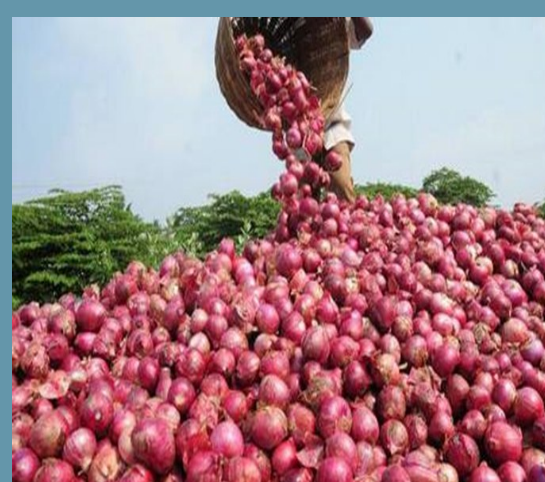
SSIGL 4

NATIONAL GUIDELINES

For Small Scale Irrigation Development in Ethiopia

Topographic and Irrigation Infrastructures Surveying



November 2018

Addis Ababa

MINISTRY OF AGRICULTURE

National Guidelines for Small Scale Irrigation Development in Ethiopia

SSIGL 4: Topographic and Irrigation Infrastructures Surveying

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FORWARD

Ministry of Agriculture, based on the national strategic directions is striving to meet its commitments in which modernizing agriculture is on top of its highest priorities to sustain the rapid, broad-based and fair economic growth and development of the country. To date, major efforts have been made to remodel several important strategies and national guidelines by its major programs and projects.

While efforts have been made to create access to irrigation water and promoting sustainable irrigation development, several barriers are still hindering the implementation process and the performance of the schemes. The major technical constrains starts from poor planning and identification, study, design, construction, operation, and maintenance. One of the main reasons behind this outstanding challenge, in addition to the capacity limitations, is that SSIPs have been studied and designed using many ad-hoc procedures and technical guidelines developed by various local and international institutions.

Despite having several guidelines and manuals developed by different entities such as MoA (IDD)-1986, ESRDF-1997, MoWIE-2002 and JICA/OIDA-2014, still the irrigation professionals follow their own public sources and expertise to fill some important gaps. A number of disparities, constraints and outstanding issues in the study and design procedures, criteria and assumptions have been causing huge variations in all vital aspects of SSI study, design and implementation from region to region and among professionals within the same region and institutions due mainly to the lack of agreed standard technical guidelines. Hence, the SSI Directorate with AGP financial support, led by Generation consultant (GIRDC) and with active involvement of national and regional stakeholders and international development partners, these new and comprehensive national guidelines have been developed.

The SSID guidelines have been developed by addressing all key features in a comprehensive and participatory manner at all levels. The guidelines are believed to be responsive to the prevalent study and design contentious issues; and efforts have been made to make the guidelines simple, flexible and adaptable to almost all regional contexts including concerned partner institution interests. The outlines of the guidelines cover all aspects of irrigation development including project initiation, planning, organizations, site identification and prioritization, feasibility studies and detail designs, contract administration and management, scheme operation, maintenance and management.

Enforceability, standardization, social and environmental safeguard mechanisms are well mainstreamed in the guidelines, hence they shall be used as a guiding framework for engineers and other experts engaged in all SSI development phases. The views and actual procedures of all relevant diverse government bodies, research and higher learning institutions, private companies and development partners has been immensely and thoroughly considered to ensure that all stakeholders are aligned and can work together towards a common goal. Appropriately, the guidelines will be familiarized to the entire stakeholders working in the irrigation development. Besides, significant number of experts in the corresponding subject matter will be effectively trained nationwide; and the guidelines will be tested practically on actual new and developing projects for due consideration of possible improvement. Hence, hereinafter, all involved stakeholders including government & non-governmental organizations, development partners, enterprises, institutions, consultants and individuals in Ethiopia have to adhere to these comprehensive national guidelines in all cases and at all level whilst if any overlooked components are found, it should be documented and communicated to MOA to bring them up-to-date.

Therefore, I congratulate all parties involved in the success of this effort, and urge partners and stakeholders to show a similar level of engagement in the implementation and stick to the guidelines over the coming years.

H.E. Dr. Kaba Urgessa
State Minister, Ministry of Agriculture

SMALL SCALE IRRIGATION DEVELOPMENT VISION

Transforming agricultural production from its dependence on rain-fed practices by creating reliable irrigation system in which smallholder farmers have access to at least one option of water source to increase production and productivity as well as enhance resilience to climate change and thereby ensure food security, maintain increasing income and sustain economic growth.

ACKNOWLEDGEMENTS

The preparation of SSIGLs required extensive inputs from all stakeholders and development partners. Accordingly many professionals from government and development partners have contributed to the realization of the guidelines. To this end MOA would like to extend sincere acknowledgement to all institutions and individuals who have been involved in the review of these SSIGLs for their comprehensive participation, invaluable inputs and encouragement to the completion of the guidelines. There are just too many collaborators involved to name exhaustively and congratulate individually, as many experts from Federal, regional states and development partners have been involved in one way or another in the preparation of the guidelines. The contribution of all of them who actively involved in the development of these SSIGLs is gratefully acknowledged. The Ministry believes that their contributions will be truly appreciated by the users for many years to come.

The Ministry would like to extend its appreciation and gratitude to the following contributors:

- Agriculture Growth Program (AGP) of the MoA for financing the development and publication of the guidelines.
- The National Agriculture Water Management Platform (NAWMP) for overseeing, guidance and playing key supervisory and quality control roles in the overall preparation process and for the devotion of its members in reviewing and providing invaluable technical inputs to enrich the guidelines.
- Federal Government and Regional States organizations and their staff for their untiring effort in reviewing the guidelines and providing constructive suggestions, recommendations and comments.
- National and international development partners for their unreserved efforts in reviewing the guidelines and providing constructive comments which invaluably improved the quality of the guidelines.
- Small-scale and Micro Irrigation Support Project (SMIS) and its team for making all efforts to have quality GLs developed as envisioned by the Ministry.

The MOA would also like to extend its high gratitude and sincere thanks to AGP's multi development partners including the International Development Association (IDA)/World Bank, the Canada Department of Foreign Affairs, Trade and Development (DFATD), the United States Agency for International Development (USAID), the Netherlands, the European Commission (EC), the Spanish Agency for International Development (AECID), the Global Agriculture and Food Security Program (GAFSP), the Italy International Development Cooperation, the Food and Agriculture Organization (FAO) and the United Nations Development Program (UNDP).

Moreover, the Ministry would like to express its gratitude to Generation Integrated Rural Development Consultant (GIRDC) and its staff whose determined efforts to the development of these SSIGLs have been invaluable. GIRDC and its team drafted and finalized all the contents of the SSIGLs as per stakeholder suggestions, recommendations and concerns. The MoA recognizes the patience, diligence, tireless, extensive and selfless dedication of the GIRDC and its staff who made this assignment possible.

Finally, we owe courtesy to all national and International source materials cited and referred but unintentionally not cited.

Ministry of Agriculture

DEDICATIONS

The National Guidelines for Small Scale Irrigation Development are dedicated to Ethiopian smallholder farmers, agro-pastoralists, pastoralists, to equip them with appropriate irrigation technology as we envision them empowered and transformed.

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ACRONYMS

AGP	Agricultural Growth Program
BM	Bench Mark
BOQ	Bill of Quantities
CAD	Computer Aided Design
CI	Contour Interval
DD	Detail Design
DEM	Digital Elevation Model
DGPS	Differential GPS
DIN	Deutsche Industrie Norm
DTM	Digital Terrain Model
E or X	Easting
EDM	Electronic Distance Measurement
Elev. or Z	Elevation
EMA	Ethiopian Mapping Agency
ESF	Elevation Scale Factor
EU	European Union
FDRE	Federal Democratic Republic of Ethiopia
FS	Feasibility Study
GCP	Ground Control Point
GIRDC	Generation Integrated Rural Development Consultant
GLONASS	Global Orbiting Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSF	Grid Scale Factor
MC	Main Canal
MOANR	Ministry of Agriculture and Natural Resource
MoH	Ministry of Health
MOWIE	Ministry of Water, Irrigation and Electricity
MSL	Mean Sea Level
N or Y	Northing
NASA	National Aeronautics and Space Administration
NGS	National Geodetic Survey
NMSA	National Meteorological Service Agency
PNT	Positioning, Navigation and Timing
RTK	Real-time Kinematic Positioning
SSID	Small Scale Irrigation Development
SSIGL	Small Scale Irrigation Guideline

SSIP	Small Scale Irrigation Project
SSIS	Small Scale Irrigation Scheme
TBM	Temporary Bench Mark
ToR	Terms of Reference
TP	Turning Point
U/s	Up stream
USA	United States of America
WAAS	Wide Area Augmentation System

PREFACE

While irrigation development is at the top of the government's priority agendas as it is key to boost production and improve food security as well as to provide inputs for industrial development. Accordingly, irrigated land in different scales has been aggressively expanding from time to time. To this end, to enhance quality delivery of small-scale irrigation development planning, implementation and management, it has been decided to develop standard SSI guidelines that must be nationally applied. In September 2017 the Ministry of Agriculture (MoA) had entrusted Generation Integrated Rural Development Consultant (GIRDC) to prepare the National Small-scale Irrigation Development Guidelines (SSIGLs).

Preparation of the SSIGLs for enhancing development of irrigated agriculture is recognized as one of the many core initiatives of the MoA to improve its delivery system and achieve the targets in irrigated agriculture and fulfill its mission for improving agricultural productivity and production. The core objective of developing SSIGLs is to summarize present thinking, knowledge and practices to enable irrigation practitioners to properly plan, implement and manage community managed SSI schemes to develop the full irrigation potential in a sustainable manner.

As the SSIGLs are prepared based on national and international knowledge, experiences and practices, and describe current and recommended practice and set out the national standard guides and procedures for SSI development, they serve as a source of information and provide guidance. Hence, it is believed that the SSIGLs will contribute to ensuring the quality and timely delivery, operation and maintenance of SSI schemes in the country. The SSIGLs attempt to explain and illustrate the important concepts, considerations and procedures in SSI planning, implementation and management; and shall be used as a guiding framework for professionals engaged in SSI development. Illustrative examples from within the country have been added to enable the users understand the contents, methodologies presented in the SSIGLs.

The intended audiences of the SSIGLs are government organizations, NGOs, CSOs and the private sector involved in SSI development. Professionally, the SSIGLs will be beneficial for experienced and junior planners, experts, contractors, consultants, suppliers, investors, operators and managers of SSI schemes. The SSIGLs will also serve as a useful reference for academia and researchers involved and interested in SSI development. The SSIGLs will guide to ensure that; planning, implementation and management of SSI projects is formalized and set procedures and processes to be followed. As the SSIGLs provide information and guides they must be always fully considered and applied by adapting them to the local specific requirements.

In cognizance with the need for quality SSIGLs, the MoA has duly considered quality assurance and control during preparation of the guidelines. Accordingly, the outlines, contents and scope of the SSIGLs were thoroughly discussed, reviewed and modified by NAWMP members (senior professionals from public, national and international stakeholder) with key stakeholders in many consultative meetings and workshops. Moreover, at each milestone of SSIGL preparation, resource persons from all stakeholders reviewed and confirmed that SSIGLs have met the demands and expectations of users.

Moreover, the Ministry has mobilized resource persons from key Federal, National Regional States level stakeholders and international development partners for review, validation and endorsement of the SSIGLs.

Several hundreds of experienced professionals (who are very qualified experts in their respective fields) from government institutions, relevant private sector and international development partners have significantly contributed to the preparation of the SSIGLs. They have been involved in all aspects of the development of SSIGLs throughout the preparation process. The preparation process included a number of consultation meetings and workshops: (i) workshop to review inception report, (ii) workshop on findings of review of existing guidelines/manuals and proposed contents of the SSIGLs, (iii) meetings to review zero draft SSI GLs, (iv) review workshop on draft SSI GLs, (v) small group review meetings on thematic areas, (vi) small group consultation meetings on its final presentation of contents and layout, (vii) consultation mini-workshops in the National States on semi-final versions of the SSIGLs, and (viii) final write-shop for the appraisal and approval of the final versions of SSIGLs.

The deliberations, concerns, suggestions and comments received from professionals have been duly considered and incorporated by the GIRD Consultant in the final SSIGLs.

There are 34 separate guidelines which are categorized into the following five parts concurrent to SSI development phases:

Part-I. Project Initiation, Planning and Organization Guideline which deals with key considerations and procedures on planning and organization of SSI development projects.

Part-II. Site Identification and Prioritization Guideline which treats physical potential identification and prioritization of investment projects. It presents SSI site selection process and prioritization criteria.

Part-III. Feasibility Study and Detail Design Guidelines for SSID dealing with feasibility study and design concepts, approaches, considerations, requirements and procedures in the study and design of SSI systems.

Part-IV. Contract Administration and Construction Management Guidelines for SSI development presents the considerations, requirements, and procedures involved in construction of works, construction supervision and contract administration.

Part-V. SSI Scheme Management, Operation and Maintenance Guidelines which covers SSI Scheme management and operation.

Moreover, Tools for Small Scale Irrigation development are also prepared as part of SSIGLs.

It is strongly believed and expected that; the SSIGLs will be quickly applied by all stakeholders involved in SSI development and others as appropriate following the dissemination and familiarization process of the guidelines in order to ensure efficient, productive and sustainable irrigation development.

The SSIGLs are envisioned to be updated by incorporating new technologies and experiences including research findings. Therefore, any suggestions, concerns, recommendations and comments on the SSIGLs are highly appreciated and welcome for future updates as per the attached format below. Furthermore, despite efforts in making all types of editorial works, there may still errors, which similarly shall be handled in future undated versions.

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UPDATING AND REVISIONS OF GUIDELINES

The GLs are intended as an up-to-date or a live document enabling revisions, to be updated periodically to incorporate improvements, when and where necessary; may be due to evolving demands, technological changes and changing policies, and regulatory frameworks. Planning, study and design of SSI development interventions is a dynamic process. Advancements in these aspects are necessary to cope up with the changing environment and advancing techniques. Also, based on observation feedbacks and experiences gained during application and implementation of the guidelines, there might be a need to update the requirements, provisions and procedures, as appropriate. Besides, day-by-day, water is becoming more and more valuable. Hence, for efficient water development, utilization and management will have to be designed, planned and constructed with a new set up of mind to keep pace with the changing needs of the time. It may, therefore, be necessary to take up the work of further revision of these GLs.

This current version of the GLs has particular reference to the prevailing conditions in Ethiopia and reflects the experience gained through activities within the sub-sector during subsequent years. This is the first version of the SSI development GLs. This version shall be used as a starting point for future update, revision and improvement. Future updating and revisions to the GLs are anticipated as part of the process of strengthening the standards for planning, study, design, construction, operation and management SSI development in the country.

Completion of the review and updating of the GLs shall be undertaken in close consultation with the federal and regional irrigation institutions and other stakeholders in the irrigation sub-sector including the contracting and consulting industry.

In summary, significant changes to criteria, procedures or any other relevant issues related to technological changes, new policies or revised laws should be incorporated into the GLs from their date of effectiveness. Other minor changes that will not significantly affect the whole nature of the GLs may be accumulated and made periodically. When changes are made and approved, new page(s) incorporating the revision, together with the revision date, will be issued and inserted into the relevant GL section.

All suggestions to improve the GLs should be made in accordance with the following procedures:

I. Users of the GLs must register on the MOA website: Website: www.moa.gov.et
II. Proposed changes should be outlined on the GLs Change Form and forwarded with a covering letter or email of its need and purpose to the Ministry.
III. Agreed changes will be approved by the Ministry on recommendation from the Small-scale Irrigation Directorate and/or other responsible government body.
IV. The release date of the new version will be notified to all registered users and authorities.

Users are kindly requested to present their concerns, suggestions, recommendations and comments for future updates including any omissions and/or obvious errors by completing the following revisions form and submitting it to the Ministry. The Ministry shall appraise such requests for revision and will determine if an update to the guide is justified and necessary; and when such updates will be published. Revisions may take the form of replacement or additional pages. Upon receipt, revision pages are to be incorporated in the GLs and all superseded pages removed.

Suggested Revisions Request Form (Official Letter or Email)

To: ---
From: ---
Date: --
Description of suggested updates/changes: Include GL code and title, section title and # (heading/subheading #), and page #.

GL Code and Title	Date	Sections/ Heading/Subheading/ Pages/Table/Figure	Explanation	Comments (proposed change)

Note that be specific and include suggested language if possible and include additional sheets for comments, reference materials, charts or graphics.

GLs Change Action

Suggested Change	Recommended Action	Authorized by	Date

Director for SSI Directorate**: ________________________Date: _________________**

The following table helps to track initial issuance of the guidelines and subsequent Updates/Versions and Revisions (Registration of Amendments/Updates).

Revision Register

Version/Issue/Revision No	Reference/Revised Sections/Pages/topics	Description of revision (Comments)	Authorized by	Date

1 INTRODUCTION

1.1 BACKGROUND

The subject guideline is prepared to maintain uniformity or consistency in the establishment of Surveying works and hence quality design documents. Moreover , this Guideline enables to lay the basic approaches, principles, procedures and techniques for Topographic and Irrigation Infrastructures Survey to be carried out in small scale irrigation projects.

Surveying is a science that is used to determine and delineate the form, extent, and position of features on or beneath the surface of the earth for control purposes, that is, for aligning land and construction boundaries and for providing checks of construction dimensions. It is the science of determining the terrestrial location or three-dimensional position of points and the distances and angles between them.

Topography in a narrow sense involves the recording of relief or terrain, the three-dimensional quality of the surface, and the identification of specific landforms. This is also known as geomorphometry. In modern usage, this involves generation of elevation data in digital form (DEM). It is often considered to include the graphic representation of the landform on a map by a variety of techniques, including contour lines, hypsometric tints and relief shading.

Topographic surveying in SSIPs in general is required at all stages of project development:

- At planning (for scoping the work);
- At study and design stage (for designing);
- At start of construction (for setting out);
- At intermediate stages of construction (for design change & quantity survey, if required); and
- At end of construction (for preparation of actual BOQ and final payment preparation).

The method of surveying shall be to the approval of the design engineer at study and design stage and to the supervisor at construction stage.

For topographic survey of irrigation projects, a control point, which is latter used for referencing, should be established at the start of commencement of field works. Control and topographic surveys are in general performed to determine the planimetric location and/or including elevation of surface or subsurface features, facilities, or utilities like roads, location of village(s), water courses, abstraction point/ i.e. the site of the proposed off take in relation to main topographic features/, surface drainage patterns, rivers and streams, vegetation, eroded land, especially gullies, wetland areas, lakes and possibly swamps, land use, cultivation and rock outcrop, etc. These surveys are normally used to prepare detailed site plan maps (and digital databases) of a project site, facilities, or utility infrastructure, for future design, on-going construction or as-built condition.

1.2 OBJECTIVE & SCOPE OF THE GUIDELINE

The main objective of this Guideline is to prepare guidelines and set standards for topographic survey works in irrigation projects. This surveying guideline is thus prepared to depict instruction, standard data collection procedures and criteria on land surveying and mapping in small-scale irrigation projects.

Surveying and mapping of irrigation projects serve the following requirements:

- Detailed topographic survey from which layout of the irrigation project showing canals, drains, roads and other infrastructures can be mapped;
- Detailed cross sections for determining capacity of rivers, canals, drains, roads and related structures;
- Longitudinal profiles of rivers, canals, drains, roads;
- Measurement for payment of construction works; and
- To estimate volume of project work and corresponding cost.

The overall scope of this guideline, which is prepared by GIRDC, is limited to ground-based survey method-specifically geo-referenced observations taken from survey instruments setup on tripods over fixed control points or benchmarks and related works.

1.3 PURPOSE OF THE GUIDELINE

The purpose of this guideline is to describe the required standards, accepted procedures and performance criteria to be used by surveyors when conducting surveys of SSIP such as data requirements, procedures for gathering and presenting the data. Such survey standards, procedures and performance criteria provide consistency of survey accuracy and reliability of mapping products for the user, i.e. it is intended to serve as a guide for those involved in the performance of engineering surveys for SSI Projects.

This guideline is intended as a reference, not as a textbook or contract document. It is not intended as a substitute for surveying knowledge, experience, or judgment. Although some of its portion include text material, it does not attempt to completely cover any facet of surveying.

In general, the requirements in this guideline are intended to control the end-product rather than intermediate activates e.g. data collector formats. The required end-product is a complete survey documentation in electronic format of control points and spot levels as well as cross sections and profiles.

1.4 TECHNICAL DEFINITIONS OF TERMINOLOGIES USED IN THE GUIDELINE

Alignment: is a series of tangents and curves identifying a centerline for an existing or proposed road/canal/drain routes.

Angle: is a measure of rotation of a line segment about a fixed point. Thus, there must be two line segments that meet at a point to create an angle. The segments are called the sides or arms of the angle, and that point is called the vertex of the angle.

Area: is the size of an enclosed region, given in terms of the square of a designated unit of length.

Azimuth: is the direction of one point or object, with respect to another, where the direction of the line is expressed as the clockwise angle from 0º to 360º.

Bearing: It is a relative measure of position in-terms of angle.

Benchmark: or bench mark is a permanent material object, bearing a marked point whose elevation above or below an adopted datum is known. Thus, it is a reference control point.

Construction surveys: These are basically the transfer of infrastructure plan details to field staking.

Control: It is a regulatory boundary taking part in survey works but not involved in the procedures affecting the rest of the work, thus acting as the standard against which the results are compared.

Control points: In surveys are defined as permanently monumented points from which additional control can be established. Therefore, the establishment of control monuments through the project area is an extremely critical step. All subsequent phases of the project development, as well as future projects, will rely on these control points. Inaccurate or inadequate control can cause unnecessary and costly delays in the project.

Coordinate: It is a relative number used for specifying position of someone or something.

Coordinate system: is a reference system for defining points in space or on a particular surface by means of distances or angles, or both, with relation to designated axes, planes, or surfaces.
Cross-section: is the elevations of the surface of the ground measured along a line perpendicular to the centerline or base line at any given station on the alignment.

Datum: It is a reference point, line, or surface used as a basis for measurement or calculation in mapping or surveying. It is a reference system whereby the position of one point can be directly related to another.

Digital terrain model (DTM): is a model of the existing terrain that is developed from elevation data collected with reference to a coordinate system.

Elevation: is height of a point with respect to a defined vertical datum.

Error: is the difference, after blunders have been eliminated, between a measured or calculated value of a quantity and the true or established value of that quantity.

Feature: is a named set of points in a Digital Terrain Model.
Foresight: is the station or location to which a horizontal angle (relative to the backsight), zenith angle and distance are measured.

Geodetic: It is relating to the precise measurement of the Earth's surface or of points on its surface.

GPS: is an abbreviation for Global Positioning System. It is a USA space based radio navigation system that provides reliable positioning, navigation, and timing services to civilian users on a continuous worldwide basis.

Grid: It is a network of evenly spaced horizontal and vertical lines on a map, used as a basis for finding specific points.

HI: is an abbreviation for Height of Instrument. It is the vertical distance from the station mark to the center of the axis of the total station or level.

Levelling rod: is a straight rod or bar with a flat face graduated in linear units with zero at the bottom, used in measuring the vertical distance between a point on the ground and the horizontal line of sight of a levelling instrument.

Line: is a series of adjacent points that extends to infinity in two directions. Although the word line can be used to refer to any stroke on paper, a line is usually considered to be straight, meaning that all of its points lie in a row.

Point: is a specific or exact place, location, or position of objects or features. They are zero-dimensional i.e. they have no length, width, or depth. Many physical objects suggest the idea of a point or some features can be represented by a point if the scale is small, e.g. town.

Position: is the coordinates, in a horizontal reference system, of station mark or feature. Latitude and longitude, and Northing and Easting are examples of position coordinates in systems used in surveying.

Projection: It is a means of representing lines, figures, or solids on a flat surface such as a map that conforms to the viewing direction or follows particular rules.

Receiver: This is the device that receives the GPS signal.

Reference point: is a point set and used at a survey point or alignment point to help reestablish it or recover it during a survey or during construction.

ROW: is an abbreviation for Right-of-Way. It is the strip or area of land around a canal or structure granted as easement or fee to the users.

Scale: It is a ratio for representing the size of an illustration or reproduction in relation to the object it represents, especially a map or a model.

Spatial data: Is information that identifies the geographic location and characteristics of natural or constructed features and boundaries of earth. This information may be derived from, among other things, remote sensing, mapping, and surveying technologies.

Stake: is a thin wooden or metal post that is driven into the ground to mark or support alignment of profiles of canals, drains, roads, etc.

Survey: It is a technique of making a detailed map of an area of land, including its boundaries, area, and elevation, using geometry and trigonometry to measure angles and distances. Surveying is the science and art of making the measurements necessary to determine the relative positions of points above, on, or beneath the surface of the earth or to establish such points.

Topography: Is the shape, configuration, relief, roughness, or three-dimensional characteristics of the earth's surface.

Topographic map: This is a map used to show a topography together with natural and artificial features such as streams, lakes, buildings, highways, etc.

Topographic survey: Is a survey made to determine the configuration of the earth's surface and to locate natural and cultural features on it.

Total station: is an electronic surveying instrument that combines angle and distance- measuring capabilities in a single unit.

Traverse: It is a way of measuring by going back and forth across something.

Triangulation: It is a method for determining location trigonometrically by dividing of survey area into triangles.

Volume: is the amount of space occupied by a three-dimensional solid body, given in terms of the cube of a designated unit of length.

2 TYPES, METHODS AND PROCEDURES OF SURVEYING

2.1 TYPES OF SURVEYING

2.1.1 General

Survey types can be classified based on required surveying works as Plane Surveying, Geodetic Surveying, Land Surveying, Topographic Surveying, Construction Surveying, Cartographic Surveying, Hydrographic Surveying and Mining Surveying. Description of each of these types are presented in following sections.

2.1.2 Plane surveying

Plane surveys treat any small segment of land or water as a horizontal plane. Such surveys are customarily projected and calculated on a horizontal rectangular grid, oriented north-south and east-west, although the grid can be oriented in an arbitrary, rather than true, north-south direction. From a given starting point, or station, of known or assigned coordinates, the horizontal distance is measured to another point, then to another convenient point, and then to succeeding points, to close on the original point or on any point of known coordinates. A succession of such lines or courses forms a traverse.

The horizontal angles between successive courses are measured with a transit or theodolite at each hub, or station. From a known or arbitrarily assigned starting direction, the directions, or bearings, of successive traverse lines can thus be calculated. Plane geometry and plane trigonometry relationships are used to determine the coordinates of traverse stations. The north or south distance of a traverse course is its length multiplied by the cosine of the bearing; the east or west distance of a traverse course is its length multiplied by the sine of the bearing. Coordinates enable the plotting of the hubs/centers to any scale on a grid that can serve as a plot or as control for further details drawn on a map or chart.

Triangulation can be used instead of a traverse, measuring only one baseline, but measuring all the angles in a chain of triangles, to calculated coordinates of successive hubs. The choice of traverse or triangulation is dictated by the type of terrain to be surveyed.

2.1.3 Geodetic surveying

For large areas, surveys must take into account the basic shape of the earth, the geoid, and are therefore called geodetic surveys. These surveys are based on a spheroidal shape approximating the geoidal or geographic (nearly spherical) shape of the earth at sea level. They are based on a true north-south meridian as defined by the earth's rotational axis and on spherical geometry. Typically, a highway-route survey extending for many kilometers would require geodetic adjustment to avoid accumulation of error resulting from the convergence of meridians. For example, in the USA, plane-coordinate systems exist for most states, with conversion between plane coordinates and geodetic coordinates made convenient by tabulated relationships.

2.1.4 Land surveying

Land surveys are made to establish boundaries of land areas by setting corner markers or monuments, to ascertain coordinates of these corners, and to obtain boundary and area information required for record-deed descriptions and for plotting parcels of real property. Property surveys are accomplished with a degree of precision depending on the value of the land involved, and permanent visible and recoverable monuments are set at the corners. These markers are desirable for public record and to ensure correct title for the rightful owner of the land. In addition to surveying techniques, land surveyors must also be knowledgeable in property law, (registration of practitioners is usually required by law).

In general, the most commonly used types of land surveys are boundary survey; topographic survey; site planning survey; subdivision survey; control survey; court exhibit survey; and construction survey. The following is a detailed explanation of the types of land surveys.

2.1.4.1 Boundary survey

This is a survey type for the purpose of locating the corners and boundary lines of a given parcel of land. This involves record and field research, measurements, and computations to establish boundary lines in conformance with the Professional Land Surveyor Act. Easement lines may also be located and/or established with this type of survey.

2.1.4.2 Topographic survey

This is a survey type for locating topographic features - natural and manmade - such as buildings, improvements, fences, elevations, trees, streams, contours of the land, etc. This type of survey may be required by a governmental agency, or may be used by engineers and/or architects for design of improvements or developments on a site.

2.1.4.3 Site planning survey

This survey type involves a combination of boundary and topographic surveys for preparation of a site plan to be used for designing improvements or developments.

2.1.4.4 Subdivision Survey

This type of survey considers subdivision of a tract of land into smaller parcels, showing documentation and survey data on a map, in conformance with local ordinances and the Subdivision Map Act.

2.1.4.5 Control survey

This is a survey type for precisely locating horizontal and vertical positions of points for use in boundary determination, mapping from aerial photographs, construction staking and other related purposes.

2.1.4.6 Court exhibit survey

Analysis of various legal description and survey maps, field locating of record, existing monuments, and physical features, and mapping showing this information for the purpose of presenting a visual exhibit to be used in a courtroom.

2.1.4.7 Construction survey

Construction staking of improvements shown on improvement plans for control of construction on developments for roads, buildings, pipelines, etc.

2.1.5 Topographic surveying

Topographic survey is the most commonly exercised survey work in irrigation projects. It consider three-dimensional viewing and employ the techniques of plane surveying and other special techniques to establish both horizontal and vertical control. The relief or configuration of the terrain and the natural or artificial features are located by measurement and depicted on a flat sheet to form a plan called topographic map. Contour lines, connecting points of the same elevation, are used to portray elevations at any one of various intervals measured in meters.

Most topographic mapping is done by means of aerial photogrammetry, which uses stereoscopic pairs of photographs taken from aircraft and, more recently, from artificial earth satellites. Horizontal and vertical ground surveys must appear in the photographs. These photos are then reconstituted into stereo models for drafting true-scale maps. Precise cameras are required; and precision-mapping equipment is used to depict natural and artificial objects in true position and to show true elevations for all points in the mapped area. Elevations on topographic maps are shown chiefly by use of superimposed contour lines, connecting points of equal evaluation, to give a readable picture of the terrain.

Topographic surveying can be classified based on its scope as identification/reconnaissance or detailed Topographic survey. Reconnaissance survey is bases for general study or a decision as to the construction suitability of areas. It enable a proper selection of those areas, relatively limited in extent, which should be covered by the more time-consuming and costly detailed topographic survey. Whereas, detailed topographic survey is based on reconnaissance survey and is a basis for detailed plans showing the layout and utilities. Detailed topographic survey is usually at a map scale of 1 in 20 to 50m whereas; reconnaissance survey is at a map scale of 1 in 120 to 300m, but depending up on the size and shape of the area and nature of the terrain, a scale of 1 in 50m or more can be adopted.

There are two techniques of topography survey:

2.1.5.1 Direct survey

This involves direct collection of vertical and horizontal displacements of surface points using surveying instruments. Thus, it is the technique used to determine accurately the terrestrial or three-dimensional space position of points and the distances and angles between them using surveying instruments, such as levelling instruments like theodolites, total stations, dumpy levels and clinometers.

2.1.5.2 Remote sensing

This approach involves collection and interpretation of satellite imageries. Thus, remote sensing is a general term for geodata collection at a distance from the subject area. The data is organized in pixel format at one station like NASA and data of point of interest is collected from this station and interpreted and used after correlating it with ground truth i.e. GCP. This technique has three different methodologies as listed below.

- Photogrammetry;
- Passive sensor methodologies;
- Active sensor methodologies.

2.1.6 Engineering and construction surveying

Engineering surveys establish control points by traverse, baseline, or other methods to obtain information required for engineering designs and to set out construction from design drawings by use of these control points. Topographic surveys, and the maps produced by them, provide horizontal location information and elevations needed for the design of structures such as buildings, dams, canals, highways, bridges, transmission lines, and sewers. Using the engineering designs, these works are then laid out from the same control points used in the original engineering surveys.

Construction surveying involves the guidance and supervision of engineering surveying dealing with the laying/setting out and building of highways, bridges, dams, tunnels, buildings, and other structures.

2.1.7 Cartographic surveying

Such surveys are used to set control points and to obtain detail for map and chart making. Charts and maps of a small scale (covering large areas) are compilations of larger-scale maps with much detail omitted. For example, Coastal charts depict the shoreline, but show only significant navigation aids along the shorelines and indicate water depths. Air-navigation charts show only significant geographical features, obstructions, air lanes, radio beacons, and guidance features such as railways and highways.

2.1.8 Hydrographic surveying

The surveying and mapping of sea, river, harbor/port, or lake bottoms to ensure safe navigation depths are done by hand soundings located by observations to or from control points on shore. Sonar soundings with simultaneous radar-type location of the sounding vessel also permit rapid and exact charting. Farther out from the shore, less accuracy of location results; Loran devices are used for this purpose, and satellite-navigation devices are also used for fairly accurate offshore positioning of vessels furnished with modern equipment.

2.1.9 Mining surveying

Mining surveying is used to establish surface location and boundaries of mining claims. During mining or tunneling operations, the mine survey helps to establish the location of the underground workings horizontally and vertically, to lay out shaft connections, and to guide the tunneling. This is three-dimensional traversing, not essentially different from surface surveying. This type of survey is not considered in this guideline

2.1.10 Photogrammetric survey

This survey type is performed to utilize the principles of aerial-photogrammetry, in which measurements made on photographs are used to determine the positions of photographed objects. This also is not considered in this guideline

2.1.11 Astronomical survey

This generally involve imaging or "mapping" of regions of the sky using telescopes, thus not considered here in this guideline.

In summary, Surveying Types can be classified based on the bases of Accuracy, Instrument Development, Method Used, Place Surveyed, Stages of Surveying and Purpose as presented in Appendix-V.

2.2 METHODS OF SURVEYING

2.2.1 Methods of topographic surveying based on data collection means

2.2.1.1 Aerial (Photogrammetric) survey

In this method, we us aerial photographs to determine distances, elevations, areas, etc. for topographic mapping.

2.2.1.2 Transit-stadia survey

In this case, distance, elevation, and location measurements are taken in the field, recorded in the field book, and then plotted on paper in the office.

2.2.1.3 Plane table

Similar to transit-stadia method except that the data is plotted in the field on paper attached to a drawing board mounted on a tripod (plane table).

2.2.2 Methods of topographic surveying based on measurement methods

Survey methods can also be categorized as:

- Electronic distance and angle measuring equipment Methods
- Traditional transit and tape Methods
- Computer systems

Modern and traditional systems aid in efficiently gathering measurements and in evaluating all collected evidence required to perform the survey. The Land Surveyor then takes pride in being able to use these instruments and computers to perform land surveys efficiently, accurately, and cost effectively.

2.3 PROCEDURES FOR TOPOGRAPHIC SURVEYING

2.3.1 Preparation of base map

This is a map employed in SSIP planning to indicate the principal outstanding physical characteristics of an area and which is thereafter used as a reference for subsequent mapping. It is the graphic representation at a specified scale of selected fundamental map information; used as a framework upon which additional data of a specialized nature can be compiled.

Thus, it shall include location of the project site and its surroundings (incorporating Northing, Legends, and Grids), road network, towns and other infrastructures, administrative boundaries, other existing features as mapped from aerial photographs. The base-map serves as a foundation for all subsequent operations and mapping. Base-maps provide the context and a framework for working with information geographically.

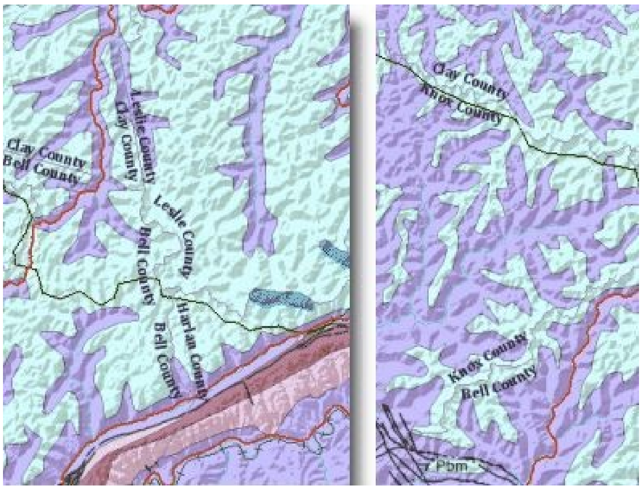


Figure 2-1: Typical geology base-map of irrigation project

2.3.2 Identifying national girds and linking

Surveying is done by transferring national trigonometric station data to project area by triangulation or traversing method (or using fixed GPS) by establishing permanent and temporary benchmarks. This need to link all permanent and temporary benchmarks by close traverse method (Easting, Northing and Elevation & Remark) with specific precision and good horizontal and vertical controls and these controls are used for the basis of the topographic survey. An error in the control can be reflected in errors in the position and/or elevation of the topography measurements, thus care should be taken. Details can be referred in successive sections of this guideline.

2.3.3 Establishing horizontal and vertical controls

2.3.3.1 General

Controls are used as the basis of the topographic survey measurements. Thus, an error in the control will be reflected in errors in the position and/or elevation of the topography.

Control points need to be placed in a clear, away from trees, buildings, and potential multi-path structures. Maximum obstruction angle shall be 200. Points should be inter-visible when possible, if not, skip the area and start placing points again on the other side. Place such points close to the projected centerline (i.e. hilltops) such that they will be of the most use to the surveyors. However, some thought should also be given to placing these points so that at least some of them will serve construction.

2.3.3.2 Horizontal control

This type of control:

- Is provided by two or more points on the ground and precisely fixed in position by distance and direction;
- Is the basis for map scale and locating topographic features;
- For small areas, horizontal control for topographic work is usually established by a traverse, but sometimes a single straight line may be used.

All primary project horizontal control stations shall be tied to 3 or 4 physical features, depending on the situation. Measure angles and distances, to tie objects, with a total station and record in the data collector. Observations to tie objects are normally recorded as a horizontal angle, slope distance, and zenith angle observation in the data collector. Distances can also be measured with a steel tape and entered into the data collector. The intent is for the ties to be plotted accurately and automatically in the digital graphics file with the rest of the survey information. Horizontal distances from tie objects should appear in reports, drawings, or computer files, unless otherwise noted.

2.3.3.3 Vertical control

- Is provided by benchmarks in or near the tract to be surveyed,
- Is the foundation for correctly portraying relief and elevation on a map,
- Vertical controls are usually established by lines of levels starting and closing on bench marks.
- A surface of a body of water is a continuous bench mark and may sometimes be used as a vertical control.
- The surveying works at different sites of the project will be connected to each other by close traversing method or triangulation method.
- The topographic survey will indicate the configuration of the terrain and location of both natural and human made objects from the known benchmarks

2.4 LOCATING DETAILS OF POINTS IN THE FIELD

The most commonly used methods to locate a point in the field are:

- One angle and the adjacent distance
- Two distances
- Two angles

Remark: The common types of topographic survey carried out in SSIPs are:

- Control survey (GCP (for medium to large scale project), BM)
- Traverse survey (Strip survey, boundary)
- Detail topographic survey (Cross- section, Profile, Headwork and command area survey)

3 SURVEY EQUIPMENT AND SOFTWARE

3.1 GENERAL

Topographic surveys are generally performed using different instruments such as tripod-mounted, manually operated, terrestrial survey equipment, such as transits, tapes, levels, plane tables, electronic total stations and GPS receivers/rovers or differential GPS. Descriptions and usage of each of these instruments in surveying are presented in succeeding sections.

3.2 GPS WITH ITS ACCESSORIES

3.2.1 Types and uses of GPS

3.2.1.1 General

GPS is an abbreviation standing for Global Positioning System. It is a space-based radio-navigation system, consisting of 24 satellites and ground support and operated by the United States military but open to civilian uses. GPS provides users with accurate information about their location and velocity anywhere in the world. GPS is one of the three satellite-based radio-navigation systems. The Russian Federation operates the Global Orbiting Navigation Satellite System (GLONASS), which also uses 24 satellites and provides accuracy similar to GPS. The European Union (EU) launched the first satellite in its planned Galileo program, also known as the Global Navigation Satellite System (GNSS).

The GPS system is designed for 24 satellites. Each satellite lasts about ten years. Replacement satellites are placed in orbit regularly to ensure that at least 24 satellites are always functioning. Handheld or wrist-mounted GPS receivers are available to the civilian population.

3.2.1.2 Types of GPS

Generally, there are two types of GPS based on accuracy:

- Handheld GPS: This has low accuracy, thus used for general serves like touring or assessment of tracks, boundaries, etc. (but not for detail survey).
- Fixed GPS: This has high accuracy of up to 2cm and used for establishing BMs.

Selection of either of them is dependent of the scope and the type of the works.

GPS work is mostly divided into three categories: positioning, navigation and timing (PNT). Most often GPS surveying is concerned with the first of these, i.e. positioning. In general, there are two techniques used in surveying: the kinematic and static surveying techniques. In static GPS surveying sessions, the receivers are motionless during the observation. Because of this, static work most often provides higher accuracy and more redundancy than kinematic work thus it is usually done to establish control. The results of static GPS surveying are processed after the session is completed. In other words, the data is typically post-processed. GPS is available in two basic forms:

- The standard positioning service (SPS), or civilian signal, and
- The precise positioning service (PPS), or military signal.

Today there is a huge selection of GPS systems catering for the needs of different applications and users. USGlobalSat has classified these systems under the following main categories.

Basic units: The basic units are just the plain old receiver with minimal set of features. These simple devices have the basic functionality of reporting the location in terms of latitude and longitude. They may also have a base map (a very high-level map that contains major highways and few Points of Interests) of a region. Basic units have limited processor and memory capacity. These units are ideal for a person with low budget who would like to use GPS for basic navigation, educational activities and fun.

Sports/training units: Sports enthusiast or training athletes will find wearable units very useful. These units can be worn in the wrist like watches. They have features such as heart rate monitors, lap/racing timers, calorie count monitors, and virtual partner software that allows us to set our workout target and objectives. Many wearable units come with associated PC software that can be used to plan and analyze our workout information.

Portable units: Portable GPS units can be used in car or by a pedestrian. Lower end portable models may have small screen sizes and little memory capacity. Due to their limited memory capacity, they can only store maps of a specific region. It may not be possible to store the whole map of a country. The maps on lower end portable units are usually stored in SD Cards, CD ROMs or in the system's built-in memory. Higher end potable units have larger screens and large memory storage capacity. They typically use a hard drive or DVD disk to store the map software. Most of the high-end portable units have other cool integrated features such a MP3 playback capability, xm satellite radio services, picture viewers, audio books and blue tooth integration.

Car GPS systems: Car GPS systems come in two flavors: (i) Portable Add-on units: Many people now a days use a portable unit in automobiles. Most of the portable units come with accessories that allow the user to use them in a vehicle. These accessories include suction cup to attach the unit to the windshield, car power adapter, battery charges, external antennas, etc. (ii) In-dash units: These are top of the range systems that provide a wide selection of features that nicely and tidily integrate with our car electronics. These units are more expensive. They have to be permanently mounted in the car. This means we cannot move such unit if we happen to take another vehicle for our next road trip. In-dash units give a professional look and feel. They have no clutter (like power adapter wires, suction cup, etc.). One of the main disadvantages of in-dash units is that they are permanently fixed to the car, and might be prone to theft.

Double DIN systems: A Double DIN (Deutsche Industrie Norm) system occupies two bays in the car dash. Since they are fitted inside the bay, they do not project out and less noticeable from the outside. This might prevent the system from being stolen when the car is unattended.

PDA based systems: A PDA, which stands for Personal Data Assistant is a hand held device that has trimmed down features of a Personal Computer. A PDA that uses the Palm operating system (OS) software is usually known as a Palm Computer, while PDA that uses the Microsoft mobile OS is called a Pocket PC. Owning a PDA based GPS system has the added advantages of using the unit as a handled computer for general productivity and entertainment as well as using it as a GPS navigation tool. If we already own a PDA, we can buy a GPS add on module, thus saving our initial investment in our PDA.

Laptop based systems: Laptop based GPS systems are relatively cheap compared with other standalone GPS units. In these systems, the map and software are loaded into the laptop hard drive. The only accessory that we need is a simple receiver that can connect to our computer (via USB or serial ports). The mapping software loaded into the computer will be able to perform the navigation. Most laptop systems come bundled with a GPS receiver. Compared with other GPS systems, a laptop system is bulkier. However, the advantage is that we are leveraging the laptop CPU power, memory and hard disk capacity for our navigation needs.

3.2.1.3 Uses of GPS

Civilian use GPS:

- For guidance (For touring/navigating etc.)
- For surveying (Search & Mark Locations, boundaries, etc.)
- For mapping (Create waypoints or area features using aerial photo data, etc.)
- For construction (Identify centerlines, find structure locations, determine area, etc.)

Note: GPS is extremely important for military purposes.

This instrument is used in SSIPs for establishing control survey network. In more recent years, GPS has been used by civilians in many new ways, such as in mobile, automobile and boat navigation, hiking, emergency rescue, and precision agriculture and mining.

An atomic clock synchronized to GPS is required in order to compute ranges from three signals. However, by taking a measurement from a fourth satellite, the receiver avoids the need for an atomic clock. Thus, the receiver uses four satellites to compute latitude, longitude, altitude, and velocity.

3.2.2 Components and forms of GPS

GPS has three components: the space component, control component, and user component. The space component includes the satellites and the Delta rockets. The control component includes the master control station and monitoring stations. The user component includes the equipment, or receivers, used by military personnel and civilians to receive GPS signals.

3.2.3 The handheld GPS

This is the simplest GPS instrument used to search and navigate BM points in the project area and it helps to find points as accurate as within 3m radius. We can also use it for feeding survey data from DTM, Google map and land sat map to delineate project area for planning purpose.

Figure 3-1: Different types of handheld GPS

3.2.4 Improvements in performance of GPS

Several techniques have been developed to enhance the performance of GPS. One technique, known as differential GPS (DGPS), employs two fixed stations on Earth as well as satellites. DGPS provides a horizontal position accurate to about 3 m. Another technique, known as WAAS, or Wide Area Augmentation System, was developed to improve the safety of aircraft navigation. WAAS monitoring stations catch GPS signals, correct errors, and send out more-accurate signals. A technique involving the use of carrier frequency processing, known as survey grade GPS was pioneered by surveyors to compute positions to within about 1-cm. SPS, DGPS, WAAS, and carrier techniques are accessible to all users.

3.2.5 Specification of GPS, currently available on the market

Table 3-1: Specification of GPS, currently available on the market

Receiver General Specifications	
Physical	
Enclosure	Magnesium alloy
Color	Varies
Dimensions	Varies
Weight	1.10kg (without battery and radio)
Antenna	Internal
Battery	Built-in, detachable/replaceable
Controller	External
Mounting	5/8-11, quick release
Seals	Silicon
Keys	Not more than three
LEDs	22 LEDs - Receiver Health - Scheduler Status - Available Power Bar - Battery Status - Satellite Tracking Bar - Position Status - Memory Capacity Bar - File Status - Wireless Status - Radio Status - Serial Port Status
Environment	
Operating temperature	2^0C to +65^0C (Battery) / -4^0C to +65^0C (Ext.)
Storage temperature	45^0C to +70^0C
Humidity	100%, condensing
Water/Dustproof	IP67 at closing all connector caps.
Power	
Built in battery	Li-ion 4,300mAh (Typical) / 7.2VDC
Battery weight	195g
Battery charging time	2.5 hours
Operating time	Over 7.5 hours
External power	1 port
Input voltage	6 to 18VDC
Consumption	4W (w/o UHF modem)
Battery charge	Quick charger
I/O	
Communication Ports	Bluetooth x 2 channel (no UHF mode) RS-232C x 1
Port specifications	COM1 : 4,800 to 115,200 bps (RS Level); 115,200bps (default)

Receiver General Specifications	
	Bluetooth: 115,200bps (SPP / Single Channel mode)
MINTER	Modem Antenna (BNC or reverse polarity TNC depending on modem type), PWR, RS232C Serial
NMEA	NMEA version Ver. 2.1, 2.2, 2.3, 3.0
Messages	GGA, GLL, GNS, GRS, GSA, GST, GSV, HDT, RMC, VTG, ZDA, ROT, GMP
Output interval	Up to 20Hz
DGPS	
Correction format	RTCM SC104 ver. 2.1, 2.2, 2.3
RTCM message type	1, 3, 9, 31, 32, 34 ;user selectable
Process interval	1Hz
Output interval for RTCM correction data	1Hz , 5, 10 or 20Hz
Elevation mask	0 to 90 degrees (independent of data logging)
RTK	
Correction format	CMR / CMR+, RTCM SC104 ver. 2.2, 2.3 and 3.0
RTCM message type	3, 18, 19, 20, 21 or 22
Ambiguity initialize	OTF(L1, L1/L2)
Output interval for CMR/RTCM	1Hz standard and 5, 10, 20Hz optional
Elevation	0 to 90 degrees (independent of data logging)
Process interval	1Hz standard and 5, 10, 20Hz optional
Survey Accuracy	
Static	L1 : 5mm + 1.0ppm x D / 10mm + 1.0ppm x D L1+L2 : 3mm+1.0ppm x D / 10 mm + 1.0ppm x D
Fast Static	L1+L2 : 5mm + 1.0ppm x D / 10mm + 1.5mm x D
Kinematic	L1+L2 : 15mm + 1.5ppm x D / 30mm + 1.5mm x D
RTK	L1+L2 : 10mm+1.0ppm x D / 20 mm + 1.0ppm x D
DGPS	0.5m
Cold start	<60sec
Warm start	<40sec(typical)
Reacquisition	<1sec
GPS Board Specifications	
Receiver Type (set by activating the proper OAF)	
Internal board	G: GPS L1
GD	GPS L1/L2
GG	GPS/GLONASS L1
GGD	GPS/GLONASS L1/L2
Tracking Specifications	
Standard channels	Not less than 200 channels (G, GG, GD, GGD) L1 GPS, L1/L2 GPS, L1 GLONASS, L1 GPS + L1 GLONASS, WAAS/EGNOS, MSAS/QZSS
Tracked Signals	GPS: L1, L1 C/A, L2, L2P(Y), L2C Code and Carrier GLONASS: L1P, L1 C/A , L2 C/A, L2PCode and Carrier
Tracking Functions	
Multi-path reduction	Code and Carrier
PLL/DLL /QLL	Bandwidth, order, adjustable
Co-op tracking loop setting	On/Off, Static Mode, Bandwidth of individual PLL, Bandwidth of common PLL
Smoothing interval	Code and Carrier
WAAS/EGNOS/MSAS	Optional
Data Features	
Formats	TPS, NMEA, RTCM, CMR
Features	-Up to 20 Hz update rate for real time position and raw data (code and carrier) - 10cm code phase and 0.1mm carrier phase precision - RTCM SC104 version 2.1, 2.2, 2.3, and 3.0 I/O

Receiver General Specifications	
	- Multiple Base RTCM - Geoid and Magnetic Variation models RAIM - Different DATUMs support - Output of grid coordinates - CMR and CMR+ support
Memory	
Internal memory	SD/SDHC card, removable
Capacity	Dependent on capacity of the installed SD/SDHC card.
Logging Time	Same as upper cell
Logging Interval	0.05 to 86,400 seconds, depending on purchased options
Bluetooth Module Specifications	
Range	Up to 10m (outdoor), up to 50m (indoor)
Type	Class 1
Service classes	Miscellaneous
Supported profiles	SPPP
Frequency Country code	North America and Europe
Controller General Specification	
Hard ware features	
Microprocessor	X Scale Marvel PXA320
Processor speed	806MHz
Operating system	Windows Mobile®6.5
Memory	250MB SDRAM, 1GB Flash Memory
Display	
Type	3.7" VGA, touch screen display, sunlight-readable TFT (640x480) Color readable
Touch panel	Amorphous Silicon Active matrix
Keyboard	
LED	
Interface	USB Type A USB Type Mini-B
Audio	Integrated Speaker and Microphone
Wireless communication	Bluetooth Class 2 Wireless LAN IEEE 802.11 b/g
Removable batteries	Li-ion Rechargeable batteries, 2500mAh each, 7.4V
Operating time	>= 8hours
Weight	700g with two batteries
Environmental	
Operating Temperature	–20 to +50^{0}C
Storage Temperature	–20 to +60^{0}C
Humidity	Up to 95% (non-condensing) (MIL-STD 810F Method 507.4)
Protection against water, sand and dust	IP67 (IEC 60529)
Drop and shock	1.2m drop with all faces (MIL-STD 810F Method 516.5 procedure IV)
Survey Software	
Description	Tailored to use with GPS / GNSS receivers in both field and office works.
Field work	Field controller software for GNSS receivers: - Fast, easy to use, - Fit for all GPS task, - Small file size, - Icon-based GUI - Intuitive, easy operation - Advanced import/export - More COGO - Advanced collection routines - Modules Available: - Contractor, Road, Robotic, GPS & GIS. - All documents, i.e. operation manuals.., available in

Receiver General Specifications	
	softcopy
Office work	A Windows PC software application for processing RTK, ETS data, and for post-processing raw data: - A free of charge PC tool for data transfer and conversion,- Powerful post-processing solution, - Network analysis and adjustment - Intuitive,easy to use interface - Modular Software: includes Post Processing, RTK, Total Station, GIS, Design, Imaging & Advanced modules. - Multiple views of the job incl. Map, Occupation, Google Earth, Tabular, - CAD, and 3D Process and Data reports.

3.3 TOTAL STATION WITH ITS ACCESSORIES

3.3.1 General

Total Station is an instrument, which senses horizontal and vertical angles (its readings of which can reach up to 1” with precession to 0.5”) electronically instead of optically, and combined them with an EDM slope distance to output the X-Y-Z coordinates of a point relative to the instrument’s X-Y-Z coordinates. It is an electronic theodolite (transit) integrated with an electronic distance measurement (EDM) to read slope distances from the instrument to a particular point, and an on-board computer to collect data and perform advanced coordinate based calculations. It is generally used:

- To collect detail topographic data,
- To collect cross-section data,
- To set out irrigation structure locations,
- To establish control points and TP points for the inaccessible area.

3.3.2 Angle measurement

Most total station instruments measure angles by means of electro-optical scanning of extremely precise digital bar codes etched on rotating glass cylinders or discs within the instrument. The best quality total stations are capable of measuring angles to 0.5 arc-second. Inexpensive "construction grade" total stations can generally measure angles to 5 or 10 arc-seconds.

3.3.3 Distance measurement

Measurement of distance is accomplished with a modulated infrared carrier signal, generated by a small solid-state emitter within the instrument's optical path, and reflected by a prism reflector or the object under survey. The modulation pattern in the returning signal is read and interpreted by the computer in the total station. The distance is determined by emitting and receiving multiple frequencies, and determining the integer number of wavelengths to the target for each frequency.

Most total stations use purpose-built glass corner cube prism reflectors for the EDM signal. A typical total station can measure distances with an accuracy of about 1.5 millimeters + 2 parts per million over a distance of up to 1,500 meters.

EDM units operate on the principle of transmitting electromagnetic waves from an instrument to a retro-reflector, which instantly returns them to the transmitting instrument. The instrument measures the time taken for the waves to travel this double path. Then using distance=velocity (of light) x time, the distance between instrument and prism can be obtained.

There is a wide range of EDM currently available and it is beyond the scope of this guideline to describe them. For simplicity, EDM can be split into two types: Microwave and Infrared. The former type is required for very long distances, typically up to 100 km, but Infrared EDM is the commonest type used for setting out purposes.

EDM can be mounted a variety of ways, either on its own tripod, or more commonly on a theodolite. All measure slope distances but depending on model, they could be made to compute other setting out data, e.g. horizontal distances, differences, differences in height, co-ordinate differences, etc., by inputting vertical and/or horizontal angles. Further, some EDM permit corrections to be made automatically for scale factor or prevailing atmospheric conditions whilst with others it is necessary to correct measured distances manually after the measuring process. Depending on the type of EDM used, electronic calculators could be attached to compute additional setting out data, or electronic data loggers for automatic recording of survey data.

3.3.4 Measuring distances with an EDM

i. Initially, an EDM is set over one point and a prism over the other,
ii. The theodolite telescope is then aligned on the appropriate aiming mark and checks made to ensure a return signal is obtained. This is done by use of visual scales or audio tone. Failure to achieve a return signal could be due to:
    - Insufficient charge in battery
    - EDM not pointing at reflector
    - Reflector not pointing at EDM
    - Obstruction between EDM and reflector
iii. Operate instrument to measure the distance,
iv. Some EDM have sensors to determine the slope of the line, whilst others require a vertical angle to be input, to obtain a horizontal distance. Basic EDM measure the slope distance only. Record the vertical angle and compute the horizontal distance from – slope distance x cosine of vertical angle,

3.3.5 Measuring difference in height

i. Proceed as above to measure the slope distance,
ii. Again some EDM will automatically compute the difference in height at the turn of a switch, others will require the vertical angle to be input,
iii. With basic EDM the difference in height is calculated from – slope distance x sine of vertical angle,

3.3.6 Setting out distances

i. Mount the prism on a plumbing pole and align by theodolite. At a trial distance, measure a slope distance. Convey this information to the chainman by hand signal or radio. Then move the prism to a new trial position. When the prism is within 2-3 m of its required position, compute a horizontal distance. Measure the difference between trial and required position with a tape and move the prism to the new position. The distance can be checked and the ground marked as required,
ii. A “tracking” facility on some EDM provides automatic e-measurement of the distance every few seconds. The prism is set on line and the distance measured in the normal way. The

EDM can then be set to "tracking" and the prism moved along the required line. The distance will be updated every few seconds. Continue until the prism is within 1-2 m of its required position and then proceed as before in (i),

iii. Some EDM have flashing colored lights which help the chainman to maintain the correct line, whilst others have one way voice communication to the prism,

iv. The Kern remote receiver fitted to a prism is most useful as it has a display of horizontal and slope distance at the prism end. Further if the co-ordinates of the point to be set out are stored at the EDM (using HP 41CV calculator), the co-ordinates of the prism can be computed using distance and bearing and compared with the required values. The calculator program will determine a distance that the prism should be moved towards or away from the instrument and an offset to left to right of the line. This information being conveyed to the remote receiver on the prism.

3.3.7 Precision and specification of total station

The precision of this instrument should be 1" for traverse work and 2"- 5" for topographic work. The minimum technical specification of this instrument should be as follows:

Telescope:

- Magnification / Resolving power 30x / 2.5"
- Length 171mm (6.7in.),
- Objective aperture 45mm (1.8in.) (48mm (1.9in.) for EDM),
- Image Erect,
- Field of view 1°30' (26m/1,000m),
- Minimum focus 1.3m (4.3ft.),
- Reticule illumination 5 brightness levels

Angle measurement:

- Display resolution 1"
- Accuracy (ISO 17123-3:2001) 1"
- Dual-axis compensator / Collimation compensation … Dual-axis liquid tilt sensor, working range: ±6' (±111mgon) / Collimation compensation available

Distance measurement:

- Laser output Reflector less mode: Class 3R /Prism/ sheet mode: Class 1
- Measuring range (under average conditions):
  - Reflector less 0.3 to 500m (1.0 to 1,640ft.)
  - Reflective sheet to 500m (4.3 to 1,640ft.)
  - Mini prisms to 2,500m (8,200ft.)
  - One prism to 4,000m / under good conditions: 5,000m
  - Three prisms to 5,000m / under good conditions: to 6,000m (19,680ft.)
- Display resolution Fine/Rapid: 0.001m/ 0.01ft/ 1/8in.
- Tracking: 0.01m /0.1ft/ 1/2in.
- Accuracy (ISO 17123-4:2001) (D=measuring distance in mm):
  - Reflector less … (3 + 2ppm x D) mm
  - Reflective sheet … (3 + 2ppm x D) mm
  - Prism … (2 + 2ppm x D) mm
- Measuring time … Fine: 0.9s (initial 1.7s), Rapid: 0.7s (initial 1.4s), Tracking: 0.3s (initial 1.4s)

Interface and data management:

- Display / Keyboard Graphic LCD, 192 x 80 dots, backlight, contrast adjustment / Alphanumeric keyboard / 25 keys with backlight
- Control panel location On both faces
- Trigger key on right instrument support
- Data storage:
  - ➢ Internal memory Approx. 10,000 points
  - ➢ Plug-in memory device USB flash memory (max. 8GB)
- Interface Serial RS-232C, USB2.0 (Type A, for USB flash memory)
- Bluetooth modem (option) Bluetooth Class 1, Ver.2.1+EDR, Operating range: up to 300m (980ft.)

General:

- Laser-pointer Coaxial red laser using EDM beam
- Guide light Green LED (524nm) and Red LED (626nm), Operating range: 1.3 to 150m (4.3 to 490ft.)
- Levels:
  - ➢ Graphic 6' (Inner Circle)
  - ➢ Circular level 10' / 2mm
- Optical plummet:
  - ➢ Magnification 3x,
  - ➢ Minimum focus 0.3m (11.8in.) from tribrach bottom
- Laser plummet (option) Red laser diode (635nm±10nm), Beam accuracy: 1.0mm@1.3m, Class 2 laser product
- Dust and water protection IP66 (IEC 60529:2001)
- Operating temperature -20 to +50ºC (-4 to +122ºF)
- Size with handle W191 x D181 x H348mm (W7.5 x D7.1 x H13.7in.)
- Weight with battery & tribrach Approx. 5.6kg (12.3 lb.)

Power supply:

- Battery Li-ion detachable, rechargeable battery
- Operating time (@ 20ºC) Not less than 30 hours (for single distance measurement every 30 seconds)

Figure 3-2: Essential features of lecia total station (L) & theodolite (R)

Note: Procedure for setting up the Total Station can be referred in Appendix-IV.

3.4 LEVEL WITH ITS ACCESSORIES

Horizontal linear measurements are usually made with calibrated rules or tapes and sometimes by electronically timing the travel of light or radio waves between points. Whereas, vertical linear measurements are made with a graduated vertical rod to find differences of elevation and heights above sea level by the so-called level or engineer's level.

It is a tripod-mounted telescope equipped with a spirit bubble and a cross wire and is used to sight the graduations on such rod. It is a highly precise instrument used for setting out of height of structures. Sometime it is used for checking the elevation of BM points in the project area.

An automatic type of engineer's level, employing a pendulum prism or reflecting light from a liquid surface, is also used in place of the spirit-level bubble for differential levelling.

Figure 3-3: Engineer’s levelling device (L) and staff (R)

3.5 LAPTOP

This is one of the devices used for surveying. It is a device used to download data from Total station and process collected survey data for checking its consistency every day on the field. It is also used:

- To record and download collected data daily for verification,
- To insert terrain of the area and infrastructure like roads and vegetation covers,
- To prepare the topography of and cross-section to indicate photographic information
- To handle softcopy files which helps the designer to facilitate their work

In addition to these, there are also other equipment that need to be prepared for survey work. These are umbrella, level forms or book, nails, pegs, ranging rods, hammer, paint and paintbrush.

3.6 SURVEY SOFTWARE

There are a number of software used for survey data processing and analysis. However, the most commonly used ones in SSI Project are:

- Tera model,
- Surfer,
- LICE CAD,
- LAND CAD,
- Auto CAD,
- Civil Designer,
- Civil Survey
- Eagle point,
- Global Mapper,
- ArcGIS, etc.

Most of these software applications techniques have been presented in separate guideline of this assignment, thus can be referred there.

4 TOPOGRAPHIC SURVEY PLANNING AND PREPARATION FOR FIELDWORK

4.1 PREPARATIONS FOR TOPOGRAPHIC SURVEY WORK

4.1.1 Preparation of survey crew & equipment

When a survey crew chief receives a survey assignment from the project team leader, he/she must classify the survey as to its type and scope and plan necessary resources required for its accomplishment. Having classified the type of survey required, a list of sources of data can then be made. Such source of data provides information needed to locate, reestablish and evaluate data needed to produce the survey information required for the specific type of survey. Thus, prior to any field survey operation, proper planning of the survey work and survey techniques need to be decided in the office.

Accordingly, followings are activities to be considered during planning of the survey work:

- Preparation of the necessary equipment,
- Selection of existing reference control points,
- Deciding observation technique and observation time (session length) for the survey,
- Selection of surveying method and logistics for the fieldwork, which need to be prepared to facilitate the fieldwork and the execution of irrigation survey in the field.
- Preparation of base-map for locate reference control points and data collecting sites, based on satellite imagery, Google map, DEM and existing infrastructures and administrative shape files.

4.1.2 Collection, compilation & preparation of existing supporting data

Before mobilizing to the project site, the assigned survey crew need to identify sources of data and prepare base map of the site. Such preparation covers all possible aspects of assessment of documents, which are generally performed by survey crew members, as follows:

- All types of available topographic maps with different types of scales from EMA & the like,
- Different orders of available surveying horizontal control points of stations with unified reference coordinate system from EMA,
- Different orders of available surveying benchmarks with unified reference elevation system from EMA,
- Weather situation in the survey area (such as rain, temperature, flood, etc.) in a period of time of history from NMSA,
- Local epidemic disease and access to health care in the project area, from MoH,
- Social customs, traditions/habits and forms of religion from client,

4.2 ON-SITE PRE-SURVEY ACTIVITIES

4.2.1 Understanding purpose and nature of the project

The first and for-most step of pre-survey activities is to know the purpose and nature of the project for which the surveys are required in order to assess the accuracy specifications, the type of equipment required and the surveying processes required to be involved. Because, the accuracy of the control network would define the quality of the equipment and the number of observations required for the intended fieldwork. Then the first stage of surveying is always establishing horizontal and vertical control: the distance, direction and difference in elevation between key fixed points

4.2.2 Consultation of local administrative bodies & communities

As local administrative bodies and communities around the project area need to know and are end users of any project implemented within their zone. Thus, communication and discussion with them on such matters as the purpose and objective of the site visit and the project itself, identification of key stakeholders, and assignment of focal person from their side are crucial and should be the first task of the fieldwork.

Note: Ahead of mobilization to the project site, the team leader need to provide orientation for each survey team and discussion is held among themselves and engineering team to perform all types of surveys, which are routinely required. They need to be oriented to enable them practically use safety precautions and procedures that may have to be utilized on surveying works and on how to use the most productive technologies available to be used.

4.2.3 Re-Scoping of the survey work

After we had general view of the field and understand its purpose and nature, it is necessary to revise the plan based on scope of the survey work of the project for effectively tackling the work either from the bottom or top or middle such that we can save resources.

This activity is to be done at inception level so that it can be used as a basis for feasibility level survey works.

4.2.4 Re-Organizing the survey team

At this stage, we need to re-organize a survey team with full package such that it enables detailed feasibility level survey works based on the re-scoped work. A typical full-time irrigation survey team normally consists of 4-6 personnel including the reflector man and chain-man depending on the required scope of irrigation project survey and site safety requirements. In order to carry out surveying works effectively, surveying team shall be organized and re-structured as:

- Reconnaissance survey team (For assessing scope of survey work)
- Control survey team (For establishing BMs)
- Detail data collection survey team (For collection of detailed data)
- Office survey team (For quality checking)

Note: It is preferred if survey teams have additional personnel (personnel related to irrigation surveying), as needed to meet project requirements if it is medium scale. It the project is small one team can handle all the above activities)

- In order to have a survey team perform its work efficiently, every member must willingly avail himself or herself to accomplish the various tedious tasks involved in surveys (Share duties and responsibilities).
- Team members should politely refer all questions to the Crew Chief who can explain, within reason, the objectives of the work.

4.3 DUTIES AND RESPONSIBILITIES OF SURVEY PERSONNEL

4.3.1 Reconnaissance survey

The Reconnaissance Survey Team is the key to the project survey, and very important in surveying. In irrigation surveying, the reconnaissance survey team should perform at least the following operations:

- Assess (prepare) the plotted maps, preliminary coordinates of points and descriptions and other documents related to the area to be surveyed to locate all points in the field,
- Verify the existence of all selected GCP points,
- Prepare practical survey scheme,
- Select suitable positions for control points (Traverse points), and turning points in the proposed survey areas for irrigation survey works,
- Prepare descriptions how to reach and sketch of selected traverse and turning points,
- Prepare the reconnaissance report of the real representation of the survey area,
- Follow up the workflow and assist the team in problem solving,
- Forward the measured (collected) data, the map and the sketch to the software expert (office survey team) for verification.

4.3.2 Control survey

A control survey team includes one instrument man, one guide (sketch-man) and minimum three to four prism holders.

Control survey team should perform the following tasks.

- Select an appropriate surveying instrument needed for the work,
- Perform survey observations and record data accurately,
- Process and store the collected data.

4.3.3 Detail irrigation survey data collection

It includes one instrument man, one guide (sketch-man) and three to four prism holders. Irrigation survey team should perform:

- Survey readings occupying traverse points and turning points to collect survey data in the field taking into account that the performed field survey should always consider the arrangement of ground and do not ignore considerable elevation variation during irrigation survey,
- Sketch any points used for irrigation surveying and relevant information.

4.3.4 Office work

One expert can handle the office survey work. He/she should perform the following tasks:

- Bring together the observed data from field survey team,
- Check and verify the collected data as per the requirements,
- Make a backup of observed data (the raw and processed data) in a form of soft and hard copies,
- Produce topographic map.

5 SURVEYING FOR FEASIBILITY STUDY AND DETAIL DESIGN

5.1 TOPOGRAPHIC SURVEY ACTIVITIES AT FS&DD OF SSIP

5.1.1 General

All topographic surveys should start from a benchmark, be it permanent or temporary. Topographic surveying for feasibility study & detail design is based on scope, findings and recommendations of topographic surveying activities identified in the office and at field during identification/reconnaissance study.

The main topographic survey works for SSI project can be sub-divided into six main different tasks for the sake of simplicity. Each of these main tasks and corresponding sub-activities are stated in the subsequent sections.

5.1.2 Task 1: benchmark establishment

- Initially, identify the Primary National Benchmark closest to the project area,
- Then locate the temporary benchmarks established during prior phases, if any. Either:
  - ➢ Check and confirm that these are correct with reference to the Primary National Benchmark, or:
  - ➢ Calculate the difference, and then update the these temporary benchmarks with reference to the Primary National Benchmark,
- Based on the above, confirm that all levels surveyed during this phase based on temporary benchmarks, can be used as part of feasibility Phase of survey works,
- If so, re-establish all prior temporary benchmarks as new permanent primary benchmarks and establish further new permanent primary benchmarks throughout the project area,
- Establishing a network of new permanent primary benchmarks throughout the project area, tied-in to the nearest Primary National Benchmark in accordance with the National Datum of Ethiopia provided by the Ethiopian Mapping Agency (EMA). BMs should be cast in concrete with dimensions of at least 30 cm x 30 cm x 60 cm (length x width x depth)

5.1.3 Task 2: assessment of existing infrastructures

Existing infrastructures shall be surveyed using GPS equipment:

- Mapping the layout (centerlines) of all existing main canals throughout the command area, if any,
- Mapping the layout (centerlines) of all existing main access roads or tracks (defined as capable of taking a 4WD vehicle) throughout the command area,
- Delineating the boundaries of all villages and congested areas of habitation, if any.

5.1.4 Task 3: cross sections, profile and detail survey works

- Site survey of the proposed headwork site, the potential saddle dam site and the reservoir area, (if dam),
- Cross-sectional survey of the source river and its flood-plain up to 5m above the floodplain (on both right and left banks) over a length of some 1km, as much as it covers existing canal up to its divergence from the river flood plain, if any or 50-100m on u/s, d/s & along axis of headwork.

- Site survey of the proposed headwork site on the River to be selected from one of potential sites, location to be selected and advised on site,
- Cross-sectional survey to determine flood embankment requirements along some ±1 km of the River and its floodplain,
- Strip survey from the diversion weir to the proposed reservoir, if any.
- Profile survey along the thalweg of the river 50-100m on u/s & d/s of headwork axis,
- Cross-sectional survey of existing canal,
- Cross-sectional survey to determine flood embankment requirements along the River for the expected overtopping reaches at crossings.

5.1.5 Task 4: command area survey

5.1.5.1 General

In this case, need to adopt Grid Survey Method and/or Spot Height Method to collect elevations of the command area and its vicinity. Here, the surveyor (s) carryout longitudinal profile surveys to provide spot levels within the command area over a total length as required within the boundary. This data can then be used separately or combined with previous survey data after conversion to same control/reference points, if any, and allow contouring of the command area.

5.1.5.2 Grid survey method

This method is a very accurate if it is drawn and collected as per the slope of the land. But it is time consuming, especially in areas covered with bushes/trees or intersected by gullies. Hence it is used only for small areas. A grid system is laid over the project area with a grid distance depending on the scale of the map to be produced. For a scale of 1:2000 which is suitable for most topographic mapping, an acceptable grid distance is 25 or 30 meters (If it has a uniform slope). Therefore, on the sheet with the plotted benchmark stations two benchmark stations will be connected by a line (known as baseline), crossing preferably the middle of the project area. Then a grid system is drawn and the distance between the benchmark stations and the intersection points of grid lines and traverse sides is scaled off, (all grid lines are parallel, but not necessary perpendicular to the base line).

With these distances, we can set out the grid in the field and mark all grid points by small numbered wooden pegs of about 25cm length. The grid lines are then numbered in alphabetical sequence, and the grid ·points get a number, positive at the right side- and negative at the left side of the baseline. The grid system has to be leveled line by line starting from benchmark and closing on a benchmark at the other side of the area. At all grid points, the ground level next to the peg has to be measured by a levelling instrument. The difference between the calculated height and the given elevation of the benchmark gives the closing error for that line, which should not be larger than the following:

Accepted error, $e = 10 * \sqrt{L}$ ………………………………………………………………………. (6-1)

Where, L is the distance in Km.

5.1.5.3 Spot height method

The Spot height method is a rapid and an efficient method in locating numerous topographic details, both horizontal and vertical, by a theodolite, RDS, Distance.

5.1.6 Task 5: sample areas survey

Detailed topographic survey of representative/sample area in the intended irrigation command area, if large scheme, otherwise full survey is required in SSIP.

5.1.7 Additional survey works

- Determining the water level of a Lake, if existing,
- Marking different drainage structures, if any,
- Giving detailed topographic data's in case the client requires.

5.1.8 Surveying in forest covered command area

There are areas, which needs especial attention than normal survey activities like that in obstacle areas like forest-covered command. In such case, the following procedure shall be followed:

- Applying site clearance along the selected weir site, if not visible,
- Gather profile data based on the topography of the area and if the slope of the area is undulating data should be collected densely, if not data collection at 10 or 15 meters is enough,
- Collect profile data at required stations' left, right and center up to 25m
- Collect cross-section data and record according to the given remark.

If the project site is bushy, then cross section method shall be selected for surveying. Thus, a nominal clearing lengths indicated below shall be adopted for estimation of work force requirement:

- For dense forest /bush land, one person can clear a strip of 25 - 30 m/day,
- For medium forest /bush land, one person can clear 35 - 40 m/day,
- If clearing a block of area is required, one junior surveyor with one daily labourer can execute 0.02 - 0.03 ha/day.

5.1.9 Survey of dam site

The location of the dam site has to be observed by the chief surveyor, while it is selected by the design engineer and the geologist. Once the dam site has been selected, a benchmark has to be established along its axis on both banks. Starting from this benchmark station, 2 surveys have to be carried out, namely a site survey covering the whole area surrounding of the dam site and a cross-section survey over the axis of the proposed diversion dam, intake, spillway & other structure.

The site survey should cover:

- The length of the dam,
- the height of the dam and
- the alignment of the dam
- As per the related structures and the estimated location
- A point where it enables to take maximum data on the upstream and downstream of the dam. It is better to plot this point on the map.

The map has to be produced for each site (dam or Diversion site) by observing their site gradient as per the following slope condition. The existing condition, natural or artificial is necessary and to be determined in scale from 1:50 to 1:1000. For each structure with their longitudinal profile, length & height as per the required paper size, the surveying data has to be taken for plotting. During plotting, difference of horizontal distance and difference of vertical distance should be shown clearly. Mostly the following vertical to Horizontal scale are applicable.

Table 5-1: Horizontal and vertical scales applicable to headwork site map

Vertical	Horizontal	Remark
1:20	1:200	
1:25	1:250	
1:50	1:500	This is the most Commonly adopted scale
1:100	1:1000	
1:200	1:2000	
1:250	1:2500	

For layouts, for canals, drain and roads the followings scale can be used.

Table 5-2: Scales applicable to layouts, for canals, drain and roads

Vertical	Horizontal
1:50	1:500
1:100	1:1000
1:200	1:2000
1:250	1:2500

For dam structures, irrigation structures, canal and drain cross-sections, the following scales can be used.

Table 5-3: Scales applicable to dam and irrigation structures

Vertical	Horizontal
1:20	1:20
1:500	1:50
1:100	1:100

Surveying data of the dam site should show the following information.

- For the recommended dam axis at least three permanent benchmarks should be established,
- The dam should be connected with the project coordinate (vertically and horizontally).
- It should show sudden change in elevation,
- Maximum flood mark level (by observing remains of debris or asking the local people),
- Actual and lowest water level (by asking the local people),
- Any features along the dam axis should be shown (geologic information or others),
- During study, there might be structures established such as borehole, test pit, etc. Thus, such structures should be surveyed and plotted with the required drawing showing Easting, Northing and Elevation,
- Map legends and scales should be presented (for Geological map, soil map, etc.)

5.1.10 Main canal survey

The main canal between the dam site & Irrigable area serves for the conveyance of the required water from the river to the top of the command area. The alignment of the canal has to be determined in the field by the design engineer and established by pegs at a mutual distance. Where the contour is uniform, pegs should be established at every 20 meters, and when the contours are closer and bends, establish pegs less than 20m apart. If there is no option to change the route of the canal, undertake the following works:

- After the route is surveyed, estimate bush trees along it for use of estimating cost,
- For steep slopes, execute detail cross section, and
- For curves prepare topographic map, which enables for estimations,
- The engineer has to look, for an acceptable canal slope, somewhere between the maximum and minimum allowable. Where required, conveyance structures should be foreseen such as drop structures on steep slopes, flumes to cross-river and gullies and culverts to cross roads. Along the proposed canal alignment, pairs of benchmarks have to be installed to carry out a site survey at visible intervals. A contour line map should be drawn in such a way that during the design phase, the possibility remains to change the canal alignment. In open survey-able areas, a cross-sectional survey is sufficient, starting at the benchmark station near to the top of the command area, or at the station near to the dam site. In case the headwork and command area are far apart, ideal length is high thus strip survey along conveyance canal for ranges of possible route shall be done,
- The cross-section has to be measured at 50 to 100 meters at the Right - and at the left side of every Center point and perpendicular to the centreline,
- Prepare the contour map from 0.25 – 1.0m interval (depending on steepness of the area, i.e. 0.25m for flat and 1m for steep terrain). The strip has to be plotted on a scale of 1:1000 in longitudinal sections with a vertical scale of 1:20, 1:50 or 1:100 (depending on slope of the area, i.e. 1:20 for flat and 1m for steep terrain)and the cross-sections to a scale 1:20, 1:50 or 1:100. During surveying, establish BM, which is useful for setting out of other canals, drains and structures,

5.2 FEASIBILITY LEVEL SURVEY REQUIRED FOR OTHER PURPOSES

Survey for Feasibility level activities other than in SSIP is required for: Site Development Planning, Boundary of Properties, Dam Design; Hydropower Design, Water Supply Design, Highway /Road & Planning Design, Power Line Design, Sewerage Line Design, Drainage Studies, Land Scape Design, Architectural Planning Design, Project Cost Estimation, Locate Historical Sites and Environmental Site bounding, etc.

5.3 PROCEDURES OF SURVEY WORKS AT FS&DD OF SSIP

- It includes organizing one instrument man, one girder (sketch) man and minimum three to four prism holders (men). Irrigation survey team should perform:
- Survey readings occupying traverse points and turning points to collect survey data in the field taking in to account that the field survey performed always should consider the arrangement of ground do not ignore considerable elevation variation during irrigation survey,
- Sketch any points used for irrigation surveying and relevant information,
- Every surveying team should start and end everyday surveying work on control points,
- Surveying data collection should be conducted to achieve the following stated accuracy relative to the site survey monuments.
    - E=2cm-4cm
    - N=2cm-4cm
    - Z=2cm-3cm
- Forward raw, verified data and the sketch to software expert (assigned personnel) to process and store the collected data,
- Collect surveying data along the rivers which cross irrigation canal if available,

- Following the shape of the river gather surveying data's at right bank, left bank, right bed, left bed, and river center then from the two bank surveying data collection should extend 50-100m both sides from the two bank so as to see it flood plain.

5.4 ESTABLISHING CONTROL POINTS

5.4.1 A detailed reconnaissance survey of control points

This is the most important part of any control survey and must always be done before any angles or distances are measured as they are the starting point of any survey work. The main aim of the reconnaissance survey is to locate suitable positions for the traverse stations and it cannot be overemphasized that a poorly executed reconnaissance can result in difficulties at later stages on site, leading to wasted time and increased costs. To carry out a detailed reconnaissance survey, the following list of activities should be considered.

To start assessment survey, information relevant to the survey area should be gathered, especially that relating to any previous surveys, to mention some:

- Initially, data from all possible sources should be collected and studied before venturing into the field; such data would comprise existing maps and plans, aerial photographs and any previous surveying data of that area,
- Following this, it is essential that the site is visited, at which time the final positions for the stations are chosen. For small and where no previous information is available, the site visit becomes the reconnaissance survey,
- When locating stations, an attempt should be made to keep the number of traverse stations to a minimum and short traverse lines should be avoided to minimize the effect of any centering errors,
- If the traverse is to be used for detail data collections and measurements, they need to be taken with a total station, link traverse is usually positioned around the area at points of maximum visibility,
- Although these would normally measure with a total station, the ground conditions between stations should be suitable for the purpose of distance measurements. Steep slopes or badly broken ground along the traverse lines should be avoided and it is better if there are as few changes of slope as possible to minimize errors. Roads and paths that have been surfaced are usually good for ground measurements,
- Stations should be located such that they are clearly inter-visible, preferably at ground level, so that it is possible to see the ground marks at adjacent stations as many others as possible so as to make it easier to measure the angles and enhances their accuracy,
- Stations should be placed on firm, level ground so that the total station and tripod are supported adequately when observing at the stations,
- When the positions of stations are chosen, a sketch of the traverse should be prepared, approximately to scale, to help in the planning and checking of fieldwork. In doing so, the stations should be given reference letters or numbers,
- Based on the specification for the traverse, the final part of the planning for the traverse is to choose the instruments to be used for the survey,
- Finally, as the cost is always important, survey of the scheme should be optimized such that it can be completed in the minimum of time, with the minimum number of personnel.

5.4.2 Station marking

When the control survey is completed, the stations have to be marked for the duration, or longer, of the survey. Station markers must be permanent and not easily disturbed, and it should be easy to set up and center an instrument over them. The construction and type of stations depend on the requirements of the survey.

For general purpose of traverses, 50 mm square wooden pegs can be used, which need to be hammered into the soft ground until only the top 50 mm of the peg is shown above the ground. In case asphalt road is required to be marked, use concrete nail of 80 mm or above size and painting ink around the nail concrete benchmark with number.

All benchmark stations with corresponding coordinate and elevations of the stations need to be listed, mapped and included in the report. A fine point on the top of the peg such as the center of a nail head may define the control point. Alternatively, longer lasting stations may require construction of some form of commercially manufactured station mark.

5.4.3 Traverse survey

As it is known to any surveyor, a traverse is a series of connected lines of measured length related to one another by measured angles. For traverse works, link traverse is recommended because a traverse that originates at a known position and closes on another known position is by far the most reliable and a check on the position of the final point as it serves to check both the linear and angular measurements of the traverse.

The link traverse has certain advantages over the remaining types, in that systematic error in distance measurement and orientation are clearly revealed by the error vector. Traversing is one of the simplest and most popular methods of establishing control networks in any engineering, cadastral, topographic and land surveying works. It gives itself ideally to control surveys where only a few intervisible points surrounding the site are required. For the majority of traverses carried out today, the field data would most probably be captured with a total station.

If a traverse fails to conform to the required standards (angular misclosure ≥ ±2'$\sqrt{n}$, where n is the number of measured angles, and relative precision in distance is <1:5000) a rerun of the traverse should be made. If a traverse conforms to the required standards, the error vector of misclosure should be quantified and distributed throughout the network, to minimize the errors in a 'link' traverse.

All traverse information collected in electronic data recorders is to be delivered to the chief surveyor or to survey Office in a format that a data is collected for adjustment. The survey team assigned to collect traverse data must download data onto the drive at designated Office locations and submit to an assigned team leader by CD or flash to adjust the data. Electronic Copies of field data (original data) and field notes are to be copied and should be kept in the Survey Office.

If the coordinates of control points are in a local (state) coordinate system, the surveyor should reduce the measured horizontal distances to its grid equivalent distances to the projection surface multiplying it by its combined scale factor or enter the combined scale factor of the point or the line to the total station before any distance measurement.

5.4.4 Scale factors

A scale factor need to be applied to the measured distances based upon the following steps or procedures.

Two-dimensional Rectangular coordinate systems are widely used in cadastral surveying, engineering surveying and land information/geographic information systems applications. Most users find it more convenient to use two-dimensional plane coordinates such as Northing/ latitude and Easting/longitude. A map projection “flattens” the Earth, and permits use of latitude/longitude control points in a two-dimensional rectangular coordinate system. The geometrical integrity of the precisely surveyed GCPs are transferred to the two-dimensional system using a properly designed and documented map projection.

The state coordinate system designed in Ethiopia enable users of the GCPs to work with two-dimensional coordinates anywhere within the zone. Most of the surveyors have been faced the problems (drawbacks) to use GCPs. The drawbacks faced in using GCPs were:

- Lack of accessibility,
- Lack of proximity,
- Lack of quality,
- Lack of understanding,
- Distortion

The first three drawbacks have been reduced dramatically with the introduction of differential GPS and Total Stations techniques through long consultancy services given from the side of consultants in this project.

Regarding the lack of understanding, many surveyors have not tried to use the state plane coordinates and have not made the effort necessary to understand their use. GPS is currently used to establish high order GCPs at readily accessible locations throughout an urban area or specific projects. With modern Total Stations, Data collectors, and computers, it is easy and economical to determine precise coordinates for traverses tide to GPS control points. Tremendous progress is also being made in the level of understanding as more mapping professionals and technicians learn to use state plane coordinates.

As far as the last drawback (distortion) i.e. the difference between ground distances is concerned, still it is a problem and is the focus area of the topic “Scale Factors”. These changes were made in an attempt to be specific with respect to using the ellipsoid, versus sea level, as an intermediate surface, and to avoid confusion with the generic use of “Scale Factors” as applied to surveying and mapping.

With the introduction of Electronic Distance Measuring/EDM/ instruments, the ratio precision for many traverses improved dramatically. No longer could the grid/ground distances difference be ignored without degrading the quality of a survey. As a result, routine practice is to compute both the Grid Scale Factor (GSF) and Elevation Scale Factors (ESF) when computing a survey (coordinates).

The concept of scale factors has been fully dealt with and it only remains to deal with their application. It should be clearly understood that, scale factors transform distance on the ellipsoid to distance on the plane of projection.

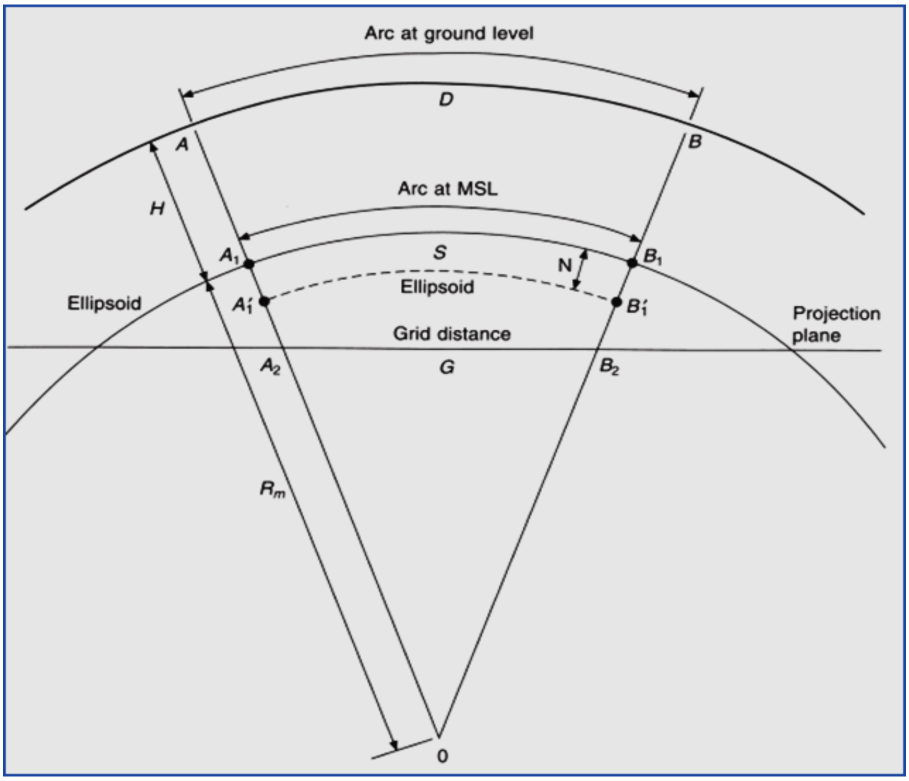


Figure 5-1: Graph showing distance reduction

From Figure above, it can be seen that a horizontal distance at ground level AB must first be reduced to its equivalent at MSL (geoid) A_1B_1, using the altitude correction, thence to the ellipsoid A_1B_1 using the geoid–ellipsoid value (N) and then multiplied by the combined scale factor to produce the projection distance A_2B_2.

The basic equation for Grid Scale Factor (GSF) is given by the following equation, where the size of the ellipsoid and the value of the Grid Scale Factor on the central meridian (F_0) are considered. The point Grid Scale Factor can be computed from:

$$F = F_o\left(1 + \frac{d^2}{2 * R^2}\right) \quad \text{(6-2)}$$

Where, F_0 = a factor equal to 0.9996

d is the difference in easting between the central meridian and the point in question

R is the average radius of the earth (≈6372000m)

Specific to Ethiopian system, the following formula may be used, which is sufficiently accurate for most purposes.

Scale difference (SD) is the difference between the scale factor at any point (*F*) and that at the central meridian (*F*$_0$) and varies as the square of the distance from the central meridian, i.e.

$$SD = K * d^2 \quad \text{(6-3)}$$

$$F = F_o + K * d^2 = 0.9996 + K * d^2 \quad \text{(6-4)}$$

Consider a point 180 km east or west of the central meridian, where F = 1:

$$1 = 0.9996 + K * (180000)^2 \quad \text{(6-5)}$$

$$K = 1.228 * 10^{-14} \quad \text{(6-6)}$$

$$F = F_o + \left(1.228 * 10^{-14} * d^2\right)$$ ……………………………………………………………. (6-7)

d=Easting – 500000m or, d = 500000m – Easting ……………………………….. (6-8)

The treatment for highly accurate work is to compute F for each end of the line and in the middle, and then obtain the mean value from Simpson's rule stated as follow:

$$F_{12} = \frac{F_1 + 4F_m + F_2}{6}$$ ………………………………………………………………. (6-9)

Where,

F12- Grid Scale Factor of a line between points 1 & 2 (Grid Scale Factor of the area between points 1 & 2)
F1- Grid Scale Factor at point 1
F2- Grid Scale Factor at point 2
Fm- Grid Scale Factor at the line's mid- point

$$ESF = \frac{R}{R+H}$$ ………………………………………………………………. (6-10)

5.4.5 Elevation scale factor, ESF

The reduction of horizontal distances to grid distances is a two-step process:

1) Reduction of horizontal distance to ellipsoidal distance using the Elevation Scale Factor

$$ellipsoidaldist = horizontaldist * \frac{R}{R+H}$$ ………………………………………………….. (6-11)

$$ESF = \frac{R}{R+H}$$ ……………………………………………………………………….. (6-12)

Where, R is Radius of Earth and H is Orthometric height

2) Reduction of ellipsoidal distance to grid distance using the Grid Scale Factor (GSF)

*Grid distance = Ground distance * Combined scale factor* …………………………. (6-13)
CSF = ESF x GSF ………………………………………………………………………. (6-14)

Thus, the value of GSF (F), ESF and CSF for two points whose coordinates E & N are computed and as shown in table below:

Table 5-4: Scale factor computation, GSF (F), ESF and CSF

Nr	Name	Easting (E)	Northing (N)	Elevation Elev.	Distance From Central Meridian (d)	Grid Scale Factor (GSF)	Elevation Scale Factor (ESF)	Combined Scale Factor (CSF)
1	1	477642.384	999603.100	2695.897	22357.616	0.999606138	0.999577094	0.999183399
2	2	475862.057	985839.907	2169.454	24137.943	0.999607155	0.999659649	0.999266938

It can be seen from the above formula for calculating the ellipsoid distance that, unless there is significant orthometric height, the elevation scale factor is very close to 1. For this reason, the GSF is often used as a close approximation of the CSF. It is up to the user to determine if the ESF can be neglected.

If the survey line is connected by the above two points, the average combined Scale Factor (CSF = (0.999183399+0.999266938)/2 =0.999225168)) must be calculated and entered to a total station to allow grid distance to be calculated value from ground distance in one-step.

Based up on the above procedures of scale factors, the combined scale factors for all GCPs located points in the project area should be calculated and tabulated.

5.5 TRAVERSE SURVEY BY TOTAL STATION

5.5.1 Approach to traverse survey

Prior to performing irrigation survey, secondary control points need to be established and run a traverse survey by less precise measurement say, by GPS using static survey method from the primary control points which are distributed over the country and connected by more precise measurements in local coordinate system (Adindan) established by EMA.

The irrigation survey then starts from these secondary control points by running a like traverse near the site using total station. The traverse station is marked with drilled hole and concrete benchmark with number and measurements are taken from these stations on the irrigation site.

5.5.2 Procedure of traverse survey

- Followings are general procedures that need to be followed while running traverse survey.
- Start from two coordinated points and terminate on one or two known point,
- The total station is then set over the station and leveled,
- The reflectors are centered over back sight station,
- With the telescope in the right face position, open and create a job as a file,
- Enter the coordinates and elevation of the instrument station,
- The instrument is then set up and initialized with all necessary parameter and the average scale factors of the starting and ending points of the traverse line are entered in to the telescope as sighted on the reflector at the back sight,
- The height of instrument of the station and the back sight reflector height are then measured and recorded,
- A back sight-reading is then taken on and the measured coordinates and elevation of the point is checked and recorded as BS, for checking it after completing the work in the field,
- Then take a fore-sight on point of interest and press the appropriate key on the controller to transmit the measured data and recorded it,
- Then turn off the system, the tripod and the reflector and move ahead to the total station instrument from where it is removed from the tripod and moved toward,
- This procedure continues until the total station instrument occupies the closing station for which the coordinates are known and the operators doing field check for the last known coordinates.
- The collected data then should be checked on site and if some error is allowable, the data is downloaded to computer for editing, computation and adjustment to determine the coordinates of the traverse station.

- TP points must not deviate from the BM and allowable difference must not be more than E=5-7cm, N=5-7cm and Z=3-5cm

5.5.3 Traverse computation

When coordinates of all the traverse points for all lines have been observed a check is necessary on the accuracy of the observation to check in a link traverse, distance, departures and latitudes are calculated from the observed coordinates for every station are listed. The algebraic sum of the departure should equal to the difference between the x coordinates at the beginning and end station of the traverse. Similarly, the algebraic sum of the latitude should equal to the difference between the y coordinates at the beginning and end station. The amount by which the difference between the 1st and the last coordinate of x and the difference between the latitude and the coordinate of y represent the error of closure of the link traverse. The closure correction in X and Y coordinates is evaluated when the accuracy of the observation is allowable then adjustment is performed.

5.6 TRAVERSE SURVEYING BY DGPS

5.6.1 Requirements for reconnaissance survey using DGPS

DGPS is not only required in case of large scale survey works, but also in small scale irrigation projects when the command area could not be accessed for total station survey. The followings are requirements for reconnaissance survey using DGPS.

- Proper field reconnaissance is essential to the execution of efficient, effective GPS surveys. Reconnaissance should include:
- Station setting or recovery,
- Checks for obstructions and multipath potential,
- Preparation of station descriptions (monument description, to reach descriptions, etc.)
- Development of a realistic observation schedule.

5.6.2 Station site selection

The most important factor for determining GPS station location is the survey's requirements (needs). After survey requirements, consideration must be given to the following limitations of GPS:

- Stations should be situated in locations, which are relatively free from horizon obstructions. In general, a clear view of the sky is required. Satellite signals do not penetrate metal, buildings, or trees and are susceptible to signal delay errors when passing through leaves, glass, plastic and other materials,
- Locations near strong radio transmissions should be avoided because radio frequency transmitters, including cellular phone equipment, may disturb satellite signal reception,
- Avoid locating stations near large flat surfaces such as buildings, large signs, fences, etc., as satellite signals may be reflected off these surfaces causing multipath errors. With proper planning, some obstructions near a GPS station may be acceptable. For example, station occupation times may be extended to compensate for obstructions,

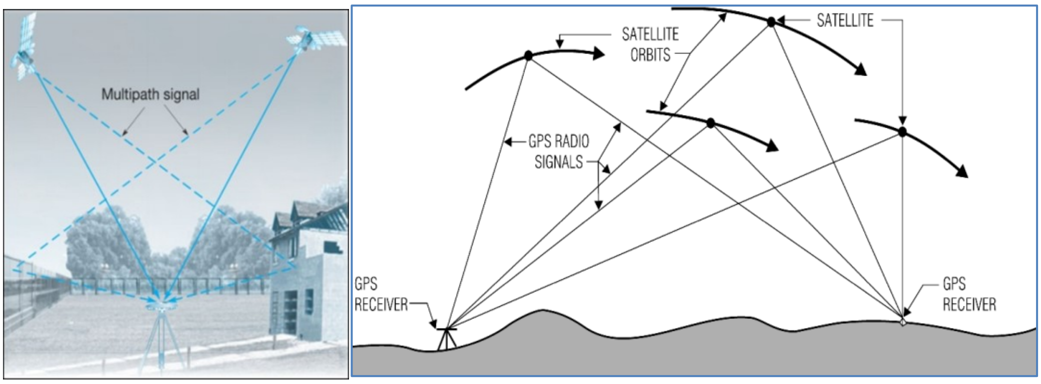


Figure 5-2: Typical multipath measurements by RTK GPS

5.6.3 Receiver setup

GPS receivers shall be set up in accordance with manufacturer's specifications prior to beginning any observations. To eliminate any possibility of missing the beginning of the observation session, all equipment should be set up with power supplied to the receivers at least 5 min prior to the beginning of the observation session. Most receivers will lock-on to satellites within 1-2 minimum of powering up.

5.6.4 Antenna setup

Blunders in antenna height measurements are a common source of error in GPS surveys because all GPS surveys are three-dimensional whether the vertical component will be used or not. Antenna height measurements determine the height from the survey monument mark to the phase center of the GPS antenna. With the exception of fixed-height tripods and permanently mounted GPS antennas, independent antenna heights shall be measured both in feet and meters (use conversion between feet and meters as a check) at the beginning and end of each observation session.

A height hook or slant rod shall be used to make these measurements. All antenna height measurements shall be recorded on the observation log sheet and entered in the receiver data file. When adjustable antenna staffs are used (e.g., kinematic surveys), they should be adjusted so that the body of the person holding the staff does not act as an obstruction. The antenna height for staffs in extended positions shall be checked continually throughout each day. When fixed-height tripods are used, verify the height of the tripod and components (antenna) at the beginning of the project.

All tribrachs used on survey works should be adjusted periodically to ensure accuracy, since centering errors represent a major error source in all survey work, not just GPS surveying.

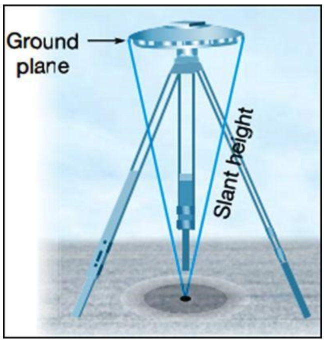


Figure 5-3: Slant height measurement

5.6.5 Horizontal positioning techniques of DGPS

Differential GPS carrier phase surveying is used to obtain the highest precision from GPS and has direct application to most cadastral, topographic and engineering survey activities. Most of the surveyors in cadastral surveying use two different GPS differential surveying techniques:

- Static,
- Real Time Kinematic, RTK.

Procedures for performing each of these methods are described below. These procedures are guidelines for conducting a field survey and manufacturers' procedures should be followed, when appropriate, for conducting a GPS field survey. Any horizontal control densification can be performed using any one of these methods.

Procedurally, both methods are similar in that each measures a 3D baseline vector between a receiver at one point (usually of known coordinates) and a second receiver at another point, resulting in a vector difference between the two points occupied. The major distinction between static and Real Time Kinematic baseline measurements involves the method by which the carrier wave integer cycle ambiguities are resolved; otherwise, they are functionally the same processes.

5.6.6 Static positioning

5.6.6.1 General

GPS receiver pairs are set up over stations of either known or unknown location. Typically one of the receivers is positioned over a point whose coordinates are known (or have been carried forward as on a traverse), and the second is positioned over another point whose coordinates are unknown, but are desired. Both GPS receivers must receive signals from the same four (or more) satellites for some periods of time that can range from a few minutes to several hours, depending on the conditions of observation and precision required.

5.6.6.2 Static baseline occupation time

Station occupation time is dependent on base line length, number of satellites observed, and the GPS equipment used. Since there is no definitive guidance for determining the required baseline occupation time, the results from the baseline reduction (and subsequent adjustments) will govern the adequacy of the observation irrespective of the actual observation time. The most prudent policy is to exceed the minimum estimated times, especially for lines where reoccupation would be difficult or field data assessment capabilities are limited. Typical Static Observation Times for different base line length should be used as follow.

Table 5-5: Typical static observation times

Length of Baseline	Minimum Observation Time *
less than 10 km	45 minutes
10 to 40 km	1 hour
40 to 100 km	2 hour
100 to 200 km	3 hour
more than 200 km	4 hour or more

5.6.6.3 Satellite visibility requirements

The stations that are selected for survey must have an unobstructed view of the sky for at least 15 degrees or greater above the horizon during the "observation window". An observation window is the period of time when observable satellites are in the sky and the survey can be successfully conducted.

5.6.6.4 Common satellite observations

It is critical for a static survey baseline reduction/solution that the receivers simultaneously observe the same satellites during the same time interval. For instance, if receiver No. 1 observes a satellite set during the time interval 1,000 to 1,200 and another receiver, receiver No. 2, observes that same satellite set during the time interval 1,100 to 1,300, only the period of common observation, 1,100 to 1,200, can be processed to formulate a correct vector difference between these receivers.

5.6.6.5 General DGPS field survey procedures

The followings are general survey procedures in the field using DGPS.

- The reference receiver is located at known control point
- Rover is set up at a point whose coordinates are to be determined

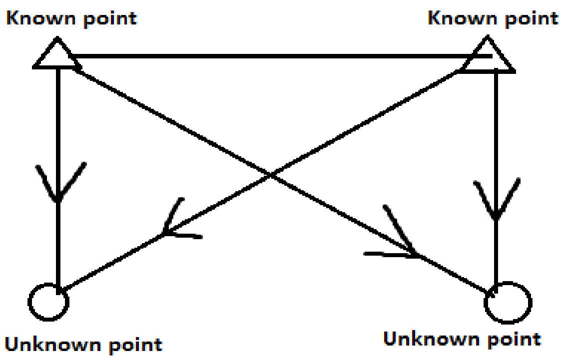


Figure 5-4: Schematic view of general DGPS field survey procedures

- Setup two DGPSs at two known points,
- Select points to be established according to baseline distance,
- Setup one/two DGPS at the unknown points to establish a new benchmark,
- Make contact with persons at these points by phone/radio when starting and finishing measurement,
- Select permanent foundation or plant new monument,
- Select material (concrete, paint, design) if new.

5.6.6.6 Data post-processing

After an observation session has been completed, the received GPS signals from both receivers are then processed (i.e., "post-processed") in a computer to calculate the 3D baseline vector components between the two observed points. From these vector distances, local or geodetic coordinates may be computed and/or adjusted.

5.6.6.7 Receiver operation and data reduction

Specific receiver operation and baseline data post-processing requirements are very manufacturer-dependent. The user (surveyor) is strongly advised to consult and study manufacturer's operations manuals thoroughly along with the baseline data reduction examples.

5.6.6.8 Accuracy of GPS static surveys

Accuracy of GPS static surveys is the most accurate and can be used for any order survey.
Note: Attention must be given to the following.

5.6.6.9 Documentation

The final GPS Survey project file should include the following information:

- Project report,
- Project sketch or map showing independent baselines used to create the network,
- Station description and GPS Station Location Sketch (photographs)

Figure 5-5: Typical digital photograph of control points (GPS station location)

- Station obstruction diagrams if possible
- Raw GPS observation (tracking) data files
- Baseline processing results
- Adjustment results
- Final coordinate list

5.7 WORKING WITH REAL-TIME KINEMATIC

5.7.1 Positioning of RTK

RTK surveying requires two receivers, recording observations simultaneously, and allows the rover receiver to be moving. RTK surveying techniques also use dual-frequency LI/L2 GPS observations and can handle loss of satellite lock.

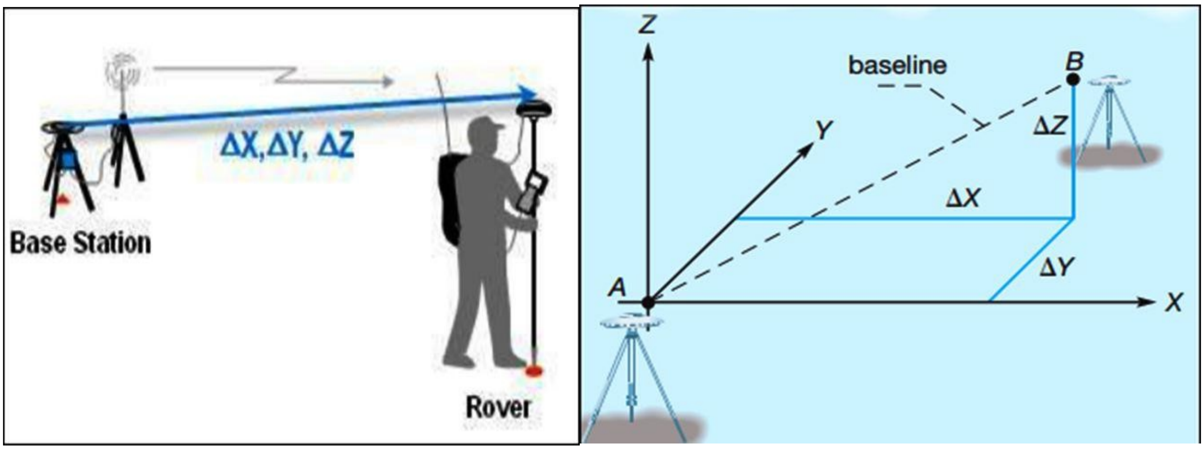


Figure 5-6: Typical setup of RTK

The RTK technology allows the rover receiver to initialize and resolve the integer ambiguities without a period of static initialization. With RTK, if the loss of satellite lock occurs, initialization can occur while in motion. The integers can be resolved at the rover within 10-30 sec, depending on the distance from the base station.

RTK techniques provide results with very little delay and therefore are suited for detail data collection. Normally, RTK methods are limited by the distance range at which that the rover can be placed from the reference. Refer to the manufacturer's specifications for these ranges and corresponding precisions. When using an RTK survey method, as the sole measurement method for survey measurement, keep the control points and detail points separated. RTK uses a radial style survey scheme with one or more reference (base) receivers and one or more rover receivers for detail survey measurements.

5.7.2 Survey procedure by RTK

RTK surveying requires dual frequency LI/L2 GPS receivers. One of the GPS receivers is set over a known point, while the other receiver may be free to travel from point to point. If the survey is performed in real time, a radio link and a processor or data collector are needed. The radio link is used to transfer the raw data from the reference station to the rover.

5.7.3 Accuracy of RTK surveys

RTK surveys can be accurate to within 0.006m to 0.0152m,(6mm to 15mm)providing a good static network and calibration were performed prior to performing the RTK survey.

Attention must be given to the following:

- Five or more satellites should be observed,
- Receiver specifications should be adhered to for consistent results,
- Each point should be occupied in a different session with different satellite geometry, unless collecting data while moving,
- The recording epoch rate should be either one or five seconds.

In RTK, the surveyor should check whether:

- The correct reference base station is occupied,
- The GPS antenna height is correctly measured and entered at the base and rover,
- The receiver antennas are plumb over the station at base and rover,
- The base coordinates are in the correct datum and plane projections are correct,
- The reference base stations or the remote stations have not been disturbed,
- The radio communication link is working,
- The RTK system is initialized correctly,
- RMS values are within manufacturer's limits.

5.7.4 Recommended best practice

Recommended best practice for each and every RTK GPS survey includes, but is not limited to:

- The minimum satellite elevation mask angle shall be set at 10° - 15° above the horizon.

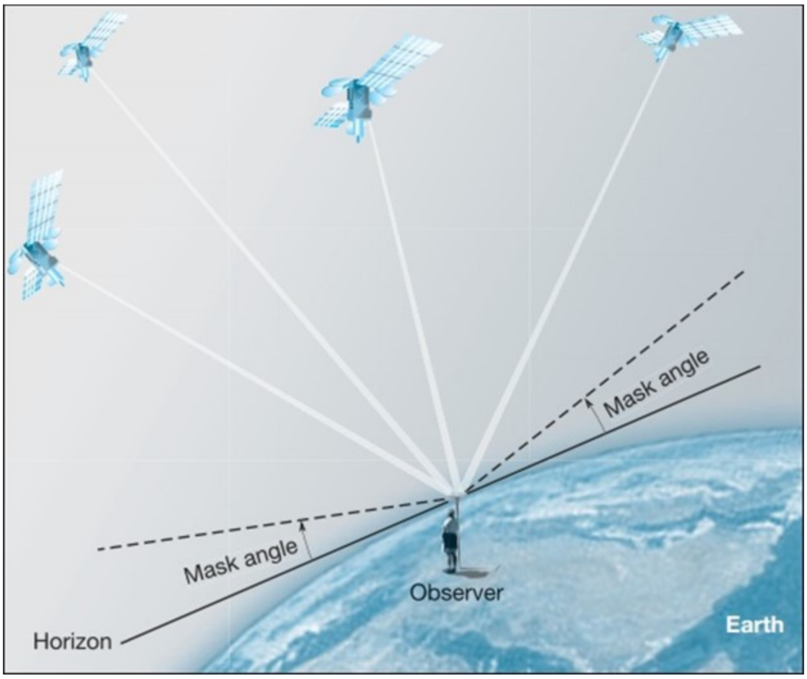


Figure 5-7: Relative positions of satellites and receivers mask angles

- Receivers should be set to record at a 1-second data collection rate (epoch) using the averaging technique.
- With traditional base/rover RTK surveying, it is much better to establish a new, completely open sky view site for the base station than to try to occupy an existing survey control mark with a partly obscured sky view.
- Bubbles are to be in adjustment. It is recommended to check bubbles before every survey.
- All surveys should connect to establish survey control marks before, during and after each RTK session. Furthermore, when collecting important positional data, established survey control marks should be checked with the same initialization a subsequent points to be collected.
- Positional data should not be collected when the PDOP exceeds 6.
- Communication (radio) between the base station and RTK rover should be continuous while locating a point.
  - Never perform RTK surveys when weather conditions obviously differ between base and rover.

- The minimum observation period for baselines less than ten kilometers should be 45 minutes
- The recording rate should be 5-30 seconds
- The satellite geometry should change significantly during the observation session
- Single frequency receivers may be used for short lines for non-high precision applications
- It is essential that the carrier phase ambiguities are constrained for lines less than 15km
- Only observation windows with a minimum of 5 satellites above 15° and a good GDOP (< 8) should be used.
- The minimum observation time in Static observation should never be less than 15 minutes.

5.8 DETAIL IRRIGATION SURVEY DATA COLLECTION

5.8.1 General

Detail survey activities include adaptation of the feasibility level designed irrigation system including headwork (s), conveyance canal or MC, crossing structure sites, and the like on the site. Thus, it is the conformation or finding ground truth for the designed irrigation system on the paper before transferring it for construction purpose.

5.8.2 Checking accuracies of the installed BMs

These are project control survey points, which serve as reference points for each project. Thus, installed BMs need to be checked on the ground for their accuracies in closeness (as shown in section 6-3) before using them as references for construction purposes.

In case, the established BMs during surveying have been destroyed or dismantled purposely or innocently, we need to relocate them as per the "Guidelines and Procedures to Replace a Destroyed BM along an Existing Level Line and Maintain Original Order of Accuracy, by NGS" presented in Appendix-II.

5.8.3 Cross sections surveys

Survey of cross sections at construction stage requires for its adequacy in covering the channel width including flood plains. This check should also identify weather

5.8.4 Main canal profile survey

The profile, which is designed by taking data from the contour map may not match with the actual terrain condition. This problem has a significant effect on the structures or other related design along the route. Hence, to avoid this problem, it is advisable to execute surveying work along the proposed alignment to check for its correct alignment and additional structure requirement.

Here also, the possibility remains to change (in a smaller extent) the alignment of the canal. The closing error in this cross-sectional levelling should not exceed the accepted $1/\sqrt{L}$ (mm), where, L = levelling distance between the benchmarks in Km.

Based on this design, for implementation (construction) purposes, the surveyor can carry out staking out work along the canal using the BM value from the topographic map and canal coordinates.

6 SURVEYING FOR CONSTRUCTION AND CONSTRUCTION SUPERVISION

6.1 BACKGROUND TO CONSTRUCTION SURVEYING

Both the Contractor and the consultant/supervisor are responsible for the surveying works during construction, which is required to accomplish the contract work. This includes:

- Laying out the job,
- setting benchmarks and grade stakes,
- taking cross section elevations,
- Laying out the location and elevation of canal profiles and
- Layout of structures.

The field method of staking is to be determined by the Consultant, as long as adequate project control is provided to allow the contractor to comply with project plans and specifications.

If applicable, permanent canal centerline monuments/stakes and approach surface markers shall be placed, by the contractor, at the canal alignment control points and approach surface locations set by the Consultant. Requirements for the locations and installation of these markers must be shown in the construction plans.

6.2 NEED FOR SURVEYING AT CONSTRUCTION STAGE

6.2.1 Necessity for construction surveying

Surveying for construction is required for construction staking (such as centerline staking for initial grading, staking structures and final survey for the preparation of record or as-built drawings) and construction inspection/supervision as well as for preparation of quantity surveying.

The purpose of surveying at this stage in general is:

- To undertake the surveying of the topography of sites where construction work is to be carried out,
- In addition to that the provision of longitudinal profiles and cross sections of streams, canals and drains that will enable the Contractor to verify if any changes occurred after the Supervisor's field survey work and plotting as well as verifying and clarifying the engineering Concept Design provided during the tender, and
- In order to develop Detailed Designs & As-built Drawings.
- The survey will also enable final verification of the Supervisor's presented Scope of Work (SoW) and Bill of Quantities (BoQ).
- Ultimately this will lead to the agreement between the Supervisor and Contractor as to the SoW and BoQ and can be agreed by signature and acceptance of the Drawings. Through this process, the Contractor is in agreement with the necessary requirements to construct the required irrigation structures and appurtenant civil works.
- Construction surveys provide the horizontal and vertical layout for every key component of a construction project. They involve horizontal and vertical control and the placement of stakes to establish a framework for the construction site. From this control, lines and grades are established by means of stakes and strings. The contractor then use these stakes and strings to place supplemental stakes that may be necessary to guide the construction activities.
- In summary, construction surveying is the process of drawing the design plans on the actual construction site at the designated location and at a scale of 1:1.

- Construction surveying techniques are also used for verifying the location and quantities of completed work (i.e. as-built).

Traditionally, a "station/offset" method is used for establishing construction control. The introduction of computers, total stations and GPS in surveying have revolutionized the way construction surveys are done now. Construction surveys are now based on the three dimensional (X, Y, Z) coordinate system with which the design was made. From the three dimensional coordinates, angles and distances are computed to facilitate radial stakeout. Radial stakeout data can be downloaded into many total stations or electronic data collectors. This data guides the surveyor to the location of the points to be staked out. Three dimensional coordinates of the construction plan can also be downloaded into a GPS receiver and used in a real time kinematics mode to stake out the site.

6.2.2 When to start construction survey works

Construction survey works should start before construction operations activate in order to avoid delay in the Contractor's operations. It is very important that the Resident Engineer and his or her(s) staff acquaint themselves with the Contractor's staking plan and give the Contractor formal approval before any staking begins. The Contractor's staking plan should be referenced throughout the project to assure that the Contractor is following this plan.

Table 6-1: Summary of main survey tasks in construction

Spec Work Item	Activity Description	Responsibility		Frequency
		Supervisor	Surveyor	
Clearing & Grubbing	Check staking limits with right-angle prism & 100 m chain	X		At beginning of job
Earthwork	- Review plans; check Contractor's survey staking: • Check catch points • Check 90 degree angles • Check slope stakes • Check alignment - Spot-check slopes w/hand level - Check each progressive lift depth	X X	X X X X	150m max. Ditto Ditto Ditto As needed, 150m max. Ditto
Lean Concrete	- Check horizontal & vertical alignment of wire staking. - Check hub & tack control with plumb-line and string-line.	X	X	60m max.
Portland Cement Concrete Pavement	- Check horizontal & vertical alignment of wire staking. - Check hub & tack control with plumb-line and string-line.	X	X	60m max.
Pipes, Culverts, and Drains	- Check Contractor's survey cut stakes: vertical and horizontal control. - Use appropriate survey instruments. - Check pipe excavation and backfill using hand level, watch grade checker.	X X	X	Short runs - both ends. All large sizes, long runs; others by request only. Check each advance.
Catch Basins, Standpipes,	- Check position: alignment & elevations.		X	Check only upon request.
Manholes	Verify conformance with design.	X		Field verify each

Spec Work Item	Activity Description	Responsibility		Frequency
		Supervisor	Surveyor	
				location.
Concrete Structures: e.g. Bridges/culverts	- Forms/soffit/falsework: verify edge of deck horizontal and vertical control; Check offsets, grades, screeds from control. - Check location & elevation of foundations prior to major pours. - Bearing pads: check initial placement and control points, prepare as-built. - Check bearing pads prior to concreting. - Check approach and anchor slabs.	X X	X X X X	Check every structure. Check all items. Verify layout at start of job only & by request thereafter. Subsequent construction. By request only.
Fences	- Check layout work & measure for payment. - Check	X	X	Prior to and when complete.
Survey Monuments	- Check Contractor's survey on permanent section corner replacements & similar.		X	Verify all key monuments.
Concrete Barriers	- Check placement and dimensions.	X	X	All critical points.
Right-of-Way Markers	- Check placement.		X	Verify all markers.
Construction Surveying & Layout	- Check locations, grades, and plumb-ness. - Inspections and random checks as detailed above per instructions of the Engineer (per the Specification).	X	 X	Check all structures. As directed.

6.3 CONTRACTORS' SIDE SURVEYING ACTIVITIES

6.3.1 *Understanding the project site*

The surveyor need to understand the project site by walking through the field and own its general topographic feature before starting commencement of any survey work both in office and the field. Consequently, the following points need to be considered.

- Site examination before starting work;
- Identifying construction works site to be executed on the irrigation site for example dam, headwork (weir), pumping station, primary canal, secondary canal, tertiary canal, drainage canals, off-take structure, drop structures (dike & ditch) etc.,
- After that, in order to implement each drawing on the construction site effectively, carry out desk study in the office. At this stage, if there is any inconvenience of reading the plan professional consultancy may require on items such as, delineating the boundaries of the irrigation area, every structures and canals layout plan (layout & cross-section fill). Additional detail structure drawings should also be studied;

6.3.2 *General preparatory and detailed survey works*

- Prepare all types of surveying instruments and check all are in a good condition;
- Collect the available Bench Marks in the vicinity established by the Mapping agency or other organizations;
- By transferring the available Bench Marks establish Bench Marks in the project area using strong materials such as concrete or on other permanent structures such as bridges, rocks, etc.;

- Undertake closed traverse by GPS or total station;
- Undertake differential levelling by level instrument;
- Start reading of the OGL and compare with the available (design data) and check its reliability to proceed the work;
- Setting out and mark the boundary of each structures and prepare the area for construction;
- Check the construction work at different level to know whether it is done according to the design or not;
- Collect surveying data to quantify the work done and payment certificate preparation according to the payment schedule (interim payments and other payments depending on the contract provision);
- Provide the client with a copy of all surveyor's notes, if requested by the engineer and submit construction surveying prior to request for payment and also include information on the record or as-built drawings prepared from actual measurements and observations made by contractor's own personnel including sub-contractor if any and submit to the engineer for approval;
- Get final confirmation of the work whether it is done according to the design or not;
- Collect final surveying data to effect the final payment certificate and to confirm project completion.

6.4 LOCATING THE SURVEYING DATA

6.4.1 Check levels and bench marks

Check levels must be run to verify the elevations of the benchmarks shown on the plans. Check levels shall begin at the nearest original bench mark just outside the beginning station of the project. Bear in mind that all benchmarks are turning points, and it is important that the level person turn through each bench as they are being checked. It is equally important that the rod person is provided with a peg book to check with the level person throughout the procedure of the work.

At the time check levels are being run, establish all necessary construction benchmarks. The benchmarks, set on the location survey, establish the vertical control of the construction projects.

The plans show all location bench marks, but they are too far apart and not established at strategic places for construction work; therefore, the following are a few established practices that can be performed at the time check levels are run that will expedite the staking of a project:

- Establish a benchmark at each end of a large structure; one benchmark at the high ground elevation and one at the low ground elevation of the structure. One bench is sufficient at a small structure,
- Establish benchmarks at frequent intervals and convenient locations for checking during cross sectioning and setting of blue tops. As a general rule, a maximum of 150 meters between bench marks should be observed,
- Establish benchmarks in rough terrain, at points of change from cut to fill and vice-versa or at high point of fill,
- Establish new guard stakes at all old benchmarks and all newly established benchmarks. The back face of the guard stake will be marked with the abbreviation "BM" and the BM number. The inside face will bear the actual elevation of the benchmark. The guard shall be driven over the benchmark at a slant with the inside face of the guard facing the iron pipe,
- In placing new benchmarks, a sound, firm ground location should be sought and a 1.6cm X 0.5m or 0.6m pin driven into the ground allowing approximately 5 centimeters to protrude.

6.4.2 Locating other surveying data

After studying plan of the project, the next survey work is locating the surveying data that are pointed out at design stage based on the given coordinates using hand GPS and for any discrepancy of data modifying or substituting is required, which we call as-built drawing in consultation with supervisor of the site. If the surveying data (coordinates) mentioned above are positioned accurately (E, N & Z), each BM should be aligned using a quality instrument. The alignment should be checked with the previous surveys and modification is necessary for any discrepancies, if any,

Based on the above reviewed layout, the location of the beginning and end coordinates of each work shall be established from the softcopy. If it is a dam, the beginning and final locations are determined from the bent centerline, if any. If it is a diversion headwork, the beginning and final locations are determined from the canals and drains alignments. If the alignment has multiple bends, each coordinate (E, N, Z) should be collected. The structures also follow the shapes and data can be gathered from that. Long structures data are gathered from posts located on every 200-meter interval on the alignment.

Afterward based on the construction schedule, OGL profile and cross section shall be determined. The dam end headwork structures alignment and its elevation data should be checked for their equity at both ends based on the benchmark. If there is any deviation, elongating or shortening, the alignment shall minimize the elevation difference by consulting the office team.

After that, by reviewing the elevation differences of the dam and headwork structure, right and left profile and cross section should be prepared based on the given slope. This should be prepared on minimum of 20-meter interval or less if there is ground change. When crossing a river both profile and cross section should be taken based on the shape of the river. For structures that cross in the middle, each boundary should be taken and at the end, it closes on the BMs.

The above profile and cross section shall be compared and contrasted by putting together with the previous design in the office. If there is any deviation, modification should be made by letting know the concerned team. Then, the dam and headwork profile and cross section drawings taken from the site should be prepared in office. The points and coordinates where the dam and headwork pass should be collected and generated further in the office. Using those data and starting from the benchmark, the upper and lower width of the dam shall be located on every 10-20 meter interval by placing pegs,

Following setting out of dam and headwork, excavation for foundation placement shall begin. This will need a continuous inspection on every elevation to make sure it is caring out as per the drawing depth. If the work is, being carried out by another contractor the list of works mentioned above shall be taken together. In addition, based on the schedule, the construction payment concerned about excavation or backfilling should be carried out within the specified timetable. Excavation and fill data are taken on site together and signed by both parties. The prepared data will be passed over to the concerned parties and based on that excavation or fill volume will be estimated.

Suitable spaces should be prepared for the planned construction materials required for the project by reviewing the design drawing. This will be handed-over for those who will perform the excavation works.

On places that require soil fill or hardcore, it should be constantly checked for their thickness according to the drawing. Adjustments shall be necessary before compaction, reduce on overly placed areas. The shapes of planned structures coordinates (E, N, Z) should be positioned appropriately on the irrigation ground. If excavation is required for placing their foundation, their elevations are taken from drawings. When reached to the required depth, concrete should be casted according to its shape and slope. This could be indicated by taking a reading and setting pegs with painted nails.

After Each and every constructed works are finalized, as-built cross-sectional profile drawing shall be prepared on 10-20 meter interval based on its shape. Coordinates of the structures (E, N, Z) shall be taken by following the shape of the structures.

For the works mentioned above, the daily taken points must not deviate from the benchmark and the allowable difference must not be more than E=3cm, N=3cm, Z=1-2cm. When the work is completed, as-built profile section drawings of the area shall be prepared based on the surveying data.

During the collection of surveying data or construction work, it may be difficult to collect data between BM due to the barriers like tree and mountain. In this case, we should establish 3-4 TP to collect surveying data around inaccessible area. The followings are major survey works during construction of irrigation project.

6.4.3 Construction stakes in surveying

Throughout the construction work, the Surveyor should see that:

- Survey stakes are always provided far enough ahead to enable the Contractor to plan his/her work.
- The location and message transmitted by these stakes shall be recorded so that the stakes may be easily replaced if destroyed,
- All stakes must be marked by a beginner's drawing pencil that should be blunt enough to sufficiently impress the markings slightly into the wood,
- All writing on stakes shall be large enough for easy reading,
- Stakes shall be driven firmly into the ground.

6.4.4 Arrangement of slope stakes

Slope stakes may be placed prior to the Contractor clearing the ground in cases of open, grassy prairie, or cultivated land, where a minimum of clearing is required; otherwise, a clearing line should be established and the canal and related structures route should be cleared prior to setting of slope stakes. Slope stakes need not always be set at every cross section; however, all the information needed for calculating quantities must be indicated in the notebook.

In setting slope stakes, the rod is read to the nearest 3 centimeters and horizontal distances measured with a metallic tape (if required) at right angles to the survey centerline also recorded to the nearest 3 millimeters. In heavy works on steep hillsides, special care shall however be taken in reading the rod and in setting slope stakes at right angles to the centerline and also in properly measuring the horizontal distances from the survey centerline to the point where rod readings are taken and where slope stakes are set.

The use of hand levels and the Rhode's Arc should generally be limited to determining elevations of inaccessible locations because elevations taken by this method are not as accurate as elevations read with the engineer's level. In rough terrain, parallel profile levels outside of the slope stake lines may be used to check hand level work. It is recommended that electronic instruments are used for this application to increase accuracy.

6.5 PROFILES SURVEYS

Profile elevations are taken on baseline stations to aid the engineer in establishing a grade line to fit field conditions. The profile and preliminary grade line also serve as reference elevations for cross sections and the soils profiles. The construction survey centerline then should be staked as centerline control points are being established and referenced. Stakes shall be driven on the centerline, with the station marked on the side facing the initial station of the survey; on tangents. Stakes shall be placed on even stations and at all breaks in topography within the profile & section that will affect the calculation of the volumes of excavations and embankments.

Profiles should be taken by differential levelling circuits beginning and ending on the previously established benchmarks. Heights of instruments and turning point elevations should be carried to the nearest 0.005 meter. Profile elevations should be recorded to the nearest 0.01 meter, unless they are on pavement, curbs, structures or other fixed objects that would require less tolerance in determination of the final grade line.

Profiles of grade line controlling features, as in case of irrigation works should be taken far enough on either side of the centerline to clearly define the grade lines of those features.

6.6 CROSS SECTIONS SURVEYS

Normally, cross sectioning should not be started until the preliminary alignment and profiles have been approved.

The photogrammetric process may be used to obtain terrain cross sections. There are some occasions, however, that will require field checking of photogrammetric sections, such as, if the terrain extends outside of covered areas or if the ground is not visible due to obstructions.
In most projects, cross sections at all 20 meter stations should be sufficient. Closer spacing may be required for street sections, uneven terrain or in areas where there are special drainage problems. The general criteria for taking extra cross sections should be determined prior to commencement of the work.

Cross sections should be taken far enough on either side of the centerline to assure that all of the proposed construction zone will be included.

In general, skewed sections for drainage pipes or other special sections not required for earthwork computation should be recorded separately or clearly marked as not for use in earthwork computations.

6.7 RIGHT-OF-WAY SURVEYS

Wherever new right-of-way may be acquired, it is necessary to tie property corners to either the centerline or the control points. Sufficient land ties must be made to accurately define the centerline with respect to property ownership or other boundaries, such as corporate limits, subdivisions, or county lines.

6.8 ALIGNMENT CONTROL SURVEYS

The new alignment should be reset from the strongest ties or reference monuments available. When a base traverse is used for development of the project, all critical alignment points should be set directly from the base traverse monuments. In any event, those alignment control points should be set only from control monuments that were originally installed in accordance with criteria for extendible points. In addition, each alignment control point should be set using the same criteria. Tacked hubs, nails and shiners or other types of semi-permanent station markers appropriate for the soil or type of surface should be used.

6.9 SURVEYING FOR MEASUREMENTS

6.9.1 General

Surveying for measurements are carried out during the construction phase of SSIP development. It is done for ground trothing, conformation and quantity surveying. Types of such measurements and required accuracy and precision are presented in following sections.

6.9.2 Types of surveying measurement

Basic field operations performed by a surveyor involve linear (such as horizontal, vertical & slope distances) and angular (such as horizontal & vertical angles) measurements. Through application of mathematics (geometry and trigonometry) and spatial information knowledge, any surveyor can convert these measurements to the horizontal and vertical relationships necessary to produce maps, plans of engineering projects, or Geographical Information System/ Land Information System (GIS/LIS).

6.9.3 Accuracy and precision for measurement

Accuracy

Accuracy is the degree of conformity with a standard or accepted value. Accuracy relates to the quality of the result. It is distinguished from precision that, it relates to the quality of the operation used to obtain the result. The standards used to determine accuracy could be:

- an exact known value, such as the sum of the three interior angles of a plane triangle is 180°;
- a value of a conventional unit as defined by a physical representation thereof, such as the international meter;
- a survey or map value determined by superior methods and deemed sufficiently near the ideal or true value to be held constant for the control of dependent operations.

Although they are known to be not exact, higher order NGS control points are deemed of sufficient accuracy to be the control for all other less exact surveys.

Precision

Precision is the degree of refinement in the performance of an operation (procedures and instrumentation) or in the statement of a result. It is a measure of the uniformity or reproducibility of the result.

Accuracy versus precision

The accuracy of a field survey depends directly upon the precision of the survey. Although through luck (compensating errors, for example) surveys with high order closures might be attained without high order precision, such accuracies are meaningless. Therefore, all measurements and results should be quoted in terms that are commensurate with the precision used to attain them. Similarly, all surveys must be performed with a precision that ensures that the desired accuracy is attained. However, surveys performed to a precision that excessively exceeds the requirements are costly and should be avoided.

6.9.4 Surveying errors and its classification

General

Statistically speaking, field observations and the resulting measurement are never exact. Any observation can contain various types of errors. Often some of these errors are known and can be eliminated by applying appropriate corrections. However, even after all known errors are eliminated, a measurement will still be in error by some unknown value. To minimize the effect of errors, the surveyor has to use utmost care in making the observations and utilizing only calibrated equipment. However, a measurement is never exact, regardless of the precision of the observations.

Although this guideline contains many guidelines and standards, the ultimate responsibility for providing surveys that meet desired accuracies remains with the field personnel. To fulfill this responsibility, the crew chief and his or her assistants must understand errors, including but not limited to:

- The various sources of errors,
- The effect of possible errors upon each observation, each measurement, and the entire survey,
- Economical procedures, which can eliminate or minimize errors and result in surveys of the desired accuracies.

Blunders/ mistakes

Many textbooks on surveying refer to a blunder as a gross error. One can easily make a case for a blunder to be considered an error. However, a blunder is really an unpredictable gross mistake made by the surveying team. It is not a hidden error that will go unnoticed, but usually it becomes apparent that something is wrong with the measurements. Examples of blunders are:

- Transposing two numbers (in field notes or computer input),
- Misplacing decimal point,
- Incorrect reading (i.e. the foot value on a levelling rod),
- Inadvertently altering set instrument constants in the middle of a project,
- Placing sighting device or the instrument at a wrong point,
- Misunderstanding verbal instructions or reading announcements (call out),
- Neglecting to level an instrument precisely,
- Using the incorrect coordinates or benchmark values.

Blunders are caused by carelessness, misunderstanding, confusion, or poor judgment. They can be, for the most part, avoided by alertness, common sense, and good judgment. Blunders are detected and eliminated by using proper procedures, such as:

- Checking each recorded and calculated value daily,
- Making independent and redundant measure check observations and measurements,
- Making redundant measurements that allow closure computation of sections of the entire survey.

Small blunders are more difficult to detect and correct especially if the number of redundant measurements is too small. Therefore, surveys must be carried out with sufficient redundancy to prevent a blunder from going undetected. All blunders must be eliminated prior to correcting and adjusting a survey for errors.

6.9.5 Types of errors

Excluding gross errors, which were discussed above, there are two general types of errors: systematic and random.

Systematic errors

A systematic error is an error that can always have the same magnitude and the same algebraic sign under the same conditions. In most cases, systematic errors are caused by physical and natural conditions that vary in accordance with known mathematical or physical laws. Systematic errors are caused by:

- Equipment out of calibration
- Use of insufficiently accurate computation equations (too few terms in a series.)
- Failure to apply necessary geometric reductions of measurements.
- Failure to apply necessary reductions of measurements due to weather related conditions.
- Personal biases of the observer.
- Use of incorrect units (feet instead of meters.)

A systematic error of a single kind is cumulative. However, several kinds of systematic errors occurring in any one measurement could compensate for each other. Some examples of systematic errors are:

- EDM that measures 99.95 feet while indicating a measurement of 100.00 feet.
- Refraction in vertical angles.
- Observer's tendency to sight on near or distant sights in a slightly different manner.

Although some systematic errors are difficult to detect, the surveyor must recognize the conditions that cause such errors. Once the conditions are known, the effect of these errors can be minimized as follows:

- Turning angles (with theodolite or total station) in direct and reverse modes,
- Balancing (maintaining similar distances between level and rod) foresights and backsights,
- Calibrating all surveying equipment,
- Calibrating EDM's yearly at a baseline calibration site,

When systematic errors cannot be eliminated by procedural changes, corrections are applied to the measurements. These corrections are documented in the user manuals of the equipment or in surveying textbooks, Undeterminable systematic errors can also be modeled into the adjustment computation, but surveyors should not rely on this. They must eliminate all the known systematic errors prior to proceeding with any adjustment of the survey data.

Random (Accidental) errors

A random error (or accidental error) is an error produced by irregular causes that are beyond the control of the observer. They do not follow any established rule which can be used to compute the error for a given condition or circumstance of the observation. The occurrence, magnitude, and algebraic sign of a random error is truly random and cannot be predicted. For a single measurement, it is the error remaining in the measurement after all possible systematic and gross errors are eliminated. An important characteristic of the random error is that if we repeat the same measurement many times, the sum of all these errors tends to be zero. This is yet another good reason to make extra measurements beyond the required minimum.

An example of a random error is the personal reading error of any scale. An observer estimates the final reading that can be either high or low in estimation since exactness cannot occur.

Unlike systematic errors, corrections for random errors cannot be computed directly. Random errors must be compensated by adjustments. The adjustment process computes adjusted observations for the actual ones in such a way that the remaining random errors are minimized. An example of such a process is computing an average distance from several measurements. The average represents the adjusted value for the distance for which the random error is minimized.

Random errors obey the laws of chance or the random theory of statistics. Therefore, they are analyzed by applying the laws of probability. A complete discussion on the mathematical laws of probability is beyond the scope of this guideline. The reference list at the beginning of this guideline cites some excellent publications concerning the topic.

6.9.6 Sources of error

Errors in measurements stem from three sources: personal, instrumental, and/or natural.

Personal errors

Personal errors are caused by the physical limitations of the human senses of sight and touch. An example of a personal error is an error in the measured value of a horizontal angle, caused by the inability to hold a range pole perfectly in the direction of the plumb line. Personal errors can be either systematic or random. Personal systematic errors are caused by an observer tendency to react the same way under the same conditions. When there is no such tendency, the personal errors are considered to be random. Common sense, self-calibration (estimating personal errors by experiments and experience) and attention to proper procedures generally keep such errors to a minimum.

Instrument error

Instrumental errors are caused by imperfections in the design, construction, and adjustment of instruments and other equipment. Instruments can be calibrated to overcome these imperfections. Examples of instrument error are:

- Imperfect linear or angular scales.
- Instrument axes are not perfectly parallel or perpendicular to each other.
- Misalignment of various part of the instrument.
- Optical distortions causing “what you see is not exactly what you are supposed to see”.

Most instrumental errors are eliminated by using proper procedures, such as observing angles in direct and reverse modes, balancing foresights and back sights and repeating measurements. Since not all instrument errors can be eliminated by procedures, instruments must be periodically checked, tested and adjusted (or calibrated.) Instruments must be on a maintenance schedule to prevent inaccurate measurements.

Natural errors

Natural errors result from natural physical conditions such as atmospheric pressure, temperature, humidity, gravity, wind, and atmospheric refraction. Examples of natural errors are:

- A steel tape whose length varies with changes in temperature.
- Sun spots activity and its impact on the ionosphere, hence on GPS surveying.

Natural errors are mostly systematic and should be corrected or modeled in the adjustment. Some natural errors such as the effect of curvature and refraction can be eliminated by a procedure. The levelling procedure to eliminate curvature and refraction corrections is to average foresights and backsights.

Worked example 1: *Suppose level readings have been taken from nine stations as shown in the following table. Based on these readings, find how much is the error in overall reading of this route while starting from and closed at station-1? Assume the reference level at this project site to be 1210m a.s.l.*

Table 6-2: Level readings given for the exercise

Station	Staff reading		
	Back sight, BS	Intermediate sight, IS	Foresight, FS
1	2.130		
2		1.680	
3		1.030	
4	1.470		1.990
5		1.120	
6		2.400	
7	2.380		1.740
8		1.510	
9			2.150

Solutions:

Based on the given datum level, the reduced level has been computed at each station and the expected error is -0.10 as shown in the following table.

Table 6-3: Solutions for computing errors in level readings

Station	Staff reading			Height of collimation, HI	Reduced level, RL	Remark
	Back sight, BS	Intermediate sight, IS	Foresight, FS			
1	2.130			1212.130	**1210.000**	TBM assumed at datum is 1210.0 m
2		1.680			1210.450	RL=HI-IS
3		1.030			1211.100	
4	1.470		1.990	1211.610	1210.140	RL=HI-BS
5		1.120			1210.490	
6		2.400			1209.210	
7	2.380		1.740	1212.250	1209.870	
8		1.510			1210.740	
9			2.150		1210.100	TBM value = 10.13
	5.980		5.880		1210.100	
Error check			-0.100		-0.100	Both cells should give same value

7 TOPOGRAPHIC DATA PROCESSING AND MAPPING

7.1 DATA MANAGEMENT AND MAPPING

The collected data in the field needs to be downloaded and mapped for use by designers. This is done in the office survey work and tasks, which are performed here, are the following:

- Collect the observed data from field survey team,
- Data's should be download every day to the computer and checked and verify the distribution of data as per the requirement and if the data brought by the surveying team indicates the need for slight modification, then the area should be modified (additional data should be collected),
- Check and verify the collected data, if it is as per the requirements (TOR),
- Make a backup of observed data (the raw and processed data) in a form of soft and hard copies,
- The surveying data could be brought and stored in Excel, text(txt), etc. file format
- The surveyor should use common remark and codes and agree with irrigation team,
- Verifying the availability of sufficient data and the data that brought in one or more of the above format will be handled in the topographic software according to the appropriate grid interval to be decided for the average grid of the area based on the slope as follows:
- For Surface irrigation
    - If the slope is 0-5% the average grid should be 20-30 meter
    - If the slope is 5-10% the average grid should be 10-20 meter
    - If the slope is 10-15% the average grid should be 10-15 meter
- For Pressurized irrigation
    - If the slope is 0-1%, CI (m) is 0.1 meter,
    - If the slope is 15-30%, the average grid should be 10-15meter

7.2 INTERPOLATION OF CONTOUR LINES

A contour is a line drawn on a map, which connects all points of equal elevation above a reference plane. The contour interval will be 0.25 -0.50m for topographic surveys. In general, it depends on:

- Scale of the map
- The requirements of the user. (Purpose for which the map is to be used, i.e. the amount of detail which is desirable for the special purpose of the map). The contour lines are interpolated between the plotted detail points and the schematic sketch in the field book will serve as a reference for the direction of the slope, extent of valleys and courses of riverbanks.
- Slope gradient of the terrain. (The amount of variation between the values being contoured).
- The map has to be produced for each site (dam or Diversion site) by observing their site gradient as per the following slope condition

7.3 COMPONENTS OF MAP

Maps have two basic components/elements:

- The map itself/map body, and
- Marginal information including legends, scales, feature classes, etc.

The map itself/map body is commonly called the 'face of the map' and it is the main part of the map that gives the service that the map is prepared for.

Marginal information is any additional information about the map, the symbols, signs & others indicated in the map. It is prepared outside the map body or on the edge of the map. It is a method of understanding or finding the relationships of features on the map.

There are basic marginal information like title, scale, etc. or additional marginal information such as publisher, sale agent, editor, etc.
Common marginal information are:

- Title of the map,
- Legend,
- Scale,
- Grid reference,
- North Arrow,
- Projection,
- Index Map,
- Production Information.

Production Information includes the following:

- Who produced/published the map,
- Date of publication and/or date of the information shown on the map,
- Limitations of the information,
- Names of organizations and individuals who contributed,
- Names of those who compiled, drew, edited or printed the map,
- The methodology that was used to produce the map,
- Edition (this is not usually added to a first edition map),
- Copyright statement.

7.4 MAP SYMBOLS

Symbols in maps represent the actual features found on the earth's surface.
There are different types of symbols that are used in maps.

- Abbreviation, e.g. names like BM
- Area, e.g. building, boundaries
- Line, e.g. road, pipe, etc.
- Point, e.g. City in smaller scale.

7.5 INDEX MAP

Index map addresses of the map related to adjacent maps.

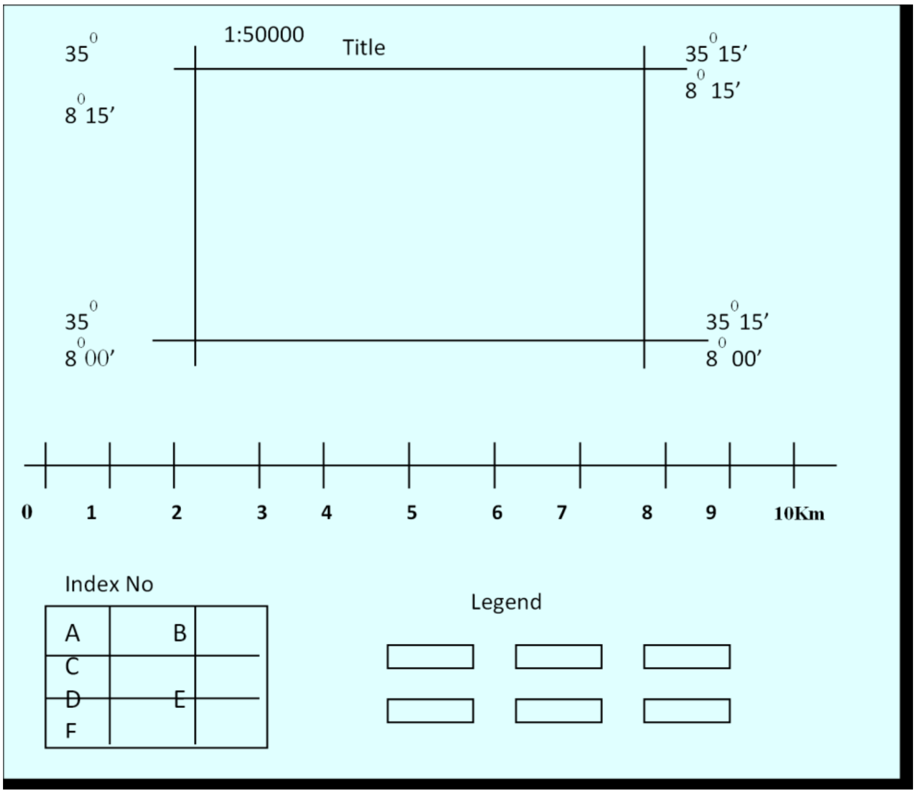


Figure 7-1: Typical layout of index map

7.6 TOPOGRAPHIC SURVEY REPORT

The most important quality in all surveying operation is accuracy. Field notes are the records of a survey data with date recorded in such from that they can be interpreted readily by anyone having knowledge of surveying. Notes or remarks should identify the survey by title, including location and purpose, identification of surveys party members and duties date, weather conditions. Notes should be recorded in a field book at the time. Work is done and not left to memory or later recopied from temporary notes. All data pertaining to one survey or project should be entered in the same field book or series of field books. Notes consist of numerical data, explanatory statements and sketches. Entries should be clear, concise and legible.

The forms in which notes are recorded varies, with different kinds of surveys, such as benchmarks circuits, profiles and cross-sections etc. However uniform system for each kind should be followed in as far as possible. Sketches in field books are important in conveying information and correct impressions to others plotting data or using the information in engineering design. Sketches should be drawn approximately to scale.

In most types of survey, some degree of field check is advisable before leaving the field. Any inconsistencies and omissions may be detected and rectified whereas the surveyor is on the spot. After the field work, the surveying team returns back to the office to work out all the surveyed data and to prepare the required maps, profiles, section, etc. Based on these data and maps the design engineers will carry out the design of the layout, and the calculations for quantities and cost of the project.

The topographic report should include the following maps, profiles, calculation sheets, photographs (of BMs and other important features) and short description of the survey area and its surroundings.

- Situation sketch of the area at approximate scale of 1:2,000 or 1:5,000 or 1: 10,000, showing all topographic features in and around the project area.
- Temporary & permanent access road, quarry area, disposal area, Irrigable area,
- River with dam site,
- Proposed route of main canal between dam site and irrigable area,
- Existing roads,
- Village, town, or any congested areas,
- Separate houses/ tukuls and near border of the area,
- Striking trees, Gullies/new gully formation, Steep slopes, Benchmark station network,
- Project area boundary survey for compensation purpose,
- Short topographic description of project area (1-2 pages).
- List of X, Y, & Z coordinates of collected data,
- Photographs of BMs,
- A contour map with benchmark stations (at a scale of 1:2,000 or 1:5,000 or 1: 10,000), Grids, Northing, Legends, Scale, Title box.

8 QUALITY AND SAFETY CONSIDERATIONS DURING SURVEYING

8.1 QUALITY CONSIDERATIONS DURING CONSTRUCTION SURVEYING

Quality complications during surveying of construction activities may arise right from calibration of the instrument up to accuracies guaranteed while reading and processing the collected data. Consequently, the following sections give how to attain quality of surveying for construction purposes.

8.1.1 Calibration

In the context of survey equipment, calibration is a comparison for confirmation between measurements of one with known magnitude or correctness made or set with one device and another measurement made in as similar a way as possible with a second device. The device with the known or assigned correctness is called the standard. The second device is the unit under test, test instrument, or any of several other names for the device being calibrated.

The validation process differs significantly from calibration in that validation goes beyond simple calibration. The validation process includes:

- The equipment:
  - Is it capable of achieving the required accuracy under project conditions?
  - Are the resulting measurements within specifications, i.e. is it properly calibrated?
- The procedures used in the field as well as in the office;
- In some cases, even the personnel become part of the process.

Procedures for calibration

Whenever a piece of equipment is to be calibrated, the following steps must be in place:

- The person(s) performing the calibration must be well acquainted with the specific procedure for that particular piece of equipment;
- The equipment owner's manual (if any) has been reviewed with respect to the procedure;
- If there is a company procedure in place, that this procedure is reviewed and fully understood;
- All the proper forms must be in hand;

When to calibrate?

There are many reasons why a piece of equipment should be calibrated. Some of them are:

- Statutory as per the Surveys Act or other relevant legislation;
- Event driven, such as:
  - Damaged equipment;
  - New equipment
  - Rental equipment;
- Time driven such as:
  - Heavily used;
  - Un used for an extensive period of time;
  - Prescribed calibration schedules;

Record keeping:

The simple fact that a piece of equipment was calibrated is in itself a good start, however unless this fact is recorded and filed in the proper format, the process becomes exercise in meaninglessness. Thus, all calibration work shall be recorded in the prescribed manner.

If any piece of measuring equipment is found to be 'out of calibration', this must be reported to the project manager at once. If the faulty equipment can be successfully calibrated or adjusted in the field so that it is no longer out of calibration, the procedure may be performed. The 'incident' must still be reported in order that appropriate steps can be taken to ensure that the particular piece of equipment in question can be inspected and cleared for further use.

When to calibrate:

The timing of the calibration or testing of equipment is dependent on a number of factors and can therefore not be prescribed in a rigid manner. This procedure outlines events that will lead to some form of testing to ensure correct readings are obtained as well as provide timing guidelines.

Events that could lead to testing are:

- Equipment is damaged;
- Equipment has been subjected to shock;
- Equipment has been repaired;
- Rental equipment;
- New equipment;
- A significant change in weather or elevation since its last test or use;
- The recommended time limit for a specific piece of equipment has expired;
- A change in the combination of total station/EDM and reflectors;

Recommended timing of calibration, assuming none of the above events would dictate additional tests are tabulated below.

Table 8-1: Recommended timing of calibration of Surveying Equipment

Device to be Calibrated	Recommended Timing of Calibration
Steel tapes	Annually and prior to an official survey
EDM and total stations	Annually or when required for an official survey
Reflectors	Annually
Barometers	Annually or when move to a significantly different elevation
Thermometers	Annually
Tribacs	Quarterly, bubble and centering device
Reflector/antenna poles & bubbles	At least weekly, bubble, verticality and straightness
Levels	Before each project & as often as required during a project to ensure its proper adjustment
Leveling rods and rod bubbles	At the start a project and in conjunction with the level

The basic methods and conditions for performing calibrations, testing or adjustments of survey equipment as adopted from "The Calibration of Survey Equipment, By H.C Engler A.L.S., 2012" are presented in Appendix-III.

8.1.2 Accuracy, precision and errors in surveying

This topic has been discussed in detail under section 7.9, thus can be referred. However, to add some more issues on sources of errors in surveying the following can be raised.

8.1.3 Errors in levelling

Error sources in digital surveying & leveling can be:

- Instrumental Errors
- Collimation Error
- Error due to Curvature & Refraction
- Other Errors

Table 8-2: Instrumental errors and recommended corrections

Instrumental Error	Recommended Correction
Collimation error	Check before use and equalize sights
Under sensitive bubble	Consult the vender/expert
Errors in staff graduation	Check the graduations
Loose tripod head	Fasten the head
Telescope not parallel to bubble tube	Permanent adjustment
Telescope not at right angles to the vertical axis	Permanent adjustment

8.1.4 Error of Collimation

Collimation error occurs when the collimation axis is not truly horizontal when the instrument is level. The effect where the collimation axis is tilted with respect to the horizontal by an angle α is as shown in figure below:

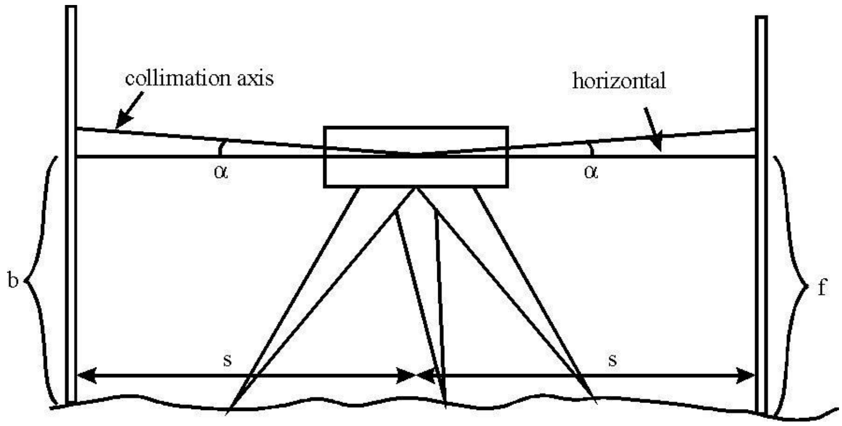


Figure 8-1: Sketch showing collimation error in levelling

8.1.5 Curvature & refraction

8.1.5.1 Curvature

The earth appears to "fall away" with distance due to its curvature. The curved shape means that the level surface through the telescope departs from the horizontal plane through the telescope as the line of sight proceeds to the horizon. This effect makes actual level rod readings too large by:

$$C = 0.0239 * D^2 \qquad \text{(9-1)}$$

Where, C is the Curvature

D is the sight distance in thousands of feet.

Effect of curvature are:

- Rod readings too large,
- error increases exponentially with distance

8.1.5.2 Atmospheric refraction

Refraction is largely a function of atmospheric pressure and temperature gradients, which may cause the bending to be up or down by extremely variable amounts. There are basically three types of temperature gradient (dT/dh):

- Absorption: It occurs mainly at night when the colder ground absorbs heat from the atmosphere. This causes the atmospheric temperature increases with distance from the ground and dT/dh > 0.
- Emission: This occurs mainly during the day when the warmer ground emits heat to the atmosphere, resulting in a negative temperature gradient i.e. dT/dh < 0.
- Equilibrium: In this case no heat transfer takes place i.e. dT/dh = 0, and occurs only briefly in the evening and morning. Thus, surveying is preferred at these times if possible.

The result of dT/dh < 0 is to cause the light ray to be convex to the ground rather than concave. This effect increases the closer to the ground the light ray gets and errors in the region of 5mm/km.

The atmosphere reflects the horizontal line of sight downward, making the level rod reading smaller. The typical effect of refraction is equal to about 14% of the effect of earth curvature.

8.1.5.3 Combined effect of curvature & refraction

The combined effect of curvature & refraction can be approximated from:

$$(C - r) = 0.0206 * D^2 \quad \text{.......... (9-2)}$$

Where, r is the Refraction, C& D as defined above

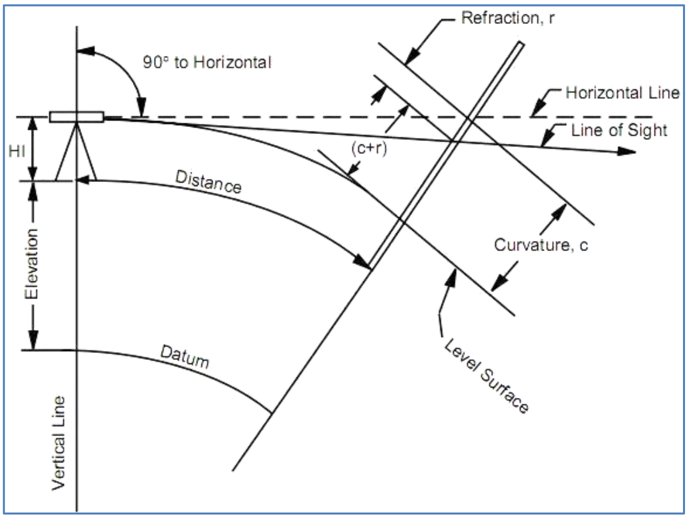


Figure 8-2: Combined effect of curvature & refraction

The formula for computing the combined effect of curvature & refraction is:

$$C + R = 0.021\, D^2 \quad \text{.......... (9-3)}$$

Where, C is correction for curvature
R is correction for refraction,
D is as defined above

The followings are considerations for eliminating error due to curvature & refraction:

- Proper field procedures (taking shorter shots and balancing shot);
- Wherever possible, staff readings should be kept at least 0.5m above the ground;
- Using short observation distances (25m) equalized for backsight and foresight;
- Air below is denser than air above thus line of sight is bent downward which negates earth curvature error by 14%;
- Simultaneous Reciprocal Trigonometrical Heighting;
- Observations made at each station at exactly the same time, cancels the effects of curvature & refraction.

8.1.6 Other sources of errors in levelling

Other sources of errors in levelling and their recommended corrections are shown in table below.

Table 8-3: Other sources of errors in levelling and their correction

Types of Error	Recommended Correction
Incorrect setting-up of instrument	• Setting-up the instrument properly
Movement of staff from position when changing level station	• Training the staff-person • Experienced/Skilled staff-person
Staff not held vertically	• Hold rod firmly; Use head/body to support it.
Parallax: Instrument knocked or moved during backsight-foresight reading	• Adjust parallax error if any
Ground heating causes chaotic refraction of light	• Shorten the length of shots Shorten the length of shots • Keep measurement 2-3 ft above ground • Avoid leveling during noon hours
Tripod or rod settles between measurements e.g. Bubble off center	• Quick measurements between rods • Avoid muddy or thawing ground • Avoid hot asphalt • Don't exert pressure on turning point

Table 8-4: Summary of possible errors in leveling survey & recommended corrections

Possible Errors in Leveling Survey	Recommended Correction
Instrumental Error	
• Telescope not horizontal	• Two peg test
• Bubble out of adjustment	• Bubble test
Handling errors	
• Circular bubble not level	• Check circular bubble
• Staff not vertical	• Check staff bubble, or rock staff back and forth
Movement of level or staff	
• Level or tripod moves	• Screw level/tripod firmly to tripod
• Position of staff changed during observation	• Ensure staff not shifted
Reading errors	
• Stadia hair read by mistake	• Place tripod firmly on solid ground
Booking errors	
• Reading written in wrong column	• Double check booking
• Wrong position noted	• Double check booking
Calculation errors	
• Mistake in rise/fall	• Double check calculations
• Mistake in reduced level	• Double check calculations
Closing errors	• Compare with accuracy allowed

8.1.7 The two peg test for surveying

This test should be carried out prior to each day's surveying, particularly if the instrument has been knocked or dropped. The test checks whether the line of collimation of the instrument is perfectly horizontal. Figure below clarifies this:

The Procedure for testing is as follows:

- Set out two pages at A and B (60 m apart), set up the level exactly midway between them and take readings on each staff.
- Move the level as close as possible to one staff (say 2m from A) and again take the staff readings at A and B.
- Compare the vertical difference in level between pegs A and B from the two instrument positions. If not identical (to within 5 mm) then the instrument's collimation should be adjusted as follow.

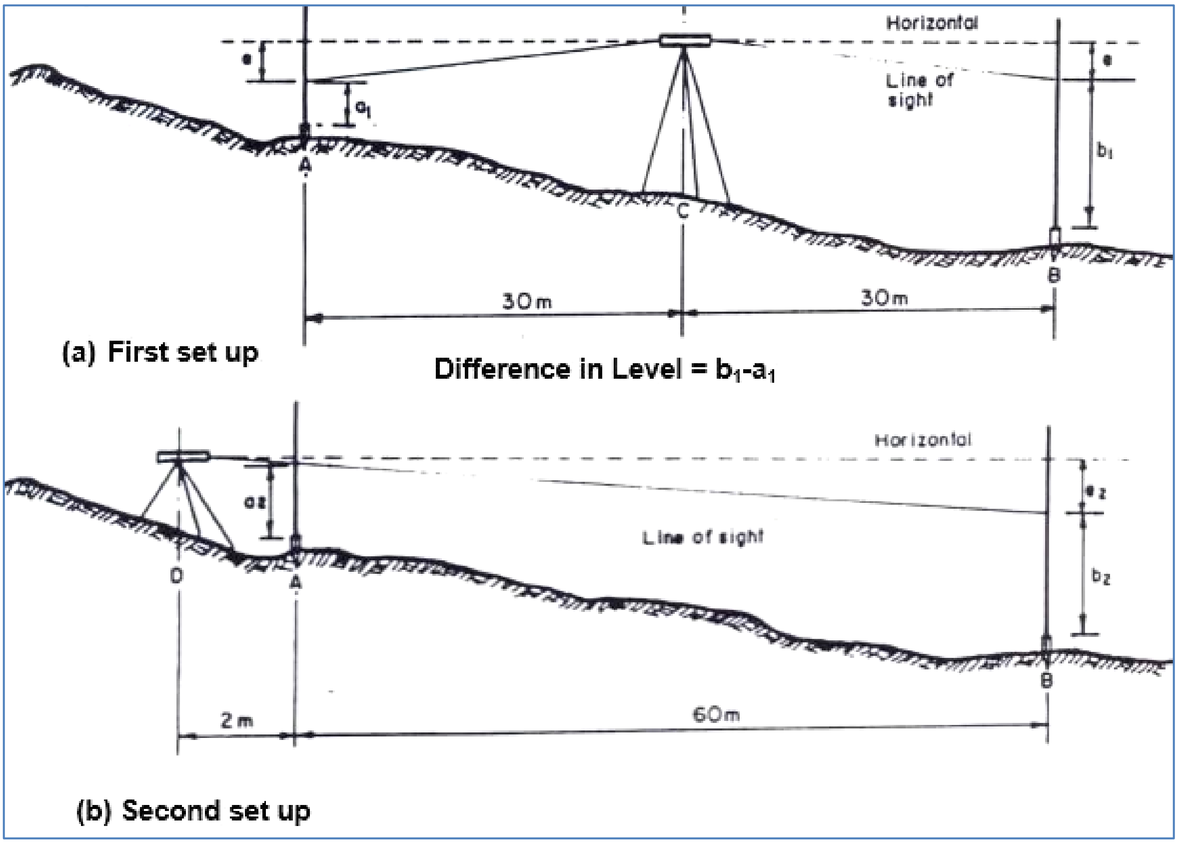


Figure 8-3: Two peg test method for checking accuracy of surveying instrument

The Procedure for adjustment is as follows:

- Sight staff at B from the instrument at position D
- Remove the eyepiece cover, rotate the adjusting screws using the special adjusting pin provided, and adjust the reading on the staff so that the difference in level between the two pegs A and B is the same as it was when viewed from position C.
- Check that the correct adjustment has been made and replace the eyepiece cover.

8.1.8 Checking and adjusting tribrachs

8.1.8.1 General

The errors generated by a tribrach that is out of adjustment depends on several factors:

- If only the bubble is out of adjustment;
- If only the plummet is out of adjustment;
- If both are out of adjustment;

These errors are basically unpredictable and impossible to correct for them. The one thing that is known is that the total station/prism is not setup over the point, thereby creating an error in distances as well as angles. The only solution is that make sure the tribrach is checked and properly adjusted. Checking tribrachs is a very important undertaking. The process consists of two main steps:

- Checking and adjusting the circular bubble;
- Checking and adjusting the optical plummet;

8.1.8.2 Checking and adjusting the circular bubble

The purpose of this process is to ensure that when the circular bubble is centered in the circle the tribrach is in fact level. In order to check the circular bubble, one needs a method of ensuring that the tribrach is in fact level. One can use a number of methods to achieve this, among them are:

- Use a target equipped with a good tubular bubble complete with marking;
- The electronic collimation in a modern total station;
- Any other means that utilizes a bubble that is superior to the circular bubble.

Once the tribrach is known to be level, the circular bubble is adjusted by forcing the bubble to the center of the circle by adjusting the screws that exist for that purpose. Ensure that the bubble is still firmly controlled by these screws.

8.1.8.3 Checking and adjusting the optical plummet

The purpose of this process is to ensure that when the tribrach is in fact level, the optical plummet is aimed exactly at a point that is known to be precisely under the center of the tribrach. The tribrach should be forced center mounted on a bracket firmly fixed to a wall. A target on the floor must be set by a suitable method that can ensure that the target is precisely under the center of the tribrach.

With the tribrach level and centered over the target, the optical plummet cross hairs are forced to point at the target by using the adjustment screws in the tribrach. We now have a tribrach that will, when leveled, in fact be directly over the point within the manufacture's specifications. This is usually in the order of 1mm per meter above the ground.

8.2 SAFETY CONSIDERATIONS DURING CONSTRUCTION SURVEYING

Safety rules are important to prevent any possible impact on survey team, local communities, properties and on the quality of the output. Consequently, the contractor shall facilitate:

- Local communities awareness,
- Check security,
- Keep to use existing tracks in order not to disturb properties (such as land, houses, fences, etc.) of the communities,
- Get permission from each spot of landowners,

- Labour safety shall include as mandatory protective like helmet, boots, Gloves, protective eyeglass, overalls, belts for drivers & operators, first Aid kits, Orientation & awareness creation on HIV, Malaria and other infectious and contamination disease,
- There shall not be any interference in culture of local communities as it may result in conflict of interest and hence delay of construction,
- Toilet & sanitation system in the camping and other areas should be reasonably far away from residential, community and public service areas.

8.3 CARE TO BE TAKEN DURING SURVEY PLANNING

When planning survey operations, safety considerations shall be given first priority. Such considerations includes, but not limited to:

- The optimum time of day (or season) to accomplish a particular job,
- Assignment of more experienced personnel for more potentially hazardous jobs, special work zone protection and traffic control requirements, and
- Discussion on any recent accident, its cause and appropriate corrective action.
- Discussion on alternative surveying techniques,
- A hard-hat, substantial footwear and reflective safety vest,
- Every surveyor need to inform objectives of site visit to the local administrators before entering in to field survey operation. Similarly, communities need to get awareness for the objective of the visit ahead of commencement of the survey work.

Survey supervisors are responsible to assure the survey crew has the necessary tools, safety equipment, and training needed to comply with the project work. The supervisor is also responsible for addressing safety concerns as they arise to assure the survey is not conducted under unsafe conditions. Survey Supervisors are required to read, promote and enforce all advisements, cautions or warnings, which pertain to survey operations of the project.

8.4 EQUIPMENT CARE, CHECKS AND SAFETY

8.4.1 Use and care of instruments in the field

Before starting traverse survey (traversing), careful attention should be given to the following points/suggestions to save needless wear on instruments and reduce the dangers of accidents to a minimum, to increase the quality and quantity of the field work.

- Equipment transportation,
- Tripod (Inspect the tripod legs and shoes),
- Handle the instrument gently in removing it from and returning it to the case,
- See that the instrument is securely attached to the tripod. Undue haste may sometimes result in costly accidents. When screwing the instrument on the tripod head, it should first be turned in a counter-clockwise direction until a slight click is heard, indicating that the threads are properly engaged,
- Always attach the sunshade regardless of the kind of weather. It is part of the telescope tube. In attaching or removing the sunshade, hold the telescope tube firmly with one hand and with the other hand twist the shade to the right,
- Before beginning the observations, focus the eyepiece perfectly on the cross hairs. This is best done by sighting the sky. Special care must be exercised so as not to sight the sun directly. Doing so can damage the Total Station. This repair is very expensive,
- When setting up in the field, bring the tripod legs to a firm bearing with the plates approximately level. Give the tripod legs additional spread in windy weather or in places where the instrument may be subjected to vibration or other disturbances. On side-hill work, place one leg uphill. With the level, place two levelling screws in the general direction of the line of levels,

- If the instrument should get wet, thoroughly wipe it dry before returning it to the case. Take the instrument indoors at night for further drying if necessary,
- Cultivate from the very beginning habit of delicate manipulation of instrument. Rough & careless treatment of field instruments is characteristic of an unskilled operator,
- In levelling the instrument, the levelling screws should be brought just to a comfortable bearing. If screws are too loose, the instrument shakes and accurate work cannot be done. If too tight, the instrument is damaged and the delicacy and accuracy of the observations are reduced. Much needless wear of levelling screws may be avoided if the tripod head is brought about level when the instrument is set up. Upon completion of setup, levelling screws must be returned to a neutral position. Levelling screws in a tribrach must not be overextended,
- Do not remove or rub the lenses of the telescope. If necessary to clean the lens, dust first with a soft, clean camel's hair brush and use a very soft cloth with caution to avoid scratching or damaging the polished and coated surfaces,
- The apparent cause for the major portion of survey equipment repair costs is the direct result of carelessness or the lack of adequate consideration in prevailing obstacles such as stone walls, all types of fences, rocky precipitous areas, shallow stream beds with unstable footing, etc. It is the sole responsibility of the instrument person to anticipate the seriousness of these obstacles when carrying a precision instrument and to utilize the assistance of other members of the crew to assure the absolute security of the instrument. It is also the responsibility of the Crew Chief to insist constantly the above precautionary measures be fulfilled.

8.4.2 Checks and safety

If the surveys are to be connected into the national or local coordinate system of the country then the position of as many national survey points as possible, should be located. Before starting any measurement in any type of surveying works, the surveying equipment like total stations must be checked. All possible sources and types of error arising from the equipment and from the procedures must be checked as follows:

Check 1 - Functioning check in two parts (Daily):

- visual checks of the equipment and accessories, general maintenance, cleaning of optical surfaces, charging batteries, drying, optical plummet; and
- Operating checks according to the instructions in the manufacturer's manual,(for example concerning warm-up time, measuring signal strength, pointing to the reflector, centering, measuring and using meteorological data). Also, site procedures and recommendations must be followed as well.

Check 2 - Performance checksum home test field for detection of changes (Daily):

The stability of the EDM instrument should be checked by comparing measurements on a home test field with known lengths for different ranges. Such test fields consist normally of one marked instrument station at the office (indoors or outside) and three permanently mounted reflectors at typical distances for the usual working range of the particular EDM instrument (e.g. from 50m to 300m. In any case, this kind of test field should be established each time a project is started for EDM checks during the whole period of the project. The first day's results will give the actual reference values and should be recorded in a logbook (and/or on disk or tape) for future reference.

Check 3 - Using calibration for (At regular intervals, 3 months to not more than 1 year):

- The best way to do this is to use existing calibration baselines. If such baselines are not accessible for different reasons (which are the normal case in many places and countries), temporary short-range baselines, specific to the needs of the check, must be established.
- Detection of the error sources, determination of the actual values of the IC parameters (additive constant, cyclic and scale corrections) and meteorological sensors must be determined.
- Install software on the instrument, which indicates necessary calibration timely.

REFERENCES

- Basic Measurements, By J.E.; L.S.P. & Associates; C.M., 2007;
- Bench Mark Reset Procedures, By NGS, 2010;
- Design Manuals on Surveying and Map Production, By MoWR, 2002;
- Control and Topographic Surveying, By US Army Corps of Engineers, 2007;
- Standards & Guidelines for Land Surveying Using GPS Methods, By The Survey Advisory Board, Washington, 2004;
- Surveying for Planning, Design, Construction & Supervision, Training Material, By GIRDC, 2015;
- Survey Manual, By Tennessee Department of Transportation, 2011;
- The Calibration of Survey Equipment, By H.C Engler A.L.S., 2012.

Web Sites

- http://www.state.nj.us/transportation/eng/documents/survey/Chapter3.shtm
- http://www.state.nj.us/transportation/eng/documents/survey/Chapter6.shtm

APPENDICES

APPENDIX I: Summary of topographic, cross sections, plan & profile standards

Nr	Item	Standard
1	Bench Mark System	Distance is 500 m to 1 000 m
2	Head works (Weir, Dam, Intake, Pump)	
2.1	Site plan	25m x 25m (or less depending on terrain) at a scale of 1:500
2.2	Length of natural stream/river cross section	
2.2.1	Length of Profile natural stream	U/s 300-500 m & D/s 500 m depending on steepness/gorgy-ness of the banks
2.2.2	Plan and Profile natural stream	1:500 H and 1:100 V
2.2.3	Cross Section	Every 25 m along each bank; 1:100 H and 1:100 V
3	Main Canal	
3.1	MC Alignment	-
3.2	Longitudinal Profile	1:500 to 1:1000 H and 1:100 V
3.3	Cross Section	Every 20 m along each bank; 1:100 H and 1:100 V
4	Other Structures	
4.1	Site plan	1:500 H and 0.25 to 0.5m CI
4.2	Longitudinal Profile	U/s 25 m & d/s 25 m for a length of 250 to 500 m; 1:500 H and 1:100 V
4.3	Cross Section	1:100 H and 1:100 V
5	Command Area	Base Map/Topographic Map 1:2000 & CI= 0.25-0.5m

APPENDIX II: Procedures to replace a destroyed bm along an existing level line

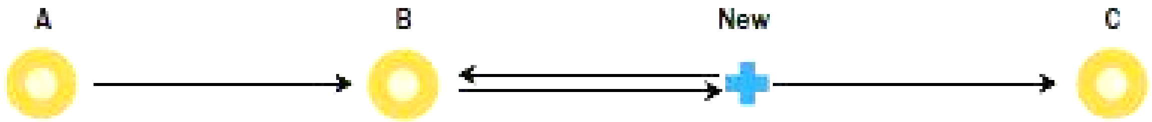
Bench Mark Reset Procedures

Attachment A. Guidelines and Procedures to Replace a Destroyed Bench Mark along an Existing Level Line, and Maintain Original Order of Accuracy

The guidelines and procedures given below were written to provide guidance on establishing, to the same order/class, one or two bench marks along a previously leveled line of bench marks, from the remaining bench marks along that line. If a large number of bench marks in a row, along a line, are destroyed, it is required that a minimum of two or three existing bench marks, depending on the intended order and class, on each side of the destroyed bench marks be tied. Alternatively, the entire line may be re-leveled.

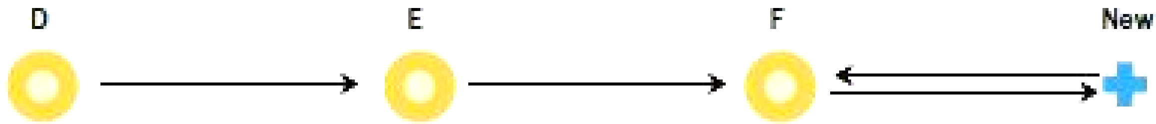
Following these guidelines and procedures will result in the height of the new bench mark published, to millimeters, and the accuracy will be published to the same order/class as the original line. The results will NOT be published as a 3rd Order "reset" bench mark.

Network Geometry for Replacing One or Two 1st Order Bench Marks



1st Order (preferred method): (A, B, and C are existing 1st Order bench marks)

A to B = single-run, must check* published difference
B to NEW = double-run, forward and backward leveling must check*
NEW to C = single-run
B to C = not directly leveled, but must check* published difference



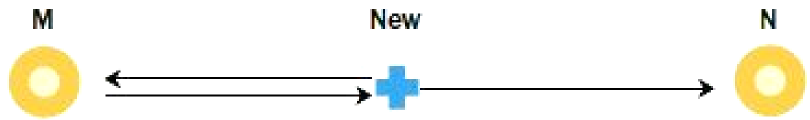
1st Order (optional method): (D, E, and F are existing 1st Order bench marks)

D to E = single-run, must check* published difference
E to F = single-run, must check* published difference
F to NEW = double-run, forward and backward leveling must check*

**Note: "Check" refers to "Maximum section misclosure (millimeters)" of $4\times\sqrt{D}$, as defined for 1st Order, Class II levels; where D is shortest length of section (one-way) in kilometers, in the publication "FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems."*

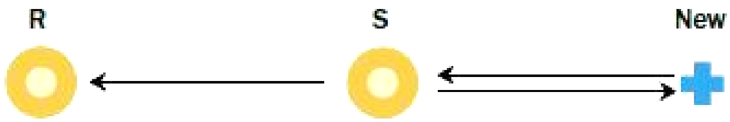
Bench Mark Reset Procedures

Network Geometry for Replacing One or Two 2nd Order Bench Marks



2nd Order (preferred method): (M and N are existing 2nd Order bench marks)

M to NEW = double-run, forward and backward leveling must check*
NEW to N = single-run
M to N = not directly leveled, but must check* published difference



2nd Order (optional method): R and S are existing 2nd Order bench marks)

R to S = single-run, must check* published difference
S to NEW = double-run, forward and backward leveling must check*

**Note: "Check" refers to "Maximum section misclosure (millimeters)" of $6\times\sqrt{D}$, as defined for 2nd Order, Class I levels and $8\times\sqrt{D}$, as defined for 2nd Order, Class II levels; where D is shortest length of section (one-way) in km, in the publication FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems.*

Source: Bench Mark Reset Procedures, By NGS, 2010

APPENDIX III: Methods & conditions for calibrations, testing or adjustments of survey equipment

Equipment	Tested Against	Conditions	Comments
Steel tapes	Approved standard tape	Both tapes to be at the same temperature & fully supported	Use tension handles
Cloth tapes	Any tested steel tape	Correct steel tape for temperature.	Use tension handles
Level rods	Any tested steel tape	Correct steel tape for temperature if rod face is metal	
Barometers	A barometer known to be correct		If done at an airport ensure that it is the absolute pressure you are given.
Pin Locators	Test at a known iron post before use	Known post should be counter sunk or keep pin locator at least 60cm away	Ensure that the batteries have enough charge.
Levels	Two peg test and adjust	Test as required, could be daily.	On larger projects setup a 'baseline'
EDM / TS distances	Approved baseline OR Project baseline	Overcast days are best	Ensure that all the required information is recorded.
Prisms	Part of baseline test	Easiest be done on unknown baseline	
Prism poles	Test for vertical with a total station	Test bubble in office testing bracket.	Adjust bubble as required
Tribrachs	Test and adjust in office test bracket	Ensure that all screws are tight	
Total stations	Check horizontal & vertical angles & 'adjust' as per the user manual		Always double critical angles

Source: The Calibration of Survey Equipment, By H.C Engler A.L.S., 2012

APPENDIX IV: Procedure for setting up the total station

When mounting or removing the instrument from the tripod, it should always be held with at least one hand. It should never be left on the tripod without being fastened by the tripod screw. Adjust the tripod legs to a height suitable for observation and set it up on the ground.

For angle measurement, set the tripod over the point of reference on the ground, using a plumb bob, and firmly push the legs into the ground. Place the instrument on the tripod head and secure it using the tripod screw. When measuring angles, lightly tighten the tripod screw and adjust the position of the instrument on the tripod head so the plumb bob hangs vertically above the point of reference, then clamp the tripod screw firmly.

Place the telescope parallel to a line connecting any two of the three levelling (or tribarch) screws, so the levelling bubble is visible. Bring the bubble to a midway position by turning each screw so that the thumbs travel either towards or away from each other. The bubble, which will always move in the same direction as the left hand thumb, should be set midway between the two screws and in-line with the third. The third screw is now adjusted to centralize the bubble by moving it until it is positioned inside the setting circle. The bubble should be checked for different horizontal alignments of the telescope to see whether it maintains is central position.

Directing the telescope at a bright section of sky, rotate the eyepiece until the cross hairs are sharply focused. Check the cross hairs remain focused when sighting an object. There should be no parallax: this means that when the eye is moved up and down, the cross hairs remain in the same position relative to the object.

Ensure that the staff is held vertically, either by using the circular bubble provided with the staff, or by requesting the staff man to rock the staff forwards and backwards through about 150 either side of the vertical. In the telescope the cross hair will appear to drop down the staff, and then rise. The minimum observed value is the correct staff reading; the staff is then vertical. Check with the staff man that the telescopic sections of the staff are pulled out until they click firmly into position. For practical purposes, make a V of toes; keep the staff straight between the V and touching the tip of the nose.

During observation, it is important to ensure that:

- The circular bubble is levelled correctly;
- The tripod is firmly pushed into the ground;
- The tripod screw is tight;
- The tripod is not grasped roughly or knocked;
- The staff is kept in the same position on the ground while taking a reading;
- When taking a backlight or foresight reading, the staff is placed on a solid object such as a benchmark on a structure, a peg, a metal change plate or a brick;
- The eyepiece is properly focused to remove parallax.

When moving the instrument, it is very important to carry it correctly by either removing the instrument from the tripod and placing it in the instrument box before moving on, or lifting the tripod with instrument attached and carrying it, held vertically, to the next instrument position. Failure to observe these precautions may result in damage to the instrument.

APPENDIX V: Summary of surveying types

Based on Accuracy	
Plane	Survey ignoring the spherical nature of the Earth and assumes meridians are parallel.
Geodetic	Survey considering the spherical nature of the Earth.
Based on Method Used	
Chaining or Tapping	Old method of surveying for linear measurements using tapes or chains.
Traverse or Boundary	Open or Closed Surveying used to determine horizontal distances in a plane often for boundary or alignment determinations.
Ranging	Surveying made to establish a number of intermediate points on a line joining two stations.
Levelling	Surveying used to determine vertical distances or elevations using a Level.
Plane Table	Surveying where Field Work and Graphical Representations are done at the same time.
Control	Surveying made to determine reference positions, objects, lines, or boundaries.
Triangulation	Surveying for large area made with a baseline distance measurement and all other angles of networks of triangles.
Topographic	Surveying made to represent the natural and artificial features of the Earth on a map.
Route	Surveying made to locate, align & set out formation levels along horizontal or curved lines
Electronic Dist. Meas. (EDM)	Surveying made to determine distances using light or radio waves.
Trilateration	Surveying based on Triangulation only with distances measurement of the networked triangles.
Aerial Photogrammetry	Surveying made by taking photograph, using camera fitted in an airplane.
Global Positioning System	Surveying made to determine position on Earth with reference to satellite datum called satellite constellations using ground control network & receiving + processing equipment.
Based on Instrument Dev't	
Pre-Light Based	Tapping, Chaining & Angle Measurement using Non-light based Surveying Instruments such as Tape, Compass and Chains.
Light Based	Traverse, Plane Table, Triangulation, Topographic and Route using Light Based surveying instruments such as Transit, Level & Theodolite.
Image Based	Traverse, Plane Table, Triangulation, Topographic & Route using Image Based surveying instruments such as Aerial Photogrammetry.
Electronic Based	Distance Measurement using EDM and all others except Photogrametry & GPS by Total Station.
Remote Sensing Based	All types of surveying except Chaining, Tapping and Plane Tabling using Remote Sensing Based Surveying Instruments such as Global Positioning System and Geographical Information system.
Based on Place Surveyed	
Land	Surveying made on land including City and/or Cadastral, Traverse, Route and Topography.
Hydrographic	Surveying made on water bodies to chart shorelines and terrain characteristics under water.
Underground	Surveying made to plan & fix positions & directions of underground structures.
Purpose	
Engineering	Surveying made to avail sufficient data for designing and constructing engineering projects.
Others	Surveying made for defense, geological, mining, geographical and Archeological purposes.
Stages in Surveying	
Desk Study and Office Work	Preparatory surveying works using existing graphical representations. Verification of Existing Map; and if necessary incorporating new features by rough survey.
Reconnaissance & Field Work	Surveying made for apportioning of sites; and Selection of routes, sites and structures.
Preliminary Design	Surveying made detail enough for designing physical infrastructures.
Construction	Surveying made detail enough for constructing physical infrastructures.

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