Introduction to Leveling
A Training Guide for Road Maintenance Personnel in Indiana's Counties, Cities and Towns

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Purpose
This booklet supplements the training seminar presented by HERPICC for county, city and town employees in Indiana. The booklet presents the basic concepts of leveling using text and figures. It is intended to be a reference for those employees performing essential leveling operations for the construction of roads and drainage structures. The purpose of the seminar and this booklet is to train persons in the skills necessary to perform these tasks, and to develop confidence and competence in leveling.

Introduction
The surveying procedure known as spirit leveling is used to determine height or elevation differences between two or more points. Leveling is the most fundamental method of establishing grades for all types of construction activities. The methods used in leveling are simple yet reliable since checks on the work may be readily incorporated into the procedure.

Leveling Equipment
The tools used in leveling are an instrument known as a level and a level rod which is sighted with the level. There are various types of levels available for use by those involved in construction. An engineer's dumpy level, like those used in the seminar, have 4 leveling screws. Construction transits and levels typically have 4 screws and a telescope shorter than that found on the dumpy level. Automatic (self-leveling) levels have 3 leveling screws and the advantage of reduced setup time when compared with the 4 screw instruments. All of these levels will provide the accuracy required for construction work, providing that they are in proper adjustment and are used by a competent operator.

Level rods are generally graduated in feet, tenths of a foot, and hundredths of a foot. Computations involving these decimal graduations of a foot are much easier to perform than computations involving feet, inches and fractions of an inch (quarter-inch, eighth-inch, sixteenth-inch, etc.). While level rods graduated in feet and inches are available, they are not recommended since they tend to increase the occurrence of reading and computational errors. The examples presented in this booklet assume the use of a level rod graduated in feet, tenths, and hundredths.

If you are not sure whether your level rod is graduated in decimal feet or inches, there is a simple check. Find the largest black number on the divisions between any foot on the rod. If this number is a "9", your rod is graduated in decimal feet. If the largest black number is an "11", your rod is graduated in inches.
Instrument Setup

Perhaps the most difficult procedure in leveling is the proper setup of the instrument. The instrument must be properly leveled in order to obtain accurate results. The setup procedure for an automatic level is quite simple: adjust the 3 leveling screws on the instrument until the bubble is centered in the "bull’s-eye". The setup procedure for a 4 screw instrument, like the dumpy level, requires patience and proper technique. This procedure is described below.

The tripod is first setup so that its head (top) is approximately level. The instrument is then screwed onto the tripod, if not already in place. Make certain that the feet of the leveling screws are in contact with the base plate of the level. Align the telescope so that two of the leveling screws are in line with the telescope (see Figure 1a).

Grasp each of the leveling screws aligned with the telescope with a hand. Two things must be remembered: turn the screws the same amount with each hand, but in opposite directions and, the bubble moves in the direction of movement of the left thumb (known as the left hand rule!). See Figure 1c & d for illustrations of leveling screw movements and the resulting bubble movement. Adjust the two screws until the bubble is centered between the marks on the glass vial.

Rotate the telescope a quarter-turn clockwise until it is aligned with the other two leveling screws (see Figure 1b). Repeat the procedure described in the preceding paragraph until the bubble is centered again. Now rotate the telescope counter-clockwise back to the original position. Adjust the leveling screws again until the bubble is centered, if necessary. Rotate the telescope a quarter-turn clockwise again and center the bubble, if needed.

Rotate the telescope another quarter-turn clockwise. Check to see if the bubble is centered, if not, use the leveling screws to move the bubble half-way toward being centered. Use care to move the bubble only half-way! Rotate the telescope another quarter-turn clockwise and repeat this procedure if the bubble isn’t centered. The instrument should now be properly set up. Always check to be certain the instrument is properly leveled before taking rod readings.

Reading the Level Rod

Figure 2 illustrates a section of a typical leveling rod. Learning to read the rod correctly is a must since incorrect rod readings will result in worthless results, regardless of leveling procedures employed. The photocopying process used to create this booklet doesn’t allow colors to be used; however, the foot designations on a leveling rod are labeled in red. The large, bold-faced 5 and 6 shown in Figure 2 would be painted red on the actual rod. Each foot on the rod is divided into tenths of a foot and hundredths of a foot. There are 10 tenths (0.10’)
in a foot and there are 10 hundredths (0.01') in a tenth; therefore, there are 100 hundredths in a foot. This subdivision is similar to the way a dollar is subdivided into dimes and pennies (10 dimes in a dollar, 10 pennies in a dime, 100 pennies in a dollar).

Tenths of a foot are marked with smaller black numbers on the level rod. The numbers 1 through 9 represent tenths of a foot between the 5 and 6 foot marks in Figure 1. Each tenth is then subdivided into 10 hundredths using black marks. The top of each black mark represents an even (0, 2, 4, 6, or 8) hundredth of a foot, the bottom of each black line represents an odd (1, 3, 5, 7, or 9) hundredth of a foot. Some black marks are longer than the others, these have special significance when reading the rod.

Locate the 5 foot mark in Figure 2, this is identified by 5.00 feet. The 5.00 designation indicates 5 feet (5.00), 0 tenths (5.00), and 0 hundredths (5.00). Notice the black mark at 5.00 feet is longer at the top than a typical mark. This indicates a full tenth of a foot. Move up the rod to 5.10 feet. The black mark here is also longer at the top, indicating a full tenth; that is, 0 hundredths.

Now locate the 5.25 mark on the rod. Notice that this black mark is longer on the bottom than a typical mark, this indicates 5 hundredths of a foot (0.05'). At this location on the rod you are between 5 and 6 feet, hence you use 5 feet. You are between 2 and 3 tenths, therefore you use 2 tenths. Finally the arrow (your crosshairs when sighting the rod with the level) points to 5 hundredths; the rod reading is 5.25 feet. When reading the rod, always read the foot number first, the tenth number second and the hundredth mark last.

Always read the rod carefully as described in the previous paragraph, take your time, you can’t get good results if you can’t read the rod! Look at the other rod readings shown in Figure 2, make certain you understand how the value of the rod reading is determined. Remember, when the crosshair is on top of a black mark the value of the hundredth must be even. Likewise, when the crosshair is on the bottom of a black mark the value of the hundredth must be odd.

**Notekeeping**

Before starting examples of leveling, it is important to mention the importance of notekeeping in surveying. Figure 4 shows a typical page of notes from a surveying field book. The use of a field book simplifies the process of notekeeping; but it is not a requirement. Notes may be kept on ordinary notebook paper. A field book generally has paper which is water resistant so that your notes aren’t destroyed in the event of rain or snow (or spilled coffee!). This may be an important consideration in the choice of paper for your notes.
Keeping notes in a standard arrangement reduces mistakes and makes it easier for others to interpret the results of your survey. When keeping level notes, the rod readings and other computations are usually kept on the left page, sketches and other relevant information are placed on the right page. The notes shown in Figure 4 follow this format. Additionally, the survey crew members, date, and weather conditions are entered at the top of the right page.

The particulars of entering rod readings and doing computations in the field notes will be discussed in the sections that follow. The data from the example problems shown will be entered into the field notes in columns. This method of notekeeping is easier to follow until the user is more familiar with the procedures and terms used in leveling. Standard surveyors' field notes for the example are shown and discussed in the appendix.

**Elevations and Benchmarks**

The problem of laying a culvert so that water will flow through the culvert is frequently encountered in road construction. Obviously one end of the culvert must be higher than the other since water flows downhill. The concept of elevation is introduced by illustration, water flows from higher elevation to lower elevation. Think of elevation as a height above some reference. For instance, if the floor you are standing on has an elevation of 100.00 feet and you are 6.00 feet tall, the elevation of the top of your head is 106.00 feet (100.00 + 6.00). Elevations increase as you go up, they decrease as you go down.

Since water flows downhill, ultimately to the oceans (seas), the water level of the ocean is a convenient reference for measuring elevations. Elevations are often specified in terms of mean sea level (msl) such as 748.32 feet, msl. This means 748.32 feet above the average surface of the ocean. Using the ocean as a reference level makes it easy to compare elevations between distant places. The highest mountains in Colorado have an elevation of about 14,000 feet, msl. Tippecanoe County, Indiana has an elevation of about 700 feet, msl, some 13,300 feet (2.5 miles!) lower than Colorado's lofty peaks.

The federal government has established points of known elevation across the United States. These points are often monumented with a brass cap marker set in concrete. These points of known elevations are termed "benchmarks". We abbreviate benchmark with BM for use in survey field notes. State, county and city surveyors also may establish other benchmarks for use by surveyors.

Construction projects require the use of elevations for a variety of reasons: to make water flow downhill, to know how deep to cut, to know high to fill, etc. Frequently a temporary benchmark (TBM) is established for a construction project. The temporary benchmark is often nothing more than a nail driven into a power pole or the top of
a fire hydrant. The temporary benchmark is simply a reference to be used for measuring elevations for the duration of the construction project. The temporary benchmark is often assigned an arbitrary elevation of 100.00 feet.

**Measuring Elevation Differences**

Let’s look at an example of a problem frequently encountered in construction which can be solved by leveling. Assume that you want to know the elevation of the invert (flowline) of a culvert. Also assume that you have a benchmark available nearby and that benchmark has an elevation of 100.00. This situation is shown in Figure 3.

The level and level rod are the tools to solve your problem - determining the invert elevation of the culvert. Setup your level approximately midway between the benchmark and the culvert, level it carefully using the vial level (remember the left thumb rule!). Once you have the instrument setup correctly, the line of sight of the instrument (the middle horizontal crosshair you see in the telescope) is horizontal or “level”. The fact that the line of sight is level enables you to determine elevation differences (what is higher or lower than what).

Now, someone holds the level rod on the benchmark and you sight it with the level. Let’s say that your rod reading is 6.25 feet. This means that the instrument is 6.25 feet above the benchmark; the instrument is at a higher elevation than the benchmark. We can now calculate the elevation of the instrument by adding the rod reading to the elevation of the benchmark. The addition looks like this: 100.00 + 6.25 = 106.25. Now that we know the elevation of the instrument, we can use it to determine elevations of other points.

Next the level rod is held on the culvert’s invert and you sight it with the level. Assume that the rod reading is 11.71 feet. The elevation of the culvert’s invert is 11.71 feet below the elevation of the instrument. You can therefore determine the elevation of the invert by subtracting the rod reading from the instrument elevation. The subtraction looks like this: 106.25 - 11.71 = 94.54.

A couple of observations are worth noting here. First, the culvert’s invert is lower than the benchmark. This is determined by looking at the elevations of the invert and the benchmark. Since the invert elevation (94.54 feet) is smaller than the benchmark elevation (100.00 feet), you know the invert is lower that the benchmark. How much lower? Simply subtract the smaller elevation from the larger elevation: 100.00 - 94.54 = 5.46. The invert is 5.46 feet lower than the benchmark.

The second observation worth noting is the rod readings. The rod reading on the benchmark was 6.25 feet while the rod reading on the
invert was 11.71 feet. Even though the invert was lower the rod reading was higher! Don’t forget this: the higher the rod reading, the lower the elevation. Of course, the lower the rod reading, the higher the elevation is also true.

Since it is difficult to remember all of these numbers, we record them as field notes. Let’s look at recording field notes for the situation in Figure 4. First, we place our point of known elevation in the notes. We know the elevation of the benchmark so place it (100.00) down first. Write “BM” next to the benchmark elevation so that we know what the elevation refers to. You can now record the rod readings which you made in the field.

When you take a rod reading on a point of known elevation, you place it below the elevation of the point sighted, in this case the benchmark. Since you had a rod reading of 6.25 feet on the benchmark as shown in Figure 3, place 6.25 below the 100.00. We call the 6.25’ rod reading a “plus sight” or “+S” since we add it to the elevation of the sighted point to determine the elevation of the instrument or “E.I.”. Plus sights are always rod readings on points of known elevation. The addition is performed as shown in Figure 3 (100.00 + 6.25 = 106.25) giving an E.I. of 106.25.

Next you took a rod reading on a point of unknown elevation, the invert of the culvert, so that you could determine its elevation. This rod reading is placed below the E.I. of the current instrument setup. Since the rod reading on the culvert’s invert was 11.71 feet in Figure 3, place 11.71 below the 106.25. The 11.71’ rod reading is called a “minus sight” or “-S” since we subtract it from the instrument elevation to determine the elevation of the unknown point. Minus sights are always rod readings on points of unknown elevation. Perform the subtraction as shown in Figure 3 (106.25 - 11.71 = 94.54) to get the culvert invert elevation of 94.54. Make certain you write “culvert” next to this elevation so you know what it refers to.

The calculations needed in order to calculate elevations of points using leveling are summarized as follows:

Starting Elev. + (+S) = E.I.


The procedure of leveling simply involves performing these two calculations over and over again. The following examples show this.

**Closed Level Loops**

The example shown in Figures 3 and 4 shows how you can determine the elevation of an unknown point from a known point. There are potential pitfalls with this method, however. Suppose you read the rod incorrectly or perhaps you record the rod reading incorrectly in
your field notes. Either of these blunders would cause you to calculate an incorrect elevation for the culvert invert. Unfortunately, you would never know that the elevation was wrong, there is no way of checking whether your work was correct or not. This method of determining elevations is known as an “open” level loop since there are no checks available.

A “closed” level loop is a method of leveling which permits checking of your work so you will have assurance that the elevations determined by your survey are correct. The open level loop illustrated in Figure 3 can be converted into a closed level loop by moving the level to a new setup location and taking another set of rod readings on the culvert and the benchmark. Figure 5 shows the new instrument setup and rod readings.

Let’s continue with the field notes from the Figure 3 situation as we make a closed level loop. The field notes in Figure 6 are for the closed level loop illustrated by Figures 3 and 5. You will notice that the top portion of the field notes in Figure 6 are identical with those shown in Figure 4. Assume now you have moved your instrument to the new setup as shown in Figure 5. Since you have already calculated the invert elevation of the culvert, it is considered known. Therefore, your +S rod reading of 7.48 feet is entered below the culvert elevation. Add this value to the elevation of the invert (94.54) to get the E.I. of the new setup: 94.54 + 7.48 = 102.02.

The rod is then held on the benchmark again and a -S rod reading of 2.01 feet is taken. Even though the elevation of the benchmark is known to be 100.00 feet, we consider this rod reading to be a minus sight for a check on your work. (Assume, for the time being, that you don’t know the elevation of the benchmark). Accordingly, enter this value below the E.I. of the current setup. The check elevation on the benchmark is then calculated by subtracting the rod reading from the current E.I.: 102.02 - 2.01 = 100.01. This is nearly (but not exactly!) the same as the known benchmark elevation. The check elevation is 0.01 feet (100.01 - 100.00) higher than the true elevation of the benchmark. This closure would be acceptable for most work. (If your check elevation is 101.00 feet, you did something wrong.)

Another Closed Loop

The previous example was the most basic type of a closed level loop. Oftentimes it is necessary to determine the elevation of a point which is too far away from a benchmark to be seen, or an obstacle exists which prevents sighting of both the benchmark and point from the same setup. These conditions, and others that may arise in the field, require that a loop containing many setups be run. Figure 7 shows a level loop which contains 4 setups.
It will be shown that the longer level loop of Figure 7 is approached in the same manner as the previous example. The same calculations are repeated. The field notes for this example are shown in Figure 8. You will notice that the column style of notekeeping is also used in this example. The field notes follow the direction of survey shown in Figure 7.

The first instrument setup is such that a level rod held on the benchmark can be seen. The +S on the benchmark is 7.82 feet. This value is added to the benchmark elevation of 491.36 feet (you don’t always have to start at elevation 100.00!) to give an E.I. of 499.18 for the first setup. Since our point of interest, the culvert, couldn’t be seen from the first setup, it was necessary to use a “turning point” or “TP”. A turning point is chosen at a convenient location along the route of the survey. The turning point should be stable so that its elevation doesn’t change and, ideally, it also should have a relatively prominent high point on which the rod should be held.

The rod is held on the first turning point (TP1) and a reading of 4.15 feet is made. This minus sight reading is subtracted from the E.I. of the first setup to give an elevation for TP1 (495.03 feet). The rod person now remains at the turning point while the instrument person moves the level forward to a location where he/she can see both the rod person and the culvert.

Once the instrument is setup and properly leveled, a reading is taken on the rod held on TP1. The rod reading of 2.87 feet is added to the elevation of TP1 to give an E.I. of 497.90 feet for the second setup. The rod is then moved ahead to the invert of the culvert and another rod reading is made. This reading (8.48 feet) is then subtracted from the current E.I. to give an invert elevation of 489.42 feet on the culvert.

Now we have an elevation for the culvert invert, but like the first example, we don’t know if we have made an incorrect rod reading along the way. We must therefore continue our level loop back to the starting point (BM) in order to check our work.

The level is then moved to a new location and setup again. A +S of 8.03 feet is made on the culvert to establish an E.I. of 497.45 feet. Since it is too far (or we can’t see) to the BM, another turning point is chosen. The -S of 8.31 feet on TP2 yields an elevation of 489.14 feet for TP2. The instrument moves forward again, this time to a location where both TP2 and the BM may be seen. After carefully leveling the instrument a +S of 3.42 feet is read on TP2 (the notes are continued at the top of the same page). The E.I. is then calculated to be 492.56 feet for this setup. A -S of 1.22 feet on the BM enables us to calculate an elevation of 491.34 feet for the benchmark.

Comparing the initial (491.36 feet) and final (491.34 feet) elevations of the benchmark tells us how well we surveyed. The difference
between the starting and ending BM elevations is only 0.02 feet. You should probably anticipate a elevation difference of between 0.00 and 0.05 feet for a similar level loop. This indicates that we have probably done a good job. Unless we close the loop we don’t know how well we have done.

The most important thing to do when surveying is to check your work. If you have checked it and it checks properly, you know you have done a good job. More importantly, your work can then be used as a basis to lay a culvert or to grade a ditch. If you don’t check your work, sooner or later it will come back to haunt you. It is much easier to re-run a level loop when you are already setup in the field than it is to explain to your boss why water “runs uphill”!

**Practical Applications**

The basic concepts and mechanics of using a level to determine elevation differences can be used to assist in the replacement of culverts, grading of ditches, or a multitude of other projects. These “advanced” uses of the level are merely a continuation and application of the principles learned earlier. Two specific examples are presented to familiarize the reader with the methods of applying elevation differences to practical problems.

**Culvert Replacement**

The task of replacing a deteriorated or undersized culvert required for passing storm drainage through a road embankment is a frequent problem encountered by road crews. The object is to remove the undesirable culvert and replace it with a suitable pipe. The new culvert should be installed such that it is sloped down in the direction of flow to facilitate the passing of water, debris and sediment. Placing a culvert at an adverse grade (downstream end higher than upstream end) effectively reduces the size of the culvert by causing the deposition of stream transported sediments within the culvert.

It is advantageous to establish a temporary benchmark (TBM) for even a task as simple as this. The reason being is that the pre-construction elevation of the culvert and the adjacent channel flowline can be referenced to the TBM. Should movement of the instrument and tripod be necessary due to equipment movements or end of the workday, the TBM may be re-observed from a new instrument setup location and the original elevations re-established.

There are probably three options available for positioning a new culvert: 1) at the same elevation and slope as the old pipe; 2) at a different slope than the old pipe without regard to the adjacent stream or ditch channel; or 3) at a slope which is consistent with the adjacent channel. The first option is probably the simplest and probably the most often used, though it may not be the best method. This option
simply requires that the flowline elevation at both ends of the existing pipe be determined using a level, the old pipe is removed and the new pipe is placed using the same elevations as the old pipe.

The second option considers the slope of the new pipe thereby ensuring that the culvert will facilitate the passage of water. Ideally the county engineer has designed the culvert and specified the pipe size and slope necessary to handle the anticipated flow of water in the stream or ditch. Since it is often the case that a culvert hasn’t been designed, the culvert should be laid at a slope of one to two percent, if possible. A 1% slope means that there should be 0.1 feet of fall in a 10 foot length of culvert. A 2% slope is 0.2 feet of fall in a 10 foot culvert. Therefore, a 50 foot culvert with a 2% slope should have a total fall of 1.0 foot (0.2 x 5) from inlet to outlet.

Laying a culvert using the second option requires knowledge of the culvert length so that the fall in the pipe may be calculated. Once the fall is known, the outlet end of the pipe may be placed at the elevation dictated by the site conditions. The inlet end of the pipe is positioned such that the proper fall is present in the culvert. Care must be taken when using the second option to avoid having undesirable inlet or outlet conditions which may lead to ponding of water or erosion of the channel. These conditions may arise when there isn’t enough fall in the existing channel.

Culvert replacement using the second method is illustrated in Figure 9. An existing culvert under a road requires replacement. The new culvert is to have the same outlet flowline (invert) elevation as the existing pipe; however, the slope of the new pipe is to be 0.2 feet per 10 feet of culvert length. Additionally, we want to place one-half (0.5) foot of pipe bedding material under the new culvert as shown in the detail in the figure. A temporary bench mark is established on the fire hydrant as shown and road readings are taken on the TBM and on the invert at the culvert inlet and outlet. The field notes for this operation are shown in Figure 10.

The field notes are organized in columns to increase their efficiency. The elevation of the instrument (E.I.) is established by adding the rod reading (+S) on the TBM to the TBM elevation as shown on the top of the left sheet of the notes. Headings for the various columns come next. Choose column headings which briefly describe the information contained in the column. The “Location” heading contains a description about where the rod was held. Notice that the culvert length of 60’ was placed in parenthesis between the two location descriptions. The “Flowline” column is used to tabulate the rod readings at flowline locations on the old culvert. The “Elev.” column is used for the calculated flowline elevations, determined by subtracting the rod readings from the E.I.
The “Grade” column is for tabulation of the computed grade elevations for the new culvert. We use the term “grade” for the desired elevation of the culvert. When the culvert is “at grade”, it is at the proper elevation. Since we must maintain the invert elevation of the old culvert’s outlet, we transfer the value from the elevation column (95.76) to the grade column. The grade of the new culvert’s inlet flowline must be calculated. We know that the required slope for the new culvert is 0.2 feet per 10 feet of length. Since we have a 60 foot culvert, we have 6 times 10 feet of length. The fall through the pipe must be 6 times 0.2 feet or 1.2 feet. Since the inlet of the new pipe must be higher than the outlet, we add the 1.2 feet to the outlet grade to yield the inlet grade (96.96).

The “Rod at Invert” column gives the rod reading which will be sighted when the new culvert is at grade. The rod reading is obtained by subtracting the grade from the E.I. The “Rod at Subgrade” column gives the rod reading when the excavated subgrade elevation is 0.5 feet below the culvert flowline. This will permit placement of adequate bedding material. These rod readings are obtained by adding 0.5 feet to the values in the invert rod column. This problem could also be performed using rod readings alone, without the calculation of existing or grade elevations. The approach is essentially the same and requires fewer calculations.

Probably the most desirable method of culvert replacement is the third option. This method also requires the most amount of surveying and computation but the results are worth the additional effort. This method is described in detail in Appendix B.

**Ditch Grading**

Leveling techniques are essential to properly grading a ditch. This holds for the construction of new ditches and cleaning existing ditches. The use of construction staking for marking the desired elevation for a ditch flowline ensures that the ditch will be graded properly and economically.

Figure 11 shows a typical problem encountered in road maintenance, grading (cleaning) a ditch between two culverts. The requirement is that the ditch be graded on a uniform slope between the two culverts. This task is often performed by an operator using a “seat of the pants” technique. The ditch is graded until it “looks about right”! More efficient use of personnel and equipment can be made if the ditch is surveyed and staked prior to the start of the grading operation.

The staking procedure begins by setting offset stakes on the bank of the ditch. The offset may be a uniform distance from the centerline of the ditch or it may be a random distance. The uniform distance offset is most useful when a new ditch is being constructed. However the offset stakes are set, they should be placed where they will be
least likely to be disturbed by equipment. The stakes should also be set at some uniform spacing (typically 50 feet) starting from either end of the ditch section to be graded.

Once the stakes are set it is necessary to determine the elevation of the top of the stakes and of the existing ditch flowline opposite the stakes (existing ground if a new ditch). Figure 12 is a set of field notes for the ditch grading problem of Figure 11. The elevation of the instrument is first determined by taking a rod reading (+S) on the TBM. Rod readings (-S) taken on the ditch flowline and the stakes are recorded in the proper column in the row corresponding to the distance along the ditch.

Note that rod readings on the ground (flowline) are taken to the nearest 0.1 feet only while those on the stakes are recorded to the nearest 0.01 feet. Why the variation? Typically rod readings made on the ground surface are read to the nearest tenth only due to the irregular nature of the ground. Moving the rod a few inches or placing more weight on the rod may change the rod reading by a few hundredths, thus the reading is made to the nearest tenth. Rod readings made on solid surfaces such as pipes, sidewalks and curbs are made to the nearest hundredth because these surfaces are generally regular and not likely to change in elevation.

The elevation of the flowline points and the stakes are computed by subtracting the rod readings from the E.I. The elevation of the flowline is computed only to the nearest tenth. The top of stake elevation is computed to the nearest hundredth.

We must now perform a few calculations in order to determine a constant slope for the ditch flowline. We use the term “grade” here for the finished elevation of the ditch flowline. Since the two culverts are fixed in position and don’t vary in elevation (unless replaced), we will assume that they define the finish grade at both ends of the ditch. Knowing the distance between the culverts, we can calculate the slope of the ditch, and the change in grade along the ditch.

Figure 13 shows the field notes of the previous figure with the addition of computed grading information. Since we are going to use the culverts as grade, we place their invert elevations in the grade column of the field notes. We must then calculate what the change in grade will be for each 50 feet length of ditch. The formula shown below the field notes in Figure 13 may be used for this purpose. The formula says that we must subtract the ending grade (culvert #2 invert elev.) from the starting grade (culvert #1 invert elev.), divide by the total ditch length and multiply by the distance between the offset stakes.

The calculation of the change in grade for this example is shown in Figure 13. The change in grade is 0.29 feet per stake, in other words, the ditch must fall 0.29 feet for every 50 feet of its length. The grade
at each stake location can be calculated knowing this change in grade. Since the grade at culvert #1 is higher than the grade at culvert #2, we must subtract the change in grade value from the grade at culvert #1. The grade at the first stake (50 feet from culvert #1) is then calculated to be 100.49 feet (100.78 - 0.29 = 100.49). The grade at the second stake (50 feet from the first stake) is calculated in a similar manner (100.49 - 0.29 = 100.20). The grade at the remaining stakes is calculated in the same way.

Once the desired grade has been calculated the cut or fill to the grade can be calculated both from the existing flowline and, more importantly, from the top of the stake. “Cut” means that material (dirt or debris) must be removed in order to reach grade. “Fill” means that material must be added to reach grade.

To calculate the cut or fill compare the elevation of either the flowline or stake with the grade. If the grade is less than the flowline or stake elevation, subtract the grade from the flowline or stake elevation and label it “C” for cut. If the grade is greater than the flowline elevation (it should never be greater than the stake elevation for a ditch), subtract the flowline elevation from the grade and label it “F” for fill. A fill within a ditch may not make sense since flow isn’t inhibited by a low spot in the ditch; therefore, small depressions may not actually be filled unless it is necessary to “waste” material.

The cuts and fills for the stake locations are shown in Figure 13. Look at the 100 foot station location. The existing flowline elevation is 100.7, the grade is 100.2 (rounded off from 100.20). Since the flowline elevation is larger, subtract the grade from it (100.7 - 100.2 = 0.5). The result is a cut of 0.5 feet, noted “C0.5” in the field notes. The cut from the top of the stake is computed in the same manner (102.51 - 100.20 = 2.31) to yield a cut of 2.31 feet or rounded to 2.3 feet. The stake should then be marked "C2.3".

It is worth mentioning the interesting situation which exists at the 150 foot location. The grade is 0.3 feet above the flowline elevation so there is a fill of 0.3 feet as noted. The grade is below the stake top so there is a cut as noted by "C1.9" in the field notes which should also be marked on the stake. It seems strange that there exists a fill and a cut at the same stake location, but careful examination of the situation confirms that it is logical. Ultimately the stake will control the grading operation and the fill from the flowline can essentially be disregarded.

Once the ditch has been surveyed with offset stakes it is useful to mark the stakes with the calculated cut to the ditch grade. One person can then use the stakes to guide the grading operation using a simple string level which may be purchased at a hardware store. This makes it possible for an operator to dig or clean the ditch to grade alone.
Figure 14 shows a detail of the ditch cross-section at the 200 foot stake. The field notes show a cut of 0.2 feet from the existing flowline to grade and a 1.9 feet cut from the top of the stake to grade. One person can check the ditch grading by the technique illustrated. A thumbtack or a nail may be used for holding the string on the top of the stake. The string level is hung on the string and the string is held level by observing the string level. The rod is held alongside the string and the rod reading is observed and compared with the cut value marked on the stake. The ditch is graded (cut in this situation) until the rod reading denoted by the level string equals the cut marked on the stake. The stake in Figure 14 would be marked “C1.9” indicating that approximately 0.2 feet must be cut to make the rod reading equal to 1.9 feet.

This simple technique using the string level can be performed by a single person, typically the operator. Two persons can stake and survey a few hundred feet of ditch in an hour or two. If this is done prior to commencement of the ditch grading, the operator can grade the ditch quickly and efficiently without the need for other persons. This method of surveying before grading may result in time and manpower savings over ditch grading procedures now employed.
Rod Reading = 6.25
(+S)

Elevation of Instrument = 106.25' (E.I.)

6.25'

Elev. = 100.00'

BM

11.71'

Culvert

Invert Elev. = 94.54'

Rod Reading = 11.71
(-S)

HERPICC
LEVELING WORKSHOP

USING A LEVEL TO
DETERMINE ELEVATION

8/93 Figure 3
<table>
<thead>
<tr>
<th>BM</th>
<th>100.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.I.</td>
<td>106.25</td>
</tr>
<tr>
<td>Culvert Invert</td>
<td>94.54</td>
</tr>
<tr>
<td>(+S)</td>
<td>6.25</td>
</tr>
<tr>
<td>(-S)</td>
<td>11.71</td>
</tr>
</tbody>
</table>

Example field notes for Figure 3:
This is an "open" level loop.

HERPCC LEVELING WORKSHOP
SAMPLE LEVEL NOTES
OPEN LEVEL LOOP
8/93 Figure 4
<table>
<thead>
<tr>
<th>R. Miller Jones</th>
<th>8/29/93</th>
<th>8/30/93</th>
<th>HERPICC LEVELING WORKSHOP</th>
<th>SAMPLE LEVEL NOTES CLOSED LEVEL LOOP</th>
<th>8/93 Figure 6</th>
</tr>
</thead>
</table>

This portion of the field notes are identical to Figure 4.

Example field notes for Figure B:

This makes a "closed" level loop.

<table>
<thead>
<tr>
<th>BM</th>
<th>(+S)</th>
<th>E.I.</th>
<th>Culvert Invert</th>
<th>(+S)</th>
<th>E.I.</th>
<th>Culvert Invert</th>
<th>BM</th>
</tr>
</thead>
<tbody>
<tr>
<td>100.00</td>
<td>+6.25</td>
<td>-11.71</td>
<td>94.54</td>
<td>+7.48</td>
<td>-2.01</td>
<td>100.01</td>
<td></td>
</tr>
</tbody>
</table>

| 106.25 | - | 94.54 | 102.02 | - | 100.01 |
HERPICC
LEVELING WORKSHOP
EXAMPLE OF A CLOSED LEVEL LOOP
8/93 Figure 7
<table>
<thead>
<tr>
<th></th>
<th>BM</th>
<th></th>
<th>TP2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>491.36</strong></td>
<td></td>
<td>489.14</td>
<td></td>
</tr>
<tr>
<td><strong>+ 7.82 (+S)</strong></td>
<td></td>
<td><strong>+ 3.42 (+S)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>499.18</strong></td>
<td>E.I.</td>
<td>492.56</td>
<td>E.I.</td>
</tr>
<tr>
<td><strong>- 4.15 (-S)</strong></td>
<td></td>
<td><strong>- 1.22 (-S)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>495.03</strong></td>
<td>TP1</td>
<td>491.34</td>
<td>BM</td>
</tr>
<tr>
<td><strong>495.03</strong></td>
<td>TP1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>+ 2.87 (+S)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>497.90</strong></td>
<td>E.I.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>- 8.48 (-S)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>489.42</strong></td>
<td>Culvert</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>489.42</strong></td>
<td>Culvert</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>+ 8.03 (+S)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>497.45</strong></td>
<td>E.I.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>- 8.31 (-S)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>489.14</strong></td>
<td>TP2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example of "Column" type field notes for a closed level loop. See Figure 7

HERPICC
LEVELING WORKSHOP
SAMPLE FIELD NOTES
CLOSED LEVEL LOOP
8/93 Figure 8
Example field notes for Figure 9.

<table>
<thead>
<tr>
<th>Location</th>
<th>Flowline</th>
<th>Elev.</th>
<th>Grade</th>
<th>Rod at Invert</th>
<th>Rod at Subgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culvert Inlet</td>
<td>5.86</td>
<td>96.61</td>
<td>96.96</td>
<td>5.51</td>
<td>6.01</td>
</tr>
<tr>
<td>(60°)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert Outlet</td>
<td>6.71</td>
<td>95.76</td>
<td>95.76</td>
<td>6.71</td>
<td>7.21</td>
</tr>
</tbody>
</table>

HERPCC
LEVELING WORKSHOP
SAMPLE LEVEL NOTES
CULVERT REPLACEMENT
10/93 Figure 10
- TBM - Spike in Power Pole
  Elev. 100.00

E.I. = 105.96

Survey Stake

Top of Ditch Bank

Existing Ditch Flowline

Culvert #1

Culvert #2

50'

50'

50'

4.46

(-5)

17.8
Example field notes for Figure 11.

<table>
<thead>
<tr>
<th>Distance</th>
<th>Flowline</th>
<th>Elev.</th>
<th>Grade</th>
<th>Stake</th>
<th>Elev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0'</td>
<td>5.1</td>
<td>100.78</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50'</td>
<td>5.2</td>
<td>100.8</td>
<td>2.87</td>
<td>103.09</td>
<td></td>
</tr>
<tr>
<td>100'</td>
<td>5.3</td>
<td>100.7</td>
<td>3.45</td>
<td>102.51</td>
<td></td>
</tr>
<tr>
<td>150'</td>
<td>6.4</td>
<td>99.6</td>
<td>4.11</td>
<td>101.85</td>
<td></td>
</tr>
<tr>
<td>200'</td>
<td>6.2</td>
<td>99.8</td>
<td>4.46</td>
<td>101.50</td>
<td></td>
</tr>
<tr>
<td>250'</td>
<td>6.3</td>
<td>99.7</td>
<td>4.31</td>
<td>101.65</td>
<td></td>
</tr>
<tr>
<td>300'</td>
<td>6.8</td>
<td>99.2</td>
<td>4.48</td>
<td>101.48</td>
<td></td>
</tr>
<tr>
<td>Culvert #2</td>
<td>7.03</td>
<td>98.93</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Ditch grading field notes for Figure 11.

<table>
<thead>
<tr>
<th>Distance</th>
<th>Flowline</th>
<th>Elev.</th>
<th>Grade</th>
<th>Stake</th>
<th>Elev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0'</td>
<td>5.18</td>
<td>100.78</td>
<td>100.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50'</td>
<td>5.2</td>
<td>100.8</td>
<td>100.49</td>
<td>2.87</td>
<td>103.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>C0.3</td>
<td></td>
<td>C2.60</td>
</tr>
<tr>
<td>100'</td>
<td>5.3</td>
<td>100.7</td>
<td>100.20</td>
<td>3.45</td>
<td>102.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>C0.5</td>
<td></td>
<td>C2.31</td>
</tr>
<tr>
<td>150'</td>
<td>6.4</td>
<td>99.6</td>
<td>99.91</td>
<td>4.11</td>
<td>101.85</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>F0.3</td>
<td></td>
<td>C1.94</td>
</tr>
<tr>
<td>200'</td>
<td>6.2</td>
<td>99.8</td>
<td>99.62</td>
<td>4.46</td>
<td>101.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>C0.2</td>
<td></td>
<td>C1.88</td>
</tr>
<tr>
<td>250'</td>
<td>6.3</td>
<td>99.7</td>
<td>99.32</td>
<td>4.31</td>
<td>101.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>C0.4</td>
<td></td>
<td>C2.33</td>
</tr>
<tr>
<td>300'</td>
<td>6.8</td>
<td>99.2</td>
<td>99.03</td>
<td>4.48</td>
<td>101.48</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>C0.2</td>
<td></td>
<td>C2.45</td>
</tr>
</tbody>
</table>

Culvert #2

100.00  
105.96  

E.I.

R. Miller  
S. Jones  
10/25/93  
Cloudy, 50'

\[
\text{Change in Grade} = \frac{\text{Starting Grade} - \text{Ending Grade}}{\text{Total Ditch Length}} \times \text{Distance Between Stakes}
\]

\[
\text{Change in Grade} = \frac{100.78 - 98.93}{317.8'} \times 50'
\]

\[
\text{Change in Grade} = 0.29' \text{ per stoke}
\]
Appendix A

Survey Noteforms

The purpose of this appendix is to introduce the reader to methods of notekeeping typically used by surveyors. These noteforms allow the surveyor to keep notes neatly and clearly. Another surveyor can pick up the field book at a later date and understand what the notes represent. The column style of notekeeping shown earlier in this paper tends to get cluttered and, therefore, hard to follow.

We use abbreviations in our field notes because page space is so limited. Look at the column headings on the left page in Figure A1. The "Pt." abbreviation stands for point, what it is you are looking at with the level. The "+S" abbreviation stands for the "plus sight" or the rod reading on a point of known elevation. The "E.I." abbreviation stands for the elevation of the instrument. The "-S" abbreviation stands for the "minus sight" or the rod reading on a point of unknown elevation. The "Elev." abbreviation stands for the elevation of the point named in the "Pt." column. Finally, the "Desc." abbreviation stands for a description of the named point.

The notes shown in Figure A1 come from the situations shown in Figures 3 and 5 of this booklet. The upper notes in Figure A1 are for the situation of Figure 3 only. This will be discussed first. First, we place our point of known elevation in the notes. (The order in which we take notes is denoted by the circled numbers in Figure 3 and bracketed numbers in the text). Write "BM" in the "Pt." column since the point is a benchmark. We know the elevation of the benchmark so place it (100.00) in the "Elev." column [1]. Also, place a description of the benchmark (assume it is a spike) in the "Desc." column. You can now record the rod readings which you made in the field.

When you take a rod reading on a point of known elevation, you place it in the +S column on the same line as the sighted point. Since you had a rod reading of 6.25 feet on the benchmark as shown in Figure 3, place 6.25 in the +S column on the "BM" line [2]. The abbreviations +S and -S are chosen because they instruct you what to do with the rod readings. Add the Elev. of the sighted point to the +S rod reading made on the point to obtain the E.I. or elevation the instrument: Elev. + (+S) = E.I. Use numbers as you previously did: 100.00 + 6.25 = 106.25. The E.I. value is then placed in the proper column on the line below the sighted point [3].

Next you took a rod reading on a point of unknown elevation, the invert of the culvert, so that you could determine its elevation. This rod reading is placed in the -S column on the line below the E.I. of the current setup [4]. Make certain you enter the point name (culvert in this case) and its description (invert) on the line below the E.I. The
elevation of the culvert is then determined by subtracting the -S rod reading from the E.I. like this: E.I. - (-S) = Elev. Using the numbers from Figure 3: 106.25 - 11.71 = 94.54. Enter the value of the elevation in the Elev. column on the line of the point sighted [5].

The lower notes in Figure A1 are for the closed loop depicted in Figures 3 and 5. The first part of these notes (from the BM to the culvert) is identical to the above example. The last part of the notes come from the values shown in Figure 5. The +S of 7.48 feet read on the culvert invert is placed on the same line as the culvert [6]. This value is added to the elevation of the culvert to give an E.I. of 102.02 feet [7]. The -S of 2.01 feet on the BM [8] allows calculation of its elevation (100.01 feet) [9] and a check on the work.

Figure A2 contains field notes for the level loop shown in Figure 7. Notice that the organization of the field notes aids in the computations of elevations during your survey. Always remember to keep your notes in pencil, it doesn’t run in the rain!
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BM</td>
<td>7.82</td>
<td></td>
<td></td>
<td>491.36</td>
<td>Brass cap</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>499.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TP1</td>
<td>2.87</td>
<td>4.15</td>
<td>495.03</td>
<td>SW Cor. Slab</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>497.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert</td>
<td>8.03</td>
<td>8.48</td>
<td>489.42</td>
<td>Invert</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>497.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TP2</td>
<td>3.42</td>
<td>8.31</td>
<td>489.14</td>
<td>Manhole</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>492.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BM</td>
<td></td>
<td>1.22</td>
<td>491.34</td>
<td>Brass cap</td>
<td></td>
</tr>
</tbody>
</table>

This is another example of a closed level loop. See Figure 7.

HERPCIC
LEVELING WORKSHOP
SAMPLE NOTES
CLOSED LEVEL LOOP
8/93 Figure A2
Appendix B

Culvert Replacement Using Ditch Slope

This appendix explains how to replace a culvert using the slope of the adjacent ditch for determining the culvert’s slope.

Once the TBM has been established determine the invert elevation of both ends of the existing culvert. It is also necessary to determine the elevation of the channel flowline at locations 50 and 100 feet upstream and downstream from the culvert in order to determine the existing channel slope which will then be used for the new culvert.

Figure B1 shows a typical situation where an existing, deteriorated culvert is to be replaced with a new pipe. A TBM is established using the top nut of a nearby fire hydrant, the elevation of the TBM is assumed to be 100.00. A level is set up at a location where all points of interest may be observed. Rod readings are then taken at the inlet and outlet of the culvert and at points 50 and 100 feet upstream and downstream.

Field notes for the culvert replacement observations are shown in Figure B2. Note that the elevation of the instrument is determined at the top of the page using the +S to the TBM. The -S rod readings are placed in a single column in the row corresponding to the rod location. Elevations for each rod location are determined by subtracting the rod reading (-S) from the E.I. Notice that there are no checks on the rod readings or the computed elevations. A check could be provided by moving the level to a new location and re-observing the rod at each location.

The rod readings taken in the ditch upstream and downstream of the culvert allow us to determine the culvert slope which will be equal to the ditch slope. This will allow for a reasonable transition from the ditch to the culvert inlet and from the culvert outlet to the ditch again in the absence of an engineered culvert. The field notes in Figure B3 are the same as those shown in Figure B2 with additional data for determining the culvert inlet and outlet invert elevations.

The ditch flowline elevations at the points 100 feet upstream and downstream from the culvert are going to be held as the grade. These elevations are then transferred into the “Grade” column of the field notes as shown. Since these locations are at grade, there is no cut or fill so 0.0 is placed in the “C/F” (Cut/Fill) column.

The change in grade per foot of ditch length can be calculated using the formula at the bottom of Figure 11. For the example shown the change in grade is 0.0042 feet per foot of ditch length. Write this value down or store it in the memory of your calculator so that you can use it again. Knowing the change in grade per foot we can
calculate the change in grade for any ditch length we desire by multiplying the ditch length by the change in grade per foot.

Since we know the grade at a location 100 feet upstream from the culvert, we should calculate it for the 50 foot upstream location. To do this, multiply 50 feet times the change in grade per foot (50 x 0.0042 = 0.21) and we get 0.21 feet. Now subtract this amount for every 50 feet we move downstream from the starting point at 100 feet upstream. The grade at 50 feet upstream is then 99.9 - 0.21 = 99.69. The grade at the culvert inlet is 99.69 - 0.21 = 99.48.

Since the culvert is only 40 feet long we need to calculate the change in grade for a 40 foot length of ditch. We do this in a similar manner as we did previously, 40 x 0.0042 = 0.17 feet. The grade at the culvert outlet is then 99.48 - 0.17 = 99.31. Finally we can calculate the grade 50 feet downstream from the culvert by 99.31 - 0.21 = 99.10. Notice that we used the change in grade for 50 feet of ditch (0.21).

After computing the grades we can calculate the cut or fill to the grade from the flowline elevation. The calculated cut or fill value should then be placed in the “C/F” column. Examine the values in the “C/F” column. None of them should be very large (greater than about 0.3 feet). If there are large values check your calculations. If your calculations are correct, you may need to choose different points for your starting and ending grades. It may be okay to use the points 50 feet upstream and downstream of the culvert for the starting and ending grades. It may be necessary to go farther upstream and/or downstream.
Example field notes for Figure B1.

<table>
<thead>
<tr>
<th>Location</th>
<th>Flowline</th>
<th>Elev.</th>
<th>Grade</th>
<th>C/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>100' Upstream</td>
<td>2.6</td>
<td>99.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50' Upstream</td>
<td>2.8</td>
<td>99.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert Inlet</td>
<td>3.02</td>
<td>99.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert Outlet</td>
<td>3.14</td>
<td>99.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50' Downstream</td>
<td>3.3</td>
<td>99.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100' Downstream</td>
<td>3.6</td>
<td>98.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R. Miller  
S. Jones  
10/25/93  
Cloudy, 55°

HERPICC LEVELING WORKSHOP
SAMPLE LEVEL NOTES
CULVERT REPLACEMENT
10/93 Figure B2
Example culvert replacement field notes for Figure B1.

<table>
<thead>
<tr>
<th>Location</th>
<th>Flowline</th>
<th>Elev.</th>
<th>Grade</th>
<th>C/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>100' Upstream</td>
<td>2.6</td>
<td>99.9</td>
<td>99.9</td>
<td>0.0</td>
</tr>
<tr>
<td>50' Upstream</td>
<td>2.8</td>
<td>99.7</td>
<td>99.69</td>
<td>0.0</td>
</tr>
<tr>
<td>Culvert Inlet</td>
<td>3.02</td>
<td>99.45</td>
<td>99.48</td>
<td>F0.03</td>
</tr>
<tr>
<td>(40')</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert Outlet</td>
<td>3.14</td>
<td>99.33</td>
<td>99.31</td>
<td>C0.02</td>
</tr>
<tr>
<td>50' Downstream</td>
<td>3.3</td>
<td>99.2</td>
<td>99.10</td>
<td>C0.1</td>
</tr>
<tr>
<td>100' Downstream</td>
<td>3.6</td>
<td>98.9</td>
<td>98.9</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Change in Grade (per foot) = \( \frac{\text{Starting Grade} - \text{Ending Grade}}{\text{Total Ditch Length}} \)

Change in Grade (per foot) = \( \frac{99.9 - 98.9}{240'} \) = 0.0042' per foot

Change in Grade (desired distance) = Change in Grade (per foot) * Desired Distance

Change in Grade (50') = 0.0042' * 50 = 0.21'
1. Replace existing culvert with new pipe.
2. Maintain inlet invert elevation of existing culvert.
3. Must have 0.1 feet of fall per 10 feet of length.
4. Must subexcavate for 0.5 feet of pipe bedding.
5. Determine rod readings for subgrade at inlet and outlet.
6. Determine rod readings for new culvert at inlet and outlet.

<table>
<thead>
<tr>
<th>Location</th>
<th>Ex. Culv. Invert</th>
<th>New Culvert Invert Subgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culvert Inlet</td>
<td>7.23</td>
<td></td>
</tr>
<tr>
<td>(55')</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert Outlet</td>
<td>7.59</td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>Flowline</td>
<td>Grade</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td>0'</td>
<td></td>
<td>3.42</td>
</tr>
<tr>
<td>50'</td>
<td></td>
<td>4.5</td>
</tr>
<tr>
<td>100'</td>
<td></td>
<td>3.3</td>
</tr>
<tr>
<td>150'</td>
<td></td>
<td>4.3</td>
</tr>
<tr>
<td>Culvert #2 200'</td>
<td></td>
<td>5.02</td>
</tr>
</tbody>
</table>

**Change in Grade** = \( \frac{\text{Starting Grade} - \text{Ending Grade}}{\text{Total Ditch Length}} \)

- Distance Between Stakes

**R. Miller**
**S. Jones**
11/25/93
Cloudy, 55°

**HERPICC LEVELING WORKSHOP**

**LEVEL NOTES FOR DITCH GRADING**

11/93 | Problem 3b
HERPICC

In Cooperation with

Indiana Counties

Indiana Cities and Towns

Indiana Department of Transportation

Federal Highway Administration