

**DESIGN MANUAL**

**SURVEYING & MAPPING**

**DM 4-805-10**

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**DEPARTMENT OF THE ARMY  
CORPS OF ENGINEERS  
SACRAMENTO DISTRICT**



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## P R E F A C E

**This manual is not intended to be a text book on the procedures and techniques of surveying, mapping and photogrammetry. Its purpose is to provide general procedures and instructions for meeting the accuracy requirements of the U.S. Army Corps of Engineers, Sacramento District.**

**The Contractor-Engineer (C-E) using this manual should give special attention to the Sacramento District's note recording format, the number of horizontal angles required and necessity for beginning and ending both horizontal and vertical control surveys on two or more points. All other aspects of surveying remain as in standard industry accepted practice.**

**3rd Order Class II accuracy will generally be required for surveying and mapping prepared for the Sacramento District. Large control projects may require 3rd Order Class I or better accuracy.**

**Photogrammetric mapping shall always meet the National Map Standards of Accuracy.**

# 1 - PRIMARY HORIZONTAL CONTROL

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1.1 Primary horizontal control shall be used as the basic horizontal control for large mapping projects, to establish new horizontal control in a remote area, or to further densify existing horizontal control in an area.

1.1.1 This control shall be established using either the District's modified Third Order Class I techniques or by Global Positioning System Surveying. The points used for this control shall generally be monumented with Brass Disks.

1.1.2 The minimum instrumentation requirements for this type of control shall be a repeating theodolite with an optical micrometer with a least count resolution of six seconds (6") or better, a directional theodolite with an optical micrometer with a least count resolution of one second (1"), an electro-optical electronic distance measuring device capable of an accuracy of 1:10,000, a total station with the same capabilities, or a G.P.S. receiver capable of multi-channel reception.

1.2 Primary horizontal control points shall be marked with permanent type Brass Disk markers placed either flush with the existing ground level, or buried a minimum of one tenth of a foot (0.10') below the surface.

1.2.1 Concrete monuments with Brass Disks shall be established prior to the accomplishment of any horizontal or vertical control. These monuments shall be established in accordance with Chapter 5.

1.3 Primary horizontal control monuments shall be occupied by a theodolite and electronic distance meter, an electronic total station or a G.P.S. receiver. Establishing points by one angle and one distance only WILL NOT be permitted (i.e., NO sideshots).

1.4 Distance measurements shall be accomplished with an electronic distance meter capable of obtaining an accuracy of 1:10,000 or an electronic total station with the same capabilities.

1.4.1 A minimum of three (3) readings shall be taken at each station and recorded in a standard field book or on an approved form. The height of the instrument and the height of the reflector shall be measured carefully (to within 0.02') and recorded in the field book. Each slope distance shall be reduced to a horizontal distance using either reciprocal vertical angle observations as outlined in Chapter 4, or from elevations obtained using differential leveling techniques as outlined in Chapter 3. See Plate 2.

1.4.2 All electronic distance measuring devices and prisms should be serviced regularly and checked frequently over lines of known length. The National Geodetic Survey has established specific calibration base lines for this purpose. EDM instruments should be calibrated annually and frequency checks made semiannually.

1.5 If a repeating theodolite (i.e., Wild T1) is used for the horizontal angles, the instrument shall be pointed at the backsight station with the telescope in a direct reading position, and the horizontal vernier set to zero (0) degrees.

1.5.1 The angles shall then be turned to the right and the first angle recorded. The angle shall be repeated a minimum of eight (8) times by alternating the telescope pointing in the direct and inverted positions. The last angle shall also be recorded. See Plate 2.

1.5.2 If the first angle deviates more than five seconds (5") from the result of the last angle divided by eight (8), the process shall be repeated until the deviation is less than or equal to 5".

1.5.3 The horizon shall be closed by repeating this process for all sights to be observed from that location. The foresight for the last observation shall be the same as the backsight for the first observation. If the sum



of all the angles turned at any station deviate more than ten seconds (10") from 360 degrees, the angles shall be re-turned until the summation is within that tolerance. See Plate 2.

1.6 If a directional theodolite (i.e., Wild T2) is used for the horizontal angles, the instrument shall be pointed at the backsight station with the telescope in a direct reading position and the horizontal vernier set to within ten seconds (10") of zero (0) degrees. The vernier shall then be brought into coincidence and the angle read and recorded in a standard field book or on an approved form. See Plates 3 & 4.

1.6.1 The angles shall then be turned to each foresight in a clockwise direction, and the angles read and recorded. This process shall continue in a clockwise direction and shall include all sights to be observed from that station. See Plates 3 & 4.

1.6.2 The telescope shall then be inverted and the process repeated in reverse order, except the vernier is not reset; it is read where it was originally set (the inverted angle reading should be within 30" of 180 degrees of the direct angle reading). The actual angles between stations may then be computed by taking the mean of the direct and reverse reading, and subtracting them. See Plate 3 & 4.

1.6.3 This process shall be repeated four (4) times (i.e., 4 sets). For the first set of angles the initial plate setting shall be at or near 0-0-10. For the second set, the initial plate setting shall be at or near 45-04-40. For the third set, the initial plate setting shall be at or near 90-05-10. For the fourth set, the initial plate setting shall be at or near 135-07-40. See Plates 3 & 4.

1.7 If an electronic total station is used for the horizontal angles, the same procedures shall be followed as outlined in Section 1.5 or 1.6. The Sacramento District Survey Section will state which procedure to follow, based on the type of total station to be used.

1.8 Each year, and whenever the difference between direct and reverse readings of any theodolite deviate more than thirty seconds (30") from 180 degrees, the instrument should be adjusted for collimation error.

1.8.1 Readjustment of the cross hairs and the level bubble should be done whenever their mis-adjustments affect the instrument readings by more than the least count of the vernier of the theodolite.

1.9 To reduce slope distances to horizontal, a vertical angle observation shall be obtained from each end of each line being measured, as outlined in Chapter 4.

1.9.1 Vertical angles shall be read a minimum of two (2) times in both the direct and inverted scope positions. If the difference between the two angles (after each is adjusted to 360 degrees) is greater than ten seconds (10"), the angles shall be repeated until the difference is less than or equal to 10". See Plate 2,3 & 4.

1.9.2 If elevations were obtained by differential levels as outlined in Chapter 3 for the points on each end of the line being measured, the vertical angle requirement may be waived.

1.10 Targets shall be set for all backsights and foresights.

1.10.1 Sights may be a reflector or other type of target in a tribrach, or a line rod plumbed over the point in a tripod, or guyed in place from at least three positions.

1.10.2 Artificial sights (i.e., a tree on the hill behind the point) or hand held sights (i.e., line rod or plumb bob string) shall not be used.



**1.11 If Global Position System Surveying is to be utilized, it shall be accomplished in accordance with U.S. Army Corps of Engineers Engineer Manual EM 110-1-1003 dated 14 June 1991**



## 2 - SECONDARY HORIZONTAL CONTROL

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**2.1** The purpose of secondary horizontal control is to establish the location of structure sections, cross sections, topography and pre-mark requirements for small to medium scale photogrammetric mapping projects.

**2.1.1** This control shall be established using the Sacramento District's modified Third Order Class II techniques.

**2.1.2** The minimum instrumentation requirements for this type of control shall be a repeating theodolite with an optical micrometer with a least count resolution of six seconds (6") or better or a directional theodolite with an optical micrometer with a least count resolution of one second (1") and an electronic distance measuring device capable of an accuracy of 1:10,000 or a total station with the same capabilities.

**2.2** Secondary horizontal control points shall be marked with semipermanent type markers (i.e., re-bar, railroad spikes, large spikes etc.), placed either flush with the existing ground level, or buried a minimum of one tenth of a foot (0.10') below the surface.

**2.2.1** Each control point established shall be referenced by a minimum of two (2) points to aid in future recovery of that point.

**2.2.2** The reference points should be within one hundred feet (100') of the control point. If there is not a well defined point on the reference object, one shall be established (i.e., nail in pole).

**2.2.3** Well defined natural or man-made objects may be utilized. If none are available, additional points shall be established to serve as reference.

**2.2.4** A sketch shall be placed in a standard field book showing the relative location of each control point to the reference points, and major physical features within one hundred feet (100') of the point. Reference Plate 2. See Chapter 11 for procedures to record field data.

**2.2.5** If concrete monuments are required, they shall be established prior to the accomplishment of any control. These monuments shall be established in accordance with Chapter 5.

**2.3** Secondary horizontal control monuments shall be occupied by a theodolite and electronic distance meter, or a total station. Establishing points by angle and distance only will not be permitted (i.e., NO sideshots).

**2.4** Distance measurements shall be accomplished with an electronic distance meter capable of obtaining an accuracy of 1:10,000 or a total station with the same capabilities.

**2.4.1** A minimum of two (2) readings shall be taken at each setup and recorded in a standard field book or on an approved form. The height of the instrument and the height of the reflector shall be measured carefully (to within 0.02') and recorded. Each slope distance shall be reduced to a horizontal distance using either reciprocal vertical angle observations as outlined in Chapter 4, or from elevations of each point obtained using differential leveling as outlined in Chapter 3.

**2.4.2** All electronic distance measuring devices and prisms should be serviced regularly and checked frequently over lines of known distance. The National Geodetic Survey has established specific calibration base lines for this purpose. EDM instruments should be calibrated annually, and frequency checks made semiannually.



**2.5** If a repeating theodolite (i.e., Wild T1) is used for the horizontal angles, the instrument shall be pointed at the backsight station with the telescope in a direct reading position, and the horizontal vernier set to zero (0) degrees.

**2.5.1** The angles shall then be turned to the right and the first angle recorded in a field book. The angle shall be repeated a minimum of six (6) times by alternating the telescope pointing in the direct and inverted positions. The last angle shall also be recorded. See Plate 5.

**2.5.2** If the first angle deviates more than five seconds (5") from the result of the last angle divided by six (6), the process shall be repeated until the deviation is less than or equal to 5".

**2.5.3** The horizon shall be closed by repeating this process for all of the sights to be observed from that location. The foresight for the last observation shall be the same as the backsight for the first observation. If the sum of all the angles turned at any station deviate more than ten seconds (10") from 360 degrees, the angles shall be re-turned until the summation is within that tolerance. See Plate 5.

**2.6** If a directional theodolite (i.e., Wild T2) is used for the horizontal angles, the instrument shall be pointed at the backsight station with the telescope in a direct reading position and the horizontal vernier set to within ten seconds (10") of zero (0) degrees. The vernier shall then be brought into coincidence and the angle read and recorded in a standard field book or on an approved form. See Plate 6.

**2.6.1** The angles shall then be turned to each foresight in a clockwise direction, and the angles read and recorded. This process shall continue to include all sights to be observed from that station. See Plate 6.

**2.6.2** The telescope shall then be inverted and the process repeated in reverse order, except the vernier is not reset, it is read where it was originally set (the inverted angle reading should be within 30" of 180 degrees of the direct angle reading). The actual angles between stations may then be computed by taking the mean of the direct and reverse reading, and subtracting them. See Plate 6.

**2.6.3** This process shall be repeated two (2) times (i.e., 2 sets). For the first set the plate shall be set at or near 0-0-10. For the second set the plate shall be set at or near 90-05-40.

**2.7** If an electronic total station is used for the horizontal angles, the same procedures shall be followed as outlined in Section 2.5 or 2.6. The District will state which procedure to follow, based on the type of total station to be used.

**2.8** Each year, and whenever the difference between direct and reverse readings of a theodolite deviate more than thirty seconds (30") from 180 degrees, the instrument should be adjusted for collimation error.

**2.8.1** Readjustment of the cross hairs and the level bubble should be done whenever their mis-adjustments affect the instrument readings by more than the least count of the vernier.

**2.9** To reduce slope distances to horizontal, a vertical angle observation shall be obtained from each end of each line being measured.

**2.9.1** The vertical angles shall be read a minimum of two (2) times in both the direct and inverted scope positions. If the difference between the two angles (after each is adjusted to 360 degrees) is greater than ten seconds (10"), the angles shall be repeated until the difference is within the stated tolerance. See Plates 5 & 6.

**2.9.2** If elevations were obtained by differential levels as outlined in Chapter 3 for the points on each end of the line being measured, the vertical angle requirement may be waived.



**2.10 Targets shall be set for all backsights and foresights.**

**2.10.1** The sights may be a reflector or other type of target in a tribrach, or a line rod plumbed over the point in a tripod, or guyed in place from at least three positions.

**2.10.2** Artificial sights (i.e., a tree on the hill behind the point) or hand held sights (i.e., line rod or plumb bob string) shall not be used.



### 3 - VERTICAL CONTROL BY DIFFERENTIAL LEVELING

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3.1 Vertical control established by differential leveling techniques shall be for the purpose of large scale mapping projects and to control various other mapping as appropriate.

3.1.1 Large scale is defined as 1"=50' or larger.

3.1.2 A construction or builders level will not be acceptable for this vertical control.

3.1.3 Elevations obtained from Global Positioning System Surveying will not be acceptable to control large scale mapping.

3.1.4 The minimum instrumentation requirements for this type of control shall be a self-leveling or automatic level designed specifically for surveying and engineering.

3.2 Establishing elevations by computations derived from a slope distance and vertical angle observation (such as that performed in a total station) will not be permitted for primary vertical control. See Chapter 4 for discussion of Vertical Control by Vertical Angle Observations.

3.3 All differential levels shall begin on a monument of known elevation that has previously been established by a reputable agency such as the U.S.G.S., U.S.C.E. or N.G.S. The monument shall have an elevation of third order accuracy or better.

3.3.1 The latest published elevation for the monument shall be used. If elevations established by one of the above listed agencies cannot be recovered, the Sacramento District Survey Section reserves the right to determine what agencies' elevations are acceptable.

3.3.2 The differential levels shall be run through each control monument established for the project. Each point shall be a turning point in the level line. Side shots WILL NOT be permitted as a means of establishing elevations on any control station.

3.3.3 Approximately every mile along the vertical control line, a TBM (Temporary Bench Mark) with a minimum of one (1) reference mark shall be established in a location that will not be subject to vandalism (i.e., railroad spike in a power pole, chiseled square in corner of headwall, bolt in NE corner of fire hydrant etc.).

3.3.4 Each point selected as a TBM shall be well defined. A concrete slab, such as the floor of a building, shall not be used when there is a point that can be positively identified (i.e., chiseled square in the northeast corner of the slab).

3.3.5 Each TBM shall also be a turning point in the level line. A sketch shall be entered in a standard field book or on an approved form, showing the TBM and its relative location to all physical features within fifty feet (50') of the point.

3.3.6 Levels shall be recorded in standard field books or on approved forms. See Chapter 11 for accepted procedures for recording field obtained information. See Plates 7 & 8.

3.4 All level runs shall terminate on a monument of known elevation that has previously been established by a reputable agency such as the U.S.G.S., U.S.C.E. or N.G.S. The monument shall have an elevation of third order accuracy or better.



3.4.1 The latest published elevation for this monument shall be used. If elevations established by one of the above listed agencies cannot be recovered, the Sacramento District Survey Section reserves the right to determine what agencies' elevations are acceptable.

3.4.2 No level line shall begin and terminate on the same monument.

3.4.3 Any level run between monuments of known elevation shall check to within .04 ft. multiplied by the square root of the length of the line in miles. Closures outside those tolerances shall be re-run to check for blunders. If the re-run verifies that the initial run was correct, it would indicate that one of the monuments may be disturbed. Additional ties shall then be made until the tolerance requirements are met.



## **4 - VERTICAL CONTROL BY VERTICAL ANGLE OBSERVATIONS**

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**4.1** Vertical control established by vertical angle observations shall be for the purpose of small scale mapping projects.

**4.1.1** Small scale is defined as 1"=80' or smaller.

**4.1.2** Generally, elevations obtained by vertical angle observations may be used when the contour interval requirements of the project are two foot (2') or greater.

**4.2** Vertical angles shall be read from both ends of the line being measured. The time span between readings shall not be greater than one (1) hour.

**4.3** Vertical angles shall be read with a theodolite with a least count vernier of six second (6").

**4.4** Vertical angles shall be read a minimum of two (2) times with the telescope in the direct and reverse positions. See Plates 4,5,6,7 & 8.

**4.4.1** The summation of the direct and reverse readings shall not deviate more than ten seconds (10") from 360 degrees)

**4.4.2** The difference between the two individual readings shall not exceed ten seconds (10").

**4.5** The mean adjusted vertical angle reading shall be used in the computation of the difference in elevation.



## **5 - MONUMENTATION**

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**5.1** Monuments shall be controlled to the accuracy stated for each project and shall be incorporated into the appropriate horizontal and vertical control scheme.

**5.2** Monuments shall be set in pairs, a minimum of one thousand feet (1000') apart, to provide for an azimuth from each station.

**5.3** The monuments shall be constructed by pouring concrete in place and inserting a standard Corps of Engineers Brass Disk in the top and center of the newly poured concrete.

**5.3.1** A hole shall be excavated in the ground a minimum of three feet (3') deep and six inches (6") in diameter.

**5.3.2** At least three (3) pieces of #5 steel reinforcing bar, three feet (3') long, shall be driven into the bottom of the hole, leaving at least one foot (1') of the re-bar protruding into the hole.

**5.3.3** The top of the hole shall be formed with a wax impregnated cardboard tube or equivalent, to provide a finished size of six inches (6") in diameter. The top of the form shall be at ground level.

**5.3.4** A standard Corps of Engineers Type II Brass Disk, shall be placed in the top of the newly poured concrete. The shank of the disk is split and shall be spread apart prior to placement. The stamping on the disk may be made before the disk is placed in the concrete, or no sooner than five days afterwards.

**5.4** Each disk shall be stamped with metal dies no smaller than one-eighth inch (1/8") and no larger than one-quarter inch (1/4") in height. See Plate 18.

**5.4.1** The AGENCY block stamping shall read U.S.C.E. SACTO.

**5.4.2** The YEAR block stamping shall read the year in which the monument was set.

**5.4.3** The STATION DESIGNATION stamping shall be numbered sequentially beginning with the numbering system provided by the Sacramento District Survey Section for the project. Only the name or sequence number provided by the Sacramento District shall be stamped in this space. Project designations such as HV-5 shall not be stamped thereon.

**5.5** Each monument established, shall be referenced by at least two (2) distance ties to either a permanent physical object (fence post, fire hydrant, etc.), or a point established in a permanent object (nail in tree, chiseled cross in concrete curb, etc.).

**5.5.1** All reference points shall be well defined. No object shall be used from which a precise measurement cannot be obtained (i.e., tree, power pole etc.).

**5.5.2** The reference points shall be within one hundred feet (100') of the newly established monument, and shall be selected so that the angle between them, as measured from the monument itself, is between forty-five (45) degrees and one hundred thirty-five (135) degrees.

**5.5.3** A sketch for all horizontal control points shall be placed in a standard field book or on an approved form. The sketch shall show the relative location of each control point to the reference points, and major physical features within one hundred feet (100') of the point. See Plates 2,5 & 6.



5.6 Monuments shall be set prior to the establishment of any horizontal or vertical control.

5.6.1 The appropriate State Coordinate System and Zone shall be established on each monument by using it as an angle point in the horizontal control line. No monument shall be controlled by a side shot, bearing-bearing, or distance-distance intersection computation. Each monument shall be occupied by a theodolite and EDM or total station.

5.6.2 An elevation shall be established on each monument by using the differential leveling procedures outlined in Chapter 3, or the vertical angle procedures outlined in Chapter 4. The procedural and accuracy requirements for each project will vary and will be established by the Sacramento District.

5.7 For each monument established, a Government form DA 1959 shall be completed, and the original provided to the Sacramento District Survey Section. See Plate 16.

5.7.1 Country shall be changed to read county on all forms and the appropriate county entered in that space.

5.7.2 Type of mark shall be the material the mark is constructed of (i.e., brass disk).

5.7.3 Station shall be the actual designation given to the mark (i.e., 100-27). This designation will be provided by Survey Section.

5.7.4 Locality shall be the closest town or major physical landmark (i.e., Mather Air Force Base, Reno, Fresno, Sacramento etc.).

5.7.5 Stamping on the mark shall be the same as entered in the Station column.

5.7.6 Agency shall be U.S.C.E. on all forms.

5.7.7 Latitude and longitude shall be computed for each station from the final adjusted coordinate values, and the results entered in the appropriate spaces. Seconds for each result shall be listed to only three (3) decimal places.

5.7.8 Datum shall contain "NAD 1927" or "NAD 1983" depending on which horizontal datum is used, unless stated otherwise by the Sacramento District Survey Section.

5.7.9 Northing and easting for each station shall be listed to only two (2) decimal places in U.S. Survey feet, unless the coordinates are of 1st order accuracy, in which case three (3) decimal places shall be shown. The designation (NORTHING) or (EASTING) that does not apply in each space shall be lined out in ink. The "(m)" shall also be lined out in each space in ink.

5.7.10 Grid and Zone shall contain the appropriate four (4) digit Zone designation as listed below:

STATE ZONE CODES					
ARIZONA		CALIFORNIA		NEVADA	
East	0201	I	0401	East	2701
Central	0202	II	0402	Central	2702
West	0203	III	0403	West	2703
		VI	0404		
		V	0405		
COLORADO		VI	0406	UTAH	
North	0502	VII	0407	North	4301
South	0503			Central	4302



**5.7.11** The elevation for each point shall be listed in feet, to two (2) decimal places if the elevation was obtained using differential leveling techniques as outlined in Chapter 3, or to one (1) decimal place if the elevation was obtained using vertical angle techniques as outlined in Chapter 4. The "(m)" shall be lined out in ink on each form.

**5.7.12** Elevation datum shall be NGVD 1929 or NAVD 1988 on all forms, depending on which vertical datum was used, unless stated otherwise by the Sacramento District Survey Section.

**5.7.13** Established by, shall contain U.S.C.E. or the contractors name if established by contract.

**5.7.14** Date space shall contain the month and year that the elevation or horizontal position was established on the point (i.e., Dec 87).

**5.7.15** Order shall contain "3rd" if the elevation was obtained using differential leveling techniques as outlined in Chapter 3, or VA if obtained using vertical angle observations as outlined in Chapter 4.

**5.7.16** It is not necessary to fill out the spaces labeled grid azimuth, object, and back azimuths.

**5.7.17** In the blank area in the lower right hand corner of the form, a sketch of the point showing adjacent natural and man made objects, and the reference points with their distances, shall be drawn in ink.

**5.7.18** Within the remaining portion of the blank area on the bottom half of the form, a more detailed description of the monument and how to reach it from a prominent location (i.e., the intersection of two major highways, courthouse building, etc.) shall be entered.

**5.7.19** All DA 1959 forms shall be in a typewritten format. Sketches shall be drawn in black ink.



## **6 - AERIAL PHOTO PRE-MARKING**

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**6.1** Pre-marking of horizontal and vertical control points shall be accomplished when the project is to be mapped with aerial photogrammetric techniques.

**6.2** The location of the pre-marks will be established so that the accuracies of the mapping required for each project, and the National Map Standards of Accuracy may be met.

**6.2.1** Pre-marks shall be located outside the boundaries of the required mapping as well as within those limits so that a stereo model is not cantilevered.

**6.3** The pre-marks shall be established of a sufficient size to be clearly visible in the aerial photography.

**6.3.1** The pre-marks shall not be constructed of a material that will cause injury to livestock if eaten.

**6.3.2** When required, all pre-marks shall be removed as soon as possible after the aerial photography has been flown and accepted.

**6.4** If any pre-marks are missing prior to the flight, they shall be replaced.

## **7 - FIELD TOPOGRAPHY**

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**7.1** Horizontal control required for these surveys shall not be less than secondary horizontal control as outlined in Chapter 2.

**7.2** Vertical control required for these surveys shall not be less than secondary vertical control as outlined in Chapter 4.

**7.3** The station occupied by the theodolite or total station, and the initial sighting point (backsight), shall always be clearly identified in the field notes.

**7.3.1** The theodolite vernier reading on the initial sighting point (backsight) shall always be zero degrees and zero minutes.

**7.3.2** Angles to topographic features to be located shall be turned to the right of the initial sighting point. The angles shall be read and recorded in a standard field book or on an approved form, to the nearest minute. Distance shall be recorded to the nearest 0.1 foot. See Plates 10,11 & 12.

**7.4** Elevations for topographic features may be obtained with a total station, by use of zenith or vertical angles and a slope distance, or by reading a rod with a level.

**7.4.1** When vertical angles are used, the symbols + or - shall always be recorded in the field notes to indicate whether the telescope of the theodolite was depressed or elevated from the normal line of sight or level position.

**7.4.2** If zenith angles are used, the + or - symbol is not required.

**7.4.3** Elevations obtained on natural ground surfaces shall only be listed to the nearest one-tenth of a foot (0.10'). Those on concrete or other surfaces of stable elevation shall be obtained to the nearest one-hundredth of a foot (0.01').

**7.5** Obtaining elevations on concrete or other surfaces of stable elevation by use of vertical angle observations shall be restricted as follows:

**7.5.1** If the vertical angle from the instrument to the reflector or rod is less than one degree of arc, the slope distance shall be restricted to three hundred feet (300').

**7.5.2** If the vertical angle from the instrument to the reflector or rod is greater than one degree, the slope distance shall be restricted to five hundred feet (500').

**7.6** Obtaining elevations on natural ground surfaces by use of vertical angle observations shall be restricted as follows:

**7.6.1** If the vertical angle from the instrument to the reflector or rod is less than one degree of arc, the slope distance shall be restricted to five hundred feet (500').

**7.6.2** If the vertical angle from the instrument to the reflector or rod is greater than one degree, the slope distance shall be restricted to one thousand feet (1000').

**7.7** A double page a field book or one page of an approved form shall be used to draw a sketch of the area being surveyed. Multiple sketches should be drawn, if necessary, to avoid crowding.



**7.7.1** Sketches are not required to be drawn to scale, however, they should have the same general relation as do the actual topographic features on the ground. See Plate 11.

**7.7.2** The sketch shall be oriented by showing a north arrow and identifying the main physical features of the surrounding area by name.

**7.7.3** As the topographic features are located, they shall be identified on the sketch and shall be numbered consecutively in their approximate relative position.

**7.7.4** Sufficient shots shall be taken so that the draftsman can prepare a map of the area that clearly shows all physical features both horizontally and vertically.

**7.8** The following checks shall be made at each instrument location where possible:

**7.8.1** Compute the H.I. and reduce the first and last shot.

**7.8.2** Observe a check shot on a known point or a point located from another setup.

**7.8.3** Upon completion of the work at the instrument location, the initial sighting point (backsight) should be checked to make sure the horizontal plate of the theodolite has not slipped. This check angle shall be within thirty seconds (30") of the initial backsight angle.

## **8 - PLANE TABLE TOPOGRAPHY**

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**8.1** Plane table topography is generally utilized when (1) the area to be mapped is small in size and a preliminary map of the area is required within a short time, or (2) the project is to be accomplished by field methods and the site is so remote that a return trip to edit the final drawing would be impractical.

**8.2** The horizontal control required for plane table topography shall not be less than secondary as outlined in Chapter 2.

**8.2.1** The positions of all control points shall be plotted accurately on the plane table sheet prior to obtaining any topographic measurements.

**8.2.2** If supplemental points are required, they shall be tied to the basic control points.

**8.3** The vertical control required for plane table topography shall not be less than that as defined in Chapter 4.

**8.3.1** If supplemental points are required, they shall be tied to the basic control points prior to obtaining the topographic measurements. The elevation for these points shall be acquired by the differential leveling techniques as outlined in Chapter 3.

## 9 - CROSS SECTIONS

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9.1 Cross sections shall be tied horizontally to secondary horizontal control as outlined in Chapter 2, and vertically to the vertical control as outlined in Chapter 4.

9.2 The spacing and length of the cross sections shall be determined by the particular project.

9.2.1 Preliminary (design) cross sections shall be of sufficient length and spacing to give the necessary information for design of the proposed project.

9.2.2 Cross sections taken prior to construction shall be of sufficient length to extend a minimum of fifty (50) feet beyond the limits of the proposed construction and spaced to show all breaks in the ground necessary to determine quantities.

9.2.3 Cross sections taken after construction shall be taken at the exact locations as the before construction cross sections and at additional locations as required to determine quantities.

9.2.4 The cross sections shall extend a minimum of fifty (50) feet beyond the construction limits.

9.3 Horizontal distances shall be measured to the nearest one (1) foot or five-tenths (0.5) foot, as required by the project.

9.4 Elevations shall be determined to the nearest one-tenth (0.1) foot on ground and to one-hundredth (0.01) foot on hard surfaces.

9.5 Cross sections shall generally be taken perpendicular to the feature being cross sectioned as indicated below.

9.5.1 Cross sections for roads shall be taken perpendicular to the centerline of the road.

9.5.2 Cross sections taken on a grid shall be perpendicular to the base line.

9.5.3 Cross sections taken along levees shall be perpendicular to the levee centerline.

9.5.4 Cross sections taken across waterways shall be perpendicular to the centerline of the waterway.

9.5.5 For cross sections not taken perpendicular to a control line, the angle at which they are taken shall be measured and recorded in the field notes.

9.6 An elevation and distance shall be obtained at each break in grade and physical feature the cross section intersects (i.e., edge of pavement, crown of levee, toe of levee, telephone line, edge of water, edge of brush, centerline of ditch, etc.).

9.6.1 A description of the feature shall be written in a standard field book or on an approved form.

9.6.2 In no case will the horizontal distance between shots exceed fifteen (15) feet on slopes of 3 to 1, or fifty (50) feet on flatter slopes and level ground.

9.7 Where cross sections include soundings that are to be taken at a later date, an out stake shall be set at some convenient location on line near the edge of water. The distance and elevation at the out stake shall be recorded in the notes and the distance and station written on the out stake.



9.7.1 When the soundings are taken, all distances shall be taken from the out stake, and the total distance shall be obtained by adding the out stake distance to the sounding distance.

9.7.2 When soundings are taken, the water surface shall be zero and all soundings referred to this zero. The elevation of the water surface shall be established at the time the soundings are taken, either by determining the elevation of the water surface at each sounding line by using the leveling techniques outlined in Chapter 3, or by using a gage which was previously established using those same techniques. The method used should be clearly indicated in the field notes.

9.8 Cross sections may be taken with a level, tape, and graduated rod; by EDM and theodolite; or total station.

9.8.1 The H.I. of each setup shall be computed, and at least one minus rod on each cross section should be reduced to make certain the H.I. has been figured and is shown.

9.8.2 A check shot should be made to another known elevation to check the H.I. This check shall be within one-tenth of a foot (.10).



## 10 - FIELD EDITING

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**10.1** Field editing is the process of obtaining information in the field which cannot be obtained from photogrammetric mapping, or the checking of information plotted from field topography notes.

**10.2** Blueline prints of the final maps or the manuscript maps shall be edited in the field to identify all major physical features within the limits of the project site.

**10.2.1** Roads shall be labeled with their appropriate name or designation. The type of material that the road is constructed of shall also be noted (i.e., concrete, blacktop, gravel etc.).

**10.2.2** Waterways shall be labeled with their appropriate name or designation. A flow arrow shall also be shown and mileage markers if previously established and published.

**10.2.3** Single family dwellings in a civil or military residential area, and small office buildings shall be labeled with their street address.

**10.2.4** Buildings on a military installation shall be labeled with their building number.

**10.2.5** Large buildings within a commercial area shall be labeled with the name of the business.

**10.2.6** Runways shall be labeled with their designated number. The type of material that it is constructed of shall also be noted (i.e., concrete, blacktop, etc.).

**10.2.7** Manholes and drop inlets shall be labeled with their type (i.e., storm sewer, telephone etc.). The elevation of the rim shall be obtained and recorded in a standard field book or on an approved form. The invert elevation and inside diameters of all pipes entering or exiting the manhole or drop inlet shall also be obtained and recorded. The pipe lines between manholes and drop inlets shall also be drawn on the field check prints. If the next manhole is not within the mapping limits, a direction of the line shall be carefully and accurately plotted on the prints.

**10.2.8** Fire hydrants, water and gas valves, telephone and power lines, and other features that cannot be identified from the photogrammetric mapping shall be located and labeled in the field on the blueline prints.

**10.2.9** In areas where dense brush or trees prohibit the photogrammetrist from obtaining the true shape of the terrain, sufficient spot elevations shall be obtained in the field to assist the photogrammetrist in better defining the contours. This data may be obtained by use of a total station. All data shall be recorded in a standard field book, on an approved form or in an electronic data collector.

**10.3** For military installations, utility maps shall be procured from the appropriate organization and used in the search for existing utilities.

**10.3.1** If necessary, a metal detector or electronic tracer of some type shall be utilized to locate the underground utilities shown on the base utility maps.

**10.4** All field editing information shall be transferred to the final drawings. If the drawings are being prepared in a computer aided drafting program, the field edit data shall also be transferred to that database.

**10.4.1** If utility lines that are shown on the base utility maps could not be located in the field, the approximate location of the line shall be transferred to the final drawing and a note attached indicating the following: *the location of this line was derived from base utility drawings - unable to field verify.*



## 11 - FIELD NOTES

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**11.1** No part of the surveying operation is of greater importance than the field notes. The competence of the surveyor is reflected more in the character of his notes than his use of the instruments. The notes constitute a permanent record of the survey.

**11.1.1** In the case of total stations (i.e., electronic field books) the data should be recorded in the data collector and later transferred to a storage media and printer on paper.

**11.1.2** All notes shall be recorded in a form that can be interpreted with ease by anyone having a basic knowledge of surveying.

**11.2** All field notes, except those taken with a data collector, shall be recorded in a standard, hardcover field book (4 7/8" X 7 1/2") or on an approved form, as the measurements are made in the field.

**11.2.1** No data will be written on scratch paper or on the back page of the field book and copied into the book later. No details be carried in the mind of the surveyor until the end of the day, or the job, and then entered in the field book. Information copied or transferred into a field book, or carried in the mind for a time before entry in the field book, is subject to error more than information recorded immediately as it is obtained. The systematic recording of data improves accuracy.

**11.3** No erasures will be made in any notes. When errors are made, they shall be corrected by lining through the erroneous figures in such a way that the original figures remain legible.

**11.3.1** When a complete page is in error, a line will be neatly made through the page, along with the word "VOID" in large letters written diagonally across the page. A cross reference will be entered on the voided page showing the book and page number where the corrected information may be found. An explanation of the error and the correction will be entered in the field notes.

**11.4** When it is necessary to copy information from another field book or other source, a note will be made which clearly states that the information was copied and the source from which it came.

**11.4.1** All field note entries shall be made with a black lead pencil. Notations made by other than the original surveyor shall be made with a colored pencil so that a clear distinction exists between the field observations and all corrections, adjustments, supplemental data or comments.

**11.5** Each person who records notes should acquire the habit of keeping neat, legible, and systematic notes.

**11.5.1** All entries should be plainly lettered and numbered with characters that fill at least one-half the space between the horizontal lines. This will leave space for corrections to be entered above erroneous notations.

**11.5.2** No figure should ever be written over another, nor should any figure ever be erased.

**11.6** It is rarely necessary for a sketch to be drawn to scale. It should, however, show all details, dimensions and explanatory notes required. See Plates 1, 2, 5, 6 & 11.

**11.6.1** The recorder should not hesitate to use a full page for a sketch, or to divide the sketch into sections of one page each if there are too many details to be shown on one page.



**11.6.2** Sketches for structure sections must be particularly well drawn. They are often the only basis for working drawings of existing structures which may require modification or replacement. All required information must be shown and labeled on the drawing so that its significance is clearly evident.

**11.7** The first two pages of each standard field book or the first page of a set of approved forms shall be reserved for the book index and shall not be numbered. See Plate 13.

**11.7.1** At the top of each page used for an index, the word INDEX shall be clearly written.

**11.7.2** Under the word INDEX, the first column of the page shall be labeled DATE. The actual date of survey for each entry shall be placed in this column. The date shall be in the form DA MON YR (i.e., 01 June 88).

**11.7.3** The next four columns shall be labeled DESCRIPTION. Within these columns, a brief synopsis of the portion of the book being indexed shall be written. The description shall first indicate the type of field activity performed. Only one of the following key words shall be used: TRAVERSE, LEVELS, CROSS SECTIONS, STRUCTURE SECTIONS, SOUNDINGS, TOPOGRAPHY. Any other heading such as pre-mark descriptions shall use the key word MISCELLANEOUS. No variations in these titles will be permitted. The Sacramento District Survey Section is attempting to standardize all field surveying and office filing procedures. Any key word not covered in this Chapter shall be brought to the attention of the Sacramento District Survey Section for resolution.

**11.7.4** The last column shall be labeled PAGES. Only the actual pages, in that book, used for that particular description, shall be written in this column.

**11.8** The remainder of the book, or forms, shall contain the actual field data and shall be numbered beginning at page one (1).

**11.8.1** The pages shall be numbered in pairs, so that when the book is opened, both the left hand, and right hand portions of any pair of pages in the field book have the same number.

**11.8.2** The first page of each entity (i.e., traverse, levels, etc.) shall contain the following information at the top left half of the page beginning at the top left side: name of the installation or project location; a specific project title,(i.e., Mather A.F.B. - Control Tower); type of survey being performed (i.e., one of the key words mentioned in 11.06.3 above); and a complete description of the work (i.e., LEVELS - from USGS BM Q956 at the southeast end of the runway, east along the runway through the horizontal control for the aerial photography to USGS Q959 near the Control Tower). This description should include as much information as possible so that no doubt exists regarding what was accomplished during the course of the survey.

**11.8.3** At the top right side of the right half of the page, the following information shall be recorded: actual date of the survey; weather conditions; type and serial number of instruments used; members of the crew and their assignment; map or other field book references; and any other remarks necessary for a complete understanding of the survey.

**11.8.4** If these notes are a continuation from another field book, a note shall also be written in the field book that states "NOTES CONTINUED FROM BK XXX PAGE XX". A similar note shall be written on the last page of each section of notes, if those notes are to be continued either in another book, or on another page which is not adjacent to that page (i.e., CONTINUED IN BOOK XXX PAGE XX).

**11.9** Traverse notes shall contain the height of the instrument (HI) above the station occupied; the height (TH) of all targets; and both the horizontal angles and the vertical angles and the distance readings obtained with an Electronic Distance Meter.



11.9.1 All horizontal and vertical angles as outlined in Chapters 1, 2, 3 & 4, shall be recorded as shown on Plates 1 to 6.

11.9.2 Even though the electronic distance meter being used is capable of computing and displaying a horizontal distance and a difference in elevation, the vertical angles shall still be recorded in the field book. These measurements shall be clearly labeled as vertical angle, slope distance and horizontal distance. See Plate 2 & 4.

11.9.3 A description of the point being occupied shall also be included along with the angle measurements. This description shall include the type of monument (i.e., 5/8" re-bar, RR spike, brass disk, etc.), general location (i.e., 10' east of centerline road & 5' south of a fence post), and where it is located (i.e., flush with paved road, 0.10' below ground, chiseled cross in concrete). A sketch shall also be provided to more clearly indicate its location relative to existing physical features and the reference ties. See Plates 2 & 5.

11.9.4 A sketch of the horizontal control line shall also be included somewhere within the traverse notes. While the sketch is not required to be drawn to scale, it should show the relative position of one point to the next, and to the basic control. See Plate 1.

11.10 Level notes shall be recorded in a standard field book or on approved forms.

11.10.1 A short description of the course of the level line shall also be entered in the notes. see Plate 7.

11.10.2 A complete description of each point on which an elevation is established shall be recorded in the notes adjacent to the station designation.

11.10.3 Entries shall be made that give the references to the traverse notes and other existing data used for the basic elevations (i.e., TRAV BK XXX PG XX, NGS quad 371212 Line 105 etc.).

11.11 Cross section notes shall be recorded in a standard field book or on approved forms in the manner shown on Plate 9.

11.12 At the end of each day's work, the field notes shall be signed and dated by the Party Chief or individual responsible for the work.



## 12 - FIELD EQUIPMENT

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12.1 The following is the recommended minimum equipment for a field survey crew:

- 12.1.1 1 - Vehicle (preferably 4 wheel drive)
- 12.1.2 1 - Self leveling level with tripod
- 12.1.3 1 - 6 second theodolite (i.e., Wild T1) with tripod
- 12.1.4 1 - Philadelphia type level rod
- 12.1.5 1 - 100 foot steel tape
- 12.1.6 1 - 100 foot cloth tape
- 12.1.7 2 - Walkie talkies
- 12.1.8 1 - Electronic distance meter with tripod
- 12.1.9 2 - Single prism reflectors with tripods
- 12.1.10 1 - First Aid Kit
- 12.1.11 1 - Fire extinguisher
- 12.1.12 Ear protectors
- 12.1.13 Road signs (2 sets with brackets, tripods etc.)
- 12.1.14 Personal equipment (safety vests, hard hats etc.)
- 12.1.15 Other normal supplies (lath, 1 X 2's, nails, etc.)

## **13 - RIGHTS-OF-ENTRY**

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**13.1** Rights of Entry shall always be obtained from the property owner prior to beginning any surveying or mapping.

**13.1.1** Permission to enter a military installation will always be acquired by the Sacramento District. While the surveyors are on a military installation, they shall adhere to all stipulations set forth by the Base Installation Commander, or his representative.

**13.1.2** Rights-of-Entry to privately owned property may or may not be obtained by Real Estate Division of the Sacramento District. The surveyor may be required to obtain the permission of the land owner during the course of the survey. The surveyor shall adhere to the property owner's wants and desires while on his land.

**13.1.3** When access is required to or work required on a State highway, encroachment permits shall be obtained from the appropriate highway district.

**13.2** Rights-of-Entry do not give the surveyor a license to excessive destruction or damage to property.

**13.2.1** Every effort should be made to avoid cutting valuable trees or shrubs. What is not valuable to you may be to the Base Installation Commander. Always check if any doubt exists.

**13.3** Government and private property shall be protected at all times.

**13.3.1** Gates should always be left in the position in which they were found. Do not leave any gate open for any period of time if it was originally closed.

**13.3.2** Always return borrowed keys to their rightful owner.

**13.4** Care should be taken to place survey points in locations that will not obstruct the use or operations of the property owner or military installation or be offensive to the view.

**13.4.1** Monuments set in open fields or in a road, railroad or utility right-of-way, should be set below ground level to prevent damage by or to any equipment or motor vehicles.

**13.4.2** Extreme care should be taken when setting a survey point on a runway or taxiway. Always check with the base operations personnel prior to this type of activity.

**13.5** Any pre-marks placed on private property or on a military installation shall be removed as soon as possible after the aerial photography has been obtained, or as the property owner or installation commander requests.

**13.6** California Law provides for access by a surveyor to private lands for the purpose of recovering and using monuments. In particular this is stated in Section 846.5 of the Civil Code and reads:

*846.5 (a) The right of entry upon or to real property to investigate and utilize boundary evidence, and to perform surveys, is a right of persons legally authorized to practice land surveying and it shall be the responsibility of the owner or tenant who owns or controls property to provide reasonable access without undue delay. The right of entry is not contingent upon the provision of prior notice to the owner or tenant. However, the owner or tenant shall be notified of the proposed time of entry where practicable.*



*(b) The requirements of subdivision (a) do not apply to monuments within access-controlled portions of freeways.*

*(c) When required for a property survey, monuments within a freeway right-of-way shall be referenced to usable points outside the access control line by the agency having jurisdiction over the freeway when requested in writing by the registered civil engineer or licensed land surveyor who is to perform the property survey. The work shall be done within a reasonable time period by the agency in direct cooperation with the engineer or surveyor at no charge to him.*

**13.6.1** It is the interpretation of Survey Section that this only applies to the use of monuments that denote the boundary line of the individual property when they are to be used to accomplish a survey relative to that or adjacent boundary lines. This law does not give the surveyor exclusive rights to enter upon private property to use a boundary monument, or for that matter, any other type of control monument for the purpose of surveys other than boundary.



## 14 - COMPUTATIONS

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**14.1** Vertical control by differential leveling shall be reduced by first checking the arithmetic of the field survey notes. Any differences in the level run between known elevations shall be prorated based on the number of turns in the level circuit. (i.e., .10' error in 10 turns = .01' correction per turn).

**14.1.1** The adjustments shall be made in the notes by using a red or blue pencil.

**14.1.2** The error of closure in feet for any primary vertical control established by differential leveling shall not exceed .04 times the square root of the length of the line in miles.

**14.1.3** All elevations used shall be based on the National Geodetic Vertical Datum of 1929 (NGVD 1929) or North American Vertical Datum of 1988 (NAVD 1988) unless stated otherwise by the Sacramento District.

**14.2** Horizontal control shall be reduced, either manually or by use of appropriate computer programs, using the following procedures:

**14.2.1** The angles shall be checked in the office by verifying the mean angle for each station as computed in the field.

**14.2.2** The horizon shall be checked, where applicable, and any error over or under 360 degrees shall be adjusted equally between each angle in that horizon, provided that the tolerances are met for the individual angles as defined in Chapters 1 & 2.

**14.2.3** Using the horizontal angles obtained in the field, the azimuths between known horizontal control points shall be computed and checked. Any error shall be distributed equally among each angle in that circuit. If the error per angle is greater than five seconds (5"), additional field checks shall be made until the error is within the stated tolerance.

**14.2.4** Slope distances obtained in the field shall be reduced to horizontal by using the adjusted elevation of the horizontal control points at each end of the line being computed, or the mean of all of the vertical angles obtained from those points. The height of the instrument and the height of the reflector shall also be taken into consideration during these computations.

**14.2.5** After the angular error has been distributed through the horizontal control line, the latitudes and departures of each course shall be computed using the adjusted azimuth of each line, and the horizontal distance, to which a combined sea level factor and grid factor have been applied.

**14.2.6** For primary horizontal control, individual combined grid factors and sea level factors shall be applied to each course. The grid factor shall be acquired by using the mean preliminary coordinate values computed for the points at each end of the line. The sea level factor shall be computed by using the mean elevation at both ends of the line being computed. The horizontal error of closure, after azimuth adjustment, for this order of control shall be 1:20,000 or better.

**14.2.7** For secondary horizontal control, a mean grid factor and a mean sea level factor for the area being surveyed may be used. The horizontal error of closure, after azimuth adjustment, for this order of control shall be 1:10,000 or better.

**14.2.8** If any horizontal control line fails to meet the above stated tolerances, either in azimuth or horizontal closure, additional field work shall be performed until the error is within the stated tolerances.



**14.2.9** All traverse computations shall be computed on the State Coordinate System in which the project is located unless otherwise directed by the Sacramento District Survey Section.

**14.2.10** The North American Datum 1983 shall be used in computing horizontal values for all projects unless otherwise specified by the Sacramento District. In NO case shall a NAD27 coordinate value be converted directly to a NAD83 value. The NAD27 values must be recomputed by using published NAD83 values and recomputing the control net or traverse.

**14.2.11** No traverse shall be computed on a local coordinate system and then scaled and rotated to the appropriate State Coordinate System.

**14.2.12** All horizontal control adjustments shall be accomplished using the Compass or Least Squares Adjustment method.

**14.3** The results of all computations (coordinates and basic elevations), except ground elevations, shall be properly adjusted and expressed to two (2) decimal places. Data listed to three or more places generally indicates an accuracy greater than required or obtained. Elevations for points on natural ground shall only be shown to one (1) decimal place.

**14.3.1** If coordinate values were obtained from G.P.S. observations, the resultant values should be listed to three (3) decimal places if the basic control values are 1st order.

**14.4** All horizontal and vertical control computations shall be presented in a neat and orderly manner.

**14.4.1** A note shall be typed stating the name of the project, contract number, delivery order number, and the contractors name and address, field book numbers and pages relative to the computations, references to the origin of the horizontal control and vertical control, and the methods used for computation and adjustment.

**14.5** The sea level factor used for any project based on NAD 1927 shall be computed using 20,906,000 as the mean radius of the earth.

**14.6** The grid factor shall be computed as outlined in the U.S. Department of Commerce publication, State Plane Coordinates by Automatic Data Processing. A copy of this manual is available from the Government.



## 15 - AERIAL PHOTOGRAPHY

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**15.1** When photogrammetric mapping is to be utilized, any new aerial photography required shall be taken with a precision mapping camera with a six inch (6") focal length lens and a nine inch by nine inch (9" X 9") negative format.

**15.1.1** The camera shall be one that has been calibrated within the last five years. A copy of this calibration certificate shall be provided to the Sacramento District with each project.

**15.1.2** The altimeter, clock, camera level bubble and exposure counter shall all be properly functioning at the time of each exposure.

**15.2** All original aerial photography, including any re-flights, shall be taken with black & white aerographic film unless otherwise stated. Outdated film, as determined by the manufacturer's label, shall not be used for any project.

**15.3** Storage, handling and exposure of all photographic materials used for any project shall be in accordance with the manufacturers recommendations.

**15.3.1** All aerial negatives shall be free from chemical and water stains, tears, scratches, abrasions, finger marks, lint, dirt and other physical defects.

**15.3.2** All black & white aerial negatives shall be processed under controlled conditions in accordance with the manufacturer's instructions.

**15.3.3** Under NO circumstances shall the aerial negatives be cut into individual frames.

**15.4** When necessary, splicing of aerial negative film shall be accomplished with three quarter inch (3/4") wide, pressure sensitive, polyester base tape.

**15.4.1** A splice shall be of the butt-joint type with the tape placed on both the emulsion and non-emulsion sides of the negative material.

**15.4.2** Particular care shall be given to the alignment of the film when splicing, with care taken to trim all of the excess tape, to insure that the film is perfectly straight after splicing.

**15.4.3** Splices shall not be closer than ten inches (10") from the image edge of any accepted and edited negative.

**15.5** Each accepted exposure shall be edited with a mechanical type lettering device in letters at least one-eighth inch (1/8") in height, but no larger than three-sixteenths inch (3/16") in height. Lettering shall be placed along the top edge of the negative which is perpendicular to the direction of the flight line as shown below:

First and last exposure of each flight line:

12-2-91	12:30	U.S.C.E.	1:6000	___ - 1 - 1
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Remaining exposures in each flight line:

12-2-91	U.S.C.E.	___ - 1 - 7
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- 15.5.1** The lettering shall be sharp, uniformly applied and easily read.
- 15.5.2** The lettering shall be placed on the non-emulsion side of the negative, and may be applied by a stamp using non-flaking ink. The lettering SHALL NOT be applied by using any type of stick-on's (i.e., KROY machine etc.).
- 15.5.3** No smears or transfers of marking ink to other parts of the negative roll will be permitted.
- 15.5.4** The date shown on each accepted exposure shall be the actual date that the exposure was taken.
- 15.5.5** The time shall be the actual local standard time that the exposure was taken, and shall be labeled using the military format (i.e., 2:30 PM = 14:30). The time shall be labeled only on the first and last accepted exposures of each flight line.
- 15.5.6** The initials U.S.C.E. shall be labeled in the center of each accepted exposure. If there is a fiducial mark in the center of the negative then the initials shall be placed to the left of the fiducial.
- 15.5.7** The scale shall be the scale of the exposure as computed by dividing the flying height above the mean ground elevation of the terrain being photographed, by the focal length of the lens. The scale shall be labeled as a representative fraction (i.e.,  $3000'/.5' = 1:6000$ ). The scale shall be labeled on each accepted exposure of each flight line.
- 15.5.8** The project symbol for each project will be provided to the Contractor within the specifications for that project. This symbol shall be labeled on each accepted exposure followed by the flight line number and the exposure sequence number.
- 15.5.9** The flight lines shall be numbered beginning with flight line one (1) at the East or South end of the project area, and run sequentially in an unbroken series to the West or North end of the project.
- 15.5.10** The exposure sequence shall be numbered beginning with exposure one (1) at the East or South end of the project area and run sequentially in an unbroken series to the West or North end of the project area (i.e., 100-1-6 followed by 100-2-7).
- 15.5.11** When multiple flights are flown on the same day, that cover the same general area but are at different flight heights, the flight line and exposure numbering shall continue in sequence as indicated above, starting at the East end of the project and continuing West.
- 15.6** A roll of aerial negatives shall consist only of exposures made with the same camera system.
- 15.6.1** Only that length of film which can be wound on a metal spool 5 3/16" in diameter, leaving a minimum of one eighth inch (1/8") of the flange exposed, shall be placed on each spool.
- 15.6.2** The film shall not be wound tightly on the spool or in any way stretched, buckled, distorted or exposed to excessive heat.
- 15.6.3** At least three feet (3') of blank, or unused film, shall precede the first used exposure, and follow the last used exposure for each project on each roll of film to serve as leader and trailer. These leaders and trailers may be spliced into the roll.
- 15.7** Aerial negatives shall be uncut and shall be placed on 5 3/16" metal spools with the emulsion side of the negative facing the core of the spool.



15.8 Aerial negatives shall be delivered to the Sacramento District in sturdy plastic cans no larger than six inches (6") in diameter.

15.8.1 A film can label shall be prepared for each can indicating the projects, flight lines, and exposures contained therein. This label shall be securely affixed to the outside of the plastic can.

15.9 Clearance for overflights of military installations will be obtained by the Sacramento District.



## 16 - CONTACT PRINTS

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**16.1** All contact prints shall be made on an electronic printer on medium weight resin-coated paper stock, on which ink, pencil, grease pencil, and other commonly employed markers can be used on both sides.

**16.1.1** The processing, including exposure development, washing and drying, shall result in finished photographic prints having a fine-grain quality, normal uniform density, and such color tone and degree of contrast that all photographic details of the negative from which they are printed show clearly in the dark-tone areas and high-light areas as well as in the half-tones between the dark and light.

**16.1.2** Excessive variance in color tone or contrast between individual prints will be cause for their rejection.

**16.1.3** All prints shall be clear and free of stains, blemishes, uneven spots, air bells, light fog or streaks, creases, scratches, and other defects which would interfere with their use or in any way decrease their usefulness.

**16.1.4** All contact prints shall be trimmed to a neat size of 9"X 9" along the image edges (without loss of image) without removing the editing information or the fiducial marks. Prints lacking fiducial marks shall be rejected.

**16.2** Contact prints delivered to the Sacramento District Survey Section shall be produced after the editing information outlined in Chapter 15 has been applied to the aerial negatives.

**16.2.1** All prints shall be delivered in a smooth, flat and usable condition.



## **17 - AERIAL PHOTO INDEX**

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**17.1** A photo index map shall be prepared by stapling together an assembly of black & white contact prints of uniform contrast from the accepted and edited negatives.

**17.2** The black & white contact prints used for the index map shall be trimmed to a neat and uniform edge along the photographic images, without removing the editing information or the fiducial marks.

**17.3** The photographs shall be overlap matched by aligning corresponding images along the flight line.

**17.4** After the various flight line assemblies have been matched, the project symbol, flight line number and exposure number of each photograph shall show clearly.

**17.5** If it is necessary to break the photographic assembly into smaller segments to more effectively utilize the space on each aerial photo index, a match line shall be clearly labeled on the index map with appropriate labeling at each point (i.e., MATCH LINE A).

**17.6** Each aerial photo index map shall contain a neat and legible title block. See Plate 17.

**17.6.1** The dimensions of the sheet and the title block shall be as shown on Plate 17.

**17.6.2** Information appropriate to the project shall be inserted into the proper locations within the title block area.

**17.7** Major waterways, streets, towns and railroads shall be identified on the aerial photo index assembly.

**17.7.1** The names of the features shall be placed on white paper with a mechanical lettering device in letters large enough to be seen with the unaided eye on the final index map, trimmed, and placed in their correct position on the assembly prior to preparation of the index negative.

**17.8** After the assembly is complete, it shall be copied photographically onto a sheet of 20" X 24" fine grain, continuous tone negative material, at not more than a four time (4X) reduction from the original contact print scale.

**17.8.1** The title block for each index negative shall be produced as a part of the negative. Splicing of the title block into the processed negative will not be allowed.

**17.9** The processed aerial photo index negative shall be used to produce the requested number of black & white contact prints on 20" X 24" Resin Coated photographic paper.



## **18 - ANALYTICAL BRIDGING**

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**18.1** The location of all field control shall be planned so that the additional control points established during the bridging process is adequate to maintain the specified accuracies of the project mapping and the National Map Standards of Accuracy.

**18.2** All diapositives (either film or glass) required for any project will be produced by a Contractor who shall have the responsibility for quality control.

**18.3** All artificial control points required for the project shall be selected and pugged on appropriate equipment.

**18.4** The plate coordinates of all pre-marked points and all artificial points on each diapositive shall be obtained by use of a comparator or appropriate instrument.

**18.4.1** All plate coordinates shall be translated to the appropriate coordinate system for the project.



## 19 - ORTHOPHOTO NEGATIVES

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19.1 The aerial photography shall be flown at a scale that will require no more than a seven time (7X) enlargement factor from the original aerial negatives to the scale of the final mapping (i.e., the aerial photo scale shall be 1"=350' or less for 1"=50' orthophotos).

19.2 The orthophoto negatives shall be produced from the newly acquired diapositives, so that the orthophoto completely fills the window of a final drawing (See Chapter 24 and Plate 14), even though the limits of the survey may cover a smaller area.

19.2.1 Only fine-grain photographic film on a dimensionally stable base shall be used for exposing the initial negative of each orthophotograph as it is compiled. Outdated film shall not be used.

19.3 The orthophoto negatives shall be produced without any of the negative editing or fiducial marks showing in the final product.

19.3.1 Each orthophoto negative shall have uniform color tone, shall have the degree of contrast which will cause all details to show clearly in the dark-tone areas and in the high-light areas as well as in the half-tones between the dark and high-light.

19.3.2 Imagery shall be free from dust marks, scratches, out-of-focus imagery and any other inconsistencies in tone and density between individual adjacent orthophotos. Negatives having excessive contrast may be rejected.

19.3.3 Exposure scan lines or match lines shall not exceed 0.04 inches and shall not be noticeable or detracting from the photographic details.

19.4 The orthophoto negatives shall meet the National Map Standards of Accuracy for Orthophoto Mapping.

19.4.1 At the edge of each sheet, which is to edge match or overlap another sheet, all photographic images transverse to, normal to, or parallel with the match line, shall match corresponding images on the adjacent sheets to within at least one-twentieth (1/20) of an inch.

19.4.2 Ninety percent (90%) of all photographic details on each orthophoto shall be accurate to within one-fortieth (1/40) of an inch of its true position. None of the photographic details shall be displaced by more than one-twentieth (1/20) of an inch from its true coordinate position.

## 20 - PHOTOGRAMMETRIC COMPILATION

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- 20.1 Compilation shall be performed at the scale and contour interval required for the project.
- 20.2 Compilation shall be accomplished on a second-order or better optical-train stereo-plotting instrument capable of obtaining the accuracies of the project and the National Map Standards of Accuracy.
- 20.3 Newly acquired aerial photography and diapositives, shall be used for all photogrammetric compilation unless otherwise indicated.
- 20.4 Compilation shall be accomplished on a mylar base (min. thickness .005") at the scale and contour interval indicated for the project.
- 20.4.1 The appropriate state grid system for the project shall be shown on the manuscripts by using either grid ticks or continuous lines at a maximum of ten inch (10") spacing. The state grid values shall be labeled around the border of the manuscript.
- 20.4.2 All horizontal and vertical control points established for the project shall be shown on the manuscript. A symbol shall be shown for each point with its station designation.
- 20.4.3 All additional control points established during the bridging process shall be shown on the manuscripts. A symbol, different than that used for established ground control points, shall be shown for each point and its designation.
- 20.4.4 All photo centers with appropriate annotations as to the exposure numbers shall be shown on the manuscripts.
- 20.4.5 Spot elevations, as outlined in 20.5, shall be shown on the manuscripts.
- 20.4.6 The horizontal and vertical control established for the project shall be shown on the manuscript maps.
- 20.5 In flat areas where the contours do not adequately portray the true slope of the terrain, photogrammetric spot elevations shall be obtained.
- 20.5.1 Spot elevations shall be shown so that no point on the map is more than one inch (1.0") from either another spot elevation or a contour.
- 20.5.2 The spot elevations shall be accurate to within one quarter (1/4) of the contour interval specified for the project.
- 20.6 In areas of dense brush where the true slope of the terrain cannot be determined, field editing shall be accomplished to provide those additional spot elevations necessary to better define the contours.
- 20.6.1 All field obtained elevations shall be placed on the manuscript maps.
- 20.6.2 The contours shall be interpreted from the field obtained spot elevations.



## **21 - MAPPING ACCURACY**

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**21.1** In areas covered with dense brush or trees, the contours shall be correct to within one contour interval, or one-half the height of the cover.

**21.1.1** When the contours are of this nature, they shall be indicated by dashed lines on the manuscript and subsequently on the final drawings.

**21.1.2** The outline of any dense brush or trees shall be outlined on the manuscripts and labeled. This information shall be transferred to the final drawings.

**21.2** Ninety percent (90%) of all elevations interpolated from the contours, shall be correct both horizontally and vertically to within one-half (1/2) the specified contour interval.

**21.3** Spot elevations obtained during the photogrammetric compilation process shall be accurate to within one quarter (1/4) of the specified contour interval.

**21.4** All spot elevations and cultural features will be considered correctly plotted if ninety percent (90%) of those tested do not exceed one fortieth (1/40) of an inch from its true horizontal position.

**21.5** All grid lines shall match to adjacent sheets on the manuscript and the final drawings, to within one hundredth (1/100) of an inch. Features crossing from one sheet to the next shall agree at the match line to within one hundredth (1/100) of an inch.

**21.6** All control points shall be so plotted that their position on the map not vary more than one hundredth (1/100) of an inch from their computed coordinate position.



## 22 - DIGITIZED CROSS SECTIONS

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22.1 Digitized cross sections shall be referenced to either a field established horizontal control line or an assumed horizontal control line generated in the office.

22.2 Digitized spot elevations obtained for the cross sections shall be accurate to within one-quarter (1/4) of the contour interval specified for the project.

22.3 The distances along the cross section line shall be referenced to the previously mentioned horizontal control line.

22.3.1 The digitized cross sections shall be matched to any field obtained soundings where applicable, to result in one continuous profile line.

22.4 When requested, digitized cross sections shall be provided to the Government in the HEC-2 format in eighty (80) column fields as "X1" and "GR" cards as outlined in the US Army Corps of Engineers HEC-2 Water Surface Profiles, Users Manual, dated September 1982. A copy of this Manual is available from the Sacramento District.

22.4.1 Card "X1" shall be completed only with fields 0 (X1), 1 (station designation) and 2 (number of elevation points on following GR cards), as described on page VII-49 of the Manual.

22.4.2 Card "GR" shall be completed for all fields as described on page VII-64 of the Manual. The "GR" cards are limited to one hundred (100) points per section or twenty (20) cards.

22.5 The distances obtained from any hydrographic soundings and digitized cross sections shall be transformed so that the horizontal control line is always zero on the section line.

22.5.1 All distances must be in increasing order progressing from left to right across the section.

22.6 The data shall be delivered to the Sacramento District on 5 1/4" or 3 1/2" floppy disks.

22.6.1 The data disks shall be IBM compatible, formatted as DSDD or DSHD.

22.6.2 The files on each floppy disk shall be in the ASCII format.

22.6.3 The stations within each file shall begin with the smallest station and increase to the largest station.



## 23 - FINAL TOPOGRAPHIC DRAWINGS

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23.1 All final topographic drawings shall be produced on sheets of 30" X 42" sensitized mylar, or equal material.

23.1.1 The mylar shall be double matte, at least .004" in thickness capable of producing black lines with no line bleeding on a clear background after processing.

23.1.2 The final drawings shall be produced with the standard Corps of Engineers border lines (28" X 39.2") and title block (5.7" X 7.8"). See Plates 14 & 15.

23.1.3 New design or proposed demolition SHALL NOT be shown on the final topographic drawings. These drawings are for the purpose of showing existing site conditions only.

23.2 The title block of each final drawing shall be completed for each project. See Plate 15.

23.2.1 In the space designated DRAWN:, the name of the draftsman who produced the drawing shall be placed, or if by contract, the firm's name in letters 0.10" high.

23.2.2 In the space designated SCALE, the place the scale indicated for that project (i.e., 1"=50').

23.2.3 The sheet numbers will be the only variable item within the title block. All other data is constant for each project and may be placed on a master negative which could be used to produce all of the final drawings.

23.3 The file number for each project will be furnished by the Sacramento District.

23.3.1 Each military installation is designated by a different three digit number (i.e., 100, 131 etc.). This is always the first part of every file number.

23.3.2 The second part of each file number designates the type of drawing. For all topography or photogrammetric drawings this number will be 13. A separate set of drawings with 13 as the center number shall always be delivered to the Sacramento District. This set of drawings SHALL NOT have any demolition or proposed construction shown thereon.

23.4 All final mapping shall be produced in a 25" X 30" window within the 28" X 39.2" border lines of the Sacramento District's standard final drawing. See Plate 14.

23.4.1 The window shall be drawn on each sheet using a continuous line equivalent to a 00 Leroy Pen. This window shall be placed .70" from the left border of the sheet and 1.50" from the bottom of the sheet to allow for the "MATCH TO SHEET" identification.

23.4.2 The appropriate state coordinates for the corners of each window will be computed for each project.

23.4.3 The window within all final drawings shall have grid ticks (+) one-half inch (1/2") long, at five inch (5") intervals within the window limits. These ticks shall be drawn with a line equivalent to a 00 Leroy Pen.

23.4.4 Around the border of the window, but within the window, a tick mark (-) one-half inch (1/2") long shall be drawn, which shall be the projection of the grid ticks within the window. These ticks shall be drawn with a line equivalent to a 00 Leroy Pen. This line shall be labeled, within the window, with its appropriate grid value (i.e., 540,000 N, 1,230,000 E). This labeling shall be positioned so that it may be read in an upright position from either the bottom, or the right side of each final sheet.



23.4.5 Where the sheets butt match to each other, outside, and along the edge of the window, the label MATCH TO SHEET \_\_\_ shall be shown. The label shall be shown only along the edges of the sheets that have matching topography.

23.4.6 If the final drawings overlap match to each other, a separate line shall be drawn within the window from border line to border line, to indicate the match line. This line shall be labeled within the window area.

23.5 The map features from the manuscripts shall be faithfully reproduced onto the final drawings by first scribing the contours and plainimetry, then superimposing it into the previously defined window, as a reverse reading, positive reproducible.

23.5.1 The sheet window line, grid ticks and labeling of the grid values may be placed on the scribe sheet with the contours and plainimetry.

23.5.2 Lettering on all final drawings shall be at least one tenth inch (1/10") in height.

23.5.3 All lettering shall be applied by ink, pencil or by photographic methods. NO lettering shall be applied to any final drawing by use of any type of stick-on's (i.e., KROY machine, etc.).

23.5.4 All control points on the final drawings shall be shown by a symbol. The station designation shall be labeled adjacent to the symbol. The elevation, coordinates and description of the point shall be placed in an appropriate space outside the 25" X 30" window. When the project requires a sheet index, this tabulation shall be placed only on that sheet.

23.5.5 The photo center of each photo used for the mapping shall also be shown on the final drawings, if it falls within the 25" X 30" window. The photo center shall be shown by a symbol, and shall be labeled with the exposure number adjacent to that symbol.

23.5.6 All field edit information shall be added to the final drawings.

23.5.7 All symbolization used on the final drawing shall be labeled within the drawing itself without using abbreviations. If the drawing is so busy that there would not be sufficient room for the labeling, then abbreviations may be used, provided that the abbreviation is completely identified in a legend on each sheet.

23.6 A graphic scale shall be shown on each final drawing. The scale shall be similar in appearance to the one shown on Plate 15.

23.6.1 The graphic scale shall be placed above the title block on each final drawing.

23.7 On each final drawing, a north arrow shall be shown. This north arrow shall be identical in size and structure to the one shown on Plate 14.

23.7.1 The north arrow shall be placed above the graphic scale on each final drawing.

23.7.2 The north arrow shall be aligned to north on each final drawing.

23.7.3 Above the point of the north arrow shall be placed a letter "N" to designate north. Above this letter, the word "GRID" shall be placed in letters 0.10" in height. If grid north was not used for that project, the appropriate designation shall be shown (i.e., TRUE, ASSUMED etc.).

23.8 On each final drawing, a legend may be placed below the Survey Notes and above the North Arrow.



**23.8.1** The legend shall be a list showing the symbols used on the drawing and a description of what each symbol represents.

**23.8.2** If required, the legend shall also include a list of other entities on the drawing that require additional clarification that cannot be placed within the drawing itself due to space limitations. These entities include rim and invert elevations on manholes, descriptions of buildings or other features. Each of these entities shall be labeled with a letter and keyed to the legend on that sheet.

**23.9** When a project requires more than two final sheets, a sheet which shall become sheet one (1) of the set of final drawings shall be prepared to serve as the sheet index for the set of final drawings. Reference Chapter 25 for the proper format of this sheet and the correct wording and placement of these notes.

**23.9.1** When the project does not require a sheet index, the required Survey Notes shall be placed on each sheet in the set of final drawings.



## 24 - FINAL ORTHOPHOTO DRAWINGS

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24.1 All final drawings shall be produced on sheets of 30" X 42" sensitized mylar or equal materials.

24.1.1 The mylar shall be double matte, at least .004" in thickness capable of producing black lines with no line bleeding on a clear background after processing.

24.1.2 The final drawings shall be produced with the standard Sacramento District Corps of Engineers border lines (28" X 39.2"), and title block (5.7" X 7.8"). See Plates 14 & 15.

24.2 The title block of each final drawing shall be completed for each project. See Plate 15.

24.2.1 In the space designated DRAWN:, the name of the draftsman who produced the drawing shall be placed, or if by contract, the firm's name in letters 0.10" high.

24.2.2 In the space designated SCALE, the place the scale indicated for that project (i.e., 1"=50').

24.2.3 The sheet numbers will be the only variable item within the title block. All other data is constant for each project and may be placed on a master negative which would be used to produce all of the final drawings.

24.3 The file number for each project will be furnished by the Sacramento District.

24.3.1 Each military installation is designated by a different three digit number (i.e., 100, 131 etc.). This is always the first part of every file number.

24.3.2 The second part of each file number designates the type of drawing. For all orthophoto drawings this number will be 13. A separate set of drawings with 13 as the center number shall always be delivered to the Sacramento District. This set of drawings SHALL NOT have any demolition or proposed construction shown thereon.

24.4 All final mapping shall be produced in a 25" X 30" window within the 28" X 39.2" border lines of the final drawings. See Plate 14.

24.4.1 The window shall be drawn on each sheet using a continuous line equivalent to a 00 Leroy Pen. This window shall be placed .70" from the left border of the sheet and 1.50" from the bottom of the sheet to allow for the "MATCH TO SHEET" identification.

24.4.2 The appropriate state coordinates for the corners of each window will be computed for each project.

24.4.3 The window within all final drawings shall have grid ticks (+) one-half inch (1/2") long, at five inch (5") intervals within the window limits. These ticks shall be drawn with a line equivalent to a 00 Leroy Pen.

24.4.4 Around the border of the window, but within the window, a tick mark (-) one-half inch (1/2") long shall be drawn, which shall be the projection of the grid ticks within the window. These ticks shall be drawn with a line equivalent to a 00 Leroy Pen. This line shall be labeled, within the window, with its appropriate grid value (i.e., 540,000 N, 1,230,000 E). This labeling shall be positioned so that it may be read in an upright position from either the bottom, or the right side of each final sheet.



24.4.5 Where the sheets butt match to each other, outside, and along the edge of the window, the label MATCH TO SHEET \_\_\_ shall be shown. The label shall be shown only along the edges of the sheets that have matching orthophoto imagery.

24.4.6 If the final drawings overlap match to each other, a separate line shall be drawn within the window from border line to border line, to indicate the match line. This line shall be labeled within the window.

24.5 If contours are required on the orthophoto maps, they shall first be scribed, then superimposed as black lines with the photo imagery as a reverse reading, screened positive reproducible, into the previously defined window.

24.5.1 The sheet window line, grid ticks and labeling of the grid values may be placed on the scribe sheet with the contours.

24.5.2 A 133 line screen shall be used when producing a set of final orthophoto contour maps. If the orthophotos will be reduced to half size for inclusion in contract plans and specs, the final orthophoto contour maps shall be produced with a 65 line screen.

24.5.3 Lettering on all final drawings shall be at least one tenth inch (1/10") in height.

24.5.4 All lettering shall be applied by ink, pencil or by photographic methods. NO lettering shall be applied to any final drawing by use of any type of stick-on's (i.e., KROY machine, etc.).

24.5.5 All control points on the final drawings shall be shown by a symbol. The station designation shall be labeled adjacent to the symbol. The elevation, coordinates and description of the point shall be placed in an appropriate space outside the 25" X 30" window. When the project requires a sheet index, this tabulation shall be placed only on that sheet.

24.5.6 The photo center of each photo used for the mapping shall also be shown on the final drawings, if it falls within the 25" X 30" window. The photo center shall be shown by a symbol, and shall be labeled with the exposure number adjacent to that symbol.

24.5.7 Only the photo image shall be screened. The remainder of the sheet (i.e., contours, plainimetry, title block, border, etc.) shall be produced as continuous tone images.

24.6 When a project requires more than two final sheets, a sheet which shall become sheet one (1) of the set of final drawings shall be prepared to serve as the sheet index for the set of final drawings. Reference Chapter 25 for the proper format of this sheet and the correct wording and placement of these notes.

24.6.1 When the project does not require a sheet index, the required Survey Notes shall be placed on each sheet in the set of final drawings.

24.7 A graphic scale shall be shown on each final drawing. The scale shall be similar in appearance to the one shown on Plate 15.

24.7.1 The graphic scale shall be placed above the title block on each final drawing.

24.8 On each final drawing, a north arrow shall be shown. This north arrow shall be identical in size and structure to the one shown on Plate 14.

24.8.1 The north arrow shall be placed above the graphic scale on each final drawing.

24.8.2 The north arrow shall be aligned to north on each final drawing.



**24.8.3** Above the point of the north arrow shall be placed a letter "N" to designate north. Above this letter, the word "GRID" shall be placed in letters 0.10" in height. If grid north was not used for that project, the appropriate designation shall be shown (i.e., TRUE, ASSUMED etc.).

**24.9** Before any final orthophoto maps are produced, the Government shall be furnished a sample orthophoto.

**24.9.1** At least three (3) samples shall be provided. The samples shall be produced at different exposure intervals to allow the Government to select the density appropriate for it's purpose.

**24.9.2** The orthophoto samples shall be produced from the accepted and edited black & white contact prints and diapositives acquired and produced for the project.

**24.9.3** The negative selected for the sample shall be representative of the project area.

**24.10** On each final drawing, a legend shall be placed below the Survey Notes and above the North Arrow.

**24.10.1** The legend shall be a list showing the symbols used on the drawing and a description of what each symbol represents.

**24.10.2** If required, the legend shall also include a list of other entities on the drawing that require additional clarification that cannot be placed within the drawing itself due to space limitations. These entities include rim and invert elevations on manholes, descriptions of buildings or other features. Each of these entities shall be labeled with a letter and keyed to the legend on that sheet.



## 25 - FINAL MAPPING INDEX SHEET

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25.1 When a project requires more than two final sheets, a sheet which shall become sheet one (1) of the set of final drawings shall be prepared to serve as the sheet index for the set of final drawings.

25.1.1 This sheet shall be produced, using as a background, a photo enlargement of the entire project area or an enlargement or reduction of an assembly of quadrangles.

25.1.2 The sheet index shall be produced as a reverse reading screened positive reproducible. Only the background portion of the index sheet shall be screened. The title block, border details, notes and sheet layout shall be produced as a continuous tone image.

25.1.3 The sheet layout shall be drawn on the front of the index map using the equivalent of a 0 Leroy pen. Only the location of the 25" X 30" mapping window of each final sheet shall be shown on the index.

25.1.4 The sheet numbers shall be inked on the front of the index map within the sheet corresponding to that sheet's number. The number shall be 0.14" in height and shall be placed on the drawing using the equivalent of a 1 Leroy pen.

25.1.5 The Survey Notes shall be placed in the upper right hand corner of this index map. The proper notes, as listed below, will be identified by the Sacramento District. Blank spaces shall be filled in as appropriate. The identifying numbers shown below shall be omitted when placing these notes on the final drawing or in a computer data file.

### SURVEY NOTES

1. GRID COORDINATES REFER TO THE NORTH AMERICAN DATUM 19\_\_ (state) STATE COORDINATE SYSTEM (zone), AND ARE BASED ON (agency & station) AND (agency & station).
2. GRID COORDINATES REFER TO AN ASSUMED COORDINATE SYSTEM AND ARE BASED ON (point & coordinates) AND (point & coordinates).
3. TRAVERSE NOT COORDINATED.
4. A COMBINED FACTOR OF (factor) WAS APPLIED TO ALL HORIZONTAL CONTROL DISTANCES.
5. ELEVATIONS REFER TO THE NATIONAL VERTICAL DATUM OF 19\_\_ AND ARE BASED ON (agency & station) AND (agency & station).
6. ELEVATIONS REFER TO AN ASSUMED ELEVATION OF (elev) ON (point) AND (elev) ON (point).
7. THIS MAP WAS PRODUCED BY PHOTOGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHY DATED (day month year).
8. THIS MAP WAS DIGITIZED BY PHOTOGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHY DATED (day month year).
9. TOPOGRAPHY BY GROUND SURVEY METHODS. FIELD SURVEY DATE (day month year).
10. CONTOUR INTERVAL IS (1 foot, 2 feet, etc.).
11. ORIGINAL SURVEY SHOWN ON DRAWING FILE NO. ( -13- ).  
NOTE: THIS NUMBER WILL BE THE SAME AS IN THE TITLE BLOCK.
12. THIS MAP MEETS THE NATIONAL STANDARDS OF ACCURACY FOR TOPOGRAPHIC MAPS PREPARED BY PHOTOGRAMMETRIC METHODS.



13. IN OPEN UNOBSTRUCTED AREAS, THIS MAP COMPLIES WITH THE NATIONAL STANDARDS OF ACCURACY FOR TOPOGRAPHIC MAPS PREPARED BY PHOTOGRAMMETRIC METHODS. IN AREAS OF DENSE VEGETATION WHERE THE GROUND IS OBSCURED FROM VIEW, CONTOURS MAY DEVIATE FROM THE CORRECT ELEVATION BY ONE HALF THE HEIGHT OF THE COVER.

14. TOPOGRAPHY SUPPLEMENTED BY FIELD LOCATION AND IDENTIFICATION OF SURFACE AND SUBSURFACE UTILITIES.

15. FOR PLOTTED CROSS SECTIONS SEE DRAWING FILE NO. ( -10- ).

16. FOR PLOTTED STRUCTURE SECTIONS SEE DRAWING FILE NO. ( -10- ).

17. SURVEY DATA REFERENCES:

- |                              |                        |
|------------------------------|------------------------|
| * TRAVERSE (1 or 2)          | * LEVELS (1 or 2)      |
| * TOPOGRAPHY (1 or 2)        | * SOUNDINGS (1 or 2)   |
| * CROSS SECTIONS (1 or 2)    | * PLANE TABLE (1 or 2) |
| * STRUCTURE SECTION (1 or 2) |                        |

18. EXCEPT FOR KEY POINTS, ADD (elev) TO ALL ELEVATIONS.

- \* 1 = FIELD BOOK NO. & PAGE NO.
- \* 2 = COMPUTER DISK FILE NO.
- IF TOTAL STATION & DATA COLLECTOR USED

**25.2** The sheet index shall be produced on sheets of 30" X 42" sensitized mylar, or equal material.

**25.2.1** The mylar shall be double matte, at least .004" in thickness capable of producing black lines, with no line bleeding, on a clear background after processing.

**25.2.2** The sheet index shall be produced with the standard Corps of Engineers border lines (28" X 39.2"), and title block (5.7" X 7.8"). See Plates 14 & 15.

**25.3** The title block of the index sheet shall be completed for each project. See Plate 15.

**25.3.1** In the space designated DRAWN:, the contractors name shall be placed in letters 0.10" high.

**25.3.2** In the space designated SCALE, place the scale indicated for that project (i.e., 1"=50').

**25.4** The file number for each project will be furnished by the Sacramento District.

**25.4.1** Each military installation is designated by a different three digit number (i.e., 100, 131 etc.). This is always the first part of every file number.

**25.4.2** Civil works projects are usually designated by an alpha code sometimes followed by a numeric designation.

**25.4.3** The second part of each file number designates the type of drawing.



## 26 - DIGITIZED DATA BASE MAPPING

26.1 When specified, mapping shall be produced in an Intergraph 3D Design File format (Name.DGN) or Autocad 3D format (Name.DWG).

26.2 Digitizing shall be in the form of north and east coordinates and their elevations (i.e., Y,X,Z).

26.2.1 Digitized data shall be translated to a format that can be read by the release of Intergraph IGDS, MicroStation PC or AutoCad currently in use by the Sacramento District. Survey Section will advise the contractor of the format required for each project.

26.2.2 Intergraph 3D design files (Name.DGN) shall be furnished either on magnetic tape in a compressed cpio format on VAX VMS 9 track tape for use on a UNIX system; or on IBM formatted 1.2mb 5 1/4"; or 1.44mb 3 1/2" floppy disks for use with Micro Station PC. The format will be specified by the Government.

26.2.3 AutoCad files shall be furnished on IBM formatted 1.2mb 5 1/4" or 1.44mb 3 1/2" floppy disks.

26.2.4 No delivery of digitized data made to the Government shall be in the form of a SIF file or format other than an Intergraph 3D design file (Name.DGN) or AutoCad file (Name.DWG).

26.3 Contours shall be digitized in a continuous string.

26.3.1 Contours shall generally be collected at a ground distance equal to one-tenth inch 1/10" at the requested final map scale (i.e., for a 1"=40' mapping scale the collection rate would be every 4 feet).

26.3.2 The contours shall not be broken for annotation and shall be continuous under bridges. They shall also have a true elevation (Z) value associated with each horizontal position (X,Y).

26.4 Lines, text and other entities shall be established on the levels listed below using the color table, line types and line weights shown.

### MAPPING LEVEL ASSIGNMENTS FOR COMPUTER AIDED DRAFTING - AUTOCAD & INTERGRAPH

.DGN	.DWG	DESCRIPTION	LINE	WGT	COLOR
1	EGENERL	Sheet Dependent Information	Solid		White
2	ESGRID	Coordinate Grid	Solid	0	Green
3	ESGRIDTX	Coordinate Grid Annotation			Green
4	EABLDG	Buildings	Solid	2	Yellow
5	EABLDGTX	Building Annotation			Yellow
6	EAROADCL	Road Centerline	Solid	0	Yellow
7	EAROADTX	Road, Railroad & Centerline Annotation			Yellow
8	EAPARKNG	Roads, Parking Lots, Walks, railroads & Trails	Solid	0	Yellow
9	EGCONC	Concrete Joint Layout	Solid	0	Yellow
10	EGCONCTX	Concrete joint Elevations			Yellow
11	EARUNWAY	Runway, Taxiway & Aprons	Solid	1	Violet
12	EARUNWYTX	Runway Annotation			Violet
13	ESPAVEMK	Pavement Markings & Signs	Solid	0	Violet
14	EASTRUCT	Structures & Headwalls	Solid	1	Orange
15	EASTRUCTX	Structure Annotation			Orange
16	EACULVRT	Culverts	Solid	1	Yellow
17	EGCULVRTX	Culvert Annotation			Yellow



**MAPPING LEVEL ASSIGNMENTS FOR  
COMPUTER AIDED DRAFTING - AUTOCAD & INTERGRAPH**

DGN	DWG	DESCRIPTION	LINE	WGT	COLOR
18	ESRIPRAP	Riprap	Solid	1	Green
19	EXWATERFE	Water features	Solid	1	Blue
20	EXWATRTX	Water Feature Annotation			Blue
21	EXVEGE	Vegetation	Solid	0	Green
22	EXVEGETX	Vegetation Annotation			Green
23	EAFENCE	Fences	Solid	0	Blue
24	EAFENCETX	Fence Annotation			Blue
25	ESBOUND	Boundary Lines & Public Land System	Solid	2	Orange
26	ESBOUNDTX	Bndry Line & P.L.S. Annotation			Orange
27	ESURVEY	Survey Control Points & Baselines	Solid	0	Violet
28	ESURVEYTX	Survey Control Point Annotation			Violet
29	EABREAK	Break Lines	Solid	0	Yellow
30	EGSPOTEL	Spot Elevations			Yellow
31	EGTMAJCON	Major Contours	Solid	2	Orange
32	EGTMAJTX	Major Contour Annotation			Orange
33	EGTMINCON	Minor Contours	Solid	0	Red
34	EXTRENCH	Test Holes, Trenches & Annotation	Solid	0	Orange
35	EUSTORM	Storm Sewer Lines & Manholes	Solid	0	Green
36	EUSTORMTX	Storm Sewer Line Annotation			Green
37	EUSEWER	Sanitary Sewer Lines & Manholes	Solid	0	Yellow
38	EUSEWERTX	Sanitary Sewer Line Annotation			Yellow
39	EUWATER	Water Lines, Valves, Tanks & Fire Hydrants	Solid	0	Blue
40	EUWATERTX	Water Line Annotation			Blue
41	EUGAS	Gas Lines, Valves & Features	Solid	0	Red
42	EUGASTX	Gas Line Annotation			Red
43	EEPOWER	Power & Telephone Poles, Lines & Lights	Solid	0	Violet
44	EEPOWERTX	Power Line Annotation			Violet
45	EUSTEAM	Steam Lines, Valves & Features	Solid	0	Orange
46	EUSTEAMTX	Steam Line Annotation			Orange
47	EXSECTION	Cross Sections & Profiles	Solid	0	Yellow
48	EXDETAIL	Details & Insets	Solid	0	White
49	EXSOUND	Soundings			Blue
50	EXCHANNL	Channel Lines & Disposal Areas	Solid	1	Yellow
51	EXCHANNLTX	Channel Line Annotation			yellow
52	EXNAVTX	Navigation Aids & Annotations	Solid	1	Orange
53	EXLEVEE	Levees, Dikes & Annotations	Solid	1	Yellow
54	EXPIPELN	Pipe Lines, Structures & Bridges	Solid	1	Yellow
55	EXPIPETX	Pipe Line Annotation			Orange
56	ESMARKER	Stationing & Mile Markers	Solid	1	Violet
57	EXREVETMT	Revetments & annotations	Solid	0	Green
58	LAYER58	Unassigned			
59	LAYER59	Unassigned			
60	LAYER60	Unassigned			
61	LAYER61	Unassigned			
62	LAYER62	Unassigned			
63	LAYER63	Unassigned			



26.4.1 Not all levels are assigned. Several remain open for working levels and should be cleared prior to delivery of the final product.

26.4.2 A cell library for Intergraph has been created by the Government and shall be used in the construction of the files for the project under consideration.

26.5 All digitized data requested by the Government shall be delivered in two individual files.

26.5.1 The master file shall consist of all planimetric items (i.e., roads, buildings, spot elevations, etc.) on their respective layers.

26.5.2 The second file shall consist of only the major contours and associated text and the minor contours.

26.6 When requested, an Intergraph Topological Triangle Network File (Name.TTN) shall be generated and delivered to the Sacramento District. This file shall be generated using a grid of spot elevations collected during the photogrammetric compilation.

26.6.1 The grid spacing shall be one half inch (1/2") at final map scale. For 1"=40' mapping the grid spot elevations shall be collected every twenty feet (20').

26.6.2 During the compilation process, three profiles shall be taken across each model, one at each end and one in the middle. These profiles will be used to verify the accuracy of the TTN file that will be generated from this spot elevation data. These profiles SHALL NOT be included in the spot elevation file that is to be used to generate the TTN file.

26.6.3 During photogrammetric compilation, break lines shall be collected to define such features as, tops and toes of levees, tops of ridges, center of swales, curbs and other features that will assist the digital terrain software in more accurately portraying the true shape of the ground.

26.6.4 After the TTN file has been generated, it may be contoured at the same interval as the original contours and used as a rough check only.

26.6.5 Three profiles shall be generated from this TTN file that correspond exactly to the location of the three profiles collected during the photogrammetric compilation. The comparison of the two sets of profiles shall be within the accuracy of spot elevations for the scale of mapping being produced.

26.7 Intergraph files shall be produced in real world coordinates at a scale ratio of 1:1.

26.7.1 The global origin for all files is considered by the Corps of Engineers to define the lower left corner of the design cube.

26.7.2 For data generated in a State Plane Coordinate System referenced to the North American Datum of 1927 (NAD27) and for some coordinates referenced to the North American Datum of 1983 (NAD83), the global origin shall be set to  $X = 0, Y = 0, Z = 2147483.648$ .

26.7.3 For data generated in a State Plane Coordinate System referenced to the North American Datum of 1983 (NAD83) where the X value is greater than 4,000,000 feet, the global origin shall be set to  $X = 4000000, Y = 0, Z = 2147483.647$ .

26.7.4 The working units for all files shall be:

Working Area	4294967 Square Feet
Sub-Units/Master Unit	10 TH



- 26.7.5** All files shall be produced with the active scales set as follows:  
X = 1            Y = 1            Z = 1
- 26.7.6** Files shall be delivered with views 2-4 turned off and the entire file fitted to view 1.
- 26.7.7** The display depth shall be set to -2000000, +2000000.
- 26.7.8** All locks shall be off except snap lock which shall be on.
- 26.8** AutoCad files shall be produced in real world coordinates at a scale ratio of 1:1.
- 26.9** All elevations shall be shown to the correct decimal place.
- 26.9.1** If the elevation is on a control monument or a hard surface (i.e., concrete slab, road, brass disk, etc.) it shall be displayed to two (2) decimal places.
- 26.9.2** If the elevation is on ground or a surface whose location may be subject to change due to natural conditions (i.e., grass, water, dirt, etc.), the elevation shall be displayed to one (1) decimal place.
- 26.9.3** Spot elevations shall have a true elevation (Z) value associated with each horizontal position (X,Y).
- 26.10** All lettering shall be entered at a size that will produce text one-tenth inch (1/10") in height at the final map scale (i.e., for a 1"=40' drawing the text height shall be four feet [4']).
- 26.11** Intergraph text shall be Font 1 and AutoCad text shall be Simplex with the following exceptions:
- 26.11.1** Intergraph Font 7 or AutoCad Complex may be used to accent some items such as names of streets.
- 26.11.2** Other variations may be used only when approved by Survey Section.
- 26.11.3** Intergraph font 0 or AutoCad Standard SHALL NOT be used for any text style.
- 26.12** Final drawings shall be prepared by plotting the previously digitized data on the Sacramento District's standard sheet.
- 26.12.1** The standard Corps of Engineers' sheet with border details, graphic scale, north arrow, 25" X 30" window and grid ticks is available in Intergraph format as a cell within the District's Civil Cell Library and as an AutoCad drawing file.
- 26.12.2** The master file and contour file shall be used to produce the final drawings.
- 26.13** No drawing requested in any digitized format shall be first plotted by conventional methods and then re-digitized or scanned to produce the desired end product.
- 26.13.1** If, however, field surveys were required to supplement the contours because of heavy brush etc., the contours may be interpolated manually and digitized back into the file.
- 26.14** The drawing file shall be submitted as individual sheets based on the sheet layout furnished by the Sacramento District.



26.14.1 All features that cross from one file to another shall have exactly the same coordinates at the match line.

26.14.2 When individual files are saved in Intergraph format, they shall all have the same global origin and working units.

26.14.3 Each file saved SHALL be saved with the standard Corps of Engineers title block and border details or their appropriate levels.



## 27 - PLOTTED CROSS SECTIONS

---

27.1 Cross sections shall be plotted on sheets of 30" X 42" grid paper with standard Corps of Engineers title block and border details.

27.1.1 The cross section portion of the sheet shall have a one-tenth inch (1/10") grid pattern with heavier grid lines at one inch (1") spacing.

27.1.2 The cross section lines shall completely fill the area within the borders of the sheet (28" X 39.2") with the exception of the title block area (5.7" X 7.8").

27.1.3 The grid may be superimposed into a standard Corps of Engineers sheet format through a photographic process.

27.2 No more than four (4) cross sections shall be plotted on any one sheet.

27.3 The cross sections shall be plotted beginning with the lowest station (0+00), and progress sequentially to the end of the project.

27.3.1 The cross sections shall be plotted with the lower station at the bottom of each sheet, and increasing stations towards the top.

27.3.2 The cross sections shall be plotted as if an observer were standing in the middle of the waterway looking downstream. The left bank shall be plotted on the left side of the sheet and the right bank shall be plotted on the right side of the sheet.

27.4 The cross sections on each sheet shall be generally centered on that sheet with the zero (0) point of each cross section, which should be the traverse line, aligned on the same heavy grid line for all cross sections plotted on that sheet.

27.4.1 Along the bottom and top of the grid area, the horizontal distances shall be labeled beginning with zero (0) at the traverse line and increasing left and right at five inch (5") intervals on the heavier grid lines (i.e., 50,100,150,etc.).

27.4.2 Along the left and right edges of the grid area, the elevations shall be labeled for each cross section at one inch (1") intervals using even ten foot (10') increments on the heavier grid line (i.e., 540, 560, 580).

27.5 All Labeling within the grid area of the cross section drawings shall be slant lettering.

27.5.1 The lettering shall be at a density that will produce a good blue-line print.

27.5.2 The lettering shall be placed parallel to the grid lines and shall be no smaller in size than one-tenth inch (1/10") or larger than one-half inch (1/2").

27.6 Additional labeling to be shown on each sheet within the grid area of the drawing is as follows:

27.6.1 Major physical features shall be labeled on each cross section and shall include, but not be limited to: fence lines, edge of water, road, power line, top of bank, brush, etc. Cross section shots taken only to define the shape of the terrain shall not be labeled.



**27.6.2** The elevation of the surface of the water at the time the section was taken, and the date, shall be labeled on a line placed on the drawing to represent the surface of the water.

**27.6.3** A direction arrow labeled "FLOW" shall be shown to indicate the direction the waterway is flowing relative to the way the cross section is plotted.

**27.6.4** Near the lower right hand corner, the label "For plotted topography see File No.XXX-13-XXX" shall be shown. These numbers will be different for each project and will be furnished by the Sacramento District.

**27.7** Below and in the center of each cross section, the station shall be labeled (i.e., 10+00). Below that labeling, the angle that the cross section was taken relative to the traverse line shall be shown (i.e., 87 30 RBS).

**27.8** The title block of each sheet shall be filled out as shown in the sample provided for each delivery order.

**27.8.1** Centered within the title block, the job title shall be as shown.

**27.8.2** Also within the title block area the project file number shall be shown: FILE NO. XXX-10-XXX. This number will be different for each project and will be furnished by the Sacramento District.

**27.8.3** The sheets shall be numbered sequentially beginning at one (1). The sheet numbers shall be placed in the appropriate space in the title block area with the sequence number followed by the total number of sheets in the set (i.e., 1/39).

## 28 - MATERIALS TO BE DELIVERED

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- 28.1 Two (2) sets of edited B & W contact prints.
- 28.2 One (1) aerial photo index map when required.
- 28.3 One (1) set of final structure section drawings.
- 28.4 One (1) set of final cross section drawings.
- 28.5 One (1) set of 35mm color photographs.
- 28.6 Original 35mm negatives.
- 28.7 One (1) set of final mylar photogrammetric contour maps with topography file numbers (XX-13-XXX).
- 28.8 Original field books.
- 28.9 Original survey computations.
- 28.10 Original completed forms DA 1959.
- 28.11 Original photogrammetric manuscripts.
- 28.12 Original scribe sheets.
- 28.13 Original bridging documentation.
- 28.14 Original aerial photo index negative.
- 28.15 Original diapositives.
- 28.16 Original aerial negatives in plastic storage can.
- 28.17 IBM format 5 1/4" or 3 1/2" floppy disks.
- 28.18 All materials furnished by the Government.
- 28.19 All materials generated by the Survey Contractor.



## **29 - SAFETY PROGRAM**

---

29.1 This safety program shall state the specific ways and means by which the Survey Contractor proposes to apply the Corps of Engineers Safety Requirements Manual (EM 385-1-1), and the Surveying Manual of Safe Practices (SPK PAM 385-1-2) to any field work requested through this contract. Copies of both manuals will be provided to the A-E and Survey Contractor.

29.2 The safety program shall contain only the accident controls and safety requirements which are pertinent to the work to be performed, and the Survey Contractor fully intends to enforce.

29.3 Four items in particular should be addressed in the safety program.

29.3.1 Identification of, and precautions to be taken around poison oak.

29.3.2 Treatment of snake bite.

29.3.3 Precautions to be taken when working on, or near water.

29.3.4 Precautions to be taken when working on, or near an active runway, taxiway or apron.

29.4 The safety program will be reviewed by the Government and discussed with the Survey Contractor prior to the start of the field work.

## 30 - ABBREVIATIONS

---

AERO	Aerographic
A-E	Architect Engineer
A.F.B.	Air Force Base
AS	Active Scale
AT	Advanced Technology IBM Computer
BK	Book
BLDG	Building
BM	Bench Mark
BPI	Bits Per Inch
CPU	Central Processing Unit
DA	Department of Army
.DGN	Intergraph Drawing File
.DWG	AutoCad Drawing File
EDM	Electronic Distance Meter
EM	Engineering Manual
GR	Ground Card for HEC 2
GPS	Global Positioning System
HEC	Hydraulic Engineering Center
H.I.	Height of Instrument
HORIZ	Horizontal
IBM	International Business Machine
i.e.	In Other Words
INV	Invert
MB	MegaByte
MIN	Minimum
MM	Millimeter
MON	Month
NAD	North American Datum
N.G.S.	National Geodetic Survey
NGVD	National Geodetic Vertical Datum
PAM	Pamphlet
PC	Personal Computer
PG	Page
RBS	Right of Backsight
RR	Rail Road
SACTO	Sacramento
SPD	South Pacific Division
TBM	Temporary Bench Mark
TH	Target Height
U.S.	United States
U.S.C.E.	United States Army Corps of Engineers
U.S.G.S.	United States Geological Survey
VCP	Vitrified Clay Pipe
XT	Extended Technology
YR	Year



## HISTORY

August 1988

Original version completed and published

December 1991

Major revisions made to the chapter on Digitized Data Base Mapping. A new chapter added for Final Mapping Index Sheet. Some of the original plates were removed and incorporated into the body of the document. Numerous other modifications made throughout the document to correct previous mistakes and clarify inconsistencies discovered throughout the years.



COVER SHEET FOR PRIMARY OR SECONDARY TRAVERSE

PLATE I

Mather A.F.B. - Control Tower

(Primary or Secondary) Traverse

The traverse starts @ six USED #7 & Mather

then south to the intersection of Sixth St. & 'G'

Ave., then west to the intersection of 'G' Ave.

& Fifth St. and ending @ Alex & A

Mather

Control:

Mather: Pl. is a std. brass cap stamped, Mather

1953, set in conc.  $\pm 0.7'$  above the gd.

Alex: Pl. is a std. brass cap stamped, Alex

1963, set in conc.  $0.5'$  above the gd.

USED #7: Pl. is a std. USCE brass cap stamped,

# 7 1979, set in conc. flush with the

gd.

Wild T - 1 S/N 13956 27 May 1988

Topcon DMC-3 S/N 21005 Supervisor: C. Boggs

Hot & Clear PC: A. Jones

PC: B. Smith

References: D. Edison

For USC & GS  $\Delta$  stations see

USGS QUAD "Mather" and dwg.

file #101-13-462 SH.#11

Levels: See BK.#47-561 pg.28

Mather

USED #7

Alex

MAIN ST.

FIFTH ST.

SIXTH ST.

G AVE

X.1

X.2

4

Wild T-1 S/N 13256 27 May 1988

Topcon DMC-3 S/N 21005 P.C. M A Jones

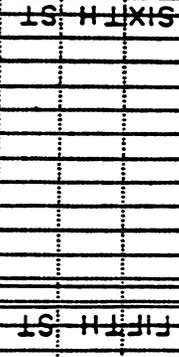
Hot & Clear X B. Smith

Remarks: O D Edison

X.1 is a L.P.R. spike set flush with pavement in the intersection of Sixth St & G Ave. The point is 50.4's of the top B. center of FH 7 and 151.7' W of a nail in the S. face of a P/P with UG

Tell

USED #7



G Ave. 4.1'

4.2'

P/P UG Tol. 151.7

Traverse Control Tower

Mather A.F.B., CA

Sta. Horiz. X

Slope Dist.

Horz. Dist.

X @ X.1 hi=4.85

1307.139

1307.139

USED # 7 00-00-00

R 267-45-36

.136

A 92-14-28

.142

MEAN

X.2 1264-03-34

D 92-14-32

SI DIST

TH. 4.50 312-27-52

R 267-45-36

1307.139

M 264-03-29

A 92-14-28

M 92-14-27

D 99-04-30

842.624

X.2 00-00-00

R 270-08-34

.628

A 99-04-28

.624

USED #7 95-56-33

D 99-04-28

SI DIST

TH. 5.10 47-32-24

R 270-08-30

842.828

M 95-56-33

A 99-04-28

M 99-04-28

H. Closure B 360-00-02

PRIMARY TRAVERSE: REPEATING INSTRUMENT

PLATE 2

PRIMARY TRAVERSE: DIRECTIONAL INSTRUMENT

Sta.	Direct.	Reversed	Mean
Photo Control McClellan A.F.B.			
⌘ @ USGS Δ "A-645"		hl. 5.28	SET I
Windy	00-00-19	180-00-24	21.5
Fred	109-52-58	289-53-01	59.5
Grant	149-12-01	329-11-58	59.5
Carey	276-43-20	96-43-18	19.0
			SET II
Windy	45-03-20	225-03-20	19
Fred	154-55-50	334-55-56	53
Grant	194-14-54	14-14-56	55
Carey	321-46-20	141-46-16	18
			SET III
Windy	90-05-47	270-05-46	46.5
Fred	199-58-18	19-58-22	20.0
Grant	239-17-20	59-17-22	21.0
Carey	06-48-43	186-48-47	45

See sketch page 8 this book.

NOTE: There should be a cover page the same as Plate 1 for this set of notes.

Wild T-2 S/N 19649		23 Feb. 1988	
Topcon DMC-3 S/N 21005		P.C. ⌘ J. Smith	
Cool & Clear	Sta.	Vert. Δ	N. Jones
		SI Dist.	H. Dist.
		90-38-54	806.490
	Windy	R 259-21-12	.494
52-38	TH 5.03	A 90-38-51	.492
19-00		D 90-38-56	Mean SD
31-19.5		R 259-21-16	806.492
		A 90-38-50	
		M 90-38-50.5	
52-34			
19-02		D 91-14-18	1002.126
31-23	Fred	R 268-45-36	.124
	TH 4.93	A 91-14-23	.130
		D 91-14-14	Mean SD
52-33.5		R 268-45-36	1002.127
19-01		A 91-14-19	
31-24		M 91-14-21	

Photo Control - Continued  
McClellan A.F.B

Wild T-2 S/N 19649  
Cool & Clear

23 Feb. 1988 (11)

P.C.M.J. Smith

Sta.	Direct.	Reversed.	Mean
⌘ @ USGS Δ "A-645"			SET IV
Windy	135-07-23	315-07-27	25
Fred	244-59-58	65-00-02	00
Grant	284-19-01	104-19-06	03.5
Carey	41-50-27	221-50-27	25

Sta.	Vert. Δ	Sl. Dist.	H. Dist.
Grant	D 89-20-33	66.382	661.340
TH. 4.99	R 270-39-23	.386	
52-35	A 89-39-28	.385	
19-03.5	D 89-20-25	Mean SD	
31-21.5	R 270-39-21	661.384	
	A 89-20-23		
	N 89-20-25.5		
Carey	D 92-10-58	1452.138	1451.088
TH. 5.02	R 267-48-58	.142	
	A 92-11-00	.146	
	D 92-11-01	Mean SD	
	R 267-49-03	1452.142	
	A 92-10-59		
	N 92-10-59.5		

⌘ N. Jones

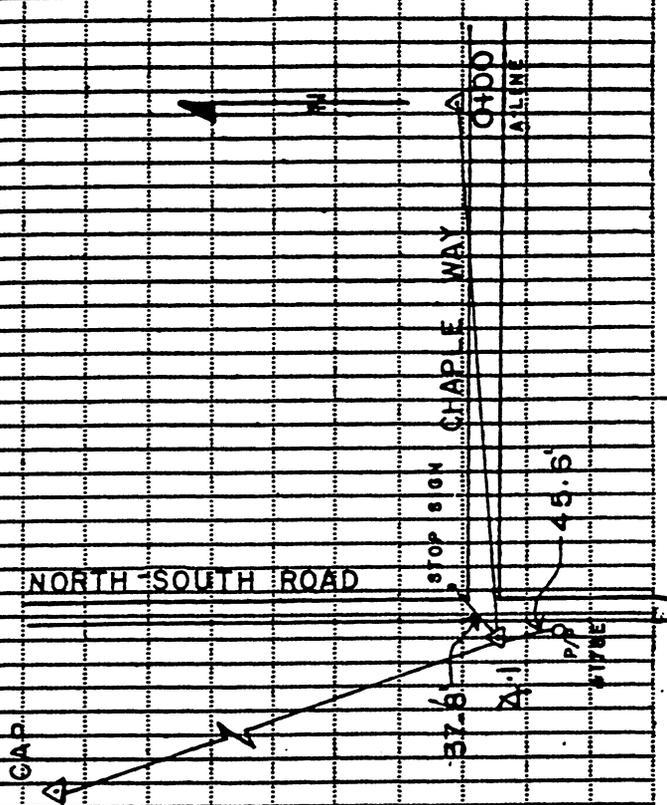
Set	I	II	III	IV	Mean Angle
109-52	38	34	33.5	35	109-52-35.125
39-19	00	02	01	03.5	39-19-01.625
127-31	19.5	23	24	21.5	127-31-22.0

PRIMARY TRAVERSE: DIRECTIONAL INSTRUMENT  
 (CONT.)  
 PLATE 4

Wild T-1 S/N 13956 25 June 1988 (23)

TOPSON DMC-3 21005 P.C. BY D. Taylor  
 Cool & foggy J. Means  
 M. Bass

X @ A: 1 hi = 5.13  
 A.I. is a 5/8" Rebar set 0.2' above ground with  
 Aluminum tag stamped A.I. P.I. is 115' W of the  
 West edge of pavement & 45.6' N of a nail in  
 West face of PYP 178E & 37.8' SW of a nail in  
 South side of the stop sign @ the NE corner  
 Intersection of N-S Road & Charles Way.



Traverse for Child Care Facility		Slope		Horz. Dist.	
Sta.	Fl. Ord. CA	Vert. Δ	Slope Dist.	Horz. Dist.	
X @ A: 1	hi = 5.13				
CAP	00-00-00	R 267-48-36	.136		
		A 92-14-26	.142		
0 + 00	120-02-20	D 92-14-32	MEAN S.D.		
	6 00-14-12	R 267-48-36	1121.139		
TH. 4.86	120-02-22	A 92-14-28			
		M 92-14-27			
		D 69-54-30	327.624	327.624	327.624
0 ± 00	00-00-00	R 270-05-34	.626		
		A 89-54-28	.624		
CAP	239-57-37	D 89-54-28	MEAN S.D.		
TH. 5.02	359-45-30	R 270-05-30	327.620		
		M 239-57-35			
		A 69-54-28			
		M 69-54-28			
	359-59-57				

NOTE: There should be a cover page the same as Plate for this set of notes.

SECONDARY TRAVERSE: REPEATING INSTRUMENT

SECONDARY TRAVERSE: DIRECTIONAL INSTRUMENT

Sta.	Direct.	Reversed.	Mean
Traverse for Electrical Substation Mather A.F.B., CA			
Δ.3 is a L.R.R. spike set in the intersection of 3rd. St. & H Ave. 39.2' NE of the top & center of FH = 3 and 42.1' SE of a Lead & Tack in E side- walk.			
Δ @ Δ.3 h1 = 5.21		SET I	
Δ.2	00-00-18	180-00-24	21
Δ.4	120-36-43	300-36-47	45
		SET II	
Δ.2	90-05-40	270-05-48	44
Δ.4	210-42-09	30-42-15	12
SET	I	II	Mean Angle
120-36	24	28	120-36-26
See sketch page 24 this book.			
NOTE: There should be a cover page the same as Plate 1 for this set of notes.			

Sta.	Vert. Δ	Slope Dist.	H Dist.
Wild T-2 S/N 19649 23 May 1988 Topcon DMC-3 S/N 21005 P.C. <input checked="" type="checkbox"/> K.HASS Warm & Clear <input checked="" type="checkbox"/> M. Bass <input checked="" type="checkbox"/> L. Lamb			
Δ.2	D 90-38-54	306.490	306.441
Δ.2	R 269-21-12	.492	
TH 5.03	A 90-38-51	.494	
	D 90-38-56	Mean SI Dist	
	R 269-21-16	306.492	
	A 90-38-50		
36-24	M 90-38-51.5		
	D 91-14-13	602.125	602.893
36-28	Δ.4 R 268-45-36	.124	
TH 5.11	A 91-14-23	.130	
	D 91-14-14	Means Dis	
	R 268-45-36	602.127	
	A 91-14-19		
	M 91-14-21		





CROSS SECTION

PLATE 9

Cross Sections for Control Tower		Dist		Rod		Elev.	
Mather A.F.B.							
Cross Sections are taken at 50' sta. over New							
Traverse for Control Tower. These sections extend							
25' North of the N EBR of G. Ave. and 150'							
South of the S EBR of G. Ave.							
Remarks	Dist	Rod	Elev.	Remarks	Dist	Rod	Elev.
Sta. C+00 90° Rt. of F.S.				Sta. 0+00 L.F.S. continued			H.I. = 64.56
0+00 = 59.46	5.10	H.I. = 64.56		Top B. Back Curb	2.0'	4.66	
Toe G. Ave.	12'	5.02		Gr.	8'	5.26	
EBR G. Ave.	24'	5.09		Gr.	50'	5.3	
Toe Gutter	25.5'	5.18		Gr.	78'	6.5	
Top B. Back Curb	26'	4.68		Gr.	100'	5.7	
Gr.	52'	4.8		Gr.	150'	5.9	
Sta. 0+00 90° L.F.S.			H.I. = 64.56	Sta. 1450 90° R.F.S.			H.I. = 64.56
Toe of Gutter	1.5'	5.14		Gr. G. Ave.	12'	5.06	
				EBR G. Ave.	2.4'	5.14	

Path - White level S/N 11691 6 June 1988 (9)

Cool & Cloudy

P.C. M. A. Clark

N. B. Jones  
D. D. Smith

References

- Traverse Bk. 45-831 pp. 4, 6
- Levels Bk. 45-831 pp. 7, 8
- Topo Bk. 45-831 pp. 14-16

Continued on page 10 this book.

Topcon DMC-3 1482 P.C.  D. Taylor

Clebr & Cold  L. Smith  
 R. Edison

Reference Data  
 Traverses BK No. 45-112 pp. 10-12  
 Levels BK No. 46-113 pp. 19-21  
 Map File No. 229-13-117 Sheets 2, 3

Shot No.	Sta.	Horz. $\angle$	Dist.	Vert. $\angle$	Rod	Elev.
	Topography of the area between bldgs 448 and 447.					
	X of FP 6	B.S.	FP 5			
	Elev. FP 6 = 1847.33				+0.426	H.I. 1851.59
1	184° 15'	20		4.2		
2	183° 14'	55		4.2		
3	182° 56'	100		4.3		
4	183° 19'	126		3.8		
5	181° 43'	98		4.5		
6	179° 10'	220		4.6		
Continued on page 7 this book.						

FIELD TOPOGRAPHY

PLATE 10

Remarks

Topog. Sketch on pg. 6

For FP 6 see sketch pg. 6

Rebar. Flush with ground. 45' N of NE corner

bldg. 448.

Cor 6' High chain link Fence

6" High chain link fence

6" High chain link fence

Top water valve

South edge 5th St.

South edge 5th St.

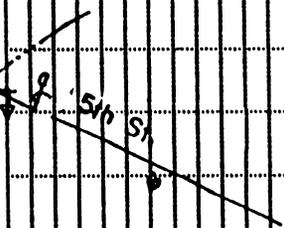
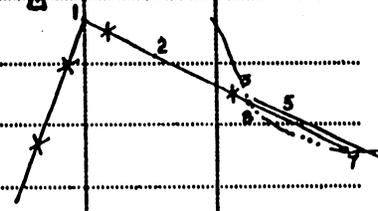
Sketch for pages 5 thru 7

SKETCH FIELD TOPOGRAPHY

PLATE 11

FP5

FP6 5/8" Rebar flush with ground



7

Drainage ditch  
Drainage ditch

Continued from page 5 this bk.  
Vert.

No.	Sta.	Horz.	Dist	Rod	Elev.
7	182° 32'	116	9.6	91° 25'	
8	185° 14'	91	10.2	90° 07'	
FP 5	00 00	150	3.6		

FIELD TOPOGRAPHY (CONTINUED)

PLATE 12

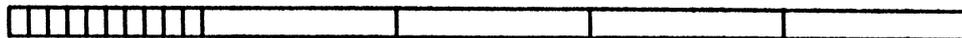




PLATE 15

DRAWING TITLE BLOCK

### GRAPHIC SCALE



△				
△				
REVISION	DATE	DESCRIPTION	BY	BY
<b>GEOTECHNICAL BRANCH</b>		<b>DEPARTMENT OF THE ARMY</b>		
<b>SURVEY SECTION</b>		<b>SACRAMENTO DISTRICT, CORPS OF ENGINEERS</b>		
<b>SACRAMENTO, CALIFORNIA</b>				
DESIGNED :				
DRAWN :				
CHECKED :				
SUBMITTED :	DATE APPROVED:	SCALE:	SPEC. No.	
		SHEET	FILE No.	
_____	_____	of		
<b>CHIEF, SURVEY SECTION</b>				

D

| Sacramento District Topography File No.

COUNTRY		TYPE OF MARK		STATION	
LOCALITY		STAMPING ON MARK		AGENCY (CAST IN MARKS)	ELEVATION (FT) (M)
LATITUDE		LONGITUDE		DATUM	DATUM
(NORTHING)(EASTING) (FT) (M)	(EASTING)(NORTHING) (FT) (M)	GRID AND ZONE	ESTABLISHED BY (AGENCY)		
(NORTHING)(EASTING) (FT) (M)	(EASTING)(NORTHING) (FT) (M)	GRID AND ZONE	DATE	ORDER	

TO OBTAIN		GRID AZIMUTH, ADD		TO THE GEODETIC AZIMUT	
TO OBTAIN		GRID AZ. (ADD)(SUB.)		TO THE GEODETIC AZIMUT	

OBJECT	AZIMUTH OR DIRECTION (GEODETIC)(GRID) (MAGNETIC)		BACK AZIMUTH	GEOD. DISTANCE (METERS) (FEET)		GRID DISTANCE (METERS) (FEET)	

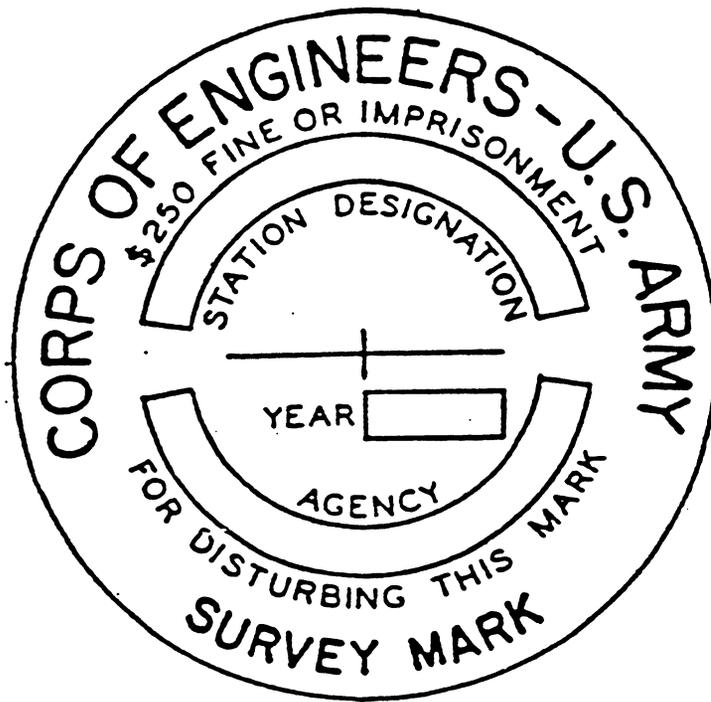


SKETCH

**DA FORM 1959** 1 OCT 64  
REPLACES DA FORMS 1050 AND 1060, 1 FEB 57, WHICH ARE OBSOLETE.

**DESCRIPTION OR RECOVERY OF HORIZONTAL CONTROL STATION**  
For use of this form, see TM 5-237; the proponent agency is TRADOC.





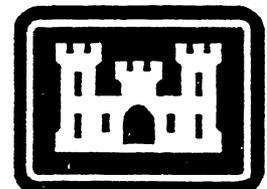
**DESIGN MANUAL**

**SURVEYING & MAPPING**

**DM 4-805-10**

**DECEMBER 1991**

**DEPARTMENT OF THE ARMY  
CORPS OF ENGINEERS  
SACRAMENTO DISTRICT**



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## P R E F A C E

**This manual is not intended to be a text book on the procedures and techniques of surveying, mapping and photogrammetry. Its purpose is to provide general procedures and instructions for meeting the accuracy requirements of the U.S. Army Corps of Engineers, Sacramento District.**

**The Contractor-Engineer (C-E) using this manual should give special attention to the Sacramento District's note recording format, the number of horizontal angles required and necessity for beginning and ending both horizontal and vertical control surveys on two or more points. All other aspects of surveying remain as in standard industry accepted practice.**

**3rd Order Class II accuracy will generally be required for surveying and mapping prepared for the Sacramento District. Large control projects may require 3rd Order Class I or better accuracy.**

**Photogrammetric mapping shall always meet the National Map Standards of Accuracy.**

# 1 - PRIMARY HORIZONTAL CONTROL

---

1.1 Primary horizontal control shall be used as the basic horizontal control for large mapping projects, to establish new horizontal control in a remote area, or to further densify existing horizontal control in an area.

1.1.1 This control shall be established using either the District's modified Third Order Class I techniques or by Global Positioning System Surveying. The points used for this control shall generally be monumented with Brass Disks.

1.1.2 The minimum instrumentation requirements for this type of control shall be a repeating theodolite with an optical micrometer with a least count resolution of six seconds (6") or better, a directional theodolite with an optical micrometer with a least count resolution of one second (1"), an electro-optical electronic distance measuring device capable of an accuracy of 1:10,000, a total station with the same capabilities, or a G.P.S. receiver capable of multi-channel reception.

1.2 Primary horizontal control points shall be marked with permanent type Brass Disk markers placed either flush with the existing ground level, or buried a minimum of one tenth of a foot (0.10') below the surface.

1.2.1 Concrete monuments with Brass Disks shall be established prior to the accomplishment of any horizontal or vertical control. These monuments shall be established in accordance with Chapter 5.

1.3 Primary horizontal control monuments shall be occupied by a theodolite and electronic distance meter, an electronic total station or a G.P.S. receiver. Establishing points by one angle and one distance only WILL NOT be permitted (i.e., NO sideshots).

1.4 Distance measurements shall be accomplished with an electronic distance meter capable of obtaining an accuracy of 1:10,000 or an electronic total station with the same capabilities.

1.4.1 A minimum of three (3) readings shall be taken at each station and recorded in a standard field book or on an approved form. The height of the instrument and the height of the reflector shall be measured carefully (to within 0.02') and recorded in the field book. Each slope distance shall be reduced to a horizontal distance using either reciprocal vertical angle observations as outlined in Chapter 4, or from elevations obtained using differential leveling techniques as outlined in Chapter 3. See Plate 2.

1.4.2 All electronic distance measuring devices and prisms should be serviced regularly and checked frequently over lines of known length. The National Geodetic Survey has established specific calibration base lines for this purpose. EDM instruments should be calibrated annually and frequency checks made semiannually.

1.5 If a repeating theodolite (i.e., Wild T1) is used for the horizontal angles, the instrument shall be pointed at the backsight station with the telescope in a direct reading position, and the horizontal vernier set to zero (0) degrees.

1.5.1 The angles shall then be turned to the right and the first angle recorded. The angle shall be repeated a minimum of eight (8) times by alternating the telescope pointing in the direct and inverted positions. The last angle shall also be recorded. See Plate 2.

1.5.2 If the first angle deviates more than five seconds (5") from the result of the last angle divided by eight (8), the process shall be repeated until the deviation is less than or equal to 5".

1.5.3 The horizon shall be closed by repeating this process for all sights to be observed from that location. The foresight for the last observation shall be the same as the backsight for the first observation. If the sum



of all the angles turned at any station deviate more than ten seconds (10") from 360 degrees, the angles shall be re-turned until the summation is within that tolerance. See Plate 2.

**1.6** If a directional theodolite (i.e., Wild T2) is used for the horizontal angles, the instrument shall be pointed at the backsight station with the telescope in a direct reading position and the horizontal vernier set to within ten seconds (10") of zero (0) degrees. The vernier shall then be brought into coincidence and the angle read and recorded in a standard field book or on an approved form. See Plates 3 & 4.

**1.6.1** The angles shall then be turned to each foresight in a clockwise direction, and the angles read and recorded. This process shall continue in a clockwise direction and shall include all sights to be observed from that station. See Plates 3 & 4.

**1.6.2** The telescope shall then be inverted and the process repeated in reverse order, except the vernier is not reset; it is read where it was originally set (the inverted angle reading should be within 30" of 180 degrees of the direct angle reading). The actual angles between stations may then be computed by taking the mean of the direct and reverse reading, and subtracting them. See Plate 3 & 4.

**1.6.3** This process shall be repeated four (4) times (i.e., 4 sets). For the first set of angles the initial plate setting shall be at or near 0-0-10. For the second set, the initial plate setting shall be at or near 45-04-40. For the third set, the initial plate setting shall be at or near 90-05-10. For the fourth set, the initial plate setting shall be at or near 135-07-40. See Plates 3 & 4.

**1.7** If an electronic total station is used for the horizontal angles, the same procedures shall be followed as outlined in Section 1.5 or 1.6. The Sacramento District Survey Section will state which procedure to follow, based on the type of total station to be used.

**1.8** Each year, and whenever the difference between direct and reverse readings of any theodolite deviate more than thirty seconds (30") from 180 degrees, the instrument should be adjusted for collimation error.

**1.8.1** Readjustment of the cross hairs and the level bubble should be done whenever their mis-adjustments affect the instrument readings by more than the least count of the vernier of the theodolite.

**1.9** To reduce slope distances to horizontal, a vertical angle observation shall be obtained from each end of each line being measured, as outlined in Chapter 4.

**1.9.1** Vertical angles shall be read a minimum of two (2) times in both the direct and inverted scope positions. If the difference between the two angles (after each is adjusted to 360 degrees) is greater than ten seconds (10"), the angles shall be repeated until the difference is less than or equal to 10". See Plate 2,3 & 4.

**1.9.2** If elevations were obtained by differential levels as outlined in Chapter 3 for the points on each end of the line being measured, the vertical angle requirement may be waived.

**1.10** Targets shall be set for all backsights and foresights.

**1.10.1** Sights may be a reflector or other type of target in a tribrach, or a line rod plumbed over the point in a tripod, or guyed in place from at least three positions.

**1.10.2** Artificial sights (i.e., a tree on the hill behind the point) or hand held sights (i.e., line rod or plumb bob string) shall not be used.

**1.11 If Global Position System Surveying is to be utilized, it shall be accomplished in accordance with U.S. Army Corps of Engineers Engineer Manual EM 110-1-1003 dated 14 June 1991**



## 2 - SECONDARY HORIZONTAL CONTROL

---

**2.1** The purpose of secondary horizontal control is to establish the location of structure sections, cross sections, topography and pre-mark requirements for small to medium scale photogrammetric mapping projects.

**2.1.1** This control shall be established using the Sacramento District's modified Third Order Class II techniques.

**2.1.2** The minimum instrumentation requirements for this type of control shall be a repeating theodolite with an optical micrometer with a least count resolution of six seconds (6") or better or a directional theodolite with an optical micrometer with a least count resolution of one second (1") and an electronic distance measuring device capable of an accuracy of 1:10,000 or a total station with the same capabilities.

**2.2** Secondary horizontal control points shall be marked with semipermanent type markers (i.e., re-bar, railroad spikes, large spikes etc.), placed either flush with the existing ground level, or buried a minimum of one tenth of a foot (0.10') below the surface.

**2.2.1** Each control point established shall be referenced by a minimum of two (2) points to aid in future recovery of that point.

**2.2.2** The reference points should be within one hundred feet (100') of the control point. If there is not a well defined point on the reference object, one shall be established (i.e., nail in pole).

**2.2.3** Well defined natural or man-made objects may be utilized. If none are available, additional points shall be established to serve as reference.

**2.2.4** A sketch shall be placed in a standard field book showing the relative location of each control point to the reference points, and major physical features within one hundred feet (100') of the point. Reference Plate 2. See Chapter 11 for procedures to record field data.

**2.2.5** If concrete monuments are required, they shall be established prior to the accomplishment of any control. These monuments shall be established in accordance with Chapter 5.

**2.3** Secondary horizontal control monuments shall be occupied by a theodolite and electronic distance meter, or a total station. Establishing points by angle and distance only will not be permitted (i.e., NO sideshots).

**2.4** Distance measurements shall be accomplished with an electronic distance meter capable of obtaining an accuracy of 1:10,000 or a total station with the same capabilities.

**2.4.1** A minimum of two (2) readings shall be taken at each setup and recorded in a standard field book or on an approved form. The height of the instrument and the height of the reflector shall be measured carefully (to within 0.02') and recorded. Each slope distance shall be reduced to a horizontal distance using either reciprocal vertical angle observations as outlined in Chapter 4, or from elevations of each point obtained using differential leveling as outlined in Chapter 3.

**2.4.2** All electronic distance measuring devices and prisms should be serviced regularly and checked frequently over lines of known distance. The National Geodetic Survey has established specific calibration base lines for this purpose. EDM instruments should be calibrated annually, and frequency checks made semiannually.



**2.5** If a repeating theodolite (i.e., Wild T1) is used for the horizontal angles, the instrument shall be pointed at the backsight station with the telescope in a direct reading position, and the horizontal vernier set to zero (0) degrees.

**2.5.1** The angles shall then be turned to the right and the first angle recorded in a field book. The angle shall be repeated a minimum of six (6) times by alternating the telescope pointing in the direct and inverted positions. The last angle shall also be recorded. See Plate 5.

**2.5.2** If the first angle deviates more than five seconds (5") from the result of the last angle divided by six (6), the process shall be repeated until the deviation is less than or equal to 5".

**2.5.3** The horizon shall be closed by repeating this process for all of the sights to be observed from that location. The foresight for the last observation shall be the same as the backsight for the first observation. If the sum of all the angles turned at any station deviate more than ten seconds (10") from 360 degrees, the angles shall be re-turned until the summation is within that tolerance. See Plate 5.

**2.6** If a directional theodolite (i.e., Wild T2) is used for the horizontal angles, the instrument shall be pointed at the backsight station with the telescope in a direct reading position and the horizontal vernier set to within ten seconds (10") of zero (0) degrees. The vernier shall then be brought into coincidence and the angle read and recorded in a standard field book or on an approved form. See Plate 6.

**2.6.1** The angles shall then be turned to each foresight in a clockwise direction, and the angles read and recorded. This process shall continue to include all sights to be observed from that station. See Plate 6.

**2.6.2** The telescope shall then be inverted and the process repeated in reverse order, except the vernier is not reset, it is read where it was originally set (the inverted angle reading should be within 30" of 180 degrees of the direct angle reading). The actual angles between stations may then be computed by taking the mean of the direct and reverse reading, and subtracting them. See Plate 6.

**2.6.3** This process shall be repeated two (2) times (i.e., 2 sets). For the first set the plate shall be set at or near 0-0-10. For the second set the plate shall be set at or near 90-05-40.

**2.7** If an electronic total station is used for the horizontal angles, the same procedures shall be followed as outlined in Section 2.5 or 2.6. The District will state which procedure to follow, based on the type of total station to be used.

**2.8** Each year, and whenever the difference between direct and reverse readings of a theodolite deviate more than thirty seconds (30") from 180 degrees, the instrument should be adjusted for collimation error.

**2.8.1** Readjustment of the cross hairs and the level bubble should be done whenever their mis-adjustments affect the instrument readings by more than the least count of the vernier.

**2.9** To reduce slope distances to horizontal, a vertical angle observation shall be obtained from each end of each line being measured.

**2.9.1** The vertical angles shall be read a minimum of two (2) times in both the direct and inverted scope positions. If the difference between the two angles (after each is adjusted to 360 degrees) is greater than ten seconds (10"), the angles shall be repeated until the difference is within the stated tolerance. See Plates 5 & 6.

**2.9.2** If elevations were obtained by differential levels as outlined in Chapter 3 for the points on each end of the line being measured, the vertical angle requirement may be waived.



**2.10 Targets shall be set for all backsights and foresights.**

**2.10.1** The sights may be a reflector or other type of target in a tribrach, or a line rod plumbed over the point in a tripod, or guyed in place from at least three positions.

**2.10.2** Artificial sights (i.e., a tree on the hill behind the point) or hand held sights (i.e., line rod or plumb bob string) shall not be used.



### 3 - VERTICAL CONTROL BY DIFFERENTIAL LEVELING

---

3.1 Vertical control established by differential leveling techniques shall be for the purpose of large scale mapping projects and to control various other mapping as appropriate.

3.1.1 Large scale is defined as 1"=50' or larger.

3.1.2 A construction or builders level will not be acceptable for this vertical control.

3.1.3 Elevations obtained from Global Positioning System Surveying will not be acceptable to control large scale mapping.

3.1.4 The minimum instrumentation requirements for this type of control shall be a self-leveling or automatic level designed specifically for surveying and engineering.

3.2 Establishing elevations by computations derived from a slope distance and vertical angle observation (such as that performed in a total station) will not be permitted for primary vertical control. See Chapter 4 for discussion of Vertical Control by Vertical Angle Observations.

3.3 All differential levels shall begin on a monument of known elevation that has previously been established by a reputable agency such as the U.S.G.S., U.S.C.E. or N.G.S. The monument shall have an elevation of third order accuracy or better.

3.3.1 The latest published elevation for the monument shall be used. If elevations established by one of the above listed agencies cannot be recovered, the Sacramento District Survey Section reserves the right to determine what agencies' elevations are acceptable.

3.3.2 The differential levels shall be run through each control monument established for the project. Each point shall be a turning point in the level line. Side shots WILL NOT be permitted as a means of establishing elevations on any control station.

3.3.3 Approximately every mile along the vertical control line, a TBM (Temporary Bench Mark) with a minimum of one (1) reference mark shall be established in a location that will not be subject to vandalism (i.e., railroad spike in a power pole, chiseled square in corner of headwall, bolt in NE corner of fire hydrant etc.).

3.3.4 Each point selected as a TBM shall be well defined. A concrete slab, such as the floor of a building, shall not be used when there is a point that can be positively identified (i.e., chiseled square in the northeast corner of the slab).

3.3.5 Each TBM shall also be a turning point in the level line. A sketch shall be entered in a standard field book or on an approved form, showing the TBM and its relative location to all physical features within fifty feet (50') of the point.

3.3.6 Levels shall be recorded in standard field books or on approved forms. See Chapter 11 for accepted procedures for recording field obtained information. See Plates 7 & 8.

3.4 All level runs shall terminate on a monument of known elevation that has previously been established by a reputable agency such as the U.S.G.S., U.S.C.E. or N.G.S. The monument shall have an elevation of third order accuracy or better.



3.4.1 The latest published elevation for this monument shall be used. If elevations established by one of the above listed agencies cannot be recovered, the Sacramento District Survey Section reserves the right to determine what agencies' elevations are acceptable.

3.4.2 No level line shall begin and terminate on the same monument.

3.4.3 Any level run between monuments of known elevation shall check to within .04 ft. multiplied by the square root of the length of the line in miles. Closures outside those tolerances shall be re-run to check for blunders. If the re-run verifies that the initial run was correct, it would indicate that one of the monuments may be disturbed. Additional ties shall then be made until the tolerance requirements are met.



## **4 - VERTICAL CONTROL BY VERTICAL ANGLE OBSERVATIONS**

---

**4.1** Vertical control established by vertical angle observations shall be for the purpose of small scale mapping projects.

**4.1.1** Small scale is defined as 1"=80' or smaller.

**4.1.2** Generally, elevations obtained by vertical angle observations may be used when the contour interval requirements of the project are two foot (2') or greater.

**4.2** Vertical angles shall be read from both ends of the line being measured. The time span between readings shall not be greater than one (1) hour.

**4.3** Vertical angles shall be read with a theodolite with a least count vernier of six second (6").

**4.4** Vertical angles shall be read a minimum of two (2) times with the telescope in the direct and reverse positions. See Plates 4,5,6,7 & 8.

**4.4.1** The summation of the direct and reverse readings shall not deviate more than ten seconds (10") from 360 degrees)

**4.4.2** The difference between the two individual readings shall not exceed ten seconds (10").

**4.5** The mean adjusted vertical angle reading shall be used in the computation of the difference in elevation.

## **5 - MONUMENTATION**

---

**5.1** Monuments shall be controlled to the accuracy stated for each project and shall be incorporated into the appropriate horizontal and vertical control scheme.

**5.2** Monuments shall be set in pairs, a minimum of one thousand feet (1000') apart, to provide for an azimuth from each station.

**5.3** The monuments shall be constructed by pouring concrete in place and inserting a standard Corps of Engineers Brass Disk in the top and center of the newly poured concrete.

**5.3.1** A hole shall be excavated in the ground a minimum of three feet (3') deep and six inches (6") in diameter.

**5.3.2** At least three (3) pieces of #5 steel reinforcing bar, three feet (3') long, shall be driven into the bottom of the hole, leaving at least one foot (1') of the re-bar protruding into the hole.

**5.3.3** The top of the hole shall be formed with a wax impregnated cardboard tube or equivalent, to provide a finished size of six inches (6") in diameter. The top of the form shall be at ground level.

**5.3.4** A standard Corps of Engineers Type II Brass Disk, shall be placed in the top of the newly poured concrete. The shank of the disk is split and shall be spread apart prior to placement. The stamping on the disk may be made before the disk is placed in the concrete, or no sooner than five days afterwards.

**5.4** Each disk shall be stamped with metal dies no smaller than one-eighth inch (1/8") and no larger than one-quarter inch (1/4") in height. See Plate 18.

**5.4.1** The AGENCY block stamping shall read U.S.C.E. SACTO.

**5.4.2** The YEAR block stamping shall read the year in which the monument was set.

**5.4.3** The STATION DESIGNATION stamping shall be numbered sequentially beginning with the numbering system provided by the Sacramento District Survey Section for the project. Only the name or sequence number provided by the Sacramento District shall be stamped in this space. Project designations such as HV-5 shall not be stamped thereon.

**5.5** Each monument established, shall be referenced by at least two (2) distance ties to either a permanent physical object (fence post, fire hydrant, etc.), or a point established in a permanent object (nail in tree, chiseled cross in concrete curb, etc.).

**5.5.1** All reference points shall be well defined. No object shall be used from which a precise measurement cannot be obtained (i.e., tree, power pole etc.).

**5.5.2** The reference points shall be within one hundred feet (100') of the newly established monument, and shall be selected so that the angle between them, as measured from the monument itself, is between forty-five (45) degrees and one hundred thirty-five (135) degrees.

**5.5.3** A sketch for all horizontal control points shall be placed in a standard field book or on an approved form. The sketch shall show the relative location of each control point to the reference points, and major physical features within one hundred feet (100') of the point. See Plates 2,5 & 6.



5.6 Monuments shall be set prior to the establishment of any horizontal or vertical control.

5.6.1 The appropriate State Coordinate System and Zone shall be established on each monument by using it as an angle point in the horizontal control line. No monument shall be controlled by a side shot, bearing-bearing, or distance-distance intersection computation. Each monument shall be occupied by a theodolite and EDM or total station.

5.6.2 An elevation shall be established on each monument by using the differential leveling procedures outlined in Chapter 3, or the vertical angle procedures outlined in Chapter 4. The procedural and accuracy requirements for each project will vary and will be established by the Sacramento District.

5.7 For each monument established, a Government form DA 1959 shall be completed, and the original provided to the Sacramento District Survey Section. See Plate 16.

5.7.1 Country shall be changed to read county on all forms and the appropriate county entered in that space.

5.7.2 Type of mark shall be the material the mark is constructed of (i.e., brass disk).

5.7.3 Station shall be the actual designation given to the mark (i.e., 100-27). This designation will be provided by Survey Section.

5.7.4 Locality shall be the closest town or major physical landmark (i.e., Mather Air Force Base, Reno, Fresno, Sacramento etc.).

5.7.5 Stamping on the mark shall be the same as entered in the Station column.

5.7.6 Agency shall be U.S.C.E. on all forms.

5.7.7 Latitude and longitude shall be computed for each station from the final adjusted coordinate values, and the results entered in the appropriate spaces. Seconds for each result shall be listed to only three (3) decimal places.

5.7.8 Datum shall contain "NAD 1927" or "NAD 1983" depending on which horizontal datum is used, unless stated otherwise by the Sacramento District Survey Section.

5.7.9 Northing and easting for each station shall be listed to only two (2) decimal places in U.S. Survey feet, unless the coordinates are of 1st order accuracy, in which case three (3) decimal places shall be shown. The designation (NORTHING) or (EASTING) that does not apply in each space shall be lined out in ink. The "(m)" shall also be lined out in each space in ink.

5.7.10 Grid and Zone shall contain the appropriate four (4) digit Zone designation as listed below:

STATE ZONE CODES					
ARIZONA		CALIFORNIA		NEVADA	
East	0201	I	0401	East	2701
Central	0202	II	0402	Central	2702
West	0203	III	0403	West	2703
		VI	0404		
		V	0405		
COLORADO		VI	0406	UTAH	
North	0502	VII	0407	North	4301
South	0503			Central	4302



**5.7.11** The elevation for each point shall be listed in feet, to two (2) decimal places if the elevation was obtained using differential leveling techniques as outlined in Chapter 3, or to one (1) decimal place if the elevation was obtained using vertical angle techniques as outlined in Chapter 4. The "(m)" shall be lined out in ink on each form.

**5.7.12** Elevation datum shall be NGVD 1929 or NAVD 1988 on all forms, depending on which vertical datum was used, unless stated otherwise by the Sacramento District Survey Section.

**5.7.13** Established by, shall contain U.S.C.E. or the contractors name if established by contract.

**5.7.14** Date space shall contain the month and year that the elevation or horizontal position was established on the point (i.e., Dec 87).

**5.7.15** Order shall contain "3rd" if the elevation was obtained using differential leveling techniques as outlined in Chapter 3, or VA if obtained using vertical angle observations as outlined in Chapter 4.

**5.7.16** It is not necessary to fill out the spaces labeled grid azimuth, object, and back azimuths.

**5.7.17** In the blank area in the lower right hand corner of the form, a sketch of the point showing adjacent natural and man made objects, and the reference points with their distances, shall be drawn in ink.

**5.7.18** Within the remaining portion of the blank area on the bottom half of the form, a more detailed description of the monument and how to reach it from a prominent location (i.e., the intersection of two major highways, courthouse building, etc.) shall be entered.

**5.7.19** All DA 1959 forms shall be in a typewritten format. Sketches shall be drawn in black ink.



## **6 - AERIAL PHOTO PRE-MARKING**

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**6.1** Pre-marking of horizontal and vertical control points shall be accomplished when the project is to be mapped with aerial photogrammetric techniques.

**6.2** The location of the pre-marks will be established so that the accuracies of the mapping required for each project, and the National Map Standards of Accuracy may be met.

**6.2.1** Pre-marks shall be located outside the boundaries of the required mapping as well as within those limits so that a stereo model is not cantilevered.

**6.3** The pre-marks shall be established of a sufficient size to be clearly visible in the aerial photography.

**6.3.1** The pre-marks shall not be constructed of a material that will cause injury to livestock if eaten.

**6.3.2** When required, all pre-marks shall be removed as soon as possible after the aerial photography has been flown and accepted.

**6.4** If any pre-marks are missing prior to the flight, they shall be replaced.

## **7 - FIELD TOPOGRAPHY**

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**7.1** Horizontal control required for these surveys shall not be less than secondary horizontal control as outlined in Chapter 2.

**7.2** Vertical control required for these surveys shall not be less than secondary vertical control as outlined in Chapter 4.

**7.3** The station occupied by the theodolite or total station, and the initial sighting point (backsight), shall always be clearly identified in the field notes.

**7.3.1** The theodolite vernier reading on the initial sighting point (backsight) shall always be zero degrees and zero minutes.

**7.3.2** Angles to topographic features to be located shall be turned to the right of the initial sighting point. The angles shall be read and recorded in a standard field book or on an approved form, to the nearest minute. Distance shall be recorded to the nearest 0.1 foot. See Plates 10,11 & 12.

**7.4** Elevations for topographic features may be obtained with a total station, by use of zenith or vertical angles and a slope distance, or by reading a rod with a level.

**7.4.1** When vertical angles are used, the symbols + or - shall always be recorded in the field notes to indicate whether the telescope of the theodolite was depressed or elevated from the normal line of sight or level position.

**7.4.2** If zenith angles are used, the + or - symbol is not required.

**7.4.3** Elevations obtained on natural ground surfaces shall only be listed to the nearest one-tenth of a foot (0.10'). Those on concrete or other surfaces of stable elevation shall be obtained to the nearest one-hundredth of a foot (0.01').

**7.5** Obtaining elevations on concrete or other surfaces of stable elevation by use of vertical angle observations shall be restricted as follows:

**7.5.1** If the vertical angle from the instrument to the reflector or rod is less than one degree of arc, the slope distance shall be restricted to three hundred feet (300').

**7.5.2** If the vertical angle from the instrument to the reflector or rod is greater than one degree, the slope distance shall be restricted to five hundred feet (500').

**7.6** Obtaining elevations on natural ground surfaces by use of vertical angle observations shall be restricted as follows:

**7.6.1** If the vertical angle from the instrument to the reflector or rod is less than one degree of arc, the slope distance shall be restricted to five hundred feet (500').

**7.6.2** If the vertical angle from the instrument to the reflector or rod is greater than one degree, the slope distance shall be restricted to one thousand feet (1000').

**7.7** A double page a field book or one page of an approved form shall be used to draw a sketch of the area being surveyed. Multiple sketches should be drawn, if necessary, to avoid crowding.



**7.7.1** Sketches are not required to be drawn to scale, however, they should have the same general relation as do the actual topographic features on the ground. See Plate 11.

**7.7.2** The sketch shall be oriented by showing a north arrow and identifying the main physical features of the surrounding area by name.

**7.7.3** As the topographic features are located, they shall be identified on the sketch and shall be numbered consecutively in their approximate relative position.

**7.7.4** Sufficient shots shall be taken so that the draftsman can prepare a map of the area that clearly shows all physical features both horizontally and vertically.

**7.8** The following checks shall be made at each instrument location where possible:

**7.8.1** Compute the H.I. and reduce the first and last shot.

**7.8.2** Observe a check shot on a known point or a point located from another setup.

**7.8.3** Upon completion of the work at the instrument location, the initial sighting point (backsight) should be checked to make sure the horizontal plate of the theodolite has not slipped. This check angle shall be within thirty seconds (30") of the initial backsight angle.

## **8 - PLANE TABLE TOPOGRAPHY**

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**8.1** Plane table topography is generally utilized when (1) the area to be mapped is small in size and a preliminary map of the area is required within a short time, or (2) the project is to be accomplished by field methods and the site is so remote that a return trip to edit the final drawing would be impractical.

**8.2** The horizontal control required for plane table topography shall not be less than secondary as outlined in Chapter 2.

**8.2.1** The positions of all control points shall be plotted accurately on the plane table sheet prior to obtaining any topographic measurements.

**8.2.2** If supplemental points are required, they shall be tied to the basic control points.

**8.3** The vertical control required for plane table topography shall not be less than that as defined in Chapter 4.

**8.3.1** If supplemental points are required, they shall be tied to the basic control points prior to obtaining the topographic measurements. The elevation for these points shall be acquired by the differential leveling techniques as outlined in Chapter 3.



## 9 - CROSS SECTIONS

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9.1 Cross sections shall be tied horizontally to secondary horizontal control as outlined in Chapter 2, and vertically to the vertical control as outlined in Chapter 4.

9.2 The spacing and length of the cross sections shall be determined by the particular project.

9.2.1 Preliminary (design) cross sections shall be of sufficient length and spacing to give the necessary information for design of the proposed project.

9.2.2 Cross sections taken prior to construction shall be of sufficient length to extend a minimum of fifty (50) feet beyond the limits of the proposed construction and spaced to show all breaks in the ground necessary to determine quantities.

9.2.3 Cross sections taken after construction shall be taken at the exact locations as the before construction cross sections and at additional locations as required to determine quantities.

9.2.4 The cross sections shall extend a minimum of fifty (50) feet beyond the construction limits.

9.3 Horizontal distances shall be measured to the nearest one (1) foot or five-tenths (0.5) foot, as required by the project.

9.4 Elevations shall be determined to the nearest one-tenth (0.1) foot on ground and to one-hundredth (0.01) foot on hard surfaces.

9.5 Cross sections shall generally be taken perpendicular to the feature being cross sectioned as indicated below.

9.5.1 Cross sections for roads shall be taken perpendicular to the centerline of the road.

9.5.2 Cross sections taken on a grid shall be perpendicular to the base line.

9.5.3 Cross sections taken along levees shall be perpendicular to the levee centerline.

9.5.4 Cross sections taken across waterways shall be perpendicular to the centerline of the waterway.

9.5.5 For cross sections not taken perpendicular to a control line, the angle at which they are taken shall be measured and recorded in the field notes.

9.6 An elevation and distance shall be obtained at each break in grade and physical feature the cross section intersects (i.e., edge of pavement, crown of levee, toe of levee, telephone line, edge of water, edge of brush, centerline of ditch, etc.).

9.6.1 A description of the feature shall be written in a standard field book or on an approved form.

9.6.2 In no case will the horizontal distance between shots exceed fifteen (15) feet on slopes of 3 to 1, or fifty (50) feet on flatter slopes and level ground.

9.7 Where cross sections include soundings that are to be taken at a later date, an out stake shall be set at some convenient location on line near the edge of water. The distance and elevation at the out stake shall be recorded in the notes and the distance and station written on the out stake.

9.7.1 When the soundings are taken, all distances shall be taken from the out stake, and the total distance shall be obtained by adding the out stake distance to the sounding distance.

9.7.2 When soundings are taken, the water surface shall be zero and all soundings referred to this zero. The elevation of the water surface shall be established at the time the soundings are taken, either by determining the elevation of the water surface at each sounding line by using the leveling techniques outlined in Chapter 3, or by using a gage which was previously established using those same techniques. The method used should be clearly indicated in the field notes.

9.8 Cross sections may be taken with a level, tape, and graduated rod; by EDM and theodolite; or total station.

9.8.1 The H.I. of each setup shall be computed, and at least one minus rod on each cross section should be reduced to make certain the H.I. has been figured and is shown.

9.8.2 A check shot should be made to another known elevation to check the H.I. This check shall be within one-tenth of a foot (.10).



## 10 - FIELD EDITING

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**10.1** Field editing is the process of obtaining information in the field which cannot be obtained from photogrammetric mapping, or the checking of information plotted from field topography notes.

**10.2** Blueline prints of the final maps or the manuscript maps shall be edited in the field to identify all major physical features within the limits of the project site.

**10.2.1** Roads shall be labeled with their appropriate name or designation. The type of material that the road is constructed of shall also be noted (i.e., concrete, blacktop, gravel etc.).

**10.2.2** Waterways shall be labeled with their appropriate name or designation. A flow arrow shall also be shown and mileage markers if previously established and published.

**10.2.3** Single family dwellings in a civil or military residential area, and small office buildings shall be labeled with their street address.

**10.2.4** Buildings on a military installation shall be labeled with their building number.

**10.2.5** Large buildings within a commercial area shall be labeled with the name of the business.

**10.2.6** Runways shall be labeled with their designated number. The type of material that it is constructed of shall also be noted (i.e., concrete, blacktop, etc.).

**10.2.7** Manholes and drop inlets shall be labeled with their type (i.e., storm sewer, telephone etc.). The elevation of the rim shall be obtained and recorded in a standard field book or on an approved form. The invert elevation and inside diameters of all pipes entering or exiting the manhole or drop inlet shall also be obtained and recorded. The pipe lines between manholes and drop inlets shall also be drawn on the field check prints. If the next manhole is not within the mapping limits, a direction of the line shall be carefully and accurately plotted on the prints.

**10.2.8** Fire hydrants, water and gas valves, telephone and power lines, and other features that cannot be identified from the photogrammetric mapping shall be located and labeled in the field on the blueline prints.

**10.2.9** In areas where dense brush or trees prohibit the photogrammetrist from obtaining the true shape of the terrain, sufficient spot elevations shall be obtained in the field to assist the photogrammetrist in better defining the contours. This data may be obtained by use of a total station. All data shall be recorded in a standard field book, on an approved form or in an electronic data collector.

**10.3** For military installations, utility maps shall be procured from the appropriate organization and used in the search for existing utilities.

**10.3.1** If necessary, a metal detector or electronic tracer of some type shall be utilized to locate the underground utilities shown on the base utility maps.

**10.4** All field editing information shall be transferred to the final drawings. If the drawings are being prepared in a computer aided drafting program, the field edit data shall also be transferred to that database.

**10.4.1** If utility lines that are shown on the base utility maps could not be located in the field, the approximate location of the line shall be transferred to the final drawing and a note attached indicating the following: *the location of this line was derived from base utility drawings - unable to field verify.*



## 11 - FIELD NOTES

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**11.1** No part of the surveying operation is of greater importance than the field notes. The competence of the surveyor is reflected more in the character of his notes than his use of the instruments. The notes constitute a permanent record of the survey.

**11.1.1** In the case of total stations (i.e., electronic field books) the data should be recorded in the data collector and later transferred to a storage media and printer on paper.

**11.1.2** All notes shall be recorded in a form that can be interpreted with ease by anyone having a basic knowledge of surveying.

**11.2** All field notes, except those taken with a data collector, shall be recorded in a standard, hardcover field book (4 7/8" X 7 1/2") or on an approved form, as the measurements are made in the field.

**11.2.1** No data will be written on scratch paper or on the back page of the field book and copied into the book later. No details be carried in the mind of the surveyor until the end of the day, or the job, and then entered in the field book. Information copied or transferred into a field book, or carried in the mind for a time before entry in the field book, is subject to error more than information recorded immediately as it is obtained. The systematic recording of data improves accuracy.

**11.3** No erasures will be made in any notes. When errors are made, they shall be corrected by lining through the erroneous figures in such a way that the original figures remain legible.

**11.3.1** When a complete page is in error, a line will be neatly made through the page, along with the word "VOID" in large letters written diagonally across the page. A cross reference will be entered on the voided page showing the book and page number where the corrected information may be found. An explanation of the error and the correction will be entered in the field notes.

**11.4** When it is necessary to copy information from another field book or other source, a note will be made which clearly states that the information was copied and the source from which it came.

**11.4.1** All field note entries shall be made with a black lead pencil. Notations made by other than the original surveyor shall be made with a colored pencil so that a clear distinction exists between the field observations and all corrections, adjustments, supplemental data or comments.

**11.5** Each person who records notes should acquire the habit of keeping neat, legible, and systematic notes.

**11.5.1** All entries should be plainly lettered and numbered with characters that fill at least one-half the space between the horizontal lines. This will leave space for corrections to be entered above erroneous notations.

**11.5.2** No figure should ever be written over another, nor should any figure ever be erased.

**11.6** It is rarely necessary for a sketch to be drawn to scale. It should, however, show all details, dimensions and explanatory notes required. See Plates 1, 2, 5, 6 & 11.

**11.6.1** The recorder should not hesitate to use a full page for a sketch, or to divide the sketch into sections of one page each if there are too many details to be shown on one page.



**11.6.2** Sketches for structure sections must be particularly well drawn. They are often the only basis for working drawings of existing structures which may require modification or replacement. All required information must be shown and labeled on the drawing so that its significance is clearly evident.

**11.7** The first two pages of each standard field book or the first page of a set of approved forms shall be reserved for the book index and shall not be numbered. See Plate 13.

**11.7.1** At the top of each page used for an index, the word INDEX shall be clearly written.

**11.7.2** Under the word INDEX, the first column of the page shall be labeled DATE. The actual date of survey for each entry shall be placed in this column. The date shall be in the form DA MON YR (i.e., 01 June 88).

**11.7.3** The next four columns shall be labeled DESCRIPTION. Within these columns, a brief synopsis of the portion of the book being indexed shall be written. The description shall first indicate the type of field activity performed. Only one of the following key words shall be used: TRAVERSE, LEVELS, CROSS SECTIONS, STRUCTURE SECTIONS, SOUNDINGS, TOPOGRAPHY. Any other heading such as pre-mark descriptions shall use the key word MISCELLANEOUS. No variations in these titles will be permitted. The Sacramento District Survey Section is attempting to standardize all field surveying and office filing procedures. Any key word not covered in this Chapter shall be brought to the attention of the Sacramento District Survey Section for resolution.

**11.7.4** The last column shall be labeled PAGES. Only the actual pages, in that book, used for that particular description, shall be written in this column.

**11.8** The remainder of the book, or forms, shall contain the actual field data and shall be numbered beginning at page one (1).

**11.8.1** The pages shall be numbered in pairs, so that when the book is opened, both the left hand, and right hand portions of any pair of pages in the field book have the same number.

**11.8.2** The first page of each entity (i.e., traverse, levels, etc.) shall contain the following information at the top left half of the page beginning at the top left side: name of the installation or project location; a specific project title,(i.e., Mather A.F.B. - Control Tower); type of survey being performed (i.e., one of the key words mentioned in 11.06.3 above); and a complete description of the work (i.e., LEVELS - from USGS BM Q956 at the southeast end of the runway, east along the runway through the horizontal control for the aerial photography to USGS Q959 near the Control Tower). This description should include as much information as possible so that no doubt exists regarding what was accomplished during the course of the survey.

**11.8.3** At the top right side of the right half of the page, the following information shall be recorded: actual date of the survey; weather conditions; type and serial number of instruments used; members of the crew and their assignment; map or other field book references; and any other remarks necessary for a complete understanding of the survey.

**11.8.4** If these notes are a continuation from another field book, a note shall also be written in the field book that states "NOTES CONTINUED FROM BK XXX PAGE XX". A similar note shall be written on the last page of each section of notes, if those notes are to be continued either in another book, or on another page which is not adjacent to that page (i.e., CONTINUED IN BOOK XXX PAGE XX).

**11.9** Traverse notes shall contain the height of the instrument (HI) above the station occupied; the height (TH) of all targets; and both the horizontal angles and the vertical angles and the distance readings obtained with an Electronic Distance Meter.



11.9.1 All horizontal and vertical angles as outlined in Chapters 1, 2, 3 & 4, shall be recorded as shown on Plates 1 to 6.

11.9.2 Even though the electronic distance meter being used is capable of computing and displaying a horizontal distance and a difference in elevation, the vertical angles shall still be recorded in the field book. These measurements shall be clearly labeled as vertical angle, slope distance and horizontal distance. See Plate 2 & 4.

11.9.3 A description of the point being occupied shall also be included along with the angle measurements. This description shall include the type of monument (i.e., 5/8" re-bar, RR spike, brass disk, etc.), general location (i.e., 10' east of centerline road & 5' south of a fence post), and where it is located (i.e., flush with paved road, 0.10' below ground, chiseled cross in concrete). A sketch shall also be provided to more clearly indicate its location relative to existing physical features and the reference ties. See Plates 2 & 5.

11.9.4 A sketch of the horizontal control line shall also be included somewhere within the traverse notes. While the sketch is not required to be drawn to scale, it should show the relative position of one point to the next, and to the basic control. See Plate 1.

11.10 Level notes shall be recorded in a standard field book or on approved forms.

11.10.1 A short description of the course of the level line shall also be entered in the notes. see Plate 7.

11.10.2 A complete description of each point on which an elevation is established shall be recorded in the notes adjacent to the station designation.

11.10.3 Entries shall be made that give the references to the traverse notes and other existing data used for the basic elevations (i.e., TRAV BK XXX PG XX, NGS quad 371212 Line 105 etc.).

11.11 Cross section notes shall be recorded in a standard field book or on approved forms in the manner shown on Plate 9.

11.12 At the end of each day's work, the field notes shall be signed and dated by the Party Chief or individual responsible for the work.



## 12 - FIELD EQUIPMENT

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12.1 The following is the recommended minimum equipment for a field survey crew:

- 12.1.1 1 - Vehicle (preferably 4 wheel drive)
- 12.1.2 1 - Self leveling level with tripod
- 12.1.3 1 - 6 second theodolite (i.e., Wild T1) with tripod
- 12.1.4 1 - Philadelphia type level rod
- 12.1.5 1 - 100 foot steel tape
- 12.1.6 1 - 100 foot cloth tape
- 12.1.7 2 - Walkie talkies
- 12.1.8 1 - Electronic distance meter with tripod
- 12.1.9 2 - Single prism reflectors with tripods
- 12.1.10 1 - First Aid Kit
- 12.1.11 1 - Fire extinguisher
- 12.1.12 Ear protectors
- 12.1.13 Road signs (2 sets with brackets, tripods etc.)
- 12.1.14 Personal equipment (safety vests, hard hats etc.)
- 12.1.15 Other normal supplies (lath, 1 X 2's, nails, etc.)

## **13 - RIGHTS-OF-ENTRY**

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**13.1** Rights of Entry shall always be obtained from the property owner prior to beginning any surveying or mapping.

**13.1.1** Permission to enter a military installation will always be acquired by the Sacramento District. While the surveyors are on a military installation, they shall adhere to all stipulations set forth by the Base Installation Commander, or his representative.

**13.1.2** Rights-of-Entry to privately owned property may or may not be obtained by Real Estate Division of the Sacramento District. The surveyor may be required to obtain the permission of the land owner during the course of the survey. The surveyor shall adhere to the property owner's wants and desires while on his land.

**13.1.3** When access is required to or work required on a State highway, encroachment permits shall be obtained from the appropriate highway district.

**13.2** Rights-of-Entry do not give the surveyor a license to excessive destruction or damage to property.

**13.2.1** Every effort should be made to avoid cutting valuable trees or shrubs. What is not valuable to you may be to the Base Installation Commander. Always check if any doubt exists.

**13.3** Government and private property shall be protected at all times.

**13.3.1** Gates should always be left in the position in which they were found. Do not leave any gate open for any period of time if it was originally closed.

**13.3.2** Always return borrowed keys to their rightful owner.

**13.4** Care should be taken to place survey points in locations that will not obstruct the use or operations of the property owner or military installation or be offensive to the view.

**13.4.1** Monuments set in open fields or in a road, railroad or utility right-of-way, should be set below ground level to prevent damage by or to any equipment or motor vehicles.

**13.4.2** Extreme care should be taken when setting a survey point on a runway or taxiway. Always check with the base operations personnel prior to this type of activity.

**13.5** Any pre-marks placed on private property or on a military installation shall be removed as soon as possible after the aerial photography has been obtained, or as the property owner or installation commander requests.

**13.6** California Law provides for access by a surveyor to private lands for the purpose of recovering and using monuments. In particular this is stated in Section 846.5 of the Civil Code and reads:

*846.5 (a) The right of entry upon or to real property to investigate and utilize boundary evidence, and to perform surveys, is a right of persons legally authorized to practice land surveying and it shall be the responsibility of the owner or tenant who owns or controls property to provide reasonable access without undue delay. The right of entry is not contingent upon the provision of prior notice to the owner or tenant. However, the owner or tenant shall be notified of the proposed time of entry where practicable.*



*(b) The requirements of subdivision (a) do not apply to monuments within access-controlled portions of freeways.*

*(c) When required for a property survey, monuments within a freeway right-of-way shall be referenced to usable points outside the access control line by the agency having jurisdiction over the freeway when requested in writing by the registered civil engineer or licensed land surveyor who is to perform the property survey. The work shall be done within a reasonable time period by the agency in direct cooperation with the engineer or surveyor at no charge to him.*

**13.6.1** It is the interpretation of Survey Section that this only applies to the use of monuments that denote the boundary line of the individual property when they are to be used to accomplish a survey relative to that or adjacent boundary lines. This law does not give the surveyor exclusive rights to enter upon private property to use a boundary monument, or for that matter, any other type of control monument for the purpose of surveys other than boundary.



## 14 - COMPUTATIONS

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**14.1** Vertical control by differential leveling shall be reduced by first checking the arithmetic of the field survey notes. Any differences in the level run between known elevations shall be prorated based on the number of turns in the level circuit. (i.e., .10' error in 10 turns = .01' correction per turn).

**14.1.1** The adjustments shall be made in the notes by using a red or blue pencil.

**14.1.2** The error of closure in feet for any primary vertical control established by differential leveling shall not exceed .04 times the square root of the length of the line in miles.

**14.1.3** All elevations used shall be based on the National Geodetic Vertical Datum of 1929 (NGVD 1929) or North American Vertical Datum of 1988 (NAVD 1988) unless stated otherwise by the Sacramento District.

**14.2** Horizontal control shall be reduced, either manually or by use of appropriate computer programs, using the following procedures:

**14.2.1** The angles shall be checked in the office by verifying the mean angle for each station as computed in the field.

**14.2.2** The horizon shall be checked, where applicable, and any error over or under 360 degrees shall be adjusted equally between each angle in that horizon, provided that the tolerances are met for the individual angles as defined in Chapters 1 & 2.

**14.2.3** Using the horizontal angles obtained in the field, the azimuths between known horizontal control points shall be computed and checked. Any error shall be distributed equally among each angle in that circuit. If the error per angle is greater than five seconds (5"), additional field checks shall be made until the error is within the stated tolerance.

**14.2.4** Slope distances obtained in the field shall be reduced to horizontal by using the adjusted elevation of the horizontal control points at each end of the line being computed, or the mean of all of the vertical angles obtained from those points. The height of the instrument and the height of the reflector shall also be taken into consideration during these computations.

**14.2.5** After the angular error has been distributed through the horizontal control line, the latitudes and departures of each course shall be computed using the adjusted azimuth of each line, and the horizontal distance, to which a combined sea level factor and grid factor have been applied.

**14.2.6** For primary horizontal control, individual combined grid factors and sea level factors shall be applied to each course. The grid factor shall be acquired by using the mean preliminary coordinate values computed for the points at each end of the line. The sea level factor shall be computed by using the mean elevation at both ends of the line being computed. The horizontal error of closure, after azimuth adjustment, for this order of control shall be 1:20,000 or better.

**14.2.7** For secondary horizontal control, a mean grid factor and a mean sea level factor for the area being surveyed may be used. The horizontal error of closure, after azimuth adjustment, for this order of control shall be 1:10,000 or better.

**14.2.8** If any horizontal control line fails to meet the above stated tolerances, either in azimuth or horizontal closure, additional field work shall be performed until the error is within the stated tolerances.



**14.2.9** All traverse computations shall be computed on the State Coordinate System in which the project is located unless otherwise directed by the Sacramento District Survey Section.

**14.2.10** The North American Datum 1983 shall be used in computing horizontal values for all projects unless otherwise specified by the Sacramento District. In NO case shall a NAD27 coordinate value be converted directly to a NAD83 value. The NAD27 values must be recomputed by using published NAD83 values and recomputing the control net or traverse.

**14.2.11** No traverse shall be computed on a local coordinate system and then scaled and rotated to the appropriate State Coordinate System.

**14.2.12** All horizontal control adjustments shall be accomplished using the Compass or Least Squares Adjustment method.

**14.3** The results of all computations (coordinates and basic elevations), except ground elevations, shall be properly adjusted and expressed to two (2) decimal places. Data listed to three or more places generally indicates an accuracy greater than required or obtained. Elevations for points on natural ground shall only be shown to one (1) decimal place.

**14.3.1** If coordinate values were obtained from G.P.S. observations, the resultant values should be listed to three (3) decimal places if the basic control values are 1st order.

**14.4** All horizontal and vertical control computations shall be presented in a neat and orderly manner.

**14.4.1** A note shall be typed stating the name of the project, contract number, delivery order number, and the contractors name and address, field book numbers and pages relative to the computations, references to the origin of the horizontal control and vertical control, and the methods used for computation and adjustment.

**14.5** The sea level factor used for any project based on NAD 1927 shall be computed using 20,906,000 as the mean radius of the earth.

**14.6** The grid factor shall be computed as outlined in the U.S. Department of Commerce publication, State Plane Coordinates by Automatic Data Processing. A copy of this manual is available from the Government.



## 15 - AERIAL PHOTOGRAPHY

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**15.1** When photogrammetric mapping is to be utilized, any new aerial photography required shall be taken with a precision mapping camera with a six inch (6") focal length lens and a nine inch by nine inch (9" X 9") negative format.

**15.1.1** The camera shall be one that has been calibrated within the last five years. A copy of this calibration certificate shall be provided to the Sacramento District with each project.

**15.1.2** The altimeter, clock, camera level bubble and exposure counter shall all be properly functioning at the time of each exposure.

**15.2** All original aerial photography, including any re-flights, shall be taken with black & white aerographic film unless otherwise stated. Outdated film, as determined by the manufacturer's label, shall not be used for any project.

**15.3** Storage, handling and exposure of all photographic materials used for any project shall be in accordance with the manufacturers recommendations.

**15.3.1** All aerial negatives shall be free from chemical and water stains, tears, scratches, abrasions, finger marks, lint, dirt and other physical defects.

**15.3.2** All black & white aerial negatives shall be processed under controlled conditions in accordance with the manufacturer's instructions.

**15.3.3** Under NO circumstances shall the aerial negatives be cut into individual frames.

**15.4** When necessary, splicing of aerial negative film shall be accomplished with three quarter inch (3/4") wide, pressure sensitive, polyester base tape.

**15.4.1** A splice shall be of the butt-joint type with the tape placed on both the emulsion and non-emulsion sides of the negative material.

**15.4.2** Particular care shall be given to the alignment of the film when splicing, with care taken to trim all of the excess tape, to insure that the film is perfectly straight after splicing.

**15.4.3** Splices shall not be closer than ten inches (10") from the image edge of any accepted and edited negative.

**15.5** Each accepted exposure shall be edited with a mechanical type lettering device in letters at least one-eighth inch (1/8") in height, but no larger than three-sixteenths inch (3/16") in height. Lettering shall be placed along the top edge of the negative which is perpendicular to the direction of the flight line as shown below:

First and last exposure of each flight line:

12-2-91	12:30	U.S.C.E.	1:6000	___ - 1 - 1
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Remaining exposures in each flight line:

12-2-91	U.S.C.E.	___ - 1 - 7
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- 15.5.1** The lettering shall be sharp, uniformly applied and easily read.
- 15.5.2** The lettering shall be placed on the non-emulsion side of the negative, and may be applied by a stamp using non-flaking ink. The lettering SHALL NOT be applied by using any type of stick-on's (i.e., KROY machine etc.).
- 15.5.3** No smears or transfers of marking ink to other parts of the negative roll will be permitted.
- 15.5.4** The date shown on each accepted exposure shall be the actual date that the exposure was taken.
- 15.5.5** The time shall be the actual local standard time that the exposure was taken, and shall be labeled using the military format (i.e., 2:30 PM = 14:30). The time shall be labeled only on the first and last accepted exposures of each flight line.
- 15.5.6** The initials U.S.C.E. shall be labeled in the center of each accepted exposure. If there is a fiducial mark in the center of the negative then the initials shall be placed to the left of the fiducial.
- 15.5.7** The scale shall be the scale of the exposure as computed by dividing the flying height above the mean ground elevation of the terrain being photographed, by the focal length of the lens. The scale shall be labeled as a representative fraction (i.e.,  $3000'/.5' = 1:6000$ ). The scale shall be labeled on each accepted exposure of each flight line.
- 15.5.8** The project symbol for each project will be provided to the Contractor within the specifications for that project. This symbol shall be labeled on each accepted exposure followed by the flight line number and the exposure sequence number.
- 15.5.9** The flight lines shall be numbered beginning with flight line one (1) at the East or South end of the project area, and run sequentially in an unbroken series to the West or North end of the project.
- 15.5.10** The exposure sequence shall be numbered beginning with exposure one (1) at the East or South end of the project area and run sequentially in an unbroken series to the West or North end of the project area (i.e., 100-1-6 followed by 100-2-7).
- 15.5.11** When multiple flights are flown on the same day, that cover the same general area but are at different flight heights, the flight line and exposure numbering shall continue in sequence as indicated above, starting at the East end of the project and continuing West.
- 15.6** A roll of aerial negatives shall consist only of exposures made with the same camera system.
- 15.6.1** Only that length of film which can be wound on a metal spool 5 3/16" in diameter, leaving a minimum of one eighth inch (1/8") of the flange exposed, shall be placed on each spool.
- 15.6.2** The film shall not be wound tightly on the spool or in any way stretched, buckled, distorted or exposed to excessive heat.
- 15.6.3** At least three feet (3') of blank, or unused film, shall precede the first used exposure, and follow the last used exposure for each project on each roll of film to serve as leader and trailer. These leaders and trailers may be spliced into the roll.
- 15.7** Aerial negatives shall be uncut and shall be placed on 5 3/16" metal spools with the emulsion side of the negative facing the core of the spool.



15.8 Aerial negatives shall be delivered to the Sacramento District in sturdy plastic cans no larger than six inches (6") in diameter.

15.8.1 A film can label shall be prepared for each can indicating the projects, flight lines, and exposures contained therein. This label shall be securely affixed to the outside of the plastic can.

15.9 Clearance for overflights of military installations will be obtained by the Sacramento District.

