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EC758 Topographic Leveling and Preparation of Topographic Maps for Irrigation Purposes

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D. E. HUTCHINSON
CONSERVATIONIST

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IN AGRICULTURE AND HOME ECONOMICS
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W. H. Brokaw, Director, Lincoln

TOPOGRAPHIC LEVELING AND PREPARATION OF TOPOGRAPHIC MAPS FOR IRRIGATION PURPOSES.

By
Ivan D. Wood
Extension Agricultural Engineer

IMPORTANCE OF TOPOGRAPHIC SURVEYS.

Detailed examinations of a considerable number of farms in the valley of the Platte which have been irrigated for many years indicate clearly the need for careful topographic mapping before irrigation is attempted. Many difficulties now being experienced in the use of water may be traced directly to a lack of knowledge of topography. Some of the things which these detailed examinations have brought to light are as follows:

1. Irrigation pumping plants have been located in the wrong position with respect to the land to be irrigated, necessitating the use of built-up ditches and even pipe lines.

2. Many main farm ditches and field laterals are so located as to make good irrigation impossible.

3. On some farms it was discovered that diagonal and contour row locations were necessary in order to secure proper grades for irrigating row crops.

4. In most cases, alfalfa and small grains were being irrigated by the so-called "wild flooding" method, that is, the water was simply turned loose and allowed to run, resulting in very poor distribution and considerable waste.

5. With carefully made contour maps, it has been found possible to lay out the row directions, ditches and borders for irrigating row crops, small grains, and alfalfa in such a way that a considerable saving of water and time results.

FARM LEVEL.

With a properly made level rod, such as is described in Appendix "A", at the end of this circular, it is possible to do good topographic work with the inexpensive farm level. The leveling instrument consists of a bubble tube which is slightly curved so that the bubble remains at the highest point. A line passing through the center of the bubble tube shown at "A" - "B", Figure No. 1, is called the axis. When the bubble is in the exact center, the axis "A" - "B" represents a plane tangent to the earth's surface.

Directly above, or to one side of the bubble tube, is the telescope. The telescope magnifies distant objects and is provided with a set of cross-hairs. The line passing through the center of the telescope at the point

where the cross-hairs intersect is known as the "line of sight", and is shown at "C" - "D", Figure No. 1. When the instrument is in adjustment the lines "A" - "B" and "C" - "D" must be parallel.

The leveling of the instrument is accomplished by screws on the head of the tripod. The telescope is placed over one pair of leveling screws and the bubble brought to the center. This process is repeated for the other pair of screws. The telescope should be checked for level at each shot because the bubble may get slightly out of center.

THE USE OF THE LEVEL INSTRUMENT.

In order to understand the use of the level instrument, reference will be made to Figure No. 2A, which shows the surface of a lake with a bottom which slopes gradually toward one end. The slope on the bottom of the lake can be determined by measurements made downward from the lake surface. Suppose that a level rod was held at point "A" and a reading of 2 feet taken where the surface of the lake cut the rod. The rod is next moved to "B" where a reading of 4 feet is obtained and at "C" the reading is 7 feet. These readings mean, of course, that the lake at "A" is 2 feet deep, at "B" 4 feet deep and at "C" 7 feet deep. It is apparent that the fall from point "A" to point "C" is 5 feet. In other words, a measurement has been taken from the surface of the lake downward to the bottom.

This is exactly what is done with a leveling instrument. Referring now to Figure No. 2B, suppose that instead of the lake surface the line of sight of the telescope be substituted. When leveling work is done we are measuring downward from the line of sight to the ground just as was done. in the case of the lake surface.

Actually, of course, the surface of the lake is curved to conform to that of the earth, while in the case of the level, the line of sight is straight but for all practical purposes the similarity between the two cases holds. Referring again to Figure No. 2A, it may be assumed that the lake surface has an elevation of 100 feet, in which case the relative elevation of any point on the bottom may be found by measuring downward from the water surface, the elevation of which is known. At point "A", for instance, the rod tells us that the lake bottom is two feet below the surface, hence 100 feet minus 2 feet = 98 feet, the elevation of point (A). The same process is used to determine elevations with the level instrument.

In Figure No. 2 B, it may be assumed that the line of sight has an elevation of 100 feet. It is now possible to determine the relative elevation of any point simply by holding the level rod on it and measuring downward from the line of sight. In other words, by taking a rod reading with the instrument properly leveled.

When using a level instrument, much confusion and many mistakes will be avoided, if the operator will think of the line of sight of the instrument as the surface of a still lake and each rod reading as a measurement downward to a point on the bottom the elevation of which is to be determined.

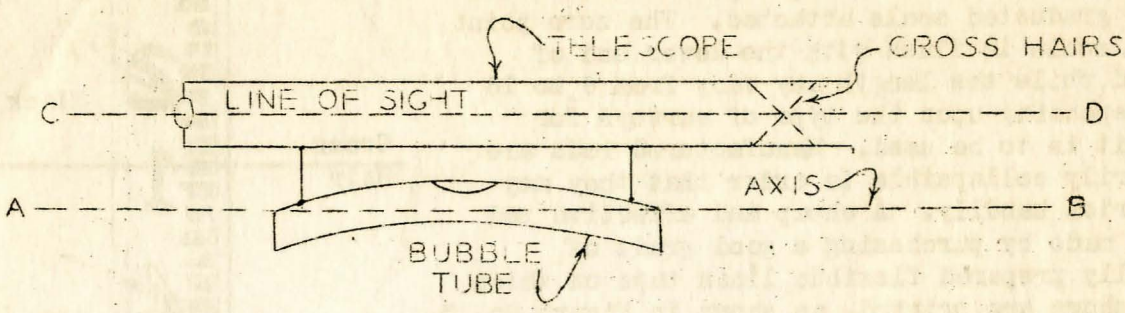


Figure No. 1.

The essential parts of the level instrument consist of a bubble tube, the inner surface of which is ground to a slight curve, and some arrangement for sighting as the telescope provided with cross-hairs. When the bubble is in the center of the tube, the axis A-B is said to be level. When in adjustment, the line of sight of the telescope and the axis of the bubble tube must be parallel.

The leveling of the instrument is accomplished by means of leveling screws which tilt the plate carrying the bubble tube and telescope.

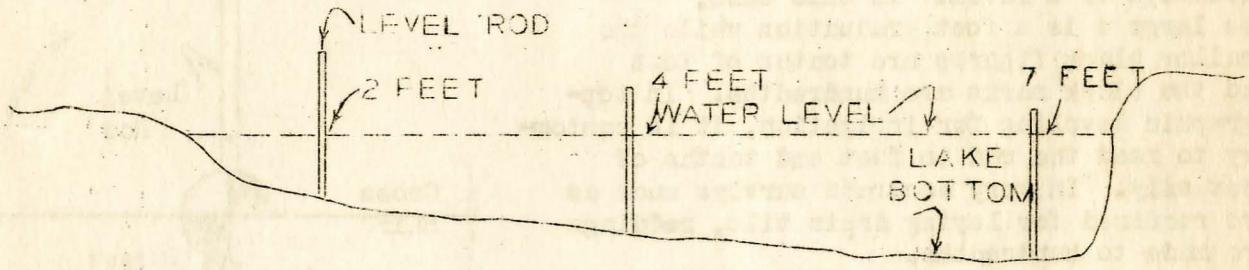


Figure No. 2A.

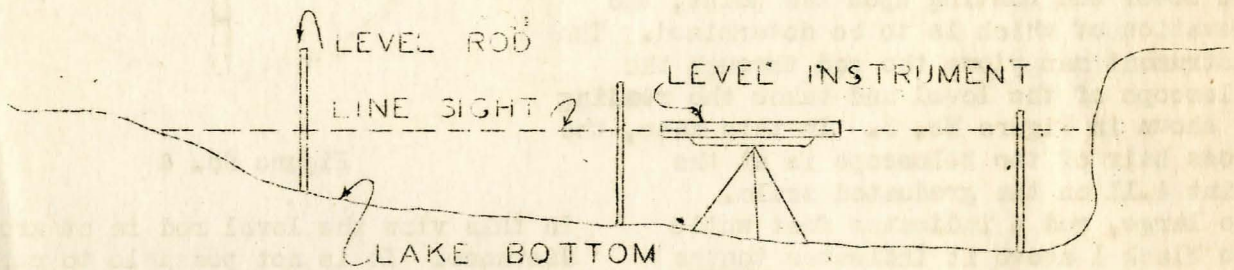


Figure No. 2B.

In Figure No. 2A is shown the surface of a lake from which measurements are made downward to determine the topographic features of the bottom. For all practical purposes the lake surface is a level plane and by measuring the depth of the water with a level rod the elevation of all points on the bottom may be determined.

In Figure 2B the line of sight of the level instrument has been substituted for the water surface. The similarity of taking level readings from the rod, with the instrument leveled, and measuring downward from the water surface is immediately apparent.

LEVEL RODS

The level rod is a rigid piece of material with a graduated scale attached. The zero point of the scale is flush with the lower end of the rod while the length may vary from 6 to 16 feet depending upon the type of surveys for which it is to be used. Manufactured rods are ordinarily collapsible in order that they may be carried handily. A cheap and effective rod may be made by purchasing a good grade of specially prepared flexible linen tape on which the numbers are printed, as shown in Figure No. 3. This tape may be attached to a piece of 1" x 2" material with thumb tacks or permanently mounted in position with cement.

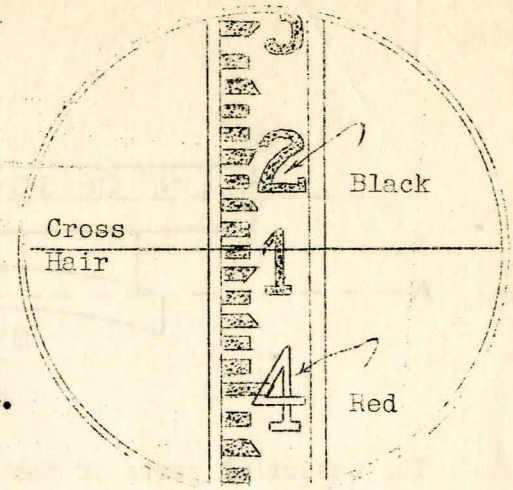


Figure No. 3

The level rod as viewed through the leveling instrument. The Cross-hair is at the Reading 4.11 Feet.

Level rods are graduated in feet and inches or in feet and tenths, the latter being the more convenient to use. It is difficult to make additions and subtractions when dealing with numerals involving feet, inches and fractions of inches. Figure No. 3 shows a common type of rod as viewed through the telescope of a level. In this case, the large 4 is a foot graduation while the smaller black figures are tenths of feet and the black marks are hundredths. In topographic leveling for irrigation, it is customary to read the rod to feet and tenths of feet only. In very accurate surveys such as are required for laying drain tile, readings are made to hundredths.

In use, the rod man stands behind the rod and holds it in a vertical position with the lower end resting upon the point, the elevation of which is to be determined. The instrument man views the rod through the telescope of the level and takes the reading as shown in Figure No. 3. In this case, the cross hair of the telescope is at the point 4.11 on the graduated scale. The large, red 4 indicates feet while the black 1 above it indicates tenths of feet. In topographic leveling, this would be read 4.1 feet (four and one-tenth feet).

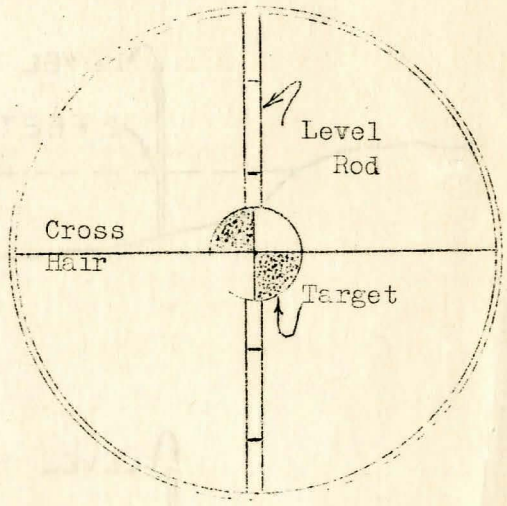
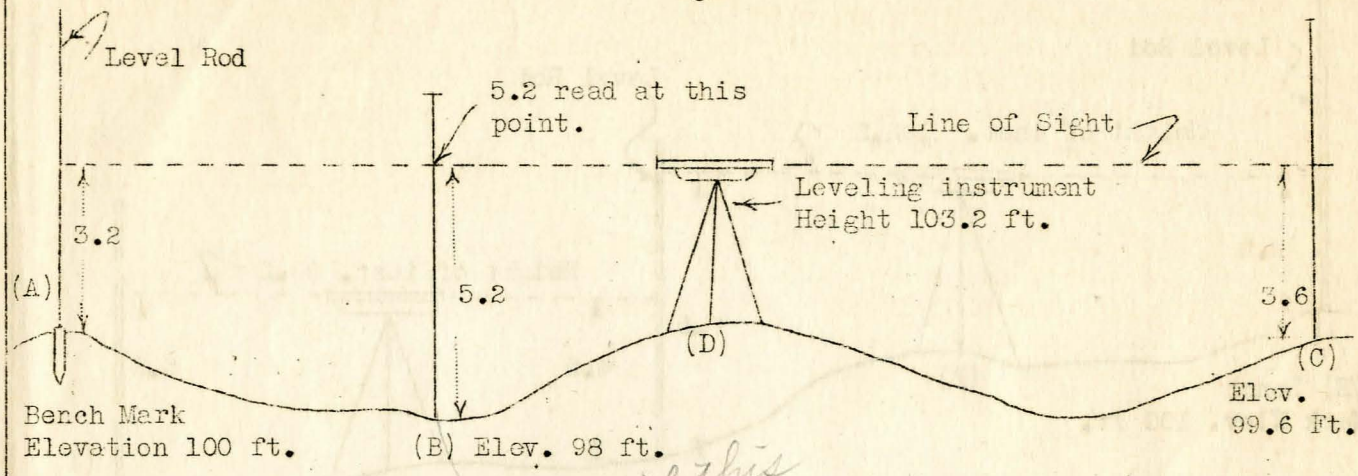


Figure No. 4

In this view the level rod is at greater distance. It is not possible to read the figures direct so the rod man sets the target as directed by the instrument man.

Some rods are equipped with a target which may be moved up and down the graduated scale and may be seen at considerable distance even through telescopes of low magnifying power. When using this equipment, the instrument man signals the rod man to move the target up or down until the center of the target is directly on the cross hair as shown in Figure No. 4. The rod man now records the reading in his notebook.

Note: On the last pages of this circular may be found directions for making a cheap, yet serviceable level rod.



what if this was a stick that rod wasn't tall enough to be in line of sight

Figure No. 5

This figure illustrates how to determine the Elevation of Points with respect to A Bench Mark with an assumed elevation of 100 feet.

USING THE LEVELING INSTRUMENT

In all important topographic surveys, elevations of the land surface are expressed in feet above sea level. The U. S. Coast and Geodetic Survey have established bench marks consisting of brass caps set in concrete at many points in this and other states. In making surveys of large tracts of land, it is customary to start the leveling from one of these U. S. G. S. bench marks of known elevation above sea level in order that all elevations taken thereafter may be expressed with reference to sea level and that the survey may be checked when other U. S. G. S. bench marks are encountered.

In making topographic surveys of small areas for irrigation purposes, the elevation above sea level is not important. It is the relative elevation of the different parts of the tract which is important and in which the owner is interested. In making such a survey, it is customary to start the levels from a bench mark which is assigned an arbitrary elevation, say 100 feet. The bench mark may be a piece of 1-inch pipe driven nearly flush with the ground surface in a fence corner. When such permanent mark has been established, it is possible to refer elevations to it at any future time.

The use of the level in determining elevations may be explained by consideration of a simple problem as depicted in Figure No. 5. It is desired that the relative elevation of points (A), (B) and (C) be determined.

The level is set up and leveled as explained previously. The rod man holds the rod on the point (A) which is the bench mark while the instrument man determines the reading which, in this case, happened to be 3.2 feet. This means that the line of sight of the instrument is 3.2 feet above the bench mark. Since the bench mark has an elevation of 100 feet, then the line of sight of the instrument has an elevation of 103.2 feet. Instead of saying the line of sight has an elevation of 103.2 feet, it is customary to say the Height of Instrument or the H. I. is 103.2 feet.

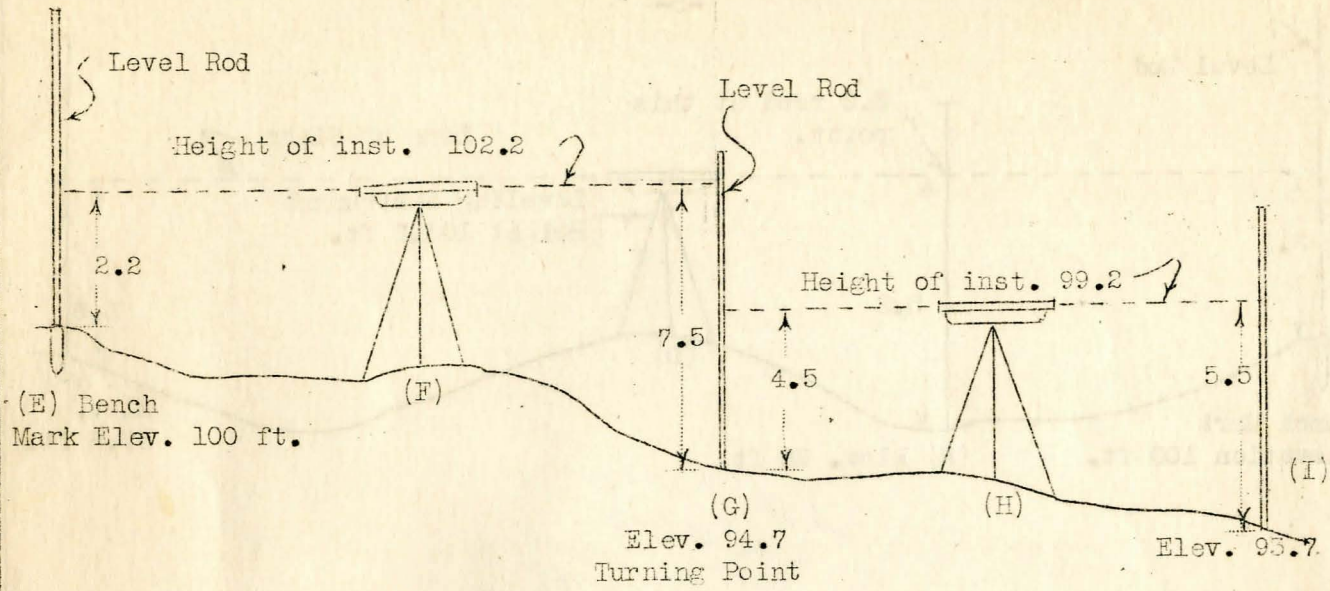


Figure No. 6

It is not possible in many cases to see all parts of a field from one set-up of the instrument. This drawing illustrates how the level may be moved from place to place, yet the elevation with respect to the original bench mark, may be maintained.

Knowing that the height of instrument or line of sight is 103.2, it is possible to determine the elevation of any other point at which the level rod can be read. Suppose it is desired to know the elevation of point (B), Figure No. 5. The rod man holds the rod at that point while the instrument man reads 5.2 feet on the rod. This means that the point (B) is 5.2 feet below the line of sight. Subtracting 5.2 from 103.2, we have 98.0, the elevation of point (B) and so on for any other point which can be seen for this set-up of the instrument. Before sighting at the rod, the instrument man should assure himself that the instrument is level.

It may be possible to take all readings from one set-up of the instrument for making a topographic map of a small area but, in most cases, the level must be moved from place to place. This process of moving the instrument and yet maintaining the proper, relative elevation is often puzzling to the beginner but is really no more complicated than the operation just described.

In Figure No. 6, it is desired to know the elevation of the point (I) with respect to the Bench Mark at (E) but due to distance it is not possible to take the reading direct and the instrument must be moved. A set-up is made at (F) and the rod sighted on the Bench Mark at (E). A reading of 2.2 feet is obtained which shows the Height of Instrument to be 2.2 feet above the Bench Mark which has an assumed elevation of 100 feet. The Height of Instrument is then 100 + 2.2 or 102.2 feet.

The point (I) is too far away to be read directly from the instrument so an intermediate point (G), known as a Turning Point, is established. When the rod is held on the point (G), a reading of (7.5) is obtained. This indicated that point (G) is 7.5 feet below the Height of Instrument. The H. I. is 102.2 as deter-

mined above. Since the elevation of point (G) is 7.5 feet below 102.2, the elevation of (G) is 102.2 - 7.5 = 94.7 feet.

The instrument is now moved to point (H) and after being leveled is sighted again at point (G) and now a reading of 4.5 feet is obtained. This indicated that the new Height of Instrument is 4.5 feet higher than the elevation of point (G) which has been determined to be 94.7 feet. The new Height of Instrument is now 94.7 + 4.5 = 99.2 feet. The rod is now placed on point (I) and a reading of 5.5 obtained. This indicated that point (I) is 5.5 feet lower in elevation than the Height of Instrument. The elevation of (I) is thus 99.2 - 5.5 = 93.7 feet. By the process just described, it is possible to carry a line of levels to any part of an area and to move the instrument as many times as necessary yet maintaining the proper relative elevations of all points.

LEVEL NOTES

Good instrument work is of little value unless the readings obtained are recorded in a manner which will permit of accurate interpretation later. The instrument man and the rod man should be familiar with a system of note keeping which will permit them to know exactly what was done in the field. The following terms are used in level notes and the meaning of each should be learned:

Station

When a line is being measured with a 100 foot tape, it is customary to designate the point at the end of each 100 foot measurement as a Station. The beginning point is marked 0 or 0 + 00, the first 100 stake is marked 1 or 1+00, the second 2+00 and so on. If some point is to be designated, which is say 240 feet from the starting point, it is marked 2+40. In making up level notes it is customary to designate any particular location as a Station. Thus on the map, Figure No. 9, the points A, B, C, D, etc. would be recorded as Stations.

Back Sight

The word Back Sight is abbreviated to B. S. in level notes. The Back Sight is the reading taken for the purpose of determining the Height of Instrument or height of the Line of Sight. In Figure No. 5 the Back Sight is the reading obtained from the level rod when held on the Bench Mark at the point (A). In this case the Back Sight reading is 3.2 feet.

Fore Sight

The word Fore Sight is abbreviated to F. S. in level notes. Any reading taken for the purpose of determining the elevation of a station is a Fore Sight. Thus in Figure No. 5 the reading taken at the point (B) is 5.2 feet and is a Fore Sight since it was taken for the purpose of determining the elevation of point (B). In contrast the Back Sight is taken for the purpose of establishing the Height of Instrument or Height of Line of Sight from some known elevation.

Height of Instrument

The Height of Instrument or H. I. as recorded in the notes refers to the elevation of the line of sight of the instrument. In Figure No. 5 the Height of Instrument is 103.2 feet. This was obtained by sighting the level rod held on the Bench Mark and reading a Back Sight of 3.2 feet. This 3.2 feet added to 100 feet, the elevation of the Bench Mark, gives 103.2 feet the Height of Instrument.

Elevation

The elevation of a point refers to the distance which the point in question is above an assumed plane. This assumed plane may be Sea Level or one point on an area may be assigned an arbitrary elevation and the elevation of other points determined with reference to it. Thus, in the problem shown in Figure No. 6, the Bench Mark or starting point was assigned an elevation of 100 feet. The elevations of points (G) and (I) were determined with reference to this Bench Mark.

Figure No. 7 shows the proper column headings for simple level notes. The proper readings are recorded for the solution of the problem shown in Figure No. 6 which should be referred to in reading the following explanation:

Column No. 1, headed "Station". In this column is recorded the number or letter which designates the point on which a level reading is to be taken.

1	2	3	4	5	6
Station	B. S.	H. I.	F. S.	Elev.	
E.	2.2	102.2		100	Bench Mark
G.	4.5	99.2	7.5	94.7	Turning Point
I.			5.5	93.7	

Figure No. 7
Column headings and simple level notes for the problem shown in Figure No. 6.

Column No. 2, headed "B.S." In this column is recorded the Back Sight readings taken for the purpose of determining the Height of Instrument.

Column No. 3, headed "H. I." Here the Height of Instrument is recorded.

Column No. 4, headed "F. S." In this column the Fore Sights are recorded.

Column No. 5, headed "Elev". The elevations for the various points are entered in this column as computed. Explanatory notes are entered in Column No. 6.

The student should now turn to Figure No. 6 and follow carefully the explanation given below. The problem is to determine the elevations of points (G) and (I) when the Bench Mark (E) has an assigned elevation of 100 feet. In column No. 1, the letter (E) is recorded since it is the first point on which a reading will be taken. In Column No. 5, marked "Elevation", the figure 100 is entered opposite the point (E) since that elevation is arbitrarily assigned to the point (E). The instrument is directed to the point (E) and a reading of 2.2 feet obtained from the level rod. This reading is recorded in the No. 2. column headed "B. S.", since it was obtained to permit a Height of Instrument to be computed.

The Height of Instrument is now computed by adding the 2.2 in the "B.S." column to the 100 in the elevation column. This gives 102.2 as a result which is recorded in the "H. I." column.

The elevation of the point (G) is now desired, hence the rod man holds the rod on that point while the instrument man obtains a reading of 7.5 feet. The (G) is recorded in the station column and the reading 7.5 in the "F.S." column. The elevation of the point (G) is now obtained by subtracting the F. S. 7.5 from the H. I. 102.2 which gives as a result the figure 94.7. This is the elevation of point (G) and is recorded opposite it in the elevation column.

The instrument is now moved and it is necessary to obtain a new H. I. before readings can be taken on other points. This is done by taking a B.S. on point (G) whose elevation is known. This B.S. is 4.5 feet which is added to the

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STATION	B.S.	H.I.	F.S.	ELE.	
B.M.	2.80	102.80		100.0	
A-0			2.90	99.9	
A-1			3.80	99.0	BENCH MARK + IRON BOLT SET IN FENCE LINE OF SOUTH WEST CORNER OF TRACT
A-2			4.10	98.70	
A-3			4.20	98.60	
A-4			4.90	97.90	
A-5			5.10	97.70	
A-6			5.30	97.50	
A-7			5.30	97.50	
A-8			5.40	97.40	
A-9			5.70	97.10	
B-9		102.80	5.50	97.30	
B-8			5.20	97.6	
B-7			5.00	97.8	
B-6			4.70	98.1	
B-5			4.60	98.2	
B-4			4.40	98.4	
B-3			4.10	98.7	
B-2			4.00	98.8	
B-1			3.90	98.9	
B-0			3.50	99.3	

Figure No. 8.
A page from a loose-leaf field book showing the actual level notes of a topographic survey for a small irrigation project.

elevation of point (G). Column No. 5 shows the elevation of point (G) to be 94.7 feet. The new Height of Instrument to be recorded in the H. I. column is 94.7 + 4.5 or 99.2 feet.
The instrument is now directed to the point (I) where a reading of 5.5 is obtained. This is a Fore Sight since it was read to obtain an elevation of a point. This 5.5 reading subtracted from the 99.2 gives 93.7, the elevation of point (I).

Figure No. 8 represents a page from a loose leaf field book with level notes of an actual topographic survey. Figure No. 9 is a field sketch of the land involved. It should be noted that a road runs along the south and west sides of the tract. The stake in the southwest corner is marked A-0. Those along the south side are set 100 feet apart and marked A-1, A-2, A-3, and so on while those along the west are marked A, B, C, D, etc. The problem in this case was to obtain the elevation of points A-0- A-1, A-2, and so on to A-9. At this point the rod man walked north 100 feet to point B-9 and returned along the line B-9, B-8, B-7 to B on the west boundary. The instrument was set up near the center of the area at point E-5 and a reading taken on the Bench Mark near point A-0 in the southwest corner. It should be observed, on the field notes, Figure No. 8, that B. M. or Bench Mark is the first point recorded under the station column and that the field notes describe the character and location of the bench mark for future reference. Opposite B. M. in the elevation column is recorded the number 100 which means that 100 feet is the elevation arbitrarily assigned to the bench mark. In the B. S. column is recorded the reading 2.80 feet. The 2.80 feet is added to the 100 feet to obtain the height of instrument 102.80 which is placed in the H. I. column. Now that the height of instrument has been obtained, it is possible to read a great many Fore Sights for obtaining the elevation of other points. The rodman holds the rod on points A-1, A-2, A-3, and so on in succession. In the Fore Sight column the readings obtained are recorded opposite those points. Thus the reading for the point A-4 is 4.90. This subtracted from the Height of Instrument 102.80 gives 97.90, the elevation of point A-4.

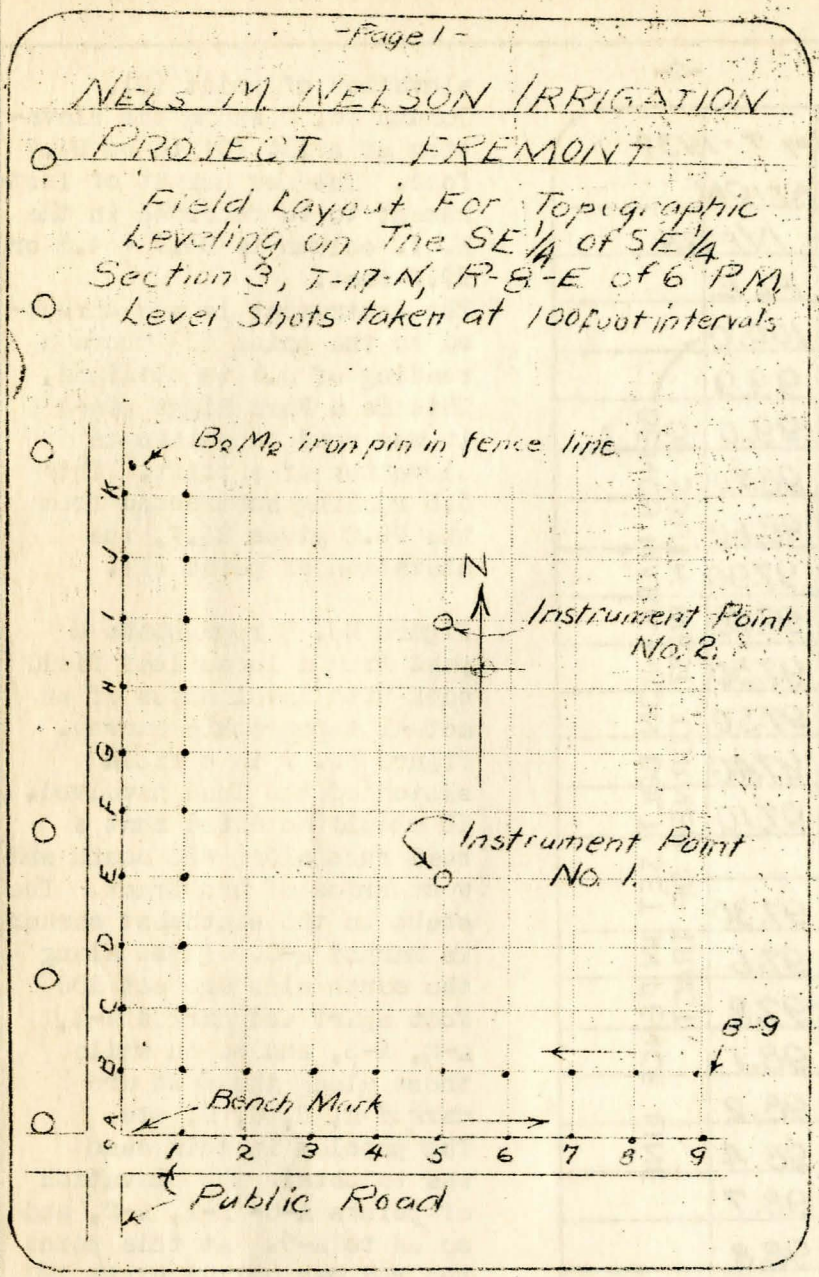

Figure No. 9
A page from a loose leaf field book showing a sketch of layout for topographic leveling on a small field. Figure No. 10 shows the completed topographic map of this area.

Level readings were taken on the stations in the line B-9 to B with the instrument in the same position from which readings were made on the line A-0 to A-9. This being the case the same height of instrument may be used for computing elevations as was used in the first instance. As an example, the rod reading on station B-4 was 4.4 feet. This rod reading of 4.4 feet is subtracted from 102.8 the height of instrument to obtain 98.4 the elevation of station B-4.

It should be observed that the slope of the ground from station A-0 to A-9 can now be computed. The level notes show that the station A-0 has an elevation of 99.9 feet and that A-9 has an elevation of 97.1 feet. The fall in the ground or slope may be determined as follows:

99.9 - 97.1 = 2.8 feet

LAYOUT OF FIELDS FOR LEVELING

Figure No. 9 shows one method of laying out a field for topographic leveling. The area is divided into squares and level readings are taken at the corner of each square. The size of the squares depend somewhat on the irregularity of the ground surface. If the topography is uniform, squares with side measurements of 200 feet may be used. In the majority of cases, 100 foot squares will be found more satisfactory. The map when drawn appears as shown in Figure No. 12. With the elevations of so many points given, it is a comparatively simple matter to draw a contour map from which the location of ditches and the row direction of fields may be planned. The map should also be of value to the owner in locating those portions of the area on which special ground preparation must be done.

In practice the field is not actually divided up into squares since it is possible for the rod man to locate the corners of the imaginary squares without the trouble of setting stakes at each point. The sketch in Figure No. 9 shows how an actual field was laid out for topographic leveling and a description of the process used should be of value in solving similar problems.

Stakes, consisting of full length lath, were set on points 0, 1, 2, 3, 4, 5, 6, etc. along the south boundary fence. A second line of similar stakes was set

parallel to and 100 feet north of the first line on the points B, B-1, B-2, B-3 and so on to B-9. The process was repeated on points A, B, C, D, E, and A-1, B-1, C-1, D-1, etc.

Figure No. 9A shows an enlarged view of a portion of the area sketched in Figure No. 9. It should be understood that stakes were set only at those positions indicated by small circles in Figure No. 9A. The movements of the rod man in locating the corners of the imaginary squares may be understood from the following explanation.

He started, let us say, from the point C and traveled eastward to Stations C-1, C-2, C-3, and so on to the east boundary. He located Stations C and C-1 by stakes but C-2, C-3, etc. are not staked yet he locates their position easily. As he walked eastward he glanced backward over his shoulder and kept himself aligned with the Stakes C and C-1. After taking about 33 steps which should have carried him about 100 feet he glanced southward and aligned himself with Stations 2 and B-2. He knew now he was at point C-2 and held the rod at that point so that a level reading might be taken. He walked on again, aligning himself with Stakes B and B-1 and when he aligned with Stakes 3 and B-3 he knew the point C-3 had been reached. In this way it is possible to take level shots over considerable area at regular intervals and yet only four lines of stakes were set.

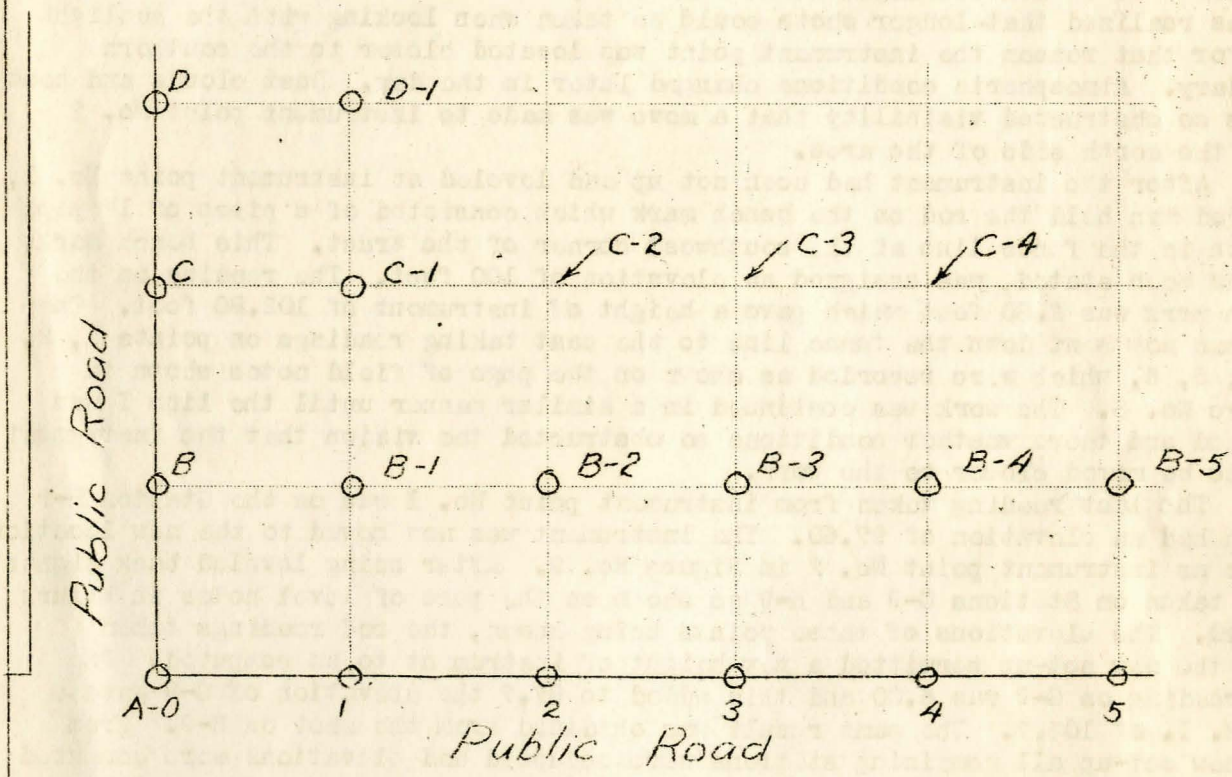

Figure No. 9A
A portion of the area sketched in Figure No. 9 enlarged to show method of setting stakes for locating interior points.

Considerable ingenuity is necessary when setting stakes for topographic leveling in order that unnecessary work may be avoided. The rodman must be able to see the stakes at considerable distance, therefore, new, white lath should be used ordinarily and they should be set so that the sunlight is reflected from them. No stake can be seen far when looking toward the sun.

Lath will contrast quite well with the green backgrounds of spring and summer. In the fall, however, it may be necessary to tie red rags on each stake due to the brown of stubble and cornstalks.

It is not always necessary for the rodman to align himself in both directions by observing stakes. Often a field may have been planted to some row crop which will serve to keep the alignment in one direction.

TOPOGRAPHIC LEVELING

After the field has been laid out preparatory to doing the instrument work, consideration should be given to the choice of instrument points from which the most readings can be taken. The distance at which the level rod can be read will, of course, depend upon the magnifying power of the land, the condition of the atmosphere and the type of rod used. It may be necessary to take a few preliminary "shots" to determine the range of visibility and then plan the location of the instrument points accordingly. With good instruments and favorable weather conditions, it may be possible to take all the level readings on a 40 acre tract from one instrument point. At other times shots of 300 to 400 feet may be difficult to make.

In the actual field work depicted in Figure No. 9, the instrument was set up at Point No. 1 with the expectation that all points on the area could be read. It was realized that longer shots could be taken when looking with the sunlight and for that reason the instrument point was located closer to the southern boundary. Atmospheric conditions changed later in the day. Dust clouds and heat waves so obstructed visibility that a move was made to instrument point No. 2 near the north side of the area.

After the instrument had been set up and leveled at instrument point No. 1, the rod man held the rod on the bench mark which consisted of a piece of 1" pipe driven in the fence line at the southwest corner of the tract. This bench mark, as has been stated, was assigned an elevation of 100 feet. The reading on the bench mark was 2.80 feet which gave a height of instrument of 102.80 feet. The rod man now went down the fence line to the east taking readings on points 1, 2, 3, 4, 5, 6, which were recorded as shown on the page of field notes shown in Figure No. 8. The work was continued in a similar manner until the line I was reached and there weather conditions so obstructed the vision that the instrument had to be moved closer to the work.

The last reading taken from instrument point No. 1 was on the Station H-9 which had an elevation of 97.60. The instrument was now moved to the new location shown as instrument point No. 2 in Figure No. 9. After being leveled back sights were taken on Stations G-9 and H-9 as shown on the page of level notes in Figure No. 10. The elevations of these points being known, the rod readings taken from the new set-up permitted a new height of instrument to be computed. The rod reading on G-9 was 6.00 and this added to 97.7 the elevation of G-9 gave a new H. I. of 103.7. The same result was obtained from the shot on H-9. From the new set-up all remaining stations were occupied and elevations were computed from the new H. I.

The process of topographic leveling just described is known as the grid or rectangular system. Elevations are obtained at points spaced at regular intervals over the surface of the area. It is evident that the elevation of other points may at times be necessary if the true character of the land is to be shown on a map. For instance, a swail or ravine might traverse an area which had been laid out in the manner shown in Figures Nos. 11 and 12. Yet no regular point might chance to be in a position which would give the depth of the ravine. In a case of

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NELS M. NELSON IRRIGATION

PROJECT FREMONT

STATION	B.S.	H.I.	F.S.	Elev.
G - 9	6.00	103.70		97.70
H - 9	6.10	103.70		97.60
I - 9			5.70	98.0
I - 8			5.50	98.2
I - 7			5.10	98.6
I - 6			4.60	99.1
I - 5			4.10	99.6
I - 4			4.30	99.4
I - 3			4.00	99.7
I - 2			3.80	99.9
I - 1			3.70	100.0
I - 0			3.60	100.1

Figure No. 10.
A page from a loose leaf field book showing the actual field notes used in the preparation of a portion of the map shown in Figure No. 12.

this kind, the rod man should take readings at each point where the ravine is crossed and signal the fact to the instrument man by some pre-arranged sign. Intermediate readings should be taken at all points where the ground changes suddenly in slope characteristics. The rod man should keep a record of distances at which intermediate readings are taken from regular stations and report his findings to the instrument man. The finished map should give a true picture of the existing topography.

MAKING THE TOPOGRAPHIC MAP

Drawing Equipment

Expensive drawing equipment is not necessary for making topographic maps of the type described here. The following items are desirable:

1 - Drawing board 18" x 24"
1 - T square 24", wooden
1 - Celluloid triangle 8"
1 - Triangular, boxwood chain scale with divisions of 10,20,30,40,50,60, divisions per inch.

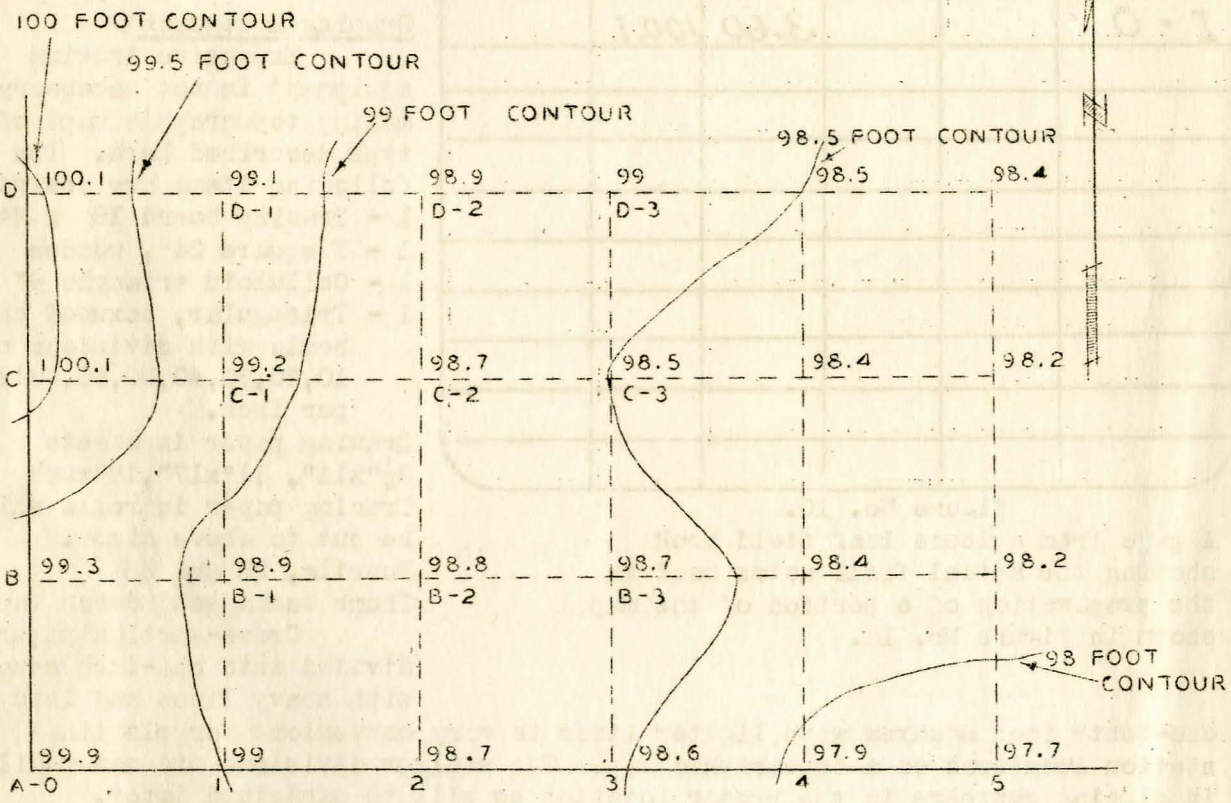
Drawing paper in sheets $8\frac{1}{2}$"x11", 11"x17",17"x22"
Tracing paper in rolls which may be cut to above sizes.
Pencils, 2H and 3H
Thumb tacks and Scotch tape.

Cross-section paper divided into one-inch squares with heavy lines and into one-tenth inch squares with lighter lines is very convenient for plotting station locations on a topographic map. The smaller divisions aid materially in placing contours in the proper location as will be explained later.

Plotting Station Locations and Placing Contours

The field sketch shown in Figure No. 9 is of help in making a decision as to the scale to use in the large map. The map shown in Figure No. 12 is drawn to the scale of 1 inch = 200 feet. As may be seen, the enlarged portion of the same map shown in Figure No. 11, which has a scale of 1 inch = 100 feet, is more easily drawn and is large enough to show detail more plainly.

The first operation in making a topographic map of the type described here is the placing of the station elevations at the points where level "shots" were taken as shown in Figures Nos. 11 and 12.



SCALE 1"=100'

FIGURE NO. 11.

The contour map may be drawn to a scale of one inch equals one hundred feet. The elevations of the various points are written on the map, after which the contour locations are determined as described in the text.

Considerable information as to the character of the land surface may be gained from the map before the contour lines are drawn. The addition of the contour lines, however, makes it possible to visualize the slope characteristics at a glance.

Figure No. 12 shows contour lines drawn at 6 inch intervals. Near the lower right hand corner is the 97.5 foot contour. All points along this line have an elevation of 97.5 feet. The next line to the left has an elevation 6 inches higher or 98 feet and so on until the 100 foot contour is reached which represents approximately the highest elevation on the tract.

The method of drawing contour lines may be better understood from Figure No. 11. It should be noted that the 99 foot contour starts from point No. 1 because that point has an elevation of exactly 99 feet. The direction of the contour line after leaving point No. 1 is determined by noting the elevation of other points. Station B-1 has an elevation of 98.9, while station B has an elevation of 99.3. It is evident that the line must go between these two points. The position of the line between stations B and B-1 may be determined by proportion as follows:

Elevation of B	99.3	Elevation of Contour	99.0
Elevation of Contour	99.0	Elevation of B-1	98.9
Difference	.3 ft.	Difference	.1 ft.

Elevation of B	99.3
Elevation of B-1	98.9
Difference	.4 ft.

From the above computations it is evident that the 99 foot contour must pass closer to B-1 than to B. Since the difference in elevation between the contour and point B-1 is .1 foot or $\frac{1}{4}$ the difference in elevation of B and B-1, it follows that the contour passes B-1 at $\frac{1}{4}$ the distance between B-1 and B. In Figure No. 11, the points are 100 feet apart, hence the contour passes 25 feet to the left of B-1 and its position may be scaled.

Since point B-1 has an elevation of 98.9 feet and point C-1 has an elevation of 99.2 feet, it follows that the 99 foot contour passes between these two points. The difference in elevation between B-1 and C-1 is .3 foot and since the 99 foot contour is .1 foot higher than B-1 it follows that the 99 foot contour passes B-1 at 1/3 the distance between B-1 and C-1. Other points along the 99 foot contour may be spotted on the map and the line drawn.

USING THE CONTOUR MAP.

Figure No. 12 represents a complete contour map of a portion of a field on which irrigation is contemplated. A glance at the map shows slope characteristics as follows:

1. Two points on the west boundary have an elevation of slightly over 100 feet. These points are about 500 feet apart.

2. The ground between the two high points is about one foot lower.

3. The general direction of slope is eastward, the actual fall being about 2.5 feet per 1000 feet, or 13 feet per mile.

4. A slight ridge traverses the area running eastward from point "J".

5. The land in the southeast corner of the tract is more level than elsewhere.

6. Irregularities in contour lines indicate a need of surface preparation with a leveling drag. The small, high area at points "C" and "D" probably could be removed with a drag and the dirt used for a fill at "E" and "F" where the surface is lower.

7. The possibilities for irrigation of row crops planted in any given direction can easily be investigated by observing the contours. It is at once evident that water cannot be carried northward from the south boundary. From the ridge running eastward from point "J", water can be carried both north and south.

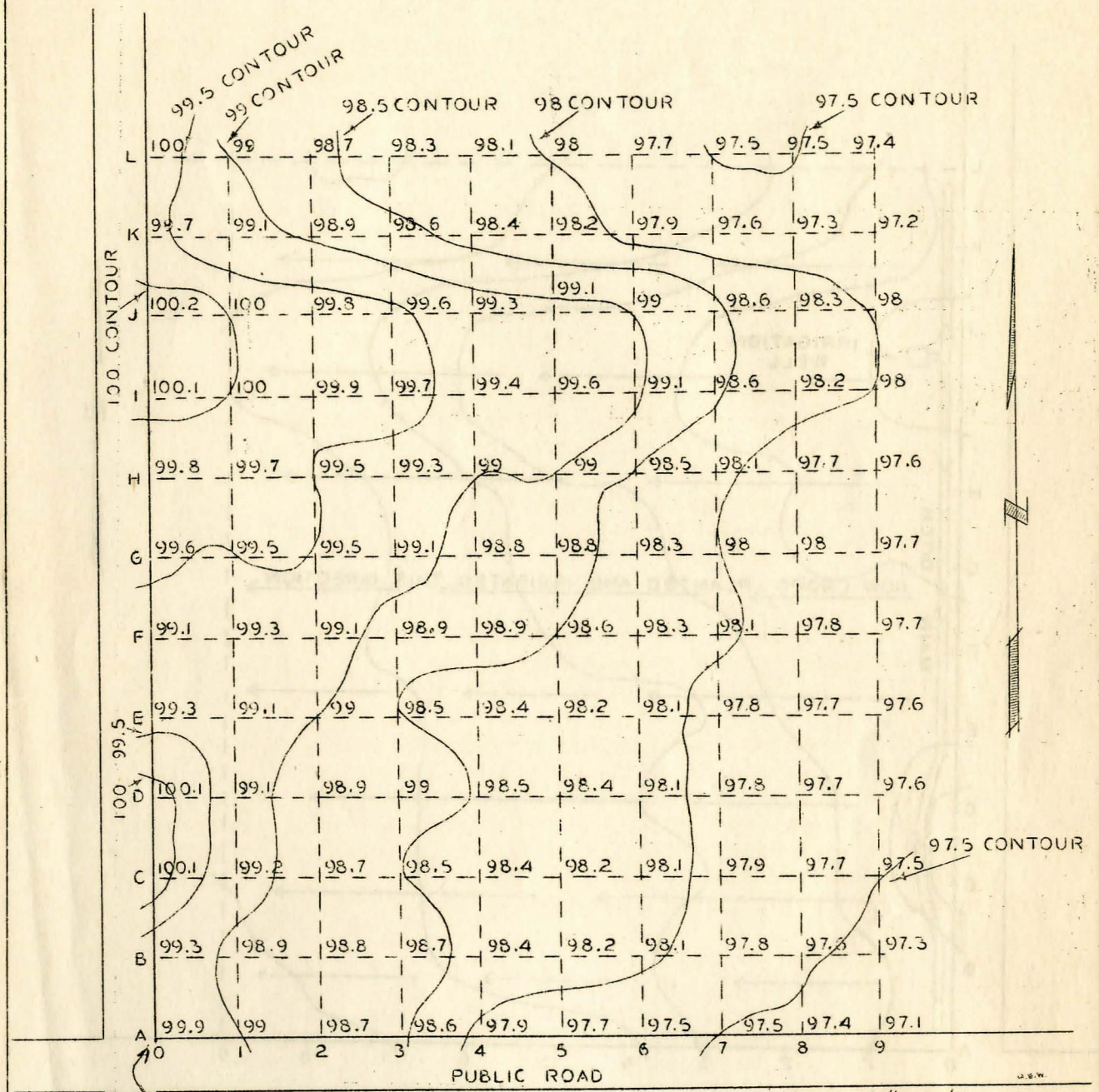
8. If the tract is properly prepared with a leveling drag, irrigation water from a well or canal should enter on the west boundary at point "J" which has an elevation of 100.2. The main field laterals arrangement for irrigation of row crops is shown in Figure 13. The main canal runs parallel to the west boundary and water is carried eastward down the rows of corn, beets, potatoes, etc.

9. In irrigating small grain or alfalfa by the use of borders or corrugations, a different system is suggested as shown in Figure No. 14.

Corrugations are used for irrigating land planted to close growing crops, such as wheat, oats, alfalfa, or land which has not previously been listed. The corrugations consist of small furrows running down the slope. These furrows, or marks, are made with special corrugating devices, or the furrow drill may be used. Corrugations have the advantage that they may be used on extreme slopes with a gradient of from 6 to 10 feet per 100 feet. The corrugations must run directly down the slope, however, as shown in Figure No. 14.

Alfalfa and small grain are sometimes irrigated by means of borders. Borders are simply dikes running down the slopes between which a head of water is turned. The dikes are placed from 40 to 60 feet apart in order that complete flooding will occur.

Note: Other circulars dealing with practically all phases of irrigation may be had by addressing the Extension Service, College of Agriculture, University of Nebraska, Lincoln, Nebraska.



TOPOGRAPHIC MAP OF THE NELS M. NELSON IRRIGATION PROJECT - DODGE CO.

S.E. 1/4 OF S.E. 1/4 SEC. 3 T-17-N R-8-E OF 6TH P.M.

FIGURE NO. 12

This complete contour map of an actual irrigation project proved of considerable value in locating an irrigation well and designing a system of field ditches.

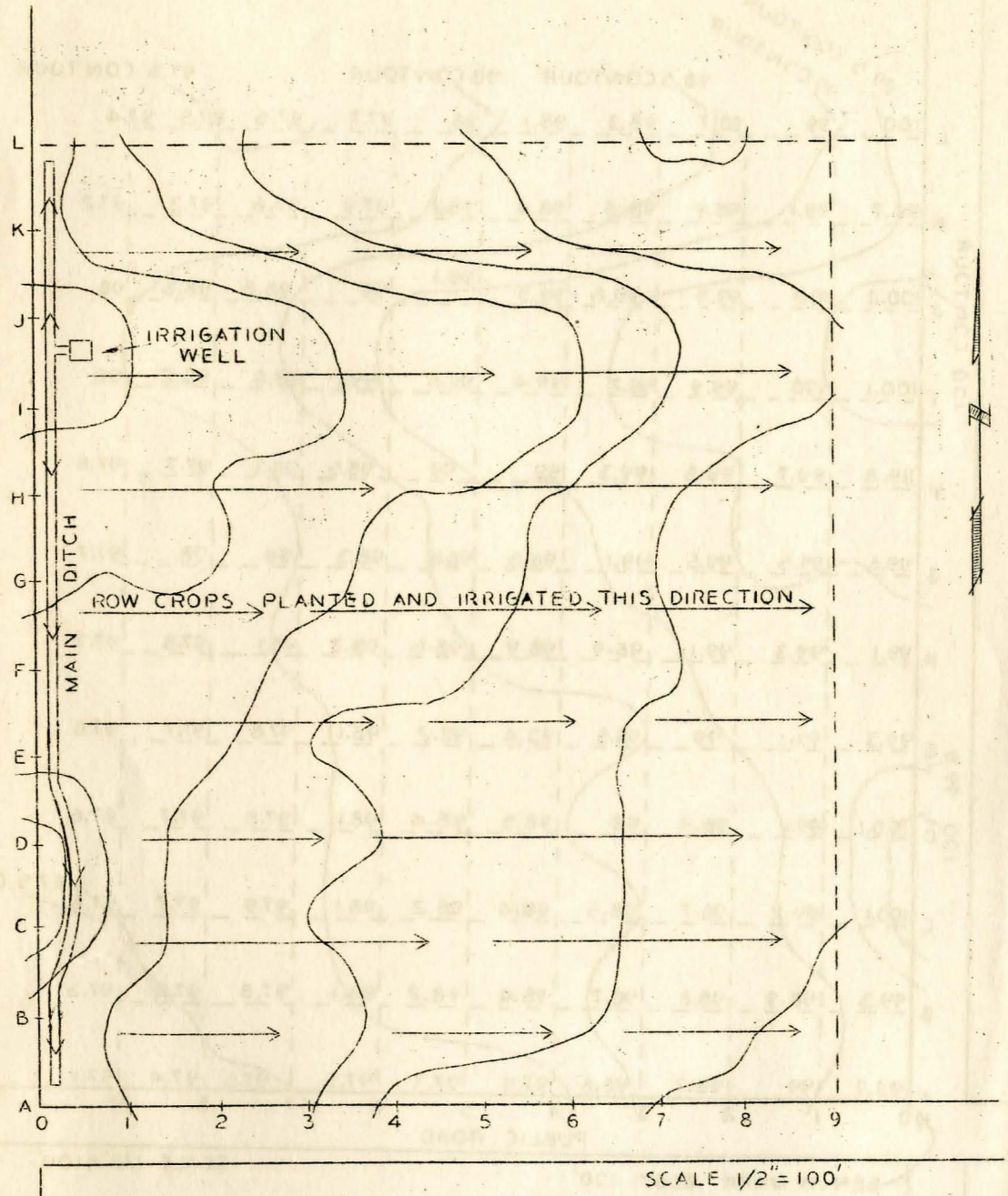


FIGURE NO.13

An arrangement of field ditches and row direction for irrigation of row crops on field depicted in Figure No. 12. The irrigation well is placed at the high point.

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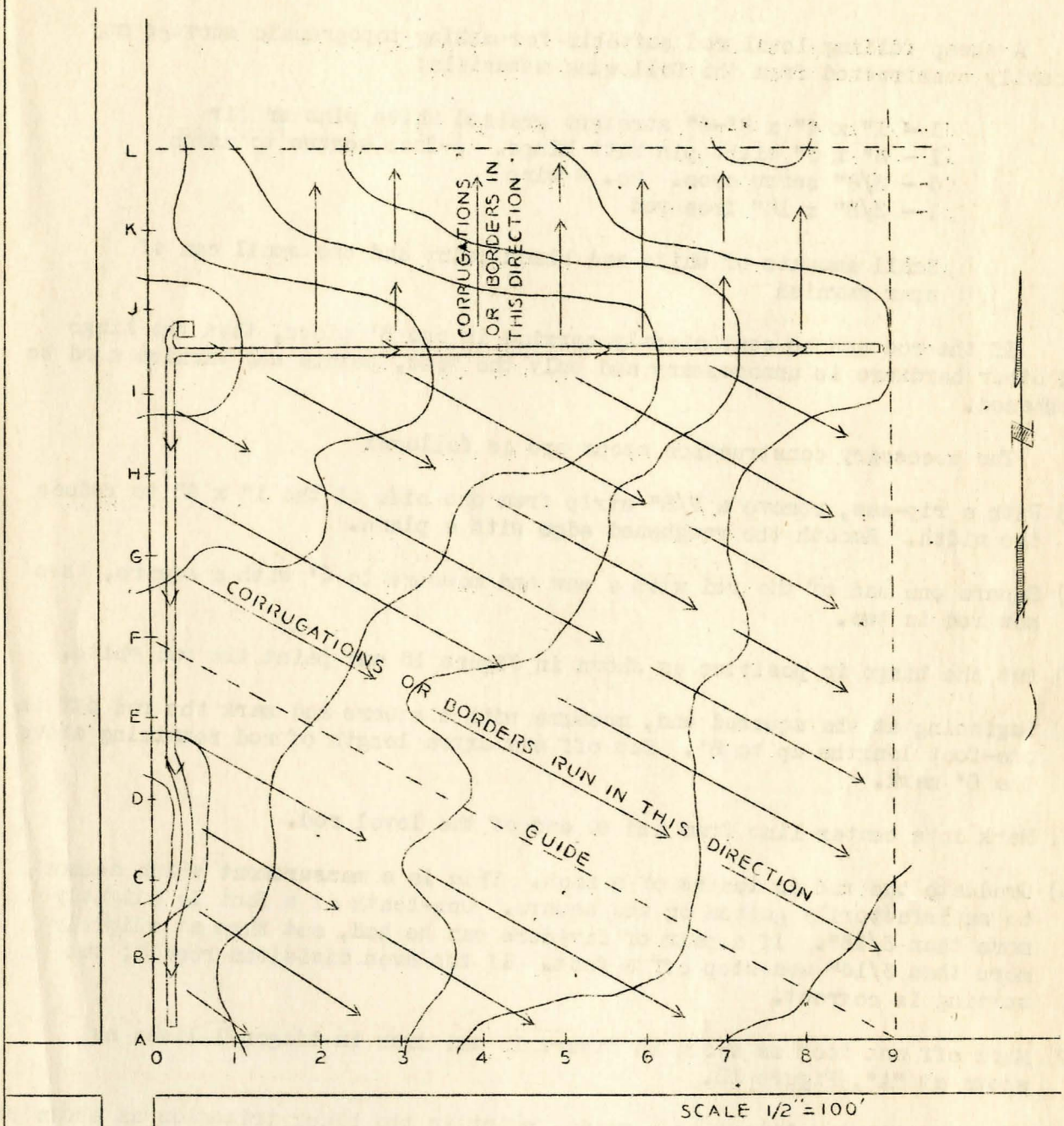

FIGURE NO. 14

Corrugations, borders or flooding ditches should run as nearly as possible in the direction of greatest fall or perpendicular to the contours.

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APPENDIX "A"

A LEVEL ROD SUITABLE FOR TOPOGRAPHIC WORK

A cheap folding level rod suitable for making topographic surveys may be easily constructed from the following materials:

1 - 1" x 4" x 8'-6" straight grained white pine or fir
1 - 3" x 3" tight pin butt hinge. $\frac{1}{2}$-inch screws to match
4 - 3/8" screw eyes. No. 8 wire
1 - 3/8" x 18" iron rod

Small amounts of white and black paint and one small can of spar varnish

If the rod can be conveniently carried in one 8' piece, then the hinge and other hardware is unnecessary and only the wood, paints and varnish need be purchased.

The necessary construction steps are as follows:

(1) With a rip-saw, remove a 7/8" strip from one side of the 1" x 4" to reduce the width. Smooth the roughened edge with a plane.

(2) Square one end of the rod with a saw and measure in 4' with a square, then saw rod in two.

(3) Put the hinge in position as shown in Figure 15 and paint the rod white.

(4) Beginning at the squared end, measure with a square and mark the rod off in one-foot lengths up to 8'. Saw off any extra length of rod remaining above the 8' mark.

(5) Mark in a center line from end to end of the level rod.

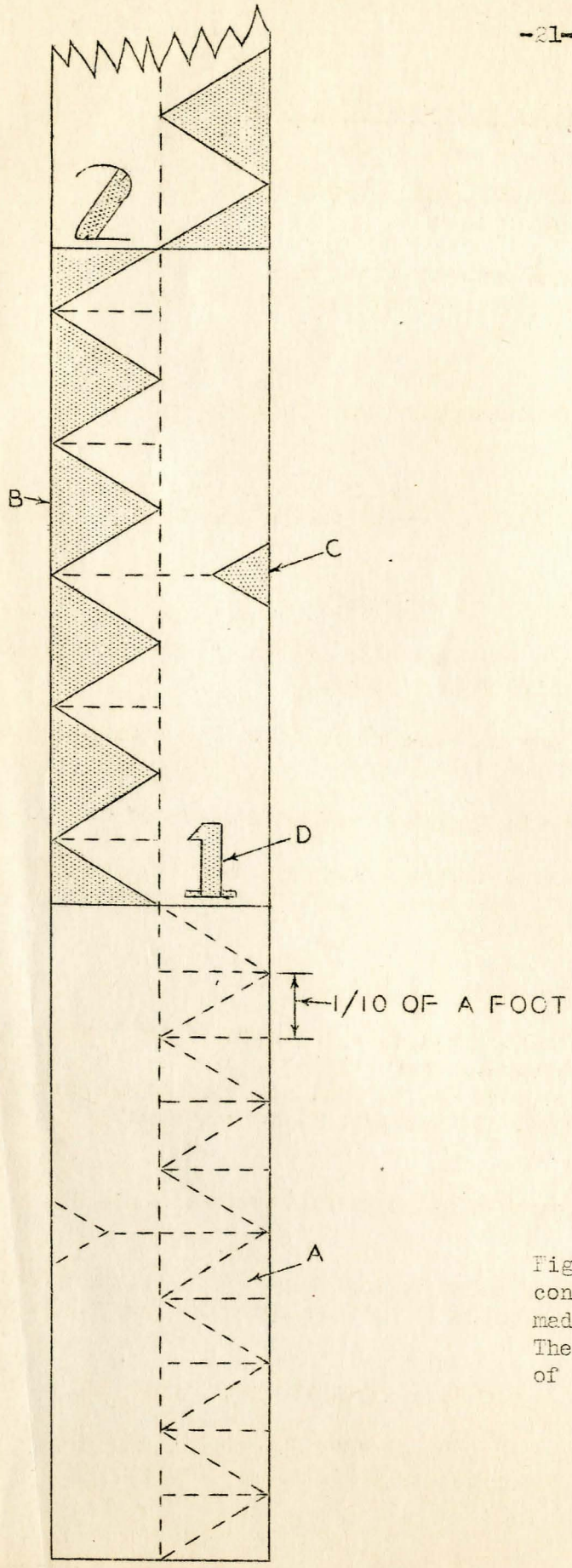
(6) Graduate the rod in tenths of a foot. This is a measurement which cannot be satisfactorily gotten on the square. One-tenth of a foot is slightly more than 3/16". If a pair of dividers can be had, set them at slightly more than 3/16" and step off a foot. If ten even divisions result, the setting is correct.

(7) Mark off one foot as shown in Figure 15 and draw in diagonal lines as shown at "A", Figure 15.

(8) Using the diagonal mark as a guide, paint in the black triangles as shown at "B", Figure 15. A small, black triangle is painted opposite the tenths mark as shown at "C", Figure 15.

(9) The large black figures are next painted as shown at "D", Figure 15.

(10) The screw eyes are next inserted as shown at "E", Figure 15, and when the rod is in an upright position, the iron bar is inserted through the screw eyes to keep it in position.



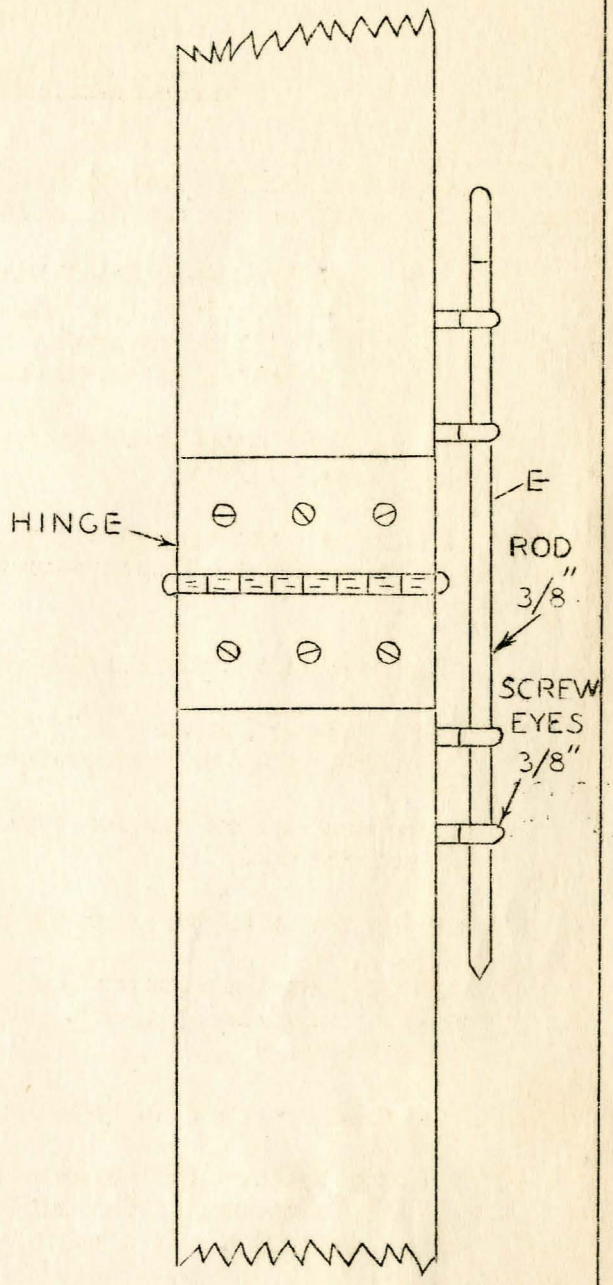


Figure No. 15. Details showing the construction of a convenient level rod made of a piece of 1" x 4" material. The divisions are in feet and tenths of feet.