

THE PRECISE DETERMINATION OF
ELEVATION OF BENCH MARKS
ON MICHIGAN STATE COLLEGE
CAMPUS AND VICINITY
THESIS FOR THE DEGREE OF B. S.

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ELEVATION OF BENCH MARKS
ON MICHIGAN STATE COLLEGE
CAMPUS AND VICINITY . . .

A Thesis Submitted to
The Faculty of
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By

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THESIS

P R E F A C E

This thesis is a practical problem selected by us to further our knowledge of Precise Leveling

Our principal source of information has been the reports of the United States Coast and Geodetic Survey, and in our field observations and computations, we have attempted to conform strictly to the methods used by this organization.

SLIP SHEET
MATERIAL
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INTRODUCTION

In past years many bench-marks have been placed about the campus and farms of Michigan State College for the use of the engineering students and the Building and Grounds Department, their elevations being based on the Government bench on the Michigan Central Depot in Lansing. However, most of the earlier ones have been lost or destroyed, or their reference marks removed in the process of improving the campus. Many of those left are hard to locate when the ground is covered with snow, or are inconveniently placed on buildings, making their use by the Building and Grounds Department unduly expensive.

This eventually led to the problem of setting several monuments in readily located and easily accessible positions, and the precise determination of their elevations. Our part of the problem was to aid in selecting the positions of the monuments, to determine their exact elevation, to check the elevation of all existing bench-marks about the campus, and to establish new ones on bridges and buildings that might be conveniently near the line of levels.

PRECISE LEVELING

Precise Leveling is the geodetic art of establishing with great precision the elevation above sea level of a few points far inland to furnish a control for all elevations in that region. It differs from ordinary leveling in that certain refinements are introduced into the methods used and into the construction of the instruments. Its relation to ordinary leveling is that of a general control of the accuracy of the work.

The datum plane, sea level, is taken as the mean level of the water as found by averaging the records, taken over a period of years, of automatic tide gauges. The United States Coast and Geodetic Survey, which has done most of the precise leveling in the United States has taken the mean elevations of the Atlantic and Pacific oceans and the Gulf of Mexico as the same in order to avoid the confusion that would result from using a different base for various sections of the country.

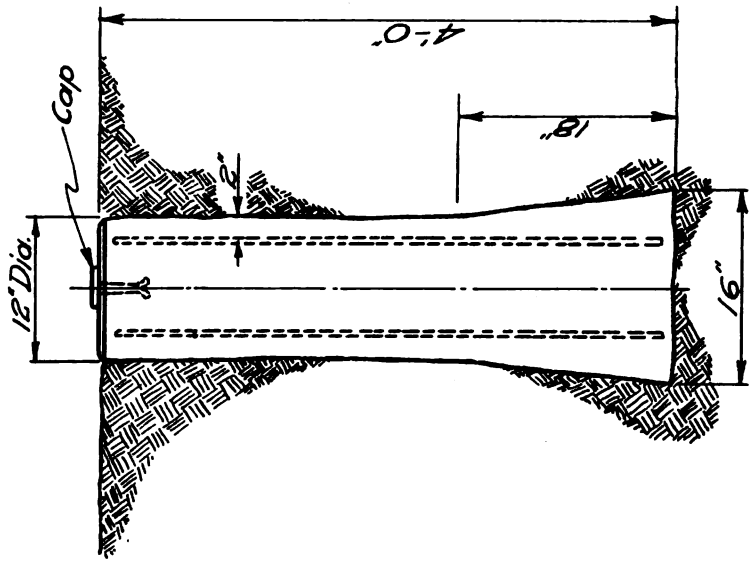
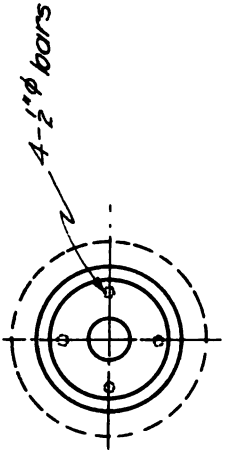
This organization has covered the United States and its possessions with a network of level lines and has established bench-marks at frequent intervals along them. The elevation and description of these bench-marks can be obtained from the published reports.

BENCH MARKS

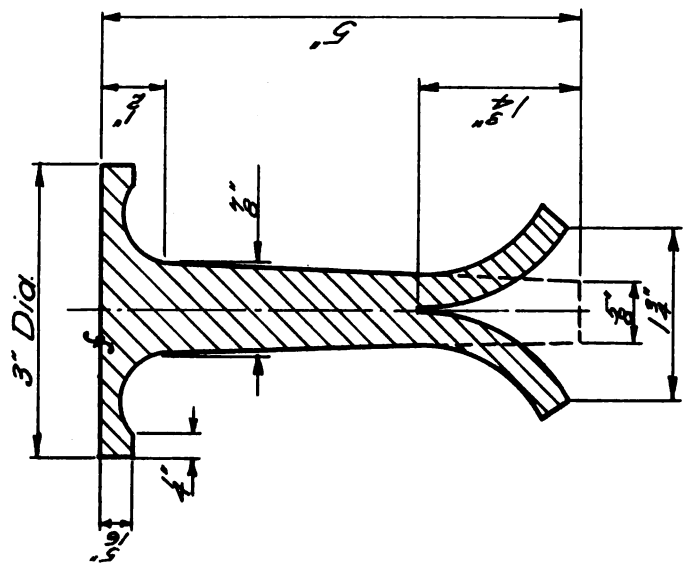
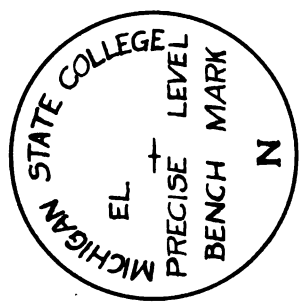
The value of a line of levels depends upon the distribution and permanency of the bench-marks. They are the only visible evidence and useful record of the work. Therefore, they should be of substantial character and in locations where they will be free from the usual causes of disturbance.

The Buildings and Grounds Department of the College set monuments of a permanent nature at points about the campus where bench-marks were needed. These monuments consist of a concrete post about twelve inches in diameter and four feet long, the lower one and one half feet flaring out to a diameter of sixteen inches. A brass cap three inches in diameter and five-sixteenths inches thick with a five inch stem was set in the top of this post. The lower one and three-quarters inches of the cap stem was split and the halves spread to a distance of about one and three-quarters inches, thus ensuring a very firmly set cap.

The post was formed by digging a hole of proper dimensions in undisturbed soil and filling it with rich concrete. For reinforcement, four one-half inch steel bars were used in each monument. The four foot depth puts the base of the post well below the frost line for this region, and the flaring butt adds to the stability of the post. Each monument was later stamped with its letter and



MONUMENT
(Poured in Place)



CAP DETAIL
(Material: Brass)

elevation in feet.

While these monuments were not constructed according to the recommendations of the U.S. Coast and Geodetic Survey, they undoubtedly are of a very permanent nature, due to the reinforcement used and the flaring butt below the frost line. They should have been precast and then set in a concrete footing placed below the frost line. This would ensure smooth surfaces through the frost section, thus eliminating the possibility of heaving due to frost action.

Other bench-marks were established on convenient bridges adjacent to the line of levels, the exact point being marked by a square chipped in the concrete structure.

THE INSTRUMENT

The instrument used is one known as the Coast Survey Level which was designed by the United States Coast and Geodetic Survey and adopted for use in 1900. Its design and the method of observing was the result of a series of exhaustive tests and careful study in an attempt to make an instrument of great precision combined with ease of operation and durability of construction. The work was so well done that for thirty years the instrument has remained unchanged except for unimportant details, and with it the most rapid, precise and economical leveling is done at the present time.

The Coast Survey Level is of the dumpy type with a three screw base. The bubble tube is set in an opening cut in the top of the telescope so as to reduce the distance between the axis of the bubble and the line of collimation to a minimum. This practically eliminates the effect of temperature changes on the parallelism of the axis of the bubble and the line of sight. The telescope and its inserted bubble tube are placed in a tube shaped support at one end of which two pivot screws provide a horizontal axis for the support of the telescope at a point a few centimeters behind the object lens. A micrometer screw in the other end of the tube furnishes the support for the eyepiece end and provides the necessary adjustment for making the line of sight exactly horizontal. The tube gives the



PLATE 2- Coast Survey Level

strongest and lightest form of support and also serves as protection for the telescope mounted in it.

The device for observing the bubble consists of a pair of prisms mounted in a tube parallel with and about two and one half inches to the left of the telescope, and a mirror set above the bubble tube in a position to reflect the image of the bubble to the prisms. The distance between the two prisms can be varied so that both ends of the bubble can be made visible to the observer. This device permits him to see either the bubble or the rod by merely shifting his attention from one to the other.

The base of the instrument is of the three screw type and cast in a single piece of hard fine-grained cast iron. The legs at a radial distance of nine centimeters are threaded for foot screws, are split and provided with clamping screws for clamping the foot screws in place. The center of the base has an unusually long conical bore which affords a good bearing for the center post of high grade tool steel. The supporting tube is fastened to a cast iron disc riveted to the upper end of this center post.

To eliminate as far as possible the effect of temperature changes on the accuracy of the instrument, the telescope, the support tube, the bubble vial support, and the reticle ring are made of a nickel-cast iron alloy which has a coefficient of expansion of .00004 per degree centigrade. The telescope pivot screws, the micrometer screw, and the screws holding the reticle ring and level tube in

place are made of a harder nickel-steel alloy which has a coefficient of expansion of .000021 per degree centigrade. The exposed cast parts are covered with a coating of cloth dust giving a desirable finish and affording considerable protection against sudden and temporary changes in temperature.

The main points in the construction of the level are:

1. The telescope is not reversible which makes the instrument the simplest possible. The bubble tube is fixed with respect to the telescope except for the small change provided for adjustment and is set as close to the line of sight as possible to minimize the effect of temperature changes.
2. The device for observing the bubble and the height of the tripod enables the observer to stand erect and see either the bubble or rod by merely shifting his attention from one to the other.
3. The design and materials used in the instrument greatly reduce errors in observation due to changes in relative temperature of different parts of the instrument.

A detailed description of this instrument is given in the U.S. Coast and Geodetic Survey report for the year 1900.

ADJUSTMENTS OF THE COAST SURVEY LEVEL

There is only one adjustment of the level which should be made in the field, and it consists of making the axis of the bubble tube parallel to the line of sight. The adjustment is made by the ordinary peg method, the bubble tube being raised or lowered at the adjusting end as may be required. The cross-hairs must never be disturbed as these have been permanently adjusted for collimation by the maker. In testing the adjustment, the rod reading is taken as the mean of the three hair readings and the rod interval as the difference between the outside hair readings, the bubble being kept exactly centered while reading each of the hairs.

Two turning points are finally driven about one hundred meters apart and the instrument set up on a line between them and about ten meters from one. Take a rod reading on each point, using the terms "near-rod" and "distant-rod" to indicate the rods with respect to the instrument. Then move the instrument to a point about the same distance from the other turning point and read both rods again. Correct the distant-rod readings for curvature and refraction. This gives four readings from which we have:

$$C = \frac{(\text{sum of near-rod readings}) - (\text{sum of distant-rod readings})}{(\text{sum of distant-rod intervals}) - (\text{sum of near-rod intervals})}$$

in which C is called the bubble error or constant for the days work. If C is less than .005 the level should not be adjusted, if between .005 and .01 adjustment is not advisable, but if it exceeds .01 the adjustment must be made. The

telescope points below the horizontal when C is positive and above when C is negative. If an adjustment is necessary the line of sight is raised or lowered on the distant rod by an amount equal to C times the rod interval. Then by means of an adjusting screw at one end of the bubble tube the bubble is again centered. The line of collimation should then be parallel with the axis of the bubble. A new determination of C is made after each adjustment.

A correction equal to C times the excess interval between the fore sights and backsights is applied to the final elevations; if the backsight intervals are in excess, the correction has the same sign as C , but if the fore sight intervals are in excess it has the opposite sign.

PRECISE LEVELING FOR A TURNING POINT

The rod used in this work is of the self reading type, 3.2 meters long, graduated to centimeters, and read to millimeters by estimating to tenths of a division. Decimeter divisions are marked with arabic figures to the left of the graduated strip and meters by Roman numerals on the right opposite each decimeter figure. To facilitate reading with the inverting telescope of the level, the figures are placed upside down.

The rod is non-extensible, cross-shaped (+) in section, made of high grade pine free from knots and blemishes, and treated with paraffin to prevent absorption of moisture. It is provided with a circular level for plumb-ing it and a thermometer reading from -23° to 55° centigrade. Its base is provided with a brass shoe terminating in a short cylinder, the bottom of which is rounded to fit the foot pin.

The foot pin is a short steel pin about ten inches long and an inch in diameter which is driven into the ground for a turning point. The head of the pin is enlarged and provided with a hemispherical hole to take the foot of the rod.



PLATE 3—Instruments

THE METHOD

The following instructions are taken from Special Publication No. 140 of the Coast and Geodetic Survey, omitting those parts which do not apply to our work.

GENERAL INSTRUCTIONS FOR PRECISE LEVELING

2. Except when specific instructions are given to proceed otherwise, all lines are to be leveled independently in both the forward and backward directions.

3. The backward measurement on each section should be made under different atmospheric conditions from those which occur on the forward measurement. It is especially desirable to make the backward measurement in the afternoon if the forward measurement was made in the forenoon, and vice versa. The observer is to secure as much difference of conditions between the forward and backward measurements as is possible without materially delaying the work for that purpose.

4. The spaces between the permanent bench marks of a line of levels should be broken by temporary bench marks into sections from 1 to 2 kilometers in length, except where special conditions make shorter sections advisable.

6. The instrument shall be shaded from the direct rays of the sun, both during the observations and when moving from one instrument station to another.

10. The thermometers on the rods should be read to the nearest degree centigrade at the beginning and end of each

section and the temperatures recorded. Where the sections are continuous the readings at the beginning of each section are sufficient except that on the last section the temperatures at the end should also be recorded.

11. At least once each month, during the progress of the leveling, a test must be made of the adjustment of the plumbing levels of the rods. A statement should be inserted in the record showing the manner in which the test was made, the error that was found, and whether an adjustment was made. With the bubble of the level rod held at the center, the deviation of the face and the edge of the rod from the vertical must be determined. If the deviation from the vertical in either directions exceeds 10 millimeters on a 3-meter length of the rod, the rod level must be adjusted.

14. As far as possible, all the permanent bench marks should be in the main line of levels and not on spur or branch lines. One of the exceptions to this rule is where the line runs several miles off the railroad to the mark of a triangulation station. In such a case the spur, or branch line, is the more economical way of doing the work and will be satisfactory. Whenever a permanent bench mark is established by means of a spur or branch line, which has only one set-up, the forward and backward lines of the spur or branch should be run at different times of the day or on different days, if practicable. If it should be necessary to have the two runnings made one immediately after the other, the height of the instrument should be materially changed

in waiting the second measure. This will help to prevent any mistake in reading one or both rods.

DETERMINATION OF COLLIMATION ERROR

15. Once each day of observation the error of the level should be determined in the regular course of the leveling and the observations recorded in a separate opening of the record book as follows: After the ordinary observations at an instrument station are completed, transcribe the last foresight reading as part of the error determination; call up the back rod man and have the rod placed about 10 meters back from the instrument; read the rod; move the instrument to a position about 10 meters behind the front rod; read the front rod and then the back rod. (The two instrument stations are between the two rod points.) The rod readings must be taken with the bubble in the middle of its tube.

The required constant C to be determined, namely, the ratio of the required correction to any rod reading to the corresponding subtended interval, is

$$C = \frac{(\text{sum of near rod readings}) - (\text{sum of distant rod readings})}{(\text{sum of distant rod intervals}) - (\text{sum of near rod intervals})}$$

The total correction for curvature and refraction must be applied to each of the distant rod readings before using it in this formula. The level should not be adjusted if C is less than 0.005. If C is between 0.005 and 0.010, the observer is advised not to adjust the level, but if C exceeds 0.010, the adjustment must be made. If a new adjustment of the level is made, C should at once be redetermined. It is desirable to have the determination of C

made under the usual conditions as to length of sight, character of ground, elevation of line of sight above ground, etc. The adjustment of the instrument to reduce δ , must be made by moving the level vial, not by moving the reticle.

LENGTH OF SIGHT

16. The maximum length of sight shall be 150 meters, and this maximum is to be attained only under the most favorable conditions.

17. The difference in length between a foresight and the corresponding backsight must not exceed 15 meters. The difference is to be made as small on each pair of sights as is feasible by the use of good judgment and care, without any expenditure of time for this particular purpose. The telescope should not be refocused between sights if possible to avoid it.

18. Chiefs of party should keep the length of sight great enough to make it necessary to do a moderate amount of rerunning. If an observer is extremely cautious and confines all his observations to sights sufficiently short to insure easy reading of the rod, it is possible to work month after month with almost no rerunning, but the progress will be slow. On the other hand, it is certain that an attempt to take sights of the limiting length, 150 meters, at all times would lead to a very large amount of rerunning and the progress would not be rapid. It is believed that the maximum speed consistent with the required degree of accuracy

will be secured by continually keeping the length of sight such that the amount of rerunning will be from 5 to 15 per cent. An extremely small percentage of rerunning indicates an excess of caution on the part of the observer. The occurrence of a moderate amount of rerunning is due largely to an attempt on the part of the observer to obtain the maximum progress consistent with the required degree of accuracy and not to inability to secure such observations that little or no rerunning would be necessary. Observers have found that a convenient rule in fixing the length of sight is to shorten the sights whenever the upper and lower thread intervals subtended on the rod are found to differ frequently by more than a selected limit. Each observer should fix this limit from his own experience by noting the relation between a provisional limit and the amount of rerunning found to be necessary while using it. Such a rule is based upon the idea that the additional errors which are encountered when the length of sight is increased are, in the main, those due to the increased accidental errors in reading the rod.

ALLOWABLE DIVERGENCE OF RUNNINGS

19. On all sections upon which the forward and backward measures differ by more than $4.0 \sqrt{K}$ in millimeters (in which K is the length of the section in kilometers), the section should be run until any two readings in opposite directions check within the limits of the formula.

20. On all sections 0.5 kilometer or less in length, a

discrepancy of not more than 2.8 millimeters between the backward and forward lines will be considered a satisfactory check regardless of the limits provided by the formula in paragraph 19. This provision, however, should not influence the chief of party in determining the lengths of sections.

21. It is thought to be inadvisable to state definitely in these instructions the allowable limit on the rate of divergence between the forward and backward lines, but this should be kept small.

REJECTION

22. If any measure over a section gives a result differing by more than 6 millimeters from the mean of all the measures over that section, this measure shall be rejected. No rejection shall be made on account of a residual smaller than 6 millimeters unless there is some good reason for suspecting an error in this particular measure, and in such cases the reason for rejection must be fully stated in the record.

MISTAKES

23. Whenever a mistake, such as misreading of 1 decimeter or 1 meter, or an interchange of sights (the backsight being recorded for the foresight), is discovered in any measure after its completion and the necessary correction applied, such measure may be retained provided there are at least two other measures over the same section which are not subject to any such uncertainty. When it is found, however,

that the mistake was made on the last instrument station of the second running of a section and the mistake is corrected on the same day and before beginning work on an adjacent section, such measure may be retained, and no further measures are required on account of the mistake, but a note describing the procedure must be made in the record.

PROGRAM OF OBSERVING

24. The program of observations at each instrument station is to be as follows: Set up and level the instrument. Read the three lines of the diaphragm as seen projected against the face of the No. 1 rod, each reading being taken to the nearest millimeter (estimated) and the bubble being held continuously in the middle of the tube, that is, both ends reading the same. Then, after the rod has been turned, read the middle wire of the diaphragm, as seen projected against the back of the rod, to the nearest hundredth of a foot (estimated). As soon as possible thereafter repeat the operation with the telescope pointed at the No. 2 rod. The foot graduations on the back of the rod need not be read on more than one running of a section.

PERMANENT BENCH MARKS

28. Every new permanent bench mark must be marked by a standard metal tablet so fastened in the rock, brick or concrete as to resist extraction, change of elevation, or rotation.

29. Traverse stations which are easily accessible and have been marked in a permanent manner should be used as

permanent bench marks.

30. A traverse station reference mark should not be used as a permanent bench mark. As a rule, the reference mark is shallow and does not have the desired stability.

DESIGNATIONS OF BENCH MARKS

31. Permanent bench marks should be designated by a capital letter followed by a number, the letters to follow in alphabetical order and the number to change as each alphabet is exhausted. This designation, together with the year in which the mark was established, must be stamped upon the tablet, preferably before it is set. The system of numbering is separate and distinct for each state. The chief of party will be furnished with the designation for the first bench mark in each State in which he may work. If two or more parties are working in the same State, each party will be assigned a certain number of alphabets. The letters I and O should be omitted from each alphabet, as they have been the source of considerable confusion in requests for data received from persons finding the marks. The designation of two sets of three consecutive bench marks is given below:

H 2	J 2	K 2
1927	1927	1927
M 2	N 2	P 2
1927	1927	1927

32. All recovered bench marks are to be called by their old designations, whether the bench mark was established by this or some other organization. The designation, in the records, of a bench mark of another organization is, how-

ever, to be followed by the initials of the organization that established the mark.

33. Triangulation and traverse stations connected with the leveling shall be called by their names and not given designating letters.

34. Each temporary bench mark is to be designated by a number, the numbers to be continuous throughout the line.

DESCRIPTIONS OF BENCH MARKS

35. A description must be written on Form 633 for every permanent bench mark established or connected with.

Temporary bench marks which may possibly be recovered for a few years after their establishment should also be described on Form 633. No duplicates of the descriptions need be furnished the office.

RECORDS AND COMPUTATIONS

36. The record and the preliminary or field computation of first-order leveling must conform to the examples given in this publication.

37. The recorder shall keep a record of the rod intervals subtended by the extreme lines of the diaphragm on each back-sight, together with the continuous sum of such intervals between each two contiguous bench marks (temporary or permanent), and a similar record shall be kept for the fore-sights. The two continuous sums shall be kept as nearly equal as feasible, without the expenditure of extra time for that purpose, by setting the instrument beyond (or short of) the middle point between the back and front rods when the

sums are unequal. The two continuous sums for a section shall not be allowed to differ by more than a quantity corresponding to a distance of 20 meters.

40. Notes for future use in studying leveling errors shall be inserted in the record. These should give the time of beginning and ending the work of each section, the weather conditions, especially as to cloudiness and strength of wind, and also the direction of the wind and sun with respect to the line of levels. Such other notes should be made as promise to be of value in studying errors.

WORK AND RESULTS

In the selection of locations for the new bench-marks great care and consideration was given to the factors of accessibility from all directions, ease of location in winter as well as in summer, and least possibility of disturbance. About the campus these locations were taken near the curb at the intersections of drives or on line with the face of some building. Proximity to shrubbery and buildings was avoided as much as possible. On the farms, where curbs were not available, locations were taken near some permanent structure such as a concrete manhole which would not effect the efficient use of the bench-mark. Having determined the locations, the Building and Grounds Department set the monuments.

In designating the new bench-marks, we started with the letter K and proceeded in alphabetical order using the same lettering system that Foth and Kurtz established in their work of 1929.

To determine the elevations of these monuments and other bench-marks to be established on buildings and bridges along the line of levels, an outside circuit was run about the bench-marks involved in our work. To pick

up other old bench-marks and check out circuit, several cross lines were run making a total of five circuits. Our error of closure in the outside circuit was 2.3 millimeters in 5.12 kilometers or $1/2,226,100$. Errors of closure in

the interior circuits ranged from 0.5 mm. to 2.2 mm.

At this time, we discovered a divergence between our lines and the established elevation of bench-mark J of over one centimeter. This divergence would most likely be due to one of three causes: a disturbance of J, an error in our work, or an error in the work of Roth and Kurtz who established the bench-mark. To check J for disturbance, we ran a line from J to I, another bench-mark in the same level net. The obtained difference in elevation checked that given by Roth and Kurtz within 3 mm indicating no major disturbance had occurred. Then to check our own work, we ran a line between DH and U, the resulting circuit closing within 1.6 mm. Also the line DH-K-J-V- was re-run, and checked our first line to within 1 mm. This convinced us that our determination of the difference in elevation between J and other bench-marks was correct within the limits of accuracy.

The five circuits so formed were adjusted for closure by the method of least squares, establishing the differences in elevation ^{of} junction bench-marks 6, 4, 1, 2, DH, K, and L. The differences of elevation of intermediate bench-marks were adjusted on the assumption that the error varies as the square root of the distance.

In the selection of a fixed bench-mark on which to base our work, we considered the previous establishment of elevations from all possible angles. The original determinations were ^{made} by Anderson and Smith in 1917, and have not

been changed nor checked since. They ran a double line from the U.S.G.S. bench-mark on the Michigan Central Depot in Lansing, and accurately established a bench-mark on the West Abutment of the old Weather Bureau. All of the old bench-marks established along this end of the line have been lost or destroyed, and the U.S.G.S. bench-mark at the junction of Michigan Avenue and Harrison Road has been moved. The level nets of Toth and Kurtz in 1929, and of Strom and Zimmerman in 1931 were based on the work of Anderson and Smith. Therefore, the most accurate available bench-marks on which to base our elevations would be one near to and established directly from the old Weather Bureau bench-mark. Since bench-mark 5 is located in a position where it is least likely to have been disturbed, has been used as a base for most previous work, and is close to and has been determined directly from the bench-mark on the old Weather Bureau, we decided to use it as a base for our level net.

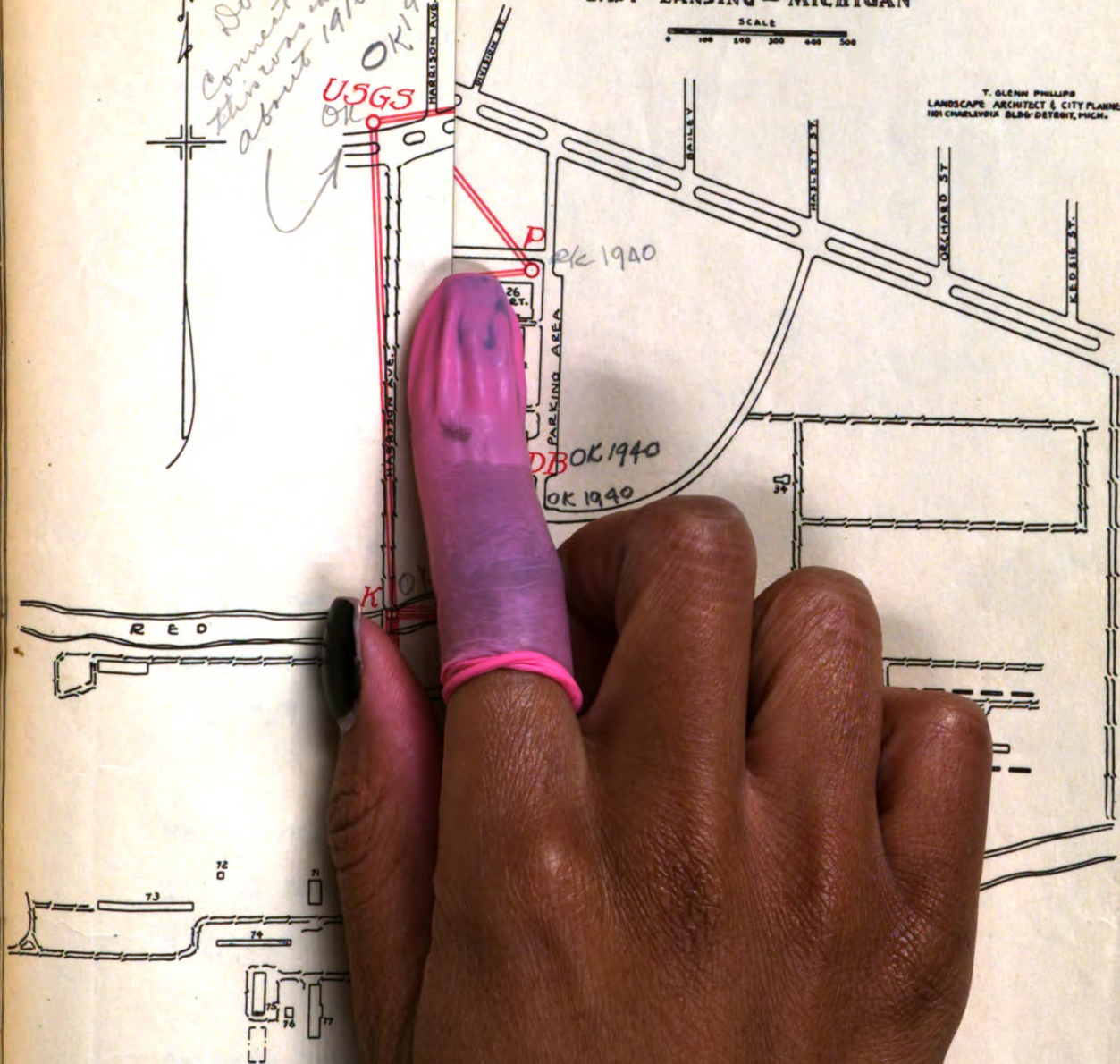
Considering that Anderson and Smith did not adjust their level net on the campus by the method of least squares, we conclude that our adjustment is more accurate and warrants the changing of their established elevations of bench-marks. However, these changes are not sufficiently large to cause any appreciable difference in any practical work.

CAMPUS OF MICHIGAN STATE COLLEGE OF AGRICULTURE AND APPLIED SCIENCE EAST LANSING - MICHIGAN

SCALE
0 100 200 300 400 500

T. GLENN PHILLIPS
LANDSCAPE ARCHITECT & CITY PLANNER
1801 CHARLEVOIX BLDG - DETROIT, MICH.

*Don't use this to
connect with USGS
about 1916*
OK 1940
U.S.G.S



KEY

- | | |
|--------------------------------|------------------------------|
| 1. U.S. WEATHER BUREAU | 37. ANIMAL LAB |
| 2. GUILD DORMITORY | 38. POULTRY GROUP |
| 3. MUSIC CENTER | 39. ANIMALS |
| 4. HOSPITAL | 40. STORAGE |
| 5. PRESIDENT'S RESIDENCE | 41. VETERINARY CLINIC |
| 6. DEAN OF WOMEN'S RESIDENCE | 42. POULTRY HOUSE |
| 7. HOME ECONOMICS No. 2 | 43. FARM COTTAGE |
| 8. MUSIC PRACTICE HOUSE No. 1 | 44. FARM COTTAGE |
| 9. HOME ECONOMICS No. 1 | 45. FARM COTTAGE |
| 10. SECRETARY'S RESIDENCE | 46. FARM COTTAGE |
| 11. BAND HALL | 47. AGRICULTURAL ENGINEERING |
| 12. GYMNASIUM ANNEX | 48. EDDIE'S CHEMICAL LAB |
| 13. ABBOTT HALL | 49. COAL STORAGE |
| 14. MUSIC PRACTICE HOUSE No. 2 | 50. INDUSTRIAL CHEMISTRY LAB |
| 15. UNION RECREATIONAL | 51. RESERVOIR |
| 16. ECONOMICS | 52. STORAGE BARN |
| 17. HOME ECONOMICS | 53. STORES |
| 18. WOMEN'S BUILDING | 54. BOILER ROOM |
| 19. BEAUMONT TOWER | 55. POWER HOUSE |
| 20. LIBRARY | 56. SERVICE GARAGE |
| 21. ADMINISTRATION | 57. ENGINEERING SHOPS |
| 22. LIBERAL ARTS | 58. ENGINEERING |
| 23. BACTERIOLOGY | 59. FORGE AND FOUNDRY |
| 24. BOTANY | 60. ROBERT LAB |
| 25. BOTANY GREENHOUSE | 61. WELLS HALL |
| 26. HORTICULTURE | 62. ENGLISH |
| 27. FORESTRY | 63. CAMPUS GREENHOUSE |
| 28. HORTICULTURAL GREENHOUSE | 64. PHYSICS |
| 29. ENTOMOLOGY | 65. GYMNASIUM |
| 30. ENTOMOLOGY LAB. | 66. STADIUM |
| 31. INFIRMARY | 67. DEN HALL AND ARMORY |
| 32. AGRICULTURE | 68. CAVALRY STABLES |
| 33. DAIRY | 69. ROOT CELLAR |
| 34. APIARY | 70. FARM HOUSE |
| 35. ANATOMY | 71. POULTRY PLANT |
| 36. POULTRY HOUSE | 72. BROODER HOUSE |



NET



DESCRIPTION AND LOCATION OF BENCH MARKS

B.M. "J"

A concrete monument, about 500' north of intersection of Stock Barn Road and Harrison Road. Across the road from the Michigan State Police Barracks. References: 45.0' S. and 3.7' W of fence corner; 29.0' E of center line of Harrison Road. Elev. 844.9088' ✓

B.M. "K"

~~844.9088~~
A square cut in N.W. corner of east walk of Harrison Road bridge over Red Cedar. Elev. 836.9065' ✓

B.M. "L"

A concrete monument in front of Demonstration Hall. References: 2.7' N of flagpole and on center line of Demonstration Hall. Elev. 835.7267' ✓

B.M. "M"

A concrete monument in front of College Hospital. References: 1.0' from curb in west corner of triangular island formed by intersection of drives. Elev. 858.0055'

B.M. "N"

A concrete monument 0.7' north of north curb of College Drive in front of Music Practice House No. 1. References: 32.4' SW of SW corner of concrete manhole; 17.1' SW of 20" maple; 45.7' S of 30" maple; 37.6' E of 30" maple. Elev. 849.2689'

3

B.M. "O"

A concrete monument 0.6' from north curb of College Drive in front of East wing of Home Economics Building. References: 43.7' SW of 20" elm on line with east face of Home Economics Building; 35.5' NW of 13" elm on south side of Drive; 25.7' SE of group of three elms. Elev. 842.6627'

B.M. "P"

A concrete monument in southwest corner of intersection of Farm Lane Road and road leading west past Horticulture Building. References: on line with east face of Horticulture Building and 50.9' N of NE corner; 14.6' due north of small elm. Elev. 846.8556'

B.M. "Q" *OK 1940 N. Ref to STATE U.S.C.B.S. Primary An*

A concrete monument 0.7' from curb in front of Agricultural Hall. References: In SE corner of triangular island formed by intersection of drives. Elev. 846.9291'

B.M. "E"

OK 1940

A concrete monument in front of Dairy Building, 0.7' from curb in NW corner of intersection of Farm Lane and College Drive. References: 18.3' SW of 20" maple.

Elev. 848.0591'

B.M. "S"

Destroyed 1940

A square cut in NE corner of concrete manhole on SE corner of Farm Lane Bridge over Red Cedar River.

Elev. 838.2635'

*Destroyed
Heaved
1946*

B.M. "1" *OK. 1940*

A concrete monument on East side of Farm Lane in front of Dairy Barn. References: 0.6'W of and on E and W center line of concrete manhole; 20.8'NE of 5" maple; 27.2'SE of 13" maple; both maples on E side of Farm Lane.

Elev. 856.3471'

B.M. "5" *OK. 1940*

A concrete monument in SW corner of intersection of Stock Barn Road and railroad. References: 0.5'S of and on N and S center line of concrete manhole; 5.6'E of N and S fence line. Elev. 848.4081'

B.M. "7" *OK. 1940*

A concrete monument in SE corner of intersection of Harrison Road and Stock Barn Road. References: 14.7'SE of 20" maple; 3.4'NE of concrete corner post; 16.5'NE of 13" maple; 57.4'S of fire hydrant in NE corner of road intersection. Elev. 848.9518'

B.M. 12 *OK. 1940*

A concrete monument in center of triangle formed by Gymnasium, old Armory and Botanical Gardens. References: 147'NE of NE corner of ^{Women's} ~~the~~ Gymnasium; ~~135'SW of SW corner of old Armory~~; 29.0'W of small maple. Elev. 842.9415'

B.M. 13

OK. 1940
A concrete monument in front of President Shaw's ~~old~~ home. References: 45'SE of evergreen tree nearest house; 63'W of SW corner of Shaw's house; 21.1'W of NW corner of steam manhole; 42.3'N of 30" elm.

Elev. 855.4472'

H

B.M. #4

A concrete monument SE of S end of boulevard past Union Building. References: 35.4'S of S curb of College Drive; 37.8'NE of 30" elm; 95.1'N of 28" ev rgreen; 64.3'NW of 30" ash. Elev. 843.2415'

B.M. #6

Stationing for the San Diego River in the City of San Diego. A concrete monument directly in front of new Library and NE of Memorial Tower. References: oak tree N80°W, distance 28.1'; fire hydrant S33°E, distance 73.0'; evergreen N9°E, distance 28.7'. Elev. 852.4371'

B.M. #18

OK 1946
A concrete monument on Athletic field just next to inside curb of east side of running track. References: 22.6'NW of point of curvature at S end of track; 110.5'W of poplar on bank of Red Cedar; 115.3'NW of ash on main entrance to field. Elev. 830.4094'

B.M. #25

Dr. H. H. H. H.
A concrete monument in NW corner of intersection of Grand River Avenue and Charles Street. References: 57.1'S of SE corner of Standard Oil station; 5.5'S of sidewalk; 2.2'W of sidewalk; 2.8'E from inside edge of curb. Elev. 843.5827'

B.M. #33

OK 1946
A concrete monument between entrance and exit at North end of Boulevard past Union Building. References: 63.6'S of base of signal post; 2.1'S of inside edge of curb; 78.8'E of NE of NE corner of old Weather Bureau. Elev. 854.2105'

B.M. "Curb"

A square cut in curb on NE corner of intersection of College Drive and Michigan Avenue. References: 4.5' NE of catch basin in curb; 17.2' W of cast iron manhole.

Elev. 840.5610'

B.M. "IB" *OK 1940*

A square cut on SE corner of casement at main entrance on S side of Dairy Building. References: 3.5' S of Dairy Building wall; 15' E of center line of Dairy Building.

Elev. 851.2402'

B.M. "D4" *OK 1940*

A square cut in the concrete coping on the NW corner of the E wing of the front steps of Demonstration Hall.

Elev. 840.4554'

B.M. "G3" *OK 1940*

A square cut on N end of curbing on W side of Gym Bridge over Red Cedar. Elev. 835.9357'

B.M. "NB" *OK 1940*

A concrete monument at intersection of Piggery Road and Farm Lane, about 400' S of Red Cedar bridge. References: 15.4' E of E fence of field; 20' NE of 12" maple on W side of road; 44.3' NW of 22" maple on E side of road; 45.3' SE of 22" maple on W side of road. Elev. 856.4682'

B.M. "stad"

A square cut on N end of Base walk at foot of W stadium bleacher. Elev. 848.2254'

B.M. "I.B.G.S." *OK 1940*

Government bench mark, an iron pipe, 0.8' above surface of ground, set next to sidewalk on NW corner of intersection of Harrison Road and Michigan Ave. References: 33' N of center line of street car track; 61' W of Harrison

Road sidewalk. Elev. 837.4925'

OK 1940

COMPUTATIONS

In the field, notes were recorded as shown on pages and . The complete set of field notes is inside the back cover of this thesis. The office computations consist d of the working up of the field notes, computing and applying of corrections, and the adjustment of the level notes.

In computations of the corrections, the standard temperature of the rod was taken as 20° centigrade, and the coefficient of expansion as .00000114. The stadia constant of the instrument used is 300.

The correction for curvature and refraction depends upon the difference in length between corresponding backsights and foresights, and must be applied to each set-up. These corrections were taken from Table III, page 70 of the U.S. Coast and Geodetic Survey's special publication No. 140 entitled "Manual of First-Order Leveling."

The correction for level error was obtained by multiplying the difference between total backsight and foresight intervals by 3, due regard being given to the sign of each factor.

The temperature correction was obtained by multiplying the difference of elevation by the average variation from the standard temperature, and by the coefficient of expansion of the rod. A temperature higher than the standard increases the difference in elevation.

After applying these corrections, the level net was adjusted for closure by the method of least squares. The corrected differences in elevation thus obtained were used to compute the elevations of the bench-marks.

A detailed explanation of this method of adjustment is given in the "Manual of First-Order Leveling" published by the U.S. Coast and Geodetic Survey. (Special Publication No. 140)

Sample Determination of C

Date: April 27, 1932		DETERMINATION OF C			
Sun: C		Wind: E			
No. of Stations	Thread Readings B.S.	Mean	Thread Intervals	Sum of Intervals	Thread Intervals
1	1395		20		
	1415	1415.0	20		162
	1435		40	40	163
					325
2	2203		163		
	2366	2365.7	162		19
	2528		325	325	18
		0713.3			37
		3079.0		325	40
				+650	-77
Corr. for curv. & ref.		-1.2		-77	
		3077.8		+573	
					573) +2.9 (+0.05

4

Sample Page of Field Notes

Date: April 29, 1932		From B.M. "U"		To B.M. "T"	
Sun: C		Wind: 0			
No. of Stations	Thread Readings B.S.	Mean	Thread Interval	Sum of Intervals	
	0542		104		
1	0676	0675.7	103		
	0779		207	207	
	2708		122		
2	2830	2830.0	122		
	2952		244	451	
	1769		130		
3	1899	1898.7	129		
	2028		259	710	
	1623		88		
4	1711	1710.7	87		
	1798		175	885	
	21345	7115.1			

Computation of Mean

Bench Marks	Forward or Backward	No. of Stations	Sum of Rod Intervals	Distance in Kilometers	Rod Intervals ZB-ZF	Mean Rod Readings		Approximate Difference of Elevation	Mean Temp of Rod
						ZB	ZF		
			mm.		mm.	mm.	mm.	mm.	°C
6-P	F	4	1153	0.346	+11	5717.7	7418.0	-1700.3	30°
	B	4	1141	0.342	+7	6118.0	4417.7	+1700.3	12°
P-25	F	1	868	0.260	0	0861.3	1858.3	-0997.0	27°
	B	1	873	0.262	+35	1985.0	0987.0	+0998.0	11°
25-0	F	1	565	0.170	+9	1373.7	1654.0	-0280.3	25°
	B	1	564	0.169	+4	1660.0	1380.0	+0280.0	11°
0-4	F	1	496	0.149	+24	2178.0	2001.0	+0177.0	23°
	B	1	490	0.147	-6	1841.0	2017.3	-0176.3	13°
4-33	F	2	658	0.197	+16	4821.3	1477.3	+3344.0	20°
	B	2	641	0.192	-31	1695.7	5039.4	-3343.7	17°
33-N	F	2	678	0.203	+44	2547.3	3962.6	-1415.3	16°
	B	2	679	0.204	+1	3847.0	2433.7	+1413.3	26°
N-3	F	1	526	0.158	+12	2320.3	0528.6	+1791.7	13°
	B	1	527	0.158	-13	0551.7	2344.0	-1792.3	26°
3-M	F	1	208	0.062	0	2155.0	1375.0	+0780.0	13°
	B	1	206	0.062	-2	1379.0	2159.0	-0780.0	27°
M-Curb	F	3	1040	0.312	+96	3231.0	8548.3	-5317.3	12°
	B	3	1023	0.307	-3	8885.3	3569.3	+5316.0	21°
"Curb"-45	F	2	891	0.267	-5	2702.7	3637.4	-0934.7	11°
	B	2	891	0.267	+11	3324.6	2389.3	+0935.3	15°

Differences in Elevation

Corrections					Difference of Elevation		Divergence B-F
Curvature & Refraction	Level Error	Index Error	Length of Rod	Temp. of Rod	Each Line	Mean	
mm.	mm.	mm.	mm.	mm.	m.	m.	mm.
0.0	0.0			-0.1	-1.7004	-1.7003	-0.2
0.0	0.0			-0.1	+1.7002		
0.0	0.0			0.0	-0.9970	-0.9974	+0.7
-0.2	-0.1			0.0	+0.9977		
0.0	0.0			0.0	-0.2803	-0.2802	-0.3
0.0	0.0			0.0	+0.2800		
-0.1	0.0			0.0	+0.1769	+0.1766	-0.6
0.0	0.0			0.0	-0.1763		
0.0	0.0	None	Negligible	0.0	+3.3440	+3.3437	-0.6
+0.1	+0.1			+0.1	-3.3434		
-0.1	-0.1			0.0	-1.4155	-1.4144	-2.2
0.0	0.0			0.0	+1.4133		
0.0	0.0			-0.1	+1.7916	+1.7920	+0.8
+0.1	-0.1			-0.1	-1.7924		
0.0	0.0			0.0	+0.7800	+0.7800	0.0
0.0	0.0			0.0	-0.7800		
-0.4	-0.1			+0.2	-5.3176	-5.3168	-1.6
0.0	0.0			0.0	+5.3160		
0.0	0.0			0.0	-0.9347	-0.9351	+0.7
0.0	+0.1			0.0	+0.9354		

Differences of Elevation

Corrections					Difference of Elevation		Divergence B-F
Curvature & Refraction	Level Error	Index Error	Length of Rod	Temp of Rod	Each Line	Mean	
mm.	mm.	mm.	mm.	mm.	m.	m.	mm.
-0.2	+0.2			0.0	-0.1581	-0.1539	-3.8
0.0	0.0			0.0	+0.1543		
+0.1	0.0			0.0	-0.1539		-0.4
0.0	-0.1			0.0	+0.1535		
0.0	0.0			+0.1	+2.4161	+2.4145	-1.2
+0.1	0.0			0.0	-2.4149		
0.0	+0.1			+0.1	+2.4142		-1.2
0.0	0.0			0.0	-2.4130		
+0.1	-0.1			0.0	+1.2313	+1.2322	+0.9
0.0	0.0			+0.1	-1.2322		
0.0	0.0			0.0	+1.2317		+2.0
0.0	0.0			0.0	-1.2337		
		None	Negligible				
+0.1	-0.1			0.0	-0.1650	-0.1660	+2.0
+0.2	-0.2			0.0	+0.1670		
0.0	0.0			0.0	+2.4190	+2.4199	+1.8
+0.1	-0.2			0.0	-2.4208		
0.0	+0.1			0.0	+0.0361	+0.0369	+1.7
0.0	-0.1			0.0	-0.0378		
0.0	0.0			0.0	-5.5497	-5.5488	-1.7
0.0	0.0			0.0	+5.5480		
0.0	-0.1			0.0	+2.9856	+2.9857	+0.2
0.0	0.0			-0.1	-2.9858		

Computation of Mean

Bench Marks	Forward or Backward	No. of Stations	Sum of Rod Intervals	Distance in Kilometers	Rod Intervals ΣB-ΣF	Mean Rod Readings		Approximate Difference of Elevation	Mean Temp. of Rod
						ΣB	ΣF		
			mm.		mm.	mm.	mm.	mm.	°C
R-D.B.	F	1	91	0.027	-3	1859.0	0889.7	+0969.3	19°
	B	1	92	0.028	+4	0863.0	1833.0	-0970.0	23°
DB-Q	F	2	773	0.232	-9	2521.0	3834.3	-1313.3	19°
	B	2	775	0.233	-3	3931.0	2616.3	+1314.7	26°
Q-6	F	1	595	0.179	+17	2541.3	0866.7	+1674.6	15°
	B	1	594	0.178	-16	0836.3	2514.6	-1678.3	28°
	F	2	625	0.188	-5	3734.3	2056.6	+1677.7	18°
	B	2	676	0.203	-14	1939.7	3617.7	-1678.0	28°
M-2	F	2	903	0.271	+11	0452.7	5042.4	-4589.7	27°
	B	3	905	0.272	+5	6797.7	2205.4	+4592.3	28°
2-G.B.	F	2	716	0.215	-6	2821.3	4651.6	-1830.3	22°
	B	2	707	0.212	+3	4075.3	2244.0	+1831.3	29°
G.B-18	F	2	593	0.178	+9	2743.7	4733.0	-1989.3	22°
	B	2	581	0.174	-1	4108.0	2118.7	+1989.3	30°
18-L	F	3	1012	0.304	-18	5559.7	3937.7	+1622.0	22°
	B	3	1030	0.309	+4	4080.7	5701.6	-1620.9	29°
L-D.H.	F	1	59	0.018	-3	1748.0	0307.3	+1440.7	20°
	B	1	84	0.025	0	0303.0	1745.0	-1442.0	26°
D.H-K	F	4	1693	0.508	-1	6296.4	7354.7	-1058.3	21°
	B	3	1675	0.503	-7	5879.0	4021.7	+1057.3	26°
	F	4	1722	0.517	-14	6311.0	7368.3	-1057.3	25°
	B	4	1707	0.512	-9	7992.1	6933.4	+1058.7	20°

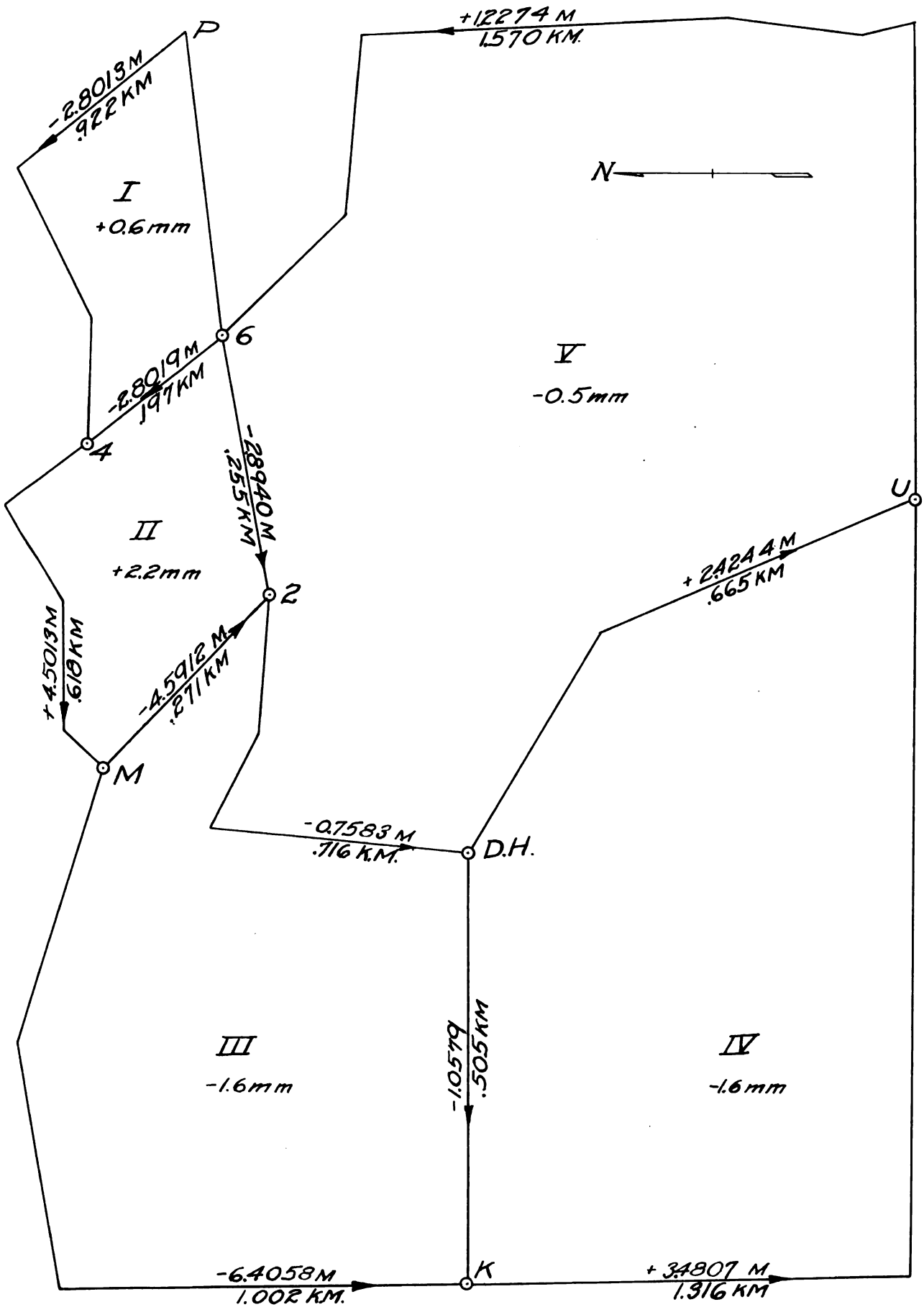
Differences in Elevation

Corrections					Difference of Elevation		Divergence B-F
Curvature & Refraction	Level Error	Index Error	Length of Rod	Temp. of Rod	Each Line	Mean	
mm.	mm.	mm.	mm.	mm.	m.	m.	mm.
0.0	0.0			0.0	+0.9693	+0.9696	+0.7
0.0	0.0			0.0	-0.9700		
+0.1	0.0			0.0	-1.3132	-1.3140	+1.5
0.0	0.0			0.0	+1.3147		
-0.1	0.0			0.0	+1.6746	+1.6781	+3.7
+0.1	0.0			-0.1	-1.6783		
0.0	0.0			0.0	+1.6777		+0.5
0.0	-0.1			-0.1	-1.6782		
0.0	+0.1			-0.2	-4.5898	-4.5912	+2.7
0.0	0.0			+0.2	+4.5925		
0.0	0.0	None	Negligible	0.0	-1.8303	-1.8308	+1.1
0.0	0.0			+0.1	+1.8314		
0.0	+0.1			0.0	-1.9892	-1.9893	+0.2
0.0	0.0			+0.1	+1.9894		
0.0	-0.1			0.0	+1.6199	+1.6205	+1.1
0.0	0.0			-0.1	-1.6210		
0.0	0.0			0.0	+1.4407	+1.4413	+1.3
0.0	0.0			0.0	-1.4420		
0.0	0.0			0.0	-1.0583	-1.0579	-0.9
+0.1	0.0			0.0	+1.0574		
0.0	-0.1			0.0	-1.0574		+1.1
-0.1	-0.1			0.0	+1.0585		

Computation of Mean

[illegible]

The Circuits



Adjustment by Least Squares

Data

No.	Line	Difference in Elevation	Correction	Distance
1	6-P-4	-2.8013	V_1	0.922
2	6-4	-2.8019	V_2	0.197
3	4-M	+4.5013	V_3	0.618
4	M-2	-4.5912	V_4	0.271
5	6-2	-2.8940	V_5	0.255
6	M-K	-6.4058	V_6	1.002
7	DK-K	-1.0579	V_7	0.505
8	2-DH	-0.7583	V_8	0.716
9	K-U	+3.4807	V_9	1.316
10	DH-U	+2.4244	V_{10}	0.665
11	U-6	+1.2274	V_{11}	1.570

Circuit I

6-P-4	-2801.3	$+V_1$
6-4	+2801.9	$-V_2$
	+0.6	

Equations

$$I \quad +V_1 - V_2 + 0.6 = 0$$

Circuit II

6-4	-2801.9	$+V_2$
4-M	+4501.3	$+V_3$
M-2	-4591.2	$+V_4$
6-2	+2894.0	$-V_5$
	+2.2	

$$II \quad +V_2 + V_3 + V_4 - V_5 + 2.2 = 0$$

Circuit III

M-K	+6405.8	$-V_6$
DH-K	-1057.9	$+V_7$
2-DH	-0758.3	$+V_8$
M-2	-4591.2	$+V_4$
	-1.6	

$$III \quad +V_4 - V_6 + V_7 + V_8 - 1.6 = 0$$

Adjustment by Least Squares

Circuit IV

K-U	+3480.7	$+V_9$
DH-U	-2424.4	$-V_{10}$
DH-K	-1057.9	$+V_7$
	-1.6	

$$IV \quad V_9 - V_{10} + V_7 - 1.6 = 0$$

Circuit V

G-2	-2894.0	$+V_5$
2-DH	-0758.3	$+V_6$
DH-U	+2424.4	$+V_{10}$
U-G	+1227.4	$+V_{11}$
	-0.5	

$$V \quad V_5 + V_6 + V_{10} + V_{11} - 0.5 = 0$$

Correlate Equations

No. of V	$\frac{1}{p}$	I	II	III	IV	V	Σ
1	.0184	+1	-----	-----	-----	-----	+1
2	.0039	-1	+1	-----	-----	-----	0
3	.0124	-----	+1	-----	-----	-----	+1
4	.0054	-----	+1	+1	-----	-----	+2
5	.0051	-----	-1	-----	-----	+1	0
6	.0200	-----	-----	-1	-----	-----	-1
7	.0101	-----	-----	+1	+1	-----	+2
8	.0143	-----	-----	+1	-----	+1	+2
9	.0263	-----	-----	-----	+1	-----	+1
10	.0133	-----	-----	-----	-1	+1	0
11	.0314	-----	-----	-----	-----	+1	+1

Normal Equations

No.	I	II	III	IV	V	N	Σ
I	+0.0223	-.0039	-----	-----	-----	+0.6	+0.6184
II		+0.0268	+0.0054	-----	-.0051	+2.2	+2.2232
III			+0.0498	+0.0101	+0.0143	-1.6	-1.5204
IV				+0.0497	-.0133	-1.6	-1.5535
V					+0.0641	-0.5	-0.4400

Adjustment by Least Squares
Forward Solution of Normal Equations

I	II	III	IV	V	N	Σ
+0.0223	-0.0039				+ 0.6000	+ 0.6184
C_1	+0.1749				-26.9058	-27.7309
	+0.0268	+0.0054		-0.0051	+ 2.2000	+ 2.2232
(I)	-0.0007				+ 0.1049	+ 0.1082
	+0.0261	+0.0054		-0.0051	+ 2.3049	+ 2.3314
C_2	-0.2068			+0.1953	-88.2507	-89.2622
	+0.0498	+0.0101	+0.0143	-1.6000	-1.5204	
(II)	-0.0011		+0.0011	-0.4766	-0.4820	
	+0.0487	+0.0101	+0.0154	-2.0766	-2.0024	
C_3	-0.2075	-3.154	+42.6537	+41.1309		
	+0.0497	-0.133	-1.6000	-1.5535		
(III)	-0.0021	-0.0032	+0.4308	+0.4154		
	+0.0476	-0.165	-1.1692	-1.1381		
C_4	+0.3463	+24.5604	+23.9067			
	+0.0641	-0.5000	-0.4400			
(II)	-0.0010	+0.4501	+0.4552			
(III)	-0.0048	+0.6549	+0.6315			
(IV)	-0.0057	-0.4049	-0.3941			
	+0.0526	+0.2001	+0.2527			
C_5	-3.8077	-4.8077				

Adjustment by Least Squares Backward Solution

I	II	III	IV	V
-26.9058	-88.2507	+42.6537	+24.5604	-3.8077
-----	- 0.7435	+ 1.2009	- 1.3186	-3.8077
-----	-----	- 5.0953	+23.2418	
-----	- 8.8188	+38.7593		
-15.4340	-97.8130			
-42.3398				

Computation of V's

1	2	3	4	5	6
-42.340	+42.340	-97.813	-97.813	+97.813	-38.759
	-97.813		+38.759	- 3.808	
-42.340	-55.473	-97.813	-59.054	+94.005	-38.759
X.0184	X.0039	X.0124	X.0054	X.0051	X.0200
-0.78	-0.21	-1.21	-0.32	+0.48	-0.78

7	8	9	10	11
+38.759	+38.759	+23.242	-23.242	- 3.808
+23.242	- 3.808		- 3.808	
+62.001	+34.951	+23.242	-27.050	- 3.808
X.0101	X.0143	X.0263	X.0133	X.0314
+0.63	+0.50	+0.61	-0.36	-0.12

Adjustment by Least Squares

Table of V 's

No.	Value
1	-0.8
2	-0.2
3	-1.2
4	-0.3
5	+0.5
6	-0.8
7	+0.6
8	+0.5
9	+0.6
10	-0.4
11	-0.1

Substitution of V 's in Condition Equations

<i>I</i>	<i>II</i>	<i>III</i>	<i>IV</i>	<i>V</i>
$+V_1$ -0.8	$+V_2$ -0.2	$+V_4$ -0.3	$+V_9$ +0.6	$+V_5$ +0.5
$-V_2$ +0.2	$+V_3$ -1.2	$-V_6$ +0.8	$-V_{10}$ +0.4	$+V_8$ +0.5
-0.6	$+V_4$ -0.3	$+V_7$ +0.6	$+V_7$ +0.6	$+V_{10}$ -0.4
	$-V_5$ -0.5	$+V_8$ +0.5	+1.6	$+V_{11}$ -0.1
+0.6	-2.2	+1.6		+0.5
	+2.2	-1.6	-1.6	-0.5

Final Adjustment

Bench Marks		$\sqrt{\text{Dist}}$	Mean Difference		Corr. ection	Corrected Difference	
Junction	Mediate		+	-		+	-
		Km.	m.	m.	mm.	m.	m.
6-4				2.8013	-0.8		2.8021
	6-P	0.58		1.7003	-0.2		1.7005
	P-25	0.51		0.9974	-0.2		0.9976
	25-0	0.41		0.2802	-0.2		0.2804
	0-4	0.38	0.1766		-0.2	0.1764	
	Totals	1.88	0.1766	2.9779	-0.8	0.1764	2.9785
	Difference			2.8013			2.8021
4-M			4.5013		-1.2	4.5001	
	4-33	0.44	3.3437		-0.3	3.3434	
	33-N	0.44		1.4144	-0.4		1.4148
	N-3	0.40	1.7920		-0.3	1.7917	
	3-M	0.12	0.7800		-0.2	0.7798	
	Totals	1.40	5.9157	1.4144	-1.2	5.9149	1.4148
	Difference		4.5013			4.5001	
M-K				6.4058	-0.8		6.4066
	M-Curb	0.56		5.3168	-0.3		5.3171
	Curb-US	0.52		0.9351	-0.2		0.9353
	US-K	0.62		0.1539	-0.3		0.1542
	Totals	1.70		6.4058	-0.8		6.4066
DH-LI			2.4244		-0.4	2.4240	
	DH-Std.	0.54	2.3685		-0.2	2.3683	
	Std-LI	0.60	0.0559		-0.2	0.0557	
	Totals	1.14	2.4244		-0.4	2.4240	

Final Adjustment

Bench Marks		$\sqrt{\text{Dist}}$	Mean Difference		Corr. ection	Corrected Difference	
Junction	Mediate		+	-		+	-
		Km.	m.	m.	mm.	m.	m.
U-6			1.2274		-0.1	1.2273	
	U-T	0.73	2.4199		-0.1	2.4198	
	T-NB	0.28	0.0369		0.0	0.0369	
	NB-S	0.38		5.5488	0.0		5.5488
	S-R	0.60	2.9857		0.0	2.9857	
	R-DB	0.16	0.9696		0.0	0.9696	
	DB-Q	0.48		1.3140	0.0		1.3140
	Q-6	0.43	1.6781		0.0	1.6781	
	Totals	3.06	8.0902	6.8628	-0.1	8.0901	6.8628
	Difference		1.2274			1.2273	
2-DH				0.7583	+0.5		0.7578
	2-GB	0.46		1.8308	+0.2		1.8306
	GB-18	0.42		1.9893	+0.1		1.9892
	18-L	0.55	1.6205		+0.2	1.6207	
	L-DH	0.14	1.4413		0.0	1.4413	
	Totals	1.57	3.0618	3.8201	+0.5	3.0620	3.8198
	Difference			0.7583			0.7578
K-U			3.4807		+0.6	3.4813	
	K-J	0.57	2.4145		+0.2	2.4147	
	J-V	0.40	1.2322		+0.1	1.2323	
	V-U	0.90		0.1660	+0.3		0.1657
	Totals	1.87	3.6467	0.1660	+0.6	3.6470	0.1657
	Difference		3.4807			3.4813	
6-2				2.8940	+0.5		2.8935

Final Elevations

B.M.	Elevation (Meters)	Elevation (Feet)
6	259.8221	852.4371
2	256.9286	842.9416
3	260.7403	855.4472
4	257.0200	843.2415
18	253.1088	830.4094
25	257.1240	843.5827
33	260.3634	854.2106
J	257.5282	844.9088
K	255.1135	836.9865
L	254.7295	835.7267
M	261.5201	858.0056
N	258.9486	849.5689
O	256.8436	842.6627
P	258.1216	846.8556
Q	258.1440	846.9291
R	258.4884	848.0591
S	255.5027	838.2635

542 611
542 542
542 542

52

[illegible]

Nov 22 '35

Aug 28 '39

May 28 '40

Sep 19 '46

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