LUANG PRABANG POWER COMPANY LIMITED
Luang Prabang HPP

Feasibility Study
Report – Volume 6 – Annex 6.2 Topography
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Report – Volume 6 – Annex 6.2 Topography
Contact

Pöyry Energy Ltd. (Thailand)
Vanit II Bldg, 22nd Floor, Room#2202 - 2204
1126/2 New Petchburi Road
Makkasan, Rajchthewi
TH-10400 BANGKOK
Thailand
Tel. +66 2 650 3171-2

Robert Braunshofer, Business Manager
Mobile: +66 92 264 0734
robert.braunshofer@poyry.com
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# STRUCTURE OF THE FEASIBILITY STUDY

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Vientiane GEOMATIC Services

REPORT

For the

Luang Prabang Hydroelectric Power Project

DGPS Network Survey
Precise Levelling Survey
Bathymetric Survey
Cross Section Survey

For the;

Luang Prabang Power Company Limited (LPCL)

Address: PT Building, Phonexay Road, Phonexay Village, Xaysettha District, Vientiane Capital, Lao PDR, Telephone:+856 21 990 266, Facsimile:+856 21 990 289, Email: ddau@ptsole.com
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1.0 Company Introduction:

Vientiane GEOMATIC Services (VGS)

VGS is fully registered Lao company, with excellent local experience and knowledge in carrying out surveying projects in Lao PDR for over 50 Hydro Power Projects and a variety of survey projects in Thailand and the South-East Asian / Indo China / Indian Subcontinent region.

The companies are jointly owned by Mr. Paul and Mrs. Somchan Simcock. As a Lao Licensed & Registered Company, Mrs. Somchan is the Director and Mr. Simcock manages the Company as the ‘Company Manager’.

Mr. Paul Simcock is a British citizen/Australian Resident, and a 26 year permanent resident of Lao PDR and was the former Manager of Kevron Lao Company Ltd., being a sister company to Kevron Aerial Surveys of Perth, Australia, previously, one of the largest single owned aerial survey companies in the world.

Mr. Simcock has been involved with aerial and ground survey work since early 1970, being 47 years in the survey industry and in more recent years, Hydrographic Surveys also.

Apart from working throughout Lao PDR, Mr. Simcock has also worked in: Australia, Bangladesh, Brunei, China, Indonesia, Myanmar, Philippines, Tahiti (French Polynesia), Thailand, Taiwan, United Kingdom & Vietnam.

Vientiane GEOMATIC Services covers a wide range of Survey services, including:

- Topographic & Cadastral Surveys as used for:
  - Hydro Power Dam sites; Dams, Tunnels, Penstocks, Power lines, Rehabilitation
  - Mining Leases, Mines, Overburden studies, Access and Haul Roads
  - Forestry and Agriculture
  - River studies at various Water Levels

- Photogrammetry:
  - From Large format Aerial Photographs both Film and Digital formats
  - From High Resolution Satellite Imagery
  - Small Format Aerial Images
  - Agent for LiDAR and GEOSAR

- High Precision GPS (Duel Frequency Units)
  - DGPS (Differential Static GPS)
  - RTK (Real Time Kinematic)
  - High Precision Positioning in moving vehicles, vessels & Boats etc.

- Mapping Produced by:
  - The GPS methods mentioned above
  - High Precision Total Stations and Prisms (Recent calibration Certificates available)
  - Differential Levelling Techniques

- Audit Surveying and Consultation

- GIS Mapping production; (Arc GIS, Arc Map etc.)

- Mapping software includes; AutoCAD 2010, Map Info, Global Mapper, GNSS Solutions (GPS Post Processing software), Arc GIS, GeoCalc Transformation software & various other software
2.0 Project overview;

The Luang Prabang HEPP is planned on the Mekong River approximately 25 km upstream of Luang Prabang, and about 4 km upstream of the confluence with Nam Ou River. The scheme will be part of a Low-Head Hydropower Cascade System along the Mekong River, with Pak Beng HEPP approximately 170 km upstream, and Xayaburi HEPP approximately 130 km downstream of the proposed site.

Due to the potential impact of the backwater on the tailwater of the upstream scheme, it is important to know the exact height differences to the neighboring HEPP Projects.

Theoretically the height difference of the cascade system can be determined by a differential GNSS (GPS) survey. As GNSS elevations are based on ellipsoidal heights the global geoidal model EGM2008 can be used to reduce elevations to orthometric height. The local accuracy of the geoidal model EGM2008 in the area is unknown and relative inaccuracies of ± 2m are expected. A precise levelling campaign shall be performed between Pak Peng, Luang Prabang and Xayabury HPP.

Following is a brief outline of the survey works carried out by VGS:

- **High accuracy levelling** performed with digital levels over a distance of approx. 500 km’s. The digital levelling cover the following ground control points:
  - LP 13 (Xayabury Dam) to Xayabury Airport to Hongsa to the proposed HPP approx. 35 kms upstream of Pak Beng, to Pak Beng Town site and the 2nd Order National Geodetic point at Pak Beng
  - LP 13 (Dam) to Muang Tadua (Bridge at the Mekong), Luang Prabang river gauges in LP town, Luang Prabang Airport the 1st Order National Geodetic point to Souphanouvong University river gauge to Pak Ou, then Houay Yor Village at the proposed Dam Site
  - Final traverse from Houay Yor to Pak Beng Town site and the 2nd Order National Geodetic point at Pak Beng …. This closed the 500km level traverse

This map indicates the 3 level traverses performed:
- White = LP13 (Dam) to Pak Beng
- Yellow = LP13 (Dam) to Houay Yor (LP HEPP)
- Orange = Houay Yor to Pak Beng
- **DGPS (Differential Global Positioning System) Network survey** –
  A 20++ hour DGPS Survey took place as per the Network Illustration shown below:

- **Bathymetric survey** –
  *A Bathymetric survey was carried over the area marked in blue below;*

The same area highlighted in Blue (Below);
• **Cross Section Survey** -

At least 348 cross sections have been surveyed from Houay Yoy (The proposed Dam Site area) to the proposed Pak Beng Hydro Power Project site.

To fully appreciate the Cross Section survey and the amount of cross sections involved, we have displayed the locations of the cross sections in 3 images below.

*Note: The Mekong River was orientated to fit the rectangle box in these images*

Specific technical details of how the survey was performed including results are found in the proceeding pages.
3.0 Methodology used on the project

3.1 DGPS Survey

Apart from the high precision digital leveling, one of the first stages of the survey was to perform a long occupation DGPS survey on the following points:

<table>
<thead>
<tr>
<th>Point No.</th>
<th>Brief description and location</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL 13</td>
<td>A main survey point at Xayabury Dam Site</td>
</tr>
<tr>
<td>3605</td>
<td>1st Order National Geodetic Point at Xayabury Airport</td>
</tr>
<tr>
<td>GPS3</td>
<td>Previous XPLC survey point at Muang Tadua (Near the new Bridge)</td>
</tr>
<tr>
<td>0200</td>
<td>LP - 1st Order National Geodetic Point Luang Prabang Airport</td>
</tr>
<tr>
<td>HY01</td>
<td>Houay Yor Village – A concrete point established by VGS</td>
</tr>
<tr>
<td>HY02</td>
<td>Houay Yor Village – A concrete point established by VGS</td>
</tr>
<tr>
<td>G172</td>
<td>GPS point near Hongsa</td>
</tr>
<tr>
<td>PGPS</td>
<td>Proposed HP Dam 35 kms upstream of Pak Beng town</td>
</tr>
<tr>
<td>G102</td>
<td>Pak Beng Town 2nd Order National Geodetic Point</td>
</tr>
<tr>
<td>MPB03</td>
<td>Supplementary concrete Network Point at the Pak Beng Bridge (Not part of the network survey)</td>
</tr>
</tbody>
</table>

A variety of duel frequency GPS were used in the 20++ hour survey, some GPS units could only receive GPS and Glonass Satellite signals, however, most units could receive GPS, Glonass, Galileo, and the Beidou system.

VGS had already commenced the precise levelling traverse at several locations along the traverse, therefore having several surveyors in the field at the same time made it a little easier at the end of the day, to have all respected DGPS teams set up their GPS units at a given time and allow the GPS units record all night and into the following day, creating as little interruption to the days levelling as possible.

**Occupations**

<table>
<thead>
<tr>
<th>Site</th>
<th>Start Time</th>
<th>Time span</th>
<th>Type</th>
<th>File</th>
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</thead>
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<tr>
<td>0200</td>
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<td>20:31:40.00</td>
<td>Static</td>
<td>G0200B99.154</td>
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<tr>
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<td>21:38:50.00</td>
<td>Static</td>
<td>GHY02A99.154</td>
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<tr>
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<td>17 Jan 2019 10:30:10.00</td>
<td>21:09:30.00</td>
<td>Static</td>
<td>S172.190</td>
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<tr>
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<td>17 Jan 2019 10:29:10.00</td>
<td>22:08:10.00</td>
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</tr>
<tr>
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<td>22:43:10.00</td>
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<tr>
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<tr>
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<td>PL13.190</td>
</tr>
<tr>
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<td>21:11:20.00</td>
<td>Static</td>
<td>3605.190</td>
</tr>
</tbody>
</table>

**Meta Data** – Following is the Meta Data for the DGPS Network Survey

**Date:** 17th Jan. 2019 **Zones:** Zone 47 (downstream) and Zone 48 (Upstream)

**Coordinates system:** WGS 84 Latitude & Longitude, presented in UTM

**Post Processing Geode used:** EGM 2008

**Elevation:** Based on the XPLC reference monument No. PL13, *(which was originally based on the Laos Vertical datum based on MSL Hon Dao Vietnam)*

**Post Processing Software:** GNSS Solutions

**GPS Units used** *(all duel frequency)*: CHC X91, CHC i80, Ashtech Pro Mark 500, Hemisphere S320, ComNav T300
DGPS Survey – Continued

DGPS Network – As a quick visual reference to the Post Processing of the GPS Network that was performed, note the diagram extracted from the DGPS GNSS solutions, post processing software (Below)

Zone Change – An important factor in this project was the ‘Zone Change’ that happens along this portion of the river. Most of Lao PDR is covered by the geographical Zone 48 however the western side of the Country is covered by Zone 47 (When referring to the Universal Transverse Mercator system, more commonly known as UTM) GPS surveying across zone boundaries can only successfully occur by post processing the results in Longitude and Latitude coordinate system, once across the boundary and all reference points have been surveyed by Lats and Longs, the data can be transformed back to UTM for easy use

For the information of the reader, if a surveyor accidently surveyed via GPS across a zone boundary e.g from zone 47 to zone 48, and post processed only using the UTM coordinate system, there would very large errors in his results.

In this projects case, to avoid any such errors, VGS supplied the Hydraulic modelers with all results in Latitude and Longitude (and UTM for redundancy checking)
DGPS Survey – *Continued*

3.2 **Reference Points** -

Another aspect of the DGPS survey are the reference points requested by the project, the ToR requested 20 Reference points however, VGS established 24 reference points. This placed the reference points close to a distance of approx. 8 kilometers apart, which was also a more convenient distance to utilize the reference points as “RTK Base Stations” for the eventual RTK survey of the cross sections.

**NOTE:** VGS works on the following GPS QC principle; Every GPS point is surveyed at least twice, if the results are within the projects accuracy tolerances, then the two measurements are averaged to produce the final results, even if there are only millimeters difference between the two results. If on the odd occasion the two results are not close, a third measurement takes place, then the closest two results are averaged to produce the final result.

**Example of VGS averaging DGPS results**

1. 1st GPS result OK → 2nd GPS result OK → 3rd GPS result OK → 2nd GPS NOT result OK → Final Averaged result
2. Final Averaged result
3. Final Averaged result
4. Final Averaged result

Some of the VGS DGPS results may involve 3 or more data-sets of GPS results which are all good results, and therefore they are all averaged for a final result. This situation can occur during the following scenario;

Once a reference point is established and the results are accepted by VGS, a reference point may be used over several days for both an RTK survey of a cross section and the establishment of a new reference point, this means that a reference point used an RTK base still holds RAW data that can be used in the post processing software thus strengthening the accuracy of the RTK Base in a multiple redundancy measurement sense.
3.3 Bathymetric Survey

The bathymetric survey was to be a fairly straightforward survey of which the VGS Company is very familiar with having performed over 1 million water depths in the Mekong river and its tributaries over years.

Firstly, note the area displayed in the image below surrounded by a blue & pink line, this is the area that had to be Bathymetrically surveyed, however, being the dry season, much of the river bed in the shallow areas of the river should have been exposed, however, the were not ‘exposed’. NOTE: these are the boundary lines in black on the image, these areas were to be surveyed by RTK GPS methodology

The Yellow lines across the river depict the beginning of the cross section survey

![Image of the area to be surveyed](image_url)

The image above is an old Google Earth image of several years ago, unfortunately, VGS found that when arriving at the area, many of the rocky exposed areas where in fact underwater, this created several problems;

- The first problem was that we found that the rocky areas were only just below the surface, too shallow for our survey vessels to sail over the rocks (30cm’s to 50cm’s deep)
- The next problem was that the river was quite dirty to due to very early Monsoon storms upstream, this made it both difficult and dangerous for VGS personnel to walk over these areas as they could not see the bottom. VGS is familiar with the areas from previous projects performed for the MRC and we are aware of the cracks and crevices that are found among these rocky areas, thus a loss of life and equipment was at risk
- VGS took to local fishing boats, the traditional 4 to 5m long flat bottomed boats that only draw around 20cm’s in draft. The idea was to use these boats as a platform to measure the bottom directly and safely using direct RTK GPS measurements, however, the semi submerged rocks created a strong turbulent current similar to a set of rapids, the local fishermen weren’t interested in working in these area for fear of loss of life and their boat, due to the strong and dangerous current flowing over the rocks
Bathymetric Survey – Continued

- VGS has continued to monitor the river levels in the Bathymetric area in the hope that the traditional rising river levels of the Mekong in April would assist the surveyors to complete this important task. At the time of writing this Report, VGS surveyors were still on standby in the area try to ‘fill-the-gaps’ in the Bathymetric survey area.

3.3.1 Methodology – Methodology is quite straightforward, except for a few tricks up the sleeves of the VGS surveyors. NOTE the image below, is a typical set up of VGS performing a Bathymetric survey, in this case, at the NTPC Channel when searching for suspected ‘holes’ in the channel.

In the foreground is one of the VGS RTK Base stations, note the GPS base on a tripod to the left, and to the right is the base station RTK radio antenna link to the onboard RTK ‘Rover’ unit.

The echo sounder, and RTK receiver are connected to a weatherproof National Panasonic ‘tough-book’ (Laptop) loaded with Carlson PC Survey software that enables all the data to come together at the same time. Apart from measuring the depth of the river bed, VGS can measure the water surface at the same time, thus obtain both a surface elevation and a river bed elevation at the same time. In a situation such as above with good clear unobstructed areas, accuracies can be as little as a few cm’s.

During the LE-HEPP Bathymetric survey, VGS believes that we were getting +/- 5cm’s or less as the equipment has the ability to accept the tolerances typed into the equipment, however .... if for some reason, Satellite receivership is bad or there is a problem with the UHF radio signals back to the base, the equipment will not record and measure the point, unless the accuracies are set within the specified tolerances.

Therefore accuracy was within +/- 5cm’s in X, Y & Z.

The Bathymetric area had a very good clear view between the base and the rover unit.
Bathymetric Survey – Continued

VGS users a variety of echo sounders, for various different situations;
- CEEStar – High accuracy echo sounder with a 200htz transponder, 8° (Degree) projection beam +/- 1cm accuracy + 1mm to 100m depth
- Furuno – Duel frequency 200/50 htz, accuracy +/- 5cm’s, depth 300m’s
- CHC D390 – 200 Hz, narrow beam transponder 7° +/- 2cm accuracy + 1mm to 100m depth

Meta Data & Statistics:
- The GPS monument HY02 was the main Base used for the Bathymetric survey, as mentioned above, this point gave excellent access to Satellite and UHF radio receivership
  - A nominal X, Y & Z coordinate and elevation was used initially as both the levelling traverse had not reached HY02 prior to the commencement of the Bathymetric survey, and Post Processing of the EGM 2008 geode was still underway
  - All Bathymetric points were adjusted in X & Y at a later date when VGS and the consultants agreed on the final coordinate results for HY02
- Grid system: WGS 84 post processed to EGM 2008
- Elevation: Based on a precise Double run Digital level traverse from PL13 being one of the main survey monuments at the XPLC Dam site
- Survey Points: To date over 161,000 points were surveyed over the area
  - This was a combination of both RTK GPS Dry land surveyed points and RTK GPS survey boat points
- Extents: The survey was taken up to the highest average known river level, based on local knowledge and assistance from local people, fishermen, and the Village Leaders.
- Total Area: To date, the following area has been covered
  - Bathymetric = 174 hectares
  - Dry Land RTK = 120 hectares
  - Total area = 294 hectares

QC Checking procedures:
- Each time the Bathymetric survey took place, surveyors set up an RTK GPS Base at HY02 in the Houay Yor village. The agreed coordinates results are placed into the RTK Base along with the agreed elevation.
  - Once the RTK Base is set up, the rover GPS units unit is coupled to the base, prior to fitting the river to Survey vessel, the rover is placed on nearby pre-established ‘peg’ and checked for continuity of the previous days results, if the results fall within the accepted tolerances the Rover unit is ready to install into the Survey vessel
- The RTK Rover unit is placed in a fixed pole directly above the echo sounder transponder, the pole is ‘fixed’ and cannot be accidently disturbed.
  - Likewise the echo sounder transponder is also mounted in a fixed position, however, a quick measurement from the base of the transponder to the RTK GPS unit is quickly checked
  - These measurement checks are fixed as default in the onboard computer, although still checked during each surveys set-up procedure

NOTE: VGS utilizes ‘Fixed’ survey poles, which cannot be adjusted on all rover RTK units
3.4 Cross Section Survey

The largest survey task to the whole project 348 cross sections over approx. 175 kms of river. This aspect of the survey project could not have happened if not for the advanced establishment of the “Reference Points” as these became valuable tools in the RTK GPS process of surveying the cross sections.

As the majority of the cross sections were surveyed by RTK, base stations were required to assist the survey of the RTK Rover units coupled to the RTK Base which were established on the Ref. Points.

As mentioned earlier in this report, each advanced Ref. Point was surveyed by DGPS units at least twice, sometimes three times, this coupled with careful post processing assured a good survey concerning X & Y.

3.4.1 Elevation: Although the ToR did not suggest the following, VGS decided to link all the Reference points by having the Precise Digital Level team survey to each Reference Point therefore producing the best possible elevation transfer to each point, in turn, this also produced excellent elevations for all the cross sections.

*Once again, note the method of surveying the Reference points in readiness for the cross section survey*

A leap frog affect is created by DGPS surveying each Ref. point at a time

3.4.2 Four Teams: Affectionately, 4 different survey teams were required to create the cross section surveys as follows;

- 3.4.2.1 DGPS Reference Point team as mentioned above
- 3.4.2.2 Precise leveling team to establish a good elevation for each Ref. point
- 3.4.2.3 Bathymetric team survey the deep waters along the cross sections line
- 3.4.2.4 RTK GPS survey team, surveying the dry land aspects of the cross sections

For sheer economics and efficiency, VGS rented a 40m boat as the ‘Mother Ship’, this housed all the above team members, including the survey boatman, transport boatman, the Captain and his wife and daughter who provided cooking and washing services.
Cross Section Survey  -  Continued

3.4.3 Cross Section survey elevation adjustments:

It was decided by the client to make minimum elevation adjustments as per the following sections of the Mekong, divided by the distance:

3.4.3.1 Proposed Dam site (km 0 to km 40)  +320 masl
3.4.3.2 Km 40 to km 80  +325 masl
3.4.3.3 Km 80 to km 120  +330 masl
3.4.3.4 Km 120 to km 160  +335 masl
3.4.3.5 Over km 160  +340 masl

NOTE: Due to the final adjustments to HY02 and consequently all the reference points, the client will find that the minimum elevation is actually 4 to 5m's (or more) more than the elevations quoted above on every cross section.

3.4.4 Deliverables – All cross sections have been produced with the following details;

3.4.4.1 Excel .csv files complete with Longitude & Latitude coordinates, including UTM coordinates, Elevations transferred from PL13 (XPLC) transferred to HY02 (Houay Yor Village)

3.4.4.2 Drawings – Drawings of all the cross sections are provided as .dwg AutoCAD files, indicating:

3.4.4.2.1 Elevations on both river banks to the specified elevations stated in item 3.4.3 above, including river bed elevations regardless of depth, to MSL
3.4.4.2.2 River levels on both sides of the river, with date, time and elevation
3.4.4.2.3 Chainage; along the entire cross section from point to point
3.4.4.2.4 Vegetation and ground material;
    3.4.4.2.4.1 Trees (Type if known) including plantations
    3.4.4.2.4.2 Scrub/bushes
    3.4.4.2.4.3 Market Gardens (Fruit growing, vegetables etc.)
    3.4.4.2.4.4 Rocks (large) Gravel, sand, mud
    3.4.4.2.4.5 Buildings and structures
    3.4.4.2.4.6 Any other obvious situations
3.4.4.2.5 PDF’s can be provided on request
3.4.4.2.6 Location of Cross Sections – A .kml Google Earth file has been provided indicating the location of all the cross sections, including (When zoomed in) all the cross section survey points

The various highlighted roads including the Mekong River to the north indicate the approx. route of the Level Traverse

NOTE: A more detailed map has been provided as a .kml file
Cross Section Survey – Continued – Example CS Drawing

- **Chainage (Distance)**
- **Elevation above Mean Sea Level**
- **River level on both sides of the river**
- **Left Bank/Right Bank indicators**
- **Minimum elevation to designated by the client**
- **Vegetation type, trees, plantations, buildings, to be inserted here**
4.0 Results

As per most survey projects, a Report helps bind the results together, however it is that actual final results that make the Report. Following is series of easy to read results, however, please note that ‘actual’ results such as Cross Sections excel file results including Bathymetric survey point results etc. are only provide in soft copy format and are not printed as hard copies.

Due to the presentation and format of the results (being in Landscape orientation), results commence after this page
### 4.1 DGPS Survey Results – Continued – DGPS Network Results

**NOTE:** All the following results have been provided as Excel files also

<table>
<thead>
<tr>
<th>Point ID.</th>
<th>Easting</th>
<th>Northing</th>
<th>Ortho. Height</th>
<th>Level Route 1</th>
<th>Level Route 2</th>
<th>UTM</th>
<th>Undulation</th>
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*Note: level results are not fully adjusted yet*
DGPS Survey Results – Reference Point DGPS Measurement results

NOTE: As mentioned in the methodology section of this report, all GPS points were measured at least twice, sometimes, three times. The **yellow highlight** indicates the data that was used for the final average results.

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DGPS Survey Results – *Continued* – Final Reference Points results

The final reference results indicated below are derived from averages created from the multiple measurements indicated in the chart on the previous page.

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DGPS Survey Results – **Continued** – Reference points in UTM & Lats and longs, indicating all elevations & Undulations

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<th>DIFF</th>
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</table>

**Note:** The elevations highlighted in yellow are the level 'results', but not adjusted

For Reference Only
4.2 Precise Level Survey
The ToR states the following deliverables for the precise level survey:

- Detailed maps indicating all levelling routes
- List of all height differences including misclosure between foresight and backsight
- List of all readings (electronically only)
- Results of network adjustment

Please note the following:
- Large scale maps have been included in this report for quick identification, however, a small scale map which includes handheld coordinates along the routes at various BM’s along the route are also included in a Google Earth image due to the lack of small scale maps in Lao PDR (Supplied as a .kml file)
- At the time of writing this report, the elevation differences including fore-sight and back-site & misclosures were still being prepared and checked
- All measurements have already been presented to the client in the form of excel files
- Final adjustments will take place after the preparation of the backsight/foresight and misclosures

The ‘real’ results are of course the actual cross section data sets, these have been presented to the client in both UTM and Latitude and Longitude coordinate systems.
4.3 Bathymetric Survey:
The Bathymetric survey results have been provided in digital form and excel files. Over 161,000 echo sounding points have been presented to the client. At the time of writing this report, not all the Bathymetric area could be completed to the unusual river conditions in the project area. ‘Gaps’ created by the Mekong River settling just above certain areas within the Bathymetric area have made it impossible to safely survey these areas. VGS has been waiting for the river to rise sufficiently to allow the survey vessel to pass over the top of what have become ‘Dangerous areas’ as the river currents have built up speed and created ‘rapids’ over what is known as ‘gaps’ in the survey.
At the time of writing this report, VGS surveyors were trying to fill the ‘gaps’ as the Mekong is slowly rising as it usually does at this time of the year.

4.3.1 An AutoCAD .dwg drawing file complete with contours and depth soundings has been presented to the client
4.3.2 .csv excel files with all the echo soundings and RTK GPS positioning points have been presented to the client also
4.3.3 Only one GPS monument was used for all the Bathymetric survey work around the Houay Yor to Tham Ting Cave/Nam Ou confluence, the monument was – HY02
4.3.4 Other monuments used for the Bathymetric survey for the cross sections were the same ‘Reference Points’ required by the client, being 20 points, however, VGS established 24 Reference Points to the convenience of the RTK Bases required to perform the Cross Section survey (See section under DGPS results)
4.4 Cross Section survey – Results and Deliverables

The following is a copy of the Deliverables extracted from the ToR, utilizing this list will make it easier for the reader to understand what has been accomplished and delivered:

Deliverables

The following data and reports shall be delivered:

- Map of cross sections – All cross sections were plotted onto Google Earth clearly indicating their location across the river including all the points of the cross section should the reader zoom in close enough
- River Cross Sections plots in scale 1:500 and photographs of each cross section (at least one from upstream an one from downstream) – River Cross section plots at a nominal scale of 1:500 (Nominal because the scale varies as the reader zooms in and out) have been presented to the client
- Hydrographic Survey Report, incl. sensor calibration protocols, control points measurements, survey plans, List of BMs or established points and photos with coordinate and Elevation (x,y,z), etc. Hydrographic sensor protocol has already been covered in this report in the Bathymetric survey task in this report, a set of Survey Summaries have also been produced and included in this report, indicating all necessary data details and photographs
- Executive Summary of the Hydrographic Survey (approx. 2 pages) The Hydrographic survey summary has been issued several times throughout this report
- Hydrographic Cross Sections in the following editable digital format:
  - ASCII files with N, X, Y, Z coordinates, station of point, waterline points with special indication and date & time of measurement – Excel files of all the cross sections have been presented to the client in both UTM and Latitude and Longitude coordinates, Z (Elevation) was provided also, including water level time and date, and a comments column describing the vegetation and any other features along the line of the survey
  - DWG file format with data in real coordinates X, Y, Z – To be plotted

The drawing of the cross section will respect the following requirements:

- Right bank is defined as right side when looking in flow direction (downstream) of the river.
  - Right bank on the right side of the figure and left bank on the left side of the figure
- X axis including both cumulative distance from left bank and intermediate distance between two ground points
- Y axis corresponding to the elevation above sea level.
- To display any place, village, kaeng, fall, bridge, tributaries, jetty, etc, which is expected to significant for the river shape and profile. The name of above locations shall be put into the drawings.
  - All aspects of the above requested data and notation on the .dwg drawings are already underway as per the sample drawing in this report
5.0 In closing

VGS found this project quite a challenge due to the size of the area to be surveyed and the extensive nature of the levelling and cross section survey, combine that with time constraints for presentation to the GoL, plus the harsh conditions (Severe heat, with higher than normal temperatures, all took its toll on the VGS survey teams)

However, we have managed to provide the data in time as stipulated by VGS several months ago. At the time of writing this report, there are still several checks and adjustments to be made to the levelling survey, however, VGS surveyors are confident that any checks and adjustments will be small and won’t affect the overall outcome of the project’s results.

VGS would like to thank the client and all other associated consultants and personnel for their patience in awaiting for this report and the respected results, VGS will continue to add more information and data as it comes to hand over the next few weeks.

VGS would also like to take this opportunity to thank the client for inviting VGS to perform the survey tasks for this very worthwhile project and would look forward to be involved in the future.

Kindest regards,

Paul Simcock
Company Manager
Vientiane GEOMATIC Services
Vientiane, Lao PDR
6.0 Annex
6.1 Survey Summaries of the Reference points

6.2 Clients supplied ToR
6.2.1 Topographic and Bathymetric Surveys – As supplied by the client
6.2.2 Precise Levelling and GNSS Survey - As supplied by the client
### SURVEY SUMMARY

**Number:** GPS1

<table>
<thead>
<tr>
<th>Vientiane GEOMATIC Services (VGS)</th>
<th>Survey Control Station Description</th>
<th>Date of Issue: March 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project:</strong> Bathymetric, Cross Section and Waterline survey</td>
<td><strong>WGS 84 (all dimensions in metres)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Client:</strong> CK Power public Company</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Station:</strong> GPS1</td>
<td><strong>Type of Mark:</strong> Steel Rod in Concrete Monument</td>
<td><strong>Date of Survey:</strong> 05/03/2019</td>
</tr>
</tbody>
</table>

**Origin of Coordinates and Elevation Datum:**

- **Dam Site point PL13 as established by XPCL**
- **Elevation:** Dam Site point PL13 as established by XPCL

**Coordinates:**

- **East:** 200102.321
- **North:** 2224115.618

**Elevation:** 300.968

**Vertical Datum:** Hon Dao Mean Sea Level Vietnam

**Method of Survey:** DGPS, Differential Leveling, Total Station

**Location Map / Diagram**

**Other Grid Systems:**

- **Lattitude:** 20 05 27.10059
- **Longitude:** 102 07 56.36793
- **Lao 97:**
  - **Easting:**
  - **Northing:**

**Location**

**Close Up**

**Photographs**

For PNPCA Only
**Vientiane GEOMATIC Services**

**SURVEY SUMMARY**  Number; GPS2

<table>
<thead>
<tr>
<th>Vientiane GEOMATIC Services (VGS)</th>
<th>Survey Control Station Description</th>
<th>Date of Issue</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>WGS 84 (all dimensions in metres)</td>
<td>March 2019</td>
</tr>
</tbody>
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**Project:** Bathymetric, Cross Section and Waterline survey  
**Client:** CK Power public Company

**Station:** GPS2  
**Type of Mark:** Steel Rod in Concrete Monument  
**Date of Survey:** 05/03/2019

**Origin of Coordinates and Elevation Datum:**  
Dam Site point PL13 as established by XPCL  
Elevation: Dam Site point PL13 as established by XPCL

<table>
<thead>
<tr>
<th>Coordinates:</th>
<th>Elevation: 303.177</th>
<th>Method of Survey: DGPS, Differential Leveling, Total Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>East: 193845.999</td>
<td>Vertical Datum: Hon Dao Mean Sea Level Vietnam</td>
<td></td>
</tr>
<tr>
<td>North: 2221393.107</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Location Map / Diagram**

Other Grid Systems:
- Lattitude: 20 03 55.11447
- Longitude: 102 04 22.85302
- Lao 97:
  - Easting: 
  - Northing:

**Photographs**

*Location*

*Close Up*
### SURVEY SUMMARY

**Number:** GPS3

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<th>Survey Control Station Description</th>
<th>Date of Issue: March 2019</th>
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<tr>
<td>VGS</td>
<td>WGS 84 (all dimensions in metres)</td>
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**Project:** Bathymetric, Cross Section and Waterline survey  
**Client:** CK Power public Company

**Station:** GPS3  
**Type of Mark:** Steel Rod in Concrete Monument  
**Date of Survey:** 05/03/2019

**Origin of Coordinates and Elevation Datum:**  
- Dam Site point PL13 as established by XPCL  
- Elevation: Dam Site point PL13 as established by XPCL

**Coordinates:**  
- East: 188237.402  
- North: 2220467.231

**Elevation:** 326.771  
**Vertical Datum:** Hon Dao Mean Sea Level Vietnam

**Method of Survey:** DGPS, Differential Leveling, Total Station

**Location Map / Diagram**

**Other Grid Systems:**  
- Latitude: 20 03 21.80924  
- Longitude: 102 01 10.57975

**Lao 97:**  
- Easting:  
- Northing: 

**Photographs**

- Location
- Close Up
## SURVEY SUMMARY

**Number:** GPS4

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<tr>
<th>Vientiane GEOMATIC Services (VGS)</th>
<th>Survey Control Station Description</th>
<th>Date of Issue</th>
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<td>Vientiane GEOMATIC Services</td>
<td>WGS 84 <em>(all dimensions in metres)</em></td>
<td>March 2019</td>
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</table>

**Project:** Bathymetric, Cross Section and Waterline survey

**Client:** CK Power public Company

**Station:** GPS4

**Type of Mark:** Steel Rod in Concrete Monument

**Date of Survey:** 05/03/2019

**Origin of Coordinates and Elevation Datum:**
- Dam Site point PL13 as established by XPCL
- Elevation: Dam Site point PL13 as established by XPCL

**Coordinates:**
- East: 809993.366
- North: 2217917.840

**Elevation:** 304.770

**Vertical Datum:** Hon Dao Mean Sea Level Vietnam

**Method of Survey:** DGPS, Differential Leveling, Total Station

**Location Map / Diagram**

**Other Grid Systems:**
- Latitude: 20 02 00.00754
- Longitude: 101 57 47.03757

**Lao 97:**
- Easting: 
- Northing:

**Photographs**

- Location
- Close Up
**SURVEY SUMMARY**

<table>
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<th>Vientiane GEOMATIC Services (VGS)</th>
<th>Survey Control Station Description</th>
<th>Date of Issue</th>
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<td>VGS</td>
<td>WGS 84 (<em>all dimensions in metres</em>)</td>
<td>March 2019</td>
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**Project:** Bathymetric, Cross Section and Waterline survey  
**Client:** CK Power public Company

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<th>Date of Survey</th>
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<td>GPS5</td>
<td>Steel Rod in Concrete Monument</td>
<td>05/03/2019</td>
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**Origin of Coordinates and Elevation Datum:**  
Dam Site point PL13 as established by XPCL  
Elevation: Dam Site point PL13 as established by XPCL

**Coordinates:**  
- East: 802811.428  
- North: 2210712.771

**Elevation:** 314.203  
**Vertical Datum:** Hon Dao Mean Sea Level Vietnam  
**Method of Survey:** DGPS, Differential Leveling, Total Station

**Other Grid Systems:**  
- Lattitude: 19 58 10.00186  
- Longitude: 101 53 35.85990

*Location Map / Diagram*

*Photographs*

*Location*

*Close Up*
### SURVEY SUMMARY

**Number:** GPS6

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<th>Vientiane GEOMATIC Services (VGS)</th>
<th>Survey Control Station Description</th>
<th>Date of Issue: March 2019</th>
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**Project:** Bathymetric, Cross Section and Waterline survey  
**Client:** CK Power Public Company

**Station:** GPS6  
**Type of Mark:** Steel Rod in Concrete Monument  
**Date of Survey:** 05/03/2019

**Origin of Coordinates and Elevation Datum:**  
Dam Site point PL13 as established by XPCL  
Elevation: Dam Site point PL13 as established by XPCL

**Coordinates:**  
East: 793742.684  
North: 2207385.478

**Elevation:** 311.364  
**Vertical Datum:** Hon Dao Mean Sea Level Vietnam

**Location Map / Diagram**

**Other Grid Systems:**  
Lattitude: 19 56 26.89806  
Longitude: 101 48 22.29192

**Lao 97:**  
**Easting:**  
**Northing:**

**Method of Survey:** DGPS, Differential Leveling, Total Station

**Photographs**

- **Location**
- **Close Up**
**SURVEY SUMMARY**

<table>
<thead>
<tr>
<th>Vientiane GEOMATIC Services (VGS)</th>
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<th>Date of Issue</th>
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<tr>
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<td>WGS 84 <em>(all dimensions in metres)</em></td>
<td>March 2019</td>
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<td>05/03/2019</td>
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**Origin of Coordinates and Elevation Datum:**
- Dam Site point PL13 as established by XPCL
- Elevation: Dam Site point PL13 as established by XPCL

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<th>Coordinates:</th>
<th>Elevation:</th>
<th>Method of Survey:</th>
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<tbody>
<tr>
<td>East: 788451.882</td>
<td>312.724</td>
<td>DGPS, Differential Leveling, Total Station</td>
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<tr>
<td>North: 2206318.528</td>
<td>Vertical Datum: Hon Dao Mean Sea Level Vietnam</td>
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<table>
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<tr>
<th>Location Map / Diagram</th>
<th>Other Grid Systems:</th>
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<tr>
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<td>Lattitude: 19 55 55.07621</td>
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<tr>
<td></td>
<td>Longitude: 101 45 19.88969</td>
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<td>Lao 97:</td>
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<td>Easting:</td>
</tr>
<tr>
<td></td>
<td>Northing:</td>
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**Photographs**

- Location
- Close Up
SURVEY SUMMARY

Number: GPS8

<table>
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<th>Date of Issue: March 2019</th>
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<tbody>
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<td>Project: Bathymetric, Cross Section and Waterline survey</td>
<td>WGS 84 (all dimensions in metres)</td>
<td></td>
</tr>
<tr>
<td>Client: CK Power public Company</td>
<td></td>
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<tr>
<td>Station: GPS8</td>
<td>Type of Mark: Steel Rod in Concrete Monument</td>
<td>Date of Survey: 05/03/2019</td>
</tr>
<tr>
<td>Origin of Coordinates and Elevation Datum: Dam Site point PL13 as established by XPCL</td>
<td>Elevation: Dam Site point PL13 as established by XPCL</td>
<td></td>
</tr>
<tr>
<td>Other Grid Systems:</td>
<td>Latitude: 19 55 22.84769 Longitude: 101 42 12.56053</td>
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<tr>
<td>Location Map / Diagram</td>
<td>Location: Lao 97: Easting: , Northing:</td>
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Photographs

Location

Close Up
### SURVEY SUMMARY

**Number:** GPS9

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<th>Date of Issue</th>
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<tr>
<td></td>
<td>WGS 84 <em>(all dimensions in metres)</em></td>
<td>March 2019</td>
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**Project:** Bathymetric, Cross Section and Waterline survey  
**Client:** CK Power public Company

**Station:** GPS9  
**Type of Mark:** Steel Rod in Concrete Monument  
**Date of Survey:** 05/03/2019

**Origin of Coordinates and Elevation Datum:**  
*Dam Site point PL13 as established by XPCL*  
*Elevation: Dam Site point PL13 as established by XPCL*

<table>
<thead>
<tr>
<th>Coordinates:</th>
<th>Elevation:</th>
<th>Method of Survey:</th>
</tr>
</thead>
</table>
| East: 779260.147  
North: 2201834.089 | 331.962  
Vertical Datum: Hon Dao Mean Sea Level Vietnam | DGPS, Differential Leveling, Total Station |

**Location Map / Diagram**

**Other Grid Systems:**  
*Latitude:* 19 53 34.16851  
*Longitude:* 101 40 01.60041

**Lao 97:**  
*East:*  
*North:* :

**Photographs**

*Location*

*Close Up*
**Vientiane GEOMATIC Services**

**SURVEY SUMMARY**  Number: **GPS10**

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<tr>
<td><strong>Project:</strong> Bathymetric, Cross Section and Waterline survey</td>
<td><strong>WGS 84 (all dimensions in metres)</strong></td>
<td><strong>Station:</strong></td>
<td><strong>GPS10</strong></td>
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<tr>
<td><strong>Client:</strong> CK Power public Company</td>
<td><strong>Type of Mark:</strong> Steel Rod in Concrete Monument</td>
<td><strong>Date of Survey:</strong></td>
<td><strong>05/03/2019</strong></td>
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**Origin of Coordinates and Elevation Datum:**
- **Dam Site point PL13 as established by XPCL**
- **Elevation:** Dam Site point PL13 as established by XPCL

**Coordinates:**
- **East:** 773582.245
- **North:** 2198871.129

**Elevation:** 329.617
**Vertical Datum:** Hon Dao Mean Sea Level Vietnam

**Method of Survey:** DGPS, Differential Leveling, Total Station

**Location Map / Diagram**

**Other Grid Systems:**
- **Lattitude:** 19 52 00.77177
- **Longitude:** 101 36 44.95500
- **Lao 97:**
  - **Easting:**
  - **Northing:**

**Location Map / Diagram**

**Photographs**

- **Location**
- **Close Up**
## Survey Summary

<table>
<thead>
<tr>
<th>Vientiane GEOMATIC Services (VGS)</th>
<th>Survey Control Station Description</th>
<th>Date of Issue: March 2019</th>
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<tbody>
<tr>
<td>Project: Bathymetric, Cross Section and Waterline survey</td>
<td>WGS 84 (all dimensions in metres)</td>
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</tr>
<tr>
<td>Client: CK Power public Company</td>
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<table>
<thead>
<tr>
<th>Station: GPS11</th>
<th>Type of Mark: Steel Rod in Concrete Monument</th>
<th>Date of Survey: 05/03/2019</th>
</tr>
</thead>
</table>

### Origin of Coordinates and Elevation Datum:
- Dam Site point PL13 as established by XPCL
- Elevation: Dam Site point PL13 as established by XPCL

### Coordinates:
- East: 774683.791
- North: 2195698.059

### Elevation:
- 326.048

### Vertical Datum:
- Hon Dao Mean Sea Level Vietnam

### Method of Survey:
- DGPS, Differential Leveling, Total Station

### Location Map / Diagram

### Other Grid Systems:
- Lattitude: 19 50 17.09598
- Longitude: 101 37 21.09791
- Lao 97:
- Easting:
- Northing:

### Photographs

- Location
- Close Up

---

For Department of Planning and Co-ordination Only
## SURVEY SUMMARY

<table>
<thead>
<tr>
<th>Vientiane GEOMATIC Services (VGS)</th>
<th>Survey Control Station Description</th>
<th>Date of Issue</th>
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<tbody>
<tr>
<td></td>
<td>WGS 84 (all dimensions in metres)</td>
<td>March 2019</td>
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### Project:
**Bathymetric, Cross Section and Waterline survey**

### Client:
**CK Power public Company**

### Station:
**GPS12**

### Type of Mark:
**Steel Rod in Concrete Monument**

### Date of Survey:
05/03/2019

### Origin of Coordinates and Elevation Datum:
- **Dam Site point PL13 as established by XPCL**
- **Elevation: Dam Site point PL13 as established by XPCL**

### Coordinates:
- **East:** 76719.349
- **North:** 2194823.559

### Elevation:
- **355.914**
- **Vertical Datum: Hon Dao Mean Sea Level Vietnam**

### Method of Survey:
**DGPS, Differential Leveling, Total Station**

### Other Grid Systems:
- **Lattitude:** 19 49 52.14834
- **Longitude:** 101 33 21.44986

### Lao 97:
- **Easting:** 
- **Northing:**

### Location Map / Diagram

### Photographs

- **Location**
- **Close Up**
Vientiane GEOMATIC Services

SURVEY SUMMARY  Number; GPS13

<table>
<thead>
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<th>Vientiane GEOMATIC Services (VGS)</th>
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<th>Date of Issue</th>
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<tr>
<td></td>
<td>WGS 84 (all dimensions in metres)</td>
<td>March 2019</td>
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**Project:** Bathymetric, Cross Section and Waterline survey  
**Client:** CK Power public Company

**Station:** GPS13  
**Type of Mark:** Steel Rod in Concrete Monument  
**Date of Survey:** 05/03/2019

**Origin of Coordinates and Elevation Datum:**  
Dam Site point PL13 as established by XPCL  
Elevation: Dam Site point PL13 as established by XPCL

**Coordinates:**  
East : 760008.671  
North : 2193994.734

**Elevation:** 349.019  
**Vertical Datum:** Hon Dao Mean Sea Level Vietnam

**Method of Survey:** DGPS, Differential Leveling, Total Station

**Location Map / Diagram**

**Other Grid Systems:**  
Lattitude : 19 49 28.95045  
Longitude : 101 28 56.20564

**Lao 97:**  
Easting :  
Northing :

**Photographs**

Location  
Close Up
### SURVEY SUMMARY

**Number:** GPS14

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<td></td>
<td><strong>WGS 84 (all dimensions in metres)</strong></td>
<td><strong>March 2019</strong></td>
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**Project:** Bathymetric, Cross Section and Waterline survey  
**Client:** CK Power Public Company

**Station:** GPS14  
**Type of Mark:** Steel Rod in Concrete Monument  
**Date of Survey:** 05/03/2019

**Origin of Coordinates and Elevation Datum:**  
Dam Site point PL13 as established by XPCL  
Elevation: Dam Site point PL13 as established by XPCL

**Coordinates:**  
East: 751897.891  
North: 2193594.542

**Elevation:** 333.400  
**Vertical Datum:** Hon Dao Mean Sea Level Vietnam

**Method of Survey:** DGPS, Differential Leveling, Total Station

**Other Grid Systems:**  
Lattitude: 19 49 19.75816  
Longitude: 101 24 17.43783

**Lao 97:**  
Easting:  
Northing:

### Photographs

![Location](image1.jpg)  
![Close Up](image2.jpg)
### SURVEY SUMMARY

**Number:** GPS15

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<th>Date of Issue: March 2019</th>
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**Project:** Bathymetric, Cross Section and Waterline survey  
**Client:** CK Power public Company  
**Station:** GPS15  
**Type of Mark:** Steel Rod in Concrete Monument  
**Date of Survey:** 05/03/2019

**Origin of Coordinates and Elevation Datum:**  
Dam Site point PL13 as established by XPCL  
Elevation: Dam Site point PL13 as established by XPCL

**Coordinates:**  
East: 747068.909  
North: 2192956.835

**Elevation:** 354.229  
**Vertical Datum:** Hon Dao Mean Sea Level Vietnam  
**Method of Survey:** DGPS, Differential Leveling, Total Station

**Location Map / Diagram**

**Other Grid Systems:**  
Lattitude: 19 49 01.24346  
Longitude: 101 21 31.27148  
Lao 97:  
Easting:  
Northing:

**Photographs**

- Location  
- Close Up
### SURVEY SUMMARY

<table>
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<th>Vientiane GEOMATIC Services (VGS)</th>
<th>Survey Control Station Description</th>
<th>Date of Issue: March 2019</th>
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<td>Project: Bathymetric, Cross Section and Waterline survey</td>
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<td>Client: CK Power Public Company</td>
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<th>Station: GPS16</th>
<th>Type of Mark: Steel Rod in Concrete Monument</th>
<th>Date of Survey: 05/03/2019</th>
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<table>
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<tr>
<th>Origin of Coordinates and Elevation Datum:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dam Site point PL13 as established by XPCL</td>
</tr>
<tr>
<td>Elevation: Dam Site point PL13 as established by XPCL</td>
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<th>Coordinates:</th>
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<tr>
<td>East: 739784.4117</td>
<td>Vertical Datum: Hon Dao Mean Sea Level Vietnam</td>
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<tr>
<td>North: 2194423.918</td>
<td>Method of Survey: DGPS, Differential Leveling, Total Station</td>
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<table>
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<tr>
<th>Location Map / Diagram</th>
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<tbody>
<tr>
<td>Other Grid Systems:</td>
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<td>Lattitude: 19 49 52.19125</td>
</tr>
<tr>
<td>Longitude: 101 17 21.75240</td>
</tr>
<tr>
<td>Lao 97:</td>
</tr>
<tr>
<td>Easting:</td>
</tr>
<tr>
<td>Northing:</td>
</tr>
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</table>

### Photographs

- **Location**
- **Close Up**
**SURVEY SUMMARY**  Number: **GPS17**

<table>
<thead>
<tr>
<th>Vientiane GEOMATIC Services (VGS)</th>
<th>Survey Control Station Description</th>
<th>Date of Issue</th>
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<tr>
<td>Project: Bathymetric, Cross Section and Waterline survey</td>
<td>WGS 84 (all dimensions in metres)</td>
<td>March 2019</td>
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**Client**: CK Power public Company

**Station**: GPS17  **Type of Mark**: Steel Rod in Concrete Monument  **Date of Survey**: 05/03/2019

**Origin of Coordinates and Elevation Datum:**
- Dam Site point PL13 as established by XPCL
- Elevation: Dam Site point PL13 as established by XPCL

**Coordinates:**
- East: 732708.32
- North: 2194836.299

**Elevation**: 362.024

**Vertical Datum**: Hon Dao Mean Sea Level Vietnam

**Method of Survey**: DGPS, Differential Leveling, Total Station

**Location Map / Diagram**

**Other Grid Systems:**
- Latitude: 19 50 08.67076
- Longitude: 101 13 18.86160
- Lao 97:
  - Easting: [image]
  - Northing: [image]

**Photographs**

[location_image]  [close_up_image]
## SURVEY SUMMARY

**Number:** GPS18

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<th>Survey Control Station Description</th>
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<td><strong>Project:</strong> Bathymetric, Cross Section and Waterline survey</td>
<td><strong>WGS 84 (all dimensions in metres)</strong></td>
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<td><strong>Client:</strong> CK Power public Company</td>
<td></td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Station: GPS18</th>
<th>Type of Mark: Steel Rod in Concrete Monument</th>
<th>Date of Survey: 05/03/2019</th>
</tr>
</thead>
</table>

**Origin of Coordinates and Elevation Datum:**
- Dam Site point PL13 as established by XPCL
- Elevation: Dam Site point PL13 as established by XPCL

**Coordinates:**
- **East:** 726626.2315
- **North:** 2196867.462

**Elevation:** 362.9735

**Vertical Datum:** Hon Dao Mean Sea Level Vietnam

**Method of Survey:** DGPS, Differential Leveling, Total Station

**Location Map / Diagram**

**Other Grid Systems:**
- **Lattitude:** 19 51 17.27161
- **Longitude:** 101 09 50.81061

**Lao 97:**
- **Easting:**
- **Northing:**

### Photographs

**Location**

**Close Up**
**SURVEY SUMMARY**

<table>
<thead>
<tr>
<th>Vientiane GEOMATIC Services (VGS)</th>
<th>Survey Control Station Description</th>
<th>Date of Issue</th>
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<td><strong>GPS19</strong></td>
<td>WGS 84 <em>(all dimensions in metres)</em></td>
<td>March 2019</td>
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**Project**: Bathymetric, Cross Section and Waterline survey  
**Client**: CK Power public Company

**Station**: GPS19  
**Type of Mark**: Steel Rod in Concrete Monument  
**Date of Survey**: 05/03/2019

**Origin of Coordinates and Elevation Datum**:  
*Dam Site point PL13 as established by XPCL*  
*Elevation: Dam Site point PL13 as established by XPCL*

<table>
<thead>
<tr>
<th>Coordinates:</th>
<th>Elevation:</th>
<th>Method of Survey:</th>
</tr>
</thead>
</table>
| **East**: 722971.392  
**North**: 2200996.829 | **324.711**  
**Hon Dao Mean Sea Level Vietnam** | **DGPS, Differential Leveling, Total Station** |

**Location Map / Diagram**

**Other Grid Systems**:  
*Lattitude*: 19°53'33.02984  
*Longitude*: 101°07'47.02596  
*Lao 97*:  
*Easting*:  
*Northing*: 

**Location Map**

**Close Up**

**Photographs**

*For PNPCA Only*
**Vientiane GEOMATIC Services**

**SURVEY SUMMARY**  Number: **GPS20**

<table>
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<td>Client : CK Power public Company</td>
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<table>
<thead>
<tr>
<th>Station : <strong>GPS20</strong></th>
<th>Type of Mark : Steel Rod in Concrete Monument</th>
<th>Date of Survey : 05/03/2019</th>
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**Origin of Coordinates and Elevation Datum:**
- Dam Site point PL13 as established by XPCL
- Elevation: Dam Site point PL13 as established by XPCL

<table>
<thead>
<tr>
<th>Coordinates:</th>
</tr>
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<tbody>
<tr>
<td>East : <strong>716525.150</strong></td>
</tr>
<tr>
<td>North : <strong>2195343.245</strong></td>
</tr>
</tbody>
</table>

| Elevation : **345.804** |
| Vertical Datum : Hon Dao Mean Sea Level Vietnam |

**Method of Survey:**
- DGPS, Differential Leveling, Total Station

**Location Map / Diagram**

**Photographs**

- Location
- Close Up
## SURVEY SUMMARY

**Number:** GPS21

<table>
<thead>
<tr>
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<td>WGS 84 <em>(all dimensions in metres)</em></td>
<td>March 2019</td>
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**Project:** Bathymetric, Cross Section and Waterline survey  
**Client:** CK Power Public Company  
**Station:** GPS21  
**Type of Mark:** Steel Rod in Concrete Monument  
**Date of Survey:** 05/03/2019

**Origin of Coordinates and Elevation Datum:**  
- Dam Site point PL13 as established by XPCL  
- Elevation: Dam Site point PL13 as established by XPCL

**Coordinates:**  
- East: 710964.550  
- North: 2195159.137

**Elevation:** 356.315  
**Vertical Datum:** Hon Dao Mean Sea Level Vietnam  
**Method of Survey:** DGPS, Differential Leveling, Total Station

**Location Map / Diagram**

**Other Grid Systems:**  
- Latitude: 19 50 28.03926  
- Longitude: 101 00 51.96023

**Lao 97:**  
- Easting:  
- Northing:

**Location Map / Diagram**

**Photographs**

- Location
- Close Up

---

SURVEYING - MAPPING - GEOLOGICAL - ROAD & TRAFFIC ENGINEERING - LAND & GEOGRAPHIC INFORMATION  
Office: 856 21 416150  
Mob 1: 856 20 5582 8964  
E-mails: vtegeomatic@laopdr.com & sirpbs@yahoo.com  
PO Box 5568 Vientiane, Lao PDR
**SURVEY SUMMARY**

**Number:** GPS22

<table>
<thead>
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<td><strong>GPS Control Station Description</strong></td>
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<td><strong>March 2019</strong></td>
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**Project:** Bathymetric, Cross Section and Waterline survey

**Client:** CK Power Public Company

**Station:** GPS22

**Type of Mark:** Steel Rod in Concrete Monument

**Date of Survey:** 05/03/2019

**Origin of Coordinates and Elevation Datum:**

- Dam Site point PL13 as established by XPCL

**Elevation:** Dam Site point PL13 as established by XPCL

**Coordinates:**

- East: 706686.278
- North: 2197034.446

**Elevation:** 343.450

**Vertical Datum:** Hon Dao Mean Sea Level Vietnam

**Method of Survey:** DGPS, Differential Leveling, Total Station

**Location Map / Diagram**

**Other Grid Systems:**

- Lattitude: 19 51 30.65537
- Longitude: 100 58 25.71344

**Lao 97:**

- Easting:
- Northing:

**Photographs**

- Location
- Close Up
## SURVEY SUMMARY

<table>
<thead>
<tr>
<th>Vientiane GEOMATIC Services (VGS)</th>
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<tbody>
<tr>
<td></td>
<td>WGS 84 <em>(all dimensions in metres)</em></td>
<td>March 2019</td>
</tr>
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### Project:
- Bathymetric, Cross Section and Waterline survey

### Client:
- CK Power public Company

### Station:
- GPS23

### Type of Mark:
- Steel Rod in Concrete Monument

### Date of Survey:
- 05/03/2019

**Origin of Coordinates and Elevation Datum:**
- Dam Site point PL13 as established by XPCL
- Elevation: Dam Site point PL13 as established by XPCL

**Coordinates:**
- East : 700062.624
- North : 2199947.849

**Elevation:**
- 366.176

**Vertical Datum:**
- Hon Dao Mean Sea Level Vietnam

**Method of Survey:**
- DGPS, Differential Leveling, Total Station

**Location Map / Diagram**
- Other Grid Systems:
  - Lattitude : 19 53 07.86369
  - Longitude : 100 54 39.22900
  - Lao 97:
    - Easting :
    - Northing :

**Photographs**
- Location
- Close Up
### SURVEY SUMMARY  Number: GPS24

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<td></td>
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<td>March 2019</td>
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**Project:** Bathymetric, Cross Section and Waterline survey  
**Client:** CK Power public Company  
**Station:** GPS24  
**Type of Mark:** Steel Rod in Concrete Monument  
**Date of Survey:** 05/03/2019

**Origin of Coordinates and Elevation Datum:**  
Dam Site point PL13 as established by XPCL  
Elevation: Dam Site point PL13 as established by XPCL

**Coordinates:**  
East: 692587.757  
North: 2200263.586  
**Elevation:** 353.955  
**Vertical Datum:** Hon Dao Mean Sea Level Vietnam

**Other Grid Systems:**  
Lattitude: 19 53 20.8378  
Longitude: 100 50 22.42238  
Lao 97:  
East:  
North:  
**Method of Survey:** DGPS, Differential Leveling, Total Station

**Location Map / Diagram**

**Photographs**

**Location**

**Close Up**
Annex. Copy of clients ToR - Precise Levelling and GNSS Survey – As supplied by the client

Luang Prabang HEPP

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**Introduction**

**General**

The Luang Prabang HEPP is located on the Mekong River approximately 20 km upstream of Luang Prabang, and about 4 km upstream of the confluence with Nam Ou River. For hydraulic analysis and design works a hydrographic surveys along the Mekong River are required.

**Engagement of Surveyor**

The Hydrographic surveys must be undertaken under the direction of a professionally qualified surveyor who shall be responsible for all survey works carried out, the post-processing and the submission of bathymetric maps, cross sections and survey report.

**Scope of Works**

The scope of works covers the following:

- Bathymetric survey of the dam site area, from approx. 2 km upstream of proposed dam site to approx. 1 km downstream of confluence with Nam Ou River, and approx. 1 km of the Nam Ou River from the confluence with the Mekong River upstream.

- River Cross Section every 500 m between the Luang Prabang Dam site and Pak Beng Dam site, covering both, the submerged river channels as well as the emerged flood plain. The distance or spacing of each river cross section (500 m) shall be measured at the center line of the river. In case of large variation of cross section or very abrupt change or water level such as water fall, the spacing of each cross section may be less than 100 m, depend on contractor judgement.

- Establish and install benchmarks or permanent ground control points (BM) for precise levelling from national levelling point of Lao PDR and/or reference levelling points identified by the Employer/Consultant prior starting of the survey. Number of new BMs are foreseen as 20 BMs (or contractor propose) while the locations of new BMs must be higher than reservoir level above flood level. It’s not only for the cross section survey but also for future reference to check water level, geometry of cross section and location of staff gauge (roughly 20 BMs or contractor propose).

- Any necessary authorizations from authorities to affect the scope of work shall be obtained by the surveyor with the assistance from Employer.
Detailed Scope of Works

General

Horizontal Positioning System
The horizontal positioning shall be controlled by Differential Global Positioning System (DGPS) or equivalent providing an accuracy of +/- 1.0 m or better.

The DGPS shall be checked against a known coordinated position (bench mark) before and after survey each day. DGPS integrity shall be performed daily in order to detect any degradation of the accuracy.

Geodetic Datum
The bathymetric survey works shall be carried out in WGS84 datum and UTM47/48N projection.

Vertical Datum
The datum used during the survey shall be Earth Global Model 2008 (EGM2008).
Care shall be taken to ensure the geodetic heights used throughout the survey are related to the same geodetic datum.

Digital Surveying System
Appropriate bathymetric software (e.g. ArcGIS) shall be used for survey preparation, field data editing and data control survey and post processing.

Bathymetric Survey

Survey Area
The survey area is shown in Figure 0-1 below. The survey area can be provided in electronic format (*.shp file format).
Figure 0-1: Area for Bathymetric Survey

The survey limits shall extend to 20 m beyond the perimeter of the survey area or up to the adjacent waterline.

The Survey Coverage Density shall be 100%.

Survey Equipment

The bathymetric survey shall be carried out using Multi Beam Echo Sounder.

The echo-sounder shall be calibrated daily, up to the maximum water depth of the survey area, before and after sounding. Calibration records shall be submitted to the employer or his representative for inspection.

The contractor shall specify the equipment to be used before start of campaign and await the Employer’s approval. References for the foreseen equipment shall be enlisted.

Accuracy of Bathymetric Survey

The accuracy of the bathymetric survey shall not exceed (accuracy at 95% confidence level):

Horizontal: 0.50 m
Vertical: 0.20 m
**Deliverables**

The following data and reports shall be delivered:

- Bathymetric maps/plots in scale 1:1000 and contour lines of 1.0 m
- Bathymetric Survey Report, incl. sensor calibration protocols, control points measurements, survey plans, etc.
- Executive Summary of the Bathymetric Survey (approx. 2 pages)
- Digital Elevation Model of the Bathymetric Survey (in editable digital format)

**River Cross Sections**

**Specifications**

The survey shall cover both, the submerged river channel as well as the emerged flood planes on both river banks up to an elevation of 320 m asl. It has to be ensured that the transition between the submerged and the emerged part of the cross section is consistent and reliable. The minimum requirements of points surveyed are given in Figure 0-2. Additional specifications for bridges with concrete or steel structures are given in Figure 0-3.

**Figure 0-2:** Schematic cross-section for bathymetric and terrestrial survey with minimum requirements of points surveyed

**Figure 0-3:** Schematic survey and drawing of heavy bridges
The river water level at each cross section has to be measured and clearly identified in the final drawings of the sections. The dates and hours corresponding to field survey performed at each cross section must be reported precisely.

The density of topographic points required for each cross corresponds to 1 point every 10 meters in average. Each existing break line in the cross section must be represented properly. The density of topographic points can be adapted depending on the field characteristics. This means that the topographic point density can be lower for area with homogeneous landscape but must be higher for area with numerous break lines (see Figure 0-4 below).

![Figure 0-4: Density of topographic points required](image1)

**Survey Area**

The survey area is shown in Figure 0-5 below. The survey area can be provided in electronic format (*.shp file format).

![Figure 0-5: Area for River Cross Section Survey](image2)

**Survey Equipment**

The hydrographic survey of the submerged river channel shall be carried out using Single Beam or Multi Beam Echo Sounder. The echo-sounder shall be calibrated daily, up to the
maximum water depth of the survey area, before and after sounding. Calibration records shall be submitted to the employer or his representative for inspection. The survey of the emerged flood plain shall be carried out by GNNS based terrestrial geodetic system. The contractor shall specify the equipment to be used before start of campaign and await the Employer’s approval. References for the foreseen equipment shall be enlisted.

**Accuracy of Hydrographic Survey**

The accuracy of the hydrographic survey shall not exceed (accuracy at 95% confidence level):

**Horizontal:** 0.10 m  
**Vertical:** 0.20 m for submerged regions  
0.05 m above the water level

**Deliverables**

The following data and reports shall be delivered:

- Map of cross sections
- River Cross Sections plots in scale 1:500 and photographs of each cross section (at least one from upstream an one from downstream)
- Hydrographic Survey Report, incl. sensor calibration protocols, control points measurements, survey plans, List of BMs or established points and photos with coordinate and Elevation (x,y,z). etc.
- Executive Summary of the Hydrographic Survey (approx. 2 pages)
- Hydrographic Cross Sections in the following editable digital format:
  - ASCII files with N, X, Y, Z coordinates, station of point, waterline points with special indication and date & time of measurement
  - DWG file format with data in real coordinates X, Y, Z

The drawing of the cross section will respect the following requirements:

- Right bank is defined as right side when looking in flow direction (downstream) of the river.
  - Right bank on the right side of the figure and left bank on the left side of the figure
- X axis including both cumulative distance from left bank and intermediate distance between two ground points
- Y axis corresponding to the elevation above sea level.
- To display any place, village, kaeng, fall, bridge, tributaries, jetty, etc, which is expected to significant for the river shape and profile. The name of above locations shall be put into the drawings.

**Study Time Frame**

The Hydrographic Surveys shall be carried out within a time frame of 3 months, planned during January 2019 to March 2019.

The Contractor is encouraged to submit his best estimate of the time input needed to carry out the said services including an earlier completion date for the said services. It is
brought to the attention of the Contractor that an earlier completion date will be favourably considered during the evaluation of the bids by the Employer/Consultant.

In his proposal, the Contractor must submit a time schedule for review including a list of equipment for the proposed services.
Annex. Copy of clients ToR - Precise Levelling and GNSS Survey – As supplied by the client

Luang Prabang HEPP

TERMS OF REFERENCE
PRECISE LEVELLING AND GNSS SURVEY
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Introduction

The Luang Prabang HEPP is planned on the Mekong River approximately 20 km upstream of Luang Prabang, and about 4 km upstream of the confluence with Nam Ou River. The scheme will be part of a Low-Head Hydropower Cascade System along the Mekong River, with Pak Beng HEPP approximately 170 km upstream, and Xayaburi HEPP approximately 130 km downstream of the proposed site.

Due to the potential impact of the backwater on the tailwater of the upstream scheme, it is important to know the exact height differences to the neighboring HEPP Projects.

Theoretically the height difference of the cascade system can be determined by a differential GNSS (GPS) survey. As GNSS elevations are based on ellipsoidal heights the global geoidal model EGM2008 can be used to reduce elevations to orthometric height. The local accuracy of the geoidal model EGM2008 in the area is unknown and relative inaccuracies of ± 2m are expected. A precise levelling campaign shall be performed between Pak Peng, Lunag Prabang and Xiabury HPP.

The following specification should provide information about the necessary surveying work. The levelling routes and GNSS points are suggestions only. Local knowledge shall be used to optimize the proposal.

The Terms of Reference are based on the following existing survey report:

- Establishment of GPS Ground Control Point and Topographic Survey for new Gauging Station Project, dated June 2014
- GPS Control Points, Topographic Map, Cross Section and Levelling Survey Work for New Gauging Station Project of Ban Xiengkeo Luang Prabang, Nam Ma Xiengkong and Prabeng Bridge, dated December 2015
- Xayaburi Dam Reservoir, Cross Section Survey & River Profile Survey of Mekong River, Nam Ou, Nam Khan, Nam Suang, dated October 2016

Scope of Works for Control Point Survey

Overview

A GNSS campaign with a minimal network layout as indicated in the layout map shall be executed followed by a precise levelling campaign. Existing benchmarks of the previous survey campaigns shall be used. If existing points are destroyed and at new locations, benchmarks shall be established. All benchmarks shall be connected by either differential GNSS or levelling to existing gauging stations and or previously surveyed river profiles.
The precise levelling shall be used to determine the orthometric height of the above points in order to verify the Undulation value derived from the Global Geoidal Model EGM 2008.

<table>
<thead>
<tr>
<th>Point Id.</th>
<th>Remarks</th>
<th>Lat.</th>
<th>Long.</th>
<th>Undulation [m] EGM2008</th>
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<td>new BM</td>
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<td>100d48'29.65&quot;E</td>
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<tr>
<td>Pak Beng GPS 102</td>
<td>existing BM</td>
<td>19d53'38.73&quot;N</td>
<td>101d07'46.04&quot;E</td>
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<tr>
<td>GPS172</td>
<td>existing BM</td>
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<td>101d18'10.43&quot;E</td>
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<td>new BM</td>
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<td>102d11'12.92&quot;E</td>
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<td>existing BM</td>
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<td>Xyaburi HPP</td>
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<tr>
<td>Xyaburi GPS 3605</td>
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<td>19d14'39.48&quot;N</td>
<td>101d42'34.74&quot;E</td>
<td>-33.793</td>
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</table>

**General Condition**

The Surveying Company (surveyor) shall provide all transportation, personnel, labour, equipment, material, consumables and record review required to accomplish the data acquisition as well as survey and mapping services specified.

Any necessary authorizations from authorities to affect the scope of work shall be obtained by the surveyor.
Field Procedures

Technical Methods

Field works shall be performed in accordance with accepted technical methods as expressed in standard textbooks on surveying theory practice and procedures. Any textbook used for surveying instruction by an accredited university or college will be considered an acceptable text for this purpose.

Differential GNSS (GPS) Method

The method used to determine the coordinates of the control points shall be differential GNSS (GPS) by using high accuracy dual frequency receivers. The baselines shall be observed according to the minimal scheme in the layout map. The duration of the observation shall be at least 4-5 hours minutes per baseline at an observation rate of 10 seconds. All baselines shall be processed by using code and phase. A minimum of 3 (ideally 4-5) GNSS receivers shall be used simultaneously.

Each control point shall be determined by at least 3 baselines. All baselines shall be adjusted using least squares adjustment technique. The maximum error of a 3d coordinate shall not exceed ± 20 mm at a confidence interval of 97.5% (2.5 Sigma).

The network layout as indicated in figure 1 shall be considered as a proposal only. Local knowledge shall be used to improve the network layout.

Differential Levelling (Precise Levelling)

Differential precise levelling shall be used to connect a representative number of GNSS point in the area in order to verify the orthometric height derived by GNSS and Geoidal model EGM2008.

Double run differential levelling shall be executed by using digital levels and 2 invar barcode level staffs per each survey team. The maximum sight length shall not exceed 30 m.

The instrument used shall have data recording capability and shall be certified by ISO 17123-2 to the following minimum standard deviation: 1 mm/km

The maximum allowable misclosure between forward and backward route shall not exceed the following value: 6 mm x \(\sqrt{k}\) where \(k\) = distance in kilometres

The maximum ground clearance shall be 30 cm.

River crossings or areas where differential levelling is not possible, Total Stations shall be used to measure the height difference. The maximum sight length of a Total Station measurements shall not exceed 150 m.

The levelling routes as indicated in figure 1 shall be considered as a proposal only. Local knowledge shall be used to improve the network layout.

Coordinate System

The baseline calculation shall be executed in WGS84 system. The GNSS network shall be referenced to official benchmarks at Xyaburi HPP site. All height differences shall be referenced to the same benchmarks.

The coordinate System shall be UTM (Universal Transverse Mercator) projection Zone 47/48 North.
Reports and submittals

Required Data Differential GNSS

The subcontractor shall prepare the following results:

- List of all baseline vectors in WGS84 coordinate system (dX, dY, dZ)
- Results of least squares adjustment of all baseline vectors in WGS84 coordinate system
- Station descriptions of all control points comprising of the following minimum content:
  - Satellite or Google Maps section indicating the location of the point
  - Photograph of the control point (distance 20-30 m)
  - Description of the location
  - Description of the control point
  - List of Coordinates in WGS84 system in geocentric and geodetic format (X,Y,Z/Lat. Lon. Height)
  - List of Coordinates and Height in UTM Projection incl. ellipsoidal height, orthometric height and levelled height.

The data shall be submitted in softcopy (e-mail or via exchange server) as specified below. Sets of hard copies are not required.

Required Data Differential Levelling

The data shall be submitted in softcopy (e-mail or via exchange server) as specified below. Sets of hard copies are not required.

- Detailed maps indicating all levelling routes
- List of all height differences incl. misclosure between forward and backward routes
- List if all readings (electronically only)
- Result of network adjustment

Field Data

Upon completion of the contract, all original field books shall be submitted to Pöyry. Field notes with sketches are required and shall be neat, clear, and concise.

Sketches shall be part of the field survey work, which includes located sketches with field ties for all control points, boundary corner monuments, grid station monuments, and benchmarks whether set or existing. Upon Completion of this contract, all original sketches shall be submitted to Pöyry.

Records

All documents prepared by the Subcontractor based on survey work carried out under this contract shall be the sole property of Pöyry. The Subcontractor shall have no right to use, reproduce or pass on to third parties any data, drawings or information without prior written permission from Pöyry.

All documents shall be in English Language.

Time Frame

The following milestones have to be considered:
Start of the survey works not later than December, 2018
Completion of survey works (for the areas indicated in Annex A) not later than end of February, 2019

QUALITY ASSURANCE

All survey works shall be performed by qualified surveyors under the direct supervision of a licensed registered surveyor. Maps and documents shall be certified with the seal and signature of the licensed surveyor responsible for the survey.

All work performed and subject to this specification shall be subject to the approval of Pöyry. However, such approval shall not relieve the subcontractor from full responsibility for the adequacy and accuracy of the survey and related documents.
LUANG PRABANG POWER COMPANY LIMITED
Luang Prabang HPP

LiDAR Drone Report
HPP Project Area
Contact

Pöyry Energy Ltd. (Thailand)
Vanit II Bldg, 22nd Floor, Room#2202 - 2204
1126/2 New Petchburi Road
Makkasan, Rajchthewi
TH-10400 BANGKOK
Thailand
Tel. +66 2 108 1000

Robert Braunshofer, Business Manager
Mobile: +66 92 264 0734
robert.braunshofer@poyry.com
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EXECUTIVE SUMMARY

A LiDAR drone survey has been performed between 23. – 24. April 2019 along the right bank of Mekong river at LP HPP.

The survey was conducted by Pöyry Energy Ltd. (Thailand) using the LiDAR system RIEGL MiniVUX-1UAV and a DJI Matrice 600 Pro drone carrier. A total number of 5 flights at an elevation of 100 m above ground were executed to cover the area. A point cloud was processed assisted by Asian Aerospace Services. The points were classified and filtered and a ground surface was extracted. A point spacing of 10-20 cm was achieved. This resulted in a point density of 20 points per square meter.

As a result, a 3D-mesh at a resolution of 0.5 m has been created. The following accuracies have been achieved:

Urban and open area: ± 10 cm
Dense canopy: ± 50 cm

Additionally, an Ortho-image with a ground resolution of 5 cm was created.
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1 GENERAL

1.1 General

The Luang Prabang Hydro Electric Power Project (LP HPP) is located on the Mekong River approximately 20 km upstream of Luang Prabang, and about 4 km upstream of the confluence with Nam Ou River. At the LP HPP site, a precise topographic survey was executed by executing a drone LiDAR mission.

1.2 Survey Team

The LiDAR survey was undertaken under the direction of Talay Jiamjaratrangssee, a professional GIS engineer, and his team of Pöyry Energy Ltd.

2 TECHNICAL SPECIFICATIONS

2.1 General

LiDAR (Light Detection and Ranging) is a very accurate, fast and cost-effective optical remote sensing technique used to create Digital Elevation Models (DEM). The survey was done by a LiDAR sensor drone (laser scanning). Despite that, the project area are mostly covered with dense forests, the LiDAR sensor can measure both the height of the canopy as well as the ground elevation.

LiDAR sensors can only collect points relative to the centre of the sensor; therefore, the sensors need to be combined with GPS (GNSS) devices and reference points at the ground (ground control points).

Once the data was collected, a DTM was generated and provided as a 3D-mesh in AutoCAD Civil-3d format.

2.2 Survey Area

The surveyed area covers the area of 1’290’000 m² at the proposed dam site of LP HPP and is shown in Figure 2-1 below.

Figure 2-1: LiDAR area marked in red
2.3 System Specification
The following drone LiDAR system and survey equipment were used:

Drone: DJI Matrice 600 Pro
LiDAR sensor: RIEGL MiniVUX-1UAV
Camera: Sony Alpha 6000
GNSS (GPS) Sensor: Trimble R2 dual frequency GNSS receiver with RTX correction service

3 MAPPING PARAMETERS

3.1 Geodetic Datum/ Projection
The geodetic Datum used was based on the GNSS campaign VGS 2019 with referenced to control point PL13 at Xayaburi HPP
The following projection and mapping parameters were used:

Reference ellipsoid (WGS-1984):
- Semi-Major axis: 6 378 137.000 m
- Inverse flattening = 1/f): 298.257223563

Projection system:
- Name: UTM (Universal Transverse Mercator)
- Zone: Zone 48 North
- False Easting: 500 000.000 m
- False Northing: 0.000 m
- Origin Latitude: 0° N
- Central Meridian: 105° E
- Scale Factor at central meridian: 0.9996

Local Scale Factor at LP HPP Area:
- Local Scale Factor: 1.0006 (Projection and Elevation)

3.2 Vertical Datum
Elevations were corrected using Geoid Model EGM2008.

3.3 Transformation / Shifting Parameters
The Ground Control Survey and the Reference System for the drone trajectories were based on Trimble RTX correction service while the following UTM-48 Shifting Parameters in were applied to all survey data:
- Shifting East: 0.05 m
- Shifting North: 1.07 m
- Shifting Height: -1.60 m
4  REFERENCE SYSTEM

4.1  Ground Control Points

Table 4-1 listed control points observed by GNSS. The accuracy is within the GNSS specification of 3-5 cm.

Table 4-1: Control points used to reference the GNSS and LiDAR data.

<table>
<thead>
<tr>
<th>Point Id.</th>
<th>Easting [m]</th>
<th>Northing [m]</th>
<th>Elevation [m]</th>
<th>Differences [cm]</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS0200</td>
<td>201699.86</td>
<td>220278.85</td>
<td>290.31</td>
<td>+ 3 - 4 + 1</td>
<td>LP Airport</td>
</tr>
<tr>
<td>HY02</td>
<td>205525.24</td>
<td>2221861.80</td>
<td>290.06</td>
<td>± 0 ± 0 ± 0</td>
<td>Benchmark at dam site</td>
</tr>
</tbody>
</table>

4.2  GPS Base Station

A GNSS base station was setup and operated during the duration of the LiDAR survey using the following parameters:

- Dual Frequency, geodetic grade 1 Hz Sampling Rate.
- Accuracy for horizontal position +/- 0.03 meter (RMSE).
- Accuracy for vertical position +/- 0.05 meter (RMSE).

4.3  Check points

In order to verify the accuracy of the LiDAR, a ground truth check was performed at several check points referring to the list below:

Table 4-2: Check points and deviations from the Lidar point clouds

<table>
<thead>
<tr>
<th>ID</th>
<th>Pöyry GNSS Trimble Reference</th>
<th>LiDAR Height</th>
<th>Deviation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pier01.01</td>
<td>2221978.65</td>
<td>282.91</td>
<td>0.01</td>
</tr>
<tr>
<td>Pier01.02</td>
<td>2221978.66</td>
<td>282.93</td>
<td>-0.01</td>
</tr>
<tr>
<td>Pier01.03</td>
<td>2221978.66</td>
<td>282.94</td>
<td>-0.01</td>
</tr>
<tr>
<td>Pier01.04</td>
<td>2221978.66</td>
<td>282.92</td>
<td>0.00</td>
</tr>
<tr>
<td>Pier02.01</td>
<td>2221974.40</td>
<td>283.19</td>
<td>-0.05</td>
</tr>
<tr>
<td>Pier02.02</td>
<td>2221974.40</td>
<td>283.16</td>
<td>-0.02</td>
</tr>
<tr>
<td>Pier02.03</td>
<td>2221974.40</td>
<td>283.18</td>
<td>-0.04</td>
</tr>
<tr>
<td>Pier02.04</td>
<td>2221974.40</td>
<td>283.19</td>
<td>-0.05</td>
</tr>
<tr>
<td>Pier03.01</td>
<td>2221969.70</td>
<td>283.46</td>
<td>0.05</td>
</tr>
<tr>
<td>Pier03.02</td>
<td>2221969.70</td>
<td>283.45</td>
<td>0.06</td>
</tr>
<tr>
<td>Pier03.03</td>
<td>2221969.69</td>
<td>283.50</td>
<td>0.01</td>
</tr>
<tr>
<td>VGS.HY02.01</td>
<td>2221860.73</td>
<td>291.68</td>
<td>0.01</td>
</tr>
<tr>
<td>VGS.HY02.02</td>
<td>2221860.73</td>
<td>291.68</td>
<td>-0.00</td>
</tr>
<tr>
<td>VGS.HY02.03</td>
<td>2221860.74</td>
<td>291.66</td>
<td>0.02</td>
</tr>
<tr>
<td>VGS.HY02.04</td>
<td>2221860.73</td>
<td>291.65</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Additionally, a comparison between with the Bathymetric data and drone LiDAR data was made to verify the accuracy in the overlapping area (see Figure 4-1). 80% of the differences were within ± 50 cm.
Figure 4-1: Comparison between LiDAR and Bathymetric survey
5 DRONE FLIGHT

5.1 Mission Planning
Prior to the data acquisition, a mission planning was done to recalculate the flight trajectories with consideration to the local terrain and the reference ground control points.

![Figure 5-1: Flight trajectories for LiDAR drone mission](image)

5.2 LiDAR / Image acquisition
The following settings were used for the LiDAR scanning and the image acquisition:

**Scanner Settings:**
- LiDAR Point density: 20 points/m²
- Speed: 8 m / s
- Elevation above ground: 100 m

**Camera Setting:**
- Image GSD: 5 cm
- Image interval: 1.5 s
- Side overlap: 50%
6 DATA PROCESSING

6.1 Point Cloud Processing

The data processing was executed with the support from Asian Aerospace Services. The collected point clouds were georeferenced using RINEX-data of both the Base Station and the drone’s GNSS system in order to calculate centimetre level of accuracy for the point cloud and for the image locations. In the second step, the point clouds were classified mainly to filter-out the ground points from the remaining points.

![Image of point cloud processing steps]

Figure 6-1: Data processing steps from right to left

6.2 Mapping

The ground points of classified point clouds were then used to generate a 3d-Mesh for the entire area. The detailed 3d-Mesh was further simplified by allowing a tolerance of maximal ±20 cm to optimize computation time.

Moreover, an Ortho-image with a ground resolution of 5cm was generated using photogrammetry software to generate GeoTiff Raster Image file.

The accuracies of both the terrain model and the Ortho-image can be summarised as follows:

<table>
<thead>
<tr>
<th></th>
<th>Urban area</th>
<th>Open area</th>
<th>Dense canopy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal (PNPCA Only)</td>
<td>± 10 cm</td>
<td>± 20 cm</td>
<td>± 30 cm</td>
</tr>
<tr>
<td>Vertical (PNPCA Only)</td>
<td>± 10 cm</td>
<td>± 20 cm</td>
<td>± 50 cm</td>
</tr>
</tbody>
</table>

Table 6-1: Accuracy achieved