GOVERNMENT OF RWANDA
MINISTRY OF NATURAL RESOURCES

RWANDA NATURAL RESOURCES AUTHORITY

LAND ADMINISTRATION SYSTEM
Manual 3.

SURVEYORS’ MANUAL

Lands and Mapping Department
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October 2012
RWANDA LAND ADMINISTRATION SYSTEM

SURVEYORS’ MANUAL

Rwanda Natural Resources Authority
Lands and Mapping Department

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FOREWORD

This Surveyors’ manual, is an instructive guide to the Licenced Land Surveyor who intends to practice land surveying in Rwanda. The purpose of the manual is to ensure uniformity of procedures and standards applied across the country and institutionalize professional best practice.

The five fields of surveying illustrated in the manual are the principle areas that the Department of Lands and Mapping has identified as the most applicable in the country, therefore requiring guidelines, including the standards and accuracies expected.

Chapter 2 and 3 cover geodetic and cadastral surveys. The geodetic surveys illustrate the level of accuracy for surveys while indicating to the Licenced Land Surveyor where to find information on the existing horizontal and vertical national geodetic network. The cadastral survey chapter gives a step by step instruction for field activities relating to land transactions that feed into updating the existing land register. While Rwanda has gone through a systematic land registration using the general boundary principle and high resolution, 25cm pixel size, ortho-photos; it is anticipated that there will be a gradual move to fixed boundaries particularly in urban areas.

Chapter 4 on engineering surveys provides a schematic guideline for survey work on construction sites before, during and after construction works and should be applied in consideration of existing norms and standards from the Ministry in charge of infrastructure.

Photogrammetry is covered in Chapter 5, which advises on the role of the Land Surveyor from flight planning, image processing, photo and ground control, rectification, to data presentation. Chapter 6 on Geographic Information Systems, the area covered in this manual relates to data presentation and GIS is specifically viewed as a tool for the Land Surveyor to process and present data as generated in previous chapters.

Finally I urge all land surveyors to utilize this manual to provide a platform for coherence and professionalism in their work, and I would like to recognize the commitment of the Land Tenure Regularisation Support Programme Senior Surveyors who drafted the manual. Valuable contributions and advice has also been provided by the staff of the Department of Lands and Mapping, in this authority.

Emmanuel Nkurunziza
Director General, Rwanda Natural Resources Authority
Registrar of Land Titles.
# TABLE OF CONTENTS

LIST OF ABBREVIATIONS ........................................................................................................ iv

1 INTRODUCTION ......................................................................................................................... 1

  1.1 Purpose of Manual .................................................................................................................. 1
  1.2 Land ownership in Rwanda ................................................................................................. 1
  1.3 Statutory Instruments ......................................................................................................... 1
  1.4 Maintenance and Calibration Procedures .......................................................................... 2

2 GEODETIC SURVEYS .................................................................................................................. 3

  2.1 Introduction To Geodetic Reference Frameworks .............................................................. 3
  2.2 Definitions .......................................................................................................................... 3
  2.3 Characteristics of the National Geodetic Reference Framework ..................................... 3
  2.4 Standards For Geodetic Control Networks ..................................................................... 6
  2.5 Existing Geodetic Systems ............................................................................................... 7
  2.6 Sources for Obtaining Control Data ................................................................................. 9

3 CADAstral SURVEYS .................................................................................................................. 10

  3.1 Introduction ......................................................................................................................... 10
  3.2 Boundaries and boundary marks ....................................................................................... 10
  3.3 Types of Cadastral Surveys ............................................................................................ 11
  3.4 Cadastral Survey Measurements ..................................................................................... 14
  3.5 Units of measurements ...................................................................................................... 14
  3.6 Coordinate system and projection ...................................................................................... 14
  3.7 Survey Equipment ............................................................................................................. 15
  3.8 Accuracy of Field Work ...................................................................................................... 15
  3.9 Declaration of authenticity and accuracy of survey done .................................................. 16
  3.10 Responsibilities of the Licensed Land Surveyor ............................................................... 16
  3.11 Information to start a cadastral survey ........................................................................... 16
  3.12 Submitting a Cadastral Survey ....................................................................................... 16

4 ENGINEERING SURVEYS ......................................................................................................... 18

  4.1 Introduction ......................................................................................................................... 18
  4.2 Methods ............................................................................................................................. 18
  4.3 Types .................................................................................................................................. 18

5 PHOTOGRAMMETRY ................................................................................................................ 22

  5.1 Introduction ......................................................................................................................... 22
  5.2 Definitions .......................................................................................................................... 22
  5.3 Image Acquisition .............................................................................................................. 23
  5.4 Control for Photogrammetry ............................................................................................. 24
  5.5 Product Compilation .......................................................................................................... 25
  5.6 Photogrammetric Procedure ............................................................................................ 28

6 GEOGRAPHIC INFORMATION SYSTEMS ............................................................................ 31

  6.1 Introduction ......................................................................................................................... 31
  6.2 Data models ...................................................................................................................... 31
  6.3 Sources of data .................................................................................................................. 32
  6.4 Data input techniques ........................................................................................................ 32
  6.5 Data format ....................................................................................................................... 32
  6.6 Data output techniques ..................................................................................................... 33
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Typical Monument of a Geodetic Control Point</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>Typical Monument of a benchmark</td>
<td>35</td>
</tr>
<tr>
<td>3</td>
<td>Existing National Geodetic Control Network</td>
<td>36</td>
</tr>
<tr>
<td>4</td>
<td>Typical monument of IPC boundary mark</td>
<td>37</td>
</tr>
<tr>
<td>5</td>
<td>Sample Cadastral Plan</td>
<td>38</td>
</tr>
<tr>
<td>6</td>
<td>Survey Report</td>
<td>39</td>
</tr>
<tr>
<td>7</td>
<td>Building Location plan</td>
<td>43</td>
</tr>
<tr>
<td>8</td>
<td>Elevation Plan</td>
<td>44</td>
</tr>
<tr>
<td>9</td>
<td>Floor plan</td>
<td>45</td>
</tr>
<tr>
<td>10</td>
<td>Unit Survey plan</td>
<td>46</td>
</tr>
<tr>
<td>11</td>
<td>Unit table of ratios</td>
<td>47</td>
</tr>
<tr>
<td>12</td>
<td>Development plan</td>
<td>48</td>
</tr>
<tr>
<td>13</td>
<td>Survey Computations</td>
<td>48</td>
</tr>
<tr>
<td>14</td>
<td>Survey Declaration of a Licenced Land Surveyor</td>
<td>49</td>
</tr>
<tr>
<td>15</td>
<td>Instruction to Survey (I/S Form)</td>
<td>50</td>
</tr>
<tr>
<td>16</td>
<td>Search Certificate</td>
<td>51</td>
</tr>
<tr>
<td>17</td>
<td>Consent to Transact on Land</td>
<td>53</td>
</tr>
<tr>
<td>18</td>
<td>Declaration of job completion</td>
<td>54</td>
</tr>
<tr>
<td>19</td>
<td>Recommended shapes for photogrammetric ground controls</td>
<td>55</td>
</tr>
<tr>
<td>20</td>
<td>Symbology and classification of features</td>
<td>56</td>
</tr>
</tbody>
</table>
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ADOS (NSWC 9Z2) datum</td>
<td>Active Duty Operational Support (Naval Surface Warfare Centre 9Z2) Datum</td>
</tr>
<tr>
<td>2. CAD</td>
<td>Computer Aided Design</td>
</tr>
<tr>
<td>3. CM</td>
<td>Central Meridian</td>
</tr>
<tr>
<td>4. DBMS</td>
<td>Database Management Software</td>
</tr>
<tr>
<td>5. DEM</td>
<td>Digital Elevation Model</td>
</tr>
<tr>
<td>6. DIS</td>
<td>Document Imaging System</td>
</tr>
<tr>
<td>7. DLB</td>
<td>District Land Bureau</td>
</tr>
<tr>
<td>8. DLM</td>
<td>Department of Lands and Mapping</td>
</tr>
<tr>
<td>9. EGM2008</td>
<td>Ellipsoidal Geoid Model</td>
</tr>
<tr>
<td>10. FE</td>
<td>False Easting</td>
</tr>
<tr>
<td>11. FN</td>
<td>False Northing</td>
</tr>
<tr>
<td>12. GCP</td>
<td>Geodetic Control Point</td>
</tr>
<tr>
<td>13. GIS</td>
<td>Geographic Information Systems</td>
</tr>
<tr>
<td>14. GNSS</td>
<td>Global Navigation Satellite System</td>
</tr>
<tr>
<td>15. GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>16. IGNB</td>
<td>Institute Geographique National Belgium</td>
</tr>
<tr>
<td>17. IPC</td>
<td>Iron pin in concrete</td>
</tr>
<tr>
<td>18. I/S</td>
<td>Instruction to Survey</td>
</tr>
<tr>
<td>19. ITRF</td>
<td>International Terrestrial Reference Framework</td>
</tr>
<tr>
<td>20. MBM</td>
<td>Master benchmark</td>
</tr>
<tr>
<td>21. MSL</td>
<td>Mean Sea Level</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>22.</td>
<td>NGVN</td>
</tr>
<tr>
<td>23.</td>
<td>OBM</td>
</tr>
<tr>
<td>24.</td>
<td>RINEX Format</td>
</tr>
<tr>
<td>25.</td>
<td>SR 92</td>
</tr>
<tr>
<td>26.</td>
<td>TBM</td>
</tr>
<tr>
<td>27.</td>
<td>UPS</td>
</tr>
<tr>
<td>28.</td>
<td>VCP</td>
</tr>
</tbody>
</table>
1 INTRODUCTION

1.1 Purpose of Manual

The Manual contains material that is of both informational and instructional in nature. Guidelines and procedures are spelled out in detail for greater uniformity and quality in surveying activities in Rwanda.

It is not the intention of this manual to describe surveying processes but rather a tool for use by a person with knowledge of Surveying as a profession; the Licenced Land Surveyor.

This manual is written to advise the practicing Licenced Land Surveyor by elaborating technical guidelines giving specifications and accuracies acceptable in Rwanda. Where Rwanda specifications are absent, international norms will be recommended but with a specific mention.

This manual covers specifications for:

- Geodetic surveys
- Cadastral surveys
- Engineering surveys
- Photogrammetry
- Geographic Information Systems

1.2 Land ownership in Rwanda

The Rwanda land ownership is regulated by the Organic Land Law of 2005 and can be held under lease hold or free hold tenure. According to Article three of the OLL ‘the State has Supreme powers to manage all the national land......and guarantees the right to own and use the land’. All land in Rwanda is categorized in three: individual land, state land in the public domain and state land in the private domain. Depending on the land use, Article 4 of the Presidential Order No 30/01 of 29/06/2007 determining the exact number of years of land lease, the land lease period is between three (3) and ninety nine (99) years.

1.3 Statutory Instruments

There are statutory requirements in the form of regulations and development controls in place to guide landowners wishing to develop their land and the Land Surveyor has to be aware to conform to them. These legal tools are defined by the State in the interest of orderly planning and development.

- Organic Law No 08/2005 of 14/7/2005 determining the use and the management of land in Rwanda
- Ministerial Order No 001/2006 of 26/09/2006 determining the structure of land registers, the responsibilities and the functioning of the District Land Bureau
- Presidential Order No 53/01 of 12/10/2006 determining the structure, the powers and the functioning of the Office of the Registrar of Land Titles
• Presidential Order No 54/01 of 12/10/2006 determining the structure, the responsibilities, the functioning and the composition of the Land Commission
• Presidential Order No 30/01 of 29/06/2007 determining the exact number of years of land lease
• Ministerial Order No 001/2008 of 01/1/2008 determining the requirements and procedures for land lease
• Ministerial Order No 002/2008 of 01/4/2008 determining modalities of land registration
• Law No 15/2010 of 07/05/2010 creating and organizing condominiums and setting up procedures for their registration
• Law No 17/2010 of 12/05/2010 establishing and organizing the real property valuation profession in Rwanda
• The Land Administration Manual, Office of the Registrar of Land Titles, 2012

1.4 Maintenance and Calibration Procedures
Maintenance and calibration of instruments will be supervised and controlled by the Department of Lands and Mapping (DLM). The following are guidelines to the Registered Land Surveyor:

• All measuring instruments must be properly maintained to provide reliable measurements.
• Measuring instruments shall be checked periodically (at least once a year) to make sure they are in good adjustment.
• All measuring instruments should be calibrated on known base lines at least once each year.
• All measuring instruments should be certified as conforming to adjustment norms and standards every 2 years by the DLM.
• The DLM reserves the right to carry out spot inspection to verify that maintenance and calibration standards are maintained.
2 GEODETIC SURVEYS

2.1 Introduction To Geodetic Reference Frameworks

The national geodetic reference frame is the basis for all spatial activities within the country e.g. mapping, cadastral systems, utility and infrastructure constructions and maintenance.

The national geodetic control network exists in several levels: primary, secondary and tertiary control networks.

2.2 Definitions

- Control point; a high accuracy coordinated point used in determining the location of other points
- Coordinated point; a point whose location is defined by a set of values that describe the exact position.
- Geodetic control; a set of control points whose coordinates are established using geodetic surveying methodology
- Geodetic datum; is a reference that defines the size and shape of the earth in relation to a coordinate system.
- Horizontal geodetic control; control points for which celestial \((x,y)\) coordinates that have been accurately determined can be identified with physical points on the earth and used to provide celestial coordinates for other surveys.
- Vertical geodetic control; control points with accurately determined orthometric heights and/or ellipsoidal heights \((z)\) identified with physical points on the earth that can be used to provide elevations for other surveys

2.3 Characteristics of the National Geodetic Reference Framework

2.3.1 Monumentation and Field Descriptions

Geodetic stations are marked in the field by using man made monuments. These monuments are constructed to indicate the following information: the name of the station, the year established and the establishing agency. The actual point of the station is also marked in the disk.

Stability of a station is very important. The chances of any movement of the marker can be minimized by carefully selecting the station site and the method of construction.

A description of the station and any peripheral marks is very important for the ease of station recovery. A description of how to reach the station from some local prominent feature should be included in the field description. Information on description of geodetic stations can be obtained in the Department of Lands and Mapping which is also responsible for record maintenance.

2.3.2 Field Measurements and Methods

Both terrestrial and satellite survey methods can be used to determine geodetic positions of stations. These horizontal control stations can also be referred to as triangulation stations or traverse stations depending on how they were established. The geodetic coordinates shall be presented in the adopted Cartesian (Plane) Coordinate System. Where observations are taken in latitudes and longitudes, these shall be converted.

2.3.3 Survey Accuracy
The reference framework shall be established at the highest level of accuracy than all other surveys to be controlled by the framework.

2.3.4 Specifications For Geodetic Control Networks

The surveyor must follow certain specifications or procedures when collecting the field survey data in order to meet the requirements for the given classes of survey in both the horizontal and vertical accuracy standards.

2.3.5 Horizontal Control Networks

Procedure

Global Navigational Satellite Systems (GNSS): GNSS technology will be used to establish and extend control stations of first and second order accuracies. This system must have dual frequency geodetic receivers and make static observations for post processing.

Triangulation: Triangulation will be used to extend horizontal control by measuring the angles of triangles formed by the control stations to be located. The angular observations need to be supported by the occasional base line measurement of one side of one of the triangles in the network.

Traverse: Traverse procedures can be used mainly to densify horizontal control for local surveys. For a traverse to meet a certain order of accuracy, criteria must be met in relation to spacing between points, the number of ties that must be made for azimuth checks, etc.

Monumentation

a) Geodetic Control Point

- This should be constructed before observations of the Geodetic Control Point (GCP) are taken.
- The monument will have a metal plate on a concrete block; the concrete block will be built at the site of the control point.
- The mark to be observed should be on the surface of the GCP and an identical sub mark established at least 40cm below the surface mark; the sub mark is useful to re-establish the GCP in the event that the surface mark is destroyed.
- The metal plate should have the name of the GCP, the year it was established, and the name of the establishing organization.
- There should be a warning sign ‘Do not Destroy Property. Government of Rwanda’.
- A written description and the location sketch of each monument should be made in the field.
- Figure 1 in the annex show the typical monument of a horizontal geodetic control point.
- Each GCP will have at least 1 witness marker with in 10 m to enable locating GCP at a later period.
- The Witness Marker will be monumented in a smaller dimension of the GCP and distinctly different in appearance.
- Observations of the Witness Marker will be made after monumentation and hold similar accuracy to GCP.
- Witness Markers can be used as GCPs where GCPs have been destroyed and therefore, form part of the National Geodetic Network.
b) Continuous Operating Reference Station

- It should be set up on a stable surface with reliable power supply.
- It should at least have the following requirements:
  - Antenna and Antenna Mounts
  - GNSS Receivers and Receiver Housing
  - Other general requirements (power, UPS, internet, security)
  - Computer with accessories.

Computations

GNSS:

- For first order accuracy a control station needs to be observed in two sessions of not less than 6 hours each of synchronised observations. The observations will use a network configuration with at least two base stations.
- For second and third order accuracies a control station needs to be observed in two sessions of not less than 4 hours of synchronised observations. The observations will use a network configuration with at least two base stations.
- Computations are computer aided and each piece of equipment used has appropriate software supplied

Presentation of work

- Observation date and time
- Observed latitudes, longitudes and ellipsoidal heights
- Sketches and diagrams of GCP and witness markers
- Photo of the GCP
- Description cards
- GCP Station Name
- GCP Cartesian coordinates
- Computation results in RINEX format
- Geodetic Network Diagram (Example in Fig 3)
- Geodetic Control Network report.

2.3.6 Vertical Control Networks

Procedure

Vertical control is established by making measurements using a levelling instrument to determine the elevation difference between points. When measurements are observed and deduced to these points, they then make up the vertical control networks. This point is the Vertical Control Point (VCP).

The levelling network shall be tied to existing VCPs that have an order of accuracy equal to or better than the intended order of accuracy of the new survey.

For geodetic work, three tier wire levelling is used. In this method a levelling instrument with an eye piece having three separate horizontal lines is used. Elevation is determined by finding the average reading for each of the horizontal lines.
GPS can only be used to obtain vertical heights for a vertical control network if the geoidal model of the country is known.

**Monumentation**

Vertical control points are part of the National Geodetic Vertical Network (NGVN) only if they possess permanence, vertical stability with respect to the earth’s crust and the vertical location that can be defined as a point.

- The monument should be constructed before observations of the Vertical Control Point (VCP) are taken.
- Typically corrosion resistant metal disks set in large rock outcrops or long metal rods driven deep in the ground and held in place by concrete have the qualities of a VCP.
- Replacement of a temporary mark by a more permanent mark is not acceptable unless the two marks are connected in timely fashion by survey observations of sufficient accuracy.
- Figure 2 in the annex shows the typical monument of a vertical control point/bench mark.

**Computations**

Computations are made to deduce heights for back sight and fore sight readings. If a known VCP A is used to establish a Vertical Control Point B, computations will be made for all readings between VCP A and VCP B and a counter check on accuracy done by computing backwards from VCP B to VCP A.

An electronic digital level performs and records the three wire levelling process automatically after sight of rod is made. Data is downloaded into a computer for complete analysis.

**Presentation of work**

- Observation date and time
- Observed readings
- Sketches and diagrams of VCP and witness markers
- Photo of the VCP
- Description cards
- VCP Station Name
- VCP Cartesian coordinates
- Computation results in RINEX format
- Vertical Control Network report.

2.4 Standards For Geodetic Control Networks

2.4.1 Classifications of Accuracy

a) Horizontal Control Networks

The Department of Lands and Mapping in Rwanda establishes the classification of horizontal control networks in terms based on accuracy. These standards certify that when points are established in any particular survey they will have datum values consistent with other points of the same classification.

The order and class that is stated for any point or set of points provide a relation of specific accuracy to other points in the survey. This relationship is expressed as the ratio of the relative positional error of a pair of control points to the horizontal separation of those points and is given as a distance accuracy.
Minimum Classification distance accuracy

First –order  1:100,000
Second-order  1:50,000
Third-order  1:20,000

b) Vertical Control Networks

The Department of Lands and Mapping establishes classifications of accuracy for vertical surveys in Rwanda, to certify that the orthometric elevations of points of a survey have a specific relationship with all other points in that and other vertical surveys.

When expressing an order and class of accuracy relating to vertical control points, the relation is expressed as an elevation difference. Elevation difference accuracy is the relative elevation error between a pair of control points that is scaled by the square root of their horizontal separation traced along existing level routes.

Elevation accuracy standards

First-order  0.003m per Km.
Second-order  0.007m per Km.
Third-order  0.012m per Km.

2.5 Existing Geodetic Systems

2.5.1 Terrestrial Control Network

a) Institute Geographique National Belgium (IGNB) implemented a national terrestrial control network for Rwanda between 1926 and 1959.

Plane coordinates in the network were computed using Transverse Mercator formulas based on the Clarke 1880 ellipsoid using following parameters:

- Central Meridian (CM)  30°E
- Scale factor at CM  0.9999
- False Northing (FN)  10 000 000 m
- False Easting (FE)  500 000 m

b) GPS Campaign of 1991-92

The GPS campaign was implemented by the Landesvermessungsamt Rheinland-Pfalz and the Universität der Bundeswehr München in cooperation with Service de la Cartographie National du Rwanda. It was planned to cover the whole country but some stations planned in the north-eastern part of Rwanda were not implemented. The network consisted of 28 central stations, each station having one eccentric station at a distance of 2-5 km. The central stations are shown in figure 4 of the annex.

The computation of the campaign was summarized and reported as:

- Overall degree of freedom  147
Mean error ellipse  
A=26 mm, B=16 mm

Mean corrections  
V(X) = 4 mm  
V(Y) = 5 mm  
V(Z) = 8 mm

c) **Systeme Rwanda 92 (SR 92)**

This is a system whereby the result of the GPS network from the 1991-92 campaign, given in ADOS (NSWC 9Z2) datum, was transformed into the old terrestrial system.

The plane coordinates in the SR 92 system have the following characteristics:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ellipsoid</td>
<td>Clarke 1880</td>
</tr>
<tr>
<td>Semi-major axis</td>
<td>6378249.145</td>
</tr>
<tr>
<td>Flattening</td>
<td>1/293.465</td>
</tr>
<tr>
<td>Central Meridian (CM)</td>
<td>30°E</td>
</tr>
<tr>
<td>Scale factor at CM</td>
<td>0.9999</td>
</tr>
<tr>
<td>False Northing (FN)</td>
<td>10 000 000 m</td>
</tr>
<tr>
<td>False Easting (FE)</td>
<td>500 000 m</td>
</tr>
</tbody>
</table>

SR 92 is a very homogeneous system, but it is a conventional 2+1 D (x, y and z) system where the height information comes from the levelling network. It is also a national system with undeveloped relations to other national and international systems.

d) **International Terrestrial Reference Framework (ITRF)**

An ITRF has been adopted for use in Rwanda and the Coordinates of all stations in the 1991-92 GPS campaign have been computed to it. The ITRF implemented has the following parameters:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projection</td>
<td>Transverse Mercator</td>
</tr>
<tr>
<td>Central Meridian (CM)</td>
<td>30°E</td>
</tr>
<tr>
<td>Scale factor at CM</td>
<td>0.9999</td>
</tr>
<tr>
<td>False Northing (FN)</td>
<td>5 000 000 m</td>
</tr>
<tr>
<td>False Easting (FE)</td>
<td>500 000 m</td>
</tr>
<tr>
<td>Reference ellipsoid</td>
<td>GRS 80</td>
</tr>
<tr>
<td>Semi-major axis</td>
<td>6 378 137 m</td>
</tr>
<tr>
<td>Flattening</td>
<td>1/298.257222101</td>
</tr>
</tbody>
</table>

This is the reference frame that is currently adopted for Rwanda. It needs to be refined as a national geodetic reference frame for all purposes in the future.

e) **Height system**
A levelling network was established in Rwanda between 1956 and 1959 under the supervision of *Institute Geographique National Belgium* (IGNB). Five of the VCPs from this network were included in the 1991-92 GPS campaign.

Geoid model EGM2008 was used to transfer ellipsoidal heights to Mean Sea Level (MSL) heights for the contour mapping in the produced orthophoto maps in 2009.

### 2.6 Sources for Obtaining Control Data

Geodetic and Vertical control data can be obtained from the Department of Lands and Mapping. The list and description cards of the existing vertical control points should be updated and made readily available for use.

The department of Lands and Mapping will handle modalities of commissioning observations that would help to calculate geoid-ellipsoidal separation for the adopted Geoid model so that independent GPS heights can be transformed to the same model. Further observations can also be done to determine the true geoid.
3 CADASTRAL SURVEYS

3.1 Introduction

The primary function of the Cadastral System in Rwanda is to define (delineate and document) ownership rights. Accurate delineation of the ownership rights will enable the development of a Cadastral Information System, which forms the basis for; land valuation, land taxation, development planning, local authority demarcation and land administration. The objectives of cadastral surveying are summarized below:

- To locate boundaries of a land parcel or portion of a building, and additional ownership and descriptive details depicted on a survey plan.
- To determine the extent (size), value (location and land use), ownership.
- To make out design plans on the use of available land.
- To ease administration in such a way that:
  - It enables proper allocation of land to citizens or cooperate bodies for development
  - It enables government collect taxes (tenant rates) from land owner’s developers)
  - It enables government control or guide land development; that land is put into practical and profitable uses.

3.2 Boundaries and boundary marks

During cadastral surveys, it would be good practice to have boundary marks that describe the physical definition of a parcel surveyed. The concept in Rwanda is that the boundary co-ordinate is prevalent over a physical boundary mark. It is therefore important to establish if the existing boundary mark is both intact and in position. Where a boundary mark needs to be re-established, it should be within an accuracy of 5cm.

The existing boundary marks defining a cadastral survey are either IPC (Iron Pin in Concrete), precast concrete or none.

The available forms of boundary marks are either IPC or pre-cast concrete in varying shapes and dimensions. An example of a typical IPC boundary mark is shown in figure 4. The precast concrete boundary marks are usually circular or rectangular in about 15cm diameter or width at the top surface sometimes with or without an X sign drawn on the surface to indicate a boundary point; it is usually around 40cm long.

Boundary marks acceptable for subsequent surveys are IPC with the description as shown in figure 4 of the annex.
3.3 Types of Cadastral Surveys

3.3.1 Survey based on a New development plan

Procedure
a) This is where a new development plan is prepared to be set out on the ground.
b) The development plan should be approved.
c) The approved development plan of an area can be collected from the District Land Bureau
d) The proposed survey must follow the development plan and in case of conflict, the
development plan takes precedence as adapted by the District Land Bureau.
e) Where the Land Surveyor compares his Survey to the Development plan and they don’t
conform, the Land Surveyor must submit and discuss the Survey information with the District
Land Bureau to facilitate a solution.
f) The new development plan can be part of one registered parcel or many registered parcels.
g) For one registered parcel the survey will also be a subdivision survey
h) For part of one registered parcel a new boundary must be surveyed
i) For many registered parcels a new boundary must be surveyed and subsequent subdivision
carried.

Presentation of the Survey
a) Survey Plan (Fig 5)
b) Survey Report (Fig 6)

3.3.2 Survey of Boundary of a parcel

Procedure
a) The new parcel boundary should conform to the approved area development plan
b) The approved development plan of an area can be collected from the District Land Bureau
c) The proposed survey must follow the development plan and in case of conflict, the
development plan takes precedence as adapted by the District Land Bureau.
d) Where the Land Surveyor compares his Survey to the Development plan and they don’t
conform, the Land Surveyor must submit and discuss the Survey information with the District Land Bureau to facilitate a solution.

Presentation of the Survey
a) Survey Plan (Fig 5)
b) Survey Report (Fig 6)

3.3.3 Condominium surveys

Important issues in condominium surveys

- The property owner requests in writing to the District Land Bureau that they want to register the property as condominium
- Show the position of the building on the land parcel
- Numbering of the units start from 1 up to the last unit
- The Z coordinate or height information is provided as floor numbers.
- The height from floor to ceiling is important because by law the area owned is limited to the area between the floor surface to the ceiling
• It is important to submit the architectural drawings because they show clearly the elevations and cross section of the building.

**Procedure**

a) Ensure that a request has been made in writing to the District land Bureau that the property owner would like the property to be registered as condominium
b) Survey the parcel boundary
c) Survey and fix the position of the building within the parcel (this gives the building location plan)
d) Survey the individually owned units and the common property areas within the building, by measuring between the walls.
e) Measure the height of each unit from the floor level to the ceiling.
f) Compute the total floor area.
g) Determine the area of the common property
h) Determine the floor area for each unit and the total sum of the floor area for the individually owned units.
i) Determine the unit ratio of each unit as: 
\[
\left( \frac{\text{floor area of the unit}}{\text{total floor area of all the individually owned units}} \right) \times 100
\]

**Presentation of the Survey**

a) Parcel Cadastral plan (Fig 6)
b) Building Location plan (Fig 7)
c) Elevation Plan (Fig 8)
d) Floor plan (Fig 9)
e) Unit survey plan (Fig 10)
f) Unit table of ratios (Fig 11)
g) Survey Report (Fig 6)

**3.3.4 Survey for subdivision of a parcel**

**Procedure**

a) Confirm the boundary of the parcel to be subdivided.
b) Confirm that the subdivision conforms to the area development plan.
c) The subdivision plan is generated by the Land Surveyor.
d) The Land Surveyor submits the subdivision plan to the District Land Bureau.
e) The District Land Bureau approves the Subdivision plan.
f) Fix the subdivision on the ground.
g) Fix the subdivision in a deed plan.
h) Confirm that the proposed land use of each subdivision is approved by the District Land Bureau

**Presentation of the Survey**

a) Approved Development plan (Fig 12)
b) Survey Plan (Fig 5)
c) Survey Report (Fig 6)

**3.3.5 Survey of a parcel for transfer**
Procedure
   a) Confirm the boundary of the parcel to be transferred.
   b) Confirm that the parcel conforms to the area development plan.
   c) Confirm the ownership of the parcel to be transferred at the District Land Bureau.
   d) Confirm the transfer transaction; this is an agreement between concerned parties witnessed by the District Land Notary/Deputy Land Registrar/Registrar of Land Titles.
   e) Record the transfer of ownership on the deed plan.

Presentation of the Survey
   a) Survey Plan (Fig 5)
   b) Survey Report (Fig 6)

3.3.6 Survey of Boundary of a merged property

Procedure
   a) Confirm that the tenure and land use categories and ownership are uniform for each parcel to be merged.
   b) Confirm that the parcels to be merged share a boundary; there is no parcel in between the proposed parcels to be merged.
   c) Confirm that the parcels to be merged are in the same cell.
   d) Survey the new parcel boundary
   e) The new parcel boundary conforms to the approved area development plan
   f) The approved development plan of an area can be collected from the District Land Bureau
   g) The proposed survey must follow the development plan and in case of conflict, the development plan takes precedence as adapted by the District Land Bureau.
   h) Where the Land Surveyor compares his Survey to the Development plan and they don’t conform, the Land Surveyor must submit and discuss the Survey information with the District Land Bureau to facilitate a solution.
   i) The new Parcel Identification Number is done by the GIS unit after the Survey has been checked and approved.

Presentation of the Survey
   a) Survey Plan (Fig 5)
   b) Survey Report (Fig 6)

3.3.7 Survey of a property to be valued

Procedure
   a) Identify the property
   b) Confirm the property boundary
   c) Confirm the parcel area

Presentation of survey
   a) Survey plan (Fig 5)
   b) Survey report (Fig 6)

3.3.8 Survey of change of Land use

Procedure
   a) Get a ‘change in land use’ instruction from the District Land Bureau (Fig 17)
b) Confirm the boundary of the parcel.

Presentation of the Survey
a) Survey Plan (Fig 5)
b) Survey Report (Fig 6)

3.4 Cadastral Survey Measurements
a) Measurements must be tied to the National Coordinate System
b) Survey measurements should be available and submitted on the Survey Computations form (Fig 13)
c) The National Coordinate System information can be obtained at the National Department of Lands and Mapping
d) When fixing a boundary observe two independent measurements so that one acts as a check to the observed boundary point
e) All accuracies to be within 5cm

GPS Measurements
a. The report of survey must include a clear description of survey procedures used.
b) A summary of the equipment used, including serial numbers and operational software has to be submitted
c) A summary indicating for each session; the stations occupied; their respective start and end time and; the number of satellites simultaneously observed has to be provided.
d) All raw data collected during the survey has to be provided and a digital field log, either digital or on paper must be maintained.
e) GPS Field log should include the following information:
   • Date of observations
   • Project name and project number
   • Session identification
   • Receiver model
   • Antenna model
   • Serial numbers of receiver, antenna and data logger
   • Height of antenna
   • Observations start and end time

3.5 Units of measurements
a) All distances shown on a survey/deed plan shall be in metres to two decimals
b) All angular measurements shall be in degrees, minutes and seconds
c) For purposes where source data being used is not in the metric system a conversion will be done to metres using acceptable international units of conversion.

3.6 Coordinate system and projection
All cadastral and all other surveys that are referred to the National Coordinate System shall be calculated in plane coordinates.
The National Coordinate System is projected using Transverse Mercator formulas, GRS80 ellipsoid and the ITRF reference frame and with the following parameters:

- Central Meridian (CM) 30°E;
- Scale factor at CM 0.9999;
- False Northing (FN) 5 000 000 m
- False Easting (FE) 500 000 m
- Reference ellipsoid in GRS 80
- Semi-major axis 6 378 137 m
- Flattening 1/298.257222101

3.7 Survey Equipment

Although the methods that shall be used in cadastral surveying are not rigidly prescribed, it is a requirement that all work be adequately and carefully checked. All recognised methods, using modern accurate instruments, are acceptable. Special requirements are however laid down when surveys are undertaken, using

- GPS (Global Positioning System),
- Total Stations and
- Photogrammetric techniques.

In Rwanda most cadastral surveys shall be done using total stations, photogrammetric techniques and Geodetic GPS with high accuracy.

3.8 Accuracy of Field Work

The proper method for adjusting measurements depends on the type and size of the survey. Small plot surveys may not require any adjustment. For larger surveys, one of the horizontal adjustments may be employed. For geodetic surveys, the least squares adjustment method is appropriate.

The following standards are for Global Navigation Satellite System (GNSS) technology and will be used to define the minimally acceptable levels of positional accuracy required for official cadastral or administrative boundary survey.

There are three classes of survey, each with the following specified accuracy limit:

- **Class A** - Surveys for the determination of the positions of reference marks in urban surveys,
- **Class B** - Surveys in urban and peri-urban areas and for mining titles in respect of precious stones and minerals,
- **Class C** - Other surveys, including farm surveys and surveys for mining titles in respect of base minerals.

**Local Accuracy Standards**

- Class A- Less than 0.005 (m)
- Class B- Less than 0.010 (m)
- Class C-less than 0.025 (m)
The photogrammetric techniques should have pixels that give a ground resolution of 0.25m.

3.9 **Declaration of authenticity and accuracy of survey done**

The Licenced Land Surveyor shall validate his/her work using an official stamp issued by the Department of Lands and Mapping and the official Survey declaration (Fig 14).

3.10 **Responsibilities of the Licenced Land Surveyor**

a) Acquire authority to do a Survey; Instruction to Survey (Fig 15)
b) Work with an approved development plan
c) Submit survey in acceptable format to the District Land Bureau
d) Ensure accuracy of survey submitted
e) To conform to all statutory requirements governing the survey

3.11 **Information to start a cadastral survey**

Maintenance of the National Cadastral Register is a responsibility of the Office of The Registrar of Land titles. The District Land Bureau is the organ responsible for commissioning a cadastral survey. All Cadastral Surveys are carried out by a Licenced Land Surveyor. The District Land Bureau reserves the responsibility to approve the work of the Licenced Land Surveyor.

The District Land Bureau will commission a Cadastral Survey with the following documents issued to the Licenced Land Surveyor:

- Instruction to Survey (I/S). (Fig15)
- Cadastral extract to scale
- Part Development Plan (Fig12)
- Proof of ownership for unregistered parcels provided by the Sector Executive Secretary where the parcel is located
- Search Certificate to certify legal information on a registered parcel. (Fig 16)

3.12 **Submitting a Cadastral Survey**

When submitting the diagrams and general plans framed from his/her survey, a Land Surveyor is obliged also to lodge the records of that survey with the district Land Bureau. These records are used to support the examination process and are then preserved in the district Land Surveyor office. Land Surveyors later refer to these records when relocating or replacing lost beacons and when extending the earlier survey.

The principal records kept are:

- The field observations, which are the primary record of the survey,
- A list of co-ordinates of the beacons and reference stations,
- A working plan,
- A plan on which is shown the comparison between the original and the new survey data, and
- The Survey Report.
These records are then stored in the document imaging system (DIS) for easier access and to facilitate the supply of information to Land Surveyors.
4 ENGINEERING SURVEYS

4.1 Introduction

Engineering surveys are carried out in relation to construction and infrastructure building projects. They are associated with all aspects of engineering design. The main purpose of these surveys is to assess and determine the conditions of a building site either pre, during or post construction and are an essential part of all large building constructions including roads, railways, dams, bridges and residential areas.

4.2 Methods

A variety of methods are used for conducting these surveys - and the methods will change depending on the particular job at hand.

4.3 Types

Engineering surveys can be divided into three survey categories: planning and design; construction and post construction.

4.3.1 Topographic surveys

Topographic data for an engineering survey should include such items as existing fencing, roads, buildings, power lines, land features, waterways, railroads, pipes, utilities etc.

Below are examples of features to be picked:

- Perimeter walls
- Gas and Petroleum Pipelines
- Water and Sewer Lines
- Power Lines
- Telephone Lines
- Buildings
- Drainage courses
- Drainage structures
- Railroads

The symbology and classification of these features are given in the annex of this manual.

4.3.2 Observations and Measurements

Observations need to originate from a known point

On most modular note forms, measurements are the only required field entries, except for perimeter information and point names. Record each required field value in its proper place.
Explanatory notes, such as unusual weather conditions, problems with equipment, etc., aid in the interpretation and analysis of the reliability of portions of a survey.

Entries which are recorded at the time observations are made, are original entries. Field notes with original entries will stand up in court and will assure maximum accuracy.

**Presentation of work**

- Field notes and computations where the control was extended
- Topographic map
- Digital Terrain modelling data
- Survey Report

**4.3.3 Route Surveys**

These surveys are conducted along the long and narrow strip of land for the construction of roads, railways, canals, sewer lines, water pipelines etc.

Sound engineering principles require that the route be chosen in such a way that the project may be constructed and operated with the greatest economy and utility; in other words, extensive surveys and cost estimates must first be made.

Route surveys are carried out in the following order:

- Reconnaissance
- Preliminary survey
- Location survey
- Construction

**Observations and measurements**

**4.3.4 Observations need to originate from a known point with established vertical control.**

Measurements and sketches are the only required field entries. Record each required field value in its proper place and prepare descriptive sketches and diagrams.

Explanatory notes, such as unusual weather conditions, problems with equipment, etc., aid in the interpretation and analysis of the reliability of portions of a survey.

Entries which are recorded at the time observations are made are original entries. Field notes with original entries will stand up in court and will assure maximum accuracy.

**Presentation of work**

- Field notes and computations
- Profiles and cross-sections
- Mass haul diagrams
- Survey Report

**4.3.5 Setting out**

Setting out begins with a plan and ends with some particular engineering project correctly positioned in the area.
There are broadly three types of works:

- Highways (including railways).
- Bridges and buildings.
- Drainage works.

Setting out is undertaken from control points already established in the area by previous work in surveying. These may be vertical control points e.g. benchmarks or horizontal control points e.g. traverse and triangulation stations.

- When setting out, once the control framework of plan and level points has been established, all design points must be set out from these and not from any design point already established. This avoids cumulative errors from one design point to the next.
- Once setting out has begun, it should be independently checked wherever possible. This ensures that any errors are detected and can be corrected at an early stage.

**Setting out involving horizontal control**

Main site control points, such as traverse stations, can be used to establish baselines from which setting out can be undertaken. Subsidiary lines can be set off from the baseline to establish design corner points.

Methods of setting out involving horizontal control include:

- Setting out by bearing and distance.
- Setting out by intersection.
- Setting out by offsetting.

**Setting out involving vertical control**

To provide a basis for vertical control, all levels on site will normally be reduced to a nearby ordinance benchmark (OBM). The actual OBM used is normally agreed on by the Surveyor and the contractor and is termed the master benchmark (MBM). Points of known level are established near and around the proposed structure and these are called transferred benchmarks (TBM). If there are other OBM nearby, their heights should be checked with reference to the MBM. This ensures that only one MBM is used.

**Observations and measurements**

- Establish site boundary
- Observe and measure angles and distances from given plan to given site

**Presentation of work**

- Site presentation
- Declaration of job completion (Fig 18)
- Survey report (Fig 6)

4.3.6 **Deformation Surveys**
It is important to measure any movements both during and after completion of many types of construction.

In such cases a horizontal and vertical control survey can be established and from the reference points set up, periodic measurements can be carried out on the structure to enable any structural or ground displacements to be detected.

**Methods of monitoring vertical deformation:**

These include:

- Spirit levelling
- Trigonometric heighting
- Hydrostatic levelling
- Scanners

The vertical controls (benchmarks) should be a good distance from the construction so that they cannot be affected by the deformation process. The reference points on the structure should be well distributed. The precision required in levelling is of first or second class; therefore extra care and caution should be observed. Some of the precautions taken include:

- Taking back sight distances which are equal to foresight distances.
- Taking readings at least 1m from the ground.
- Keeping the sight distances as short as possible i.e. below 25m.
- Running the level circuit from both directions

**Frequency of observations:**

Observation may begin at the foundation level but often the frequency of observations depends on the amount of deformation in time and space. This process is called *consolidation*. When 25% of the foundation weight has been constructed, observations may begin. The cycle of observation will continue when 50%, 75% and 100% of the foundation weight is constructed. This is because it is suspected that the biggest part of deformation takes place during construction.

The frequency of measurement after completion of the construction may be two or three times in a year up to the time when the deformation stabilizes i.e. when the rate of deformation is 1-2mm per year. Observations may then take place after an interval of 2-3 years.

**Methods of monitoring horizontal deformation:**

Horizontal deformation can be either relative or absolute. These are mostly caused by tectonic forces. In order to monitor such deformations it is necessary to put permanent points that can be observed over a long period of time, approximately three times a year for ten years, to measure the difference in the relative positions. These can be measured using GNSS high precision technology to first and second order accuracies.
5 PHOTOGRAMMETRY

5.1 Introduction

In general photogrammetry has three main components, which are image acquisition, image control and product compilation. The surveyor’s role is mainly in image control and product compilation.

Images used for photogrammetry can originate from a metric camera, an ordinary camera or from digital sensors. The image can be recorded from a device mounted on a satellite, on an airplane (including helicopters), or on a tripod (terrestrial photogrammetry) which is set up on the ground. In this Manual, only applications that are based on aerial photographs recorded with a metric camera will be discussed.

5.2 Definitions

- Analytical Control: The photo control that is developed by analytical aerotriangulation procedures to supplement field control.
- Conventional Control Point: A photo control point that is located by ground survey procedures.
- Culture: Features of the terrain that have been constructed by man.
- Digital Terrain Modelling (DTM): is a process for developing a mathematical model of the existing terrain from collected elevation data that is referenced to a coordinate system.
- Endlap: The amount by which one photograph covers the same area as covered by the successive photograph along the flight strip. To be suitable for mapping, this amount shall be between 55 and 65%.
- Flight Strip: A succession of aerial photographs taken along a single flight line.
- Hang-Out Point: A targeted or post-controlled control point that is not part of a horizontal traverse.
- Horizontal Picture Point (HPT): A photo identifiable horizontal control point that is horizontally positioned by a field survey.
- Pass Point: A photo control point developed and used in the analytical triangulation process that ties adjacent photographs together. The analytical aerotriangulation process develops “xyz” values for each selected pass point.
- Photo Control Point: A photo identifiable point identified on a photograph and having a horizontal and/or vertical position. A series of photo control points provides for the scaling and leveling control for the photogrammetric process.
- Photo Identifiable: A point or feature that is identifiable on both the aerial photograph and the ground.
- Photo Index: The photo index is a reduced scale copy of the project aerial photography. It consists of a photographic copy of the composite of all the contact prints laid out by flight strips showing the relationship of all the photos in the project.
- Post Control: Post control consists of photo identifying horizontal and vertical picture points after the photography has been obtained.
- Quality Control Point (QP): A point that is used as a vertical check on the photogrammetric process. It is a field-surveyed point.
- Side Lap: The amount of overlap between two or more parallel flight lines. For mapping projects this amount should be a minimum of 30%.
- Stereo Model: The three dimensional image formed by two successive overlapping photographs.
- Target: An artificial symmetrical pattern that is placed over a control point before aerial photos are taken. Targets are used as horizontal and/or vertical control points. Also called a “panel”.
- Vertical Picture Point (VPT): A vertical control point that is photo identifiable and has been vertically positioned by a field survey.
- Wing Point: A picture point located within 20% of the outside edges of the photograph and normally used for vertical control.

5.3 Image Acquisition

5.3.1 Flight Mission Planning

This is done to give two items:

- Preparation of a flight map. This is a medium scale Topographic map on which the flight lines are drawn. It shows the starting and ending points of each line, and is used by the pilot for navigation and by the photographer for taking the pictures. The number of flight lines, their location, the spacing between them, and their orientation depends on the characteristics of the project area to be mapped and on the specifications of the flight mission.
- Specifications which outline how to take the photos, including camera and film requirements, scale, flying heights, end lap, side lap, tilt and crab tolerances, etc.

5.3.2 Aerial Cameras

Aerial mapping cameras record the image on which the photogrammetric principles will be applied. They must be able to produce very sharp images, almost distortion free, in rapid succession under the adverse conditions of a moving aircraft. Any error, distortion, or compromise in the clarity of the image will result in mapping and positioning errors.

5.3.3 Aerial Films

Aerial films should be stable and fine grained, made of high speed photographic emulsion on a stable polyester film base. The fine grain is necessary for identifying features as small as 1 micron on the negative while high speed film permits short exposure time so that the image smear due to the movement of the aircraft.

To insure dimensional stability, the film should not be stretched or deformed in any way. It should not be subjected to extreme changes in humidity and temperature. The film should be sealed in its container and stored at a temperature recommended by the manufacturer at all times, except when in actual use during the flight mission or when being processed.

5.3.4 Image Scanning
Until recently, photogrammetric products were developed from diapositives or paper prints. With the emergence of digital photogrammetry, photographs are now scanned into a digital format that is compatible with digital image processing software. Scanners for digital photogrammetry are precision devices that maintain the radiometric and geometric integrity of the scanned image.

5.4 Control for Photogrammetry

The photogrammetric control process is used to establish the position and orientation of the camera at the instant of exposure. The necessity, accuracy and the rigor of photogrammetric control depends on the particular product sought. Photo mosaics used for annotation may not require any control. Rectified aerial photographs used for photo plan sheets may require partial control in the form of measured distances. Photogrammetric products, such as mapping and orthophotography, require full control information. The control must be more than the minimum necessary to establish a stereo model, which is two points with known horizontal positions and three points with known elevations (for orientation).

Photographs can be controlled using three different methods:

- Ground control points that were surveyed on the ground using ordinary surveying techniques.
- Bridging control through aerial triangulation. Bridging is accomplished by measuring on the photographs common points that appear in three consecutive photographs or in two adjacent strips and computing their 3 D coordinate values.
- Aerial photography control through kinematic GPS technique in which the position and the attitude of the camera are computed without ground control.

In most photogrammetric projects, a combination of all or some of these methods is utilized.

5.4.1 Ground Control

Ground control can be targeted and photo-identifiable (picked) control points, they can also be classified as horizontal control, vertical only control, or as 3-D control. The surveyor needs to know what type of control is called for when he or she attempts to pick or photo-identify the point. Accessibility for surveying should also be considered when selecting the locations for control points.

5.4.2 Targeting

Targeting operations are to be considered prior to establishing a control survey. Specifications for Preflight targeting, which is performed to make ground locations of control points visible on the photographs, should include Easy identification, clear image of the control points on the photograph, careful planning for optimal target placement. It is important to either paint them on a hard surface or schedule the field paneling operation as close as possible to the anticipated flight so as to reduce the possibility of pre-marked points being moved or lost prior to the aerial mission. The Photographic targets should be of symmetrical shape (Figure 19), adequate size, and be located where shadows will not adversely affect their visibility.

5.4.3 Field Survey of Photogrammetric Control
Field surveys for photogrammetric control should be treated as ordinary surveys. The key issue is to select suitable survey procedures that address the project requirements. GPS is the better suited surveying method for most large photogrammetric projects. And the ground control points should be monumented accordingly.

5.4.4 Aerial Triangulation

Aerial triangulation, or aerotriangulation, is the process of determining X, Y, and Z ground coordinates of individual points based on measurements from photographs. It is used in densifying ground control. Aerial triangulation is used to provide the necessary control for each stereo model with only a limited number of field surveyed control point.

Other advantages of aerial triangulation are:
- The control densification is done in the office.
- Field surveys in difficult or unsafe areas are minimized.
- Access to much of the (private or public) property within a project area is not required.
- It provides accuracy and consistency checks for the field surveyed control points.

5.4.5 GPS as Control for Photogrammetry

GPS has been demonstrated to be able to replace, partially or entirely, the need for ground control. The basic concept of GPS controlled photogrammetry is to use GPS equipment to determine the position and orientation of the camera at the instant of exposure. The only reason for using ground control in photogrammetry is to recover the position and orient a photograph in space at the time that the photograph was taken. If the values of these parameters can be resolved at the time of photography with GPS and/or additional instruments, there is no need for ground control to compute them. GPS controlled photography is not yet at a level of maturity to be able to completely replace the need for ground control.

5.5 Product Compilation

5.5.1 Photogrammetric Plotters

Stereo plotters are used to reconstruct the actual orientation and geometric integrity of an image at the instant of exposure and to collect three dimensional (3D) data. Data collection is done in two stages, the first stage is orientation, which consists of:
- Inner orientation
- Relative orientation
- Absolute orientation

In the second stage, the operator collects X,Y,Z coordinates of the features when viewing the image of the ground in 3D.

Stereo plotters can be analog, analytical, and digital. Each of these can be classified as first, second or third order plotters according to their accuracy. Another classification of stereo plotters is as precision, topographic, or simple plotters.
Other photogrammetric instruments used in aerial triangulation are the point transfer device and the comparator. The point transfer device is used to drill a hole into the diapositive to mark a pass or a tie point. This is done by using a floating mark in stereo vision. Comparators are precise digitizers with which image coordinates of pass, tie and ground control points are measured. They are either Mono comparators or stereo comparators. If a mono comparator is used, pass points must be marked on each photograph and if a stereo comparator is used, the pass points are marked only on one photograph.

5.5.2 Data Collection and Mapping

The collected data can be presented in the following formats:

- Planimetric maps
- Topographic maps
- DEM's
- Special purpose
- Photo-mosaics
- Map updating
- Orthophotos

5.5.3 Digital Orthophoto Production

The steps involved in production of digital orthophotos are:

- Project and flight mission planning.
- Image acquisition with precise aerial cameras.
- Film processing, annotation etc.
- Image scanning.
- Control points and aerial triangulation.
- Image rectification
- Mosaicing and Image Enhancement
- Quality Control
- Output Design and Cartographic Enhancement.

The first five steps have been discussed; the other procedures are as follows:

Image rectification

This is the process of correcting scale distortions resulting from the perspective projection of an image. It uses pixel elevations interpolated from a Digital Elevation Model (DEM). DEM data can be obtained from field surveys, photogrammetry, Kinematic GPS or digitizing contours from topographic maps. The decision on which DEM to use depends on the scale of the orthophoto.

Each (digital) photograph, or part of it, is rectified individually using special software when all data (image, orientation and DEM) is available. The rectified photos are then mosaiced together into a seamless and continuous orthophoto.
Mosaicing and Image Enhancement

- Spatial continuity or edge matching
- Radiometric

Quality Control

The quality control involves inspecting the orthophoto for incorrect rectification, image matching problems and missing images due to hidden ground problems.

Output Design and Cartographic Enhancement

This consists of formatting the image and enhancing it by adding:

- line information that either appears fuzzy or does not exist on the image (e.g., parcel boundaries)
- area (polygon) information (for example shading a park area)
- a contour layer to show hypsography (relief features)
- coordinate graticules and North arrow
- annotation (text and symbols)
- legend, product information etc.

Accuracy and Quality Issues

The elements that contribute errors to an orthophoto product are:

- Camera characteristics and calibration
- Scanner characteristics calibration and resolution or image scale
- Ground control accuracy, distribution, and abundance
- Aerial triangulation design, measurement, and computation
- Digital Elevation Modeling (DEM) - (method of compilation; quality of the source material; characteristics of the terrain; sampling spacing, with or without breaklines; type of breaklines used; method of interpolation into pixel grid and availability of height information on or above surface features, such as buildings.)
- Rectification process (method and software)

Image quality issues of orthophotos are:

- Pictorial defects caused by orthophoto production:
  a) Contrast and brightness differences
  b) Dirt and scratching marks that appear on the image

- Image defects caused by inaccurate DEM:
  a) Missing images
  b) Image blurring
c) Double image  

d) Discontinuities of features  

The spatial accuracy of the orthophoto is assessed using the same procedure used for line maps.  

**Accuracy and Errors**  

The two factors that affect the attainable accuracy of a photogrammetric product are the scale of the photographs and the second is related to errors in the photogrammetric process.  

### 5.6 Photogrammetric Procedure  

#### 5.6.1 Project Planning  

Project planning is comprised of the following steps:  

- Convert project requirements to specifications; (area to be mapped, desired map scale and contour interval). These depend on the required accuracy of the final map and on cost constraints.  
- Determine photogrammetric specifications; (flight height, flight lines, approximate location for exposure stations, and equipment to be used, ground control, aerial triangulation, and compilation methodology).  
- Develop a schedule for aerial photography, field work, and map compilation.  
- Define the expected deliverables, including details on what features are to be mapped and their graphic representation.  

#### 5.6.2 Procedure for Aerial Photography  

The aerial photography process consists of the following:  

- Verify that the weather conditions are suitable for flying.  
- Mount the aerial camera according to the established procedure  
- Fly the designed routes and take the photographs according to plans.  
- Process the film according to specification to ensure radiometrically and geometrically quality images.  
- Print on the negatives the missing photo information (titles), (eg. serial number, date, project name)  
- Prepare contact prints from the negatives  
- Inspect the photographs for image quality and for coverage completeness. (including end laps, side laps, and identifying the preset targets for visibility, sufficiency and stereo coverage).  
- Select photographs that will be used for data compilation and develop diapositives for them.  

#### 5.6.3 Procedures for Ground Control  

- Research project region for existing control. Existing control that can be targeted can save time and money by avoiding unnecessary field surveys.  
- Place targets according to the discussion in above section of this manual.
• Perform field surveys as discussed in sections above of this manual. Field surveys of picked points could be necessary after the aerial photography is completed.
• Compute and adjust the field data and establish coordinate values for the control points.
• Prepare a report on the surveys and on the results. An accuracy analysis of the results should be included in the report. The analysis should indicate the methodology used to determine that the results are in agreement with the project specifications.

5.6.4 Procedures for Aerial Triangulation

• Order the photographs as a continuous strip, or a block
• Select and mark pass and tie points. Pass and tie points should be clearly marked and numbered on the paper prints.
• Mark artificial pass and tie points on the diapositives with a point transfer device.
• Measure and record pass and tie points with a photogrammetric plotter (including digital workstations) or a comparator. At least an inner orientation must be performed prior to measuring pass and tie points so that image coordinates of these points can be obtained.
• Compute and adjust the aerial triangulation measurements. Check the results for possible measurement, marking, identification and control errors.
• Prepare a report on the aerial triangulation results. The report should include the photogrammetric block layout and a diagram showing the location and names of all the points that participated in the adjustment. Erroneous points that were removed from the computation or had to be measured again should be listed. The results of the computations and an accuracy analysis of final adjustment with respect to the project specifications are to be documented as well.

5.6.5 Stereo Compilation

Mostly CAD based digital mapping software is used for simplified manuscript preparation, editing and error checking of the stereo compilation process. The stereo compilation process is as follows:

• Select models to be used for mapping. The selection should include a layout of what areas are to be mapped from which stereo model. Mapping from the fringes of the stereo model is usually less accurate than at the centre. Therefore, the operator should be instructed on the limits of stereo model that should be used for mapping.
• Set up the stereo models by performing interior and exterior orientations.
• Compile the planimetric features according to the project specifications. The specifications should be clear in terms of what features are to be mapped and their graphic representation in terms of color, shape, symbol, and other attributes.
• Compile elevation features as contours or spot elevation. Contours should be compiled according to the specified contour interval. Nowadays, contouring is performed by interpolating a DEM, instead of plotting them directly from a stereo model. DEM must be comprised of spot elevations (regularly or irregularly spaced) and breaklines. A DEM that does not include breaklines will probably produce unacceptable contouring accuracy.
• Inspect the map for completeness, consistency and accuracy. The purpose of inspecting the map for completeness is to verify that all the required features have been mapped. Modern photogrammetric plotters have a capability of superimposing the map on the photographic image so that both of them can be viewed simultaneously with correct spatial registration.
This superimposition makes it very easy to perform the completeness inspection. The stereo model is visually checked for required features and the features can be immediately verified. Consistency and accuracy inspection is performed to verify that the features are mapped in the correct location with the correct attribute. One has to make sure that features are mapped continuously and accurately.

- Edit the map and make the necessary corrections.

5.6.6 Field Completion

Field completion is carried out to test the accuracy of the resultant maps and to map missing features that may be obscured and not visible on the photos.

Drafting

Drafting of photogrammetrically derived maps is performed with CAD software. It consists of the following:

- Sheet Layout
- Sheet Format
- Scale Change
- Edit and Final Corrections

All of these parameters should be part of the project specifications and should be performed accordingly.

Quality Control

A final report on the quality and accuracy of the maps should be prepared to review the accuracy of the control. It should document the procedure used to determine the map's spatial and content accuracy. Any claim of accuracy or standard must be substantiated by an actual test and analysis, the methodology used and the findings should be documented in a final report.

Presentation of work

The materials to be submitted to include coordinates, sketches and photographs of observed and established photo and ground controls, field Books for both the vertical and horizontal work, and any other material outlining the traverse and level lines or field procedures used to control the project.
6 GEOGRAPHIC INFORMATION SYSTEMS

6.1 Introduction
GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. A GIS performs map making tasks faster and with more sophistication than do traditional manual methods.

The important factor is the level of integration of these tools to provide a smoothly operating, fully functional geographic data processing environment.

A GIS has four main functional subsystems. These are:

- Data input subsystem
- Data storage and retrieval subsystem
- Data manipulation and analysis subsystem
- Data output and display subsystem

6.2 Data models
A successful GIS operates according to a well-designed implementation plan and business rules, which are the models and operating practices unique to each organization.

The basic data type in a GIS reflects traditional data found on a map. Accordingly, GIS technology utilizes two basic types of data. These are: Spatial and attribute data.

6.2.1 Spatial data model
Spatial data in a GIS environment is represented in three ways: point, line and polygon. The standard way of representing features and feature classes in Fig. 20)

6.2.2 Image data
Image data is most often used to represent graphic or pictorial data. This could be satellite scenes or orthophotos, or ancillary graphics such as photographs, scanned plan documents, etc. Image data is typically used in GIS systems as background display data (if the image has been rectified and georeferenced); or as a graphic attribute. This data has to be converted to vector if it is to be used analytically in GIS.

Image data should be stored in the following format: JPEG, Bitmap, TIFF.

6.2.3 Attribute data model
A separate data model is used to store and maintain attribute data for GIS software. These data models may exist internally within the GIS software, or may be reflected in external commercial Database Management Software (DBMS). A variety of different data models exist for the storage and management of attribute data. The most common are:
• Tabular
• Hierarchical
• Network
• Relational
• Object Oriented

6.3 Sources of data
A wide variety of data sources exist for both spatial and attribute data. The most common general sources for spatial data are:

• Hard copy maps
• Aerial photographs
• Remotely-sensed imagery
• Point data samples from surveys
• Existing digital data files

Existing hard copy maps, e.g. sometimes referred to as analogue maps, provide the most popular source for any GIS project.

Potential users should be aware that while there are many private sector firms specializing in providing digital data, state government agencies are an excellent source of data.

Any textual or tabular data can be referenced to a geographic feature, e.g. a point, line, or area, can be input into a GIS. Attribute data is usually input by manual keying or via a bulk loading utility of the DBMS software. ASCII format is a de facto standard for the transfer and conversion of attribute information.

6.4 Data input techniques
There are at least four basic procedures for inputting spatial data into a GIS. These are:

• Manual digitizing
• Automatic scanning
• Entry of coordinates using coordinate geometry
• Conversion of existing digital data

6.5 Data format
IGDS - Interactive Graphics Design Software (Intergraph / Microstation); This binary format is a standard in the turnkey CAD market. It is a proprietary format, however most GIS software vendors provide DGN translators.

DXF - Drawing Exchange Format (AutoCAD); This ASCII format is used primarily to convert to/from the AutoCAD drawing format and is a standard in the engineering discipline. Most GIS software vendors provide a DXF translator.
EXPORT - ARC/GIS Export Format; An exchange format that includes both graphic and attribute data. This format is intended for transferring ARC/GIS data from one hardware platform, or site, to another. It is also often used for archiving.

ARC/GIS data. This is not a published data format, however some GIS and desktop mapping vendors provide translators. EXPORT format can come in either uncompressed, partially compressed, or fully compressed format.

6.6 Data output techniques

GIS data can be presented in the following formats;

a) A map, which should have:
   - A title
   - A compass
   - A scale
   - Source of data
   - Date of production
   - A legend
   - A frame

b) Tabular data:
   GIS can provide tabular summaries of all attributes, which can be produced by statistical investigations, and database queries.

c) Charts and diagrams

d) Reports
ANNEXES – FIGURES AND FORMS
Figure 1: Typical Monument of a Geodetic Control Point

- The GCP should have a wide base and a narrow surface
- Witness marks should be established around the GCP as pointers to the GCP and should have a different physical description from the GCP.
- Witness marks should be 1-2 in number and within a radius 10m.

Figure 2: Typical Monument of a benchmark

- Elevation: 4500 M above mean sea level
- Vertical control point/benchmark
Figure 3: Existing National Geodetic Control Network

Central stations in the 1991-92 GPS campaign
Figure 4: Typical monument of IPC boundary mark

- The height of the boundary mark should be no less than 40 cm
- The height of boundary mark above ground surface should be no more than 10 cm.
- The shape of the top surface should be circular and have a diameter of not less than 15 cm.
- The boundary mark should be gradually wider towards the base.
- It should be placed such that the centre of the iron pin forms the boundary.
- The iron pin should be no less than 45 cm long and a diameter no less than 10 mm with a rounded bottom having a cross at its centre.
Figure 5: Sample Cadastral Plan
**Figure 6: Survey Report**

**REPORT HEADING**

<table>
<thead>
<tr>
<th>SURVEYOR’S COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(The following summary descriptions have been added to assist you complete your reports)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plan Type &amp; No:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lodging Surveyor:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Firm:</th>
</tr>
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<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surveyor’s Reference:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1 Survey Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Include information on client, reason for survey and intended use of result of survey</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2 Dataset Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ensure correct type has been assigned to dataset (is their existing Survey information on parcel and what type?-fixed survey or general boundary survey?)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3 Physical description of area to cover survey:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide general sketch diagram to describe area for survey including land use of area. It is also important to highlight existence of any public infrastructure and description of size eg road, communication antenna, etc</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4 Equipment and Methods Used:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Describe the type of equipment and methods used to ensure compliance with the accuracy standards</td>
</tr>
<tr>
<td>This information may also assist in providing evidence of correct orientation in section 5 below.</td>
</tr>
<tr>
<td>REPORT HEADING</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>5 Datums and Orientation:</td>
</tr>
<tr>
<td>a) Horizontal Datum:</td>
</tr>
<tr>
<td>i) Orientation:</td>
</tr>
<tr>
<td>ii) Geodetic Control points used:</td>
</tr>
<tr>
<td>b) Vertical Datum:</td>
</tr>
<tr>
<td>6 Old Survey Marks:</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>7 Boundary Definition</td>
</tr>
<tr>
<td>a). Defined by survey</td>
</tr>
<tr>
<td>b). Defined by adoption</td>
</tr>
<tr>
<td>c). Accepted boundaries</td>
</tr>
<tr>
<td>Neighbor 1:</td>
</tr>
<tr>
<td>Contact:</td>
</tr>
<tr>
<td>Neighbor 2:</td>
</tr>
<tr>
<td>Contact:</td>
</tr>
<tr>
<td>REPORT HEADING</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td><strong>Umudugudu Leader:</strong></td>
</tr>
<tr>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>8 Occupation:</strong></td>
</tr>
<tr>
<td><strong>9 Parcel Areas:</strong></td>
</tr>
<tr>
<td><strong>10 Conflict with Cadastre:</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>11 Non-primary Parcels:</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>12 Additional Information and Legal:</strong></td>
</tr>
<tr>
<td>REPORT HEADING</td>
</tr>
<tr>
<td>----------------</td>
</tr>
</tbody>
</table>
| 13 Survey System Maintenance: | Please report on the following cadastral system maintenance issues:  
**Anomalies**  
Please note any anomalies you have noticed with existing surveys and documents that you haven’t already reported on.  
**Discrepancies:**  
Please list the issues and discrepancies that you would like investigated by RNRA Staff  
**Physical survey network:**  
Please identify any marks or survey structures that require maintenance - for possible addition to the RNRA annual programme for survey maintenance.  
You are also welcome to suggest ideas for new survey control in the vicinity of your survey that would enhance the survey system |
| 14 Additional Notes: | Additional notes not covered elsewhere in this report that may assist validation or other surveyors. |
Figure 7: Building Location plan
Figure 8: Elevation Plan

<table>
<thead>
<tr>
<th>Floor Level</th>
<th>Unit</th>
<th>Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6th Floor</td>
<td>17&amp;18</td>
<td>2.245</td>
</tr>
<tr>
<td>5th Floor</td>
<td>15&amp;16</td>
<td>2.265</td>
</tr>
<tr>
<td>4th Floor</td>
<td>13&amp;14</td>
<td>2.265</td>
</tr>
<tr>
<td>3rd Floor</td>
<td>11&amp;12</td>
<td>2.265</td>
</tr>
<tr>
<td>2nd Floor</td>
<td>9&amp;10</td>
<td>2.265</td>
</tr>
<tr>
<td>1st Floor</td>
<td>7&amp;8</td>
<td>2.265</td>
</tr>
<tr>
<td>Mezzanine Floor</td>
<td>5&amp;6</td>
<td>2.265</td>
</tr>
<tr>
<td>Upper Ground Floor</td>
<td>3&amp;4</td>
<td>2.265</td>
</tr>
<tr>
<td>Lower Ground Floor</td>
<td>1&amp;2</td>
<td>2.265</td>
</tr>
</tbody>
</table>
Figure 9: Floor plan
Figure 10: Unit Survey plan
Figure 11: Unit table of ratios

<table>
<thead>
<tr>
<th>HOUSE UNIT NUMBER</th>
<th>LOCATION</th>
<th>PROPRIETOR</th>
<th>AREA (m²)</th>
<th>RATIO (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>lower ground</td>
<td>CARITAS</td>
<td>396.52</td>
<td>6.4</td>
</tr>
<tr>
<td>2</td>
<td>lower ground</td>
<td>0R A S.</td>
<td>295.47</td>
<td>4.7</td>
</tr>
<tr>
<td>3</td>
<td>upper ground</td>
<td>CARITAS</td>
<td>396.52</td>
<td>6.4</td>
</tr>
<tr>
<td>4</td>
<td>upper ground</td>
<td>0R A S.</td>
<td>295.47</td>
<td>4.7</td>
</tr>
<tr>
<td>5</td>
<td>Mezzanine Floor</td>
<td>CARITAS</td>
<td>396.52</td>
<td>6.4</td>
</tr>
<tr>
<td>6</td>
<td>Mezzanine Floor</td>
<td>0R A S.</td>
<td>295.47</td>
<td>4.7</td>
</tr>
<tr>
<td>7</td>
<td>1st floor</td>
<td>CARITAS</td>
<td>396.52</td>
<td>6.4</td>
</tr>
<tr>
<td>8</td>
<td>1st floor</td>
<td>0R A S.</td>
<td>295.47</td>
<td>4.7</td>
</tr>
<tr>
<td>9</td>
<td>2nd floor</td>
<td>CARITAS</td>
<td>396.52</td>
<td>6.4</td>
</tr>
<tr>
<td>10</td>
<td>2nd floor</td>
<td>0R A S.</td>
<td>295.47</td>
<td>4.7</td>
</tr>
<tr>
<td>11</td>
<td>3rd floor</td>
<td>CARITAS</td>
<td>396.52</td>
<td>6.4</td>
</tr>
<tr>
<td>12</td>
<td>3rd floor</td>
<td>0R A S.</td>
<td>295.47</td>
<td>4.7</td>
</tr>
<tr>
<td>13</td>
<td>4th floor</td>
<td>CARITAS</td>
<td>396.52</td>
<td>6.4</td>
</tr>
<tr>
<td>14</td>
<td>4th floor</td>
<td>0R A S.</td>
<td>295.47</td>
<td>4.7</td>
</tr>
<tr>
<td>15</td>
<td>5th floor</td>
<td>CARITAS</td>
<td>396.52</td>
<td>6.4</td>
</tr>
<tr>
<td>16</td>
<td>5th floor</td>
<td>0R A S.</td>
<td>295.47</td>
<td>4.7</td>
</tr>
<tr>
<td>17</td>
<td>6th floor</td>
<td>CARITAS</td>
<td>396.52</td>
<td>6.4</td>
</tr>
<tr>
<td>18</td>
<td>6th floor</td>
<td>0R A S.</td>
<td>295.47</td>
<td>4.7</td>
</tr>
</tbody>
</table>

Floor area: 6227.91 m² 100.0%

Common Property: 3183.138 m²
Total floor area: 9411.048 m²
Figure 13: Survey Computations

a) These will be dependent on technology and equipment used.

For modern survey techniques these are electronically recorded and computed producing coordinates in a format that can be plotted in any GIS environment.

For traditional survey techniques, these will be recorded and computed manually. The computation of each survey will be dependent on the type of survey and analogue instrument. There are conventional acceptable computation methods used and these will be submitted with survey report (Figure 6)

b) GPS Field log Format

<table>
<thead>
<tr>
<th>Project Name:</th>
<th>Project Number:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiver Model:</td>
<td>Station Name:</td>
</tr>
<tr>
<td>Receiver Software Version:</td>
<td>Station number:</td>
</tr>
<tr>
<td>Data Logger Type/Model:</td>
<td>Date:</td>
</tr>
<tr>
<td>Antenna Model:</td>
<td>Operator:</td>
</tr>
<tr>
<td>Data Collection:</td>
<td>Receiver position:</td>
</tr>
<tr>
<td>Start Time:</td>
<td>Latitude:</td>
</tr>
<tr>
<td>End Time:</td>
<td>Longitude:</td>
</tr>
<tr>
<td>Number of observations made:</td>
<td></td>
</tr>
</tbody>
</table>
Figure 14: Survey Declaration of a Licenced Land Surveyor

I ............... certify that all the work done in the field and in the office was personally carried out and I take full responsibility for all work and submissions.

Signed:
Date:
Stamp:
Figure 15: Instruction to Survey (I/S Form)

REPUBLIC OF RWANDA

RWANDA NATURAL RESOURCES AUTHORITY

OFFICE OF THE REGISTRAR OF LAND TITLES

INSTRUCTIONS TO SURVEY

I/S No: Date:

File No: Other ref:

To: ........................................ consultants - KIGALI
Copy to: Director General Surveys and Mapping Dept.

Parcel Location:
UPI No ..................................

Please survey the above for: ....................................District

Class of survey: Subject to the land being available and without dispute.

(a) Connections will be made to adjacent old surveys.

(b) Topo surveys are required for all roads crossing and near boundaries. These should also prove that the road reserve has been correctly set out.

(c) Control: Tie to existing surveys in the area.

Authorised by:..................................................
DISTRICT LAND OFFICER

Date: ..............................................................

The above survey is completed. Before survey, the boundaries were retraced by lessee agent and Mr/Mrs/Miss ...........the Village (Umudugudu) Leader of ...........................................Village ...................... during the presence of .......................................................... ..........................................................the neighbors of the lessee.

I further certify that no person has been included in the survey against his will.

Sign ..............................
Surveyor

Date ..............................
1. **Application for official search**

Title or lease number ……………………………

Made at district land bureau …… (district name) …..

Particulars of applicant ………………………………………..

Reason for applying for the search/use of the search ……………………………..

Fee paid …………… (amount) ………………… And receipt number or details ………………………. 
2. Certificate of official search

(This gives the copy of what is registered in the database held by ORTL)

Title or lease number ……………………..

Search number ……………………….

On the …………………. (date) …………… day of …………………. (month) ……… (year) ………….,
the following were the subsisting entries on the register of the above mentioned title or lease:

Nature of the title …………………..

Approximate area of the parcel ………………………

Name and address of the proprietor ………………………

Inhibitions, cautions and restrictions ………………………

Existing Servitudes on the parcel ………………………

Encumbrances such as subleases or charges …………………..

The following applications are pending ………………………

Prepared and issued by …………. (name) ……………….. (signature) ……………..

District land bureau …………………. (district name) ……..

Fee paid ……………. (amount) ……………….. And receipt number or details ……………………..

Date …………………
Figure 17: Consent to Transact on Land.

REPUBLIC OF RWANDA

RWANDA NATURAL RESOURCES AUTHORITY

OFFICE OF THE REGISTRAR OF LAND TITLES

Letter of consent or permission for land transaction

With reference to your application dated the …….. (date) …….. (month) …….. (year) ……..
permission for the following controlled transaction was given on …….. (date) …….. (month)
……….. (year) ……..

Special reference or minute of the approval …………………………………………………

The nature of transaction

Title or lease number ………………………

Locality ………

Transaction (Sale, lease, sub-division, mortgage, land use change, other)
………………………………………………

Names of the parties concerned

From ………… (name of owner) …………………

To ………… (name of interested person) …………………

Length of the term …………………………………

Consideration or cost ……………………………

Special conditions of approval of sub-division
……………………………………………………
………………………………………………
………………………………………………

Prepared by ……………………………

Date ………………………………………

Of the District Land Bureau …….. (name of district) …………………
**Figure 18: Declaration of job completion**

The above survey is completed according to requirements and satisfaction of Client. Before survey, the boundaries were retraced by the owner; Mr/Mrs/Miss……………………………………………………………………………………………..

Survey work completed is for: ……………….(use), ……………………(description) and

Location:

Parcel ID:………….; Village:………….; Cell: …………….; Sector:………….; District:……………………….

I further certify that no person has been included in the survey against his/her will.

Sign  ……………………….  Sign  ……………………….

Surveyor  

Owner  

Date  ………………………  Date  ……………………….
Figure 19: Recommended shapes for photogrammetric ground controls
Figure 20: Symbology and classification of features

### Standards for spatial data representation

#### Transportation Features - Roads

<table>
<thead>
<tr>
<th>Feature Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tarmac Road</td>
<td>![Symbol for dual highway]</td>
</tr>
<tr>
<td>Tarmac Road</td>
<td>![Symbol for more than 2 lanes]</td>
</tr>
<tr>
<td></td>
<td>![Symbol for 2 lanes]</td>
</tr>
<tr>
<td></td>
<td>![Symbol for less than 2 lanes]</td>
</tr>
<tr>
<td>Stone/Paved Road</td>
<td>![Symbol for 2 lanes or more]</td>
</tr>
<tr>
<td></td>
<td>![Symbol for less than 2 lanes]</td>
</tr>
<tr>
<td>Murrum Road</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Road under construction</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Foot path</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Round about</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Highway route number</td>
<td>-NR102-</td>
</tr>
</tbody>
</table>

#### Transportation Features - Railways and Airports

<table>
<thead>
<tr>
<th>Feature Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway - multiple track</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Railway - single track</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Railway sidings</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Railway - rapid transit</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Railway - under construction</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Railway - abandoned</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Railway on road</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Railway station</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Airfield; Heliport</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Airfield, position approximate</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Feature Name</td>
<td>Symbol</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Airfield runways; paved, unpaved</td>
<td>![symbol]</td>
</tr>
</tbody>
</table>

**Hydrographic Features - Naturally Occurring**

<table>
<thead>
<tr>
<th>Feature Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falls</td>
<td>![symbol]</td>
</tr>
<tr>
<td>Direction of flow arrow</td>
<td>![symbol]</td>
</tr>
<tr>
<td>Stream - intermittent</td>
<td>![symbol]</td>
</tr>
<tr>
<td>Sand in Water</td>
<td>![symbol]</td>
</tr>
<tr>
<td>Flooded area</td>
<td>![symbol]</td>
</tr>
<tr>
<td>Marsh</td>
<td>![symbol]</td>
</tr>
<tr>
<td>Swamp</td>
<td>![symbol]</td>
</tr>
<tr>
<td>Well; Spring</td>
<td>![symbol]</td>
</tr>
<tr>
<td>Rocks in water or small islands</td>
<td>![symbol]</td>
</tr>
</tbody>
</table>

**Terrain Features - Elevation**

<table>
<thead>
<tr>
<th>Feature Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal control point; Bench mark with elevation</td>
<td>![symbol] 187.8</td>
</tr>
<tr>
<td>Precise elevation</td>
<td>![symbol] 224</td>
</tr>
<tr>
<td>Contours; index, intermediate</td>
<td>![symbol]</td>
</tr>
</tbody>
</table>

**Terrain Features - Geology**

<table>
<thead>
<tr>
<th>Feature Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Escarpment</td>
<td>![symbol]</td>
</tr>
<tr>
<td>Sand</td>
<td>![symbol]</td>
</tr>
<tr>
<td>Quarry</td>
<td>![symbol]</td>
</tr>
</tbody>
</table>
**Cave**

**Human Activity Symbols - Recreation**

<table>
<thead>
<tr>
<th>Feature Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sports track</td>
<td><img src="image" alt="Sports track symbol" /></td>
</tr>
<tr>
<td>Swimming pool</td>
<td><img src="image" alt="Swimming pool symbol" /></td>
</tr>
<tr>
<td>Stadium</td>
<td><img src="image" alt="Stadium symbol" /></td>
</tr>
<tr>
<td>Golf course</td>
<td><img src="image" alt="Golf course symbol" /></td>
</tr>
<tr>
<td>Golf driving range</td>
<td><img src="image" alt="Golf driving range symbol" /></td>
</tr>
<tr>
<td>Campground; Picnic site</td>
<td><img src="image" alt="Campground symbol" /> <img src="image" alt="Picnic site symbol" /></td>
</tr>
<tr>
<td>Historic site or point of interest; Navigation light</td>
<td><img src="image" alt="Historic site symbol" /> <img src="image" alt="Navigation light symbol" /></td>
</tr>
</tbody>
</table>

**Human Activity Symbols - Agriculture and Industry**

<table>
<thead>
<tr>
<th>Feature Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind-operated device; Mine</td>
<td><img src="image" alt="Wind-operated device symbol" /> <img src="image" alt="Mine symbol" /></td>
</tr>
<tr>
<td>Landmark object (with height); tower, chimney, etc.</td>
<td><img src="image" alt="Landmark object symbol" /> <img src="image" alt="100" /></td>
</tr>
<tr>
<td>Oil or natural gas facility</td>
<td><img src="image" alt="Oil or natural gas facility symbol" /></td>
</tr>
<tr>
<td>Pipeline, multiple pipelines, control valve</td>
<td><img src="image" alt="Pipeline symbol" /> <img src="image" alt="Control valve symbol" /></td>
</tr>
<tr>
<td>Pipeline, underground multiple pipelines, underground</td>
<td><img src="image" alt="Pipeline symbol" /> <img src="image" alt="Underground symbol" /></td>
</tr>
<tr>
<td>Electric facility</td>
<td><img src="image" alt="Electric facility symbol" /></td>
</tr>
<tr>
<td>Power transmission line multiple lines</td>
<td><img src="image" alt="Power transmission line symbol" /> <img src="image" alt="Multiple lines symbol" /></td>
</tr>
<tr>
<td>Telephone line</td>
<td><img src="image" alt="Telephone line symbol" /></td>
</tr>
<tr>
<td>Fence</td>
<td><img src="image" alt="Fence symbol" /></td>
</tr>
</tbody>
</table>
## Human Activity Symbols - Buildings

<table>
<thead>
<tr>
<th>Feature Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>School; Fire station; Police station</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Church; Non-Christian place of worship; Shrine</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Building</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Service centre</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Customs post</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Cemetery</td>
<td>![Symbol]</td>
</tr>
</tbody>
</table>