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Use the Farm Level for Better Irrigation and Soil Conservation

By

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"ON THE LEVEL"

The "farm level" is used on the farm for running level and grade lines or in comparing elevations of different points. The instrument is essentially a precision spirit level equipped with leveling adjustments and telescope with an eyepiece and a set of cross-hairs to control the line of sight. It is constructed to be mounted on a portable tripod. When the instrument is in adjustment and the leveling bubble is centered in the vial, the line of sight is exactly level.

The farm level is simple but adequate for such farm needs as laying out contour lines and terrace lines for soil conservation work. lines for farm drainage work, profile lines for land leveling, and ditches for irrigation.

In this bulletin you will find information and instructions for doing your own farm leveling work.

Use the Farm Level for Better Irrigation and Soil Conservation

Owen K. Brown* **and Max C. Jensen†**

The farm level is simple and yet adequate for your farm needs. Its use in laying out contour lines for soil conservation work, lines for farm drainage, profile lines for land leveling, and ditches for irrigation will save time and expense over the trial and error methods. A farm level will help you make a topographic map which is an invaluable aid in doing your land development work.

This bulletin gives you information and instructions for doing your own farm level instrument work.

General Instrument Instructions

There are several types of farm levels in use. Some of these types are shown in Figure 1. The general operation of these instruments is essentially the same. Some are more complicated than others and require more careful handling. Unless you are proficient at setting up and operating a level instrument, avoid purchasing the precision type. The utility type shown in Figure 2, and the turret type shown in Figure 3, are the most common types and will be used in the following instrument handling instructions. The gunscope instrument shown in Figure 4 is a recent development and is designed to eliminate complicated adjustments.

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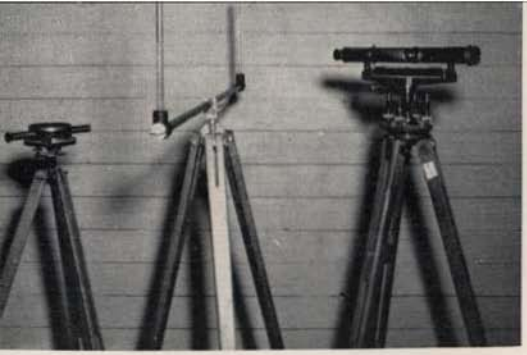


Figure 1. Three common types of levels.

Figure 2. Utility type level showing parts.

Setting Up and Leveling the Instrument

Set up the tripod with its legs sufficiently spread to insure steadiness. Keep the leveling head as near level as possible. Screw the instrument on the tripod head and tighten it securely but barely snug. **Be careful.** Too much stress on these screw-threads can cause trouble and damage the instrument.

Turn the telescope over two of the tripod legs and spike these legs firmly into the ground so that the vial bubble is fully visible; then rotate the telescope over the third leg of the tripod and force the spike into the ground, shifting it again enough to keep the bubble fully visible in the vial. This method of keeping the bubble roughly centered in setting up the tripod makes brief the final adjustment with the leveling screws and avoids distorting of the spring and pivot screw.

Tighten the wing nuts on the tripod snug enough to prevent further spreading of the legs.

Set the telescope over two of the level screws and center the bubble by turning the two screws equal turns in opposite directions as shown in Figure 5.

Next set the telescope over the other two screws and re-center the bubble by turning these two screws.

Repeat this centering process until the bubble remains centered with the scope turned in either of the two directions.

Move the telescope in line with the target or object to be observed by a slight sidewise pressure with the tips of the forefingers or by use of the tangent screw if your instrument is equipped with one.

Focus the telescope by moving the eye piece in or out until objects beyond 50 feet are clearly visible.

Do not touch any part of the instrument while sighting.

Always check the position of the bubble before and after each sight to be sure it is still in adjustment.

To Test the Bubble Vial

After the instrument is leveled as outlined above, turn the turret so that the bubble vial tube is directly over two of the leveling screws and check to make sure the bubble is centered. Then

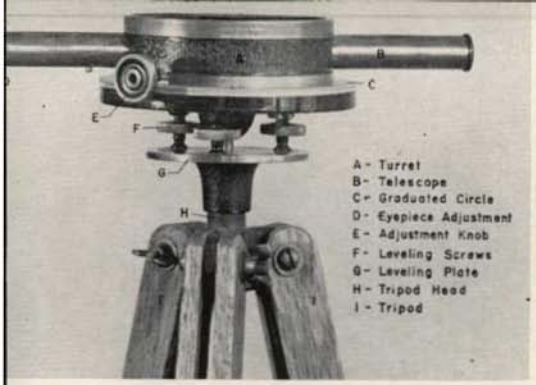


Figure 3. Turret type level showing parts.

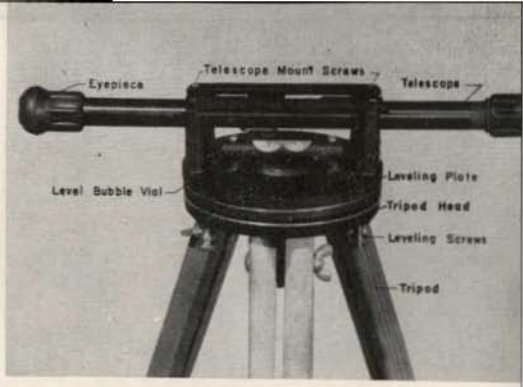


Figure 4. Gunscope type level showing parts.

turn the telescope in the opposite direction (180°). If the bubble still remains in the center, the vial is in good adjustment. If, however, the bubble shifts, then adjustment is necessary.

To Adjust the Bubble Vial

Figure 6 shows the turret removed from the plate of a turret type instrument. The bubble vial adjustment screws are indicated. Adjustment of this bubble vial is made by raising or lowering one end of the vial by turning either set of screws. If one of the top screws is loosened then the bottom screw on the same end of the vial must be tightened or vice versa.

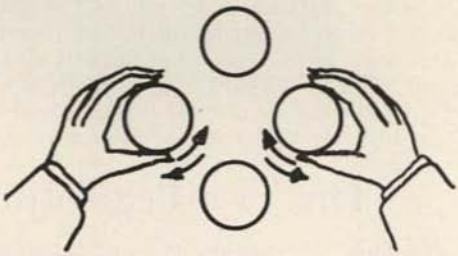
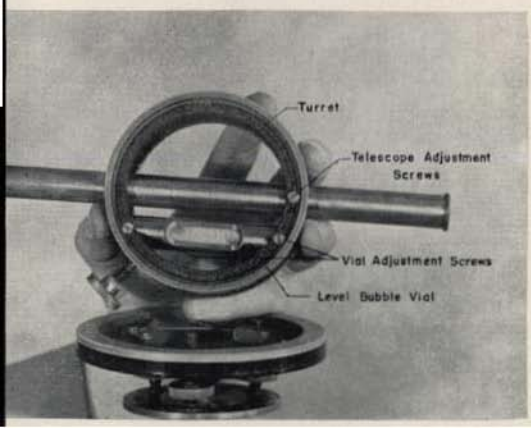


Figure 5. Movement of fingers while turning the leveling adjustment screws.

The bubble will move toward the raised end of the vial. Replace the turret and relevel the instrument. Check the bubble again. Repeat the procedure until the bubble remains centered at any position of the telescope.



The bubble vial adjustment screws for the utility type instrument are shown in Figure 2. The procedure for adjustment is the same as above except that a special tool is used instead of a screwdriver.

Figure 6. Turret removed showing the bubble vial adjustment screws.

Testing and Adjusting the Telescope

The telescope may be tested for accurate adjustment by several methods. We recommend the two simple and effective methods (1) inverting the telescope or (2) the direct or peg adjustment. In all cases the line of sight must be parallel with the axis of the bubble. Let's look at these methods.

Inverting the Telescope Method

This method is only applicable to those instruments that have telescopes that can be inverted, such as the turret type.

Set up the instrument on firm footing and level it properly. Measure off 100 feet from the instrument and drive a stake. With the level rod on this stake and the telescope in normal position, take a reading on the center horizontal cross-hair. Then invert the telescope and sight on the rod. Do not disturb the tripod. If your reading remains the same, then the telescope is in good adjustment. If the reading changes, then the difference in the readings is equal to twice the error of the instrument. Make the necessary adjustment by turning the small screws at the front mount where the telescope goes through the turret as shown in Figure 6. Repeat the process until the rod readings remain the same when taken with the telescope in normal and inverted position.

Some instruments such as the gunscope type shown in Figure 4 do not have telescope adjustment screws. In these cases the manufacturer has built his instrument so as to eliminate telescope adjustment. If the telescope of this type of instrument proves to be out of adjustment, it should be returned to the manufacturer for repair. Possibly the telescope or framework is bent.

The Two-Peg Adjustment Method

Select two points A and B a known distance apart (100′ to 200′). Set up the level close to A so that when a rod is held upon it the eyepiece will be only about an inch from the rod as shown in Figure 7. Look through the telescope WRONG END TO at the rod and find the reading opposite the center of the field. Because only a small portion of the rod is visible, you will find it convenient to move a pencil point along the rod to help you get the reading. Turn the telescope toward B and take a rod-reading on it in the normal way. In each case **be certain that you have centered the bubble.**

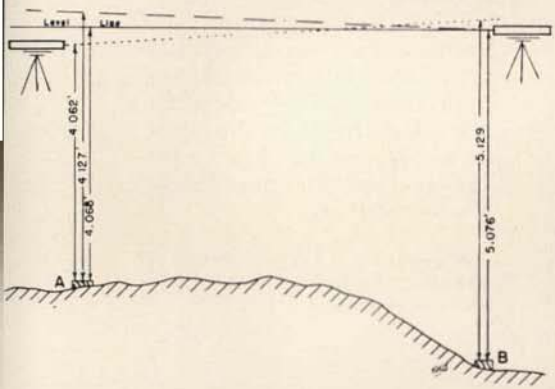


Figure 7. Two-peg adjustment.

The difference between these two rod-readings is the difference in elevation of the two points PLUS or MINUS the error of adjustment.

Next set up the instrument at B and repeat the above procedure. The result here is the difference in elevation PLUS or MINUS the same error of adjustment.

The average of these two results is the true difference in elevation of points A and B. Knowing the difference in elevation between the two points and also the height of the instrument above B, you can compute the rod reading at A to bring the target on the same level as the instrument. Here are some example calculations:

INSTRUMENT AT A—Rod-reading on A, 4.062; rod-reading on B, 5.129. Difference in elevation of A and B, 1.067. INSTRUMENT AT B—Rod-reading on B, 5.076; rod-reading on A, 4.127. Difference in elevation of B and A is .949. Average difference in elevation (1.067+.949)÷2=1.008 (true difference in elevation). Instrument is now 5.076 above B. Rod-reading at A should be 5.076—1.008=4.068 to give level sight.

To make the line of sight parallel to the axis of the bubble in the above example lower the front end of the telescope by loosening the lower adjustment screw and tightening the top screw shown in Figure 7.

Level Line Method

This method is used instead of the two-peg method where conditions are suitable. It will save checking time once the method is established and also eliminates figuring.

Set up the instrument exactly centered between two points such as two long stakes driven in the ground or between two buildings. Select points approximately 200 feet apart. Care must be taken to be sure that the instrument is exactly centered between the two points as shown in Figure 8. After the bubble is exactly centered in the tube, locate a point on each building. A line AB connecting these two points is a level line no matter how much the instrument is out of adjustment.

Take the instrument to A and set it up aligning the cross-hair with the point A. Now sight through the telescope at point B. If the cross-hair is on point then the instrument is in adjustment. If, however, the cross-hair rests at B then the telescope is in error by the amount BB' as shown in Figure 8(b).

To adjust the instrument, lower the end of the telescope until the line of sight falls on point B.

We recommend that the two-peg method be used to adjust farm levels because more accurate results are obtained. However, the level line method will give equally good results if care is taken to establish points A and B accurately.

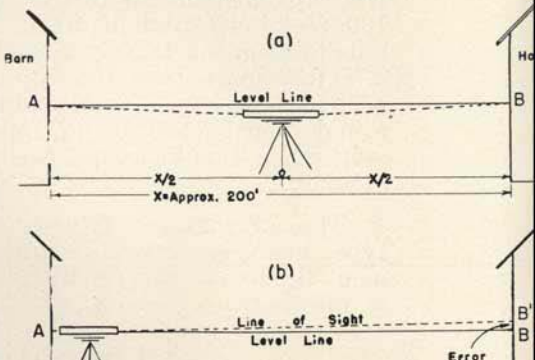


Figure 8. Level line method
(a) First step. (b) Second step.

Testing the Cross Hair

While the level is still set up make the cross-hair test. Focus the center of the horizontal hair on a definite point, then move the telescope slowly back and forth from side to side. If the ends of the cross-hair remain on the point, it is in adjustment.

If the ends of the cross-hair move off the point, the cross-hair needs to be adjusted. Usually it is best to send the instrument to the factory or have it done by someone experienced in the repair and adjustment of surveying equipment.

Leveling Rods

The two types of rods you will be most likely to use are the target rod shown on the left in Figure 9 and the level rod shown on the right. The simple farm target rod shown on the left is marked off in feet and inches and is read by the rodman after the instrument man has directed the setting of the target on the line of sight.

Figure 9.

The level rod shown on the right in Figure 9 is designed to be used either with the target or read directly from the instrument. It can also be used with instruments that have stadia cross-hairs to read the horizontal distances from the instrument to the rod. The rod is marked off in feet, tenths and hundredths of a foot. The amount of rod seen between the two instruments' stadia-hairs is a measure of the horizontal distance from the instrument to the rod. Each foot on the rod represents 100 feet horizontal distance. For example: if the bottom stadia-hair falls on the 1.25 foot mark and the top stadia-hair falls on the 2.75 foot mark then the difference between these two readings is 1.50 feet. The horizontal distance from the instrument to the rod would then be 100x1.5 or 150 feet. The above example is correct only when the instrument is level when the reading on the rod is taken.

The advantages of using the stadia rod instead of the other types are speed, more accuracy, and elimination of the two chainmen. Of course the accuracy depends on the skill and experience of the instrument man.

Operation of Level

In order to run a level properly it is necessary to have a crew consisting of one instrument man, one rodman, and two chainmen. Often the instrument man and rodman do their own chainwork, thus eliminating the chainmen. Unless absolute accuracy is necessary, the rodman often can step off the distances or use some other method of estimating.

Instructions for the Instrument Man

The duties of the instrument man are setting up, checking, and operating the instrument properly. Instructions for setting up and leveling the instrument are given on page 2. Check and adjust each time before you use the instrument to insure accuracy. Check in order the tube, telescope, and cross-hairs. For details see instructions on your type of level.

Handle your instrument with care and caution and it will last longer and give you less adjustment trouble.

Focus the telescope by moving the front lens of the eyepiece in or out. Due to the differences in individual eyes, proper focus for one person may not be correct for another.

The proper length of sight will depend upon the distance at which the rod appears distinct and steady to the instrument man, upon the variations in readings taken on the same point, and upon the degree of precision required. Under ordinary conditions the length of sight should not exceed 300 feet where elevations to the nearest .01 ft. are desired. "Boiling" of the air or "heat waves" are frequently so troublesome that long sights cannot be taken accurately.

Instructions for the Rod Man

The level rod with its target is used to measure elevations or comparative heights of objects in their relation to the height of the instrument. For example, with a rod reading of 4 ft. at one point and 6 ft. at another point, the elevation difference of these points is 2 feet.

It is extremely important that you hold the rod plumb. Vertical lines on buildings are a great aid to the rodman in plumbing the rod. On a still day balancing the rod on the point helps in plumbing. Be careful to see that the rod does not lean toward or away from the instrument man. If the rodman promptly and attentively holds the rod plumb it increases accuracy and efficiency.

Instructions for Chain Men

Chaining or tape-measuring is necessary when accurate distances are required and cannot be read with the instrument. Strive for accuracy—check and re-check readings.

Here are some common sources of errors in measurement of lines. Failure to pull the tape taut, careless plumbing or failure to keep the tape horizontal, incorrect alignment, wind effect, variation in temperature, and erroneous length of tape all cause error and trouble. In addition to those errors, we are likely to make some common mistakes in reading and recording measurements of distances. Failure to observe the position of the zero point of the tape, omitting a whole tapelength, reading the tape wrong, as 40 ft. for 60 ft., or transposing figures in notes such as 46.24 for 46.42 are common reading errors. For most farm jobs measurements to the nearest 0.1 foot are sufficient.

You can avoid mistakes in counting the tape lengths by having a helper keep tally. You can avoid mistakes in foot mark readings by noting not only the foot-mark preceding but also the one following.

Differential Leveling Illustrated

To obtain the difference in elevation between two points, hold the rod vertical at the first point and, while the instrument is level, take a rod-reading. This is the distance from the bottom of the rod up to the line of sight of the level. Then take a rod-reading on the second point, and the difference between the two rod-readings is the difference in elevation of the two points.

When the two points are far apart or have considerable difference in elevation, then a series of back-sights and fore-sights must be taken while moving the instrument along the line between the points. The process is continued as shown in Figure 11 until a foresight is taken on the last point. The elevation of the last point (B) above the first (A) is equal to the sum of all the back-sights minus the sum of all the foresights. If the result is positive (+) then the point B is above point A. If the result is negative (—) then B is below A.

One form of notes which you may use for this work is shown in Table I. The field work is shown below in Figure 10.

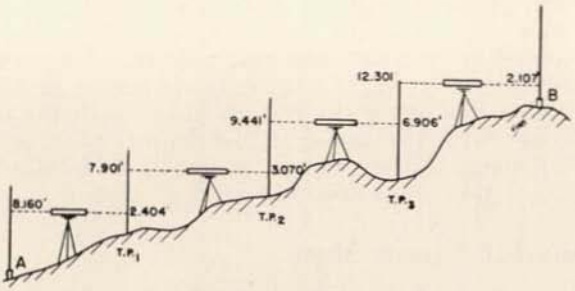


Figure 10. Diagram illustrating differential leveling.

Point	B.S. (+)	F.S. (—)	REMARKS
A	8.160	.....	Bench mark, S.W. corner X and Y Stas.
T.P.$_1$	7.901	2.404	
T.P.$_2$	9.441	3.070	
T.P.$_3$	12.301	6.906	
B	.....	2.107	New Point
Total.....	37.803	14.487	
Difference ..	37.803 — 14.487 = 23.316 (B above A)		

Table I. Field notes of work shown in Figure 10.

Running a Grade Line

Farmers often want to run a uniform gradient line for a farm ditch or for making contours. Depending on the specific conditions of the soil and topography, the most desirable grade for farm ditches is in the range of .05′ to .5′ drop per 100 feet. By use of the farm level it is relatively easy to establish a grade line within the above limits so that it may be followed by a plow or ditcher to construct a ditch. Such a line is usually staked every 50′.

Example Problem: Stake a uniform grade line for a farm ditch with a gradient of .5′ drop per 100′.

Procedure

Locate the instrument within the range limits of the telescope and rod and near the ditch to be staked. Set up the instrument for operation following the setting-up procedure given on page 2. Place the rod on the beginning point of the ditch and focus the scope on the rod. Direct the rodman to raise or lower the target until it is level with the line of sight. In Figure 11 this reading is 2.62′. The rodman then proceeds to the next 50-foot interval or station 0+50 and raises the target to grade (add .25′ to the rod

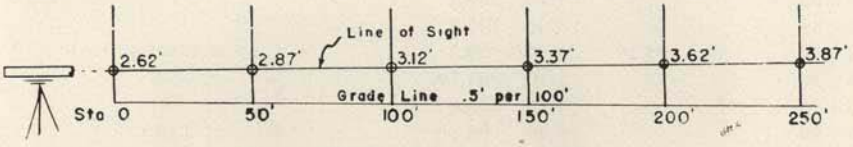


Figure 11. Running a grade line.

reading for a grade of .5′/100′). Thus the target setting for station 0+50 becomes 2.62+.25=2.87′. The rodman moves the rod up or down the hill, as directed by the instrument man, until the target falls on the line of sight. The rodman then drives a stake at the point where the instrument man signals that the target is on the line of sight. Repeat the procedure as far as the ditch is to be run at this particular grade. To change the grade merely change the amount the target is raised at successive stations.

The rodman should be alert, hold the rod vertical, watch the instrument man for signals and locate the rod on average ground for all shots. The accuracy of the grade line depends largely on the accuracy and judgment of the rodman.

Running a Profile Line and Plotting the Profile Curve

Profile leveling is for the purpose of determining the changes in elevation of the surface of the ground along some definite line. The line is first "stationed" or marked at 50- or 100-foot intervals. Set up the instrument and take a backsight on a bench mark or reference point to determine the height of the instrument. Foresights are then read on as many station points on the line as can

be conveniently taken from the position of the instrument. Make foresights on in-between points where sudden changes of ground slope occur. **Remember the meanings of the backsight and foresight**—don't get them mixed. Backsight is the rod reading taken on a station of known elevation, foresight is the rod reading taken on a station of **unknown** elevation.

When it is necessary to move the level to a new position, select a turning point and determine its elevation. Then move the level and determine its new height (H.I.) by taking a backsight on the turning point. Continue the general procedure to the end of the line. Connecting the line of levels with a new bench mark at the end makes a good check for accuracy.

PROFILE OF PARK ROAD—NOVEMBER 15, 1949

Brown—Martin

Sta.	B.S.	H.I.	F.S.	Elev.	B.M. and T.P. Elev.	REMARKS
B.M.s	7.80	107.80	.....	.....	100	Elev. Assumed 100 ft. on pipe
0+00	.....	.....	8.20	99.6		located on wall at N.W. corner
1+30	.....	.....	5.40	102.4		
2+00	.....	.....	1.70	106.1		
2+80	.....	.....	3.90	103.9		
3+40	3.90	103.20	8.50	99.3		On top of marked rock
3+90	.....	.....	8.10	95.10		
5+20	.....	.....	1.20	102.00		
5+80	.....	.....	6.90	96.30		Water level in drain

Table II. Notes on Profile Line Survey.

Table II shows the field notes of a profile line survey. It is a good idea to master this method of making notes. It is the recommended form and will help you eliminate errors in your work.

The field notes tabulated in Table II are plotted in Figure 12. Figure 12(a) shows how the field work was done to obtain the information for Table II. Figure 12 (b) shows the profile curve plotted using the station elevations from Table II. This curve shows how the desired grade line is located in order to balance the amount of cut and fill. If you find you have more cut than fill after placing your grade line, then slide the grade line up until the amounts of cut and fill are approximately equal. Figure 12(c) shows how the grade line is plotted. Figure 12(d) shows how the amount of cut or fill as determined in Figure 12(b) is marked on the field stakes.

For land leveling, a profile in one direction isn't enough. A complete topographic map is necessary in order to make the cuts and fills in the right places. With the foregoing profile line as a start, it is easy to proceed and complete a topographic map. Merely run a series of profile lines parallel to line No. 1 at about every 50 or 100 foot mark depending on the unevenness of the ground. For the more rolling type of land, more profile lines are necessary.

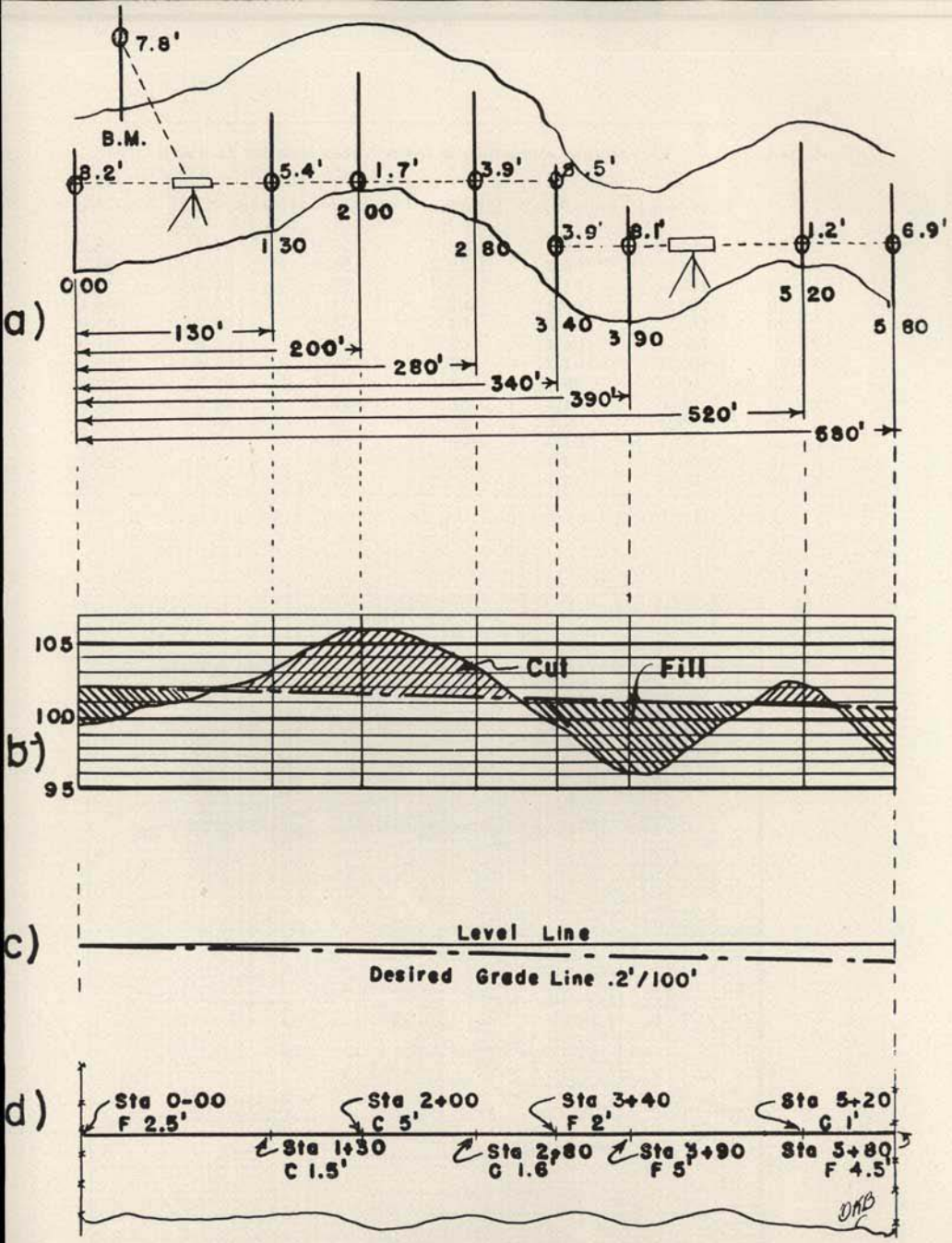


Figure 12. Plotting the notes from Table II.

(a) Field work on profile line survey.
(b) Profile curve showing grade line drawn in at the approximate future land line.
(c) Plotted desired grade line for use in (b) above.
(d) Marked field stakes using data in (a) and (b).

Stations	Elevations (Determined from Notes Similar to Table II)					
	Line No. 1	Line No. 2	Line No. 3	Line No. 4	Line No. 5	Line No. 6
0+00	99.6	99.1	98.2	98.0	97.8	98.2
0+50	101.0	100.4	99.3	98.9	98.5	98.3
1+00	102.0	101.2	100.4	99.8	99.1	98.8
1+50	103.8	103.1	102.3	101.6	100.7	100.1
2+00	106.1	105.3	104.5	103.9	102.7	102.0
2+50	105.0	104.4	103.5	102.8	102.0	101.9
3+00	102.0	101.3	101.1	100.7	101.2	100.8
3+50	99.0	98.4	98.1	97.7	98.3	99.1
4+00	96.1	94.5	96.1	96.2	96.9	97.5
4+50	99.0	98.2	98.0	98.0	98.2	98.1
5+00	102.0	101.3	100.7	100.1	99.5	99.0
5+50	100.0	99.4	99.1	99.2	99.3	99.1
6+00	96.6	96.1	96.8	97.5	98.3	98.9

Table III. Elevations for plotting the contour map in Figure 13.

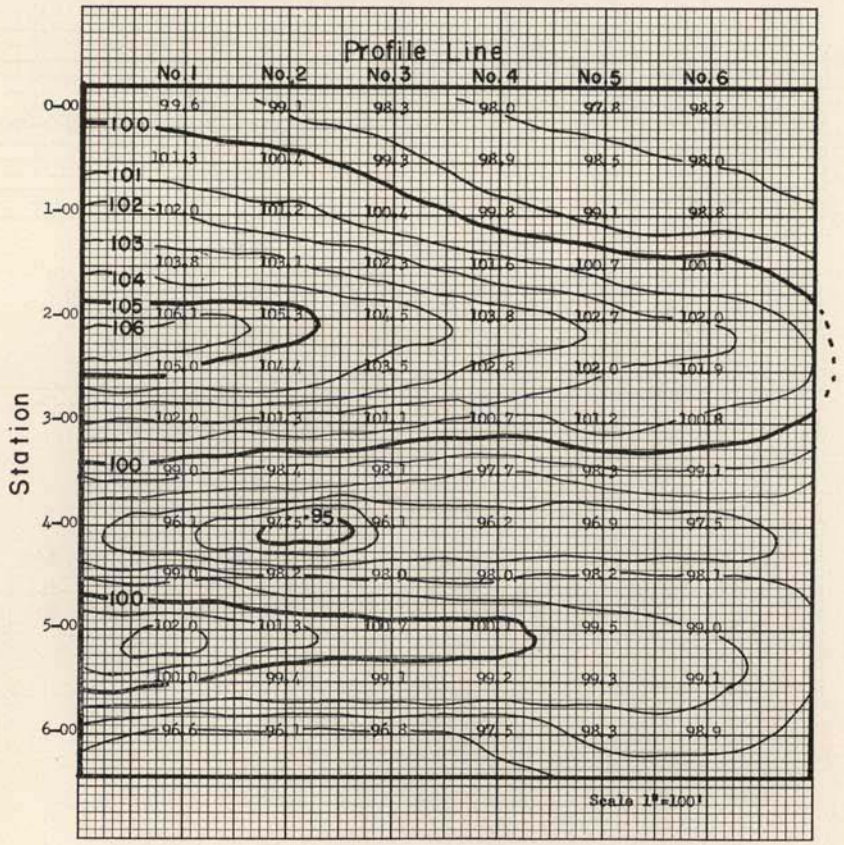


Figure 13. Contour map using notes in Table III.

Take the profile notes and plot the elevations of the various stations on a scale map of the field. Now draw in the contour lines by connecting (grid paper) points of equal elevations. Figure 13 shows the elevations plotted and the contours drawn in using Table III as the field notes of a profile line survey. This topography is extreme for farm leveling but is used to simplify the illustration.

When the contour map is considered as a whole, it is noted that the general slope of the field is from west to east. Leveling to irrigate in that direction would be least costly. For satisfactory irrigation it is necessary to change the contours by leveling to come within the slope limits of the method you are going to use. For satisfactory irrigation, the following approximate limits are necessary:

Method of Irrigation	Slope Limits ft./100' Perpendicular to Flow	Parallel to Flow
Border	0 to .3	.02 to 3
Corrugation	0 to 4	.02 to 5
Contour Furrow	2 to 12	.5 to 2

Hold the lengths of run for efficient irrigation to approximately 330 to 440 feet for light soils, 440 to 550 feet for medium soils, and 550 to 660 feet for heavy soils. For the steeper slopes use the shorter runs.

You will learn from experience just how far you'll need to go with your surveying and map work in order to do any particular job.

Summary

For successful operation of any farm level the following points must be remembered:

1. The level instrument is a delicate one. **Handle it carefully.**
2. Set up the instrument properly. **Follow directions.**
3. **Be sure the instrument is properly adjusted.** Check all three of these parts in order before running a level: (1) bubble tube, (2) telescope, and (3) cross-hairs.
4. **Check the bubble before and after each sight to be sure it is centered.**
5. **Do not touch the instrument while sighting.**
6. Bring the telescope in line with the target by slight sidewise pressures with the tips of the fingers.
7. Make readings as accurate as possible.
8. **Don't take extra long shots.** Maximum recommended is 300 feet.
9. **Don't** run a rag through the telescope to clean it. If you do you'll tear out the cross-hairs which are expensive to replace.

Definitions of Surveying Terms

In order to understand clearly the principles of profile and gradient leveling, it is necessary to know the meaning of the following generally used terms:

Bench Mark (B.M.) A station or mark of established or assumed elevation from which relative elevations for other stations are calculated. Usually located where it will not be disturbed and can easily be located.

Stations (Sta.) Any point where a rod reading is taken and is generally along the line being run.

Height of Instrument (H.I.) The relative elevation of the line of sight as compared to the elevation of the B.M.

Back Sight (B.S.) The rod reading taken on a station of known elevation. Therefore the beginning sight on a B.M. is a B.S. Used for the purpose of obtaining the H.I. (H.I.=B.S. + elevation of back sight point).

Fore Sight (F.S.) The rod readings taken on stations of unknown elevations.

Elevation (Elev.) The relative height of the point as compared to the height of the B.M. (Elev.=H.I.—F.S.).

Turning Point (T.P.) It is generally impossible to take all the readings on a line without moving the instrument. The T.P. is the reference point used by the rodman when the instrument is being moved. A back sight (B.S.) is taken on the turning point (T.P.) to determine the new height of instrument (H.I.).

Differential Leveling The term given to the process of finding the difference in elevation of any two points.

Gradient Line A line with uniform grade such as 2 ft. in 100 ft.

Profile Leveling Determining the changes in elevation of the surface of the ground along some definite line.

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