

## SECTION I - RECONNAISSANCE SURVEYS

**1. Definition.-** Reconnaissance Surveys are surveys not conforming to rigorous standards of departmental survey, due to limitations of time or movement of personnel on account of terrain and climatic conditions, or civil, political or military disturbances.

**2. When employed.-** Such surveys are employed to produce maps by the quickest means in connection with expedition and exploration parties. Often they are made for geographical or military purposes, and they differ from normal topographical surveys in two ways. Firstly, the time at the disposal of the Surveyor is usually limited and his movements confined to certain lines of advance ; secondly, there is neither the necessity nor the possibility of obtaining the minute accuracy insisted on in rigorous topographical surveys.

**3. Methods employed in the past.-** Normally all such surveys were carried out on scale 1-Inch = 4 miles or 1 : 250,00, except important routes and localities which were surveyed on larger scales. These surveys were based on triangulation wherever possible even of lesser accuracy. Astronomical observation, base measurement and wireless time signals established the required connection and checks. A number of rough instruments like the Barr and Stroud range-finder, Perambulator, Pedometer, Barometers, Parallax attachments to sight rules, etc. were in use, in addition to the usual theodolites, tachs and plane-tableing equipment.

**4. Changed condition.-** With the emergence of **air born or space born** techniques, reconnaissance surveys will normally be based on aerial photographs / **high resolution satellite imageries**. Techniques for preparation of photo-mosaics / **ortho-photo** have replaced the conventional ground methods **and analogue photogrammetry method** and are briefly described in the following paragraphs :

**5. Rapid Air Surveys.-** As reconnaissance survey implies, the ground control is either sparse or not available, and the areas are unmapped or have some kind of reliable or less reliable old maps. Aerial photographs / **satellite imageries** can, however, fulfill the mapping requirements of the areas and achieve considerably high relative accuracy in detail and depiction of hill features. Three specific materials can be processed for the purpose in digital environment:

- (i) **Vector maps.**
- (ii) **Photo –mosaics/ ortho photos,**
- (iii) **Annotated photo-maps /satellite imageries**

*Vector maps* contain **all informations which are represented either point, line or area features with or without attributes & proper symbology . The feature identification / attribute collection can be done while ground truthing.**

*Photo-mosaics/ Orthophoto* give more information **and** can be quickly prepared; but they require a certain amount of **skilled manpower for its preparation and** correct interpretation.

*Annotated photo-map/satellite imagery* is a mean between **vector** map and a photo-mosaic/**Orthophoto** ; but the preparation of this map requires **skilled manpower** and consumes more time in case old map of the area is not available.

**6. Photography.** – Before taking up any project for rapid mapping, the available maps, ground control etc, should be systematically analyzed and a suitable flight plan decided. In view of the scanty ground control and urgency of work, optimum enlargement from photo scale to map scale, within the limitations of **digital photogrammetric work station**, should be thought of and the smallest photo scale chosen to keep the number of models minimum. The strips should be planned to cover ground control and map detail to the best advantage of subsequent extension of control **by digital photogrammetric methods**.

However, in case of digital photography optimum Ground Sampling Distance(GSD) for map scale to be decided while finalizing pixel size.

**7. Control extension.** –In digital photogrammetry only a few plan and height control points are required as compared with analogue photogrammetric methods. With the help of these control points sufficient tie points can be generated for the block adjustment and desired accuracy can be achieved.

Provision of height control by aerial triangulation is equally a problem owing to sparse ground heights available for strip adjustment. **With latest terrain mapping techniques like Airborne Laser Terrain Mapping(ALT M)** , height control sufficiently accurate for topographical mapping with large contour interval can be provided **throughout the area**.

**8 Feature Extraction.-** Using the **modern digital photogrammetric method** various digital models ie Digital Elevation Model(DEM), Digital Terrain Model(DTM), Digital Surface Model(DSM) etc. can be generated. Digital Terrain Model(DTM) can be used for generation of contours at desired interval. DTM can also be utilized for generation of orthophoto/rectified photo from which 2D feature extraction can be carried out.

If reliable small scale maps are available, they can be **scanned and digitized**. Insertion, correction and completion of detail **from photograph/ satellite imagery along with contours are appended on vector data generated from the small scale map**.

**9. Photo-mosaics.-** A vertical **aerial photograph/ satellite imagery** of a flat area resembles a **vector-map** and is almost true to scale and sometimes easier to read. A mounted mosaic (either uncontrolled or semi-controlled ) of photographs/ **satellite imagery**, taken on a desired scale, can be used for reconnaissance and exploration.

Names of streams, villages etc., and remarks as available can be **annotated** on the **digital mosaic/orthophoto before printing** in suitable colours. In case **vector-maps** are required, **it can be prepared by digital methods**. The **vector** can also **superimposed over digital mosaic to understand the area better**.

**Digital photo mosaic can be printed on desired scale depending upon the resolution of raster.**

Such **digital** mosaics can be prepared if the ground is either gently undulating or covered with low hills. They are not possible for mountainous areas with excessive height variation, and consequent variation in the scale of photography from photo to photo. A reasonably accurate mosaic can be prepared if the ground relief does not exceed 25% of the flying height.

**10. Ground Survey.-** Orthophoto/vector map may be supplemented by ground verification as and when possible, by the personnel of the reconnaissance team or by the army survey units, who will, in any case, carry out special road surveys along all possible routes available for marching. This includes addition of detail and hill features left out on either side of the road for about 3 to 4 km, or even more, if convenient.

**11. Degree of accuracy of maps.-** It is essential that sufficient notes are prepared for inclusion in the History Sheet and Compilation Index regarding the reliability of the map with special emphasis on the following points :-

- (a) Material from which the map is compiled, giving date of survey, photographs /imageries used , maps consulted, etc.
- (b) The reliability of the control points used.
- (c) How hill features have been depicted, whether they are form-lines with little or no height control; or contours generated from DTM with height control, or contours surveyed by ground methods.
- (d) The source from which the names have been collected.
- (e) Classification of roads.

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## SECTION II.-----RECTANGULATION AND SETTLEMENT SURVEYS

### PART I – OBJECTS AND BRIEF HISTORY

**12. Objects.**—Rectangulation is the process of dividing up any portion of land surface into rectangles of a fixed size by accurate methods and demarcating their corners with permanent marks. It satisfies, in a single operation, the requirements of the Irrigation and Revenue Departments as regards engineering, consolidation of holdings and revenue administration. Rectangulation provides a simple, quantified, graphic record of irrigable areas, and facilitates assessment of irrigation duty, land revenue and crop statistics. The contoured maps prepared on the basis of rectangulation, supplemented by spirit leveling, with necessary topographic features, are essential for correct design or layout, estimate and economic construction of water courses. For obvious reasons the total rectangulation system is maintained on an equal-area map projection—the Cassini’s spherical rectangular. In this projection, all bearings refer to the longitude at origin, and distances are kept true. The use of this rectangular co-ordinates has serious limitations. The area which can be divided by rectangulation should normally not extended beyond 2 degrees east or west of the origin.

**13. Brief History.**—The system of Rectangulation was first introduced in Punjab for Lower Chenab in 1890 and executed by the Irrigation Department. The aid of the Survey of India was subsequently sought in laying out the frame-work of the rectangulation by base-lines at about 8 kms intervals. The divisions into units and sub-units was carried out by the Irrigation and Revenue Departments. Since then, the Survey of India has carried out surveys for Lower Bari Doab Canal, Gujrat Rectangular Survey; Upper Jhelum Canal, Sind Sagar Doab (Thal Project), Satluj Valley Project and Haveli Project, during the period 1906 to 1926.

An account of these surveys is given in Professional Paper No. 21 of the Survey of India ‘Irrigation and Settlement Surveys 1926’.

Rectangulation for the Bhakra Irrigation System and Rajasthan Canal Project has been undertaken in recent years. Sheets published in F.P.S. system for these projects have been appended as Annexures F and G respectively.

Rectangulation in metric system has not so far been undertaken in the Department. However, specifications in this respect have been worked out for a block ( 50km x 50 km ) of 2,50,000 hectares, medium rectangles ( 5 km x 5 km ) of 25 hectares and small rectangles ( 500 meters x 500 meters ) of 25 hectares each, leveling mesh at 25 hectares rectangle corners will be provided and sheets of 10 km x 10 km will be published on 1 : 15,000 scale with a contour interval of 0.5 metre. Charts and indexes etc., appended as Annexure A and D are all as per these specifications and future rectangulation surveys should conform to these.

## PART II. PRELIMINARY CONSIDERAZTIONS FOR DECISIONS WITH INDENTERS

**14. Layout.-** The main considerations for layout of rectangulation are :-

- (i) Size of blocks, main and small rectangles leading to subdivisions of the dimensions required by the indenter.
- (ii) Orientation of the rectangles.
- (iii) Design, content and dimensions of map sheets.
- (iv) The numbering system for sheets and corner mark-stones.

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**15. Block.--** The area for survey is divided into blocks, the dimensions whereof are so determined as to lead by method of division and subdivision to land units of area and dimensions required by the irrigation or revenue departments or other indenters. A block is thus a multiple of main rectangles, and forms a convenient basis for design of main traverses and leveling circuits. The letter and/or index designating a block forms part of the numbering systems of corner stones within a block. For purposes of mapping, a block is divided into a number of sheets comprising uniform groups of main rectangles. After these decisions are taken in consultation with the indenters, the work of Rectangulation comprises the following sequence of operations :-

- (i) *Administration*
  - (a) Selection of origin and orientation.
  - (b) Division of the area into blocks.
- (ii) *Field work*
  - (a) Subdivision into main rectangles and laying and numbering of corner stones.
  - (b) Further subdivisions into small rectangles.
  - (c) Levelling.
  - (d) Detail survey.
- (iii) *Processing*
  - (a) Compilation.
  - (b) Printing.

**16. Main Rectangles.-** (a) *Size.--* The size of main rectangles is governed by survey considerations alone, and should be the largest possible compatible with the possibility of subdivision, within permissible limits of error, into small rectangles by the methods employed. They must be capable of subdivision into rectangles of the dimensions required by the indenter and their sizes should be determined after that of the small rectangles has been decided. The actual size of the sides will, however, depend upon the nature of the country and may vary from 2 to 5 kilometers.

(b) *Orientation.-* The orientation of the main rectangles will be decided considering the extent of the entire area for the project and the general slope of the ground. North-South and East-West are the most convenient and should be adhered to wherever possible. In the method of demarcation described later, all sides of main rectangles and only those sides of small rectangles which are parallel to the short sides of main rectangles, are cleared on the ground. As cleared lines greatly facilitate leveling, main rectangles should be so oriented that their short sides lie in the direction of leveling, which is usually that of the slope of the ground.

**17. Small Rectangles.**—(a) *Size*—The size of small rectangles is decided in consultation with the indenters, according to the local system of land measurement. The governing considerations are that they should be capable of subdivision into final plots of the desired dimensions and that they should be of the size necessary to provide levels at the points required for the planning of the project. In Punjab, the sizes of small rectangles was 25 acres ( about 10 hectares ) whereas in Rajasthan it was 25 bighas (about 6 hectares ). Under the metric system of land measurement, a uniform size of 10 hectares for the rectangles can easily be adopted for all States.

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(b) *Orientation.*—The orientation of the small rectangles is not of much importance if the difference between the long and the short sides is not great. As level lines are generally run along the short sides of the rectangles in order to give a denser network of heights, it would be preferable to orient the rectangles in such a way that their shorter sides lie in the direction of the slope of the ground. However, this point should be decided with the indenter.

**18. Numbering of Stones.**—The system of numbering should be simple and symmetrical so that the lower grades of revenue and irrigation staff are able to calculate the number of any stone within a main rectangle easily from the map or chart, when the number is not entered thereon. In general, blocks are numbered by letters of the alphabet, with suitable indices when more than 26 blocks cover one scheme. The blocks are divided into numbered main rectangles. The corners of the small rectangles (i.e. the ultimate units ) are serially numbered as denominator of the number of the main rectangle. All numbering starts from the north-west corner running from North to South. A diagram showing a method of numbering stones in a 2,500 hectares block is given in Annexure ‘A’. Any convenient variation may be used in consultation with the indenter.

**19. Levelling.**—Levels are provided at the corners of small rectangles and at intermediate points along their sides in order to help designing of distributaries and irrigation channels. The number and position of spot heights will therefore require decision in consultation with the indenter. As these heights are also utilized for contouring, additional heights may be observed for small ridges, depressions and other topographical features not covered by regular network of spot heights. **The ground height points should be co-ordinated (x,y) to facilitate auto generation of contours.**

**20. Detail Survey.**—The area rectangulated will be generally open and flat, or with occasional low sand dunes with sparse habitations. As the existing detail is likely to undergo minor changes with development, it may not be necessary to carry out fresh detail survey on a large scale. The existing topographical sheets of the area are brought up-to-date by rapid revision or verification and enlarged to the scale of the final map to provide background topographical detail for the contour sheets.

**21. Deleted**

**22. Irrigation and Settlement Map.**—The division of a block into convenient map and printing of irrigation/settlement maps should be carefully considered, keeping in view the use to which they will be put. The irrigation engineers have to use these maps to prepare their plan of distributaries etc. The revenue administrators need the maps for assessment of land revenue, betterment levy and crop yields. It will normally be sufficient to print the maps in 3 colours, viz. black ( for spot heights ), brown (for contours and sand features ) and blue ( for detail and marginal items etc. ) The scale of the maps should normally be 1:15,000, but

may vary, if required by the indenters. The layout and size of the sheet, the colour scheme and the number of copies required, need to be decided with the indenter. The verified detail and /or contours can be later utilized in updating the basic topo-maps.

### **PART III.—PRELIMINARY WORK PRIOR TO TAKING THE FIELD**

**23. General.** – In addition to the usual correspondence with local officials when a party takes the field, a government notification should be got issued to ensure that the survey marks and stones are not tampered with.

In addition, the district officers should be asked to issue stringent orders to village officials, to ensure that any activity connected with the survey is not impeded. A duly certified copy with official seal should be given to every field hand.

**24. Rectangulation.**—(a) *Origin.*—The most suitable origin is selected and cutting points for the plotting of the required grid on 1:50,000 and 1 : 250,000 maps calculated.

(b) *Indexes* –(i) The existing topo maps with the rectangular grid plotted thereon to show all blocks, rectangles and their numbers, should be issued to traverses so that they plan traverse circuits to run as near the sides of the main rectangles as possible and provide traverse stations near the corners to facilitate embedding of stones.

(ii) A small scale (say 1: 250,000 ) index showing the layout and numbering of blocks, main rectangles and sheets etc, with skeleton detail should be prepared for use as stone-depot charts, and for progress and other indexes, etc. Specimen of such index is given in Annexure ‘B’.

(iii) Indexes showing subdivisions to small rectangles should also be prepared for each block on 1:50,000 scale. These indexes will be used for record of work of rectangulators. A specimen Index is given in Annexure ‘C’.

(c) *Assessment of control.* – The available triangulation and traverse data in the area should be plotted on the index map to determine further extension or revision necessary. It is desirable that topo triangulation and traverse are carried out a season in advance or well before the commencement of other field-work.

**25. Levelling.**—(a) *Secondary Levelling.* Areas taken up for rectangulation will seldom have any extensive precise or secondary leveling line. If fresh secondary leveling is required, a request will be made to D.G. & R.B. at least one season in advance of tertiary double/single leveling for the project.

(b) *Bench-marks.*—Before leveling is commenced, sufficient interred bench-marks (Type B-Sec Annexure E) should be constructed 6 to 12 km apart. Secondary leveling is usually carried along roads or other easy routes. These Bench-marks will accordingly be embedded along the selected route, on stable ground and on sites where they are likely to be preserved, such as in compounds of public buildings.

A reference pillar has also to be built about 3 metres north of the interred Bench-mark.

This construction work will normally be carried out by the indenter, and should be completed one season in advance, and in any case before the rains.

(c) **One copy of Index (Annexure C)** with details of the stones embedded in the block will be procured from the rectangulation camp for use by the leveler. One Index (**Annexure**

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**D)** for each project sheet, showing corners of small rectangles, will be maintained by the levelers to record staff position and offsets.

(d) *Stone Depots.*—The area for rectangulation should be divided into zones with a stone depot in the center. The number of mark-stones required at each depot will be calculated carefully, with a provision of 5% for breakage, and a chart issued to the stone contractor with target dates of completion of supply.

**26. Transport.**-- As the field hands have to shift camp very often and to transport mark-stones from the depots to the rectangle corners, provision of permanent transport has always been found necessary. The scale of transport is given in Chapter II of the Hand-book of Topography.

Tender enquiries for supply of camels and mark-stones should be floated well in advance, so that agreements can be signed before the **GDC** takes the field. The prescribed proforma for the agreements are also given in Chapter II of the Hand-book of Topography.

**27. Co-ordination and Plan of work.**—Different operations like rectangulation, leveling and detail survey will be so co-ordinated that the programme is completed and maps delivered to the indenter before the target date. For obvious reasons, rectangulation should be completed sufficiently in advance of leveling, to allow time for the mark-stones to get established before they are connected by levelling.

Detail survey, where necessary, may be carried out after rectangulation, so that the mark-stones can be used as control points for the survey.

## PART IV ----METHOD OF WORK

**28. Methods.**—(i) *Rectangulation.* —Main rectangles are de-marcated with reference to **primary GCPs** located as near their corners as possible. The corner-stones are then located by measurement of distance and bearing from the nearest station. As a check on accuracy, the embedded stone should be connected to another station by traverse.

Exterior rectangulation is carried out to establish mark-stones at corners of small rectangles along the sides of the main rectangles, to serve as take-off points for the interior rectangulation.

Interior rectangulation is then run along sides parallel to the shorter sides, and establishes corner-stones of the small units entrusted for demarcation to the Survey of India. In the case of Rajasthan Canal and Irrigation Projects in the Punjab, the Survey of India demarcated corners of alternate smaller rectangles only. Further subdivision was carried out by the indenter.

(ii) *Levelling.*—Tertiary double levelling is carried out along the longer sides delimiting the proposed map sheets, to provide heights for all corner-stones of smaller rectangles falling

along the sides. This double levelling is connected to permanent interred bench-marks at both ends, and is normally limited in length to 60 km.

Tertiary single levelling emanates from and closes on the stones heighted by tertiary double levelling, and is carried out along the shorter sides of the rectangles.

**29. GPS Observation—GPS observation** may be resorted to in the case of very open ground with occasional mounds or low hills.

**30. EDM Traverse. ---( I ) Main Circuits.—EDM** traverse is the more usual method of fixing corner-stones of main rectangles. Main circuits of higher accuracy, based on topographical triangulation, are run along the longer sides of blocks and along longer sides of sheets as necessary to provide control for subsequent sub-circuits. The actual alignment of main circuits will, however, depend upon the size and layout of the blocks. Main circuits of a precision of 1:4,000 should be sufficient to control sub-circuits of 1 : 2,000 precision.

(ii) Sub-circuits.—The sub-circuits are run approximately along the shorter sides of the main rectangles plotted on maps. These sub-circuits will commence from and close on stations of the main circuits. Traverse stations are made as near the estimated corners of main rectangles as possible.

The traverse stations will be marked by temporary wooden pegs of suitable size driven firmly into the ground, as they would not be required after computations are completed and the corner-stones embedded.

**31. (a) Embedding of Corner-stones.**—The computations are carried out at the camp headquarters, and soon as a circuit is completed, the traverser is supplied *Khakas* or diagrams showing the distance and angle (with traverse leg ) of the corner from the nearest station. The corner is located by setting out the angle from the adjoining station and measuring the distance as given in the *Khaka*. The corner-stone is embedded and the number of the corner is engraved on the top and/or in position as desired by the indenter. After the corner-stone is embedded, the theodolite is set up centrally on it and traverse angle and distance for the direction stone is observed as given in the *Khaka*. The theodolite is then fixed on the direction stone, and traverse angle and distance for the next traverse station is recorded.

This short traverse is computed to check that the corner and direction stones have been embedded at the correct places.

The mark-stones demarcating corners of main rectangles are generally 30 cm x 30 cm x 90 cm in size, and are embedded with 30 cm above ground. Those for small rectangles are 15 cm x 15 cm x 75 cm, and are embedded with 20 cm above ground.

The embedding of corner-stones must be completed and check observations computed within a period 4 weeks of completion of the traverse; otherwise temporary pegs marking stations may get damaged by weather or white ants or displaced otherwise.

(b) Direction Stone.—The *Khaka* supplied to the traverser shows data for embedding not only the corner-stone, but also the next corner of the small rectangle, to provide starting direction for exterior rectangulation. This stone is embedded *pari passu* with the corner-stone.

**32. Exterior Rectangulation.**----This process involves embedding of mark-stones at corners of small rectangles along the four sides of the main rectangles. Before commencing work, the exterior rectangulator is supplied a *Khaka* indicating corner-stones of the main rectangles and direction stones embedded by the traverser, with their numbers, for each main rectangle. He may also be supplied the *Khakas* made for the traverser for embedding the corner-stones. He normally camps in the center of the area and completes the job as explained below :-

(a) Flags are erected at a corner-stones of a main rectangle and at adjacent direction stone. The distance between the two is measured, to check that the direction stone has not been disturbed. Using a **total station**, the rectangulator prolongs this line by aligning flags at suitable intervals in the line of the first two flags by setting off angle of 180°. The **reflectorman** follow the line between the flags and plant wooden pegs at the positions of the intermediate corner-stones. The process is continued till the opposite corner-stone of the main rectangle is reached. The rectangulator then measures the closing error both in distance and direction by right angle offset to the stone. The error is distributed proportionately and a table of corrections to be applied at each intermediate peg is prepared.

The maximum closing error allowed in distance is 1 in 1,000. If larger error is noticed, the matter will, at once, be reported to the Camp Officer, who will check and correct the concerned corner-stones.

(b) The rectangulator goes over his line again in the reverse direction, applies corrections at intermediate positions and embeds mark-stones at the finally determined positions. The new line is cleared and distances from stone to stone are measures. Similarly, the alignment is checked with flags from stone to stone till the starting corner is reached.

The stones are embedded with their sides facing the adjacent stones, to enable determination of direction. The numbers of the corners are either engraved or written in tar paint on the top or on a side of the stone as desired by the indenter.

The rectangulator records the numbers of the stones embedded, and final distances, on the *Khakas*, for subsequent use by the interior rectangulator after **checking**.

**33. Interior Rectangulation.**—This process consists of sub-division of the main rectangles into small rectangles by running lines between the stones fixed by the exterior rectangulator along the longer sides of the main rectangle, and embedding corner-stones at appropriate intervals along them.

The general method of work is the same as adopted by the exterior rectangulator, except that the interior rectangulator does not use a theodolite. He starts his line by taking a right angle with **total station** from two flags on adjacent stones, one on either side of the starting stone along the exterior line, and placing a third flag at the mean of the two positions obtained from the two flags. Closing errors of 1 in 750 can be accepted in this work.

The interior rectangulator records the numbers of stones and the distances on the *Khakas* supplied to him for subsequent use by the *partaller*.

**34. Partal.**—The work, both of the exterior and the interior rectangulators, should be checked with a **EDM** to the extent of 50% of the lines. Mistakes, if any, should be rectified on the spot and stones re-embedded. The distances as measured by the *partaller* are recorded on the *Khaka* and in case of correction, the new distances are also recorded in a different colour. It is not necessary to adjust small errors below ½ metre.

The exterior rectangulator's work should be *partalled* before the interior rectangulation is commenced, so that the latter is not affected by any mistakes in the frame-work.

**35. Levelling.**----(i) *Secondary.*- Secondary Levelling should be done preferably before tertiary levelling is commenced, so that reduced levels are available to plan, check and compute tertiary double levelling. Sufficient bench-marks should be provided so that the subsequent operations are not stretched unnecessarily to cover long lines. Permanent bench-marks established by Secondary Levelling serve also as permanent reference marks for use by engineers during and after the construction of the canals.

(ii) *Tertiary Double.*- Tertiary double levelling circuits are run along the sides of the map sheets in a direction at right angles to the one to be followed for tertiary single levelling.

All mark-stones along the route are connected. These circuits will be connected at both ends to secondary bench-marks, and should not, normally, exceed 60 km in length. The levelling may be carried out by a single leveler using a precision instrument and taking two sets of observations with the instrument set at different heights. The difference in level between the two observations at one station should not exceed 2 mm. If two levelers are employed, the difference in height between successive main corners between the two, should not exceed 4 mm. The final closing error should not exceed  $0.012\sqrt{K}$  metre, where K indicates distance in kilometers.

(iii) *Tertiary Single.*—Tertiary single levelling is carried out normally in the direction of the slope of the ground and along the shorter sides of the rectangles. Each levelling line commences from one double-levelled stone along one side of the sheet and closes on a similar stone on the other side. The aim is to provide a spot height at the middle points of sides and at corners of the ultimate rectangles, i.e., those to be obtained after subdivision by the irrigation staff ( para 19 ) or as decided by the indenter.

The tertiary *leveller* connects all mark-stones along the line (recording both top and ground levels near them ). He also observes spot heights at intermediate points and at right

angles on either side of the stone or presumptive corner. Additional heights for contouring will depend upon the terrain, contour interval and distance apart of the stones.

The spot heights should be recorded to depict the general level of the ground and should not be recorded on artificial elevations or depressions unless specifically demanded by the indenter.

The final closing error in tertiary single leveling should not exceed  $0.024 \sqrt{K}$  metre for distance K in kilometers.

(iv) *Computations.* The tertiary double leveling should be computed and heights reduced in the field. The accuracy of tertiary single lines is checked *pari passu* and faulty work revised immediately. A small section of computers is maintained at the camp headquarters for this purpose.

**36. Detail Survey.**—As discussed already, it may not be necessary to carry out fresh detail survey on the map scale. Available topographical maps of the area can be enlarged to provide back ground details for the project sheets. **The new details can be updated either by Total Station or Mobile Mapping System in field or using high resolution satellite imageries in office.**

If it is necessary to incorporate village boundaries in the project sheets, the possibility of transferring them from the available cadastral plans should be duly examined as their survey on large scale on the round will be time consuming and prohibitively costly. Also, in unirrigated areas the boundary markers are seldom replaced when once destroyed.

## PART V -WORK IN RECESS

**37. General.**---The work in recess consists of **downloading of captured data, DTM preparation, Contour generation and map compilation.**

**38. Reproduction and Printing.** --- The proofs of the sheets may be examined and final P.O.P prepared in the unit responsible for the survey of the project. **If the requirement of number of hard copy is very few, then they can be supplied to Indenter by GDC**

In order to help the indenter expedite planning of the distribution system, uncorrected proof may be supplied to him.

A specimen of the printed sheet of Rajasthan Canal Project in F.P.S. system is given in Annexure 'G'.

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## ANNEXURES

A---INDEX TO 2,500 HECTARE BECTANGLES.

B---STONE DEPOT CHART

C---RECTANGULATION KHAKA.

D---LEVELLING KHAKA.

E---DIAGRAM OF PRIMARY BENCH-MARKS.

F---BHAKRA PROJECT SHEET.

G---RAJASTHAN CANAL PROJECT SHEET.

## SECTION III.----RIVER VALLEY PROJECT SURVEYS

### PART I---GENERAL

**39. Object and Scope.**—Surveys for River Valley Projects are required variously for planning water storage, utilization and distribution. They differ from regular topographical surveys in greater stress on accuracy of heights ( needing establishment of a network of leveling bench-marks ), than on high relative planimetric precision. These projects are undertaken either as integrated schemes to control and channelise flood waters, provide regulated irrigation, generate hydro-electric power for all round development of the area ; or as projects of limited scope for one or more of the above purposes.

River Valley Project Surveys can be broadly divided into the following four categories :-

(a) *Reservoir Surveys* —For evaluation of water storage capacity and the area of submergence, are confined to the area upstream of the proposed dam up to the highest anticipated flood level. Usual scale for survey ranges from 1 : 15,000 to 1 : 25,000, with maps to be printed on 1 : 10,000 to 1 : 25,000.

(b) *Site Surveys*---Are undertaken for investigating suitable location for dam, power house and other works connected with the project. The usual scale for survey and mapping are 1 : 1,000 to 1 : 5,000 for dam site and 1 : 250 to 1 : 1,000 for power-house site.

(c) *Commanded Area Surveys*.--- Are undertaken to assess the area which is likely to be benefited from the project and its economic potential, and, primarily, to design canals, irrigation channels and the communication system etc. The usual scales are 1 : 25,000 to 1 : 50,000 for survey and 1 : 15,000 to 1 : 30,000 for published maps.

(d) *Survey of subsidiary schemes*.--- For extension area, tunnel alignments, flood control and related works. Tunnel site surveys are carried out along possible tunnel alignments usually on 1 : 1,000 to 1 : 5,000 scales.

Railway and Highway surveys are normally carried out by the survey parties of the railway and highway authorities for the construction of access roads and railways, where necessary, for movement of construction equipment and materials to construction site of a project.

**40. Preliminary considerations and decisions.**--- The considerations influencing the final specification of the map, its scale and vertical interval, and technical methods to be employed are :

- (i) Purpose of the survey,
- (ii) extent of the area and nature of the terrain,
- (iii) accuracy required,
- (iv) availability of existing surveys, maps and aerial photographs.
- (v) Any special requirements, such as items not required to be shown and those that are to be emphasized; trigonometric data required ; provision of reference points, bench-marks and density of heights,
- (vi) Cost and time limitations etc.,
- (vii) Future extensions and
- (viii) Use of the surveys for departmental purposes.

The proforma 'Questionnaire' to be addressed to the indenters for obtaining relevant information before taking up survey is given at Annexure H. On receipt of the detailed information, necessary technical advice will be tendered to the indenter on scale and contour intervals, lay-out of maps, standards of accuracy consistent with the purpose of the survey, and his requirements finalized. High and/or rigid standards of accuracy and consequent refinements in methods of survey and fair mapping will increase the overall cost, and cause delay in the completion of the task without corresponding increase in the utility of the maps.

**41. Methods of survey.**---Depending on time limitations and availability of basic material like aerial photographs/**satellite imageries**, the survey will be **planned** either by ground survey ( plane-tabling ) or by air survey (graphical or photogrammetric ). The choice of the method also depends on the extent of the area, nature of terrain, scale and contour interval. Air survey method is preferred in wooded and intricate areas where plane-tabling is difficult, slow and uneconomical, or where extensive areas are involved. Plane-tabling will normally be used where small isolated areas are to be surveyed, and where scales larger than 1 : 10,000 are involved.

**42. Estimate of cost and provision of funds.**--- River Valley Project Surveys are taken up as 'paid –for jobs' except in the case of those declared as National Projects by the appropriate authority. Accordingly, the estimated cost of survey, fair mapping and printing is to be worked out. In the case of National Projects, printing charges are recovered from the indenter. However, charges are not levied on a service department of the Government of India or Union Territory when surveys are undertaken for such a department.

A proforma for preparing estimates is given at Annexure I, The estimated cost will be communicated to the indenter, after finalizing the specifications of the maps and the technical methods, for the necessary certificates of availability of funds. No survey will be undertaken till availability of funds is assured in the proforma at Annexure J. This condition is also applicable to all 'Post Deposit' parties i.e. companies, corporations and autonomous organizations which are wholly fed by Government grants and have given a written undertaking to our administrative Ministry through their controlling Ministries that they will arrange payment of bills within seven days of the receipt of Demand Notices. Failing this, advance payment should be obtained and a formal agreement signed.

As regards the jobs from other organizations partially fed by Government funds as well as private firms and individuals, advanced payment of the full cost should always be insisted upon, and a formal agreement signed.

The detailed estimates will be forwarded to the Administrative Officer for obtaining the sanction of the Surveyor General of India to undertake the surveys. Towards the close of each financial year or at intervals convenient to the indenter, and on completion of the job, Book Debit invoices in respect of cost of surveys etc., will be sent for his acceptance and return on the proforma at Annexure K.

**43. Specifications for River Valley Project Surveys.**—(a) *Scale and Vertical Interval.*---A map should normally be prepared at the smallest scale with the largest contour interval that will serve the purpose of the project. The scale and contour interval will depend upon the nature of the terrain and the purpose of the survey. In hilly areas a large contour interval will be adequate. In plains a small contour interval will be required. The final decision, however, rests with the indenter.

The scales and vertical intervals for different types of surveys will change from project to project. Some typical examples are given to serve as a guide.

Sl. No.	Name of Survey	Vertical Interval In metres	Scale of survey and fair drawing	Scale of publication	Overall cost* per sq km	Remarks
1	Reservoir Survey	! 5,10	1 : 25,000	1 : 15,000	Rs. 550	
2.	Commanded Area Survey	2 to 5	1 : 15,000	1 : 15,000	700	
3.	Site Surveys :	5	1:5,000	1 : 5,000	3,200	
	(i) Dam site ..					
	(ii) Power-House site	1	1 : 2,000	1 : 2,000	5,500	
	(iii) Tunnel Site	2	1 : 5,000	1 : 5,000	3,700	

\* Costs given are approximate and do not include printing charges.

! The highest level of the submergence area should be accurately fixed, since the payment for compensation depends on this ( vide IS : 5497-1960-Indian Standard Guide for Topographical Surveys for River Valley Projects).

(b) *Layout*.---Each project map will have a rectangular lay-out on Lambert/Grid. Every 1,000 metres, 500 metres and 100 metres grid line will be drawn on maps on 1 : 25,000 to 1 : 15,000, 1 : 5,000 and 1 : 1,000 scales respectively. Every tenth line will be drawn thick. Ticks will be shown in the borders of maps on 1 : 15,000 to 1 : 25,000 scale for spherical graticule at 1 minute interval. On larger scale maps these ticks will be shown at closer interval of 30 seconds and 10 seconds. However, no grid and graticule lines will be shown to project maps falling in Restricted area.

The area of survey will be divided into a minimum number of sheets to cover the maximum area, keeping in view the capacity of printing machines available with the concerned printing office.

Some dimensions of maps on different scales used in the past are given below :-

<i>Scale of Survey</i>	<i>Scale of publication</i>	<i>Coverage of sheet in grid metres</i>	<i>Dimensions of published sheet Excluding borders And margins</i>
1:2,000	1 : 1,000	900 x 800	90 cm x 80 cm
1 : 5,000	1 : 5,000	4,500 x 4,000	90 cm x 80 cm
1 : 25,000	1 : 15,000	13,000 x 12,000	86.67 cm x 80 cm
	1 : 25,000	As per standard 1 : 25,000	departmental sheet.

*Note :-* Maximum overall printing space for a map with the largest printing machines available in the department is 122 cm x 91.5 cm.

It is usual with these maps of standard dimensions to prepare a standard mock-up for the border and north and south marginal items when a project involves a number of sheets. For items to be shown in the North and South margins, see Para 56. In order to reduce the number of maps, the indenter may sometimes desire printing of the heading and symbol tables on the reverse of the map.

**44. Heights.**---Heights are very important for evaluation of potentialities of the project and for formulation of future plans. Density of heights will be on considerations of type of survey and nature of the terrain. In surveys for commanded area or for flood control, a mesh of heights at an interval of about 2 cm on the scale of publication will be necessary. The heights will generally be provided by spirit-levelling and connected to the National Level Net, with a relative precision of less than 1/5<sup>th</sup> of the contour interval. For planning engineering works the indenters normally desire provision of permanent and semi-permanent bench-marks in the area for their reference. The location and density of such marks should be decided in consultation with the indenter. *Pucca* pillars to the specifications of the standard departmental (Type B) Bench-marks should be constructed by the indenter before the survey detachments take up the work.

In surveys of reservoir areas, the indenters sometimes desire the top contour to be marked on the ground, and may desire establishment of series of bench-marks on both banks close to the level of water, for reference of soundings required for the cross-section of the river-bed.

In Dam-site surveys, bench –marks indicating specified levels along the dam-axis may sometimes be required.

**45. Aerial photography.**---Surveys of commanded areas and for flood control have generally a large extent. If suitable aerial photography exists or can be procured within the time schedule prescribed by the indenter, digital photogrammetric survey method will be economical and speedy. In addition, aerial photography combined in photo-mosaics provides a cheap and quick tool for model studies and preliminary investigations of the project.

The scale of photography will be decided considering the scale of survey, contour interval, extent of area and nature of terrain and method of survey. For surveys of commanded areas, reservoirs, and flood control, photography on 1 : 25,000 scale will be suitable.

**46. Photo-mosaics.**--- Photo –mosaics may be uncontrolled, semi-controlled or controlled ( also see Para 9 ). It has to be remembered that photo-mosaics cannot be prepared for areas other than flat areas. For areas having relative elevations of over 3% of the flying height, only orthophotos can be utilized. A close mesh of spirit-levelled heights marked on controlled or semi-controlled photo-mosaics of plain areas is very useful for planning purposes and can be prepared with ease and speed. These mosaics with contours interpolated from the height mesh may sometimes replace the contoured map.

**47. Colours.**---Project maps will generally be prepared in **full colours**.

**48. Special requirements.**---Certain items of detail need not be shown on project maps which have limited purpose. Similarly, certain other items of detail may have to be

emphasized. Inclusion of items such as administrative and reserved forest boundaries, vegetation, telegraph / telephone/power lines, land holdings, cultivated areas etc., results in extra work and expense. These issues will have to be settled with indenter before survey is commenced.

## PART II----FIELD WORK

**49. General.**—Plan and height control consistent with the purpose, scale, nature of the terrain, method of survey, and contour interval, will be provided as a frame-work plotting, survey of detail and contours will comprise identification and collection of data pertaining to topography, and classification and names of cultural detail. Plane-tableing involves complete survey of detail and contours and is used to the best advantage in open and hilly country.

Although cost and expediency influence most of the decisions regarding project surveys, the need for their utilization for departmental mapping must be kept in view during field-work and subsequent compilation. The accuracy and specifications of surveys should be suitably modified to serve this purpose without detriment, however, to the needs of the indenter.

**50. Basic principles.**---(i) In all methods of surveying, the errors due to imperfection of the instruments used and imperfection of the human eyes are limited and controlled by the triangulation, trilateration or traverse frame-work. The principle governing the quality and density of control points is that no perceptible distortions are introduced in the resultant map.

(ii) All project surveys should be connected to the national frame-work, viz. the Geodetic triangulation ( or reliable topo triangulation) series. However, for remote or small isolated areas where the cost and time involved in establishing such a connection are prohibitive, the work may be started assigning an arbitrary origin **and using Total station with azimuth from Polaris. Establishment of GPS control points is also an option for open country.** Such instances should, however, be very rare and prior approval of the Director must be taken before doing so.

(iii) **M.S.L.** heights are very important in project surveys. Every effort must, therefore, be made to connect the proposed height control with the precision leveling net. In very remote isolated areas where such a connection is not feasible, the project authorities should be intimated of the fact, before hand.

(iv) In order to incorporate ground truth, **photo map** may be either preceded by photo verification or followed by ground verification using normal plane-tableing methods. **Using latest techniques like Mobile Mapping System can accelerate work**

**51. Methods.**---(a) *Control.*—

(i) Procedures outlined in THB Chapter III and THB Chapter IV will be followed for planimetric and height control by triangulation, trilateration and theodolite traverse respectively.

(ii) The control required for **georeferencing of aerial photograph /satellite imageries** will be fixed in keeping with the criteria laid down in THB Chapter XII.

(iii) For photogrammetric compilation, pre-pointing is preferred. The size of the opaque signal ( + or λ ) in this case should be  $\frac{S}{4,000}$  metres and its thickness  $\frac{S}{24,000}$  metres where 'S' is scale denominator. Thus, for 1 : 25,000 scale photography the size would be  $\frac{25,000}{4,000}$  i.e. 6.25 metres and its thickness  $\frac{25,000}{24,000}$  i.e. 1.04 metres.

(iv) Standards of accuracy prescribed for normal topographical triangulation and main traverses are acceptable for almost all types of surveys except for large scale surveys, the criterion being that there should be no appreciable error of distance or azimuth between any two control points plotted on one map sheet.

The closing error for tertiary leveling should not exceed those given below :

			Error of closure in mm
Double tertiary	..	..	$\pm 12 \sqrt{K}$
Single tertiary	..	..	$\pm 24 \sqrt{K}$

Where K is the distance in kilometers.

(b) *Map compilation* ---(i) Plane-tableing---Detail is surveyed by methods of radiation, resection, intersection, and P.T. traverse; and contours using clinometer with or without clinopole. Tacheometric method of survey can also be sometimes employed. Instructions given in the pamphlet ' Instructions to Plane-tablers; and THB Chapter V will be followed.

(ii) *Digital Photogrammetry*. – For accurate surveys especially on medium scales from aerial photographs/satellite imageries , photogrammetric methods are to be used. Before any work is planned for photogrammetric survey, it would be desirable to consult the photogrammetric branch regarding location of control.

The choice of methods will depend upon the type of survey, scale of survey, contour interval, topography and extent of area, standard of accuracy, time and cost.

**52. Reference points.**--- Any permanent points required by the indenter for further connection or extension of work should be selected and constructed beforehand by the indenter. Their positions and heights will be accurately fixed by connection to existing triangulation and the level net.

Reference points required at the inlet and outlet and at intermediate points in construction of tunnels, to enable simultaneous construction from both ends and from intermediate stations, require a very high degree of precision and should normally be undertaken by the Geodetic Branch.

## PART II--- DIGITISATION

**53. General.**---Time being a great importance in project surveys, **digitisation** and printing of the sheets will be completed in as short a time and as economically as possible. Executive Officers will, therefore, not insist on excellence in the standards of **digitisation**, as is normally done for departmental mapping. The usual specifications for **digitisation** will in general remain the same.

**54. Alternatives available.**-- In case the final map is required in single colour and fineness of drawing is not required, **digitisation** should be dispensed with completely. P.T. and / or **photo-map** sections will be so designed as to correspond to the published sheet, and names

and descriptive remarks will be typed on the section itself. Headings and footnotes etc. will either be completed on the section or on a separate mock-up.

In order to keep the section neat and fit for reproduction, only essential detail will be inked. Any information picked up in the field for assistance in **compilation** will be entered on colour traces only.

**55. Digitisation.**—Departmental specifications for fair drawing and typing will be suitably modified to suit the specific requirements of the project maps, paying due regard to readability and presentability.

**56. Borders and marginal items.**---The title of the sheets and other notes and symbol tables etc., to appear in the margins of sheets should be decided with the indenter. A specimen mock-up for marginal items is given in Annexure L for guidance.

**57. Disposal of records.**--- **Final digital data** and other records of project surveys will be forwarded to the regional Director after the sheets are printed.

After the sheets are published, the Director may order the destruction of records except in the case of ‘record jobs’.

**58. Miscellaneous.**---The print order for river valley project varies from 100 to 250.

**59. Specimen maps.**---A typical map of this type of survey is placed at Annexure M.

## **QUESTIONNAIRE TO BE FILLED UP BY DEPARTMENTS/INDENTERS REQUESTING FOR PROJECT SURVEYS FROM SURVEY OF INDIA**

### **A. TECHNICAL**

1. (a) Name of Project .....  
(b) Title of Map ...
2. Purpose of survey, specifying the accuracy in position and height required. A brief description giving background and execution including expansion schemes, if any, should be mentioned.
3. Have any surveys been done by the Project authorities for the Project ?
4. Scale of final map required --
5. Contour interval. Also indicate whether larger contour interval Acceptable if the terrain does not permit depiction of contours at the required interval.  
(Note : Larger contour intervals cost less and speed up survey).
6. Upper and lower contour limits.

7. Whether contours are required to be shown in dry river-beds and islands. If so, at what interval and in which areas ?
8. Area of survey with limits indicated on 1 : 250,000, 1 : 50,000 or any suitable scale map or index giving Latitude and Longitude. Also Indicate the name of Tahsil, District etc. in which the area falls.
9. Whether photo-mosaics would serve the purpose.
10. (a) Map detail to be emphasized, e.g. cart-tracks, roads, etc.  
(b) Items of detail in which the indenter is particularly interested.
11. Items of detail which can be omitted, e.g., administrative boundaries, forest boundaries, vegetation, cultivation limits, wells, springs, telegraph/telephone lines, power/pipe lines isolated huts village boundaries, land holdings, etc.  
(Note : Omission of unnecessary detail reduces cost and speeds up the production of maps.)
12. Final **output requirement** :  
(a) **Scanned field section**  
(b) **full colour map.**  
(c) **Digital map in pdf format(otherwise specify format)**
13. Number of copies of maps required :  
(a) On map paper ( specify, if any of them are to be cloth mounted ).  
(b) On tracing paper.

(NOTE : It is economical to place your maximum print order at the first instance ).

14. Are negatives to be kept standing ? If so, for what period ?  
(NOTE : Due to acute shortage of storage capacity, the maximum period for which these can be stored in 3 months for which charges will be borne by the indenter).
15. Period by which maps are required. Divide areas in 2/3 priorities where possible.
16. Fixing of special reference points, if any, ( bench-marks, pillars, etc.) Full specifications including interval and accuracy in position/height should be supplied. B.Ms./pillars will have to be erected by the indenter before the survey is take up.

## B. FINANCIAL

17. (a) Is the job to be take up as a National Project ? If so, quote authority.
- (b) To be completed if (a) is not applicable :
  - (i) Are adequate funds available for survey ?  
Also state, in which financial years they can be utilized.
  - (ii) Has the approval of the competent authority been obtained ?
  - (iii) To whom are the estimates to be submitted, for issue of certificate of availability of funds ?

Designation and address of indenting officer to whom printed maps are to be supplied and from whom advance payment has to be obtained or book debit has to be raised.

C. ADMINISTRATIVE

18. What is the most direct rail/rod approach route to the area of survey from the nearest State Capital ?
20. Is the area of survey approachable by motor transport ?
21. Communication facilities in the area—whether jeepable roads exist. If not, what other means of transport are available and what are their normal rates of charges per km/day ( trucks, carts, camels, ponies, porters ).  
(NOTE : In case of river areas, indicate the mode of river crossing, etc. ).
22. (a) Can your department provide motor transport for conveyance of personnel in the field ?  
( NOTE : This will reduce the cost of survey ).  
  
(b) Has the area any tidal streams ? If so, can you provide water transport ?
23. What are the modes of postal communication in the area ? Name of nearest post office/telegraph office. Inspection Bungalows, petrol pumps and banking facility may be indicated.
24. What are the ideal months for outdoor work in the areas ? The type of area and the maximum and minimum temperatures during this period may also be indicated.
25. Is any jungle clearing necessary ? If so, can your department help with men ?  
(NOTE : Also state whether permission for jungle clearing has been obtained from the concerned authorities. )
26. Is local labour available in the area ?
27. Are rations locally available ? If not, where from and how can these be procured on payment ?
28. Do wild animals frequent the area ? If so, what protective measures are necessary ?
29. In case the area is politically disturbed, can security personnel be arranged from the local Govt./authority.
30. Are any special preventive measures necessary against diseases such as Malaria, Kalazar etc. ?
31. Is any medical help available in the area ?  
Name of the nearest hospital/dispensary should also be given.

D. MISCELLANEOUS

32. Other special requirements/informations if any.

33. If the project is likely to affect any adjoining state ( or states ), has the concurrence of that state ( or those states ) been obtained.

*Place*.....

*Signature*.....

*Date*.....

*Full Address*.....

NOTE : No proof/advance print of any kind as per item 13above can, however, be supplied to the indenter before security clearance is obtained from the Service Intelligence Directorate in respect of maps falling in restricted areas and containing defence installations, or vetted by the concerned Ministry in respect of maps of other areas containing civil vital points.

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## ANNEXURE I

### ESTIMATES OF COST, TIME AND POTENTIAL FOR

#### PART I ---GENERAL INFORMATION

1.	TITLE OF JOB	..	...	...
2.	LOCATION	...	...	...
3.	DESCRIPTION OF COUNTRY		...	...
4.	PURPOSE OF SURVEY		...	...
5.	AREA TO BE SURVEYED		...	...
6.	MAP SPECIFICATION		...	...
	(a)	Scale		
		(i) Survey	...	....
		(ii) Publication	...	...
	(b)	Contour Interval	...	...
	(c)	Colours		
	(d)	Any special requirement		
	(e)	Size of sheets and No. of sheets		
	(f)	No. of copies of map required.		

7. BRIEF SUMMARY OF GTECHNICAL METHODS TO BE USED

- (a) Method of provision of control
- (b) Method of survey / compilation
- (c) Fair drawing

PART II --ESTIMATES

1. TASKS INVOLVED AND TIME REQUIRED FOR COMPLETION

- (a) Preparation and Miscellaneous
- (b) Field work :
 

<i>Item</i>	<i>Total work Involved</i>	<i>Expected out-turn</i>	<i>Man—months required</i>
(i) <b>GPS Observation</b>			
(ii) <b>EDM</b> traverse			
(iii) Levelling			
Double tertiary			
Single tertiary			
(iv) Plane-tabling			
(v) Photo verification			
(vi) Computation in the field			
(vii) Field supervision			
- (c) Office work :
  - (i) Computations, if any
  - (ii) **Photogrammetric** Survey
  - (iii) Rectification
  - (iv) Preparation of mosaics etc.
  - (v) **Digitization**
  - (vi) Supervision
  - (vii) Proof correction etc.

2. COST

	<i>Item</i>	<i>Rate/Man-month</i>	<i>Cost Rs.</i>
(a)	Preparation and Miscellaneous		
(b)	Field work		
	(i) <b>GPS observation</b>		
	(ii) <b>EDM</b> traverse		
	(iii)		
	(iv)		
(c)	Office work		
	(i) Computations		
	(ii) <b>ortho Photo map</b> compilation		
	(iii) <b>Digitization</b>		
	(iv)		
	(v)		
	(vi)		
	(vii)		

Total cost for survey and mapping  
 Party Overhead Charges  
 (.....% of above )

Total ..... ..

Conveyance of stores and T.A./Contingency of all field while moving  
To field and returning from field.

Total

General Overhead Charges ( 30% of above )	.....	.....
Cost of disapositives / prints etc.	.....	.....
Total cost of survey and mapping.	.....	.....
Cost of printing		
Cost of Aerial Photography	.....	.....
Total cost of the Project	.....	.....

PART III ----SUMMARY

Potential required for the project	.....	.....
Estimated time for completion of the Task		
Total cost of the Project	.....	.....

NOTE :----For print charges etc. refer to the Rate Chart for various reproduction tasks brought out by **DMP**. No Overhead Charges are to be added to reproduction costs as the same are included by **DMP**.

ANNEXURE J

**CERTIFICATE OF AVAILABILITY OF FUNDS FOR**

.....

I certify that funds are available to meet the estimated cost of Rs.....(Rupees.....only) or the actual expenditure to be incurred during 200 † and subsequent years on account of surveying, compilation and printing of the \*.....Project maps.

It is also certified that :

- (i) the work has received the administrative and expenditure sanction of the competent authority.
- (ii) funds will be made available in 200 † financial year to the tune of Rs.....(Rupees.....only) and the balance will be made available in the subsequent years.
- (iii) requisite funds exist in the sanctioned budget of the year and funds will be arranged to meet the estimated expenditure.
- (iv) debit for the work executed during any year either in whole or part will be acceptable during the same year.

Signature.....

Name and Full Address of

Indenting Officer.....

For and on behalf of the Governor ‡

---

\* Enter name of the Project.

† Enter financial year as applicable.

‡ This should invariably be added in the case of State Governments, and the certificates should be signed by an officer duly authorized under Section 299 of Constitution.

#### SECTION IV.---LARGE SCALE SURVEYS

**60. General.---** Large scale surveys are required for maintaining records of lands, quantitative measurements and various other planning purposes. These will generally include surveys for Air Fields, Cantonments and other Military lands, Naval dockyards, refineries, factories, canal systems, roads and railway lines, cities and towns, guide maps, dam-sites, reservoir ( submergence ) areas, commanded areas, hydro-electric projects, cadastral and settlement maps etc. Except for Guide maps, which are our Departmental commitments, large scale surveys are normally taken up as 'paid for' jobs.

**61. Definition.---**Any survey on scales larger than that of topographical survey ( 1 : 25,000 ) is termed as 'Large scale survey'. The scales generally used for large scale surveys are 1 : 500, 1 : 1,000, 1 : 2,000, 1 : 5,000, 1 : 10,000, 1: 15,000 and 1 : 20,000.

**62. Specifications.---**Hard and fast specifications cannot be laid down for any large scale survey as each large scale map is required for a specific purpose. The smallest scale, commensurate with the requirements of precision of distances road off from the map and the desired contour interval, should be adopted. The scale, contour interval and other map content are dependent on the purpose for which the large scale maps is required. The following general specifications have been used in the past for vario0us large scale maps :-

<i>Scale</i>	<i>Contour Interval</i>
1 : 500	½ Metre
1 : 1,000	½ to 2 metres
1 : 2,000	1 to 2 metres

1 : 5,000	2 to 5 metres
1 : 10,000	5 metres in plains and 10 metres in hills
1 : 15,000	10 metres
1 : 20,000	10 meters

All drainage, communications, villages and buildings will generally be shown. Any or all details like telegraph and telephone lines, distance stones, bridges, culverts, temples, mosques, churches springs, wells, P.O., P.T.O., I.B., R.H. etc. may be omitted in consultation with the indenter.

**63. Aerial photography applied to large scale surveys.**--- Aerial survey is very useful for large scale surveys. Where large scale photography is available, a photo mosaic (controlled or uncontrolled ) suitably annotated, may serve the purpose of the large scale map. Supplemented with leveled or otherwise heighted network, the photo-mosaic can be if conveniently contoured, required.

Rectified photos or mosaics prepared there for, can easily replace actual field surveys in plains.

When a fresh survey becomes necessary and the area is already covered by aerial photography or is large enough to admit of fresh photography, aerial survey by photogrammetric methods provides a quick and more accurate mode of map compilation.

In digital photogrammetry, ortho images for mapping at larger scale can be prepared in office. The resolution of digital photographs and satellite imageries will be decided keeping view of final product and contour interval.

#### PART I.---CANTONMENT SURVEYS

**64. General.**---Cantonment surveys are taken up by the Survey of India at the request of the Deputy Director of Military Survey in the Geographical Section of the General Staff at the Army H.Qrs.

Applications for surveys should be [placed on the Chief Engineer of the Command, who will, on examination of the work required, and later, with the concurrence of “Q” Branches and Deputy Director, Military Lands and Cantonments, at his Headquarters, submit a consolidated list of surveys required in his command, to the Engineer-in-Chief, Army Headquarters. The survey demands will then be sent through the Ministry of Defence ( Director, Military Lands and Cantonments ) for approval to the Deputy Director of Military Survey, who will pass them to the Surveyor General by 1<sup>st</sup> May each year with a request for an estimate of cost for the surveys to be undertaken.

Estimates of cost of surveys, will be submitted by the Surveyor General of India to the Deputy Director of Military Survey by 1<sup>st</sup> June of each year. These estimates will be sent to the Ministry of Defence ( Director, Military Lands and Cantonments ) for acceptance before the end of June of each year. Charges should not ordinarily be made in the programme of survey as approved by the Ministry of Defence, but they are , for any strong reasons, inevitable, they should be communicated to the Engineer-in-Chief, who will communicate to the Deputy Director of Military Survey the sanction of the Ministry of Defence.

**65. Definition.**---Cantonment Surveys include surveys of Military Airfields, Naval Dockyards, Military stations and other Military lands.

**66. Specifications and Special Requirements.**--- (a) Cantonment Surveys are carried out on 1 : 5,000 and 1 : 10,000 scales. Certain portions of the cantonments (corresponding to old bazaar areas ) are, however, surveyed on 1 : 1,000 scale. The Executive Officers of the Cantonment Boards or the Military Estate Officers will indicate the exact areas to be surveyed on the larger scale.

For survey of other military lands, different scales may be adopted, depending upon the requirements of Army authorities.

(b) The contour interval will vary with the nature of the ground ; it is usually 1 or 2 metres in undulating country, and 5 metres in hilly areas. In very flat areas, contours may be omitted and extra bench-marks provided instead. In all cases, the local officer of the Military Engineering Service will be consulted.

(c) The margin ( or overlap ) to be surveyed beyond the actual boundaries will be preferably up to the nearby permanent detail with a maximum of 100 metres away from the cantonment boundary. Any area required to be surveyed in excess of this, will require the approval of the Engineer-in-Chief.

(d) The area of a cantonment may be divided into a number of sheets of convenient sizes.

(e) A list of conventional signs will be printed on one of the sheets, while the linear scales in metres and kilometers, as well as height and contour legends, will appear on each sheet.

(f) The index plan of the sheets covering the cantonment will be shown on one of the sheets. This index will also show the relative position of the cantonment with reference to the surrounding details such as railways, main roads, rivers etc. It will be on 1 : 50,000 scale, or larger where necessary.

(g) The heights of geodetic bench-marks and other Survey of India bench-marks should be entered to the second place of decimal in metres, in upright and slant types respectively, and of other bench –marks to one place of decimal. A few permanent theodolite traverse stations should be plotted, and their numbers and heights entered on the map. Other heights should also be entered in type and style accordingly to their degree of accuracy.

(h) Schedules of boundary pillars, permanent traverse stations and bench-marks, with descriptions sufficient for locating each ( para 67), will be printed on one of the sheets.

(i) The magnetic variation ( delineation ) of the year of survey, with the amount of secular change ( annual variation ) will be printed on the title sheet of the set of maps. Magnetic North and Grid North legends, with an illustrative diagram, will also appear on this sheet.

(j) Items such as Surveyor General's imprint, grid legend, edition number, year of survey etc., will appear on each sheet.

**67. Preparation of Schedules.**---

(a) *Boundary Schedule.*—A schedule of all cantonment and defence zone boundary pillars and, where possible, cantonment and regimental *bazaar* pillars, showing intervening horizontal distances in metres (correct to one place of decimal ), bearings referred to true

north at origin (i.e., the grid bearings ) and the rectangular co-ordinates of each pillar will be prepared in the following form and printed at a suitable place in one of the sheets :-

**BEARINGS AND DISTANCES OF BOUNDARY PILLARS**

Numbers of Boundary Pillars	Grid Bearings from back station		Direct horizontal Distances between pillars in metres	Grid co-ordinates of the second station in the First column	
	Degree	Minute		Easting Grid metres	Northing Grid metres

(b) *Schedule of Permanent GPS /EDM Traverse Stations* :- A schedule of permanent *GPS /EDM Traverse* stations with co-ordinates and sufficient description for locating each mark, will be printed at a suitable place in one of the sheets, in the following form :-

**LIST OF PERMANENT *GPS /EDM TRAVERSE* STATIONS  
(Protected by M.E.S.)**

Sheet Nos	<i>GPS / EDM Traverse</i> Station Nos	Grid co-ordinates		Descriptions	Ground height in metres above mean sea-level
		Easting Grid metres	Northing Grid metres		

(c) *Schedule of Bench-marks*.-----A schedule of bench-marks with approximate co-ordinates read off from the survey section ( or accurate co-ordinates where these are connected to *GPS /EDM Traverse* stations ), will be prepared in the following form and will appear in one of the sheets :-

**LIST OF BENCH - MARKS**

Sheet Nos.	Grid co-ordinates ( Approximate )		Description	Height in metres above mean sea-level
	Easting Grid Metres	Northing Grid metres		

**68. Liaison with Military authorities.**—Close liaison will be maintained with the local and other military authorities concerned throughout the survey, contour interval, details to be surveyed, overlaps beyond cantonment limits, map format, schedule of boundaries etc.

Before printing, and as early as possible after the completion of a survey, a set of grey prints with all names, numbers etc., entered by hand, should be sent to the Commander Works Engineer, the Military Estate Officer and the Executive Officer of the Cantonment Board concerned. The first two authorities are responsible for correctness of names of

roads, localities etc., and numbering of buildings, holdings and boundary pillars. The Executive Officer of Cantonment Board will certify that the alignment of the boundaries depicted on the print, are correct. These three authorities are, however, not responsible for the geographical accuracy of the survey.

The verification of names, numbers and boundaries may, in cases of urgency, be carried out immediately after completion of field-work, on the field records and traces themselves instead of grey prints as mentioned above.

New buildings, road etc. constructed after the survey, should not be entered either on the field records or on grey prints sent for verification.

The M.E.S. will provide, without levy of departmental charges, a number of stones or concrete pillars in each cantonment under survey, to mark permanently, a proportion of the traverse stations. The actual cost of providing these marks will be met from the annual army allotment for cantonment surveys.

These permanent *GPS /EDM Traverse* stations will be placed in the custody of the local M.E.S. authorities.

**69. Method of Work.**—Cantonment surveys are carried out as Original Surveys or Revision Surveys. Normal departmental methods are followed.

(a) *Planimetric and Height Control.*---Depending upon the terrain, planimetric and height control is provided by *GPS* or *EDM* traverse or both. Heights are further controlled by spirit-levelling.

In built-up areas surveyed on 1 : 5,000 and 1 : 10,000 scales, a control point is provided at every 250 and 500 metres respectively and in open areas at approximately double these distances. For survey on 1 : 1,000 scale, it will be necessary to *provide control points by GPS OR TOTAL STATION* main streets. The density of control will be such that a plane-table can carry out chain survey conveniently.

(b) *Detail survey.*—On 1:5,000 and 1 : 10,000 scales, normal plane-tabling methods using resection, intersection and radiation will be used. *Bazar* areas on 1 : 1,000 scale, will be *surveyed by total station*.

(c) *Contouring.*—In undulating ground, the contours are surveyed with the help of graduated poles, deducing the contour positions and distances from clinometric readings i.e., by clinopole method.

In hilly areas, the contours are surveyed by normal planetabnlng methods.

**70. Criteria for Accuracy.**--- In cantonment surveys, the relative accuracy of all details is the main criterion. It should, therefore, be ensured that the control provided for cantonment survey is mutually consistent. Accurate geographical positioning is not an essential requisite. However, if a G.T Station or Point or *GPS Station* is available close by, it should be connected. The work may, otherwise, be started from a topo triangulation station.

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**71. Symbols and Abbreviations.** Conventional signs, symbols and abbreviations used in cantonment surveys are given in the pamphlet titled ‘ Instructions to Plane-tblers.’.

**72. Fair Drawing.**---Fair drawing is carried out on the scale of publication.

**73. Publication Instructions.** ---The total press order for cantonment maps will be 200 copies, the distribution of which is given below :-

(a) Director of Military Lands and Cantonments, Military of Defence	....	....	2 copies (mounted)
(b) Chief Engineer (Command)	....	....	2 Copies (mounted)
(c) Deputy Director, Military Lands and Cantonments (Command)		....	2 ‘ ( ‘ )
(d) Zonal Chief Engineer (Concerned)	....	....	2 “ ( “ )
(e) Commander Works Engineer (Concerned )	....	....	2 Copies (mounted)
(f) Garrison Engineer (Concerned) .....		....	2 Copies (mounted)
(and as many unmounted copies as required)			
(g) Military Estates Officer (Circle)....		....	2 Copies (mounted)
(h) Surveyor General of India Dehradun	....	....	1 copy (unmounted)
(i) Regional Director of Survey of India (for Departmental use)		....	12 copies ( “ )
(j) Director, Map Publication (M.R.I.O.)	....	....	3 copies (unmounted)
(l) H.Q. 502 Photo Mapping Engineers Group	....	....	Remaining copies For stock

**74. Mounting of Cantonment Maps.**—All mounted copies mentioned above, will be cloth mounted and folded in A 4 size. Suitable covers will also be provided. Large maps will be split into sections of convenient size and bound separately. An index map of the whole cantonment will be pasted outside each cover, showing the area contained within the cover by red wash.

**75. Maintenance.**—Survey of India is not responsible for maintaining office copies of cantonment maps. Garrison Engineers concerned are responsible for keeping cantonment maps on 1 : 5,000 and 1 : 10,000 scales upto-to-date, and Cantonment Boards for maps of *Bazar* areas on 1 : 1,000 scale, on the copies supplied to them.

Reprints are made at the request of the Deputy Director of Military Survey, if the Cantonment is not due for revision survey in the near future.

## PART II.—CITY AND TOWN SURVEYS

**76. General.**---City and town surveys are normally conducted by the State Survey Departments in cities and towns with large built-up areas. There is detailed measurement

of each house and each holding. The survey records are of great statutory importance in relation to questions of boundaries and ownership.

In the case of metropolitan areas, the Survey of India may be called upon for the purpose.

**77. Purpose and Scope.**--- The purpose of city and town survey are administrative, fiscal and legal,. It provides an accurate map of all cultural details and of occupied houses, offices etc., for Postal, Municipal, Sanitary, Police and Census purposes. The revenue due from land is ascertained and a watch is kept over the development of future revenue. All titles to holdings are cleared and encroachments watched to prevent and remove possible litigation. The map is normally supplemented by a register of ownership and areas.

Town survey records provide very useful base material or drawing up Master, Regional and Outline plans for various development schemes.

**78. Specifications.**—(a) *Scale* —The following metric scales are used according to necessities :-

- (i) 4 hectares or close-block scale i.e. 1 : 250 or 1 : 500.
- (ii) 16 hectares or medium block scale i.e. 1 : 500 or 1 : 1,000.
- (iii) 64 hectares or open-block scale i.e. , 1 : 1,000 or 1 : 2,000  
(Scale 1 : 2,000 is also called as Ward-map scale ).

(b) *Area to be surveyed.*—The area of survey should include the scheduled municipal limits, town planning scheme map and all other areas for lay-out plans whether approval or pending for approval. The Chairman of the Municipality will depute an officer to mark the limits of survey on available cadastral or topographical maps of the town.

( c ) *Contours.*---Contours are generally not surveyed.

(d) *Details.*--- All physical and cultural details will be surveyed.

**79. Method of Work.**--- The survey may be carried out either on the ground or by photogrammetry.

In ground method, sufficient control of the desired accuracy is provided either by **Total Station or GPS** as suitable and should preferably cover all the block boundaries. A large size map of the municipality is prepared with reference to old cadastral and/or the old town survey records as available. The municipal limits are marked.

The boundaries of wards or divisions into which the municipality has been split, are also marked. The wards/divisions are further split into survey blocks to facilitate the survey operations. Normally the formation of such blocks are :-

- ( i ) 4 hectares in crowded localities.
- (ii) 16 hectares in medium localities.
- (iii) 64 hectares in cultivated and open localities.

The boundaries follow streets, rivers, roads etc., except in open localities where they follow field bunds. **Detail Survey** is then **carried out** by **Total station by offset** method as usual.

In photogrammetric survey, **all control points should be post pointed on photographs/imageries. Addition control on well defined photo points may be observed by GPS incase existing control over the area is not sufficient or suitable for photogrammetric**

survey. The vector map prepared from the orthophoto should be then verified on the ground to incorporate details not visible on the photos, and also to pick-up names and other such information viz., Hospitals, Schools, Temples, Mosques etc., which cannot be incorporated from the photogrammetric survey.

**80. Symbols and Abbreviations.**---Symbols and abbreviations of large scale and cadastral surveys, as approved by the State Government, are normally used.

**81. Record of Linear Measurements and Areas.** --- The responsibility for linear measurements and calculation of areas of different holdings, is that of the revenue officials and is outside the scope of this chapter. Method of calculation of areas from co-ordinates of property corners is given under 't IV- Cadastral Surveys' of this section

**82. Digitization.**---- **Digitization** will normally be done on the scale of survey.

**83. Printing.**----Maps are normally printed in **full colour**

### **PART III.---GUIDE MAPS**

**84. General.**---The orders regarding preparation of guide maps, as laid down in this section, should be generally followed, but a limited amount of flexibility is permissible to enable local requirements to be met. Before taking up the fair drawing of a guide map, the schedule of information as detailed in para 399 of 'Hand-book of Topography, Chapter VI, Tenth Edition 1971, TOPOGRAPHICAL MAPPING', should be submitted to the Surveyor General of India ( through the Director, Map Publication ) for orders. Any proposed departures from these orders should be clearly stated with reasons.

The guide maps of the capitals of the States and Union Territories, and other important towns and hill stations, will always be prepared. In addition to these towns, the regional directors will recommend to the Surveyor General of India, the names of additional towns in their areas of responsibility, which should be surveyed for preparation of guide maps.

While making the recommendations, all relevant factors such as population according to latest census (over 50,000), local importance of the town from administrative, commercial and tourist point of view, and probable demand of the map will be mentioned.

**85. Purpose and Scope.**----Guide maps are meant to enable people to find their way around large towns, hill stations and other places of interest to tourists, and are useful for civil defence, town and country planning and civil administration. These maps will usually show little ground outside the town limits or the limits of places of local interest. A guide map should, therefore, be so designed as to show clearly all routes in and about the town, and to particularize on it all the important public buildings, such as police stations, civil courts, collector's office, municipal office, hospitals, gardens, recreation facilities like clubs, cinemas, theaters, hotels and other places of interest to the general public and tourists.

A guide map will normally be published in one sheet with clear borders, headings, footnotes, reference list and insets. Main routes to places of interest in the city/town, panoramae, if any, are shown as insets. A skeleton map of the surrounding area will appear on the back cover.

**86. Scale.**----The normal scale for guide maps will be 1 : 20,000 in plains and 10 metres in hills. No departure from the scale proposed should be supported by strong reasons justifying the adoption of a different scale.

**87. Contours.**---The normal contour interval will be 5 metres in plains and 10 metres in hills. No contouring will be carried out inside built-up areas. Spot height should normally be given to all places of interest, important road junctions, railway stations, dak bungalows, etc.

Hillocks and rock outcrops should be depicted by form-lines or rock outcrop symbol, where otherwise contours do not appear in the sheet.

**88. Details to be surveyed.**----All details normally shown on a topographical map will be surveyed. In addition, cantonment and municipal limits are also picked up. Important buildings, such as government offices, hospitals, principal hotels, important clubs, cinemas, churches, mosques, temples, post and telegraph offices, police stations, markets etc., should be surveyed and inked up in black on the plane-table or **photo map** sections so that these can be shown prominently on the printed map.

**89. Symbols.**---Conventional signs and symbols will be the same as laid down for topographical and large scale maps. These may, however, be slightly modified or drawn heavier and bolder to suit the larger scale. Cantonment and municipal boundaries are shown as follows :-

Cantonment-----      -----      -----      -----  
Municipal      -----      -----      -----

**90. Methods of Work.**---Method for preparing each guide map will depend upon a number of factors such as :-

- (a) Material available,
- (b) Control available,
- (c) Nature of terrain.

A guide map may be compiled from various sources or prepared afresh. When new survey is required, normal departmental methods will be followed.

Photogrammetric survey/**update from high resolution satellite imageries** will be preferred to ground survey, as it is more economical, convenient and quicker.

**91. Digitization**---For **Digitization** of Guide Maps, the relevant section of the 'Hand-book of Topography' Chapter VI, Tenth Edition 1971, TOPOGRAPHICAL MAPPING', should be consulted.

#### **PART IV.---CADASTRAL SURVEYS**

**92. General.**---Cadastral Survey is done to prepare maps ancillary to the compilation of the Cadastre by Numerical or Graphical method, i.e. preparation of the records of areas, identifying numbers, ownership and tenancy of the land-holdings.

**93. Definition.**---Large scale maps of Cadastral Survey show limits, revenue numbers, and situations of different fields. A field comprises a plot or contiguous plots of the same class of land held in the same right and under the same ownership, by the same tenant or group of tenants holding jointly, in the same tenancy. The general scale of Cadastral Survey is 1 : 4,000 ( formerly 16 inches to a mile in the F.P.S. System). However, there is great variation in the scales adopted by various states and in different belts of land. Under the metric system, the areas are calculated in hectares ( one hundredth part of a square kilometers).

**94. Purpose and scope.**---Cadastral Surveys ( also called Settlement Surveys) are carried out mainly to determine the location, class, ownership, tenancy and area of each field, for entry in the records for the purpose of determining the land revenue. Cadastral Surveys are generally carried out village-wise ( i.e., *mouza-wise* ) and *tahsil or taluk-wise*. The word village or tashil means the habitation as well as the revenue lands attached to it. The cadastre prepared from the surveys may be “Fiscal” or “Legal” . In a “Fiscal Cadastre”, the accuracy of dimensions ( to one hundredth of a hectare), adequate for the assessment of revenue is necessary, whereas in a “Legal Cadastre” where the tracings from the map are necessary to be attached to the sale deeds, the map errors should not exceed plottable limits.

Cadastral maps also show main topographical detail such as railways, prominent trees, telegraph/telephone poles, *pucca* structures and paths / tracks as and when they form field limits. Habitations (except *pucca* buildings ) are shown conventionally. Besides the plan of fields, a cadastral map depicts the identifying number of each field, which is allotted serially after the Settlement Survey is completed. The limiting rectangular grid corners are depicted along the periphery of the map. The map also shows the names of village, district, subdivision and *thana* ( or equivalent administrative partition ) in which it falls, the scale and year of survey/publication, and the names of the adjoining villages. The maps of big villages may fall in more than one sheet.

Contours are not shown on cadastral maps.

**95. Considerations affecting specifications.**----The main considerations affecting the specifications are ( i ) the size and value of fields and (ii) the extent of survey.

The smaller the fields or the larger their revenue values, the larger should be the scale of survey. Thus, in orchard areas, the scale of survey may be as large as 1 : 1,000. On the other hand , in barren and less developed areas, the scale may go as small as 1 : 20,000.

Sometimes the whole district or part of a province may be taken up for survey. In these settlement operations, the headquarters of the district will be adopted as the origin of survey for co0ordinagtes and bearings. Alternatively, the center of the degree sheet may be adopted as the origin. If a small area is to be surveyed, the origin may be based at a convenient station on the boundary. The traverse will be run around the area concerned, as a closed traverse, so that the closing angular and linear errors in the circuit are easily determined and distributed. When the extent of survey is comparatively large, topo triangulation and/or theodolite traverse of 1 : 5,000 precision ( or better ) will be required.

**96. Methods of Field-work and Digitization (ground and photogrammetric ).**--- (a) *Ground Method.*---A **GPS/EDM** traverse is run along the periphery of the village,

connecting all the village trijunction pillars and permanent stations of similar traverse of adjoining villages, if existing.

In case, however, a block of villages is taken up for survey, main and sub-circuits of traverse are run in such a way that traverse stations are established along the periphery of each village. The main circuits should start from and close on G.T. station and should be of a high order of accuracy, i.e. 1 : 5,000 or better.

For detail survey, the traverse surround is divided up by sub-traverses or tie-lines at convenient intervals according to the density of fields. In open country these tie-lines may be about 1 km apart. The parcels of land bounded by these tie-lines are further sub-divided into quadrangles of 200 to 30 metre sides by joining :

- (i) traverse station,
- (ii) chained *katans* (i.e., terminal points of measure portions along the traverse lines),
- (iii) well-fixed intersected points of permanent nature like building corners and distance stones fixed by **Total Station**.

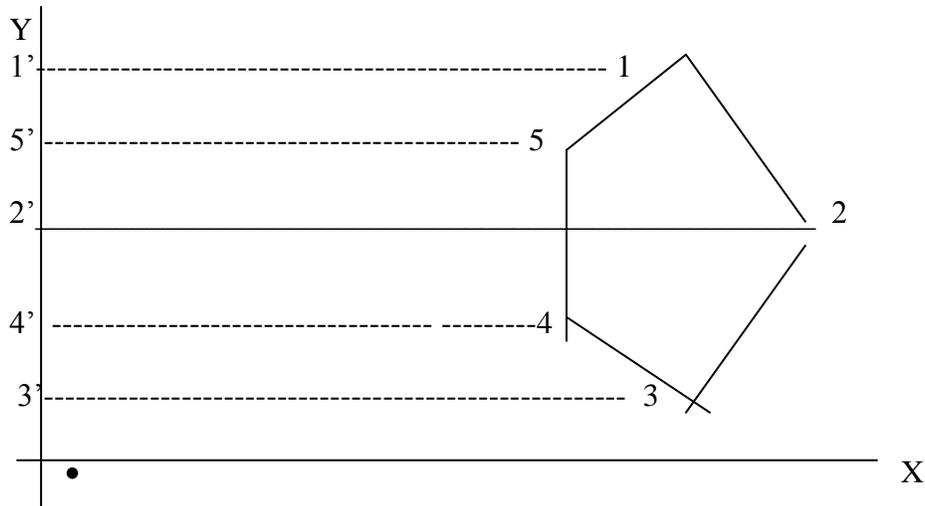
NOTE :- All distances and angles determining the quadrangle apexes are recorded in the field-books and treated as permanent record along with the traverse records and records of offsets (described below ).

In order to survey field limits, sub-lines joining *katans* at measured ( and recorded ) points along the sides of quadrangles are run. The lines are so run that they follow the general direction of the field boundaries. Offsets ( using optical squares ) are then measured to field corners and bends in the field boundaries. The density of sub-lines should be such that the lengths of offsets do not exceed 20 to 30 metres. In order to provide a check on the survey, *partal* lines should be run as usual.

Plotting/mapping of cadastral sheets is carried out by **modern techniques.i.e. either by downloading from Total Station or Digitization**. While digitization the co-ordinates of all traverse stations are plotted first. Thereafter, all intersected points and *katans* are marked. Quadrangle sides and all sub-lines are then digitized. Lastly, all offset points of field corners are plotted. Torough checking is necessary while **plotting**. Comparing the area enclosed by traverse surround as calculated from co-ordinates with that obtained by **measuring the shape area digitized** provides a reliable check on the overall accuracy of the work. The field numbers are entered at the time of preparation of records of rights (*khandpuri*) on the ground. Marginal items are entered to complete the map.

- (c) *Photogrammetric method*.---Photogrammetric method has already been employed for cadastral survey in some pilot projects. In this method, trijunction pillars and other salient points connected by **GPS** or traverse, are whitewashed or so marked on the ground that these points appear in the aerial photographs taken subsequently. Field limits are linked up in the field **while going for GPS observation**, on a matt set of prints of the photographs. These are consulted at the time of photogrammetric **survey**. Areas can be **measured once digitization of field boundaries completed**.

**97. Calculation of Areas**.---The idea of having a row of traverse stations along the periphery of a village, is to help calculation of the area of the closed polygon so formed, from the values of the co-ordinates as explained below :-



Let O be the origin of the rectangular co-ordinates and  $(X_1, Y_1)$ ,  $(X_2, Y_2)$ ,  $(X_3, Y_3)$ ,  $(X_4, Y_4)$  and  $(X_5, Y_5)$  be the co-ordinates of points 1,2,3,4 and 5 forming the polygon.

Let  $11'$ ,  $22'$ ,  $33'$ ,  $44'$ , and  $55'$  be the perpendiculars on the ordinate passing through the origin.

The area (A) of polygon 12345 = sum of areas of trapeziums,  $122'1'$  and  $233'2'$  minus sum of areas of trapeziums  $155'1'$ ,  $155'1'$ ,  $544'5'$  and  $433'4'$  i.e.,

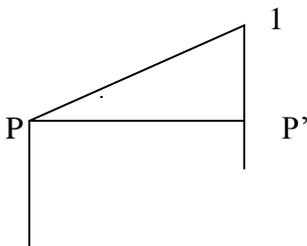
40

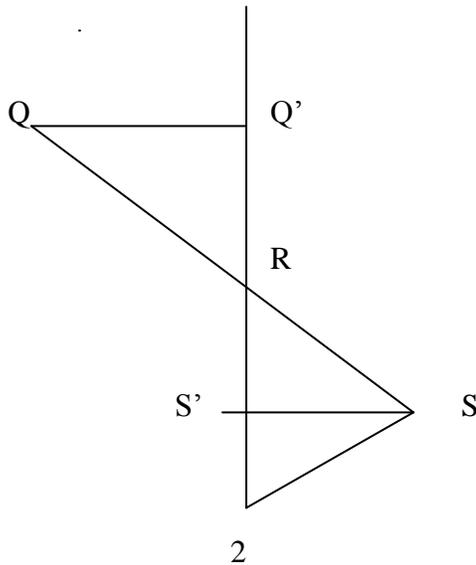
$$(A) = \frac{(X_1 + X_2) \cdot (Y_1 - Y_2)}{2} + \frac{(X_2 + X_3) \cdot (Y_2 - Y_3)}{2} \\ - \left[ \frac{(X_1 + X_5) \cdot (Y_1 - Y_5)}{2} + \frac{(X_5 + X_4) \cdot (Y_5 - Y_4)}{2} \right. \\ \left. + \frac{(X_4 + X_3) \cdot (Y_4 - Y_3)}{2} \right]$$

Which on rationalizing becomes

$$= \frac{1}{2} \left[ (X_1 + X_2)(Y_1 - Y_2) + (X_2 + X_3)(Y_2 - Y_3) \right. \\ \left. + (X_3 + X_4)(Y_3 - Y_4) + (X_4 + X_5)(Y_4 - Y_5) \right. \\ \left. + (X_5 + X_1)(Y_5 - Y_1) \right]$$

In order to obtain the area of the village, it is necessary to know the area between the actual boundary of the village and the traverse lines 12, 23 etc. This is determined as given below :-





Let 12 be the traverse leg and IPQRS 2 the village limit crossing the traverse leg at R. The distances PP' and SS' are offsets at points P', Q' and S' respectively along the traverse leg and the area of the triangles 1P'P, QQ' R, RS 2 and of the trapezium PP'Q'Q, i.e. area of figures 1RQP1 and S2RS is calculated and allotted ( + ) or ( - ) sign according as the boundary falls outside or inside the traverse circuit. Similar offsets to bends in the village boundary are observed from the traverse legs 23,34 etc., and areas are calculated. The algebraic sum when added to the area of the polygon 12345....., gives the area of the whole village.

The total area is useful as a check on the area obtained by totaling the areas of the individual fields, and for other statistical purpose.

Measurements 1P', P'., P'Q', Q', Q'R, RS', SS' etc., obtained above, can be used for plotting the village limit on the map.

The area of each field is calculated with the help of the offset measurements in the same way as explained above. Area Combs are also used for calculating these areas. An Area Combs is a rectangular hollow frame, in the middle of which equally spaced string are stretched, so that on placing the comb over the map, a field is divided into parallel strips of fixed known width. The total length of these strips ( measured with a pair of dividers ) when multiplied by the width, gives the area of the field. Area Combs can also be made by engraving or printing equally spaced straight lines on suitable transparent material.

The total area of all the fields in a village is checked against the calculated area of the village obtained by the method already explained. Various methods of checks and cross-checks may be adopted before the area of the field is finally accepted and recorded.

The above manual method of area calculation is not relevant in the digital environment where one can directly measure area very easy.

## SECTION V.—BOUNDARY SURVEYS

**98. General.**—Boundary Surveys are required for delimiting, demarcating, delineating and relaying of boundaries. The Survey of India is often called upon to give advice on the correct alignment of a boundary in a disputed area, based on cartographic guidance and descriptions.

In this section only the aspect concerning preparation of maps has been dealt. The advisory role of the department is outside its scope.

**99. Definitions.**—*Delimitation*. of a boundary refers to the agreement on alignment of the boundary, natural or artificial, and its descriptions with respect to topographical features and/or co-ordinates on the ground or on an agreed map.

Demarcation of a boundary involves identification of the delimited boundary on the ground and establishment of pillars and other markers wherever necessary to identify the line on the ground in an unambiguous manner. Usually the geographical co-ordinates of such pillars and markers, and sometimes of other points on the boundary or reference pillars, are also fixed, and a schedule of co-ordinates is prepared

*Delineation* involves survey and portrayal of the demarcated boundary in correct relation to topography on a map of suitable scale.

Relaying of a portion of a boundary means recovery of the old site of the boundary markers by rigorous ground survey, and re-erection or replacement thereof.

**100. Types of Boundaries.**--Surveys may be required for different types of boundaries like :-

- ( a ) Property boundaries,
- ( b ) Village and *Thana* boundaries,
- ( c ) Municipal or Cantonment boundaries.
- ( d ) District boundaries.
- ( e ) State boundaries.
- ( f ) Forest boundaries.
- ( g ) International boundaries.

The specifications for survey of a boundary will depend upon the terrain, value of land and type of boundary. The Survey of India will normally be entrusted with demarcation, survey and relaying of State or International boundaries.

**101. Survey Tasks.**---Normal survey and cartographic tasks that the department may be called upon to carry out are :-

- (a) preparation of a map and a description to finalize an agreement pertaining to delimitation ;
- (b) demarcation of a boundary for which delimitation has been agreed upon ;
- (c) delineation of a demarcated boundary on an accurate map ;
- (d) relaying a boundary on the ground for which documents and records exist but the boundary is either not clear on the ground or the markers have been washed away or disturbed.

**102. Delimitation.**--- Maps and descriptions for delimitation frequently have to be prepared in a very short time. It will frequently be necessary to make use of existing maps and descriptions with suitable modifications. According to international practice, unless

specifically agreed otherwise, in the case of a conflict between the map and description, the description will prevail.

The map for delimitation, and the description of the boundary, should avoid the under mentioned types of defects, which may later cause problems in demarcation : -

- (i) Use of ambiguous or imprecise terms ;
- (ii) Inaccurate description, including use of wrong place names ;
- (iii) References to non-existent features ;
- (iv) Contradictory description, including difference between description and map ;
- (v) Inaccurate map enclosed to the agreement.

**103. Demarcation and delineation.**---Demarcation survey caters to the following requirements:-

- (a) marking the boundary on the ground by prominent permanent markers ;
- (b) defining the boundary in an unambiguous manner ;
- (c) providing a description of the boundary with respect to topography ;
- (d) ensuring that the boundary is capable of being re-laid, should necessity arise, by providing description of markers and reference markers, by :
  - (i) absolute geographical co-ordinates ( specially in a featureless terrain ).
  - (ii) Approximate astronomical co-ordinates or bearings and distances to identifiable permanent objects in the vicinity.
- (e) delineating the boundary on special map ;
- (f) formalizing the work through a joint agreement.

**104. Scope of demarcation.**-- In an ideal case, the following will form the sequence of operations :-

- (a) Examination of delimitation documents, or past treaties and maps if no delimitation documents exist ;
- (b) Provision of Primary/Secondary Order Control as near the boundary line as possible;
- (c) Provision of EDM traverse of 1 : 3,000 precision close to the boundary line, based on (b);
- (d) Selection of pillar positions, establishment of pillars and their definition by co-ordinates, and preparation of a schedule ;
- (e) Survey of the boundary line with pillar positions and a strip of ½ km to 5 km width on both sides of the boundary, on a suitable scale depending on the terrain.

The documents on which the boundary information is incorporated may be :

- (i) maps on 1 : 15,000 scale ( or larger as necessary in case of flat valuable land where boundary takes many turns at short distances ).
- (ii) maps on scale 1 : 50,000 or so in difficult and unfrequented areas where the boundary follows unalterable natural features ( like sharp well defined ridges in high hills ).
- (iii) from-lined maps on 1 : 50,000 scale giving the location for the pillars/markers with reference to local detail.

(iv) aerial photographs/satellite imageries, photo maps orthophoto map on a convenient scale ( say 1 : 15,000 ) , photography being taken after the demarcation is completed and boundary pillars/markers constructed and pre-pointed.

(f) Acceptance and authentication of the maps and the boundary schedule.

**105. Preliminary Appreciation.**---The following available records , documents and maps should be studied to evaluate the procedure to be adopted :-

- (a) Notifications or bilateral agreement.
- (b) Authoritative boundary maps referred to in the notifications or bilateral agreements.
- (c) Topographical maps of the largest scale.
- (d) Cadastral maps.
- (e) Settlement reports.
- (f) Any awards with legal binding.

**106. Conflicting Records.**---In all types of demarcation, the concerned records should be carefully studied and evaluated. Cases may arise when when some records pertaining to a particular boundary are found to be conflicting or disagreeing. Steps should be take to ascertain the cause of discordance, which may be due to different claims or faulty maps. The degree of reliability and authenticity of the maps should be established by studying the methods, purpose and authority under which the maps were prepared and also be consulting relevant agreements, notifications and descriptions. Final decision should be taken after considering all possible alignments and in consultation with the parties concerned. Details like old field *bunds* and other landmarks can render valuable assistance in determining the correct position of a boundary.

Sometimes it may be possible to make apparently conflicting records agree by eliminating obvious errors from them. In case of different claims, it will be necessary to arrive at some agreements before a boundary can be re-laid or demarcated.

It should be noted that reconciliation of conflicting records is beyond the scope of a surveyor's responsibility. This should be done jointly by accredited agents of the two sides and the surveyor will only be responsible to demarcate the agreed boundary on the ground.

107. Terrain.---The terrain through which the boundary passes, greatly influences the requirements and methods of demarcation. If a boundary follows prominent watersheds, only the description, and sometimes, construction of a few pillars, may serve the purpose. In the case of a boundary following the middle or one bank of a river, special types of pillars may be designed or reference pillars constructed on firm ground on both sides of the boundary. Special consideration will be necessary in the case of a boundary following the thalweg or mid-deep-water-channel of a river ( usually of a navigable river according to international practice ). The number of pillars to be constructed will depend upon inter-visibility and alignment of the boundary. In areas where land is very costly or of strategic importance, the accuracy required for the demarcation and the number of pillars to be constructed will be very high. In flat and open terrain every change of alignment should, preferably, have a pillar.

**108. Use of Photography.**---Air photographs can be usefully employed in boundary demarcation. They can be useful before demarcation as well as after demarcation.

(i) *Before demarcation.*—Based on available control, **Photomap** Sections are prepared. A boundary alignment as per the best available information is marked on the **Photomap** of this survey. This boundary is compared against notifications, awards and treaty documents and tentative positions of proposed boundary pillars are marked on the **Photomap**. Pillars are constructed after confirming on the ground.

(ii) *After demarcation.*—The pillars are co-ordinated **preferably with GPS** and the final pillar positions and boundary alignment are corrected on **Photomap** mentioned above. Ground verification and final strip survey is carried out on the **Photomap**.

If co-ordinates of salient points are required, it will be more accurate to determine them by aerial triangulation than by reading co-ordinates from the map.

### **109. Boundary Pillars.---**

(a) *Positioning*—(i) All changes in alignment should be marked by pillars ( and their co-ordinates determined ) as it will be found advantageous to treat the boundary as a series of straight lines except where it follows prominent permanent natural features.

(ii) Adjacent pillars should be intervisible.

(iii) Distance between pillars should not be excessive in order that lay men can easily find the boundary by looking towards the next pillar. Whenever practicable, a minimum of three pillars should be constructed in one kilometer.

(iv) Pillars should be prominent.

(v) Historical, traditional and geographical background should be considered.

Utmost care should be taken before selecting a pillar position as it may not be found possible to alter it at a later stage even if an error is discovered. The boundary loses its sanctity and respect in the eyes of the public if pillar positions are changed often. Also, any subsequent change involves agreement between two or more parties.

(b) *Construction.*—After pillar positions are marked unambiguously on the ground, the constructing agency is asked to construct the pillars according to agreed specifications. Adequate precautions should be taken against accidental errors in erecting the pillars on correct spots and or engraving correct numbers. Responsibility for correctness of position lies with the demarcating agency and not the constructing agency.

(c) *Numbering.*---A suitable system of numbering of boundary pillars should be agreed between the concerned parties. Normally the boundary should be considered as a whole ( and not in parts ) and efforts should be made to keep the numbers continuous from one end to the other. Different sets and systems of numbers for different parts may sometimes result in confusion.

(d) *Types.*---the types of pillars suitable for a particular area should be decided in consultation with P.W.D. authorities after taking into consideration the needs of the area, material available and size desirable. The pillars should be strong and long-lasting.

(e) Co-ordinates.---Co-ordinates of all pillars should be determined by **GPS** or **EDM** traverse. List of co-ordinates should be prepared on the following proforma and signed by the executive officers : -

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List of co-ordinates, bearings and distances of boundary pillars

Boundary Pillar Nos.	Co-ordinates		Grid bearing of Forward pillar From North	Distance from Previous pillar	Type of pillar
	Easting	Northing			
	Grid metres	Grid metres		metres	

**110. Boundary along the middle or mid-channel of rivers.-** Where the boundary lies along the middle or mid-channel of a river (vide para 107 ) it may not always be possible to construct pillars along the boundary. In such cases only co-ordinates of points can be calculated from the traverse line or read off the final map. Sometimes hydrographic survey will have to be carried out for determining the mid-channel before it can be demarcated. Riverain boundaries are, generally, marked by reference pillars on solid high ground on both sides of the river. The design of these pillars should be different from that of ordinary boundary pillars, to avoid confusion. The number of reference pillars should be kept to the minimum.

**111. Strip Survey.---**Strip Survey covering agreed width of area on both sides of the boundary is carried out and is based on the final co-ordinates of the pillars. The scale of survey may vary from 1 : 4,000 to 1 : 50,000 or depending upon the needs. Particular care should be taken to show the boundary in correct relation to the topography. The boundary should be shown in its correct geographical position and, if necessary, nearly detail may be shifted out of position on the correct side of the boundary for clarity. The detail to be surveyed will depend upon mutual agreement between the two sides.

**112. Digitization.-**The entire length of a boundary should be divided into a number of sheets of convenient size which should be serially numbered from one end to the other. A suitable layout and mask may be designed for the series. This layout and the position of the concerned sheet with respect to the boundary as well as its incidence on 1 : 50,000 sheets, will be printed on each sheet. Names of administrative partitions ( districts, states and countries ) should be typed boldly in blank spaces on the respective sides of the boundary in the sheets. If it is decided to have grid lines as the limits of the sheets, ticks for geographical graticule should be drawn in the borders. When the description of the boundary has been agreed upon, the relevant portion will be printed on each sheet, and should be duly signed by the authorized representatives of the two sides.

A facsimile copy of the boundary schedule relevant to the sheet will be printed on the obverse of the concerned sheet, or on its reverse as space permits.

Colours in which sheets are to be printed will be decided jointly by the two sides.

A specimen of a boundary map prepared for India-Pakistan boundary is placed at Annexure N.

**113. Description of Boundary.**---The text of the boundary description should be very precise and should leave no doubt about the exact location of the details with respect to which it is described. The nature of the terrain and points through which the boundary passes should be mentioned. Where pillars are erected and co-ordinates of every pillar and change of alignment are agreed upon, the description loses much of its utility.

**114. Special Features of International Boundaries.**—In the case of international boundaries, the work is usually done jointly by the two countries. All observations are signed by the technicians of both sides. The observations are either recorded in duplicate by using carbon paper so that each side can take a copy, or Photostat copies or facsimiles are prepared. The original records and facsimiles are shared half and half. Computations may be done jointly or separately and compared later on. Agreed number of copies of lists are signed by Executive Officers of the two sides. A few copies of the final maps are signed by the plenipotentiaries of the two countries as a mark of acceptance by the two governments before they become legally binding documents. These copies become part of international treaties and are kept in the custody of the governments concerned. Later on, more copies, as decided mutually by the two governments, are printed and they carry the printed signatures of the plenipotentiaries.

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