizontally, the drone's GPS is accurate enough to stitch 2D models and create point clouds, which are basically obtained by transforming pixels into points. In order to create a model accurate enough to perform volume calculations, a 3D mesh model is required. This is a refined 3D model based on the point cloud model. The geotag in the drone is not accurate enough to create such a model, instead, GCP's, or Ground Control Points, need to be added to the model. More information can be found in appendix F, Data collection.

The following models can be obtained using the Pix4D software:

- Orthomosaics
- Contour lines
- DSM's/ DEM's
- 3D models

On the next page, examples of these models, obtained with the ITC drone, can be found.

**Challenges for the drone**

The final goal of the research is determining whether or not it is possible to use the drone to calculate the storage capacity of some of the biggest reservoirs in the Bago Region. The research will focus on the applicability of the used method on the Ma Zin Reservoir[9], close to the ITC. As can be read in appendix E, Reservoirs around Bago, these reservoirs cover a large area with different kind of edges made from different types of materials. Besides that, trees and other vegetation enclose the reservoirs tightly, blocking the aerial view of the drone.

[8] Appendix F, Data collection

[9] More information in appendix E, Reservoirs around Bago

*Figure 6: Orthomosaic*

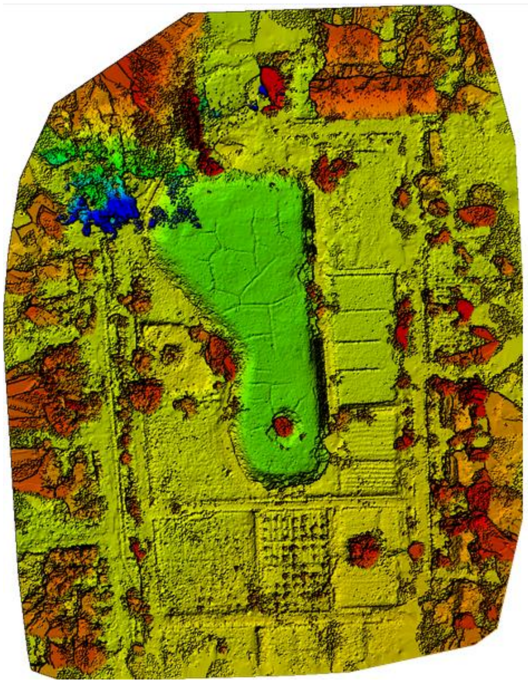


*Figure 5: DSM*

*Figure 4: Contour lines*

*Figure 3: 3D model*

**Method**

Mapping a reservoir as vast as the Ma Zin Reservoir is a highly time-consuming process[10]. This is mostly due to the limited flight time of the drone's battery, but also processing all the images in the software will be highly time consuming. That being said, there is no limit on the number of images that can be inserted in the program and thanks to the Pix4D application, numerous separated grids can be flown over the reservoir and stitched together. Therefore, theoretically, the same method can be applied for mapping the Ma Zin Reservoir as for any other smaller reservoir with the same characteristics.

Given the limited available amount of time spend in Myanmar, the Ma Zin Reservoir itself could not me mapped and modelled. Therefore, the decision has been made to test the technologies in different test pilots. The goal is to face and tackle all challenges the drone will be facing when used on the Ma Zin Reservoir by the ITC in the future.

Three reservoirs have been mapped as test pilots for this research. More information on the test reservoirs and the choice provision can be found in appendix E, Reservoirs around Bago.

*ITC reservoir*

This reservoir has been chosen for its characteristics and because it was completely dried out during the time of mapping. Volume calculations are executed widely with the Pix4D software, but these calculations always focus on a fill volume instead of a cut volume. Basically this means that a volume of soil is measured. Calculating the storage capacity of a reservoir works the other way around; the volume of air inside of the reservoir is to be measured, not the soil. This pilot will determine whether or not this is possible.

Okthoa Golf Course Reservoir

With many trees, roads and buildings positioned closely to the reservoir, the Okthoa Golf Course pond's characteristics are very similar to those of the Ma Zin Reservoir. The edges of the reservoir consist of different materials and the slopes differ strongly from each other. Besides that, is the reservoir relatively empty but is water still present. Calculating the volume of this reservoir is much more challenging than the other two reservoirs, but will also be the most similar to mapping the Ma Zin Reservoir.

Bago Fish nursery ponds

In these ponds, both the Fishfinder and the drone will be tested. The goal is to obtain both aerial and under water data. This will give the available storage capacity of the reservoir above the water surface, and an indication of the amount of water present in the reservoir. With these two datasets combined, the total storage capacity of the reservoir can be calculated, even when water is still present.

Information on how the datasets have been obtained can be found in appendix F, Data collection

[10] Appendix E, Reservoirs around Bago

## 3.3 *Usage of the Fishfinder*

**Introduction to the Fishfinder**
The Garmin Echomapper 43, from now on referred to as 'the Fishfinder', is a fishing tool consisting of a displayed controller with a transducer attached. This transducer is equipped with a 77/200kHz dual-beam sonar, which allows it to view fish, vegetation, bed levels or terrain structures in (cloudy) water at depths up to 750 feet. The images obtained can be seen live on the display of the controller, but can also be saved on an SD card. The controller features an antenna with a 5Hz GPS/GLONASS receiver. This allows the device to track your route and attach georeferenced data to the measurements of the transducer.

There are several similar tools from different manufacturers available on the market. With Garmin being one of the marked leaders, the in 2014 launched Echomap 43 is one of the best in its price range. The device comes with the free-download software program 'homeport,' which can be used to easily transfer, view and process data so it can be inserted into different software programs such as QGIS. More specifications on the Fisfhinder can be found in appendix F, Data collection.

With the Fishfinder, it is also possible to perform depth point measurements. The data from these measurements consist of a coordinate and a depth in meters. This function will be used for the reservoirs.

**Previous application and testing**
The Dutch concultancy company 'HKV lijn in water', has executed several tests with the Fishfinder. The main goal of the company is to determine if the Fishfinder can be used for other purposes as well, other than recreational fishing.

In 2015, two students of the Rotterdam University of Applied Sciences have conducted a research to the accuracy of the Fishfinder in Ghana. In this research, several aspects of the accuracy of depth measurements with the Fisfhinder led to some conclusions and advice for future data collection with the Fishfinder.[11]

Students Jesse van der Weide and Tom Arnold Bik tested the following aspects of the Fishfinder:

- General accuracy of depth point measurements with the transducer attached to the side of a boat.
- General accuracy of depth point measurements with the transducer towed behind the boat on a raft.
- Influence of an angular position of the boat on the accuracy of the depth point measurements.
- Influence of turbulent current on the accuracy of the depth point measurements.
- Accuracy of the GPS recordings.

The most important conclusions of the research are unsurprising. Measurements with an accuracy of 0.023m on average can be obtained by attaching the transducer to the side of the boat, while balancing the boat as horizontally as possible. An angle between the boat and the bed level will increase the depth measurements with approximately 12cm. The report concludes that neither a turbulent current nor a sail velocity of 5m/s will influence the accuracy of the measurements. Finally, it is concluded that the GPS tags made with the controller are highly accurate, as claimed on the Garmin website.

When testing in the field, conclusions of this research have been used to gain as accurate data as possible. Unfortunately, there is no information on the soil material on which the Fishfinder has been tested. HKV has requested for more data on the influence of different soils on the Fishfinder results, since no testing

[11] More information on previous testing can be found in appendix I, Ghana Report.

has been done yet. For this reason, a soil sample has been obtained on location. The ITC features a soil lab where the texture of ground samples can be tested. Results of the soil test can be found in appendix M, Results Soiltest.

Colleague student Leon Brok from the Rotterdam University of Applied Sciences, has conducted a similar research with the Fishfinder in Myanmar. His research focusses on comparison of the Fishfinder with conventional methods used in Myanmar. The soil sample from the reservoir will be compared to his conclusion. Since the thesis focusses on whether or not it is possible to include underwater data in 3D models for volume calculations, no deeper focus will be put on the accuracy of the measurements in the reservoir.

**Benefits in comparison to conventional techniques**
In general, the Myanmar authorities lack huge amounts of data on bathymetries of rivers, reservoirs and lakes throughout the country. The biggest reason for this is the lack of expensive monitoring equipment. Currently, there are two devices available in Myanmar which can be used for gaining bathymetry data: The Sonek m9 and the Sonek s5. Unfortunately, the hydrology branch could not give clear information on the pricing, but the cheapest models on the internet cost roughly 9.000 USD. In appendix H, Field report measuring the Bago river, the used method for the m9 is described. 4 people are needed to operate the device and within the hydrology branch, only 2 persons know how to process the software.

The Garmin Echomapper 43, is already available starting from $320 US. It can be operated by one person and one boatman. The necessary amount of time for measuring, is completely dependent on the size of the area that needs to be mapped and the boat's velocity. Taking a measurement every second, the boat can sail at maximum speed and still gain enough clear data. Therefore, the Fishfinder is not limited by a maximum flow velocity, unlike the Sonek devices which are operated manually using a rope.

Processing the Fishfinder data can be done by a single staff member and is found to be much easier than processing the Sonek data, of which only two people are capable of in the entire Hydrology Branche.[12]

**Goals for the Fishfinder**
As described earlier in paragraph 3.2, the drone is not capable of measuring bathymetry under water. The big reservoirs in Bago Region never dry out completely, because the outlet is positioned above the bed level. Therefore, in order to gain full storage capacity data, an underwater bathymetry measurement tool, like the Fishfinder, is needed.

Introducing innovative, but more important, affordable techniques and equipment in Myanmar is an important part of the thesis project. Conducting a successful research using the Fishfinder will hopefully draw positive attention from the Myanmar authorities to the technique. Since bathymetry data is lacking throughout the country, ideally the Fishfinder could be introduced as a cheap variant for the expensive conventional methods and could be used for many different purposes, including measuring reservoirs, in the future.

**Method**
The Fishfinder measures depth point locations, meaning that a certain value of a water depth (m) is measured at a particular geographic location. The exported data from Homeport[13] to any other software program will contain a longitude, latitude and depth point measurement. The amount of time between each measurement can be preset manually on the device. Since the test pilot will be executed in a fish pond, there is a good possibility for flawed data to occur due to fish swimming underneath the sonar

[12] Appendix H, Field report measuring the Bago river.
[13] Appenidx F, Data collection

device. Therefore, the settings are preset to take a measurement every second. This way flawed data can easily be detected and removed from the dataset.

The accuracy research that has been conducted on the Fishfinder in Ghana has concluded that the most accurate data can be obtained by attaching the transducer next to the boat, rather than towing a raft behind it.[14] Based on this conclusion, it has been decided to craft a frame out of a pallet, similar to the experiment in Ghana, to perform the measurements. In appendix F, Data collection, more information can be found on preoperational measures for the Fishfinder.

The depth measurement points have been inserted into GIS together with the stitched, 2D mosaic model made in Pix4D. Thanks to the geotag-based datasets, the two models align with each other. The border of the reservoir will be set on h=0m. All the measurement points inside the reservoir contain their own depth measurement. With this information, the total volume can be calculated.

***Figure 7: Fishfinder data aligned with Pix4D orthomosaic***

[14] Appendix I, Analysis Ghana report

# 4 RESULTS

## 4.1 Process in obtaining results

Several different steps in processing must be taken in Pix4D before volume calculations can be made. The Flowchart below gives a representation of the different phases and intermediate outputs of the process.

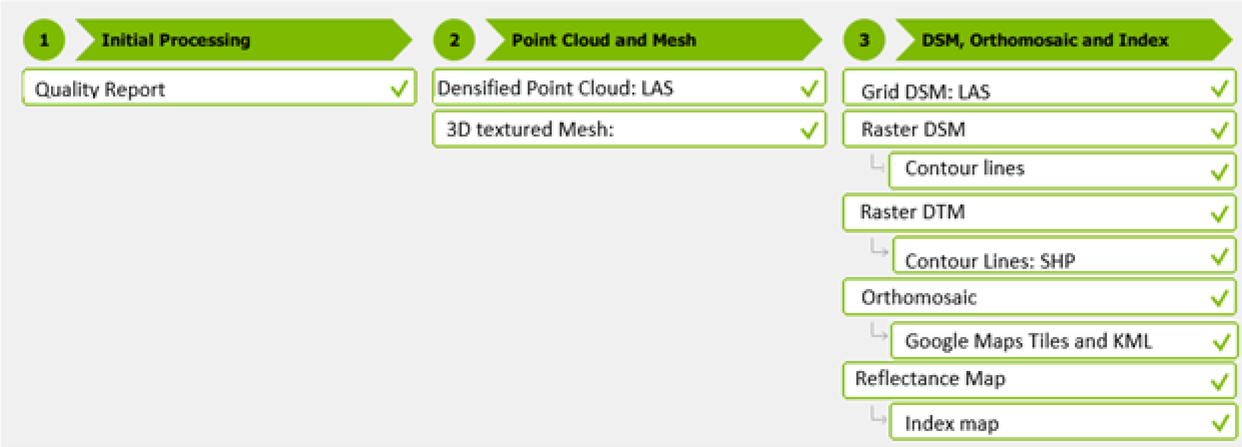



*Figure 8: Flowchart of Pix4D processing (SOURCE: Pix4D program)*

In the first step, a model made out of individual points is obtained. The other two steps in the process are necessary for creating more point in the model in order to densify the cloud. The images below show the density of a model in different steps of the process.

**Initial processing:**
In this phase of processing, the images inserted in the program are matched, calibrated and georefferenced.

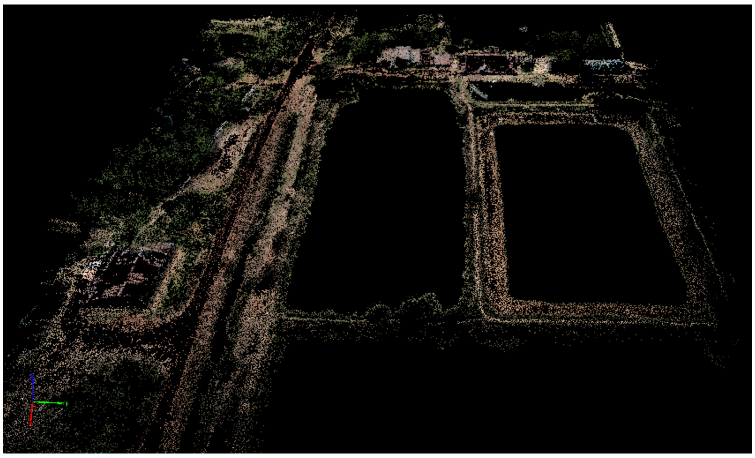


*Figure 9: Ray cloud after first processing step*

**Point Cloud and Mesh:**

In the second processing phase, the ray cloud is densified into a point cloud and Mesh. This is also the phase where GCP's, as described in chapter 4.2, can be inserted into the program. Inserting GCP's into the model increases the number of points in the model by 4 times. The number of points in the cloud model determines how detailed the model is, more points give a denser model.

***Figure 10: Ray cloud after performing second processing step***

**DSM, orthomosaic and Index:**
Only when this last step of processing is done, volume calculations can be obtained in the model

***Figure 11: Ray cloud after third processing step***

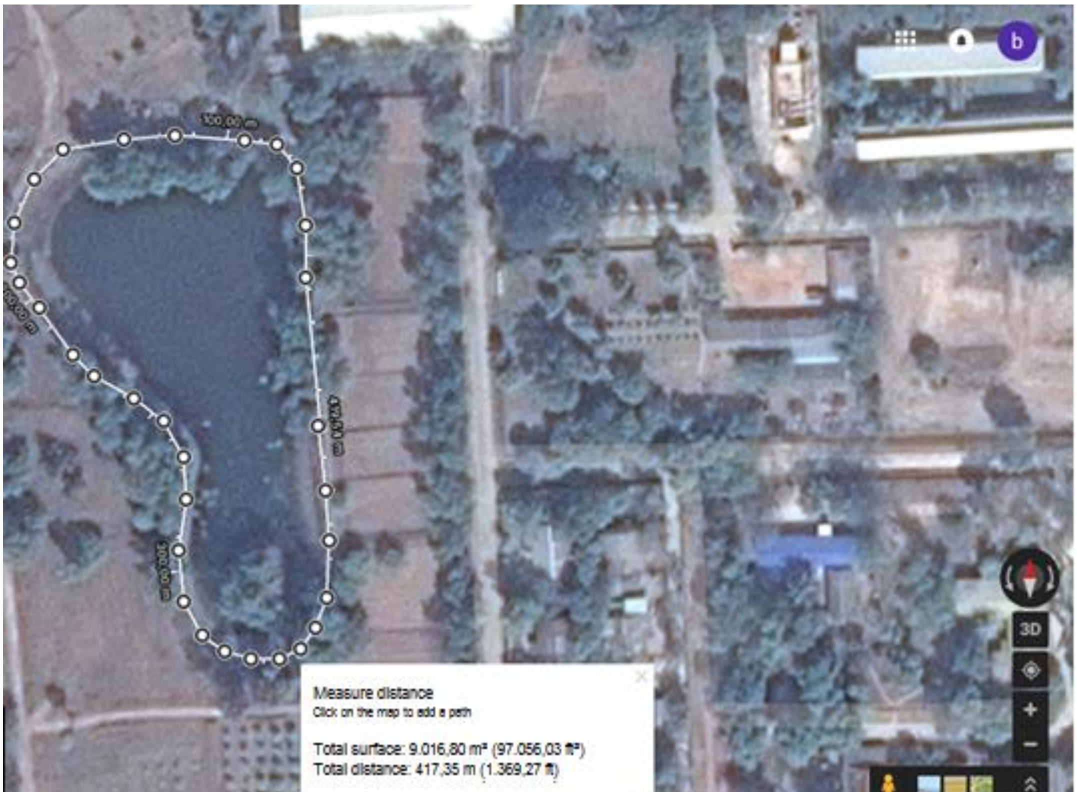
Images 3,4,5 and 6 on page 14 show the other results which can be obtained after the last step of processing.

## 4.2 *ITC reservoir*

The ITC reservoir is an excavated reservoir of which there are abundant in the Bago region. The reservoirs served as a first testing pilot to make sure whether or not if it is possible to perform volume calculations of empty volumes with the software.

**Expectations**

The total area of the reservoir can be measured in the program. The program measured an area of 9285m$^2$, which is close to the value of 9017m$^2$ measured in google maps.


*Figures 12 & 13: Area ITC pond measured in Pix4D and Google Earth*

The average depth of the reservoir is 3.5m, meaning that the volume calculation should roughly indicate a volume of around 31,500m$^3$. The first calculation however, gave a very different value.

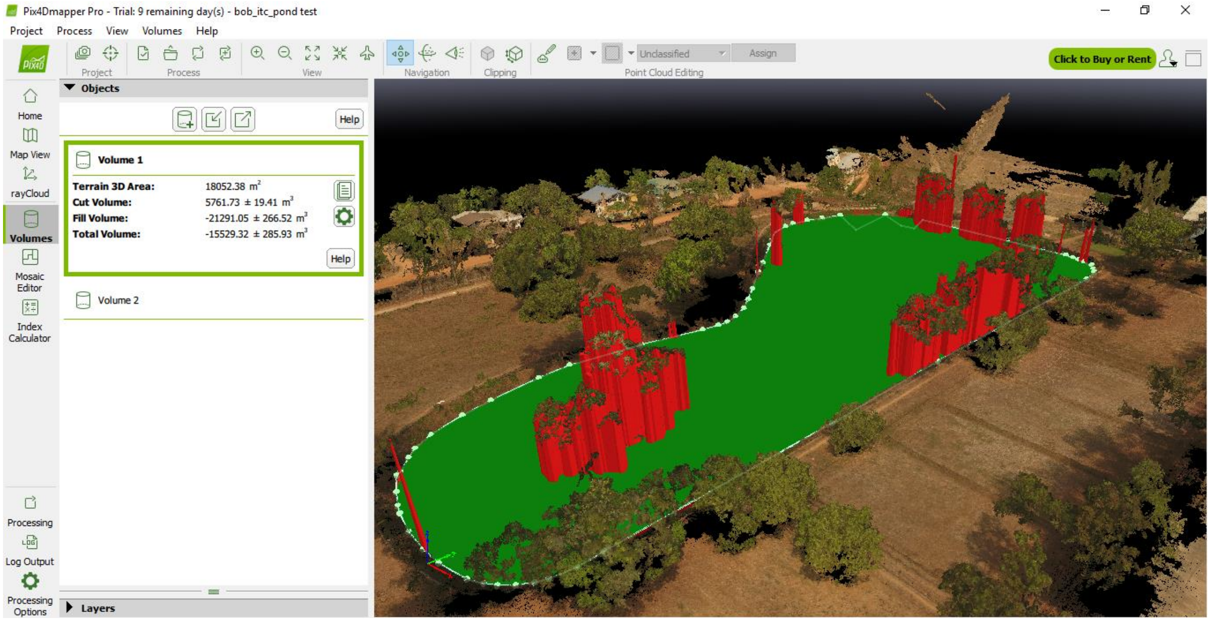



***Figure 14: First outcomes volume calculation***

The program calculated the volume as 21.300m$^3$, a miscalculation of about 30%. On the image above, the cause for this underestimation is clearly visible:

The program calculates the dense points of the trees' canopy as a cut volume, meaning that, according to the program, water cannot be stored in these locations because there is no 'empty volume' at this point.

In order to solve this problem, the flaw dense points had to be removed from the project. On the image below, a small soil hill with a tree on top of it inside the reservoir is visible. The soil hill is an actual volume and cannot contain water, however, the canopy is much higher than the edges of the reservoir and will therefore not decrease the storage capacity.

In the ray cloud, dense points can be removed from the model by drawing a polygon around the unwanted points. This way the canopy can be removed, together with the canopy of the surrounding trees.

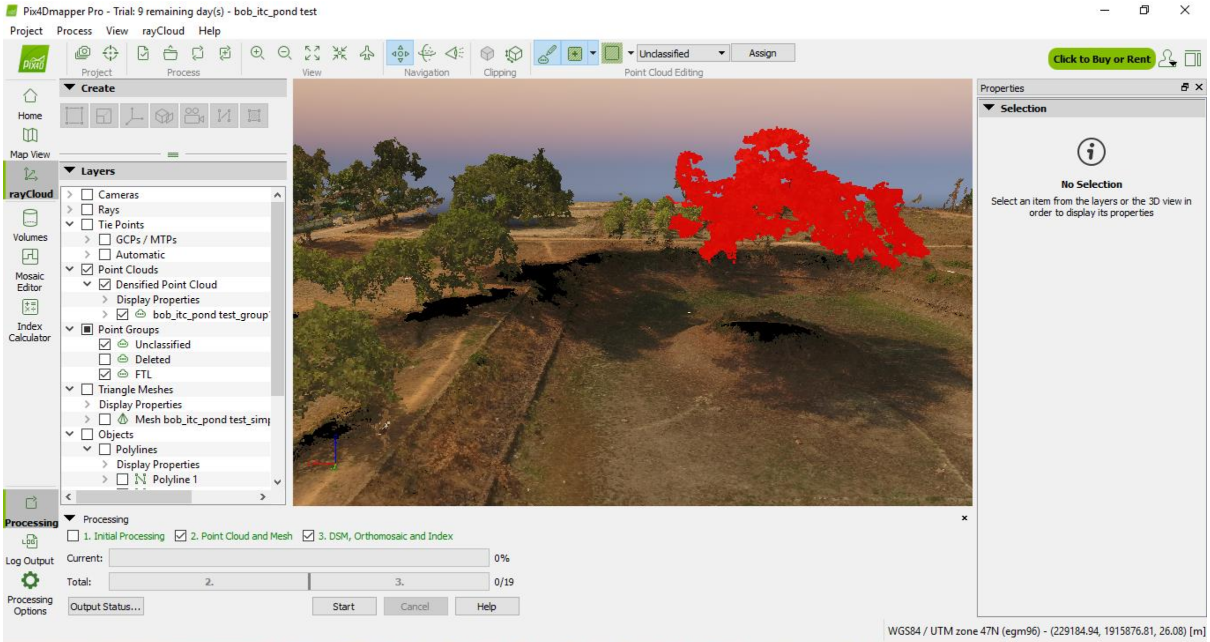



***Figure 15: Removal of interfering canopy pixels***

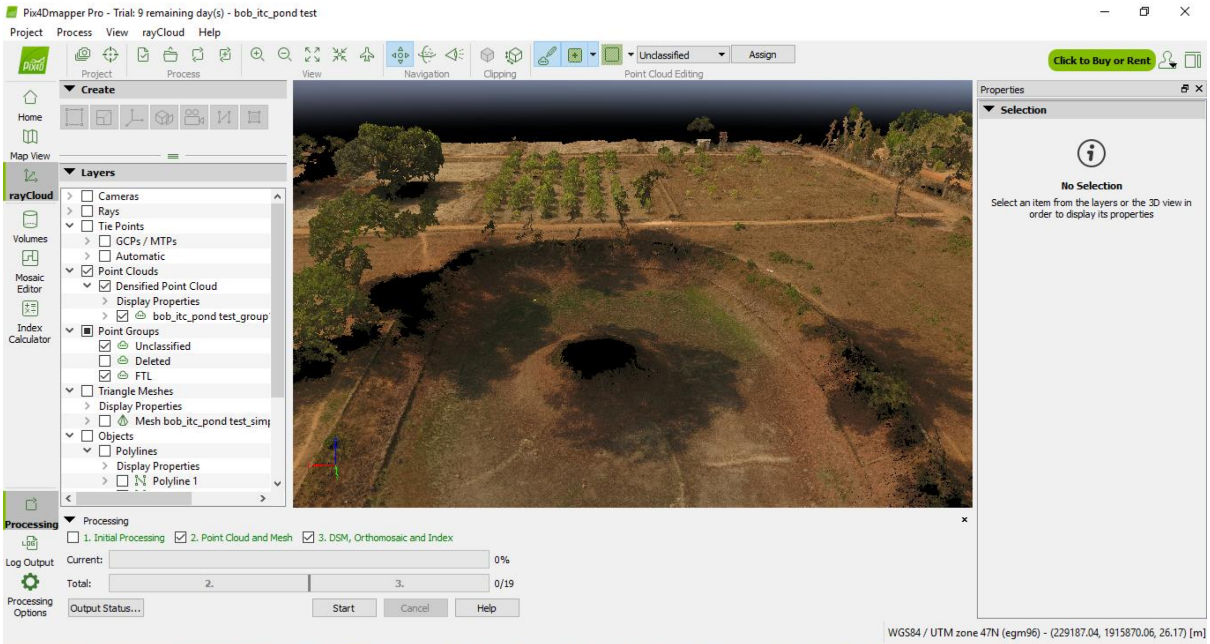



***Figure 16: Removed canopy***

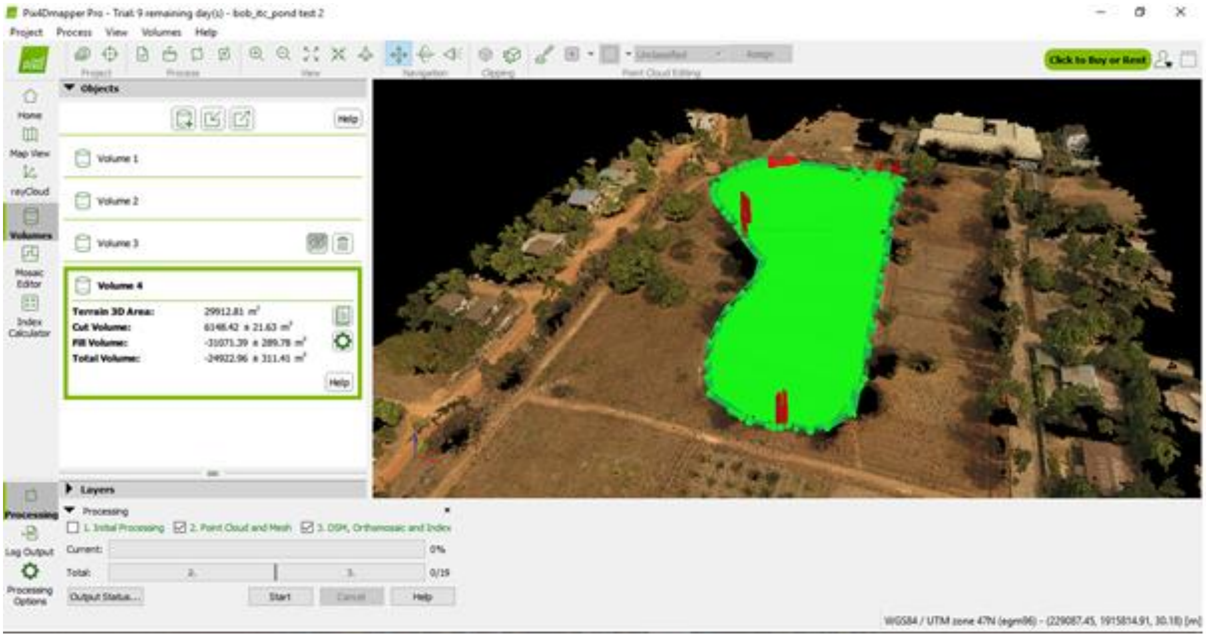



*Figure 17: Second outcomes volume calculation*

After removing all obstacles from the model, a new volume calculation has been executed. The program now calculated a volume of 30.940m$^3$, which is very close to the estimated volume. The first conclusion, and the answer to the first research question can hereby be given: It is possible to use the pix4d software to calculate the empty volume of a reservoir.

## 4.3 Golf Course

The Okthoa Golf Course Reservoir was expected to be much harder to map than the ITC reservoir. First of all, the surface area is significantly larger. The flight height had to be increased by 30m in order to map the reservoir in one flight. Second, the reservoir contains many obstacles next to the water and the slopes of the reservoir are barely visible from the sky at some places. Third, this reservoir contains water which will complicate the process.

In the ray cloud, it was clearly visible that the program responds very differently to the water surface than to normal ground. The program has converted the smooth water surface into green cloudy lumps of dense points.

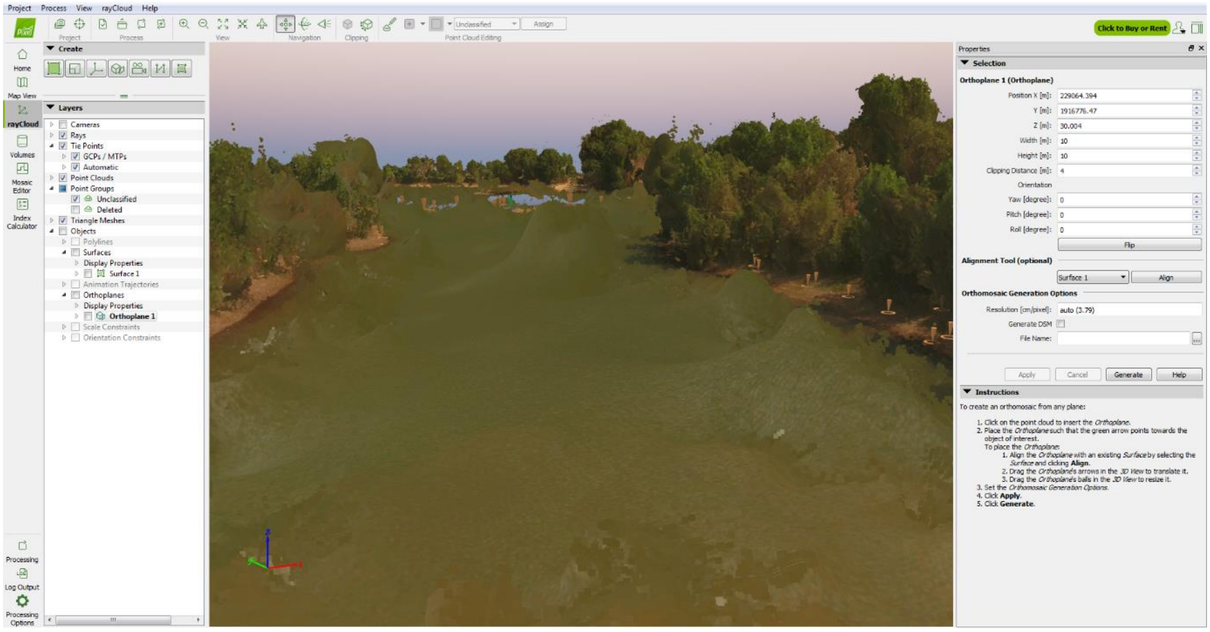



***Figure 18: Green dense lumps on water surface in ray cloud***

In the volume calculation screen, the lumps have disappeared and there are no points visible at the water surface. It is clear that the program is not able to map water surfaces. This is no surprise, since this is clearly stated on their website.

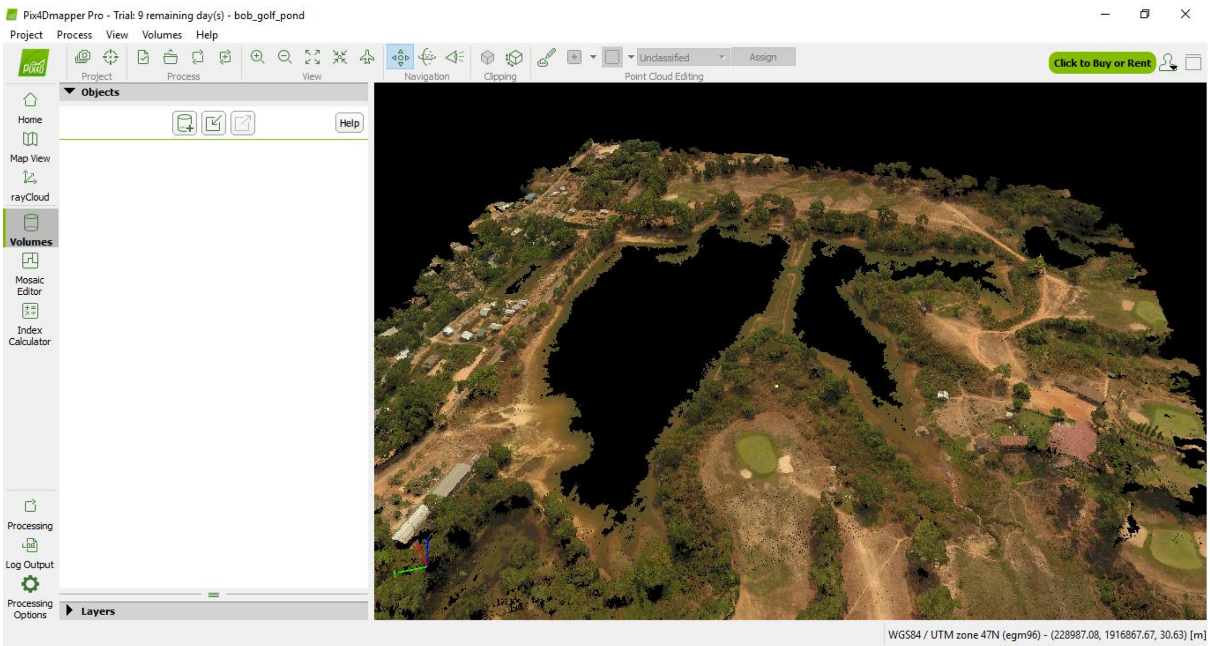



***Figure 19: Ray cloud view Golf Course Reservoir***

Unlike the water surface inside the reservoir, the surrounding shore is very clear and is mapped in high quality. A first volume calculation was executed in order to determine if the program is able to calculate the volume of the empty pixels. Ideally, the program will determine the lowest visible point as the bottom and calculate the volume between that point and the drawn polygon.

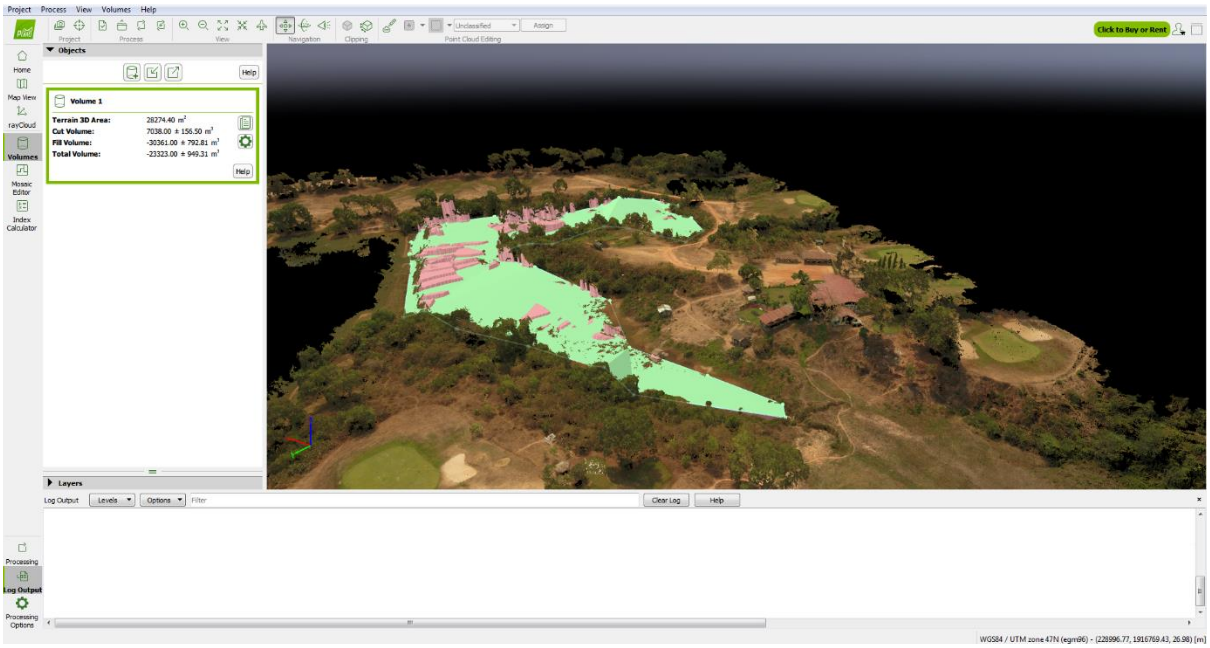



***Figure 20: First results volume calculation***

The first results are very promising. The program is able to calculate the volume of the seemingly empty reservoir and shows no errors. Unfortunately, the calculated volume of 30.000m$^3$ is extremely over calculated. The reservoir has a surface of roughly 19.000m$^2$ and according to the golf course manager, the water rises up to almost the top of the sand bank in the middle of the reservoir, about 0.80m above the water surface. The estimated volume of the reservoir is 0.8m * 19.000m$^2$ = 15.200m$^3$.

In the volume calculation screen, a lot of 'noise' is visible around the edges of the reservoir. The program has processed dense points on a height of about 2m above the reservoir. This has led to a big increase in the calculated volume.

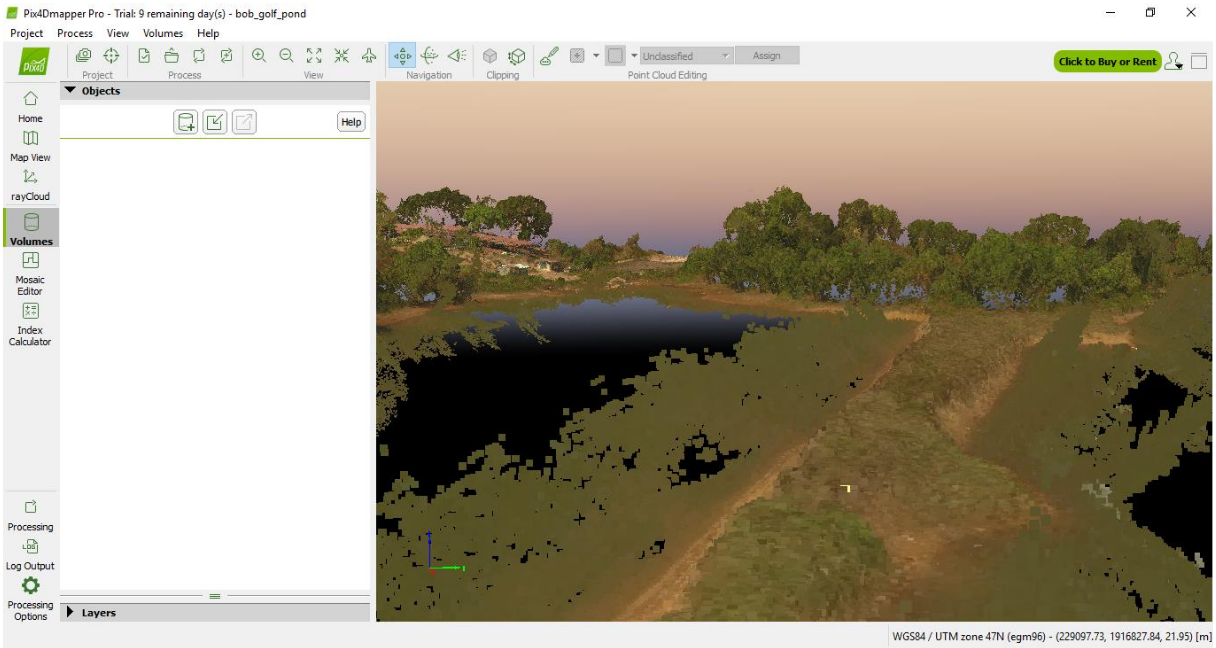



*Figure 21: Noisy pixels in ray cloud*

Using the same method as was used in the ITC reservoir, the unwanted pixels can be removed from the model. The pixels are present on every location where the water surface meets the edge of the reservoir.

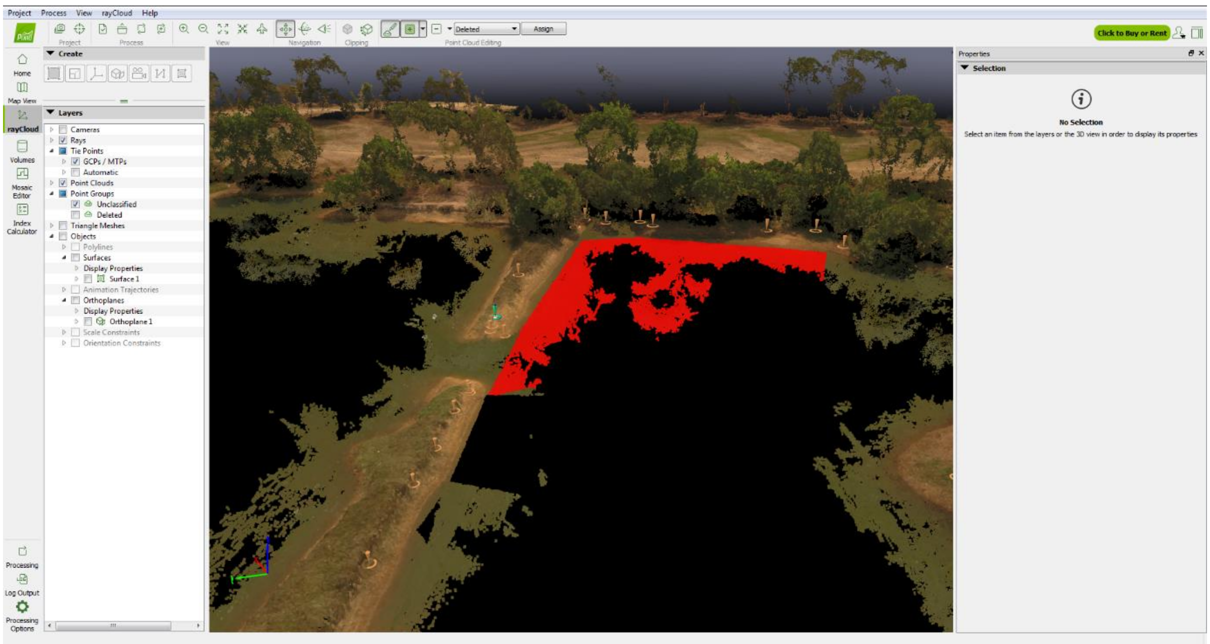



*Figure 22: Process of removing noisy pixels*

After deleting the noise pixels, the volume calculation has been performed again. This time, fewer red cut volume was vissible in the calculation and the calculated volume almost halved. The program now calculated a volume of 16.600m$^3$, which is close to the estimated 15.200m$^3$.

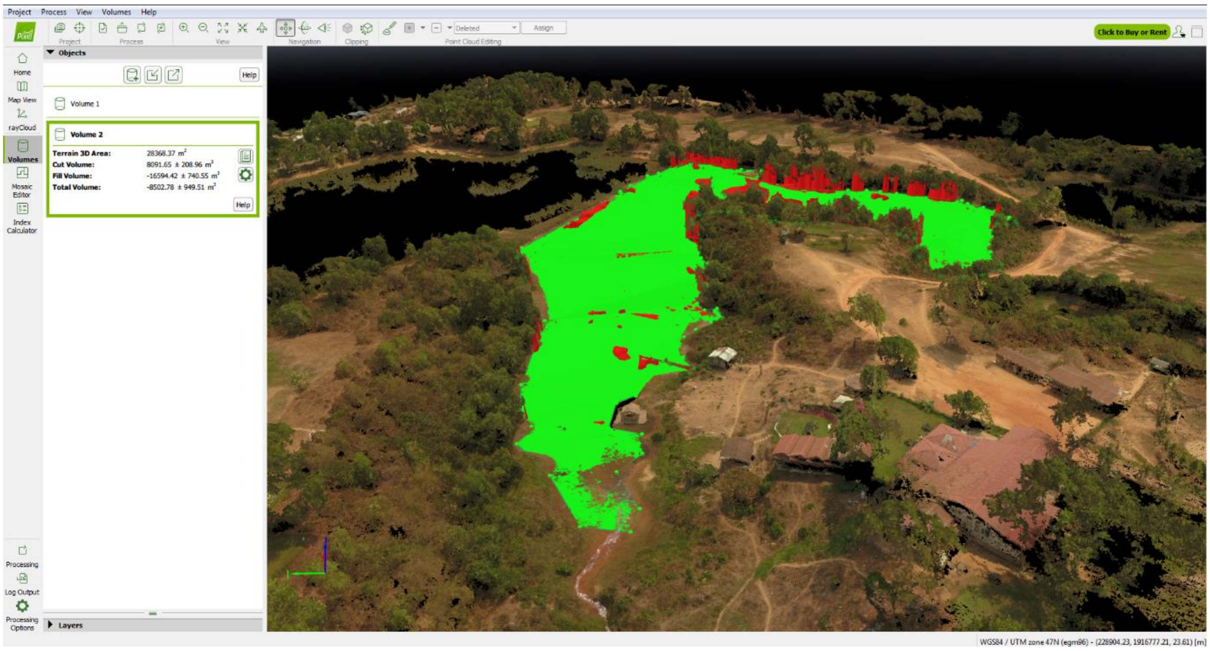



***Figure 23: Results volume calculation***

From this results, it can be concluded that it is indeed possible to perform volume calculations on a water surface, as long as some modifications to the model are made first. Hereby, the second sub question of the research is answered as well.

## 4.4 *Fish pond*

The last field trip served as a global testing pilot for numerous aspects to the drone. Therefore, a relative small and easy to map reservoir was chosen. The demands to the reservoir were the presence of water with a maximum water depth of at least 1.5m, clearly visible slopes and steep edges. Therefore, the Fishponds were the ideal location. Since the fish nursery contains many different ponds, it was possible to fly the drone over several different ponds, two flights have been executed.

### 4.4.1 *First dataset: Combining pix4d with Fishfinder*

Thanks to the smaller size of the reservoir, the flight altitude could be adjusted to just 40m, giving a very dense model. Some trees and bushes were present at the reservoir, positioned very closely to the water. Before volume calculation could be executed, these obstacles, together with noise pixel next to the shores, had to be removed.

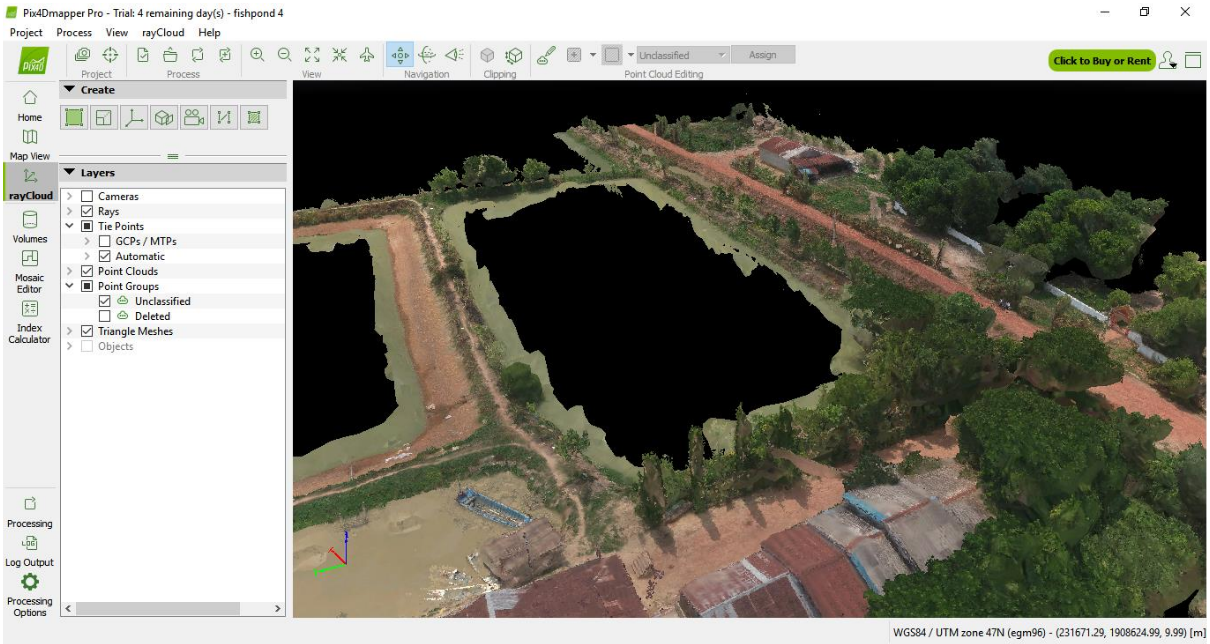
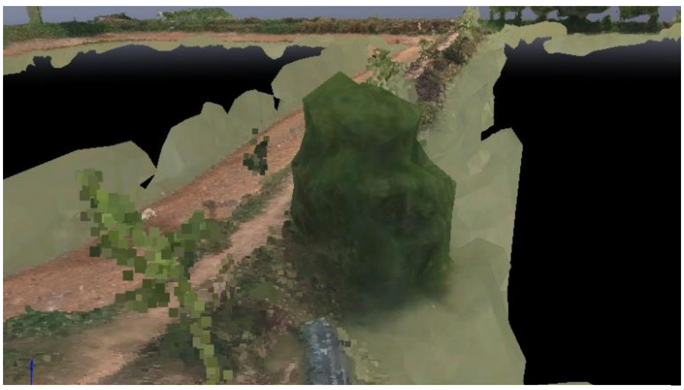
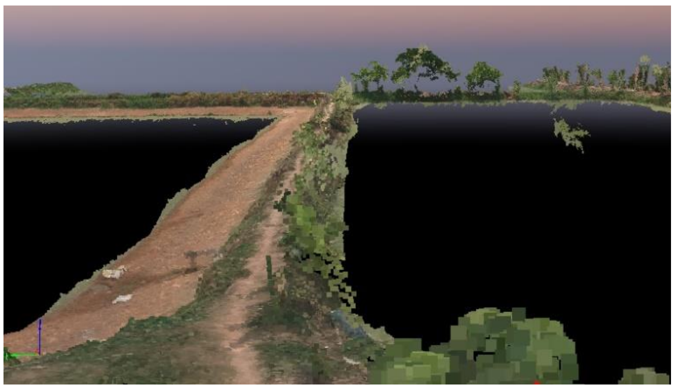



***Figure 24: Ray cloud Fishpond 1***





***Figures 25 & 26: Removal of interfering pixels***

The fish pond has a surface of 7.260m$^2$, measured in google maps. On side, it was estimated that roughly 1m of water could be stored on top of the available water inside the pond. The measured volume of 6.700m$^3$ , found on the next page, is 7% lower than the estimated volume and is considered reliable.

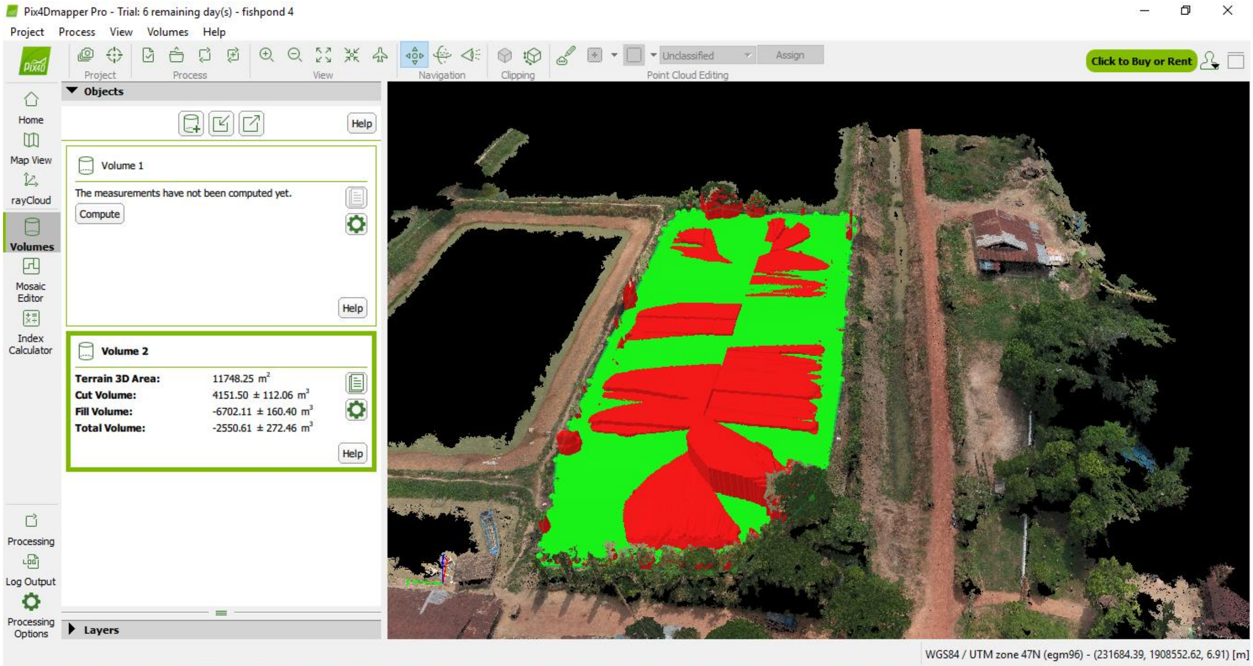



***Figure 27: Outcomes volume calculation***

## Results Fishfinder

In order to calculate the amount of water inside the fish pond, a different program had to be used. The decision has been made to use QGIS, since it is a free to use software and the staff of the ITC has completed a QGIS course in the same period as the research has been conducted. Since the staff already knows how to work with QGIS, gaining result with this program will be beneficial to the ITC if volume calculations will be executed by the staff in the future.

Although it was expected that some of the measurements taken in the pond would be influenced by fish swimming underneath the transducer, no flaw data was found in the whole dataset. Due to the transducer being positioned underneath the water surface, 34cm[15] was added to every measured value in Excel.

On image 7 on page 18, the results of the Fishfinder inside the pond can be seen. Every green dot on the image contains a depth measurement in meters. In order to gain depth data (estimated) of the full surface of the reservoir, these measurements had to be interpolated. The image below has been obtained by using the function *interpolation* in the *raster* tab in QGIS. Every pixel in the model, contains a value between 0m and 2,86m, which are the maximum and minimum measured values.

***Figure 28: Values Fishfinder aligned with drone's orthomosaic***

[15] Appendix F, Data collection.

In QGIS it is possible to calculate the average value of all pixels in the raster. In appendix F, Data collection, a brief explanation is given on how this is done. The image below shows the results from the attribute table, containing the calculated values obtained when following the instructions in the appendix:

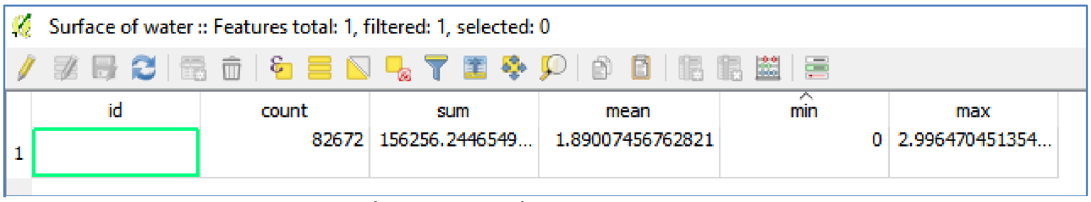



***Figure 29: Outcomes zonal statistics (SOUCRE: QGIS)***

The table above shows that the sum of all pixels is 156256,2 meter. In the *layer properties* of the newly created metadata layer, the pixel size can be found.

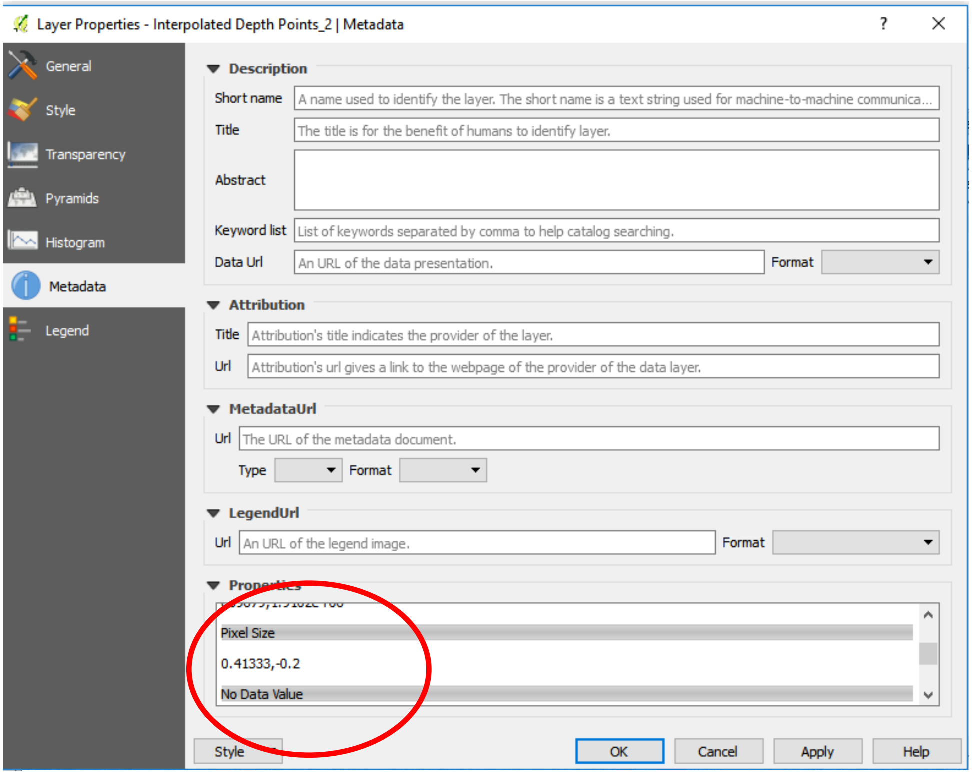



***Figure 30: Layer properties screen (SOURCE: GIS)***

When the project CRS is set on UTM projection, the pixel size is given in meters. Meaning that every pixel has a surface of 0,413*0.2=0,826m$^2$. By multiplying the sum of all values by the pixel size in meters, the total volume can be calculated:

156256,2m * 0,826m$^2$ = 12.917m$^3$

Together with the Pix4D results, now can be concluded that a total volume of 12.917 + 6.702 = 19.619m$^3$ can be stored inside of the reservoir and that, at the time of measurement, the reservoir was filled for 34%. With this test result, the third research question has been answered. Since volume calculation have now been performed successfully on all three different shaped reservoirs, the answer to sub question 4 has been given too.

### 4.4.1 *Second dataset: determining the accuracy of volume measurements without inserting GCP's into the project.*

If the research comes up with successful result and the Myanmar authorities are interested in using the drone to map reservoirs in the future, the ITC might become interested in faster ways of using the drone to determine storage capacities. The act of determining the exact location of the GCP's is by far the most time-consuming activity in the process. The second dataset has been processed in the program without including GCP's in the model in order to determine if accurate volume calculations can still be obtained without the time-consuming act of including GCP's.

**First results**

Since no GCP's were added to the project, only 4 times less points were created in the point cloud. This decreases the processing time by roughly 75%, but also leads to a quarter less points in the dense cloud. The obtained ray cloud was visibly less detailed but still looked promising since the reservoirs were clearly visible.

**Volume calculations:**

Similar to the Golf Course Reservoir, some noise in the pixels around the edges of the reservoir was visible. In order to perform clear volume calculations, this noise had to be removed. Then, the volumes of three fishponds included in the dataset have been calculated. The volumes of Fishpond 1 and 2 have already been calculated, the results will be compared with each other to determine the accuracy of volume measurements without inserting GCP's in the project.

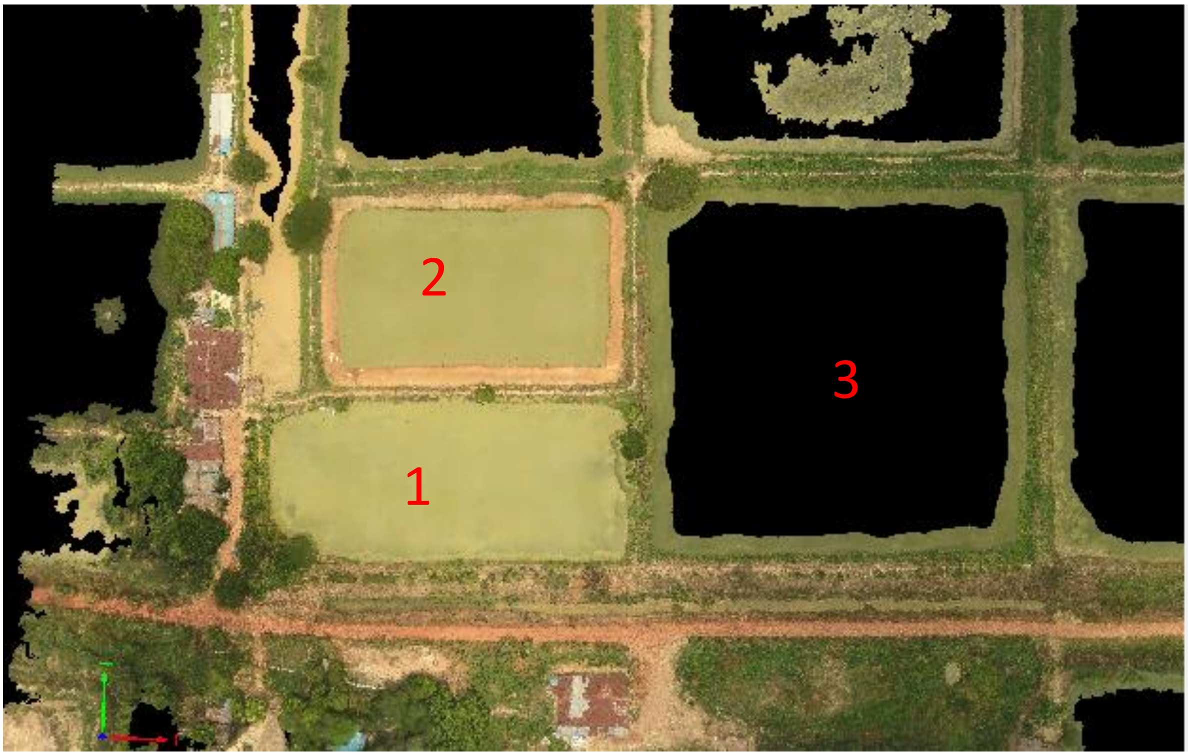



***Figure 31: Numbering fishponds***

The second fishpond can be clearly distinguished between a sandy slope and a vegetated slope[16]. The volume has been calculated on both edges of the pond.

The table below shows the results of the measurements.

***Table 1: Results volume calculations***

| Reservoir | Dataset 1 | Dataset 2 | Estimation |
|---|---|---|---|
| **Fishpond 1** | 8.730m$^3$ | 10.340 m$^3$ | 10.200 m$^3$ |
| **Fishpond 2a** | 6.720 m$^3$ | 6.490 m$^3$ | 5.400 m$^3$ |
| **Fishpond 2b** | 17.910 m$^3$ | 16.490 m$^3$ | 16.300 m$^3$ |
| **Fishpond 3** | - | 38.550 m$^3$ | 36.000 m$^3$ |

[16] Appendix F, Data collection

## 4.5 Additional tests

### 4.5.1 Obtaining depth storage curves

Most of the smaller reservoirs, like the ITC reservoir, which can be found in small townships and villages run out of water completely at the end of the dry season. For the people using these water reserves, a good understanding of how much water is left at any time would increase the efficiency with which they could use their reserves. Additional to the original research questions, ways for obtaining a Depth Storage Curve have been looked into.

The goal is to place a gauge in the reservoir which indicates the water level. Then, by creating a graph using Pix4D, the available amount of water inside the reservoir can be read from this graph.

In order to do so, 4 different surfaces have been drawn inside of the reservoir on 0m, -1m, -2m and -3m measured from ground level. The volume calculated at 0m is the total storage capacity of the reservoir.

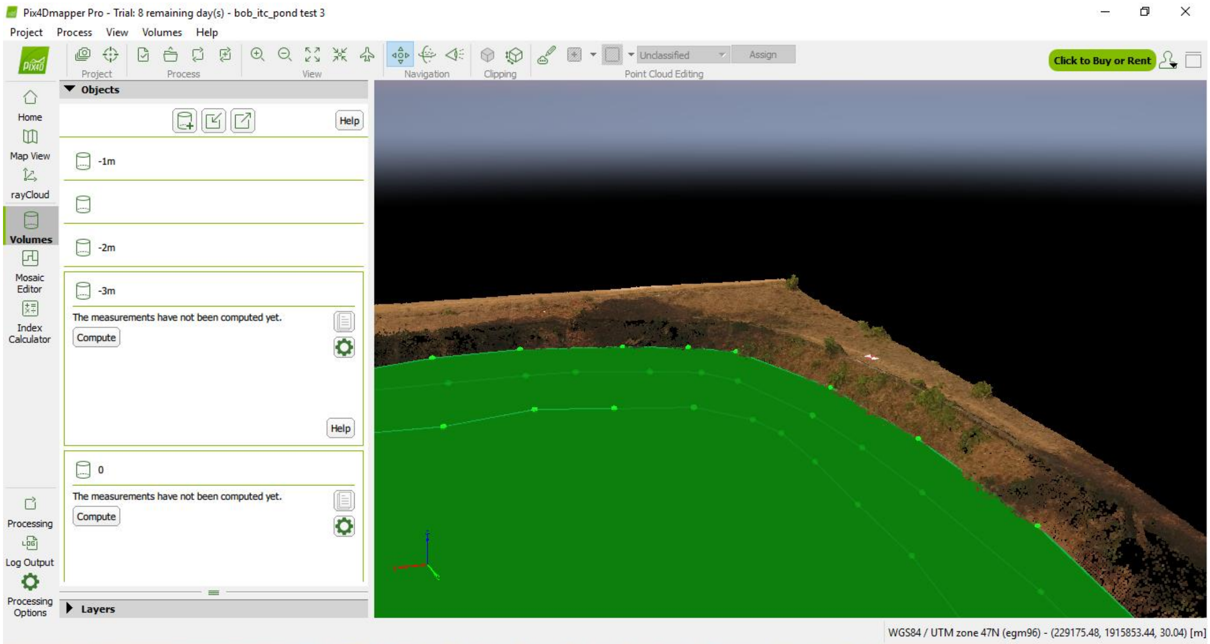



*Figure 32: Different volume polygons drawn above eachother*

The following volumes have been calculated:

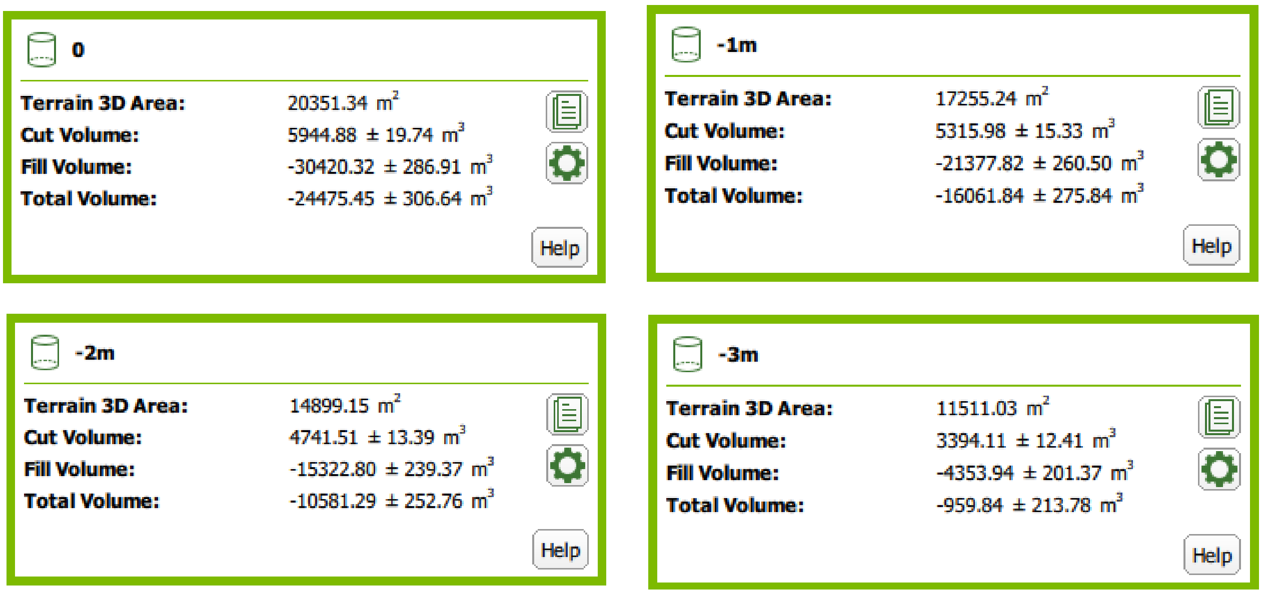



*Figure 33: Results volume calculations*

These volumes have been inserted into Excel to create a DSC.

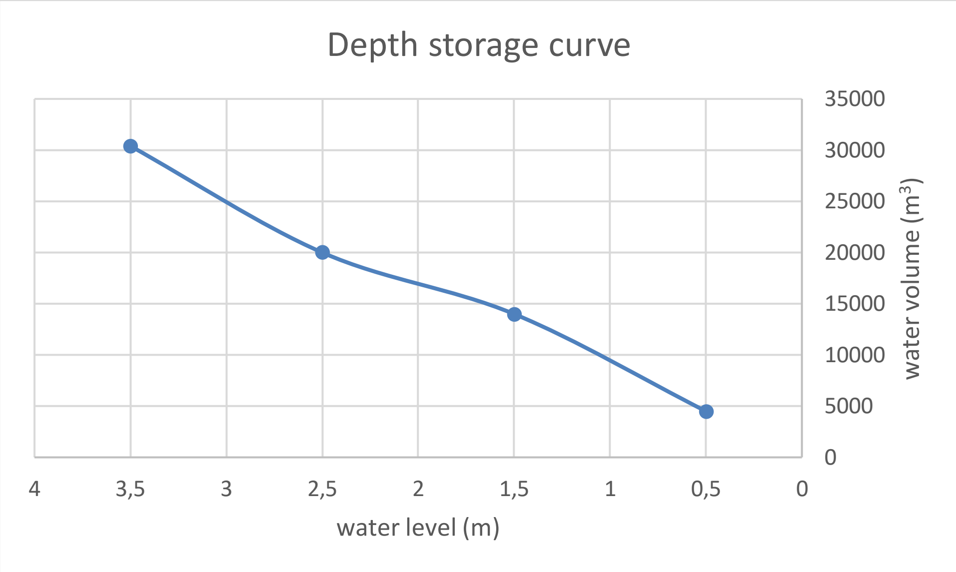



***Figure 34: DSC ITC Reservoir***

The graph gives an indication of the amount of water stored inside the ITC reservoir at a certain water level, but the accuracy of this graph should be questioned. Taking the shape of the reservoir into account, an exponential curve would be more realistic. Due to the angular edges of the reservoirs, the area of the water surface increases as the water level rises. This leads to a bigger volume of water being add to the reservoir. The polygons were drawn roughly 1 meter above each other, but since no reclamation points were added to the reservoir at the time of mapping, it was hard to determine the exact height. Still, the obtained graph should give a good representation of the situation.

## *4.5.1 Accuracy without GCP's*

The table below shows the results of the volume calculation with and without GCP's

| Reservoir | Flight heigth (m) | Area google maps ($m^2$) | Area Pix4D ($m^2$) | Estimated volume ($m^3$) | Calulated volume ($m^3$) | Time needed for clearing the model |
|---|---|---|---|---|---|---|
| **ITC reservoir** | 50m | 9.032 | 9.258 | 31.500 | 30.190 | 0,5 hour |
| **Golf Course** | 80m | 19.130 | 18.740 | 15.200 | 16.600 | 1,5 hours |
| **Fishpond 1.A** | 40m | 7.260 | 7.200 | 10.200 | 8.730 | 0,5 hour |
| **Fishpond 1.B** | 70m | 7.260 | 7.270 | 10.200 | 10.340 | 0,5 hours |
| **Fishpond 2 sand, A** | 40m | N/A | 7.195 | 5.400 | 6.720 | 15 minutes |
| **Fishpond 2 sand, B** | 70m | N/A | 7.140 | 5.400 | 6.490 | 0,5 hour |
| **Fishpond 2 grass, A** | 40m | 7.800 | 7.900 | 16.300 | 17.910 | - |
| **Fishpond 2 grass, B** | 70m | 7.800 | 7.680 | 16.300 | 16.490 | - |
| **Fishpond 3** | 70m | 18.080 | 18.150 | 36.000 | 38.500 | 0.5 hour |

***Table 2: Results volume calculations fishponds***

Fishpond datasets A are with GCP's
Fishpond datasets B are without GCP's
Fishpond 2, sand is measured on the sandy edge
Fishpond 2, grass, is measured on the grass edge

| Reservoir | Inaccuracy | Direction |
|---|---|---|
| **Fishpond 1** | 3% | Under calculated |
| **Fishpond 2, sand** | 16% | Over calculated |
| **Fishpond 2, grass** | 8% | Under calculated |

***Table 3: Accuracies in %***

The results are rather remarkable. Some of the measurements give an overcalculation to the first datasets while others give a lower value. In two of the three measurements, the calculations from the dataset without GCP's are even closer to the estimated value

# 5 CONCLUSIONS

## 5.1 *Introduction of new technologies*

During the staying in Myanmar, three new methods for data collection have been introduced to the authorities. Mr. Myint Soe, director of the Ministry of Agriculture Livestock and Irrigation, was introduced to the benefits of digitalizing data using QGIS and personally requested for a manual to use this program. The decision was made not to write a manual on how to work with the software, but rather to emphasize the benefits of new ways of data handling, compared to the current method. The own excecuted activities served as examples for this manual.

3 field excursions have been carried out together with coworkers of the ITC, to fly the drone over different reservoirs and obtain datasets for executing the volume calculations. The ITC staff is able to perform every step in the progress of volume calculation completely by themselves. The positive outcomes of the research will hopefully inspire them to proceed the activities of volume calculation in the future on the locations were the data is most needed.

The same staff was present at- and helped with, the activities concerning the data collection using the Fishfinder. The staff has broadly been introduced to the method of using the Fishfinder and the collected data has been shared with Mr. Sai Wunna, staff director at the ITC. After finishing the research, the outcomes and used methods of the QGIS volume calculations performed with the Fishfinder have been carried out to the right persons within the ITC.

## 5.2 *Answers to the research question*

´´Can drone techniques, sonar instruments and digitalized protocols for data collection, be used and implemented in Myanmar as a method for determining the storage capacity of reservoirs in the Bago region and in the way increase the efficiency of the regulation of water recourses?´´

No big errors in the obtaining and processing of all 4 datasets have been encountered and all results were very plausible in comparison to the estimated values. The positive answers to the first 4 sub questions of the research have determined that calculating the storage capacities using the tested techniques is indeed possible and has a tremendous potential for Myanmar in the future. The research has tested and demonstrated possible methods for using new techniques in Myanmar, some being already available and others being obtainable and affordable.

## 5.3 *Exposition of the 5$^{th}$ sub question: Improvements of current data processing in Myanmar*

A good management of the available water recourses is one of the key elements for every country to have control over, in order to sustain a successful society. Myanmar as a country, features amazing natural resources and has great potential in context of crops production on a world-wide scale. However, the extreme differences in the country's climate between the different seasons makes it that the country is experiencing problems today, and challenges tomorrow.

Living in Myanmar for 10 weeks, while being dependent on local authorities, has emphasized how the lack of structure between the different ministries slows down important processes tremendously. The current method that is carried out for the collection, handling and storing of hydrological data is outdated, inefficient and insufficient to withstand the challenges the country is facing. In order to gain full control on the water management and a maximum efficiency of natural recourses while maintaining nationwide safety against flood hazards, the Myanmar authorities will have to implement new and more efficient ways for data handling and collection. More importantly, the different regional authorities will have to join forces, work together and interchange data structurally. Currently, data is measured by eyes, written by pen, and stored on paper. Digitalizing this system will solve most of all above stated problems.

The lack of new technologies has led to an absence of data as well. Filling up this gap in data absence, by implementing affordable methods of data collection, is a high priority for the country. The goal of this thesis was not just to determine if it is possible to calculate storage capacities in reservoirs, it was about analyzing the country, finding bottlenecks in any way, and find ways for improvement. The research has deflected from finding a way to design, calculate or build a civil structure, into finding ways of collect data more efficiently, as clear data is the key for every successful civil project.

Midway the research, the need for- and absence of clear data on the water reserves stored in reservoir was found to be a solvable problem with a high priority. The positive outcomes of the research will hopefully not only contribute to a better understanding of water reserves, but has also been a small step in the process of the introduction of the highly needed standardizing of protocols in Myanmar.

## *5.4 Additional outcomes*

Due to the quick, positive results and answers to the research questions, there was room for deepening the research. Additional to the original research questions, two more experiments have been executed.

### *5.4.1 Speeding up the process of volume calculations*

The results from chapter 5.5.2 show that the calculated values from the two datasets differ from each other, but not strongly. When excluding GCP's from the project, mapping small reservoirs will be an act consuming merely minutes. With only one night of processing the dataset, relatively accurate calculation can be obtained. However, the research shows that the estimated values of each of the reservoirs are surprisingly close to the calculated values. This bags the question how valuable the knowledge of slightly more detailed information can really be.

### *5.4.1 Obtaining DSAC's*

The research showed that it is possible to obtain DSC's fairly easily in an empty reservoir. With the ITC being in possession of both the necessary drone and software, DSC's can be obtained in local townships quickly and easily.

## *5.5 Application to the Ma Zin Reservoir*

None of the research outcomes have concluded that mapping the Ma Zin reservoir with the researched methods will not be possible. In contrary, since the program is not able to map the water surface, but still can perform a volume calculation over the 'empty pixels', only the edges of the Ma Zin Reservoir need to be mapped to calculate the volume. This drastically decreases the necessary flight time for the drone. In appendix G, manual Ma Zin Reservoir, the amount of necessary flights has been calculated, By using the Pix4D application.

# 6 RECOMMONDATIONS AND DISCUSSION

## 6.1 *Recommendations*

As can be read in the conclusion, the outcomes of the research are positive and the foreseen cause of calculating the storage capacity of reservoirs is possible. The used techniques and data handling methods are either already available for the ITC, or affordable and getable on short notice. The staff of the ITC is also already good capable of working with the used techniques. For these reasons, other applicabilities for the techniques have been looked into.

### *6.1.1 Recommendations on mapping the Ma Zin Reservoir*

In appendix G, Manual Ma Zin, a brought description is given on several possible methods that can be used for calculating the storage capacity of the Ma Zin Reservoir. The conclusions of this appendix are summarized below.

If the ITC decides on mapping the Ma Zin Reservoir, using the techniques used in this research, it can be done in three different ways:

- Method 1: Using only the Drone
- Method 2: Using only the Fishfinder
- Method 3: Using both drone and Fishfinder

**Method 1: Using only the Drone**
Since the ITC already possesses both the drone and the necessary software, the drone would be the first choice for calculating the volume in this reservoir. The biggest downside of this method, is that no information on the bathymetry of the reservoir can be obtained.
Before taking the drone to the reservoir, it should be clear that the causes as described in chapter 6.5: Further studies, should be tested first, since a positive outcome of these test can greatly reduce the necessary time for mapping the reservoir. The following notes should also be considered:

- The act of drawing a polygon around the edge of the entire reservoir, is something that needs to be done very precisely. Adding a point just a few centimeter below or above another point, will greatly increase the calculated volume, since the effect stretches over the entire width of the reservoir.
- It is unsure how the software reacts to the described method, as it has not been tested on full scale yet. More information about insecurities of the method can be found in chapter 6.6: discussion. The Ma Zin Reservoir has been chosen for that reason, since it is located closely to the ITC and thus limited time is needed for the operation. It should be clear that mapping the Ma Zin reservoir, is still part of the test phase.

If the described method is used, it will take the ITC approximately the time as described in the table below. No total time is added, since it is up to the ITC to decide how tight they plan the schedule.

| **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 |

***Table 4: Necessary time Method 1***

**Method 2: Using only the Fishfinder**
The biggest advantage of this method, is that an estimation of the volume of the water stored inside the reservoir at a certain point in time can be calculated in just one day. This value is estimated to be have an accuracy of 80%, although this is roughly estimated based on the cover area of the grid.

The following notes should be considered:

- This method is only likely to give accurate results if sedimentations occurs gradually over the reservoir bed and it can be assumed that the bathymetry inside the reservoir is generally smooth. The denser the grid sailed with the Fishfinder, the more accurate results can be given.
- The volume of water stored in the reservoir is only calculated between the outermost DPM's and does not include water outside the grid. In QGIS it is possible to manually at DPM's with a value of 0m, at the edge of the reservoir. This is much easier and much more accurate if an orthomosaic is obtained with the drone. Pix4D provides the option of just making a 2D model which can be done much quicker than a 3D model and can be obtained by flying on maximum height.
- If a very detailed volume calculation is needed, and the ITC decides to sail two girds in two days, it is important that the water level inside the reservoir does not change.

For this method, the following necessary time is estimated:

*Table 5: 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 |

**Method 3: using both Drone and Fishfinder**
This is the only method which gives the full storage capacity of the reservoir. This method is also likely to give the most accurate results since a clear border is visible between water and land.

- The Fishfinder and the drone should be used simultaneously and the water level inside the reservoir may not change during the time of gaining datasets.
- The most accurate result can be obtained when the water level reaches its lowest point.
- Sailing as close to the edge of the reservoir gives the most accurate results.

Combining both method will take the following time approximately:

| **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 |

*Table 6: Necessarry time for method three*

### 6.1.2 Recommendations on using Pix4D in the future

Obtaining Depth Storage Curves of small reservoirs is relatively easy using Pix4D and could be beneficial if implemented on a small scale. The research has concluded that accurate volume calculations can be made, even without using GCP's. This way, obtaining a DSC is just a matter of one day of work.
It is up to the ITC to consider the value for local townships, when provided with data like DSC'S. Fact is that small reservoirs dry out completely every year and a better understanding of the amount of remaining water could increase the efficiency of the water consumption of the people relying on the reservoir.

Instead of calculating the storage capacity of reservoirs, the Pix4D software can be used for calculating volumes of soil too. When mapping a certain area before and after it is flooded can help the ITC to determine the amount of sedimentation that has occurred as result of this flood.

The Pix4D software can be used for different causes than calculating volumes as well. According to information on the Pix4D website, it is possible to export DSM's into programs as QGIS. The software can then be used for predicting the flow of water. There are numerous utilities of models like this, which the ITC should take into account.

### 6.1.3 Recommendations on using the Fishfinder in the future

As been stated in this report many times before, the lack of data is a big problem in Myanmar. The field trip to the Bago Bridge and the Tawa sluice, executed in name of Leon Brok's research, has shown that the lack of clear bathymetry data of the big rivers in Myanmar is due to the lack of equipment. The Fishfinder can serve as a good alternative for the conventional techniques, which are occupied by the hydrology branch most of the time.

Like the Pix4D software, the Fishfinder too can serve as a tool for determining the amount of sedimentation. The image below shows the bathymetry of the Yangon river, between Yangon and Dala. It was taken from the JICA report, made in 2015. It shows the occurrence of sedimentation in the river bed. The Fishfinder can be used for calculating the amount of sediment that occurs in a specific period of time on a location like this.

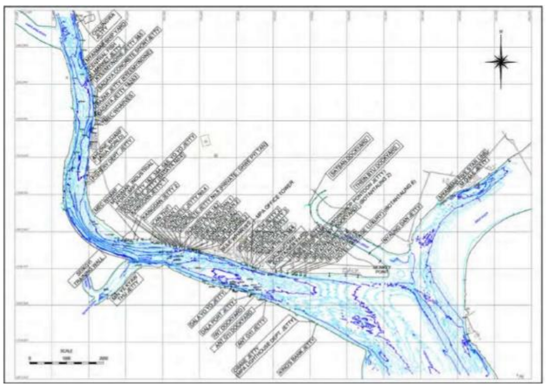


***Figure 35: Impression of sedimentation in the Yangon River (SOURCE: JICA master plan Yangon)***

## 6.2 Further studies

The test pilots of this research were the first tests done with the Pix4D software. Further studies are needed to determine the exact accuracy of the tested techniques.

Comparing the Fishfinder with the M9 in a full reservoir, could determine the accuracy of the technique. The M9 is capable of scanning exact bathymetries and should give more accurate results. If tested simultaneously in the field, the exact inaccuracy of the Fishfinder could be determined.

The same goes for the Pix4D software. All the calculated values were very plausible and compatible with the estimated results. If the technique is tested on a reservoir where the exact storage capacity is known, the accuracy can be determined. It is very unlikely that the calculated volumes in the models are inaccurate, but when executing several tests on the same reservoir, the decrease of accuracy can be determined. The effect of increasing the flight height to 150m or changing the flight plan from a double grid to a single grid can then be found. These measures will decrease the number of images in a dataset and speed up the process of gaining DSM's. These aspects should most definitely be tested before mapping the Ma Zin reservoir, as a positive result of these tests would decrease the necessary time tremendously.

## 6.3 Discussion

With the three test pilots, it is predicted as good as possible in the available amount of time in Myanmar whether or not it is possible to calculate the volume of the Ma Zin reservoir. Still, none of the tested reservoirs were nearly as vast as the Ma Zin. Some assumption had to be made when concluding that the used methods should indeed be applicable to this reservoir.

First of all, it has not been tested how the Pix4D software reacts to datasets consisting of separately flown grids. It is assumed that just mapping the edges of the reservoir should be sufficient to perform a volume calculation, since no data was visible underneath the water surface of the test pilots. How the program reacts to the absence of images in the middle of the dataset, is something that still needs to be tested.
Also the size of the entire dataset is an aspect that could cause problems in the software. There is no limit on the number of images one can insert into Pix4D, but it is unsure how much the processing time will increase in comparison to the test pilots. In appendix G, Manual Ma Zin Reservoir, it has been estimated that it will take 6 days to process the dataset. This is a very rough estimation of two necessary days per processing step.

Another point of discussion of the research, is the accuracy of the calculated volume. As said earlier, an adaption in the polygon of just a few centimeters will have a huge effect on the calculated value. Therefore, two separately drawn polygons will never come up with the same result. The book: ''Bago region: Agriculture, livestock and irrigation in brief'' that has been used as an important informational source for this research, already contains values of the storage capacities of all the dam-made reservoirs in the Bago region. These values are obtained at the time of construction of the dams and have never been adapted. It is certain that these values are not entirely correct anymore, since the occurrence of sedimentation in the reservoirs is a fact. It does however beg the question if the calculated values in Pix4D or QGIS will be more accurate.

At last, the efficiency of the used method should be questioned. Another method could be used for determining the volume of water in reservoir, that could be used for irrigation. This method is much more efficient, but can only be applied as long as three assumptions can be made:

- At the end of the rainy season, the water level hits the overflow, meaning that the absolute maximum capacity of the reservoir is reached.
- At the end of the dry season, the water level lowers to a point underneath the crest level of the lowest outlet of the reservoir, meaning that no water can be tapped from the reservoir anymore and the remaining amount of water stored in the reservoir is irrelevant.
- The difference in height between these two water levels is known.

If these three assumptions can be made, the following method can be applied in order to determine the effective storage capacity in a reservoir.

At the very end of the dry season, when the water level reaches just below the crest level of the lowest outlet, an othomosaic of the total surface of the reservoir is to be obtained. As can be read in appendix F F: Data collection, Pix4D features an option of just creating an orthomosaic. This can be done with a single grid mission while flying on maximum height. The processing of this dataset will take roughly 2 hours. The same is done at the end of the rainy season, when water abundances reach the overflow and the maximum storage capacity is reached. Now, two 2D maps of the same reservoir are obtained.

Then, by drawing a polygon around the entire edge of the reservoir, the surface area in both models can be calculated. Adding up the two calculates surfaces, and dividing the sum by 2, the average surface area of the reservoir is calculated. Multiplying this value by the difference in height between the two water levels, gives the effective volume of the water stored in the reservoir.

Since the average surface is multiplied by the height difference, the found value will not be 100% accurate, as the shape of the bed level around the edges is interpolated between two points, as demonstrated on the image below.

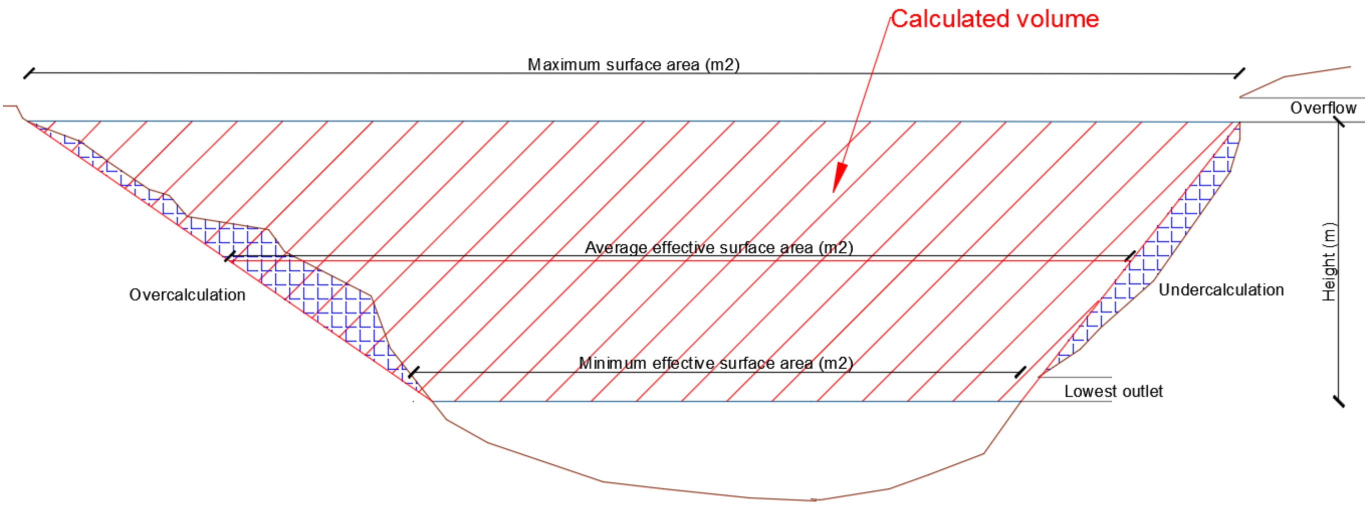



*Figure 36: Visualization of alternative method*

This method roughly gives the amount of water inside the reservoir which can be used for irrigation purposes. Unfortunately, the time spend in Myanmar was insufficient to test this method, and could therefore not be tested in this thesis research.

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