PLANNING FOR THE FUTURE

AGRICULTURE

ON FARM WATER MANAGEMENT FIELD MANUAL

Volume II
Precision Land Leveling

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DECEMBER 1980

Presented to:

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by :
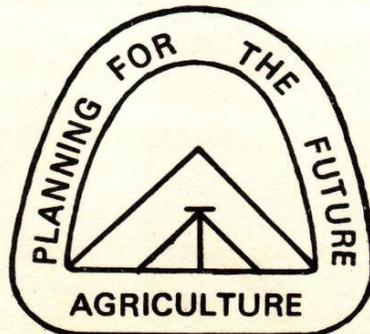
Water   Management   Wing
Ministry of Food, Agriculture & Cooperative
Government of Pakistan

ON-FARM WATER MANAGEMENT FIELD MANUAL

Volume II - Precision Land Leveling

C O N T E N T S

LIST OF FIGURES

ON-FARM WATER MANAGEMENT FIELD MANUAL

Volume II - Precision Land Leveling

I. INTRODUCTION

Precision land leveling consists of grading and smoothing the land to a smooth level field with little or no slope. This practice, if done precisely, will improve soil and water use. The precision leveled fields will have a more uniform stand and growth, improved crop yield and savings of irrigation water, labor and other expenses will result. On steep areas erosion is eliminated. More efficient use of fertilizer applied to the crop is another benefit. When an uneven field is irrigated, the high spots are watered too little and the low spots too much. (See Figure 1). This factor alone is enough to result in a spotty crop and reduced yields.

The purpose of this guide is to assist the field worker while implementing precision land leveling in Pakistan. Precision land leveling will make a major contribution toward the national goal of self-sufficiency in food. One of the primary objectives is to present an acceptable procedure for the field worker to follow while planning and constructing a land leveling project. It is the aim of this guide to present a procedure that will make it possible for the sub-engineer and assistant with some good technical supervision and simple arithmetic to complete the survey and calculations, to relieve the supervisor of some jobs and to increase their effectiveness. As a result the supervisor can direct many instead of a few projects. He is then able to devote more time to the feasibility of new projects, improvement of existing projects, etc. The sub-engineer and assistant, once they gain experience, will be able to cope with some of the more complex problems.

II. FARM CONSERVATION PLANNING FOR PRECISION LAND LEVELING

Precision land leveling is probably the most intensive practice that is applied to agriculture lands, and much expense can be saved by carefully studying the farm. When a farmer indicates he wants to level a field or his entire farm the LDO or other technician responsible for the job must work with the farmer in developing a complete farm conservation plan before any soil is moved. A good topographic survey is always helpful and is usually necessary in planning a farm irrigation system. Precision land leveling is usually accomplished on a field-by-field basis. It is extremely important, therefore, to study the entire farm before attempting any portion of it. The required complete plan includes the following items and actions:

A. The first step is the completion of a resource inventory with the farmer. The required data is listed on the Farm Conservation Plan form. (See Fig. 2) Data includes information on soils, water supply, equipment available, livestock, labor, cropping history, and any special problems and considerations the farmer may identify. Complete all items with the farmer.

B. The second step is the design of the complete farm irrigation system. The map should be placed on the grid sheet provided in the plan form. It should include:

1. Topographic survey map.

2. Water supply location point. Where does the water reach the farm? Show water surface elevation of entry point.

3. Nucca locations.

BEFORE PRECISION LAND FORMING

SEEDING

Points A: Seed placed too deep
Points B: Seed placed at proper depth
Points C: Seed placed too shallow

Note: Uneven moisture distribution
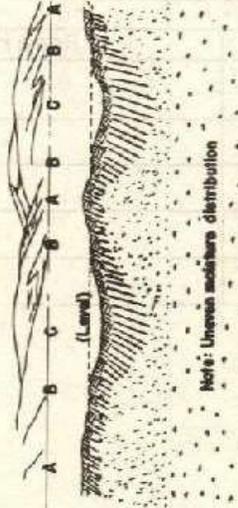
GERMINATION...

Points A: Seed placed too deep
Points B: Seed placed at proper depth
Points C: Seed placed too shallow

Note: Uneven moisture distribution

RESULTS

Weeds

High A: Grain is short, immature, but ready for harvesting
Medium B: Grain is taller, fuller heads, but still green, not ready
Low C: Drowned out or failed to germinate due to shallow planting, and to much water. Weeds become a problem and rob the crop at B of moisture and nutrients.

AFTER PRECISION LAND FORMING

UNIFORM MOISTURE DISPERSION

ALL SEEDS...

Placed at uniform and recommended planting depth
Note: Uniform moisture dispersal, assuring greater germination
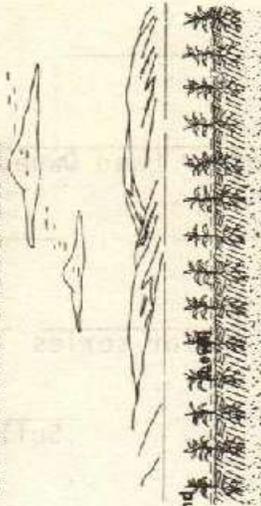
SEEDS- placed at recommended depth, in a well prepared seed bed which gives better moisture distribution, result in greater germination, more even emergence and uniform growth -Easier and Better Cultivation- INCREASED YIELDS.

Irr. Canal
Bund
(Level) 0.0% Slope
Normal Moisture Penetration Line

Figure 1. Diagram showing results of precision land forming

Courtesy of Eversman Mfg Co. Colorado, U.S.A.

FARM CONSERVATION PLAN
RESOURCE INVENTORY FOR SOIL AND WATER MANAGEMENT

Name	Farm Size	Other Land Owned or Operated

Location of other Land Owned or Operated   Plan Number

Tehsil	District	Village

Soil Type (Texture and/or series   Depth   Intake Rate

pH	Soil Condition (Tilth)	Special Soil Problems

Water Supply: _____ _____ _____   Schedule (wari bundi)
              Source   Amounts   Quality

Farm Equipment) Tractor   Planter   Cultivator   Scraper
   (Mechanical))

) Leveler   Trolley   Other   Other

Farm Equipment)_____
(Animal Drawn)) Plow   Plank   Other

Farm Animals. Bullock   Buffalo   Other

Labor Available:_____ _____   Market Available: _____
                Full Time Seasonal

CROP YIELDS FOR PAST TWO YEARS (3 Crops)

Year	Crop	Variety	Yield	Remarks

Remarks (include Problems and Opportunities)

(Problems may include availability of inputs, credit
  or custom operations)

Figure 2

FARM PLAN - BEFORE

½ Ac.

½ Ac.

N

Check + Nucca

W.C.
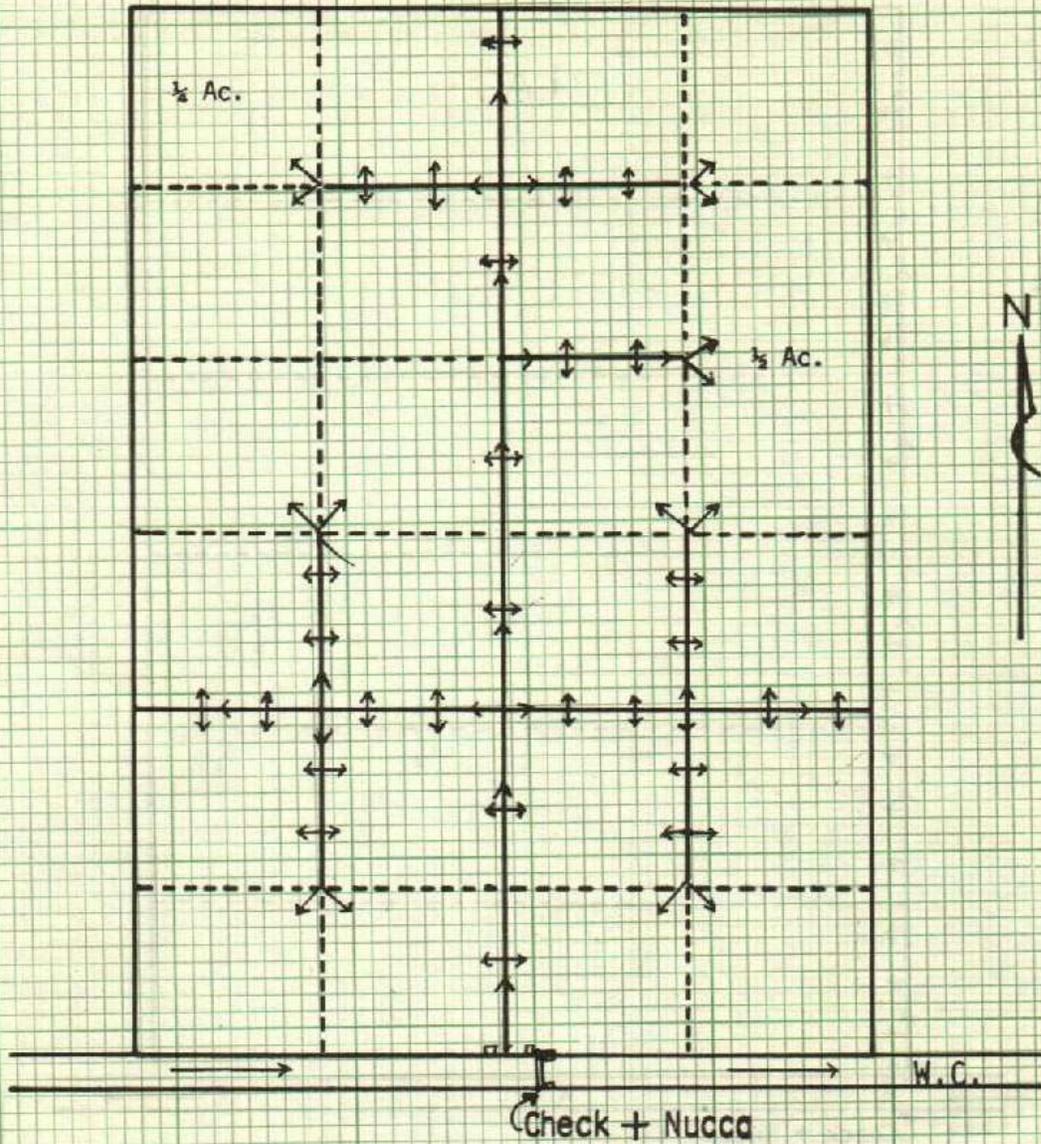
6 Acres

Scale: 0.5cm = 6 Meters

WC ⟶   Watercourse

⟶ ⟶   Farm Lateral

------   Field Boundry

FARM PLAN - AFTER

I AC

N
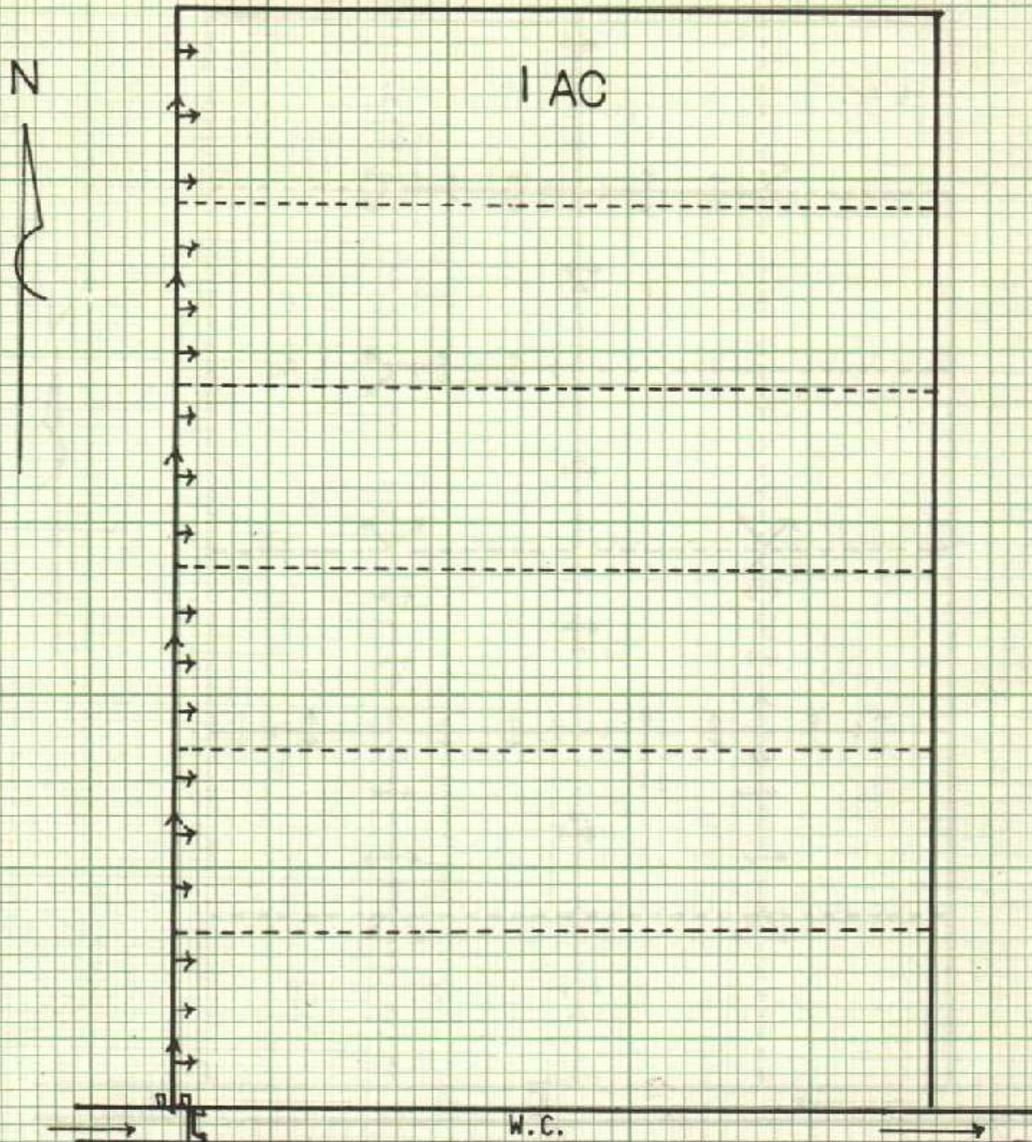
W.C.

Check + Nucca

6 Acres

Scale :   0.5cm = 6 Meters

Watercourse
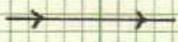
Farm Lateral
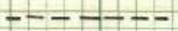
Field Boundry

Field No.		Planned		Applied	
		Date	Acres Decares	Date	Acres Decares
	Land Leveling				
	Chiseling				
	Subsoiling				
	Fertilizer				
	Commercial (Kind & amount)				
	FYM (Kind & amount)				
	Green Manure Crop				
	Planned Crop and Variety				
	_____ _____				
	Seeding Method_____				
	Planting Date _____				
	Irrigation Method_____				
	Field channel lining (Ft)___				
	Nuccas (No.) _____				
	Other Treatment				

FOLLOWUP CONTACTING

Date	Technican	Notes

7

4. Field boundaries.

5. Direction of irrigation. Use arrow.

6. Grid survey elevations and cuts and fills.

7. Roadways or field access points.

8. Drainage points. Where is it planned for the water to leave the farm.

9. Planned crops.

10. Other special features such as buildings, trees, power poles, etc.

C. The third element of the complete plan is the Cropping Program details. These should be discussed with the farmer and entered on the back page of the Farm Conservation Plan Form. For a complete discussion of conservation irrigation planning procedures See Volume 1 - Reference, Section 2, Inventory and Planning. This reference provides useful information on resource inventory, the planning process, and complete irrigation planning.

III. DESIGN PROCEDURE

A. Planning the Grid System

The grid system for planning a survey will be used. A grid system of 20 meter intervals will be suitable for most jobs. In some instances, it may be necessary to use a different grid interval i.e. mango gardens, leveling with bullocks, etc. In any case, sharp breaks in the natural slope should be located and identified so that proper planning will be possible.

Vegetation in the area to be leveled should be cleared since it will interfere with the staking and will make it difficult to see and locate construction stakes. It is advisable to float or smooth the surface to eliminate rows, furrows and other minor irregularities of the surface. As a minimum, the area where the grid rows are to be established should be smoothed.

B. Staking a Grid System on Regularly Shaped Field Using Tape and Level. Figure 3.

1. In the field to be leveldd establish a corner where at least two straight edges intersect at approximately right angles. The longest edge should be taken as the base line and the shorter edge as the perpendicular line.

2. At a distance of one-half grid interval in from the base line and perpendicular to base line set a grid stake. At a widely separated location, at a distance of one-half grid interval from the base line,

8
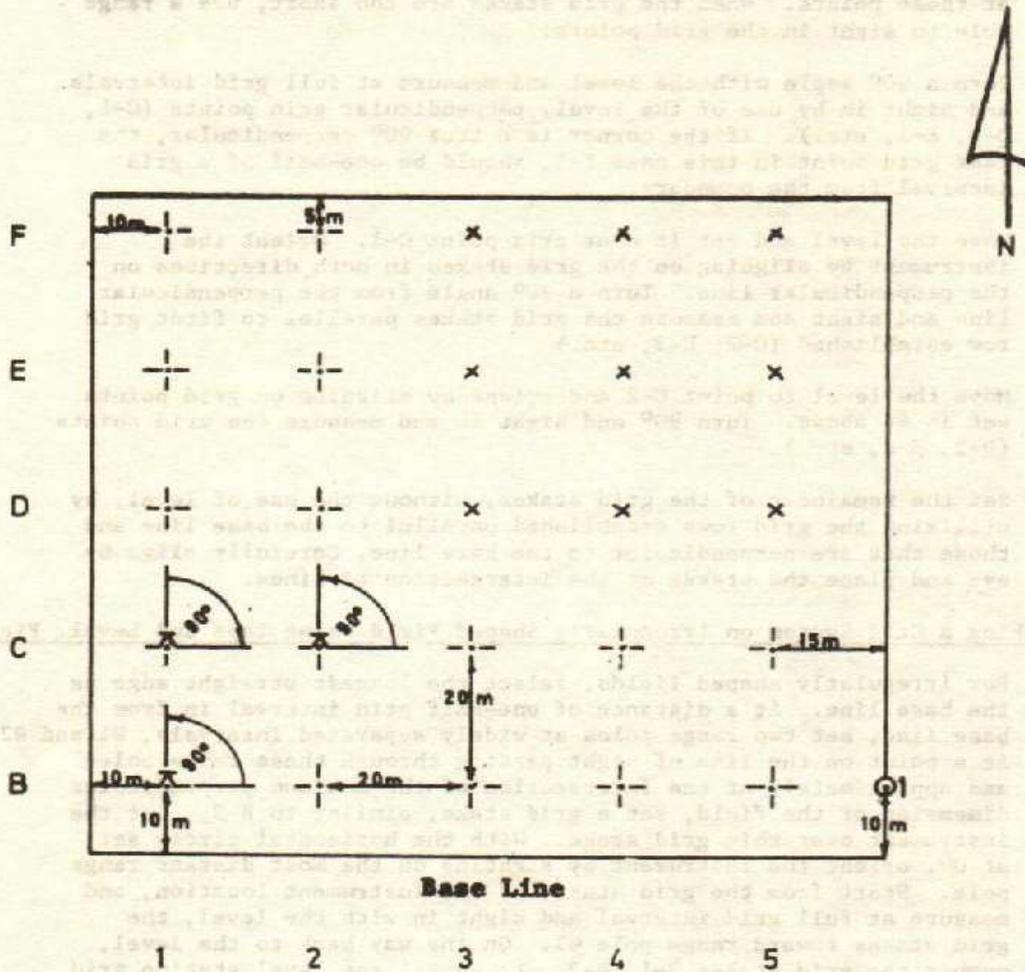
**FIGURE   3.   DIAGRAM OF GRID SYSTEM ON REGULAR SHAPED
FIELD USING LEVEL AND TAPE**

- $-\!\cdot\!\!\!\!-$ **Measured Grid Points**
- ✕   **Sighted Grid Points**
- ⊙   **Range Pole**
- 𝗫   **Level Location**

set a range pole, θ1[1]. Set the level or instrument over the grid
stake, and with the horizontal circle set at 0°, orient the instrument
by sighting on range pole θ1. From this grid point, measure,
at full grid intervals, and sight in, with the instrument, the
remaining grid points (B-2, B-3, B-4, B-5) setting the grid stakes
at these points. When the grid stakes are too short, use a range
pole to sight in the grid points.

3. Turn a 90° angle with the level and measure at full grid intervals
and sight in by use of the level, perpendicular grid points (C-1,
D-1, E-1, etc.). If the corner is a true 90° perpendicular, the
last grid point in this case F-1, should be one-half of a grid
interval from the boundary.

4 Move the level and set it over grid point C-1. Orient the
instrument by aligning on the grid stakes in both directions on
the perpendicular line. Turn a 90° angle from the perpendicular
line and sight and measure the grid stakes parallel to first grid
row established (C-2, C-3, etc.)

5. Move the level to point C-2 and orient by aligning on grid points
set in #4 above. Turn 90° and sight in and measure the grid points
(D-2, E-2, etc.)

6. Set the remainder of the grid stakes, without the use of level, by
utilizing the grid rows established parallel to the base line and
those that are perpendicular to the base line. Carefully align by
eye and place the stakes at the intersection of lines.

C. Staking a Grid System on Irregularly Shaped Field Using Tape and Level. Figure 4

1. For irregularly shaped fields, select the longest straight edge as
the base line. At a distance of one-half grid interval in from the
base line, set two range poles at widely separated intervals, θ1 and θ2.
At a point on the line of sight passing through these range poles
and approximately at the intersection of the maximum perpendicular
dimension of the field, set a grid stake, similar to B-3. Set the
instrument over this grid stake. With the horizontal circle set
at 0°, orient the instrument by sighting on the most distant range
pole. Start from the grid stake, at the instrument location, and
measure at full grid interval and sight in with the level, the
grid stakes toward range pole θ1. On the way back to the level,
number the grid stakes B-1, B-2, etc. until the level station grid
point is numbered. Turn the level telescope 180° and orient on
range pole θ2, continue to set grid stakes toward this point.

2. Turn the level 90° and in the same manner establish the perpendicular
line, measuring and setting grid stakes. Extend the numerical and
alphabetical numbering of the perpendicular grid points, C-3,
D-3, etc.

3. Move the level and set it over grid point C-3. With the horizontal
circle set at 0° orient the instrument by aligning on the grid
stakes on the perpendicular line. Turn a 90° angle from the
perpendicular line and sight in and measure the grid stakes on one
side (C-1, C-2, etc.). Turn the level 180° and set the remaining
grid stakes (C-4, C-5, etc.). This grid row should be parallel
to the first grid row, B.

4. Move the level to the next parallel grid point, C-4, and
establish another perpendicular line using same method as in
previous steps.

Note: 9 Stakes per acre will be required.

[1] θ Range Pole
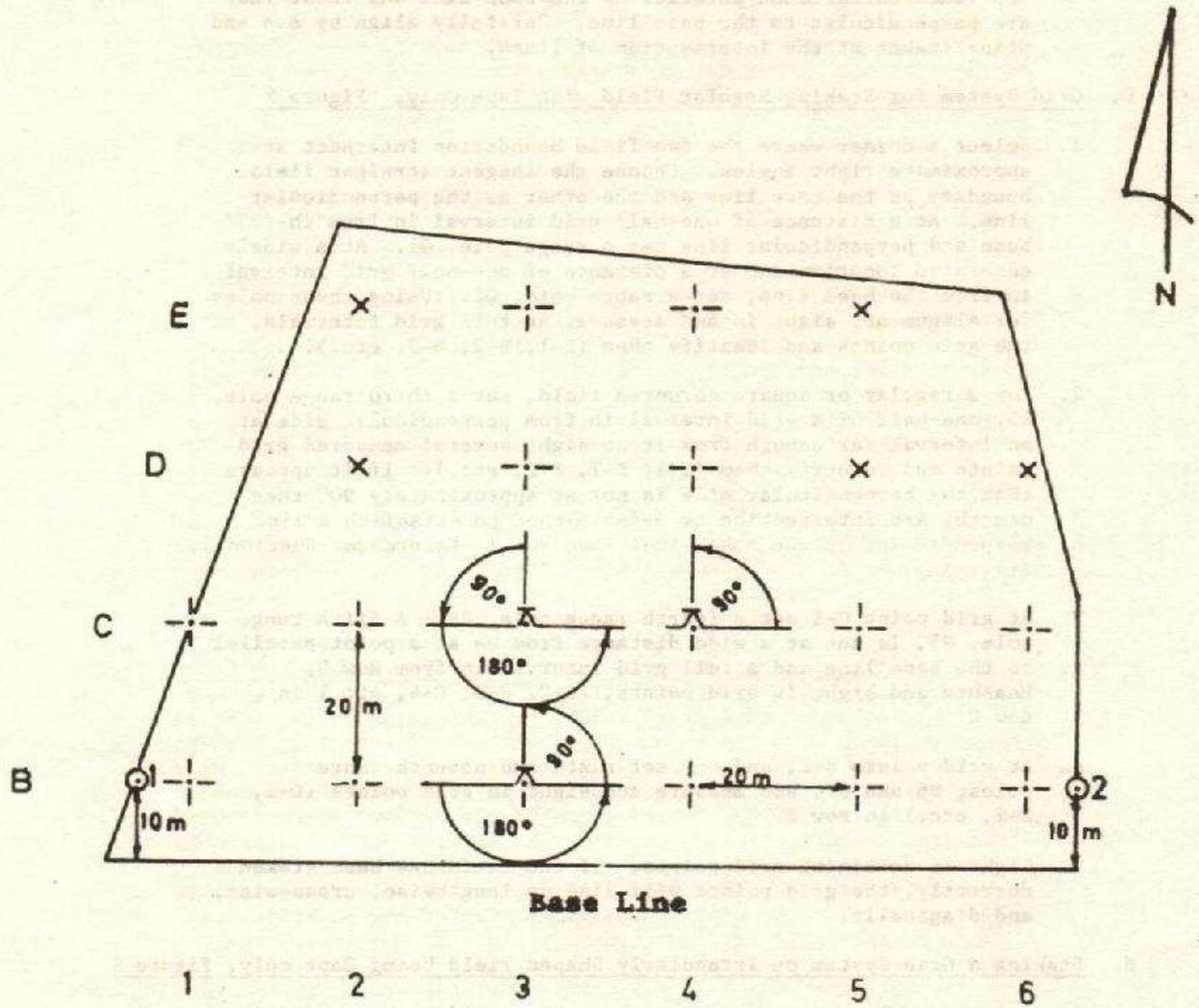
FIGURE 4. DIAGRAM OF GRID SYSTEM FOR IRREGULAR FIELD, USING LEVEL AND TAPE

-¦- **Measured Grid Points**

✕ **Sighted Grid Points**

⊙ **Range Pole**

⤳ **Level Location**

5. Sight in the remaining grid points in the field by utilizing the two lines established parallel to the base line and those that are perpendicular to the base line. Carefully align by eye and place stakes at the intersection of lines.

D. Grid System for Staking Regular Field with Tape Only, Figure 5

1. Select a corner where the two field boundaries intersect at approximate right angles. Choose the longest straight field boundary as the base line and the other as the perpendicular line. At a distance of one-half grid interval in from the base and perpendicular line set a range pole, Ө1. At a widely seperated location and at a distance of one-half grid interval in from the base line, set a range pole, Ө2. Using these poles for alignment, sight in and measure, at full grid intervals, the grid points and identify them (B-1, B-2, B-3, etc.).

2. For a regular or square cornered field, set a third range pole, Ө3, one-half of a grid interval in from perpendicular side at an interval far enough from it to sight several measured grid points and identify them (C-1, D-1, E-1, etc.). If it appears that the perpendicular side is not at approximately 90° then use the Arc Intersection or 3-4-5 Method to establish a line perpendicular to the base line. (See Vol.I, Reference, Section 5, Surveying).

3. At grid point C-1 set a fourth range pole, Ө4. A fifth range pole, Ө5, is set at a wide distance from Ө4 at a point parallel to the base line and a full grid interval in from Row B. Measure and sight in grid points, (C-2, C-3, C-4, etc.) in Row C.

4. At grid points B-2, and C-2 set sixth and seventh range poles, Ө6 and Ө7, and measure and sight in grid points (D-2, E-2, etc.) in Row 2.

5. Sight in remaining grid points. If the field has been staked correctly, the grid points will line up lengthwise, cross-wise, and diagonally.

E. Staking a Grid System on Irregularly Shaped Field Using Tape only, Figure 6

1. Select the longest straight edge of the field as the base line. Measure one-half grid interval in from the base line and set two range poles at widely seperated locations, Ө1 and Ө2.

2. At a point on the line of sight passing through the two range poles and at the maximum perpendicular dimension of the field, set a grid stake, B-3, measure remaining grid points, at full grid intervals, toward range poles Ө1 and Ө2.

3. Set a third range pole, Ө3, at the grid point, B-3, which will allow a perpendicular line to be established through the maximum field width. The perpendicular line can be established by use of the Arc Intersection or 3-4-5 Method (See Vol.1, Ref. Sect.5, Surveying). This will establish a fourth range pole, Ө4. Then sight in and measure, at full grid intervals, the grid points C-3, D-3, etc.) in Row 3.

4. At a full grid interval, from Row 3 and Row B, establish grid point C-4 and set a fifth range pole, Ө5. Sighting through this range pole and grid point C-3, set grids points in Row C. Then by sighting through grid point B-4 and fifth range pole, Ө5, set grids points in Row 4.
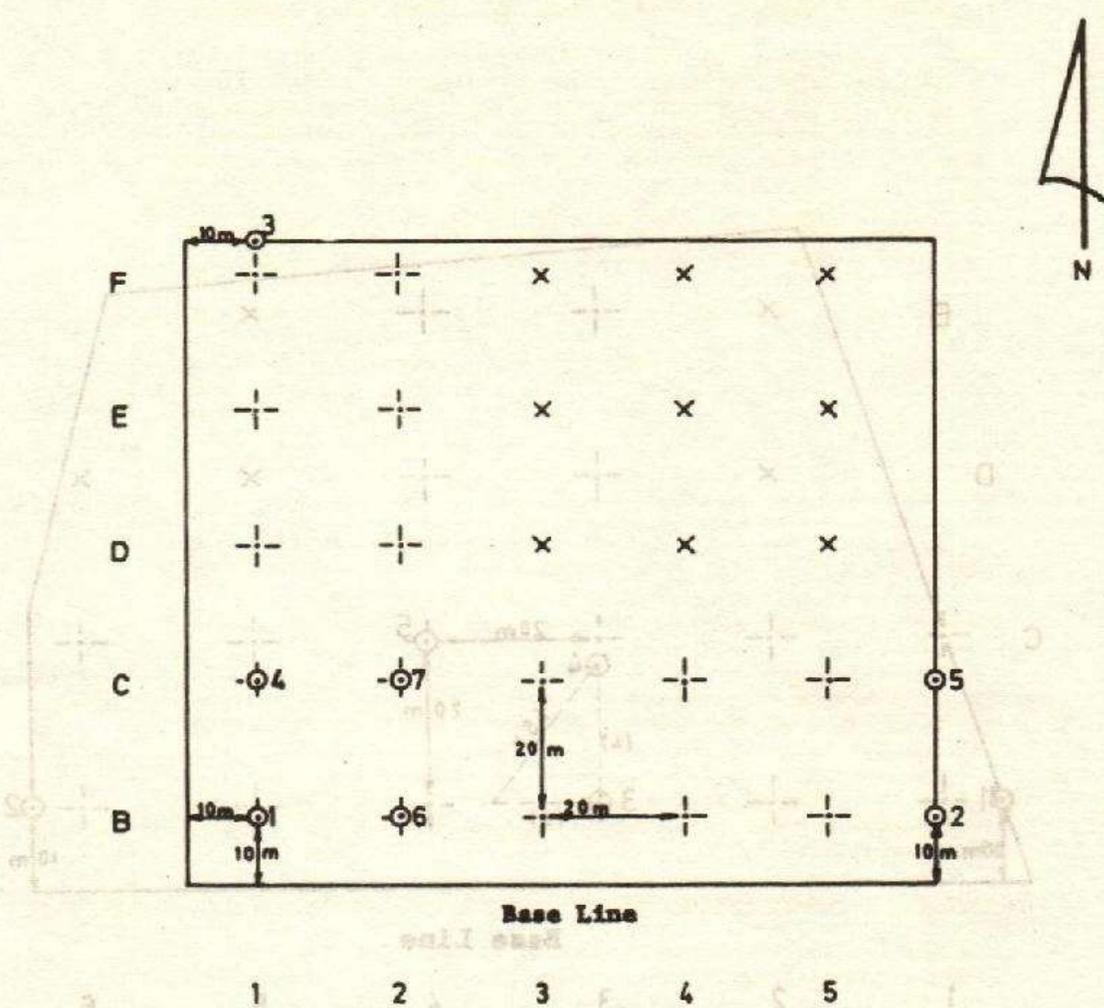
FIGURE 5. DIAGRAM OF GRID SYSTEM ON REGULAR SHAPED FIELD,
USING TAPE ONLY

-|- Measured Grid Point

× Sighted Grid Point

⊙ Range Pole

FIGURE 6. DIAGRAM OF GRID SYSTEM FOR IRREGULAR SHAPED FIELD,
USING TAPE ONLY

-|-   Measured Grid Point

×   Sighted Grid Point

⊙   Range Pole

5. Sight in remaining grid points in the field by utilizing the two rows established parallel to the base line and those perpendicular to the base line. Carefully align by eye and place stakes at intersection of lines.

F. The Grid Sheet, Figure 7

1. This sheet can best be prepared on graph or cross section paper.

2. Prepare the grid sheet showing location of all grid points and plus stakes if used. Locate the field boundaries by measuring from the boundary to the nearest stake. Depending on the size of the field and available paper, make the scale of the grid map as large as possible.

3. Locate irrigation canals, drainage canals, pump sites, wells, pipelines, farmstead and any other topographic or cultural feature of importance.

4. Record directional orientation. North should generally be the top of the sheet.

5. Make sure the scale and location of farm are noted.

G. Survey for Precision Land Leveling

In surveying for precision land leveling the same general procedure is used as for differential leveling. It is assumed that the individual has some basic knowledge about surveying. If he does not, it is suggested that he study Surveying Section on the Vol. 1, Reference, Section 5, Surveying.

1. Establish a bench mark so that the survey can be easily reoriented at a subsequent date. Use known elevation if available; if not, assume an elevation. If there is not much difference in elevation in the field, assume an elevation of 3.00 meters so that all recorded data will not have more than 4 figures. Properly identify benchmarks (BM or TBM). Set up instrument and close BM circuit when there is more than two BMs that cannot be seen from one instrument location.

2. If field size and topography are such that all grid point rod readings can be taken from a single instrument setup, make the setup near the center of the field, such as near grid point D-3, Figure 8.

3. If the field size is too large for one set up divide the field by visual inspection into as many parts as necessary and locate instrument near the center of each part.

4. When a single instrument setup is used, record all essential survey data on grid sheet, i.e. BM Elev., BS, HI and FS. See sample survey notes Figure 8. Where more than one instrument setup is used the survey data should be recorded in a field note book or on plain paper in similar format. (See Vol.1, Reference, Section 5, Surveying.)

5. The instrument man and rodman should proceed as follows after the HI has been determined.

   a. The rodman should start at one end of a grid row next to a field boundary, as an example Row B, taking readings at grid points B-1, B-2, B-3, etc., and then return on next grid row C, taking readings at grid points C-5, C-4, etc. See Figure 8.
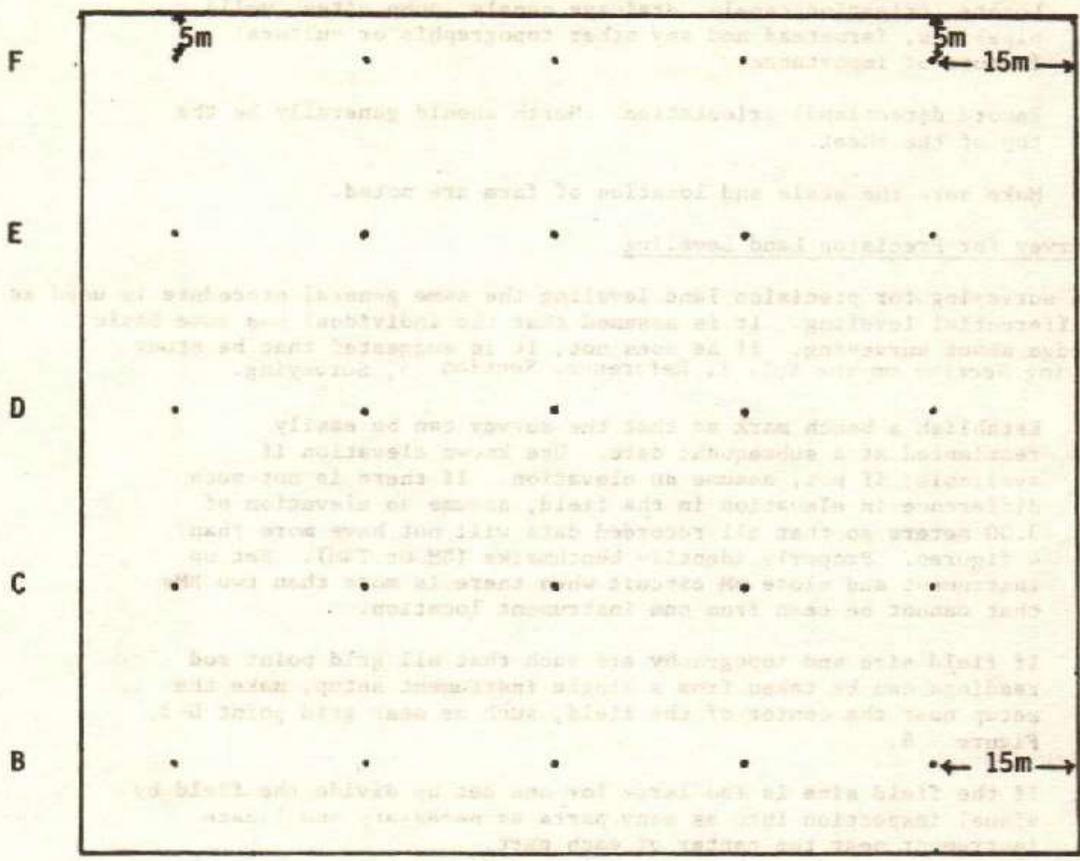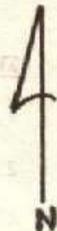
FIGURE 7. GRID SHEET FOR AREA

TBM - Top of Road Marker (Mile 261) Assumed Elevation 3.00m

**Top of
Road Marker, Mile 261
TBM 3.00 m**

STA.	BS	HI	fS	ELEV.
TBM	1.00	4.00		3.00
TBM			0.98	3.02

```
     1        2        3        4        5
   ┌────────┬────────┬────────┬────────┬────────┐
F  │.75     │.75     │.75     │.75     │.94     │
   │   1.22 │   1.30 │   1.26 │   1.37 │   1.55 │
   ├────────┼────────┼────────┼────────┼────────┤
   │        │        │        │        │   1.25 │
E  │ 1.33   │ 1.34   │ 1.33   │ 1.43   │ 1.72   │
   ├────────┼────────┼────────┼────────┼────────┤
   │        │        │        │        │   1.25 │
D  │ 1.34   │ 1.37   │ 1.43   │ 1.39   │ 1.52   │
   │        │        │  ⋏     │        │        │
   ├────────┼────────┼────────┼────────┼────────┤
   │        │        │        │        │   1.25 │
C  │ 1.40   │ 1.39   │ 1.37   │ 1.31   │ 1.45   │
   │        │        │  RODMAN RETURN           │
   │        │        │ ←──────────────          │
   ├────────┼────────┼────────┼────────┼────────┤
   │        │        │        │        │   1.25 │
B  │ 1.43   │ 1.40   │ 1.34   │ 1.33   │ 1.46  /│
   │ RODMAN START HERE  ──── →               │  │
   └────────┴────────┴────────┴────────┴────────┘
```

N ↑

Top of
culvert
TBM 3.02

FIGURE 8. ROD READINGS RECORDED ON GRID SHEET

b. The instrument man should read, record, and signal the rodman to move to the next grid point. Record rod reading to nearest .01m. The surveyor should signal the rodman when he wants him to proceed to the next grid point.

c. The rodman must be alert for the signal and must move only when he is given the signal. Following are a few points to discuss while orienting the rodman.

    (1) He should hold the rod plumb.

    (2) He should use his best judgment on where to place the rod so that the resulting rod reading will give as near a true field surface elevation as possible. Since the grid point is to remain during the construction phase it should be as near to the grid point as possible but never place the rod in a deep depression or on a bund. The grid point, if the field is staked at 20m intervals, is to represent an area 10m in each direction from it. Theoretically, any location of the rod in this area which represents its true surface elevation could be utilized.

    (3) He should make sure the grid point stake is firmly driven into the ground or the grid point near where the rod is located is easily identifiable.

d. The instrument man should confirm the location of the rodman frequently, by noting the movement of the rodman, to assure that data is recorded in proper location on grid sheet or in field notebook. If there is a question relative to a particular rod reading, signal the rodman to return to location in question for a check reading.

H. Recording of Survey Data

1. Single instrument setup

    a. Use grid sheet that has been prepared, as in Figure 7, paragraph F, to record rod readings at grid points and all other essential readings.

    b. Show instrument location.

    c. Show benchmark location.

2. More than one instrument setup.

    a. Use sheet that has been prepared, as in Figure 7, paragraph F.

    b. Transfer elevation data from field note book or similar format to appropriate grid points.

    c. Transfer any other essential elevations, i.e. ditch elevations, high water, etc.

    d. Show instrument location for each setup.

    e. Show benchmark location.

    f. Show location of T.P's.

C A L C U L A T I O N S

I. Determining Field Segments

Determine whether the field should be leveled in a single plane or in segments using different planes. Plotting contours will greatly facilitate making this determination.

 1. First, consider leveling the area to a single plane.

 2. If leveling to a single plane is too costly, adhere closer to the natural topography by dividing the field into segments. Shallow top soil or excessive yardage are factors that must be considered.

J. Determining the Average Rod Reading or Average Elevation

Determine the average rod reading or the average elevation of the segment to be leveled in a single plane. If there is a more than one segment, handle each separately.

Procedure:

 1. Determine proportionate size of odd grid areas. Each grid point represents a specific area. The standard or normal area in this example has an area of 400 square meters (20 meters X 20 meters) The odd areas may be either larger or smaller than the standard area. Determine and write the proportionate part in the upper left hand corner of each odd grid point area. For example, grid points F-1, F-2, F-3 and F-4 are 0.75 (15m X 20m = 300÷400 = 0.75) of the standard 400 square meter area, Figure 8. Do not describe the standard grid areas since they automatically will be a full unit or 1.00.

 2. Prepare a worksheet (See Table 1 for an example) for determining the average rod reading or average elevation.

 a. Record in Column 1 the total number of grid area that have the same proportionate size.

 b. In Column 2 record the proportionate size.

 c. Total the rod readings or elevations for each of the proportionate sizes and record in Column 3.

 d. Adjust the sum of the rod readings or elevations by multiplying each total (Col.3) by the appropriate proportionate size (Col.2) and record in Column 4.

 e. Adjust the number of specific grid areas (Col.1) by multiplying by the appropriate proportionate size (Col.2) and record in Column 5.

 f. Total Column 4 and Column 5.

 g. Find the average rod reading.

 3. The average rod reading equals the sum of adjusted rod readings (Col.4, Table 1) divided by the sum of adjusted grid areas (Col. 5, Table 1). The average elevation is obtained in the same manner.

SPECIAL NOTE: Paragraphs K and L apply to fields where graded-borders and graded-furrows will be used. Paragraph P applied to fields where basins, level-borders, and level-furrows will be used.

TABLE   1.   WORKSHEET TO FIND THE AVERAGE READING[1/] OF FIELD
WHEN STANDARD GRID AREA IS 400 SQ.M

(Data Form Figure 8)

(1) No. of specific sized grid areas	(2) Portion of standard grid area	(3) Sum of readings by areas	(4) Adjusted readings (Col.)x(col.3)	(5) Adjusted grid areas (col.1)x(col.2)
No.	Portion			No.
16	1.00	21.93	21.93	16
4	1.25	6.15	7.69	5
4	0.75	5.15	3.86	3
1	0.94	1.55	1.46	0.94
		Total	34.94	24.94

Average Reading $= \dfrac{Col. 4}{Col. 5} = \dfrac{34.94}{24.94} = 1.401$ m

1/ May use either rod readings or determined elevation.

K. <u>Determining the Centroid of a Field</u>

The centroid of a field needs to be located <u>only</u> when a field is designed to have downfield slope.

1. The centroid of rectangular field is located at the intersection of its diagonals. See Figure 9.

2. The centroid of a triangular field is located at the intersection of lines drawn from its corners to the midpoints of the opposite sides. See Figure 10.

3. The centroid of an irregular field can be located with sufficient accuracy by assuming that each stake in the field represents the same area. Figure 11 shows how the centroid can be located in this manner.

Assume a line of reference 20 meters south of line B. The number of stakes in each line multiplied by the distance from the reference line is:

Line	Distance	No. of Stakes	Product
F	100	5	500
E	80	6	480
D	60	6	360
C	40	5	200
B	20	3	60
Total		25	1600

The distance of the centroid is then found by dividing the sum of the products by the total number of stakes or $\frac{1600}{25}$ = 64 meters from bottom of reference line. Another line of reference is assumed to be 20 meters west of line 1 and the location of the centroid in the east-west direction computed in the same way. In this case the centroid was located 73.6 meters to the left of the reference line.

L. <u>Determining the Planned Rod Readings or Planned Elevations for Fields with Downfield Slope</u>

Fields, for which downfield slope or grade is planned, can have any of the following grade or slopes:

Grade		Slope		Fall
0.0005 meter/meter	=	0.05%	=	0.01 meter/20 meters
0.001 meter/meter	=	0.1 %	=	0.02 meter/20 meters
0.0015 meter/meter	=	0.15%	=	0.03 meter/20 meters
0.002 meter/meter	=	0.2 %	=	0.04 meter/20 meters

Surface drainage <u>must</u> be provided for fields that are leveled with slopes of 0.05% or greater. If surface drainage can not be provided then level borders should be seriously considered. When level borders are being considered for border strip lengths over 180 meters then a 0.05% slope should be considered.

After the average rod reading or average elevation has been determined and the centroid is located, the planned rod reading or planned elevation can be computed for each row of grid points perpendicular to the direction of irrigation.

The average rod reading or average elevation is that of the centroid. If the centroid does not fall on a grid point the average rod reading or average elevation will have to be adjusted to the nearest row of grid points which are perpendicular to the direction of irrigation. The following can be used to determine the adjusted average rod reading or adjusted elevation.
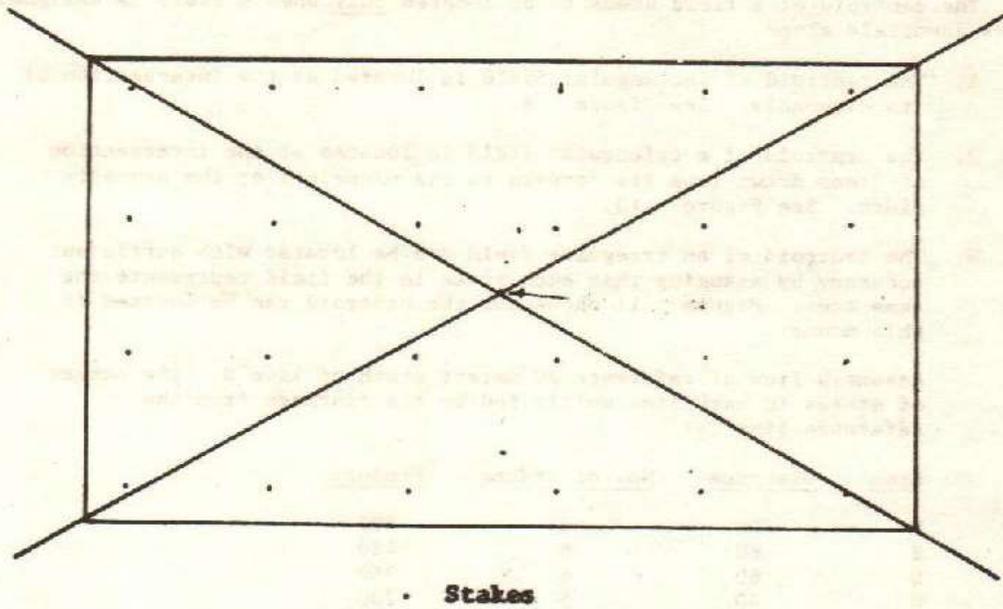
. Stakes

FIGURE   9.   CENTROID OF RECTANGULAR FIELD
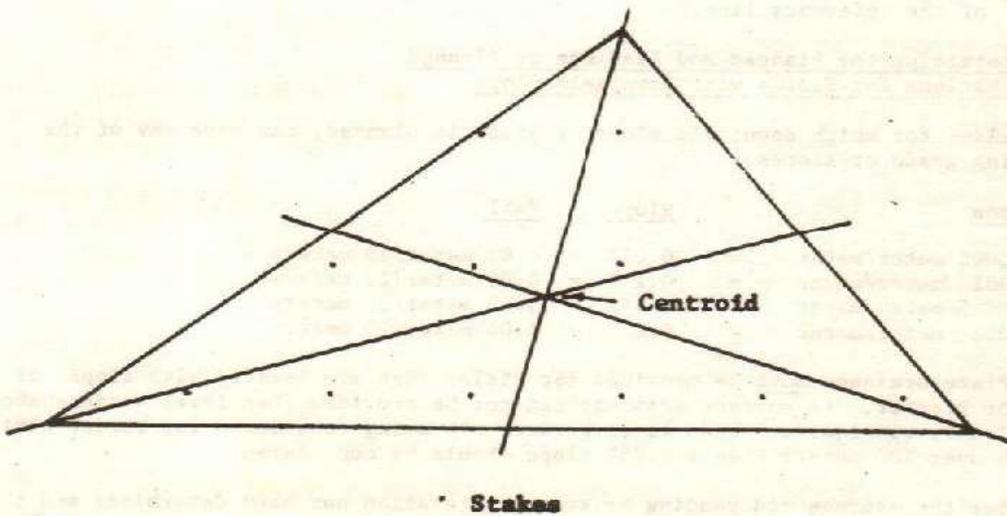
Centroid

Stakes

FIGURE   10.   CENTROID OF TRIANGULAR FIELD

100	5	500	F	
80	6	480	E	
60	6	360	D	
40	5	200	C	
20	3	60	B	
Total	25	1600		

Reference line

Centroid

73.6 m

64 m
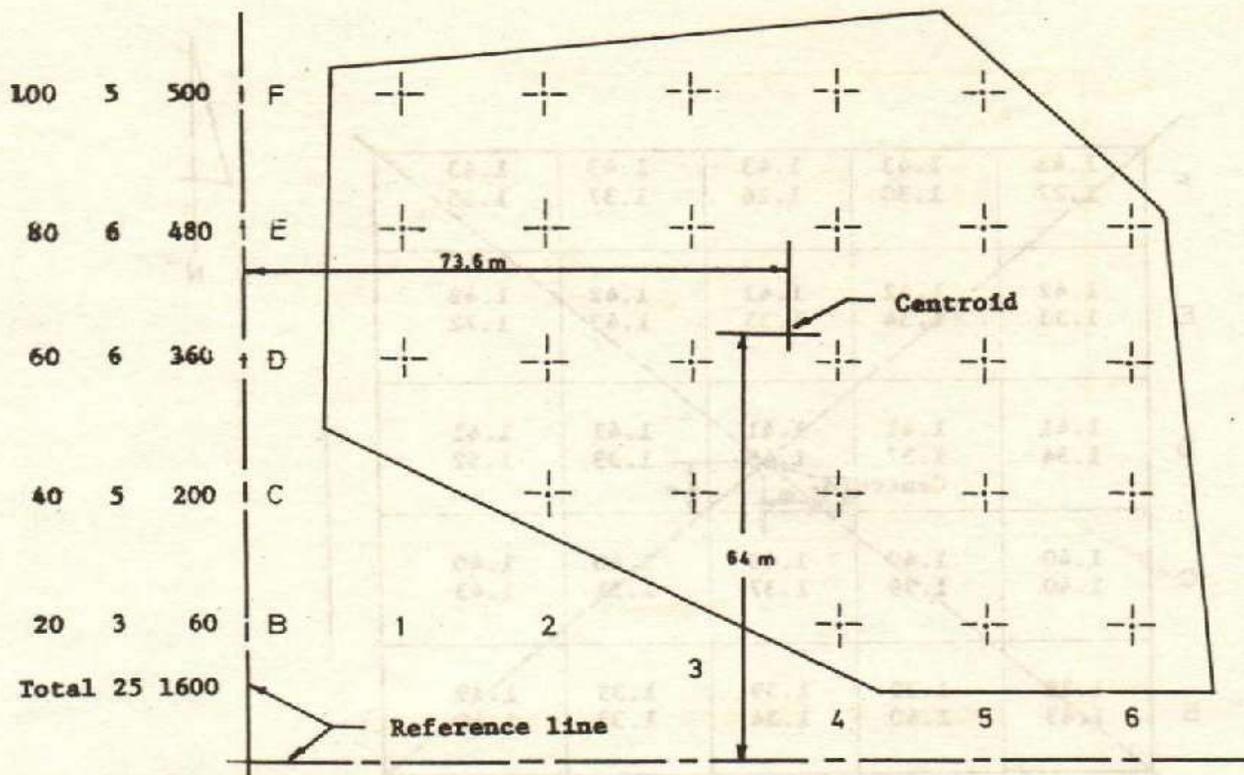
Distance	20	40	60	80	100	120	Total
No. Stakes	3	4	4	5	5	4	25
Product	60	160	240	400	500	480	1840

$$\frac{1600}{25} = 64 \text{ meters}$$

$$\frac{1840}{25} = 73.6 \text{ meters}$$

Location of Centroid:

64 meters up from bottom reference line

73.6 meters to the right of left reference line.

FIGURE   11.   CENTROID OF IRREGULAR SHAPED FIELD

23

	1	2	3	4	5
F	1.43 / 1.22	1.43 / 1.30	1.43 / 1.26	1.43 / 1.37	1.43 / 1.55
E	1.42 / 1.33	1.42 / 1.34	1.42 / 1.33	1.42 / 1.43	1.42 / 1.72
D	1.41 / 1.34	1.41 / 1.37	1.41 / Centroid 2 m	1.41 / 1.39	1.41 / 1.52
C	1.40 / 1.40	1.40 / 1.39	1.40 / 1.37	1.40 / 1.31	1.40 / 1.43
B	1.39 / 1.43	1.39 / 1.40	1.39 / 1.34	1.39 / 1.33	1.39 / 1.40
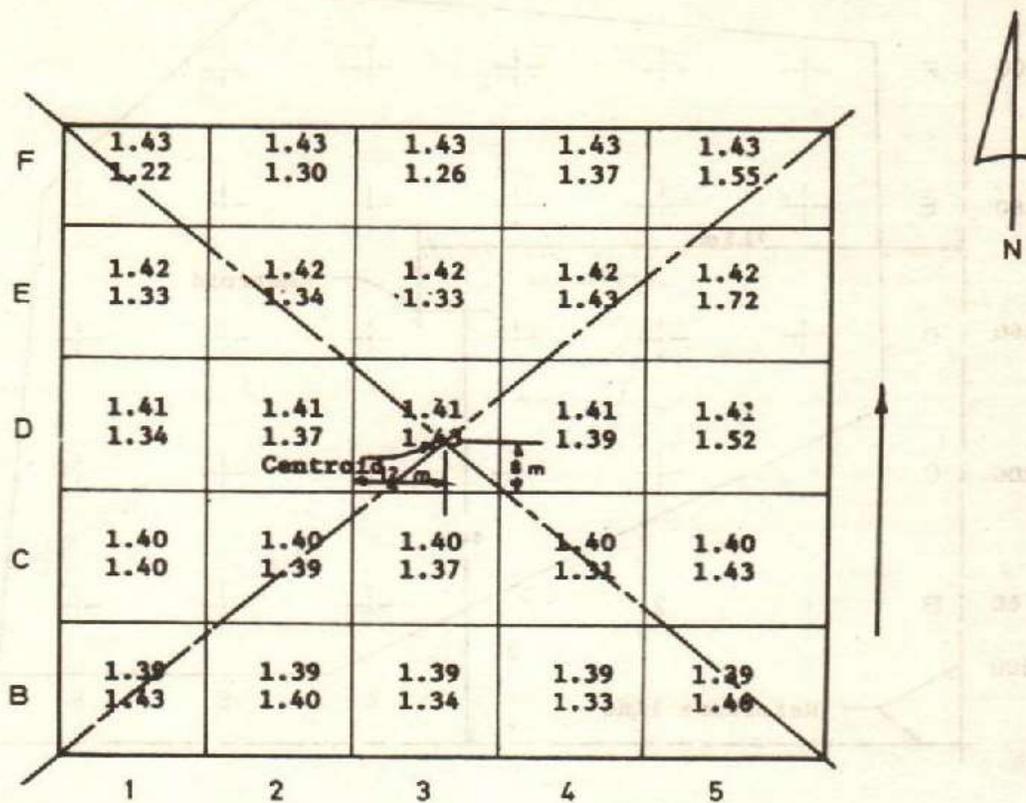
Average Rod Reading	=	1.401
Adj. Average Rod Reading 1.401+(0.0005X2m)	=	1.402
H_B (Adjustment for borrow)	=	0.006
Adjustment for shrinkage	=	0.010
New adjusted rod reading	=	1.418
Planned rod reading (Round up)	=	1.42

FIGURE 12. GRID SHEET SHOWING ROD READINGS, PLANNED ROD READINGS AND CENTROID FOR A YEAR DOWNFIELD SLOPE.

Adjusted average rod reading equals average rod reading plus (slope in meters per meter times the distance from the centroid to the nearest grid row)

<center>or</center>

Adjusted average elevation equals average elevation plus (slope per meter times the distance from the centroid to the nearest grid row)

The adjusted average rod reading or elevation should then be further adjusted for shrinkage, borrow, and extra fill, paragraphs M, N and O. The final adjusted average rod reading or elevation becomes the planned rod reading or planned elevation for all grid points in that row nearest the centroid.

For example, Figure 12 is to be designed with a downfield grade to the north. The following has been determined:

Location of centroid = 2 meters east of grid row 3 and
2 meters south of grid row D.

Distance to nearest grid row = 2 meters to grid row D.

NOTE: Grid row D is perpendicular to direction of irrigation.

Average rod reading   1.401 m (Table 3-1)
Grade   0.0005 m/m
Adjusted average rod reading = 1.401 + (0.0005m/m X 2m) = 1.402m
Borrow for ditch -

Ditch pad is to be 105 meters long, 1.8 meters wide and 0.3 meters high. The amount of borrow needed is 105X1.8mX0.3m = 56.7 cu.m. The adjustment for borrow (paragraph N) is as follows:

$$H_B = \frac{56.7}{24.94 \text{X} 400} = 0.0057m$$

Round up to 0.006m. The value H_B = 0.006m is then added to the adjusted average rod reading of 1.402m which gives a new adjusted rod reading of 1.408m (1.402+0.006 = 1.408). There is no extra fill material available.

Adjustment for shrinkage will be 0.01m for the first trial. The new adjusted rod reading becomes 1.418m (1.408+0.01 = 1.418), which should be rounded up to 1.42m. The 1.42m becomes the final adjusted rod reading, which becomes the planned rod reading.

For each upslope row of grid points, which are perpendicular to the direction of irrigation, the planned rod reading is decreased by 0.01 meter. For each downslope row of grid points the planned rod reading is increased by 0.01 meter. Figure 13 gives an example.

<center>FIGURE   13</center>

Direction of Irrigation	Increased by 0.01 meter			Decreased by 0.01 meter	
Grid Row No.	F	E	D	C	B
Planned Rod Reading	1.43	1.42	1.41	1.40	1.39

Row where final adjusted rod reading is used which becomes the planned rod reading.   (See Figure 12 for use)

Where elevations are used, the planned elevation is increased by 0.01 meter for each row of grid points upslope and decreased by 0.01 meter for each row of grid points downslope.

The planned rod readings or elevations are recorded above each rod reading or elevation. The amount of cut and fill are determined in the manner described in paragraph Q.

M. Adjustment of Average Rod Reading or Average Elevation for Shrinkage

Adjust the average rod reading or average elevation to allow for soil texture, construction equipment used, condition of the field (i.e. plowed or unplowed field and the depth of cut and fill.

Shrinkage of soil is expressed as the cut/fill ratio. For example, if one cubic meter of excavation of earth will make 0.80 cubic meter of fill, it may be stated:

$$\frac{Cut}{Fill} \text{ Ratio} = C/F = 1.0/0.80 = 1.25$$

Cut/fill ratios usually vary from 1.10 for heavy leveling on firm field surfaces to as high as 2.00 for leveling with very shallow cuts and fills. Generally the ratio will be between 1.15 and 1.75. On the average field a ratio of about 1.50 will balance yardage. Where the soil is unusually fluffy, a ratio of about 1.85 may be needed. A well compacted field or sandy field may require a ratio of about 1.25. Experience in a particular area will aid the technician in determining the proper cut/fill ratio.

With the modified-plane method of leveling, it is convenient to assume that the entire field surface will be lowered by a certain amount by compaction from the earth-moving equipment. This lowering can range from as little as 0.01m for very compact soils to as high as .03 for very loose soils. Thus, to allow for shrinkage the average rod reading or average elevation has to be adjusted.

Procedure:

1. To adjust for shrinkage, add the amount of adjustment to the average rod reading or subtract the amount from the average elevation.

2. If there is no adjustment for borrow or extra fill material,[2] the adjustment for shrinkage should be such that the adjusted average rod reading or elevation is made to an even 0.01 meter. The shrinkage adjustment should be at least 0.01 meter but probably less than 0.03 meter. For example, if the average rod reading happened to be 1.405 meters, do not use 1.40, but round to 1.41 meters; the allowance for shrinkage would be 0.005 meter.

3. It is suggested that for the first trial adjustment that a shrinkage value of about 0.01 meter be used. See the example page 2-21

N. Adjustment of Average Rod Reading or Average Elevation for Borrow

In many cases, it is desirable to provide for borrow from a field to construct farm roads and/or ditches. In order to do this, it is necessary to adjust the average rod reading or elevation. The adjustment for borrow may be calculated as follows:

$$H_B = \frac{cu.m \text{ of borrow}}{(N)(A)}$$

H_B = the adjustment necessary in meters.

N = Total number of adjusted grid areas (Col. 5, Table 1)

A = Area of standard grid area

The amount of adjustment is then added to the average rod reading or subtracted from the average elevation. Then proceed to make the adjustment for shrinkage, paragraph M above.

Procedure:

1. Determine the volume of borrow need to build the ditch and/or road. See example page 2-21.

2. Calculate for "H_B", the amount necessary for adjustment. See the example page 2-21.

3. Add the value "H_B", to the average rod reading or subtract from the average elevation to get the adjusted average rod reading or elevation. See example page 2.21.

4. Make the necessary adjustment for shrinkage as given in paragraph M.

5. Final adjustment should be made to the nearest 0.01 meter.

O. Adjustment of Average Rod Reading or Average Elevation for Extra Fill Material

In some cases, excess soil material (such as spoil material from a watercourse embankment, sand dume, high mound, or other sources where there is extra soil material) can be used as fill material in a leveling job. In order to allow for use of this extra material, it is necessary to adjust the average rod reading or elevation. The adjustment for extra fill material may be calculated as follows:

$$H_B = \frac{\text{cu.m of extra fill}}{(N)\ (A)}$$

H_F = the adjustment necessary in meters

N = Total number of adjusted grid areas (Col.5, Table 1)

A = Area of standard grid area.

The amount of adjustment is then subtracted from the average rod reading or added to the average elevation. Then proceed to make the adjustment for shrinkage.

Procedure:

1. Determine the value of extra fill available.

2. Calculate for "H_F", the amount necessary for adjustment.

3. Subtract the value "H_F" from the average rod reading or add to the average elevation.

4. Make the necessary adjustment for shrinkage as given in paragraph M.

5. Final adjustment should be made to the nearest 0.01 meter.

P. Use of the Adjusted Rod Reading or Adjusted Elevation
for Fields with no Downfield Slope (Flat)

Field for which no downfield slope or those fields that are to be flat, the adjusted rod reading or elevation is used for all grid points. See Figure 14.

Procedure:

1. Determine the average rod reading or elevation (See paragraph J)

2. Make necessary adjustment for shrinkage (Paragraph M), borrow (Paragraph N), and extra fill material Paragraph O), which then given the adjusted rod reading.

3. Final adjustment should be made to the nearest 0.01 meter.

4. The adjusted rod reading or elevation are then recorded above each rod reading or elevation at each grid point. See Figure 14.

5. Compute cut and fill as described in paragraph Q and proceed from there.

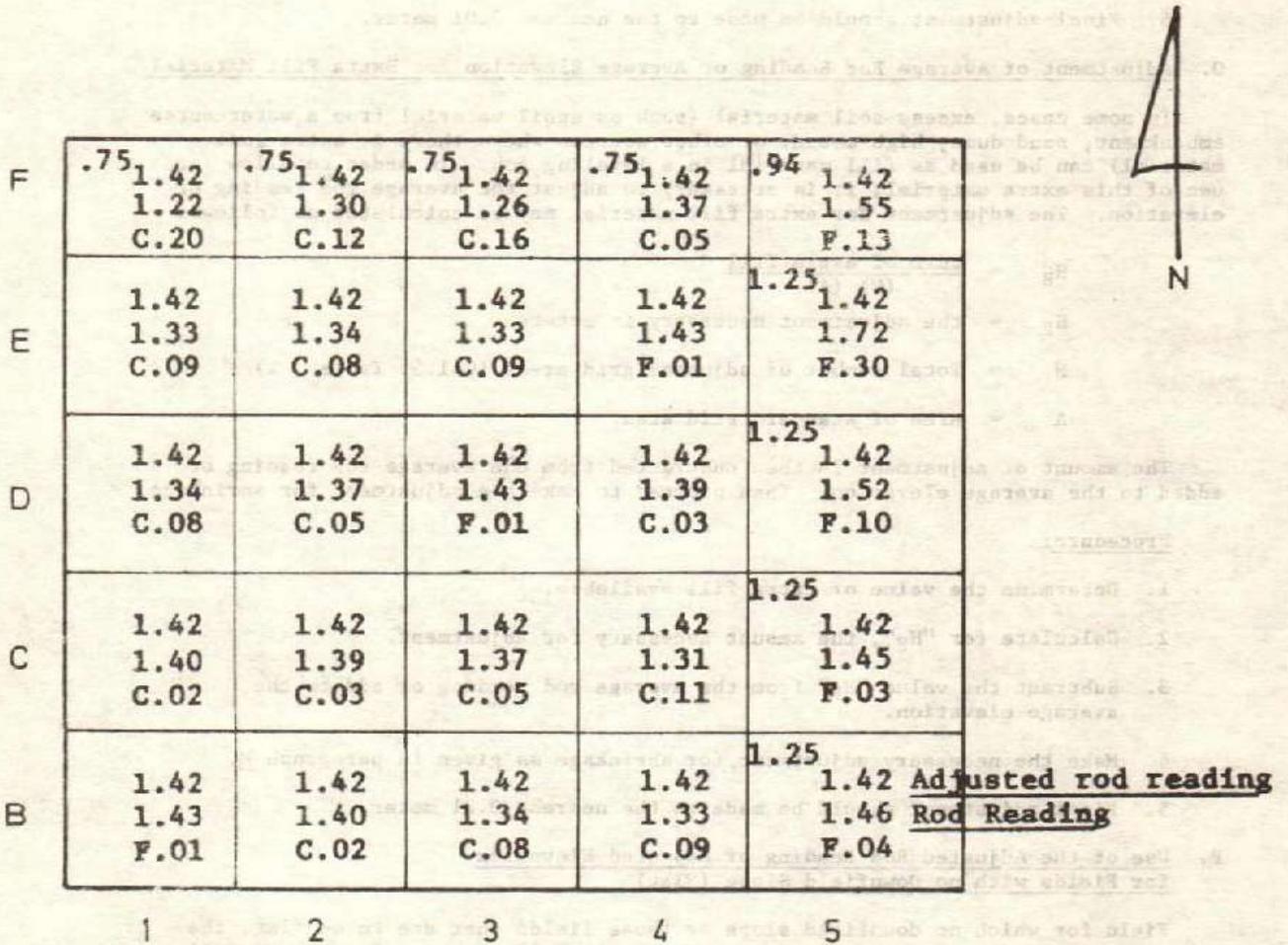|	1	2	3	4	5
F	.75 1.42 1.22 C.20	.75 1.42 1.30 C.12	.75 1.42 1.26 C.16	.75 1.42 1.37 C.05	.94 1.42 1.55 F.13
E	1.42 1.33 C.09	1.42 1.34 C.08	1.42 1.33 C.09	1.42 1.43 F.01	1.25 1.42 1.72 F.30
D	1.42 1.34 C.08	1.42 1.37 C.05	1.42 1.43 F.01	1.42 1.39 C.03	1.25 1.42 1.52 F.10
C	1.42 1.40 C.02	1.42 1.39 C.03	1.42 1.37 C.05	1.42 1.31 C.11	1.25 1.42 1.45 F.03
B	1.42 1.43 F.01	1.42 1.40 C.02	1.42 1.34 C.08	1.42 1.33 C.09	1.25 1.42 **Adjusted rod reading** 1.46 **Rod Reading** F.04

N

FIGURE 14 GRID SHEET SHOWING ROD READINGS, ADJUSTED AVERAGE
ROD READING, IDENTIFIED ODD AREAS, AND FILL AND
CUT DESIGNATIONS FOR A LEVEL FIELD.

Q. Determining the Amount of Soil to Cut and Fill

Procedure:

1. Record adjusted average rod reading (for field with no slope) or planned rod reading (for fields with downfield slope) above each rod reading on grid sheet. Record difference below the rod reading, as in Figure 3-14. If the adjusted average rod reading or planned rod reading is larger (a plus value) then the grid point rod reading, a cut will be required. Record the difference below grid point rod reading and identify with a "C" (for cut) in front of the difference (or use a red pencil to designate cut). If adjusted average rod reading or planned rod reading is smaller (a minus value) than the grid point rod reading, record difference below and identify with "F" (for fill) in front of it (or use a blue pencil to designate fill) as in Figure 14. Continue the procedure for the entire field area. If elevations are used the same procedure is used except the cuts will be smaller (a minus value) and fills will be larger (a plus value).

R. Determining the Volume of Earth Work

Prepare a worksheet similar to Table 2 to find the volume of cut and fill.

1. Volume of cut (Use top half of Table 2).

   a. List in Column #2 the proportionate sizes of the various grid areas that have cut.

   b. In column #1 record the number at grid point areas with that particular proportionate size that has cut.

   c. Total the amount of cut for each proportionate area and record in column #3.

   d. Multiply the figures in column #2 times the figures in column # 3 and record in column 4. This adjustment is necessary so all odd sized areas conform to the standard grid area.

   e. Total column #4. This gives the total cut for the area.

   f. Multiply the total in column #4 times 400 cubic meters per 1 meter of cut (column #5) to get the total volume of cut and record in column #6.

2. Volume of fill (Use bottom half of Table 2). The same procedure is used except the fill figures are used.

S. Earthwork Balance

In order to determine if a reasonable value for shrinkage has been used, it is necessary to determine the actual cut/fill ratio. This is done by taking the total cut and total fill, Column 6 Table 3-2, and computing the C/F ratio.

$$\text{C/F ratio} = \frac{\text{Sum Col. \#6, Cuts (487)}}{\text{Sum Col. \#6, Fill (295.88)}} = 1.65$$

This ratio should conform to the discussion on shrinkage, paragraph M. If a reasonable C/F ratio is determined it is said that the earthwork is balanced.

Where the Cut/Fill ratio is not within reasonable limits of what was planned then the entire calculations are repreated. The average rod reading or elevation or the adjusted rod reading or elevation is readjusted upward or downward. In the example in Figure 3-14, lowering the place 0.01 meter provided a C/F ratio of about 1.65. Lowering an additional 0.01 meter would raise the C/F ratio to about 2.28 and raising it a 0.01 meter would give a C/F ratio of about 1.28. Generally, after acquiring some practical experience in an area, the proper adjustment can be made and ratio obtained on the first trial.

Table 2   WORSHEET TO FIND VOLUME OF CUT AND FILL

To Find the Volume (Cu.Meters) of Cut

(1) No. of grid areas w/cuts No.	(2) Portion of standard grid area Portion	(3) Sum of cuts for each size grid area Meters	(4) Adjusted sum of cuts (2)x(3) Meters	(5) Vol. of cut soil per m of col. (4)	(6) Total vol. of cuts (4)x(5)
4	.75	.53	0.40		
0	.94	–	–		
13	1.00	.82	0.82		
0	1.25	–	–		
Total 17			1.22	400m³	488

To Find the Volume (Cu.Meters) of Fill

(1) No. of grid areas w/fills No.	(2) Portion of standard grid area Portion	(3) Sum of fills for each size fill areas Meters	(4) Adjusted sum of fills (2)x(3) Meters	(5) Vol. of fill soil per m. of col. (4)	(6) Total vol. of fills (4)x(5)
0	,75	–	–		
1	.94	.13	0.12		
3	1.00	.03	0.03		
4	1.25	.47	0.59		
Total 7			0.74	400m³	296

$$\text{C/F Ratio} = \frac{\text{Volume of cut}}{\text{Volume of fill}} = \frac{488}{296} = 1.65$$

In the case, where an adjustment was made for borrow (Paragraph N.) or for extra fill material (Paragraph O) a some what different procedure has to be used to determine the Cut/Fill ratio.

Where borrow has been used, the volume of such has to be subtracted from the CUT SUM in Column 6, Table 2, before the C/F ratio is calculated.

If there is extra fill material, then the volume of such has to be added to the CUT SUM in Column 6, Table 2, before the C/F ratio is calculated.

IV. CONSTRUCTION

A. Construction Map

    1. Prepare a map similar to the one shown in Figure 15.
    2. Show cuts and fills as determined in paragraph Q.
    3. The technician must in consultation with the scraper operator, go over the final construction map. He must help the operator to orient the map with the field and show him what system he should use to make the final job of soil moving the most efficient and consequently economical.

B. Marking the Grid Stakes for Tractor-Scraper Operator Guidance

    1. The grid stake points must be marked for easy guidance during construction. The primary purpose is to depict to the tractor-scraper operator the job he is to accomplish. Numerous methods have been devised and used. It is proposed in the beginning to use a system which is used in road construction and is called the "Blue Top" system. A wooden peg is driven into the ground and sighted in by use of the level, to the adjusted rod reading or elevation. Using the example in Figure 8, the instrument is set up and a back sight (BS) is taken on the bench mark (BM). This time it reads 1.05m, then the height of instrument (HI) would be 4.05m, and since the original adjusted rod reading was 1.42m and the HI was 4.00m, the rod would have to read 1.47m. The difference between HI's would be added to or subtracted from the new BS, (4.05-4.00 = .05; 1.42+.05 = 1.47) to determine reading of the rod at which all pegs should be set. When elevations are being used the instrument must be set up and a back sight (BS) taken on the bench mark (BM elevation 3.00). If it read 1.05m, then height of instrument (HI) would be 4.05m. The original adjusted rod reading 1.42m gave the Blue Tops an elevation of 2.58m. (4.00-1.42 = 2.58) To obtain rod reading at which all pegs should be set subtract planned elevation (2.58) from HI (4.05), (4.05-2.58 = 1.47).

    2. It will work best to have a rodman and an assistant. They will need something to pound with, either axe or hammer, and something to dig soil with. They will proceed from grid point to grid point and drive pegs to levels as directed by the instrument man. The instrument man can signal by motioning downward with his hand to indicate that the peg should be driven down and to indicate that peg should come up, the can motion his hand upward. It is desirable to set these pegs on the same side of the grid stake so that they can be found much easier when they become buried.

    3. The operator must be instructed and realize that these stations are not to be disturbed until construction and final checking is completed!

PRECISION LAND LEVELING OR GRADING DATA SHEET

-- ---------------------------- ----------------
           Name   Acres-Decares   Plan No.

-- ---------------------------- ----------------
        IRD Markaz   District   Village

SURVEY AND DESIGN

Party--- Date----------------------------

Designed by--- Date----------------------------

Approved by--- Date----------------------------

Scale of Plan, 1cm = ---------------------------------

Area to be leveled-----------------------------------

Hectares X 2.47--
                              Acres

Cubic Meters--

Cubic Meters Per Acre-------------------------------

Computations checked by------------------------- Date------------   Vicinity Map
                                                                        Show North Arrow

CHECK

Party--- Date----------------------------

Method used in Checking---

Acres leveled---Cubic Meters---------------

   This practice meets specifications:

                                              Signed------------------Date--------

Note: Show plan of leveling to scale on reverse side or on attached sheet, or
       on topographic map which may or may not be attached. Record graphically
       on plan: principal dimensions of area to be leveled, laterals, permanent
       borders, etc., design grade, cuts & fills at stations, necessary yardage
       computations, bench marks, north arrow, & drainage system, if applicable.
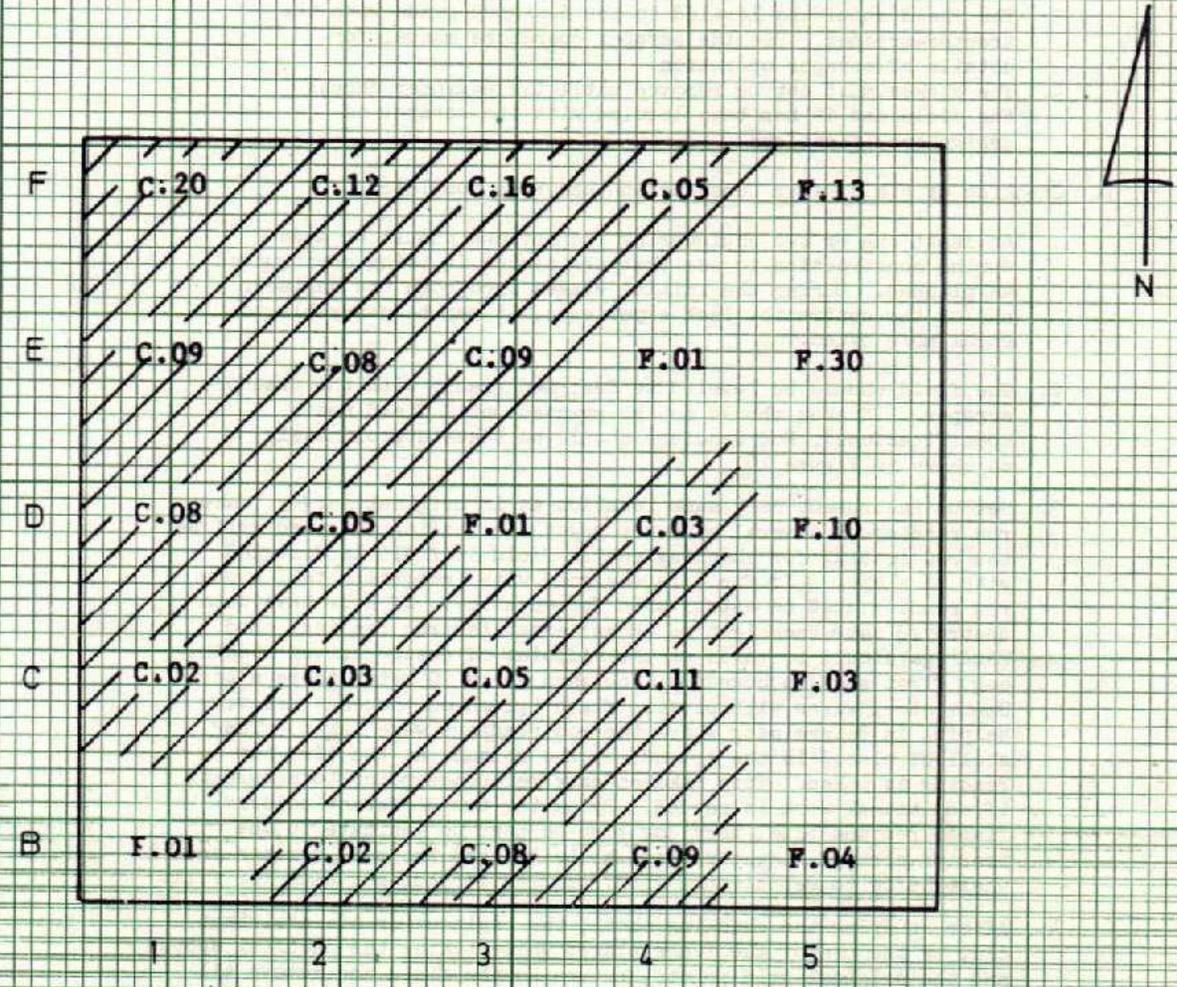
Figure 15.

	1	2	3	4	5
F	C.20	C.12	C.16	C.05	F.13
E	C.09	C.08	C.09	F.01	F.30
D	C.08	C.05	F.01	C.03	F.10
C	C.02	C.03	C.05	C.11	F.03
B	F.01	C.02	C.08	C.09	F.04

N

FIGURE   15.   CONSTRUCTION MAP SHOWING CUTS AND FILLS

C. Construction with the Tractor-Scraper

    1. All vegetation and crop residues should have been removed.
    2. If the soil is dry and hard it may be necessary to disk or chisel the cut areas.
    3. The field should be leveled to the designed grade with the tractor-scraper. See the scraper operators manual for details of scraper operation.
    4. The stakes must not be removed until the engineer checks the field and it has been leveled with the scraper to design specifications.

D. Checking of Field After Construction has Been Completed

    1. At least one or two engineering inspections should be made during construction to see that the system is being constructed as planned. During the initial stages when both the engineer and/or the contractor lack experience, it may be desirable to check more often.

    2. The field should be leveled to designed grades with the tractor-scraper. (Stakes should not be removed until field meets specifications). Rod readings should be taken approximately as shown in Figure 16.

    3. Set up instrument near same location as in original survey. Take rod reading on several blue top pegs; the reading obtained will be the rod reading for checking entire field if field is designed with 0% slope. If field is designed with irrigation fall a new rod reading must be established for each row. If hubs have been destroyed take backsight on BM and establish rod reading. Rod readings should be taken at the midpoint of desig- survey stakes, e.g. first shot on boundary line then every 20 meter there after. Small steel wires with plastic flags (glued on the end) are very helpful in determining where the rod readings were taken. They shall be placed in the ground, by the rodman, at the time the reading is taken. They make an easy reference point to return to if additional work is needed. By having two different colored flags, red and blue, they can also be used to indicate to the tractor-scraper operator where he is to load the soil scraper and where he is to deposit his load. Use red for cut and blue for fill.

    4. After studying the checking shots, the engineer or his assistant can, by the use of the flags placed while taking the checking spots and the original grid points, return to the field and remove all flags at locations that are at the correct elevation and place red flags where cuts are to be made and blue flags where fills are to be made. The number of colored flags may further be coded to indicate to the operator how many loads he is to take from a particular location or how long he is to work around the coded location. As technician and operators get practical experience and become familiar with the system, many helpful methods will evolve.

E. Preparing the Field for Planing

    1. After the field is leveled to designed specifications with the tractor-scraper, remove the stakes prior to using the leveler.

    2. After the stakes are removed it may be necessary to use the tractor-scraper to remove any high areas left around the cut stakes.

    3. Chisel or disk the entire field to a depth of 10 or 15cm to provide a loose surface for the scraper-float to smooth. This is necessary because the scraper-float blade will not cut into hard soil.

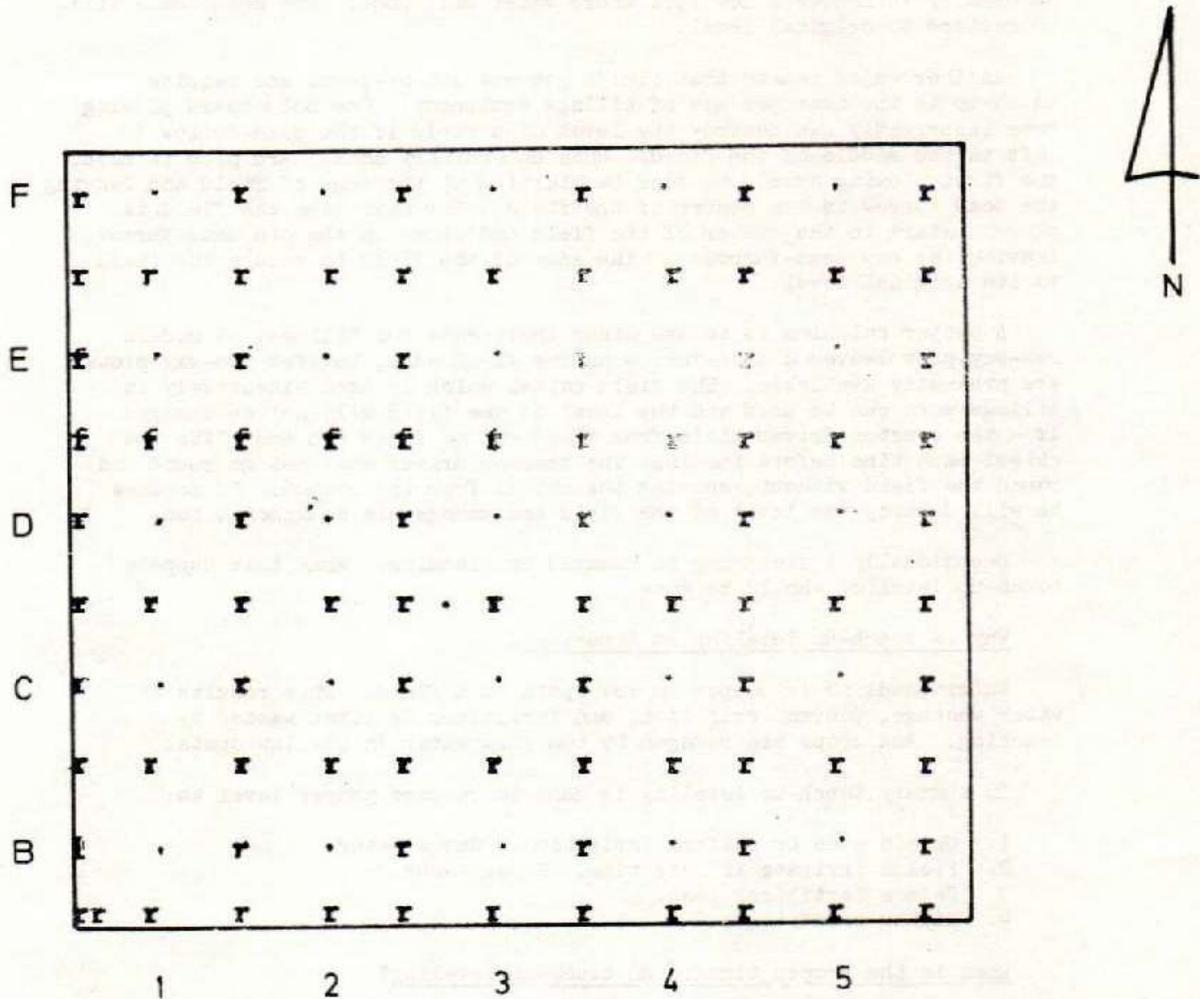   4. Refer to the scraper-float manual for operating procedures.

FIGURE 16. CHECKING CONSTRUCTION JOB USING GRAPH PAPER

Original grid stakes take rod reading at a location representative of finished level near grid point.

r Rod reading at one-half interval.

V. **PLL MAINTENANCE (TOUCH-UP LEVELING)**

   What causes tough-up leveling to become necessary? If the field was leveld correctly, whey doesn't it stay level?

   Heavy fills often settle more than anticipated and when a fill settles abnormally it leaves a low spot where water will pond. The solution - fill to restore to original level.

   Another major reason that fields get out out-of-level and require touch-up is the improper use of tillage equipment. One mold-board plowing done incorrectly can destroy the level of a field if the dead-fullow is left in the middle of the field. When an ordinary mold-board plow is used, the first plowing should be done by starting at the edge of field and leaving the dead furrow in the center of the field. The next time the field is plowed, start in the center of the field and close in the old dead-furrow, leaving the new dead-furrows at the edge of the field to return the field to its original level.

   A better solution is to use other implements for tillage. A modern two-way plow leaves a dead-furrow on the field edge, but few two-way plows are presently available. The field chisel which is used extensively in tillage work can be used and the level of the field will not be damaged if - the tractor driver tills from field end to field end and lifts the chisel each time before turning. The tractor driver must not go round and round the field without removing the chisel from the ground. If he does he will destroy the level of the field and damage his equipment, too.

   Occasionally a field may be damaged by flooding. When this happens touch-up leveling should be done.

   Why is touch-up leveling so important?

   Water ponds or is deeper in low spots in a field. This results in water wastage, uneven irrigation, and fertilizer is often wasted by leaching. And crops are damaged by too much water in the low spots.

   In summary touch-up leveling is done to restore proper level to:

   1. Obtain even or uniform irrigation. Saves water.
   2. Fields irrigate in less time. Saves labor.
   3. Reduce fertilizer loss.
   4. Higher crop yields.

   When is the proper time to do touch-up leveling?

   The need for touch-up leveling can be noted after a heavy rain or several irrigations have thoroughly settled the fills. After the first crop has been grown the farmer should have all high and low spots identified and can touch-up as needed before planting the next crop. Fields should be in perfect condition before perennial crops are planted.

   How can touch-up leveling be done?

   Several different conditions may exist requiring touch-up leveling:

   1. Fields with minor variations in elevation or grade (+2 to 5cm.)

      a. After a rain mark high spots.
      b. When dry enough, disc or chisel high spots to loosen soil.
      c. Then use landplane or leveler in several directions. The farmer may choose to use his bullock drawn Kerah. It will also do the job if used properly.

2. Fields with moderate variations in elevation or grade
(±5 - 8cm.).

    a. After a rain mark high and low spots with stakes or
lime.

    b. When dry enough, loosen soil on high spots with disc
or chisel and pull soil from high to low spots. This
may be done by removing the tail piece from the land-
plane or as previously mentioned the farmer can do the
work with bullocks and Kerah.

    c. Float or landplane in several directions.

3. Fields with considerable variation in grade (more than ±8cm.)

    a. Get field restaked on regular land leveling intervals.
    b. Make cuts and fills with scraper.
    c. Finish by loosening the soil with disc or chisel
before floating or landplaning.

To Keep It Level

1. Use two-way plows, chisels, roto-tillers, and other tools
that do not leave dead furrows.
2. Use a landplane or leveler between crops.
3. Maintain surface drainage systems.
4. On bench-leveled fields maintain berms, borders and
irrigation structures to prevent water overtopping of
borders along escarpments.

VI. GLOSSARY TERMS AND DEFINITIONS USED IN PRECISION LAND LEVELING

1. ### Arc Intersection Method

Method of finding a perpendicular point to a base line while using
only a tape.

2. ### Backsight (BS)

Rod reading at the point of known elevation and is always added to
the elevation of the point to get the height of instrument.

3. ### Bench Mark (BM)

A BM is a permanent established mark, the elevation of which is known,
to use as a reference point in obtaining the elevations of subsequent
stations. This elevation may be assumed.

4. ### "Blue Top" Stakes or Hub Stakes

These are stakes where the tops are set to a planned rod reading or
elevation.

5. ### Centroid

A point of intersection in the exact center of the field. A plane
passing through the average elevation of this point will give equal
amount of cut and fill. For a field with no slope it is not necessary
to locate the centroid.

6. **Cuts, Adjusted Sum of**

   This is the sum, in meters, of the computed cuts of the grid areas requiring cut with appropriate proportioning adjustment for each grid area.

7. **Elevation**

   A measurement of the vertical distance to a point above or below a fixed datum which may be assumed, or be related arbitrarily to the mean sea level (MSL).

8. **Field Book**

   The notebook used by instrument man for writing down the reading and other records during the surveying.

9. **Field Worker**

   As used in this handbook, it is any individual trained in the techniques of precision land leveling and related subjects.

10. **Fills, Adjusted Sum of**

    This is the sum, in meters, of the computed <u>fills</u> of the grid areas of <u>fill</u> with proportionate adjustment for each such grid area.

11. **Float**

    The smoothing of minor irregularities of the land's surface by the use of log or rail drags, suitable agricultural equipment, or small land planes, to firm the soil to make it easier to obtain a dependable level and rod survey of the land's surface.

12. **Foresight** (FS)

    Rod reading at the point of unknown elevation, and is always subtracted from the height of the instrument (HI).

13. **Grid Point**

    A point on the field area marked by a stake or by other means. Generally grid points will be located on 20m X 20m intervals unless otherwise indicated.

14. **Height of Instrument** (HI)

    Height of the horizontal line passing through the telescope above the datum. It is determined by adding the backsight (BS) to a point of known elevation.

15. **High Point**

    The point of highest elevation in the field where water must be delivered.

16. **Instrument**

    See level.

17. **Instrument Man**

    Person who makes readings at the rod with level and keeps notes in field notebook.

18. **Irrigation Grade**

   The percent grade, or meters fall per 100 meters in the direction
   the irrigation water must travel in furrows or within the confines
   of borders.

19. **Level**

   A level is an instrument used in surveying to obtain difference in
   elevation.

20. **Land Forming, Land Grading or Land Leveling**

   Reshaping the surface of the land to be irrigated in which cutting
   and filling an area or field is planned and done to achieve a desired
   grade to improve management and control of irrigation water or
   precipitation.

21. **Land Plane or Leveler**

   An implement with three points of soil contact connected by a rigid
   frame which automatically removes high points and fills low spots.
   The center blade is generally adjustable for varying field conditions.
   By its use, undulating irregularities in the soil surface are removed
   to facilitate uniform water application and germination. Land smoothing
   is generally accomplished with a land plane. Proper operation of this
   machine is critical since it is not designed to move large quantities
   of soil.

22. **Land Smoothing or Floating**

   The planing of the ground surface by mechanical means to eliminate or
   reduce minor depressions and high spots in the field's surface. Usually
   accomplished by land plane.

23. **Marking**

   The marking or coding of "stakes" to show the amount of cut or fill at
   a grid point. Various materials can be utilized for "stakes". What-
   ever is used it should indicate to the operator the cut or fill necessary
   at that point.

24. **Operator**

   The driver of the tractor or farm machine which is used to move the soil
   for a land forming project. Soil scrapers are the commonest and most
   practical implement used for this purpose; however, donkeys, head
   baskets, dozers, utility blade and various other implements can be used.

25. **Permanent Structure**

   Any permanent established structure at the farm to be used as bench-
   mark, such as a bridge over a farm ditch, concrete footing of an
   electric pole, etc. When used as a benchmark be sure and properly
   identify.

26. **Planned Rod Reading**

   This is the rod reading at which the plane of the field is set in
   order to compute the cut and fill and to set the blue top stakes.

27. **Plot**

   A field or unit area of land used for crop growth.

28. **Rod or Stadiaboard**

Rod is used with level to obtain the height of line of sight above the point on which rod is held and is marked in 0.01 meter intervals.

29. **Rodman**

Person who carries the rod in the field.

30. **Rod Readings, Adjusted Sum of**

This is the sum of the natural surface rod readings of grid point areas each of which represents 400 square meters or a proportionate part of such an area.

31. **Rod Reading, Average**

This is the sum of the adjusted rod readings divided by the sum of the adjusted grid areas.

32. **Scraper**

An earth cutting and moving implement usually pulled by a power unit and will move soil by carrying or pushing. Tractor powered scrapers for agricultural purposes usually move from 1 to 20 cubic yeards per trip.

33. **Soil**

The soil may be defined as a natural body, engendered from a variable mixture of broken and weathered minerals and decaying organic matter, which covers the earth in a thin layer and which may supply, when containing the proper amount of air and water, mechanical support and in part sustenance for plants.

34. **Soil Shrinkage**

The reduction of a volume of soil due to compaction by soil moving equipment and is expressed as a cut to fill ratio.

35. **Stake**

A device for temporarily designating visibly and physically a point on the earth surface for layout and reference of planned work. The stakes may be of several types of material such as sharpened tree limbs, bamboo shaped and sharpened, laths, scrap wood from packing cases and demolished structures, wire, metal, etc. The lengths, diameters and other dimensions may vary to meet job requirements. Consideration should be given to materials that are cheap, readily available, not susceptible to pilferage, and are suitable for making or coding for the guidance of personnel responsible for the performance of the planned work.

36. **Station**

A point or position on a measured line which represents a measured distance; in meters e.g., station 23+15, station 40+00 and etc. from the beginning station 0+00.

37. **Surveyor**

See instrument man.

38. **Temporary Bench Mark** (TBM)

Point conveniently established usually a stake securely driven into the ground or a culvert that will not be molested.

39. **Three-Four-Five Method**

Procedure for finding a perpendicular point to a base line while using only a tape.

40. **Turning Point** (TP)

A point where an elevation is established in order to change location of level.