PROCEDURE MANUAL

TOPOGRAPHICAL AND BATHYMETRIC SURVEYS

Presented By:

ORBITAL AFRICA LTD.

We MAP. You Explore!

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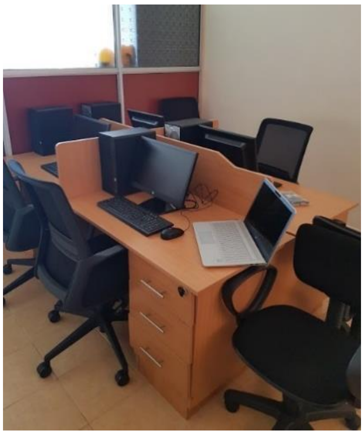
1. ABOUT ORBITAL AFRICA



Orbital Africa is a registered company under the laws of Kenya. Orbital is a Geographic Information System (GIS), ICT, Remote Sensing (RS) and spatial planning consulting firm helping to deliver geospatial solutions that enable our clients to become high-performance businesses.

Orbital Africa is offers survey and mapping consulting services in Kenya and Eastern Africa at large with more than 8 years of proven track record in delivery of robust geoinformation services including land and topographical surveying, mobile and web mapping, spatial planning, land-use and urban planning including Geospatial training services here in eastern Africa region.

Established in the year 2008, **Orbital Africa** was incorporated in 2nd August 2011 and began operations thereafter. By providing outstanding client-tailored Geospatial services, we ensure customer satisfaction at all stages of project planning and execution.

Orbital Africa offers an array of Geospatial services in the following areas: topographical and land surveying services; GIS and mapping services; web mapping application development; 3D mapping; map production services; enterprise GIS solutions; project planning and management; GIS data capture; urban/spatial planning, Geoinformation training and capacity development; sales and support and technical support services.

Orbital Africa has undertaken several GIS, mapping and engineering design projects to a wide range of clients in Kenya, Uganda and Tanzania, and has a proven track record in areas of capacity building and systems development.

Orbital Africa is differentiated in the marketplace by consistency in building long-term, trust-based relationships with clients; focusing on value creation and business outcomes; fostering a culture of innovation, collaboration and teaming, leveraging on our delivery networks and project management for quality, speed and cost effectiveness; attracting, developing and retaining the best talent.

Orbital Africa is led by a diverse management team with a broad base of business and technical industry experience in Geospatial service delivery. Our management team provides strategic and operational direction to the staff members of the company thus fostering competency in service delivery and execution of big projects.

2. TECHINICAL PROPOSAL

3.1 Background

Fiveght contacted Orbital Africa to provide a detailed technical and financial proposal for carrying out Topographical and Bathymetric Survey along R. Tana in Kitui County. The Terms of Reference (ToR) and scope for this consultancy were found to be fairly well written and clearly reflects the Fiveght intention in accomplishing the task efficiently and expeditiously. The in-depth information we have on the project has enabled us to prepare a technical proposal that will afford the client optimum service at an affordable cost.

3.2 Objectives

- ❖ To establish Ground control Points (GCPs) on project area;
- ❖ To carry out detailed topographical survey;
- ❖ To conduct detailed bathymetric survey
- ❖ To generate longitudinal and cross-section profiles of the river channel;
- ❖ To produce topographical and contour maps

3.3 Location of Project Area

The project area is located along R. Tana near Usueni in Kitui County. The coordinates of the project area are **0° 9'15.81"S, 38°11'36.30"E.** The figure below depicts the location of the project area.

Fig 1: Location of Project Area

3.4 Project Reconnaissance

Before the execution of the project, the site pre-visit is of paramount importance as it allows our team of Surveyors get acquainted with the nature of site, terrain, whether bush clearing is needed among other tasks. The details obtained will be used among other things to approximate the project duration, amount of resources that need to be mobilized and other logistical arrangement prior to commencement of the project.

3. TOPOGRAPHICAL SURVEY

4.1 Introduction

The aim of any topographical survey exercise is to determine the relative locations of points (places) on the earth's surface by measuring horizontal distances (x and y), differences in elevation (z) and directions (θ). The topographical maps that are produced often give the locations of places (observable features within the study area) and information about changes in elevation depicted using contours and spot heights. The topographical and cadastral maps also serve as base maps.

Plate 1: Topographical Survey and Field Data Collection

4.2 General Approach

The general approach is based on the objectives and scope of works. Basically, it consists of office work, field data collection and map production works. The reconnaissance field visit is very important to set out the proposed control points and decide on the number of benchmarks required for complete topographical map preparation. The GPS crew establishes the control points based on available National Grid Points and makes ready for further topographic data collection.

The topographic survey crews collect all necessary data points and encodes them into the project database. The coded points are later imported into AutoCAD Civil 3D for plotting, contouring, profile generation and topographical map production. There is daily communication and follow-up by the data processing and map preparation/production team in ensuring seamless workflow in data transmission from field to office for quality control/quality assurance as well as processing.

The feedbacks and field verification of the processed contour map are done to check whether the client's requirements are adequately met. Thus, considering the above aspects of the approach, our strategy in planning the feasibility, topographic and bathymetric survey works have been described in detail in the subsequent sections.

4.2.1 Requirements for Topo Survey

- The selection of **a Scale** to adopt in advance (depends on extent of project area); this determines the plotable error.
- Our principle is to work from the **most accurate to least accurate** methods with minimal errors.
- The orientation of each survey must be and preferably with respect to the **True North (N).**
- The first stage of surveying exercise is will entail establishing both horizontal controls (traversing) and vertical controls (levelling): the distance, direction and difference in elevation between key fixed points. The control points (known points) shall be used as benchmarks for the survey work.
- Once the horizontal and vertical control points have been established, readings are made from a total station or geodetic GPS (RTK) placed on the known points. The readings on features within the project area (e.g. edge of road, fence, corner of building, tree etc) are picked in 3D format i.e. X, Y and Z.
- Lastly, we shall obtain a survey plan from lands office that will help us to check on the accuracy, e.g. redundant points, pacing of measured distances, surveying between fixed positions, etc.
- The collected field data is downloaded, and error checking is done before plotting and drawing the features in AutoCAD Civil 3D.

4.2.2 Project Datasets

The topographical survey data shall be obtained directly from the field using modern survey equipment. The secondary data such as survey plans shall be purchased from lands office.

i. Primary Data e.g. Ground Control Points, Spot heights, topo features data (X, Y and Z).
ii. Secondary Data e.g. Survey Plans, Topo maps of Scale 1:50,000, previous site plan, cadastral maps etc.

4. BATHYMETRIC SURVEY

5.1 Introduction

Bathymetric (Hydrographic) Survey is the survey of physical features present underwater. It is the science of measuring all factors beneath water that affect all the marine activities like dredging, marine constructions, offshore drilling etc. Bathymetry is performed to map the under-water bottom with a high level of accuracy. It will help correlation and interpretation of the data obtained from other methods, which yield sub-bottom information and allow a quality check of the results.

The principle of the method is to send an acoustic signal and measure the travel time to derive a depth. This depth conversion process is done by first measuring the velocity of sound in the water at different depths. This calibration is done twice a day to ensure a good accuracy. The water depth measurements can be expected to be accurate to within ±10 cm. The bathymetry equipment is a small equipment which is mounted on a boat and survey conducted along with other geo-physical methods. Survey is conducted in a grid pattern. The line spacing is decided based on the resolution required. The accurate positioning is achieved using a Differential Global Positioning System.

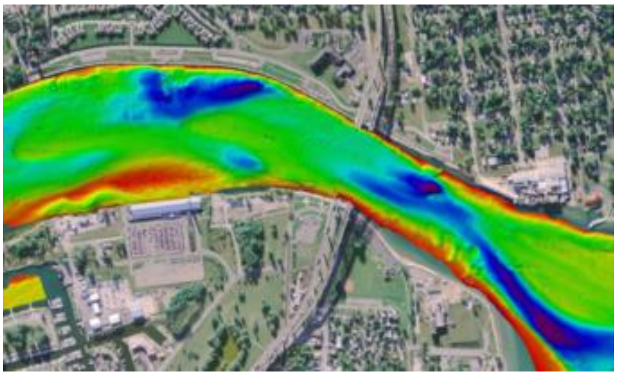


Plate 2: Bathymetric Survey and a Digital Elevation Map

The bathymetric survey works will be carried out over and along the river in question to determine its depth at various sections and the terrain of its floor surface. Thereafter, detailed bathymetric surveying work with the average cross-section at every 20m shall be carried out for preparation of the recent **Area–Capacity–Elevation** Curve of the river at above predefined intervals. A boat will be used to carry the measuring instrument and take depth as well as co-ordinate data at designed locations.

5.2. Bathymetric Survey Methods

- **Multi-beam surveying:** A multibeam echo sounder attached to a boat sends out a wide array of beams across a "swath" of the waterbody floor. As the beams are bounced back from the waterbody floor, the data is collected and processed. The processed data can be viewed in real time on the boat during the survey. Multi-beam surveying is generally done in larger water bodies.
- **Single-beam surveying:** Rather than sending out a wide set of beams, single-beam bathymetry measures the water depth directly under the boat. Single-beam surveys are generally used for smaller water bodies.
- **Acoustic Doppler Current Profiler (ADCP):** ADCPs are used throughout USGS to measure streamflow. ADCPs measure water velocity by transmitting sound waves which are reflected off sediment and other materials in the water. Data collected from ADCPs can then be used to for bathymetric mapping.
- **Sub-bottom Profilers:** Sub-bottom profilers are most commonly used to view the layers of sediment and rocks under the water body floor. A transducer sends a sound wave to the water body floor. This sound wave can penetrate the water body floor. The data returned from the sound waves can be mapped to show the layers beneath the water body floor.
- **Ecomapper Autonomous Underwater Vehicle:** The Ecomapper can collect detailed bathymetric data, down to one-foot contours, in places that are difficult to reach with boats. The Ecomapper uses side-scan sonar and a Doppler velocity log.

5. METHODOLOGY

6.1 TOPOGRAPHICAL SURVEY

6.1.1 Introduction

The proposed methodology will focus on primary (field) and secondary data collection and management including data editing, cartographic map production and quality assurance and control.

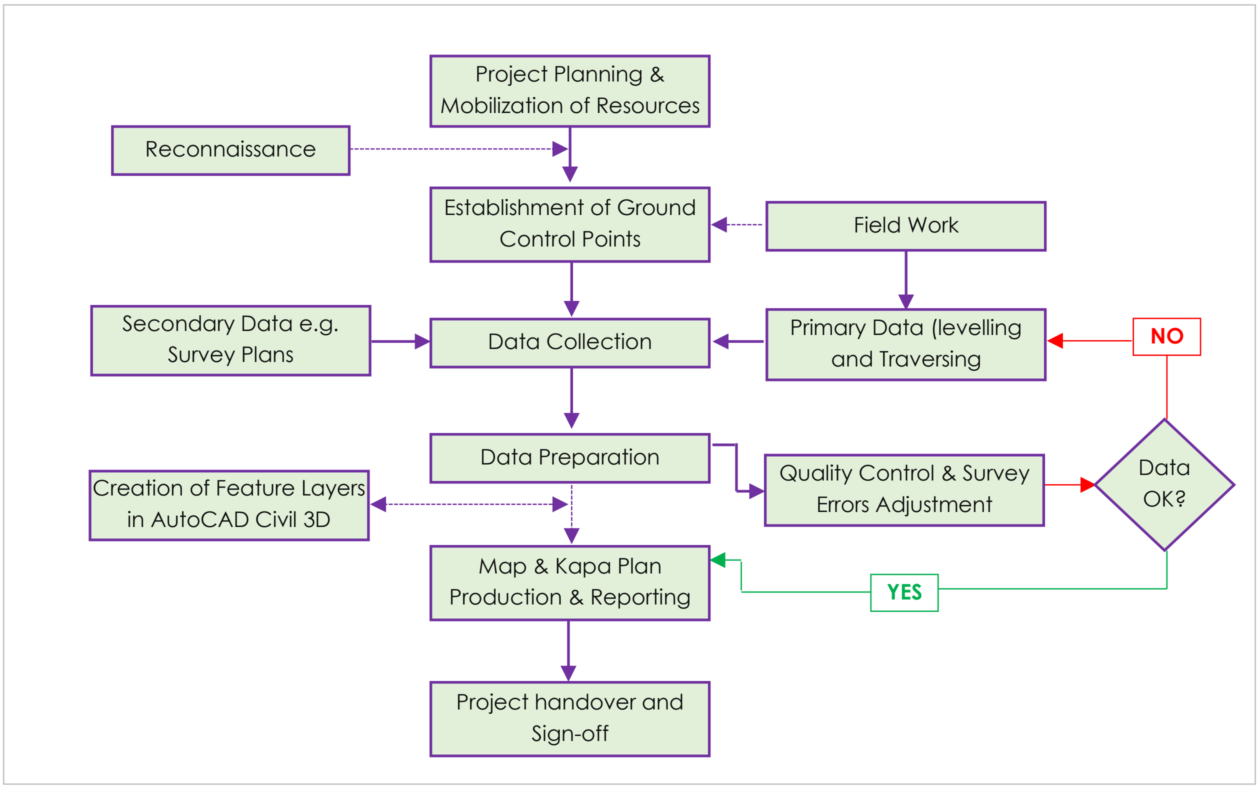


Fig 2: Topo Survey Methodology

6.1.2 Project Planning

The main output of this phase is the project plan and its associated plans for the functional areas of scope, project schedule/timeframe, cost, quality control and assurance, human resources, change management, communications, risks and mitigations, and procurement of products, services as well as resources that need to be acquired for successful implementation of the project.

6.1.3 Site Pre-visit

Before the execution of the project, the site pre-visit is of paramount importance as it will allow our team of surveyors get acquainted with the nature of site, terrain, planning on logistics, whether bush clearing is needed etc. The details obtained will be used to approximate the project duration, amount of resources (finance, time and personnel etc.) that need to be mobilized and other logistical arrangement prior to commencement of the project.

6.1.4 Horizontal Ground Controls

The method that we shall employ to establish the horizontal controls is *closed traverse* where readings begin and end at fixed control points of known location. This permits the checking, calculation and adjustment for closure error obtained during the readings from the total station.

6.1.5 Vertical Ground Controls

The aim of obtaining vertical distances is to determine the differences and changes in elevation from one location to another. This task will be done using **levelling** method with a digital/automatic level machine and a levelling staff.

6.1.6 Proposed Topo Features/Data

- Edges of the Rivers;
- Roads/Foot paths;
- Spot heights;
- Trees and bushes;
- Wetland Areas;
- Building Structures;
- Utilities onsite e.g. electricity line & poles etc.

6.1.7 Topo Survey Process

A general topographic map shall be prepared at a scale not more than 1:1,000 showing ground features (drainage line, rivers, water points, settlements, foot path, gullies, trees, bench marks, hills, flood plain, wetland, catchment, spot heights etc.) and levels at a contour interval of 1.0 meter on flat terrain and at 0.5m contour interval in undulating and steep terrain. The specific major topographical and drainage structures on the project area shall be mapped at 1:500 scales with 0.5-meter contour interval to enable typical layout preparation during preliminary planning and detail design stage.

The topographic maps of the river channel will be prepared at scale of 1:1,000, 1:500 or at appropriate scale depending on the client's specification. The contours are generated at a contour interval of 0.5m. We believe that using a topo-map with this proposed scales and contour interval at 0.5m has an advantage to have representative and detailed survey data. The topographic survey and map to be produced covers the river basin area which is inundated during seasonal flooding. The topographic survey will indicate the configuration of the terrain and location of both natural and manmade objects, if any, from the known benchmarks.

The topographic detail maps of the site shall be compiled at a target scale of not less than 1:1,000 for the general area. The mapping and related digital product shall meet or exceed ASPRS (American Society of Photogrammetry & Remote Sensing) Horizontal Accuracy at 95% Confidence Level accuracy standards (RMS error in X coordinate limited to 15 mm). Appropriate instrumentation and procedures, consistent with accepted professional surveying and mapping industry standards and practice, shall be selected to achieve the accuracy required.

The topographic survey of the project area shall provide basic water surface level and bed levels. Further, detail topographic survey will be conducted upstream and downstream to indicate the surrounding topographic conditions and produce a detailed topo-map. The surveying work shall entail ground surveying comprising of ground control points establishment using Fixed GPS and data collection using total station and digital level machines.

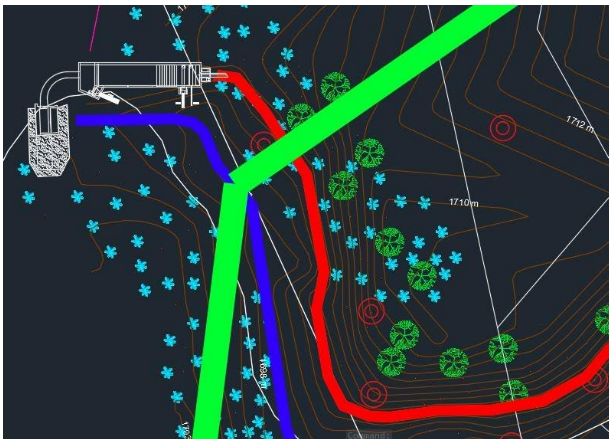
A fully equipped survey crew consisting of professional survey personnel, experienced in performing the required surveys and capable of completing the work within the allotted time frame (e.g. 10 days) executes the project. All field observation data required to set and establish project control shall be digitally recorded. The use of GPS referenced drones shall also be employed if we deem it fit. All survey work shall be performed under adequate supervision and quality control measures. The deficiencies shall be recognized and steps to initiate corrective actions shall be taken as required.

The maps shall contain all the topographic and planimetric features encountered. The maps will properly depict the existing site conditions as necessary. The final mapping products shall comply with and contain but not be limited to the following:

- ❖ All terrain features including contours of the riverbed, upstream and downstream;
- ❖ The turning points that define drainage channels, ditches, etc., will be consistent in depicting correct alignment and direction of drainage if available;
- ❖ Spot elevations shall be established and shown on the maps at selected points, such as hill tops, depressions, at intersections and along centrelines of streets and bridges;
- ❖ Surface and sub-surface utility systems, water, storm water drainage features and structures, platforms, individual trees and existing water sources etc.

6.1.8 Data Processing and Analysis

The survey plans shall be obtained from the Survey of Kenya offices. The plans indicate the property boundary information and details such as acreage, location of beacons and their coordinates. Survey plans will be scanned, georeferenced and the boundary and beacons digitized in AutoCAD Civil 3D software. The cadastral information will be overlaid on the topographical data obtained during field work. Finally, topographical maps with reasonable scale e.g. 1:1,000 shall be produced with all details such as boundary information, topographic features (power lines, buildings, water basins/bodies, trees, roads etc) plotted to scale. The spot heights and contours will also be captured at a grid resolution of 0.5 metres by 0.5 metres. Finally, a 3D DEM of the site will be produced.



6.2 BATHYMETRIC SURVEY

6.2.1 Introduction

We propose to conduct the bathymetric survey using a combination of **Garmin Striker 4 Mobile** device, **Stonex S800A GNSS** equipment, **Ranging Rods** and a Boat.

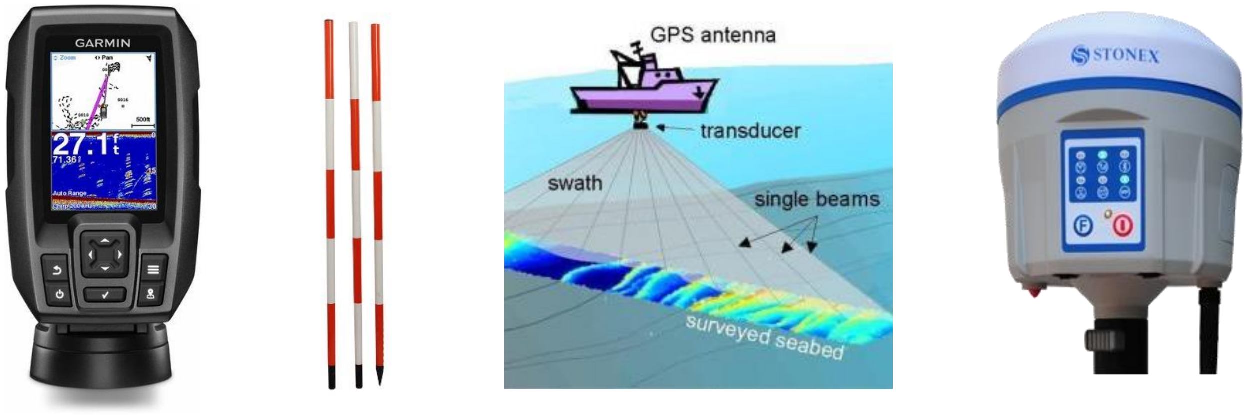


Fig 3: Bathymetric Survey Equipment

6.2.2 Methodology

We propose to employ **Single-beam Bathymetric surveying** method. Rather than sending out a wide set of beams, single-beam bathymetry measures the water depth directly under the boat. Single-beam surveys are generally used for smaller water bodies. A boat will be used to carry the measuring instrument (echo-sounder) and take depth as well as co-ordinate data at designed locations. The depth recordings are provided with 16 grey scales. The echo-sounder is fitted with high precision GPS for recording co-ordinates with a maximum error of + or - 3 cm.

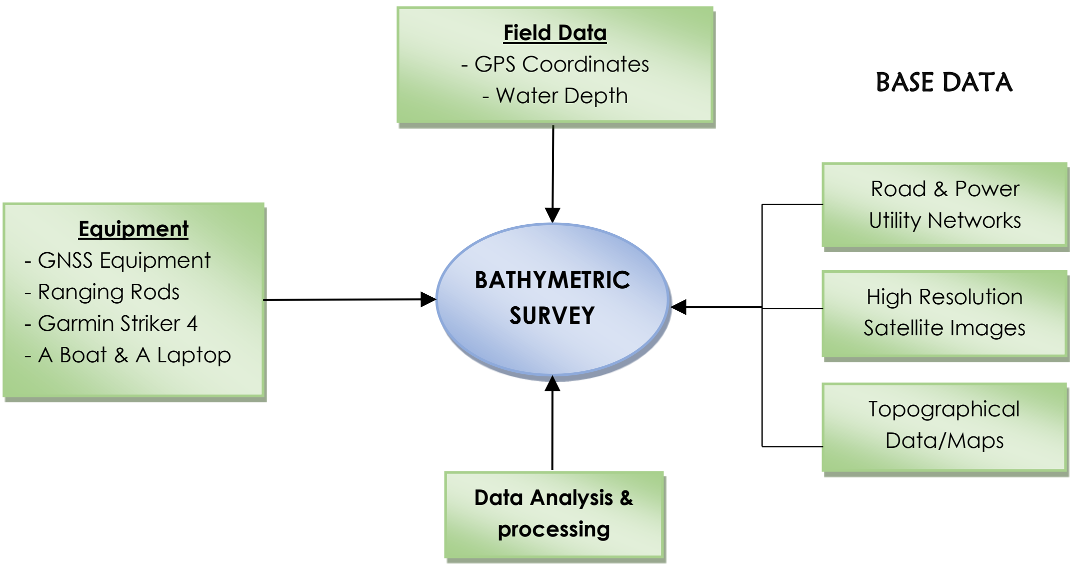


Fig. 4: Bathymetric Survey Methodology

6.2.3 Bathymetric Survey Process

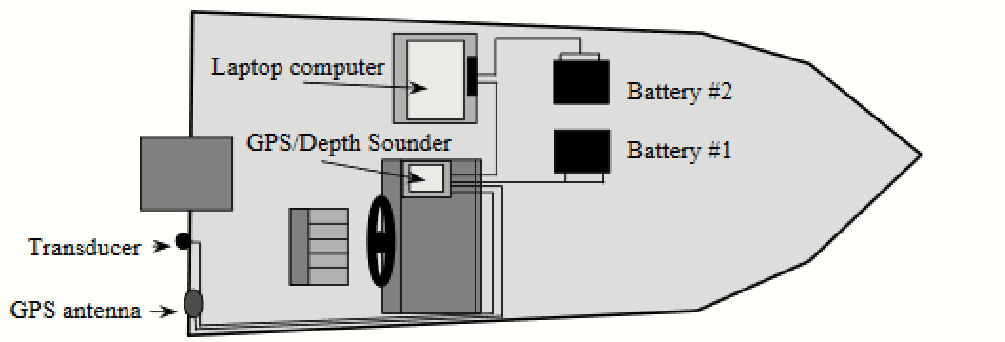


Fig. 4: Bathymetric Survey Workflow

The Garmin Striker 4 GPS includes a Garmin CHIRP (77/200 kHz) transducer, which provides a visibly higher level of clarity and detail for fish and structure than traditional 77/200 kHz transducers. Instead of sending just 1 single frequency, CHIRP sends a continuous sweep of frequencies, ranging from low to high, then interprets them individually upon their return. High-performance Garmin CHIRP technology provides crystal-clear sonar images with even more remarkable target separation and resolution from shallow to deeper section of the river. The bottom contours are more visible, even at higher speeds, and signal noise can be suppressed at greater depths to provide a timely interpretation of the surface at the riverbed.

The combination of GNSS equipment, ranging rods and Garmin Striker 4 and a boat are used to conduct bathymetric survey. The GNSS will be used to record the x, y coordinates while Garmin Striker 4 will be used to capture the water depth (i.e. z coordinates) simultaneously. The data will be collected at an interval of 20 metres across and along the river as depicted in Figure 5 below.

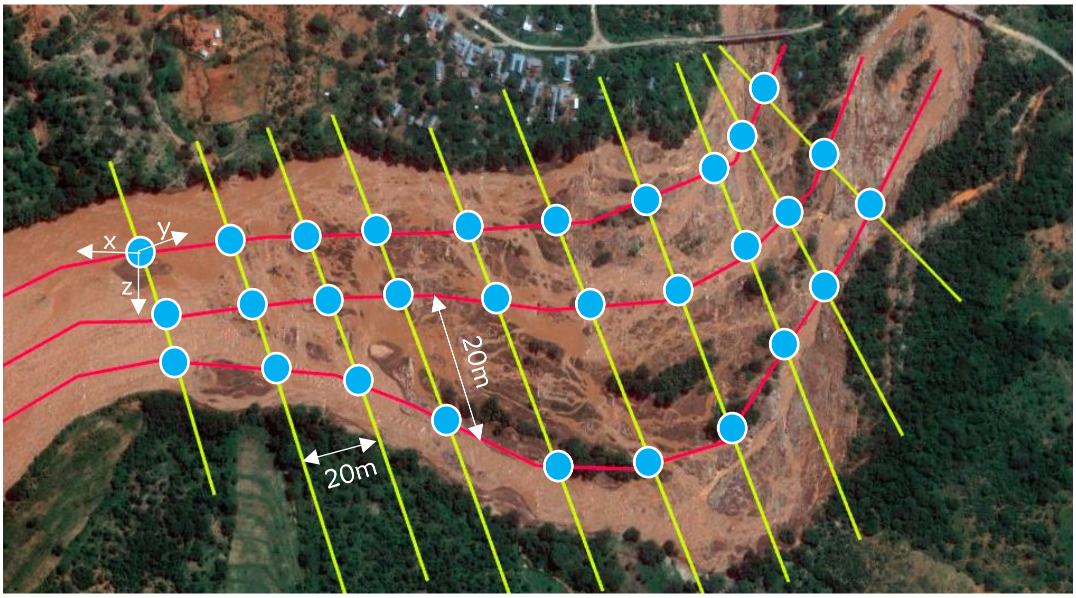


Fig. 5: Sample of Field GPS Point Data

The screen of the Garmin handheld GPS will display the water depth, bearing etc. at every point along the river channel as shown in figure 6 below.

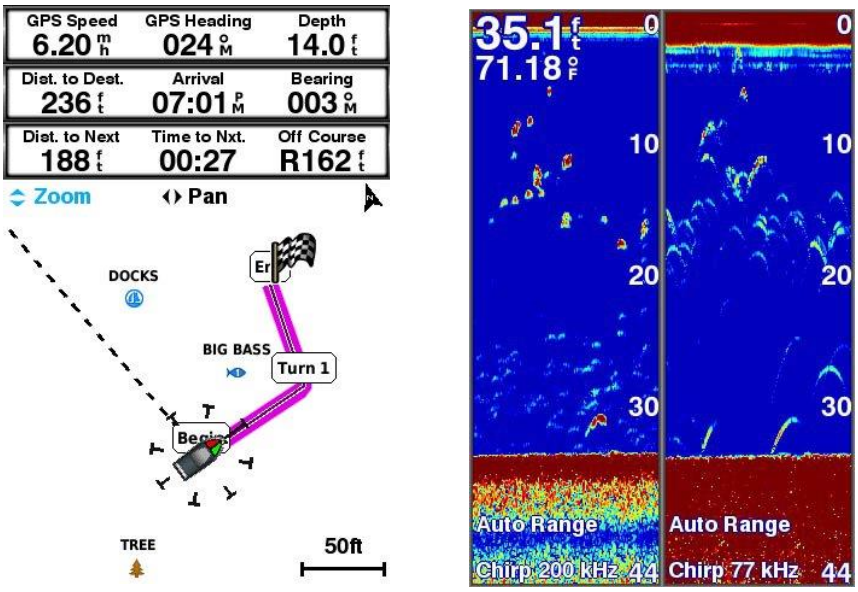


Fig. 5: Sample of Garmin Striker 4 Bathymetric Data

The data collected in the field will be analysed using ArcGIS Software to generate the digital terrain of the riverbed. The river cross-section and longitudinal profiles will be produced in AutoCAD software.

4.5 Surveying Crew Organization

The process of organizing the survey crew to carry out topographic survey of the project area and its surroundings is very important. The ground surveying crew will consist of 2 survey crews for topographic survey and one fixed GPS crew for transferring co-ordinate to project area and for triangulation analysis. In addition, one boat operator and one bathymetric specialist form the bathymetric survey crew. The necessary ground control points will be prepared by the ground survey team prior the commencement of bathymetric survey and the two teams work closely to facilitate the smooth accomplishment of the assignment.

6. LIST OF SOFTWARE

- **AutoCAD Civil 3D** – For topographical data processing in 3D such as heights of power lines.
- **Esri's ArcGIS 10.5** – Used to analyse vector data and creation of cartographic maps.
- **Surfer 11** – The software will be used to smoothen the generated contours.
- **MS Office Suite** – MS word & Excel will be used for report writing, data analysis respectively.

7. SURVEY EQUIPMENT

6.1 Automatic Level Machine

We intend to use Stonex DL 1000 automatic level machine to establish vertical controls via levelling. It has a finely tuned auto-collimation system. The proposed level machine has a telescope with a magnification of **32x.** It also comes with a Pendulum compensator with magnetic damping system. With a completely new small lightweight design, DL 1000 has excellent visibility of horizontal circle, superior gear ratio for shock and vibration and improved tangents and knobs. Some of its Key features are:-

- Rapid, accurate, and stable automatic compensation;
- Ultra-short 20cm focusing and All-weather dependability;
- Endless fine horizontal and vertical adjustments.

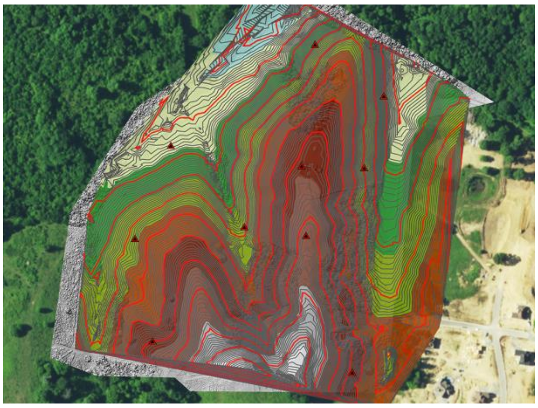
6.2 Total Station

Stonex R1+ total station has been proposed to be used in measuring horizontal angles and distances during the establishment of horizontal controls. It has accuracy of **2"** in angular measurements. Built with legendary Topcon precision and durability, the GTS-102N provides the professional a dedicated lay-out solution construction. It has 2 screens, dot matrix graphic LCD display. It has internal memory capable of storing up to 24,000 points of data storage. This total station is ideal for this nature of work.

6.3 GNSS/RTK/Geodetic GPS

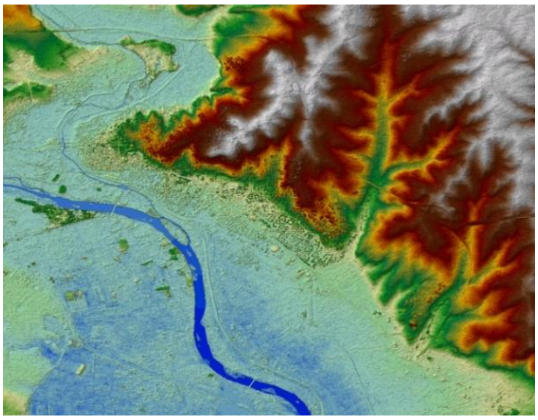
In survey process using RTK, the elevation points are taken at evenly spaced distances (i.e. 25 m) along transects stratified from high to low elevations. To navigate to each measurement point, the surveyor uses the CAD gridline file uploaded to the RTK GPS map to aid in identifying the stakeout points. The Stonex S800A can be configured with the radio and cellular modem that best fits the project needs. We can choose from Digital UHF, CORS or Spread Spectrum radio for sending corrections to the rover.

8. SAMPLE DELIVERABLES

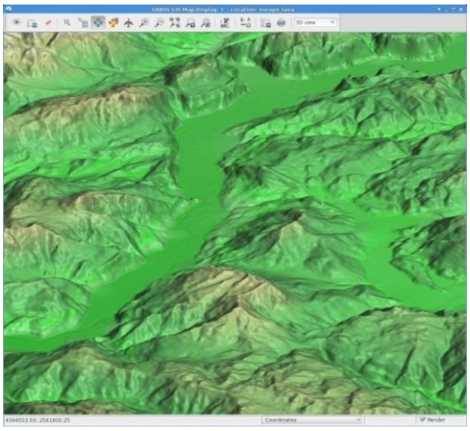


Contours on Satellite image

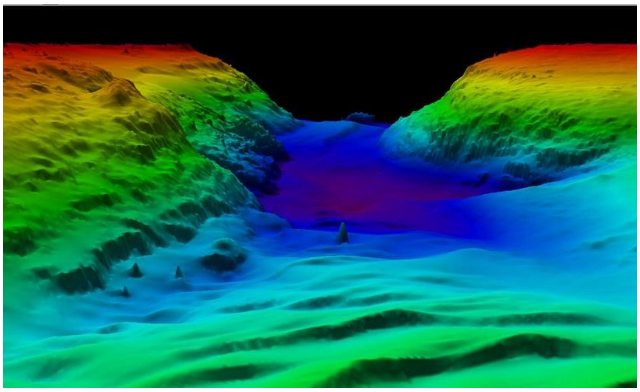
A Digital Surface Model



Digital Elevation Model (DEM)



Sample Shaded Relief



River Profile

9. PROPOSED WORK PLAN

	ACTIVITY		TIME FRAME (DAYS)								
NO.	**DESCRIPTION OF ACTIVITY**	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**
1.	Site Pre-visit										
2.	Preparation of the Proposal										
3.	Negotiation and Contract Signing										
MILESTONE 1: Site Previsit, Proposal and Contract											
4.	Purchase of Maps from Survey of Kenya										
5.	Establishment of Ground Control Points										
6.	Topo & Bathymetric Survey–Data Collection										
7.	Data Processing and Maps/Plans Production										
8.	Analysis of Topo & Bathymetric Data										
MILESTONE 2: Completion of Field work, Data Processing & Map Production											
8.	Printing of Maps/Plans – Size A0, A1 etc.										
9.	Presentation of All Deliverables										
10.	Hand over of Final Project Reports										
MILESTONE 3: Handover of Evaluation and Final Report											

Fig. 8: Proposed Work plan, Timelines and Milestones

*D = Day