THE HYDRO FLATTEN SOLUTION FOR LiDAR APPLICATION ON TOPOGRAPHIC MAPPING: THE PERSPECTIVE FROM MALAYSIA SURVEY AND MAPPING DEPARTMENT

Hazri bin Hassan
Department Survey and Mapping Malaysia (JUPEM)

(This article has not been published)

Abstract *

Light Detection and Ranging (LiDAR) is a method of capturing high-density of XYZ point data that is also known as point cloud. These point cloud data are highly accurate and commonly used to visualize topographic surface in three-dimensional (3D). Today, we can see that there are several forms of LiDAR data capturing techniques ranging from airborne (fixed wing, helicopter, UAVs) to mobile and fixed terrestrial LiDAR scanning. The selection of LiDAR data capture technique mostly depends on the product or output requirements, specifications and intended usage of the point cloud.

JUPEM as the authoritative government agency for any survey and mapping activities in Malaysia have been exploring and implementing LiDAR technology since the year of 2004 until today. With the experience at hand, numerous government agencies namely Department of Minerals and Geoscience (JMG), Department of Public Work (JKR), Department of Irrigation and Drainages (JPS), Malaysian Centre for Geospatial Data Infrastructure (MaCGDI) among other agencies within Malaysia have been consulting JUPEM in pursuant of implementing activities or projects related to LiDAR. In 2016, the National Audit Department have recognised JUPEM's expertise and have appointed JUPEM as the data auditor at national level for all government LiDAR project implementation.

This paper shall highlight JUPEM's experience on LiDAR data processing - focusing on issues and mitigation efforts of hydro flattening process on Digital Elevation Model (DEM) acquired within Malaysia's tropical rainforest.

1 INTRODUCTION

OPTECH ALTM 30/70 was JUPEM's first acquired LiDAR system in the year of 2004. A fixed terrestrial CYRAX 2500 sensor was subsequently purchased to be used as a training equipment to further expand the understanding of LiDAR technology. While the most recent LiDAR system acquired was a UAV fitted with VELODYNE PUVK VLP 16 sensor meant to be used primarily for 3D mapping of small area such as accidents scene and terrain modelling of landslides among other usage. Apart from operating owned equipment's, JUPEM have also managed LiDAR acquisition projects utilizing Leica ALS70, Riegl LMS-Q560, and most recently Leica CityMapper in 2020.

LiDAR derived product, such as Digital Terrain Model (DTM) have been used to visualise the elevation models of the Earth's surface. However, today, DTM are not the only dataset used for visualisation, the visualisation itself can be value added by incorporating other spatial information that fit the visualisation context therefore extending their usefulness.

Although acknowledging the vast benefit of LiDAR dataset application for topographic mapping especially in depicting height, slope and terrain information, these derivative products are only as good as the Digital Terrain Model (DTM) from where it is derived. High quality DTM to a certain extend relies on hydrology breaklines, whereby delineating it remains a challenge due to the characteristic of a tropical rainforest such as thick forest, limestone area and water bodies which are quite common in Malaysia.

In facilitating the production of large-scale topographic map using DTM derived from LiDAR, the following section attempts to address the challenges encountered during DTM production focusing on point cloud data classification, hydro-flattening process and uncorrelated patches over water surfaces issues.

2 LiDAR POINT CLOUD

LiDAR point cloud generally comprised of Digital Surface Model (DSM), Digital Elevation Model (DEM) and Digital Terrain Model (DTM). Each are described in detail at Para 2.1, 2.2, 2.3 and visually depicted in Figure 1.

JUPEM manages and keeps LiDAR point cloud in accordance to it's MY Series tile format which are 1:5,000 scaled with each tile having aa 2.5 km by 2.5 km coverage. Each dataset is accompanied with it's corresponding metadata based on the Malaysia Geospatial Metadata Standard format (MGMS). MGMS in turn are in conformance to ISO 19115-2: 2009 Part 2: Extensions for imagery and gridded data, ensuring metadata standardization across all LiDAR dataset in JUPEM.

Point clouds are kept in LASer (LaS), American Standard Code for Information Interchange file (ASCII) and Geographic Tagged Image File Format (GeoTIFF) data format. ASCII and GeoTIFF format are having 1-meter resampled data resolution while LAS data resolution is kept as per collected.

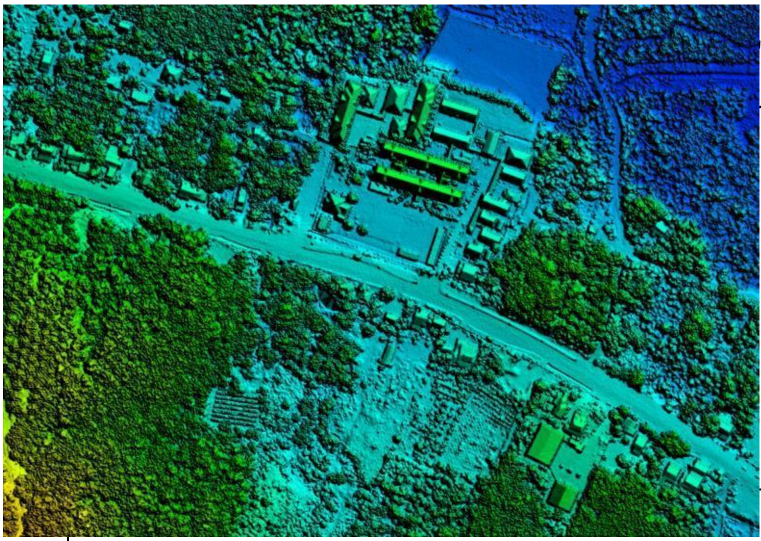
2.1 Digital Surface Model (DSM)

DSM is a digital surface model representing the earth's surface with the average height of the sea level including all its natural and man-made objects such as trees, buildings, and other features high above the ground.

2.2 Digital Elevation Model (DEM)

DEM is a digital surface model representing the earth's surface with the average height of the sea level excluding all objects above it, in other words all natural and man-made features are eliminated from the surface **without considering the break line** on land and water bodies. DEM is not a product produced by JUPEM.

2.3 Digital Terrain Model (DTM)

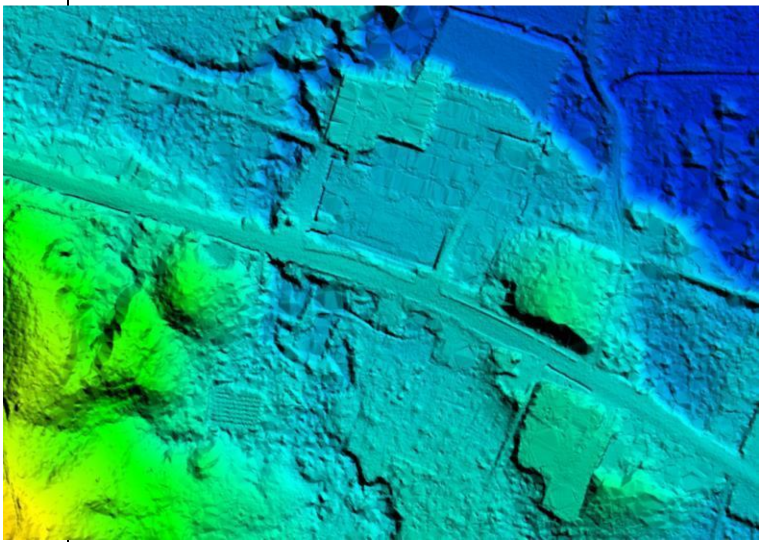


s surface with the average height

words all natural and man-made

ng into account the break line

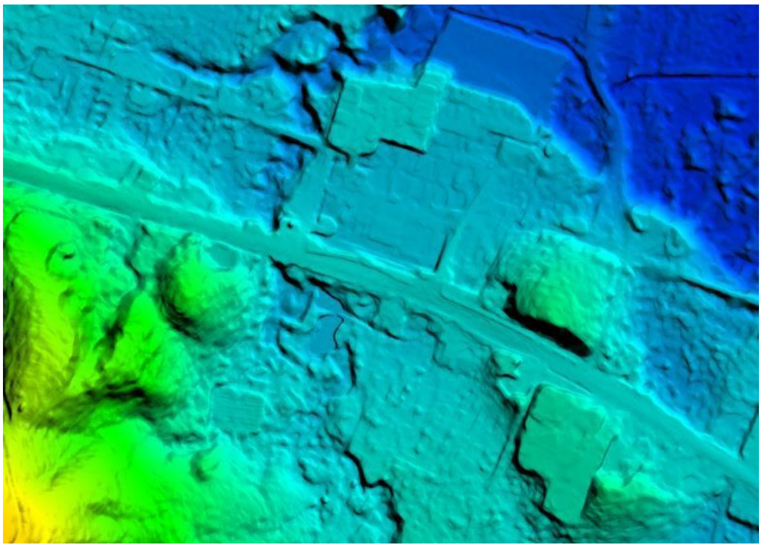
n between objects on land and



Digital Surface Model

(DSM)

Digital Elevation Model
(DEM)



Digital Terrain Model (DTM)

Figure 1: Depicting the characteristic of DSM, DEM and DTM

3 STUDY AREA

The selected study area is in Dungun, Terengganu, east Peninsular Malaysia. It is located approximately 360 km from the capital city of Kuala Lumpur. Study area has a coverage of 6.25 km^2 identified by tile number GA24071 from JUPEM MY701 Map Series.

4 CHALLENGES

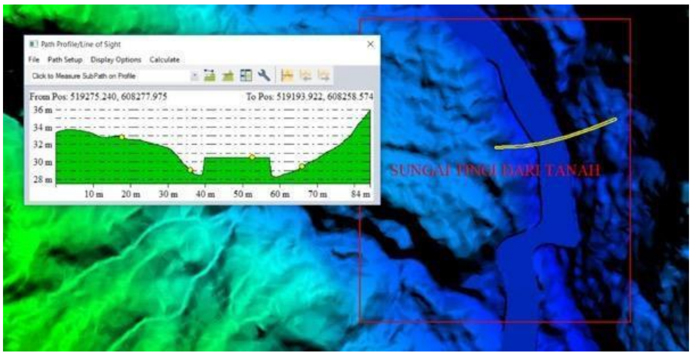
Typically, the following scenarios arises during the processing of hydrology features for LiDAR data:

1. Water body has elevated height value than the nearby riverbank.
2. Hydrology features does not correlate with DTM against orthophoto.
3. Riverbanks vector are not well defined.

Hence, by understanding the causes of these errors, preventive and remedial measures can be incorporated in the work process to improve product generation by choosing the right parameters and approach.

4.1 Hydro features are higher than Ground

In the natural of flow of river, water level would normally not be higher than the riverbank (except if there’s a flood wall constructed at the nearby riverbank). Water level higher than the riverbank will cause overflow.



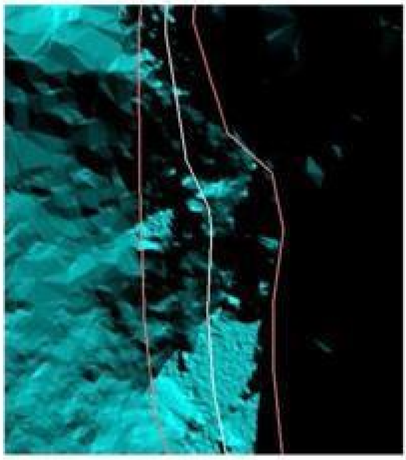
4.2 Hydrology features does not correlate with DTM against Orthophoto.

Hydrology features (red) does not correlate with DTM and orthophoto.

4.3 Riverbank are not well defined

Digitizing of break line such as river outline corridor (riverbank) must not solely depends only to orthophoto images. The challenges are to correctly identify riverbank that are covered extended tree branches. The following approach are suggested to mitigate the issue:

- 3D stereo digitizing.
- Additional DTM data source (overlay and adjust opacity of orthophoto)
- Field verification.



5 RULES AND PARAMETERS

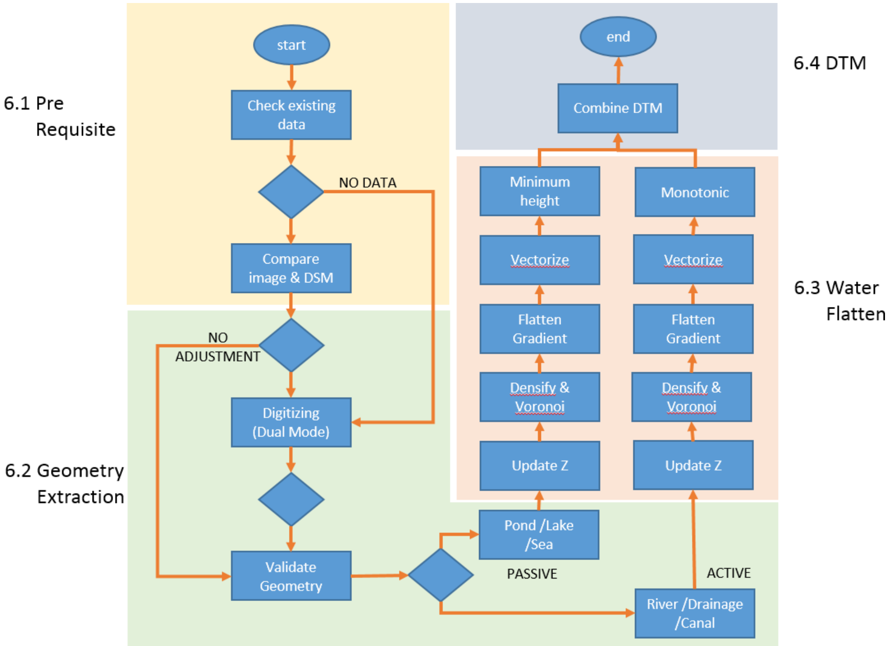
JUPEM have its own specifications and procedures in performing hydro flatten processes of LiDAR DTM data. These specifications are slightly different in comparison to United States Geological Survey (USGS). For example, a minimum parameter for pond and lake areas to be flatten was set to 400 m^2 and greater. Meanwhile the width for streams and rivers is being set to be at minimum of 2m. Monotonic decreasing value are determined at every 10cm from upstream to downstream along the river. Lastly all water surface edge must not exceed 2 meter in depth. A table of comparison can be found below;

<table>
<tr><th>JUPEM LiDAR Specification</th><th>USGS LiDAR Specification
(https://www.usgs.gov/core-science-systems/ngp/ss/product-standards)</th></tr>
<tr><td>Inland Ponds and Lakes
- 400 m^2 or greater surface area
- Flat and level water bodies
- water surface edge must not exceed 2 meter in depth
- Long impoundments to be treated as rivers</td><td>Inland Ponds and Lakes
- 8,093.71 m^2 (2 acres) or greater surface area
- water surface must be at or below the surrounding terrain / riverbank
- Flat and level water bodies
- Long impoundments to be treated as rivers</td></tr>
<tr><td>Inland Streams and Rivers
- 2m nominal width
- Flat and level bank-to-bank
- gradient to follow the immediately surrounding terrain
- water surface edge must not exceed 2 meter in depth Stream channels are required to break at road crossings (culvert locations)
- Bridges are required to be removed from the DEM. (bridges are defined as elevated)
- Manmade structure culvert cannot be made reliably</td><td>Inland Streams and Rivers
- 30.5m (100 feet) nominal width
- Flat and level bank-to-bank
- gradient to follow the immediately surrounding terrain
- water surface must be at or below the surrounding terrain / riverbank
- Stream channels are required to break at road crossings (culvert locations)
- Bridges are required to be removed from the DEM. (bridges are defined as elevated)
- Manmade structure culvert cannot be made reliably</td></tr>
<tr><td>Great Lakes
- Flat and level water bodies</td><td>Great Lakes
- Flat and level water bodies</td></tr>
</table>

JUPEM LiDAR Specification	**USGS LiDAR Specification (https://www.usgs.gov/core-science-systems/ngp/ss/product-standards)**
- water surface edge **not exceed 2 meter in depth**	- **water surface must be at or below the surrounding terrain / riverbank**
Islands - Permanent islands 1 acre or larger - includes the Great Lakes	**Islands** - Permanent islands 1 acre or larger - includes the Great Lakes
Single-Line Streams - line stream break lines are at or below the immediately surrounding terrain - Single-line stream break lines to create a non-topographic DEM - **All river line should be connected / not break**	**Single-Line Streams** - line stream break lines are at or below the immediately surrounding terrain - Single-line stream break lines to create a non-topographic DEM
Hydrology enforcement /flatten /condition - Water bodies greater than **2m width** - A gradient every **10cm** except for rapids, dam, waterfalls - Monotonic decreasing value every 10cm (**upstream to downstream**) - Water courses break at road/bridge - Sinks must not be fill	**Hydrology enforcement /flatten /condition** - Streams and rivers of **30.5m (100 feet)** nominal width, shall be flattened to present a flat and level water surface bank-to-bank having a **gradient downhill** water surface. The entire water-surface edge shall be at or below the immediately surrounding terrain

6 SUGGESTED APPROACH METHODOLOGY

There're 4 stages of the processing workflow, namely setup or pre-requisite, extraction of geometry, water flattening process and finally DTM production. The diagram below depicts the workflow of the 4 stages.



6.1 Pre-Requisite

Check, compare and evaluate existing vector topographic data with newly acquired imagery and DTM. A small deviation can be addressed with minor editing, while huge changes warrants for the digitizing processes as described at Para 6.2.

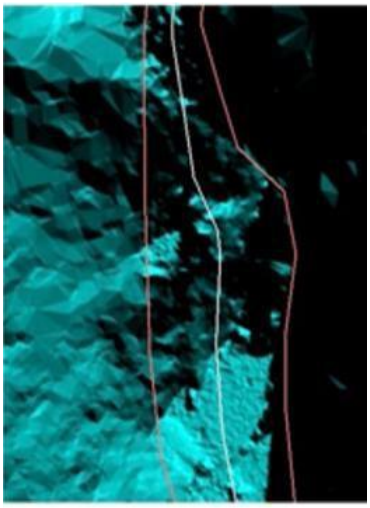
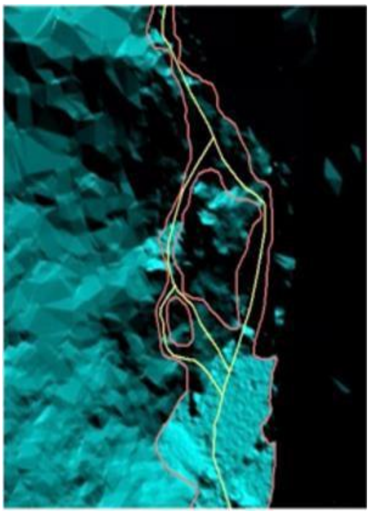
6.2 Geometry Extraction

Both raw LiDAR data and orthophoto images are used as input data sources. It is crucial to ensure that all points data are well classified, and low point are properly identified. The DEM dataset then are used for generating Orthophoto and mosaicked images. This shall ensure that both DEM and Orthophoto are consistent with each other can are ready to be used the hydrology digitizing processes.

While looking at the ability to semi-automate riverbank feature extraction such as using centerline and perpendicular centerlines, the automation generally works better with water bodies bigger than 30 meters. Still centerlines need to be first digitized.

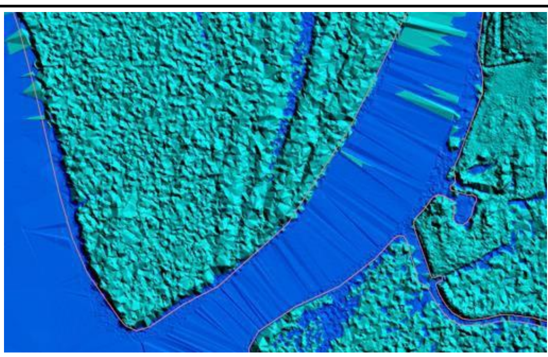
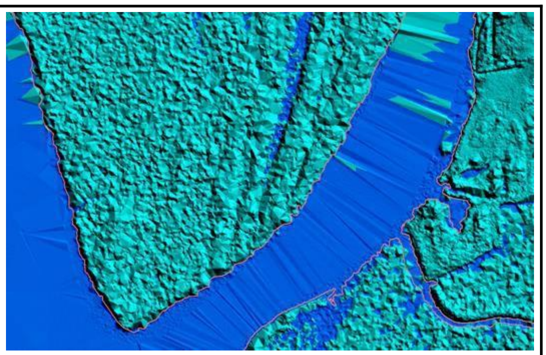
Manual digitizing is still the best option (to fit specification) to go with by using 2 screens, one screen with DEM and another with an Orthophoto View. But, if its already been digitized in Orthophoto, the output needs to be verified in DEM. In Global Mapper, we can adjust water display to verified optimum riverbank.

Riverbank defined by DEM can be a little bit jagged. But the surface can be smoothed if needed. All 2D hydro then converted to 3D using the elevation from DTM.

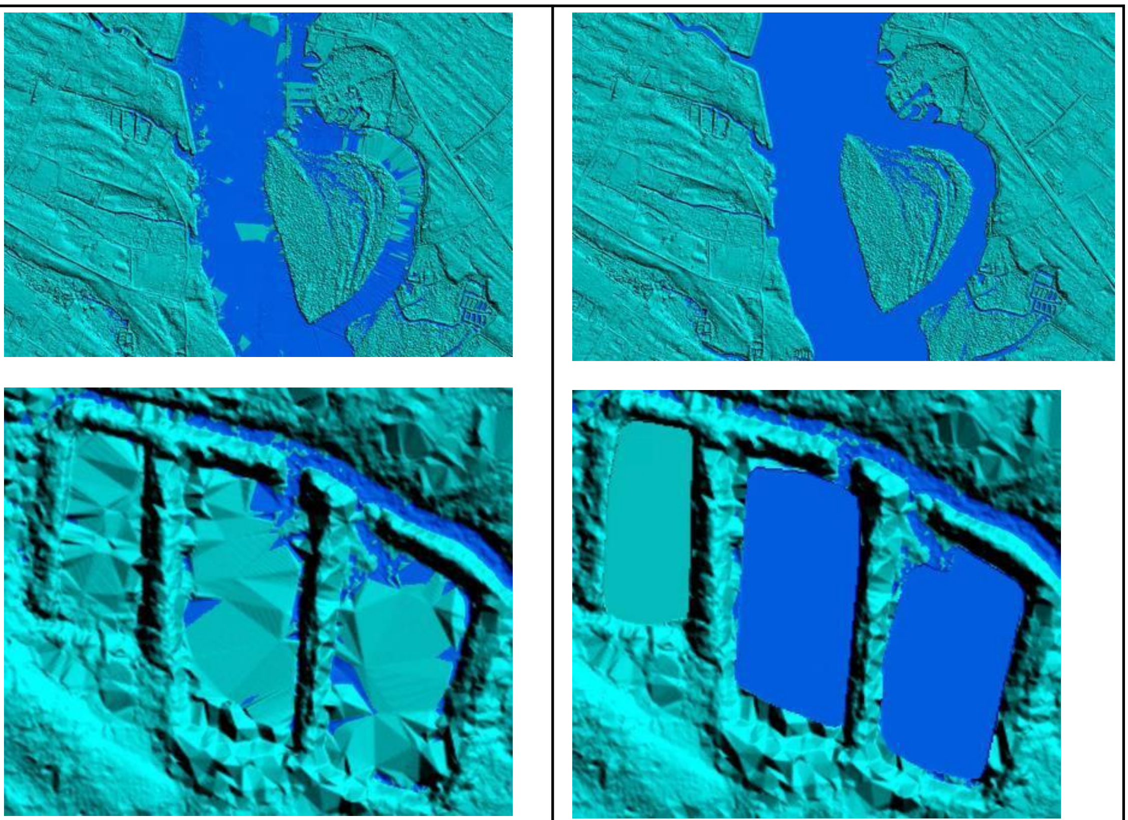
	
Before Fixing	After Fixing

6.3 Water Flatten

For the inland water area which covered by dense secondary forest but it actually occupied by water on DTM surface such as stagnant area, paddy fields with water and mud should be identified, validated and undergo hydro-flattening process. Water value displayed on DTM will help give better interpretation for riverbanks, lake and swam areas. It will minimize the gross error and increase time efficiency and accuracy of hydro flattening.

	
Before	*After*

From the interpretation on Riverbanks, lake and swarm (riverbank) it will produce good vector breakline. Run DTM process by using LAS data and breakline vector data together to have water body flatten.



Before Hydro flattening | After Hydro flattening

7 CONCLUSIONS

This method is to extract bank shoreline, and to perform hydro flattening of LiDAR data using the advantage of LiDAR that it can see through vegetation. Hydro flattening are done in Global Mapper conforming to the JUPEM specification of Hydro Flattening. The monotony calculation and stair-stepped gradient was not discussed although in the workflow.

8 REFERENCES

i. USGS (Lidar-Base-Specification-version-2-1) - https://www.usgs.gov/core-science-systems/ngp/ss/product-standards
ii. A semi-automatic method to hydro flatten lidar data (Sagar S. Deshpande and Alper Yilmaz) - http://www.asprs.org/a/publications/proceedings/IGTF2016/IGTF2016-000172.pdf
iii. Flattening water areas in DEMs- https://www.imagico.de/map/dem_water_en.php
iv. Case Study on Hydro-Flattening - https://www.sanborn.com/hydro-flattening-case-study/