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Bridge Survey Practice

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BRIDGE SURVEY PRACTICE

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Present day highway traffic is unceasing in its demand for more and better roads and bridges usable with safety and comfort at all seasons and in all weathers. It is not sufficient that good weather demands are satisfied. Bus and trucking schedules and through traffic of every kind depend on constantly usable roads and bridges.

The extent to which a completed bridge will meet the requirements of strength, height, width of roadway, and waterway adequacy will depend on the amount and accuracy of the information obtained in the preliminary survey.

It is the intention in this paper to outline for general use the information that should be obtained in a survey for a proposed bridge in order that it may be designed with a full knowledge of the conditions it must meet satisfactorily in service.

The Manuals herein are written for conditions that exist in the Mississippi Basin and particularly the North Central States but will find general application with minor changes.

The manual for a major bridge survey is built up for a design and construction practice as follows. A survey party of three men makes a complete survey, submitted in the ordinary transit note field book, on a proposed center line roughly designated by the Responsible Engineer. The field book goes to the drafting room and a layout sheet is drawn whose essential features are a detailed contour and topographical map and a profile. With the field book and layout sheet before him, the Responsible Engineer makes the final detailed recommendations requiring study plans from the drafting room for economic and other comparisons if necessary. From the final recommendations the detailed plans are drawn and field checked, the contract for construction is let, and work proceeds.

The minor survey manual is applicable to a two man party, small structures and organizations where the cost of the preliminary survey must be kept to the minimum. The Responsible Engineer will take the plotted profile and the field book into the field and after a thorough inspection of the site write his detailed recommendations.

The major survey manual best covers surveys for those streams requiring from twenty feet of span up to the smaller navigable streams.

It is not the intention in this paper to give any discussion of the principles of bridge location, it being assumed that the location is fixed or that a decision will be made as to the line to be used from comparisons worked up from the several surveys. It is also assumed that if a road survey is being made, it is by a separate party.

Following the survey manuals will be given a short discussion of field practice not covered in the body of the manual and completing the paper, some characteristics of stream and flood flow that are to be noted as affecting bridge surveys and designs.

MINOR BRIDGE SURVEY MANUAL

TABLE OF CONTENTS

1. PURPOSE OF SURVEY. The purpose of the survey procedure outlined below is to obtain the bare essentials necessary for the proper design and construction of a bridge when the funds available for survey are limited and the resulting structure is to be built as force account work, on a lump sum basis or the quantities of the various items of the work will be determined exactly as construction proceeds.

This type of survey may also be used to lessen the preliminary field work when it is intended to compare the bridge costs on several proposed lines.

It is assumed that the Responsible Engineer has the familiarity with local conditions that would be expected of a County Engineer and will have available drainage and road maps and the information as to labor and material costs necessary to make an estimate of the cost of the completed structure.

2. GENERAL INSTRUCTIONS REGARDING NOTES. The Chief of Party should always have in mind the use to be made of the notes and should use his judgment rather than follow the manual blindly. He should always be sure that the notes, as far as they go, are complete and understandable to any competent person.

The notes should be kept neatly and above all legibly and in natural sequence. Space should be left between surveys in the same field book for additional information that may be obtained later.

The structure designation, date, and the names of the men taking the notes shall be shown on each page. The Chief of Party shall place his name and address on the front fly leaf of every book used in the field.

Distances and elevations that are estimated shall be followed by the plus or minus sign.

Sources of information should be given unless self evident.

Sketches should be tied in to the center line and datum plane when it is necessary for clearness.

3. FORM OF NOTES. The survey shall be separated into divisions as listed below, it being necessary for the Chief to arrange the space in the field book so that each division is complete and by itself.

a. Index

b. General Information

c. Stream Data

d. Transit Notes

e. Levels

f. Waterways

g. Test Pits

h. Testimony of Local People

When it is necessary to depart from this form, the divisions may be headed and arranged as desired.

4. INDEX. The first right-hand page of the survey notes for a structure shall be an index made up as shown in the type form following.

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C. A. Johnson, Chief of Party
A. B. Moore

Survey started Oct. 14, 1927 Survey finished Oct. 15, 1927

SIMPSON CREEK

On Section Line, Sec. 2 & 3, T24NR5W
Clinton County Indiana

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Index

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General Information

26 & 27

Stream Data

Etc.

5. GENERAL INFORMATION. The following information should be obtained to locate the structure and to call attention to any special features.

a. Name of stream, road, and bridge.

b. State, County, and Civil Township.

c. Section, Township, and Range and the approximate location in the section.

d. Special features affecting the design or construction, such as tile lines, pipe lines, interference of present structure, and other drainage structures. If necessary make sketches both in plan and elevation exactly locating the interfering features.

e. Requests and suggestions of local authorities or interested citizens.

f. Give any unusual purpose of the survey, what work has been done previously at the site, and refer to any known correspondence or previous field data.

6. STREAM DATA. Information regarding stream action is important in anticipating what is necessary in a structure, and the other data asked for assists in determining the waterway area required and the arrangement of spans.

a. Drainage Basin.

(1) Area in acres.

(2) Mountainous, hilly, rolling, or flat.

(3) Wooded, cutover, or open prairie.

(4) Character of soil and extent of cultivation.

b. Probable drainage projects such as dredging or tiling that will affect stream flow and elevations.

c. Location and extent of scour in the banks and bed of the stream in the vicinity and apparent reason for same.

d. Probability of trouble from ice jams and drift lodgement.

e. The following information is required for dredge ditch crossings.

(1) Official name of project with case number, court, and date filed.

(2). Superintendent of Construction-name and address.

(3) Contractor's name and address. Date of contract, progress, and probable date of crossing the road.

(4) Contractor's intention about crossing the road and maintenance or replacement of the present structure.

(5) Data from the Ditch Plans as follows.

(a) Bottom width.

(b) Side slopes.

(c) Slope.

(d) Grade elevation.

(e) Bench mark or other datum plane tie-in.

(f) Station of ditch at crossing.

(g) Station of road at crossing.

(h) Angle of crossing.

7. TRANSIT NOTES. In establishing the center line, consideration should be given to the possibility of using the present structure during construction, to quantities, to cost and advantages of relocation, and to right of way difficulties.

Curves may or may not be run in the field, preferably not, as it is only necessary to take the time to turn the intersection angles, make the computations for degree of curve, tangent distance, length of curve, and external distance. If these are satisfactory on the ground, show them in the transit book as recommended.

It will be sufficient to show a sketch of the referenced line with the present structure, road, and stream drawn roughly in place. The center line should be run using short pieces of lath at each station marked with the station number and offset distance in case they must be driven at the side of the road. The Engineer making the recommendations will use these stakes in tracing out the line.

The sketch of the line should show the following.

a. Intersection angles.

b. Control point stations with references thereto.

c. Bearing of each portion of the line, looking in the direction in which the chaining increases.

d. Approximate location of the present road, bridge, and stream. Give the station and plus at each edge of water.

e. Recommended degrees of curve, tangent distances, length of curve, and external.

f. Adjacent property owners.

8. LEVELS. Level notes will be kept in the usual manner. Cross sections will not be taken unless specific instructions are given. The notes should include the following.

a. Description, location, and elevation of bench marks.

b. Profile the length of the line and at least from high water mark on one side of the flood plain to high water mark on the other.

c. Accurate profile across the stream from edge of water to edge of water.

d. Elevations on the present structure or on other features likely to affect the design.

e. Maximum and average high water elevations with date and source of information. Be sure to differentiate between head and backwater. Elevation of the base of waterway ordinates on the present structure.

f. Water elevation on date of survey and if this is not the approximate low water, ascertain what low water is and show the elevation.

g. Elevations of the tops of test pits, and of outcrops of any adjacent rock or other hard materials.

9. WATERWAYS. As the determination of required span must ordinarily be made from experience with structures already in service on the same stream or the use of a waterway formula, it is very important that adequate information be obtained at existing structures.

At the present structure, information as to high water and waterway adequacy should be obtained preferably from three or more, and not less than two, well informed people.

Show the following for each waterway at which information is obtained.

a. Highway or railroad bridge.

b. Distance upstream or downstream from the proposed site.

c. Approximate greater or less drainage area than at the proposed site.

d. Thumbnail sketch showing skew of stream and bridge if any.

e. Line diagram.

(1) Clear span.

(2) Ground, present water, and high water ordinates.

f. Area below extreme high water or low superstructure if the latter is below high water.

g. If high water is over the approaches, give the approximate distance and average depth.

h. Information from local people.

(1) Informant's name, place, and length of residence.

(2) High water marks and dates.

(3) Does water go over the approaches.

(4) Is the waterway too large, adequate, or too small.

The Chief of Party must use his judgment as to the number of other structures at which to obtain information. It should rarely be less than two where that number exist and the number should increase with the size of the structure. The requirement is satisfied when sufficient information is obtained to determine a waterway which is neither too large nor too small.

10. TEST PITS. The determination of subsoil is one of the most important portions of bridge survey. The exact determination will allow the most economical design for the conditions to be met and will prevent costly changes when the foundations are actually opened up.

A sufficient number of test pits, borings, or rod soundings should be put down so as to determine the condition at the possible foundation sites and to closely locate the top of any hard material.

An effort should be made to get at least five feet below the flow line of the stream.

When the stream bed is dry, give the elevation at which water stands in the holes in order that the tops of wood piles, if they are used, can be placed below the water line.

A sketch of each test pit should be made showing the information listed below.

a. Location by station, plus, and distance out to right or left.

b. Elevations between which each kind of material was encountered.

c. Elevations between which each kind of tool was used.

d. Description of each kind of material, size of particles, and classification of particles from very soft and loose to very hard and firmly bonded.

11. TESTIMONY OF LOCAL PEOPLE. Much of the information listed below is mentioned elsewhere in the manual but is summarized here for ready reference. Men living near the stream are to be interviewed and questioned in regard to each of the points mentioned. It is advisable to call on the County Engineer for information as to proposed drainage projects, adjacent bench marks, local bridge data and so forth.

Give each informant's name, place, and length of residence.

The following points are suggested.

a. High water.

(1) Maximum and dates.

(2) Average.

(3) Does water go over the grade.

b. Flood conditions at this and adjacent structures.

c. Are this and other structures adequate. Opinion as to required span for the new structure.

d. Low water

e. Property owners, pole and gas line owners.

f. Drainage projects or other proposed work.

g. Drainage basin character and area.

h. Liability of trouble from ice and drift.

i. Accidents due to narrow roadway or bad alignment.

j. Desirability of relocation and right of way difficulties.

k. Material in wells, gravel dippings or soundings, and any other excavations near.

l. Location of adjacent tile lines.

m. Any past tendency to scour.

n. Bridge history.

(1) Date built and by whom.

(2) Foundation conditions encountered.

(3) Is there piling under the footings.

(4) Has a structure at this site ever been washed out or endangered by floods, ice, or drift.

(5) Approximate span and adequacy of previous structures at this site.

MAJOR BRIDGE SURVEY MANUAL

TABLE OF CONTENTS

1. PURPOSE OF BRIDGE SURVEYS. The principal purpose of a bridge survey is to furnish the information which the office uses in the design and estimate of the cost either of a new structure or of repairs to an existing structure. Except for a possible field inspection by some member of the office force and any correspondence, the office is entirely dependent on the survey notes for its knowledge of the present condition and the needs of the bridge site. The notes are used directly to plot the Layout Sheet consisting of a profile and topographic map, usually with a contour interval of one foot. This sheet, together with recommendations of the field men and others who know the location, is the basis for determining the design of the structure. The contour map may also be used for computing quantities of excavation for the structure and for clearing waterway. Local information concerning the length of haul, the shipping point, and the sources of material is used in the estimate of the cost. If approach grading is included with the structure, cross sections are plotted from the survey notes to determine quantities of cut and fill.

2. GENERAL INSTRUCTIONS REGARDING NOTES. The Chief of Party should always have in mind the use to be made of the notes as partially outlined in Article 1 and should use his judgment rather than follow blindly the detailed instructions of this manual. He should look at his notes from the standpoint of the office to see if they can be plotted in such a way as to give an accurate picture of the conditions. It is well to be on the safe side in making notes very clear and to give more rather than less data than seems necessary. Various men plot the notes and they are not always familiar with the methods and practices of the men taking the notes.

An effort should be made to keep the notes neat. Use sufficient space to avoid an appearance of overcrowding and leave some space between surveys for additional data if such should be necessary at some later date. Cross references to other pages and to other books should be in conspicuous places, usually at the top or the bottom of a page.

The Chief of Party shall place his name and temporary address on the inside of the front cover of each book used in the field. A structure designation, date, and the initials of the men taking the notes shall be shown on each page.

Dimensions will be in feet and tenths except in sketches of the present structure where feet and inches should be used. Distances or elevations which are estimated should be followed by the plus or minus sign.

In order not to hold up the work while a part of the party is using the field book, and to avoid copying notes, one or more note divisions may be completely taken on loose leaf paper, stitched together, and then gummed into the field book.

Sources of information should be given unless self evident.

All sketches should be tied in to the survey line and for vertical control either elevations should be used or vertical distances from points of known elevation.

Books containing notes, if transmitted by mail, should be registered.

3. FORM OF NOTES. For the average structure, the notes will be recorded in divisions as outlined in Articles 4 to 15 and listed below. Ordinarily Divisions a, b, c, d, and e will be in the order given and the photos placed last. The other divisions can be in any convenient order.

a. Index

b. General Information

c. Stream Data

d. Recommendations

e. Reasons for Recommendations

f. Topography and Transit Notes

g. Level Notes

h. Present Structure

i. Waterways

j. Test Pits and Borings

k. Testimony of Local People

l. Four Blank Pages

m. Photos

For very large structures or those involving unusual features, a special form should be devised by the Chief of Party to suit the conditions.

4. INDEX. The first right-hand page of the survey notes for a structure shall be an index made up in the following type form.

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C. A. Johnson, Chief of Party
A. B. Moore
G. D. Morrison

Survey started Oct. 14, 1927 Survey finished Oct. 16, 1927

SIMPSON CREEK
On Section Line, Sec. 2 & 3, T24N.R5W
Clinton County Indiana

5. GENERAL INFORMATION. The following information should be obtained locally and listed for use in exactly locating the structure, estimating the cost, and assisting in the determination of the design.

a. Name of stream and local name of bridge.

b. State, County, and Civil Township.

c. Section, Township, and Range and the approximate location in the section. A sketch of the vicinity may be used showing the road, stream, and possible detours for use during construction.

d. Common name of road. The distance in miles and tenths to the nearest towns and shipping points. The names of railroads, the unloading facilities, and the type of road over which the wagon or truck haul must be made.

e. Traffic of unusual nature requiring special strength or clearance. Estimate of the normal and the maximum traffic per day. Probability of any large increase in traffic from any known or forecasted cause.

f. Any accident record at the site particularly due to narrow roadway or bad alignment.

g. Special features affecting the design or construction such as tile lines, pipe lines, and interference of present structure or other drainage structures. If necessary make sketches both in plan and elevation exactly locating the interfering features.

h. Requests and suggestions of local authorities or interested citizens.

i. All possible local sources of materials and supplies, giving names, addresses, locations, costs, quality, and quantity available.

(1) Piling.

(2) Falsework timber.

(3) Dimension lumber for formwork.

(4) Filling material. Give possible locations and amounts in borrow pits.

(5) Sand and gravel and whether the same can be obtained locally washed and screened or in such form as to pass the specifications used.

(6) Crushed stone.

(7) Cement.

(8) Labor, teams, and trucks.

j. Give any unusual purpose of the survey, what work has previously been done at the site, and refer to any known correspondence or previous field data.

6. STREAM DATA. Information regarding stream action is important in anticipating what is necessary in a structure and the other data listed below assists in determining the waterway area and the arrangement of spans.

a. Drainage Basin

(1) Area in acres.

(2) Moutainous, hilly, rolling, or flat.

(3) Wooded, cutover, or open prairie.

(4) Character of soil and extent of cultivation.

b. Probable drainage projects such as dredging or tiling that will affect stream flow and elevations.

c. Location, extent, and apparent reason for any scour in the banks and bed of the stream in the vicinity.

d. Probability of trouble from ice jams and drift lodgement.

e. Some special information is required for the crossing of an existing or proposed dredge ditch. When a structure is in place that could remain after the dredge has passed, the Chief of Party may be asked to submit a report covering the details that are listed below. If a new structure is to be built, either before or after the passing of the dredge, the same information is required together with the usual survey. Item (5) will not apply in this case. If the survey is for a new structure over an existing dredge ditch, the usual survey will be made and the listed dredge information obtained omitting items (2), (3), (4), and (5). It is assumed in the last two cases that the data on the present structure will be obtained as detailed in Article 11.

(1) Official name of project with case number, court, and date filed.

(2) Name and address of the superintendent of construction.

(3) Contractor's name and address. Date of contract, progress, and probable date of crossing the road.

(4) Contractor's intention about crossing the road and maintenance or replacement of the present structure.

(5) Sufficient data on the present structure for plans of all the work proposed. See particularly Articles 11, 17, and 18. Footing elevations and conditions are especially desired.

(6) Data from ditch plans as follows.

(a) Bottom width.

(b) Side slopes.

(c) Slope.

(d) Grade elevation.

(e) Bench mark or other datum plane tie-in.

(f) Station of ditch at crossing.

(g) Station of road at crossing.

(h) Angle of crossing.

7. RECOMMENDATIONS. The Chief of Party shall make detailed recommendations that will be used as a guide by the Responsible Engineer when the final recommendations are made. Recommendations should be clear and concise and if intelligently made will require considerable time and thought on the part of the Chief of Party. He should be familiar with the standards and practices of his organization so that his recommendations are practicable of application.

Recommendations should include the following points and any others pertinent to the design, estimate, special provisions, or construction. Reference should be made to any important information or sketches in some other division of the notes.

a. Station of proposed center line of span. Proposed center line of roadway if it is different from the survey line.

b. Size and type of structure and if square or skew. Width of clear roadway.

c. Elevation of crown of roadway.

d. Elevation of bottom of footings.

e. Necessity for foundation piling and approximate length.

f. Allowable foundation bearing pressure on the subsoil in tons per s uare foot. The following table outlines safe bearing values for the different soils but other values may be recommended if the test pits or soundings make this seem desirable.

SAFE BEARING VALUE OF SOILS

Character of soil	Safe working load in tons per sq. ft.
Loam, silt, or quicksand	0.5 to 1.0

Soft or wet clay	1 to 2
Fine sand or medium clay	2 to 4
Hard, dry clay, gravel, or coarse sand	4 to 6
Hard pan or very dry clay	6 to 8
Cemented gravel	8 to 10
Rock (Poor brick masonry)	5 to 10
Rock (Best brick masonry)	10 to 20
Rock (Best Ashlar masonry)	20 to 30
Very hard bed rock	30 to 100

g. Elevations of spring lines of arches.

h. Angles of wings to faces of the abutments and any unusual lengths required.

i. Riprap. Amount, place, and method of placing.

j. Dikes, mattresses, or other bank protection.

k. Channel change or clearing waterway and specific lines and grades for the work recommended.

l. Changes or repairs to be made to any other adjacent structures. Alterations in any natural features.

m. Check up on the other drainage features in the vicinity and how they will be affected and taken care of.

n. Necessity for special borrow to complete the grade or the backfill over [redacted] arches.

o. Necessity for a temporary bridge and approaches during or prior to construction. Give the best location, sketching the alignment if it is necessary for clearance.

p. Detours or other features of maintaining traffic during construction. See detour sketch under Article 5. Give the approximate width, kind, and condition of metal on the proposed detour.

It often happens that a face of abutment or some other point rules the location of the structure and this should be given as well as the center line of span. Where the distance below the flow line determines the top of footing, both top and bottom of footing should be given. Similarly when low superstructure clearance above high water determines the crown of roadway, the recommended clearance should be given.

It is found in practice that piling is cheaper protection against wash than deep footings in most cases. Gravel and sand have good bearing values when confined but have poor resistance to wash. They often boil badly when a cofferdam must be pumped dry much below the water line.

Any concrete or stone from the old structure should be disposed of as riprap and additional material may sometimes be required.

8. REASONS FOR RECOMMENDATIONS. Give the reasons for each of the recommendations as outlined in Article 7. The recommendation might be based on some information or condition that is known to the man in the field but not apparent in the notes.

When the waterway area of the present structure cannot be used in determining the length of span required, the profile on the proposed center line should be plotted on cross section paper and the span length to give the required waterway area is then found. The sketch should be made to a small scale and placed in the photo envelope.

9. TOPOGRAPHY AND TRANSIT NOTES. In establishing the proposed center line, consideration should be given to the possibility of using the present structure during the construction of a new structure, to cost and advantages of, and quantities involved in, relocation, and to right of way difficulties.

Stations should increase from south to north or from west to east, according to the general direction of the road. This directs the north point up or to the right when the notes are plotted from left to right in the usual manner.

All curves should be staked out in the field using the tables for a one degree curve. There should be at least fifty feet of tangent between the PC or PT and the end of the proposed structure and at least one hundred feet of tangent between curves. Under ordinary conditions, seven degrees should be the maximum curvature. Circumstances may raise or lower any of these limits.

Notes shall be taken with stations increasing from the bottom of the page up so that the various features shown on the right or left of the center line are in their true relation. The usual method of data on the left page and sketches on the right should be followed with remarks or stations in line with the representation on the sketch. Separate sketches can be used for the line and references, large scale map of the immediate bridge site or other features whenever it is desirable. Topography notes will usually be neater if the feature is sketched on the right-hand page and the notes locating it on the left.

The notes should include the following.

a. Permanent points properly referenced, at least one such point lying on each side of the proposed structure. Tie-ins should be approximately at ninety degrees to each other. Sketches of the referenced points can be shown on the left-hand page giving the objects to which the ties are made, distances, station, and whether control point is an iron pin or wood hub.

b. Survey of sufficient length to establish a grade, to locate all level notes taken, and to connect with the present road or with the original surveys in case of relocations.

c. Sufficient width of survey to take in any structures or natural features affecting the proposed structure or its approaches. Detailed topography accurately taken should

be as wide as the proposed right of way and cover the main features out to one hundred feet each way. Within the limits of the Layout Sheet, which usually represents a width of two hundred feet and a length of four hundred feet plus the proposed structure length, detailed topoggraphy should be taken.

d. Compass bearing of the survey line looking forward and a north point on all sketches. Compass bearings should be used as a check in turning angles.

e. Present road, edges of metal, guard rails, and a note about the kind and condition of the metal.

f. Fence and property lines and the names of the property owners.

g. Pipe lines and pole lines with the number of wires and the character of the line. Note the owner's name and address as correspondence may be necessary in case the pipes or poles must be moved.

h. Intersecting public or private roads, gates and drives to fields.

i. Location of the present structure. (Detailed under Article 11)

j. Location of the stream and the angle upstream and downstream if the channel is well defined. In case of a proposed channel change, a traverse should be run to locate the center line of the channel change and the stream at least one hundred feet beyond the ends of the channel change. In any case either transit or level notes should locate the flow line, the edges of the water, and the bank lines within one hundred and fifty feet of the center line.

k. Points where scour is apparent and the direction and location of ordinary and flood currents.

l. Arrowed, continuous lines showing the water courses now dry but acting during a rain.

m. Location and description of culverts, tiles, and other drainage features.

n. Total of the angles in a closed circuit to check any appreciable error.

10. LEVEL NOTES. Transit and level notes should supplement each other and an effort should be made to see that they are consistent. Unless otherwise noted, it will be assumed in the office that offsets recorded in transit notes are the more accurate and will govern in case they differ from level notes.

If no survey has previously been made, a bench mark or bench marks will be established at some point near the stream and along the center line in such positions that they will not be disturbed during construction. They should be clearly described for future identification. An effort should be made to use government bench marks or other sea level data, and the bench marks of other surveys of roads or drainage projects.

The columns on the left-hand page will be used in the usual manner of Station - Plus - HI - Minus - Elevation. It is a good practice to use two lines in making turns, one for foresight and one for backsight.

Station numbers should be spaced every other line. On the right-hand page the rod readings should be placed above the line and the distance out below the line. Any note such as EW or TB is placed below the distance out and computed elevations are later shown over the rod reading.

Readings shall be recorded on the left or right of the line representing the survey line, corresponding to left or right on the ground looking in the direction in which the chaining increases, regardless of whether stations run from the bottom or the top of the page. In cases where it will help in making the direction clear, notes of North and South or East and West may be used at the top of the page.

When the stream is nearly perpendicular to the center line or the drop from the top of the bank to the water line is large, it is usually best to cross section from a base line or base lines approximately parallel to the stream. This is saving of time both in the field and in the office and will better establish the bank contours.

Dirt shots should be taken to 0.1', bench and turn readings to 0.01'. Level circuits should check to 0.01' per turn up to four turns and not over 0.10' error per mile but in the latter case the HI's should be adjusted.

Notes should include the following.

a. Profile of sufficient length to establish a grade line with a minimum of two hundred feet each way from the ends of the proposed structure. Note the approximate grade percent beyond the limits taken.

b. Cross sections as far each side of the structure as is necessary for computation of approach quantities and of width sufficient to show the contours out to the natural ground on each side of the present road and for any cut, fill, or borrow necessary. The minimum is one hundred feet on each side of the center line, two hundred feet

each way from the ends of the proposed structure, and whatever additional is necessary to locate the stream out to one hundred fifty feet. Beyond the limits just given, it will be sufficient to take sections at the even stations and at breaks in the ground. Within the limits of two hundred feet of the proposed structure, sufficient sections must be taken for an accurate contour map. The minimum is a section across the ends of wings, the back of abutments out to masonry line, the face of abutments on the ground, and at the center line of the stream. Some notes such as EM, TB, EWL help to explain notes. At every section shots should be taken at the center line, the crown of the present roadway, the edge of metal, the right of way line, forty feet, and one hundred feet in addition to the breaks in the ground.

c. Cross sections on the center line of any proposed channel change should be taken in order to estimate the earth quantities involved.

d. Profile of the stream bed five hundred feet each way and the water elevation at the five hundred foot points. Distances can be paced, but all variations in the deepest point of the bed should be taken.

e. Elevations on the present structure such as the base of waterway ordinates, the floor at each end, the bridge seats, the tops and ends of the wings, and the top and bottom of the footings if possible.

f. Elevations on other structures or natural features affecting the design.

g. Maximum and average high water elevations with the mark on which the elevation was taken, date of the high water, and the source of the information.

h. Water level on the date of survey with a note as to whether this is an average low water. If not, ascertain what average low water is and show the elevation.

i. Elevation of the top of the test pits.

j. Elevations on any adjacent bridges, railroad tracks, flow lines of culverts and tiles.

k. Tie-in of datum plane for any stream gauges.

l. Elevations of low water and high water of any other streams near. Be sure to differentiate between head and back water at the proposed site.

m. Elevations of any other proposed work with equation of bench marks and chaining.

n. Close every level circuit checking back on the bench mark even though no turn has been made.

o. In rare cases a good contour map can be drawn from elevations on the controlling points located by angles turned from an instrument set up on center line and measured or stadia distances.

11. PRESENT STRUCTURE. The amount of detail in sketching the present structure will depend on whether or not consideration should be given to leaving it in place for some time. The decision as to whether such consideration should be given will be based on the width of clear roadway, the estimated strength of the floor system and superstructure, the adequacy of the waterway, the alignment of the approaches, and if the road is hard surfaced or hard surfacing is definitely projected.

Sufficient sketches and notes should be given for a drawing of the present structure on the Layout Sheet and for a marking diagram of steel structures. See Articles 17 and 18 for special information for a floor repair and strength survey. Enough information should be given to show the condition of the present structure, the necessity for its immediate or future replacement, and its interference with the construction of a new structure.

The following details are suggested when consideration should be given to leaving an existing steel structure in place and for all concrete and masonry structures.

a. Plan of superstructure and substructure tied in with the proposed center line with station and offsets or angles and distances so that it can be plotted. See that overall and detailed dimensions check.

b. Section of substructure, if necessary, showing footing elevations if possible.

c. Elevation of superstructure and substructure showing the length of clear span, the distance center to center of bearings, the length of the floor, the distance end to end of truss shoes, the panel lengths, the distance center to center of chords and whether the trusses are pin connected, full riveted, or shop riveted and field bolted. Ground, water, and high water ordinates should be shown on this sketch with a reference to the page in the division "Waterways" where further information may be found.

d. Section of superstructure showing the substructure elevation, the width of clear roadway, and the distance

center to center of trusses.

e. For trusses in "c" above, a line diagram with letters L for lower chord and U for upper chord and panel points L sub-zero, L sub-one, and so forth with accompanying table of sizes and composition of members is easier to draw and clearer than an ordinary elevation.

f. In taking steel sections, give the depth of the section and the width of the flange and if possible the web thickness so that the section may be identified in the steel hand books.

g. For arches make an elevation and a transverse section showing the springing line, crown of arch, clear span, points to establish the arch curve, and the thickness of the arch ring if possible. For other concrete or masonry structures give the same sketches and applicable dimensions as in a, b, c, and d above with the addition of the dimensions of the various concrete sections and whatever information is available as to reinforcement.

h. Note the nature and quality of all materials. Give the average size of stone in stone abutments. State if there is any possibility of using any part or the whole of the structure in a new structure, in a temporary structure for a run-around during construction, or for reerection elsewhere.

i. Note any heavy loads carried safely by the structure.

j. Sketch any special or important features.

k. If there is a possibility of its being economical to place a new superstructure on the old substructure, the latter should be detailed with sufficient accuracy to determine the feasibility in the office and to plan any necessary additions or changes.

l. Give the date of construction and the name of the builder and any other pertinent information obtained from local people. See Article 14. Obtain the plans and specifications, if possible, or note where these can be obtained.

m. Make a careful inspection of the entire structure and describe fully any defects, weaknesses, and deterioration.

n. State the necessity for replacement, permanent or temporary repairs, and any other information of interest.

It is advisable to devote a page or pages to the information as outlined in h, i, l, m, and n above.

When the strength of the present steel structure is not a factor,

or the removal of the structure in the immediate future is probable, less detail is requires in sketching and the following is suggested.

a. Plan of superstructure and substructure as in "a" above with the addition of the width of clear roadway and the distance center to center of trusses shown.

b. Elevation of superstructure and substructure showing the clear span, the distance center to center of bearings, the panel lengths, the distance center to center of chords and whether a low or high truss, pin connected, full riveted, or shop riveted and field bolted. Show ground, water and high water ordinates, and footing elevations if possible. The superstructure elevation will ordinarily be a line diagram as outlined in "e" above but with no tabulation of members.

c. Measure the floor beams and stringers in detail and give the following information.

(1) Stringer span and spacing.

(2) Size and length of each floor beam if different.

(3) Number, size and length of each corresponding size and length of stringer.

(4) Give number, size, and length of any other free I-beams and channels.

d. State whether truss should be classified as heavy, medium, or light.

e. Give the information as in h, i, j, k, l, m, and n above but perhaps in not so much detail except as to the condition of the structure.

f. If the front elevations of the abutments are such that a sketch is necessary to make clear some important feature, this may be shown.

Whenever there is a possibility that a new or partially new structure will be joined to an existing or adjacent structure, full details in plan, elevation, and section of the existing or adjacent structure at and near the probable point of junction should be given. Measure accurately the plan dimensions at the top of wall or underneath the coping and the wall batter if present.

12. WATERWAYS. As the determination of required span must ordinarily be made from a study of the waterway adequacy of structures over the stream in question or the use of some waterway formula, it is very important that adequate waterway information be obtained at existing structures.

For the structure nearest or at the proposed site, information as to high water and waterway adequacy should be obtained preferably from three or more and not less than two well informed people.

A resume' of the pertinent information in Articles 11 and 14 should be given here for the present structure. The following listed information is suggested for all other structures at which information is obtained.

a. Highway or railroad bridge.

b. Distance upstream or downstream from the proposed site.

c. Approximate greater or less drainage area than at the proposed site.

d. A thumbnail sketch showing skew, if any, of stream and bridge.

e. Line diagram.

(1) Clear span.

(2) Ground, present water, and high water ordinates.

f. The area below extreme high water or low superstructure if the latter is below high water.

g. If high water gets over the approaches, give the approximate distance and average depth.

h. Information from local people.

(1) Informant's name, place, and length of residence.

(2) High water marks and dates.

(3) Does water go over the approaches.

(4) Is the waterway too large, adequate, or too small.

The Chief of Party must exercise his judgment as to the number of other structures at which to obtain information. It should rarely be less than two where that number exist and the number should increase with the size of the structure. The requirement is satisfied when sufficient information is obtained to determine a waterway which is neither too large nor too small.

13. TEST PITS. The determination of subsoil conditions is one of the most important parts of a bridge survey. The exact determination will allow the most economical design for the conditions to be met and will prevent costly changes when the foundations are actually opened up.

A sufficient number of test pits, borings, or rod soundings should be put down to determine the condition at the possible foundation sites

and to closely locate the top of any hard material within the limits of the bridge in plan. An effort should be made to get at least five feet below the flow line.

When the stream bed is dry, give the elevation at which water stands in the test holes in order that the tops of wood piling if they are used, can be placed below the water line.

A sketch of each test pit, boring, or rod sounding should be made showing the information listed below.

a. Location by station, plus, and distance out to right or left.

b. Elevations between which each kind of material was encountered.

c. Elevations between which each kind of tool or equipment was used.

d. Description of each kind of material, size of particles, and classification of material from very soft and loose to very hard and particles firmly bonded together.

Note here any information from local people as to subsoil conditions or refer to this if it is given in the division "Testimony of Local People".

If rock is probable or visible above or near a reasonable assumption as to the approach grade line, a rock profile along the proposed center line should be obtained. This profile may be elevations on outcrops or test pits or a combination of both. Ordinarily a standard cut section in rock is very different from the cut section in earth and a proper balance of quantities cannot be made or an economical grade line laid without some knowledge of the depth of rock cut.

14. TESTIMONY OF LOCAL PEOPLE. Much of the information listed below is mentioned elsewhere in the manual but is summarized here for ready reference. Men living near the stream are to be interviewed and questioned in regard to each of the points mentioned. It is advisable to call on the County Engineer for information as to proposed drainage projects, adjacent bench marks, local bridge data and so forth. The person in charge of the maintenance of the road will usually have observed high water conditions closely.

Give each informant's name, place, and length of residence.

The following points are suggested.

a. High water.

(1) Maximum and dates.

(2) Average.

(3) Does water go over the approach grade.

b. Flood conditions at this and adjacent structures.

c. Are this and adjacent structures adequate. Opinion as to the required span for a new structure.

d. Low water.

e. Property owners. Pole and pipe line owners.

f. Drainage projects or other proposed work.

g. Character of drainage basin and approximate area.

h. Liability of trouble from ice and drift.

i. Accidents due to narrow roadway or bad alignment.

j. Desirability of relocation and right of way difficulties.

k. Material in wells, gravel dippings or soundings, and any other excavations near.

l. Local stream name.

m. Location of adjacent tile lines both at the bridge site and in the vicinity of a probable channel change.

n. Any past tendency to scour.

o. Distance to towns and shipping points.

p. Availability of local materials mentioned in Article 5.

q. Bridge history.

(1) Date built and by whom.

(2) Foundation conditions encountered.

(3) Is there piling under the footings.

(4) Has a structure at this site ever been washed out or endangered by floods, ice, or drift.

(5) Approximate span and adequacy of previous structures at this site.

16. PHOTOS. The purpose of photos is to supplement the other notes in giving the office force an accurate idea of the bridge site. They also serve as records of the present structure for publicity purposes, and for explaining to non-techinal men the deficiency of

the present structure and the requirements of the proposed structure. Very often they supply information lacking in the notes or clear up inconsistencies. The number required is variable but should include views of the present structure with special attention to defects, views of the stream, and of the proposed center line of roadway.

Each print should be marked with the date, structure designation, the location from which the photo was taken, the direction in which the camera was pointed, and a note of what the photo is intended to show. Ink lines showing the proposed center line are desirable. A post card size camera should be used if possible. Prints and films should be placed in an envelope which has been glued to the last right-hand page of the notes.

16. SPECIAL INSTRUCTIONS FOR RAILROAD GRADE SEPARATIONS. All of the data in Articles 4 to 15 applicable to these surveys will be supplied. In addition the following points are suggested.

a. Information about dangers and accidents at the present grade crossing or structure.

b. Character and amount of traffic on both the highway and the railroad.

c. Name of railroad company, division engineer, and the division headquarters.

d. Any survey records, plans, or proposals of the railroad company.

e. Survey of the site including alignment and profile sufficient for any possible track changes in connection with the proposed work, the elevation of the top of each rail at the center line of road, the weight and height of rail, the exact angle between the center line of track and the center line of roadway, right of way and fence lines, cross sections near the structure and wherever quantities will be desired, switch points, mile posts, and other points that can be identified on railroad maps and equations of datum plane and chaining. If the crossing falls on a track curve, turn off a base line and take ordinates from it to the center line of the track or to a gauge line in order that the curve may be plotted.

f. Cross sections of borrow pits for filling material if their location is known.

g. Drainage conditions including adjacent high waters, existing outlets, and location and profile of existing ditches. When a subway is to be drained to a nearby stream, the flow line, low, high, an average high water should be determined at each possible outlet along the stream.

h. Test pits as described in Article 13.

17. FLOOR REPLACEMENTS AND REPAIRS. Occasionally an old steel superstructure may be retained in service for many years by replacing the entire floor system or a portion thereof. When such a procedure is contemplated the entire structure should be closely examined in order to determine its probable life with a new floor. Some field investigation of the adequacy of the waterway should be made in order that an undesirable condition is not perpetuated. This question of the perpetuation of undesirable conditions should be applied to any bad features of alignment, grade, and width of roadway.

All the information suggested in the first part of Article 11 should be given with special attention to the details of the connection between the substructure and the present superstructure and floor system.

Some necessary details are suggested below.

a. Sufficient details in plan, elevation, and section of the substructure and floor system at abutments and piers so that necessary changes in expansion joint details and in masonry stringer and bridge seats can be made. Vertical dimensions should be tied in to some definite horizontal plane such as that through the center line of pins or the tops of floor beams. Likewise, horizontal dimensions should be given with reference to the center line of end pins, the center line of shoe, or the center line of the end floor beam. Be sure to obtain the horizontal relation of the ends of the end panel stringers to the reference plane as above.

b. Details of present floor beams and stringers with the connection of the floor beams to the intermediate and batter posts and of the stringers to the floor beams. Show the size, spacing, and condition of rivets.

c. Details of expansion joints of the superstructure.

d. Handrail connections, and the height of the handrail tied in to the reference plane.

e. All lateral clearances of the floor such as between batter and intermediate posts.

f. Any small defects that should be repaired, with sufficient details for the connection of the new work to the old.

g. Condition of the paint and the necessity for repainting at the time the new floor is put on.

18. STRENGTH SURVEYS AND SURVEYS FOR REPAIRS. In general a strength survey will require sufficient drawings and details such that the original plans can be reproduced in the office in their entirety. In addition, full information must be given as to the quality of the materials and the extent of rust, disintegration, and dete-

rioration, and an approximation of the percentage which the present strength of each part of the structure is of the original strength.

The same principles apply to the portions of a structure that are to be repaired with special care in the detailing of the connections between the portions to be repaired or replaced and the remainder of the structure.

When the original plans are available, the work is simplified to a rough field check of the plans to the structure as built, and the information as to strength and deterioration.

A manual covering the details of strength surveys would be too lengthy to include with this general survey manual and will not be attempted.

19. STRUCTURES OVER STREAMS LISTED AS NAVIGABLE BY THE WAR DEPARTMENT. When the proposed bridge is to span a navigable stream, the ordinary survey must be made and supplemented by special information required in the application to the War Department for a permit to cross such a stream.

Following is listed the additional data to be obtained in the field.

a. Location of the stream for a mile both above and below the proposed crossing and soundings across the stream at each one thousand foot interval over the two mile distance. Each sounding across the stream shall show the elevation of the stream bed at not greater than one hundred foot intervals. The soundings may be referre to the datum plane used or more easily to the water level at the point with the elevation of the water obtained simultaneously at the point of crossing. If the maximum depth of the bed varies widely, sufficient soundings should be taken at the deepest point in the bed at intermediate points, so that a stream bed profile can be drawn.

b. Current velocities at high and low water at the point of crossing and at one mile up and one mile downstream.

c. Direction of low and high water currents in the vicinit of the point of crossing.

d. Data on other structures adjacent and sometimes on all structures downstream to the mouth of the river. This data should show location, horizontal clearances, and vertical clearance above high and low water. Waterway information as outlined in Article 12 should be obtained at the same time as the above. Data on movable spans should be given.

e. Survey must be tied in to a government bench mark such as Coast and Geodetic, Geological Survey, or U. S. Corps of Engineers.

f. Stream gauge readings with reference to the place where the records are kept.

g. Character and amount of river traffic.

20. ABBREVIATIONS. The following abbreviations should be used as standard in order that confusion will not result from nonconformity of practice.

EM	Edge of metal	CFP	Corner fence post
℄	Center line	Br. St.	Bridge seat
TB	Top of bank	PL	Property line
TS	Toe of slope	Sec.	Section
EWR	Edge of water right (facing downstream)	T	Township
		R	Range
EWL	Edge of water left (facing downstream)	HW	High water
		Rdwy.	Roadway
F	Fence	RR	Railroad
FL	Flow line	R	Right
R/W	Right of way	L	Left
TP	Telephone pole	N	North
PP	Power pole	S	South
PC	Point of curvature	E	East
PT	Point of tangency	W	West
PI	Point of intersection	p	Page
POT	Point on tangent	pp	Pages
POST	Point on subtangent	cc	Center to center
BM	Bench mark	o to o	Out to out
TP	Turning point	in to in	Inside to inside
El.	Elevation	ft.	Foot or feet
Sta.	Station	In.	Inch or inches
Abut.	Abutment	Mi.	Mile or miles
FP	Fence post		

21. EQUIPMENT. The following equipment should be carried.

Transit, tripod, and accessories
Level and tripod (transit may be used as a level)
Two range poles
Post hole auger with five three-foot shank extensions and couplings
Two 18" pipe wrenches
One-half inch round steel rod twelve feet long
Three-fourths inch round steel rod six feet long
Axe
Six pound iron maul
Small pick and shovel
Two corn knives
One hundred-foot steel tape
Fifty-foot steel box tape in inches
Fifty-foot metallic box tape in tenths
Six-foot rule
Two pound ballpeen hammer
Hand level and home-made staff for its support at height of eye

Building lath
Boat spikes
Heavy hinge nails
Hub tacks
Two-inch hub stakes
Red cambric
Red, yellow, and blue keel
Waterproof cover for instrument when set up
Camera

The Chief of Party should have the following supplies.

Survey manual
Scales, triangles, pencils, protractor, and so forth
Field and office tables (curve tables and so forth)
Tabulation of the organization's standard designs
Tabulation of waterway formulas
County road maps
Any drainage maps available
Stationery as necessary for reports and correspondence

The Chief of Party should watch constantly the care of the equipment entrusted to him. Each piece of equipment should have its proper place and always be returned to it after use. Levels and transits should be kept dry, clean, and in adjustment. Steel tapes must be cleaned and oiled after each day's work if they have been wet and should be cleaned and oiled periodically in any case.

A level or transit when set up in the traveled roadway must have someone with it all the time.

Every piece of equipment should be taken in each night, and the last thing before leaving the job in the evening, the party should enumerate all the equipment used that day to see that those pieces used and all the other equipment is in place.

DISCUSSION OF FIELD PRACTICE

The Major Bridge Survey Manual has been evolved during several years' experience and the practices outlined have been built up to supply the necessary information to the office and to be practical of application in the field. Certain procedures and methods have been developed that may not be clear in the manual and some explanation of these will now be given.

All transit and level notes are placed in one field book and it will be found that to avoid copying of notes and a rush of notes into the book at the end of the survey, it will be necessary to keep notes of some kind going into the book all through the working day. The book should be changed after each survey in order that the Chief of Party may use it during the beginning of the next survey for writing the recommendations and for a final general check of the notes.

Specific information has been placed under indented heads so that when the survey is completed, the notes can be quickly checked against the manual for omissions of important information.

After the center line has been chained out, two processes will ordinarily be kept under way at one time by one man working separately. The Chief of Party will often wish to outline the work to be done at the beginning of a half day and then work on the notes of the previous survey or obtain the general and waterway information. It is best that he, so far as is possible, obtain waterway and high water information at the present structure and be present when the subsoil investigation is made.

The Chief of Party should have had some experience in design and construction of bridges or considerable survey experience. He should have one man who is capable of taking charge in the Chief's absence. The work is sufficiently variegated that it is possible in a well organized party to keep each man busy at work near the limit of his capability.

Drainage area up to twenty-five square miles are actually traced out in the field by driving around them. County or other maps showing the streams are used to find the approximate limits and by staying just within or without the drainage area and noting the direction of flow in the small watercourses and the ground contour, a line representing the drainage area boundary can be closely drawn on the map. Drainage areas over twenty-five square miles are taken from any available drainage maps, as in using the usual type of waterway formula, the probable error in the drainage area by this procedure has less effect than a small error in the selection of a constant.

Waterways are not usually cleared below one foot above low water and never so that the clearing merely makes a pocket under the structure.

In very rough country where a few feet variation in the alignment very materially changes earthwork quantities and maximum grades and

curves, it is desirable to make a contour and topographic map in the field and lay the final line on this map. The map line is then run in the field in the usual manner.

The contour map can be drawn in the field by taking the profile on a preliminary line and any necessary additional traverse lines, and then finding the contours on the ground at right angles each way from the lines by the hand level method.

Center line stations are set with short pieces of marked lath except in the traveled roadway. In the latter case, heavy, two and one-half inch hinge nails are driven to mark the stations. Short pieces of lath are then driven by the roadside opposite and marked with the station and offset distance. Before being driven the hinge nails are run through three or four thicknesses of red cambric forming a tag about two inches square. The red cambric acts as a marker in case the station is to be recovered exactly but for the ordinary purposes of topography and cross sections, the offset lath is sufficiently accurate.

Control points are wood hubs or boat spikes with not less than three references. Nails with a square of red cambric driven in fence posts, stumps, trees, and poles are the usual reference points.

When unusual accuracy in locating structures or other features is desired any of the three following methods may be used to locate the desired points. (a) Two angles from known center line transit point. (b) Angle and distance from a known center line transit point. (c) Accurately measured tie lines from two known center line points.

Boat spikes driven in tree roots, poles, and large fence posts are the usual bench marks although any definite and permanent point which can be accurately located may be used.

The hand level method of extending sections from a center line or base line profile in woods, brush, or very rough country will save time and is sufficiently accurate. In rough open country, the transit may be set up exactly twelve feet below the level and used as a level to obtain a twenty-four foot variation in the ground contour.

Deep places in a stream bed have a tendency to shift and it is desirable to locate such places by the stream bed profile a distance of five hundred feet each way.

The Chief of Party will ordinarily establish a code of signals covering all communications necessary between members of the party while working beyond hearing distance of each other. If the organization has more than one party, the same code should be used by all so that if an interchange of personnel is made, there will be no necessity for any member of a party to become familiar with a new code.

In the usual case of a stream having a flood plain and the maximum high water above the bankful stage, the required waterway area is first determined and then the span length found that will give the required area. The waterway area is bounded by the ground profile along the center line of roadway, the faces of the abutments, and the actual or assumed high water line. The ground profile is plotted to a small

scale on cross section paper and the horizontal line representing the maximum high water drawn. The faces of abutments are then so placed that the required waterway area is obtained. If more than one span is required, a suitable and economical arrangement of spans is determined, shifting the abutments as necessary but keeping the waterway about the same.

The required waterway area is determined by a study of the waterway areas of the existing structures and the required area as given by one or several of the common empirical formulas of which Talbott's is perhaps the best known.

At existing structures, the total span and ordinates from some base on the superstructure, such as the top of the floor, to the ground line and to maximum high water are measured. The span length multiplied by the average ordinate between the ground line and maximum high water will give the waterway area with no great error. Ordinates are usually taken at the panel points of steel structures and the spacing between them in any one span is always made equal. If the ground line varies greatly, the waterway may be separated into spans or parts of spans for the purpose of computation.

The waterway adequacy of any existing structure must be determined by an inspection of the site and the opinions of local people.

For skew structures it is assumed that the actual waterway area is the waterway area measured along the center line of roadway multiplied by the cosine of the skew angle. This applies also to waterways measured, and allowances must also be made when the bridge is square and the stream is skewed for both skew and projection of abutment corners. Interference of piers must also be considered when they are present.

Subsoil conditions are none too accurately determined even with the extensive equipment required for wash, churn, or core drillings. Heavy equipment is impractical for a small survey party and for this reason a post hole auger and two steel rods have been found to give the best results for light equipment.

The post hole auger with shank extensions is used as deep as is practical. If under twelve feet, which will be the case in sand and gravel, the rod is driven and from its driving and the feel when turned and pulled with pipe wrenches, a fair idea of the subsoil conditions is obtained. Longer rods can be obtained for special cases but cannot be conveniently carried. The six-foot rod is used for hard driving near the surface and to start a hole for the twelve-foot rod.

On the larger jobs it will be necessary to supplement the above information with more extensive investigation with heavier equipment or borings by one of the usual methods.

STREAM CHARACTERISTICS.

Following are given some stream and flood flow characteristics that have been noted during bridge surveys, a number of which are very important in any consideration of proposed bridge layouts. There has been no attempt to make a connected discussion except as related characteristics of certain types of streams have been grouped together.

NATURAL STREAMS

It has been noted that the rise from water elevation on the date of survey to the maximum high water elevation on a stream with flood plain not completely spanned, does not vary greatly at the different bridge sites in a vicinity unless at some site the approach fill has not been built up above the level of the flood plain or there is some constriction.

If a departure from this characteristic is found at any bridge site, suspicion is aroused that the information as to the maximum high water is incorrect or that there is a constriction at or near the bridge site.

This characteristic of constant rise allows an assumption to be made as to the high water elevation at a bridge site where no information is available or on a relocation where information cannot be obtained. It should be remembered that in most cases a bridge is a constriction in a greater or less degree and a rise transferred from a high water mark where there is no bridge must be increased by say fifteen percent for practical use. Similarly, on a relocation with no bridge site near but an accurate high water mark available, an assumption must be made that with a bridge in place, equal flood flows cannot be passed except by an increased rise.

At any bridge crossing where the flood plain is partially closed by approach fill, it must be expected that some backing up of flood water will occur. If the water were the same elevation on the two sides of the fill or bridge, there could be no flow.

In this connection it should be noted that the difference in elevation of the water on the two sides of a grade, say five hundred feet from the bridge site, is not a true measure of the amount of backing up as the hydraulic gradient between the two points by way of the bridge opening is involved. The flood plain normally offers considerable resistance to free flow because of timber, fences, and other obstructions and unless there are well defined flood channels the flood water velocity is low and the flood plain storage is a material factor in handling flood flow. Often it can be noted that the flow in the flood plain during a rise is outward toward the edges of the flood plain at a material angle to the main channel and during the fall is inward toward the main channel. The result is that the flow in the flood plain parallel to the main channel is not the only assistance

the flood plain gives in passing the flood flow and the step in the hydraulic gradient at the edge of a flood plain due to an approach fill does not have the importance often given it.

Flood flow along a stream equalizes by greater fall causing greater velocity and less rise.

Bridge discharges equalize by greater rise at a short span balancing the less rise of a long span. As between adjacent bridges, the storage and additional runoff between them is involved.

As before stated, the bridging of a stream having a flood plain is nearly always a constriction since approach fill is built out into the normal high water flood passageway. The resulting constriction causes the water to back up and a head is created with consequent greater velocity. Flood height is raised and the waterway area per lineal foot of opening is increased.

However the discharge will never equal the original free flow condition and the difference between the old and new discharge is forced out into the flood plain as storage. Hence the result of the constriction is felt for some distance upstream in a higher water stage, especially at the edges of the flood plain, and in the greater time that is required for the flood waters to recede.

This tendency to additional storage helps to explain the oft repeated contention of interested parties some distance upstream that water is being backed up and held on their land by a new bridge. It would be possible in any particular case, to determine all the factors involved and compute theoretically the upper limit of the backwater curve.

Runoff is complicated by many local topographical and geological features that are too numerous to mention here. Drainage areas vary from mountainous, rocky slopes to flat sandy plains with a wide variation of vegetation and cultivation. Streams show an equal variation from heavy fall over rock beds to flat hydraulic gradients in sandy, shifting beds. Unusual conditions are constantly met with, such as the sinkhole drainage of limestone areas and streams that in effect are a series of lakes.

A bridge waterway that is too small is evidenced by the presence of scour, especially immediately downstream, and by excessive difference in elevation at flood stages of the water on the upstream and downstream sides of the bridge and resulting excessive velocity.

Scour at piers and abutments is not necessarily an evidence of insufficient waterway. Scour at foundations will be caused by drift lodgement, eddy currents about the stems, and excessive eddy and cross currents from foundations not being parallel to the thread of the stream at flood conditions.

Clearing under the approach spans to gain additional waterway is only effective down to [illegible] and immediately adjacent

on either side except as side ditches may be cut some distance back on both upstream and downstream sides to act as feeders and dischargers.

A deep, narrow valley with little or no flood plain and heavy fall in the stream bed will require much less bridge waterway area than a wide, flat valley with comparatively large flood plain and light fall in the stream bed though both are on the same stream and only a short distance apart.

Special attention in determining the total span required must be given when it is proposed to cross a stream with a wide flood plain and light fall in the stream bed. The rich bottom lands are under cultivation and flood heights should not be raised materially or flood water held up any appreciably greater length of time than under the conditions existing previous to the crossing. Damage to growing crops and other property increases with the time of immersion. A crop in the backwater area may be completely lost by a few hours of immersion in stagnant or nearly stagnant water under a hot sun.

Maximum flood flows on small drainage area are the result of short duration, high intensity rainstorms. The average maximum rainfall over any period will decrease with the size of the drainage area, and for large areas periods of general rainfall cause the maximum floods. Hence the size, shape, and topography of drainage areas affect flood heights. A full discussion of the relation of runoff, drainage area, and rainfall is impossible here.

Careful study must be given the advisability of a channel change on swift streams on gravel, boulder, and loose stone beds. These have a tendency to pile up this large material as well as drift and ice to form a low dam and the stream seeks the old bed or an entirely new channel.

The Law usually will hold the person making a channel change responsible for any damage resulting from the altering of the natural channel. It should then be certain that the new channel will not shift and that scour either upstream or downstream is not altered in location or direction or materially increased.

Judging from statements of men who have lived a lifetime along some stream with an originally timbered drainage area, runoff passes through three stages with the removal of the timber.

During the timbered stage, much moisture is retained and runoff is slow and fairly steady. After the land is cut over, runoff is flashy and much scour over the whole drainage area and in the stream bed and banks occurs. Gradually the land is put under cultivation and its power of absorption and retention of precipitation is increased though probably not up to the capacity of the timbered stage. Runoff and scour again become less though perhaps never back to the timbered stage except as the drainage area may in many years be sufficiently advanced along its life stage to reach old age.

It may here be stated that it has not been conclusively proven that deforestation has the effect on floods in large streams that is generally attributed to it. Such direct evidence as is available is for small areas.

It is conceivable that increased flood flow in many large streams is largely due to the dredge ditch systems that may be found along the tributaries.

DITCHES

Dredge ditches display different characteristics from natural streams and bridging them presents different problems.

A properly designed dredge ditch should carry away all normal runoff below bankful stage. It is not usually economical to provide for the extreme flood condition such as will occur once in say fifteen years and during this extreme flood the water will rise above bankful stage.

If the ditch is properly designed, bridging is then a matter of spanning the channel from top of bank to top of bank with perhaps a slight addition for possible floods above the bankful stage.

Many of the smaller ditches are too large for the actual requirements of runoff since the minimum size is determined by a practical width of bottom cut. Such a ditch should be spanned at least between the intersections of the top plane of the highest known water stage with the bank lines. If so spanned, that portion of the ditch section actually used will not be encroached upon. In practice a longer span than the minimum requirement as given above will usually be found economical due to the wing lengths required. The spill of the earth embankment around the ends of the wings must be held back of the top of the bank and five feet of additional superstructure will reduce the total wing length required on the four wings ten feet measured parallel to the center line of roadway.

Each ditch crossing is a separate problem to be solved from a study of the evidence of what has transpired in the past or some computation of the probable discharge capacity as compared with the probable runoff from the drainage area.

In general, runoff is increased but flood heights are lowered by dredging. The following factors are to be noted.

1. In general the drainage area is increased by the tapping of formerly undrained land or the reversal of natural drainage by lateral ditches or tiles.

2. The flow line is usually, though not always, lowered. Some dredge ditches are built only as channel straightening with no cut in the sections of old channel passed over.

3. The ratio of waterway area to wetted perimeter is raised resulting in greater velocity.

4. The fall per mile and the total distance to travel is increased and decreased respectively by channel straightening.

5. Brush, drift, and other obstructions are removed.

6. Laterals assist in a quick runoff from the outside edges of the drainage area.

The first and last factors would tend to raise flood heights but are more than compensated for by the opposite tendency of the other factors.

It is necessary to know the dredged condition of the drainage area in a general way and the probability of the continuation of the system. For instance a dredge may be stopped a short distance upstream from a bridge site resulting in the water being discharged in increased volume at the end of the dredge system with no provision for the increase on downstream.

It is generally held that the dredging of a stream with or without the lowering of the flow line will result in the decrease of flood heights from a short distance above the beginning of the work to some distance, usually short, above the end of the work unless there is some natural condition at the end of the work that allows the increased discharge to be adequately handled. If the increased discharge cannot be adequately handled, flood heights will be raised on downstream from a point a short distance above the end of the work.

When a dredge ditch crosses a road making an old and new channel or such a condition exists from some other cause, in both cases it being necessary to provide waterway outside the limits of the main channel, such overflow waterway is often added at the end or ends of the main channel span instead of building a separate bridge over the overflow channel in order to save the cost of one abutment complete and the excess of another abutment over a pier. It is often most economical per square foot of effective waterway to divide them on account of the greater clear height obtainable at an old channel and the presence of an additional well defined channel for collection and distribution.

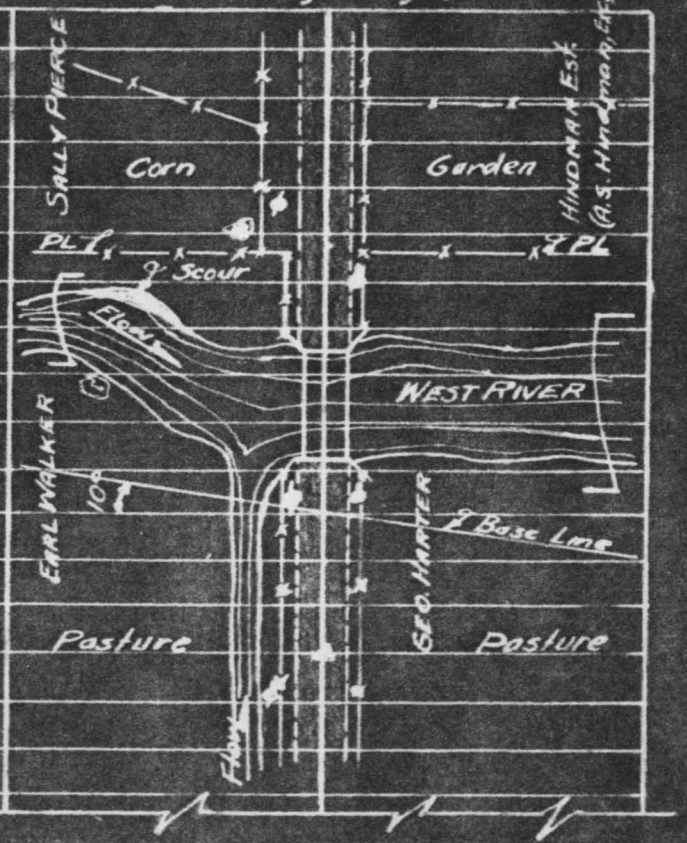
Many natural streams meandering in a flood plain have banks which are several feet higher than the ground some distance back from the channel. During high waters pronounced flood water channels appear over the lowest portions of the flood plain and when very definitely defined, it is economical to span them rather than provide the same waterway opening adjacent to the main channel.

TYPICAL TOPOGRAPHY

(Left Page)

F 30'L 16'R
21+00 EM 6'L 6'R
+80 F. Corner 18'R
+83 F. Corner 30'L
+48 Line of fence intersects ℄
+20 12" Elm 35'R
+38 TP 17'L
+16 F. Corner 18'R
EM 6'L 6'R
+15.6 F. Corner 17'L
20+00 F 17'L 18'R
+02 PP 17'R
+58 30" Syc. 93'L
+12 PP 15'R
EM 6'L 5'R
+09 TP 17'L
19+00 F 18'L 17'R
+00 Base Line
+FP
FP
26.19'
22.42'
+40 POT
+40.0 POT
Iron Pin
20.93'
FP
+21 TP 18'L
EM 5'R 6'L
18+00 F 18'R 16'L
Note: Structure detailed on P. 20
Stream located in "Levels"

(Right Page)



TYPICAL TEST PIT

38-K-673

TEST PIT N/1
24'R Sta. 19+23

El. 977.2 ℄

10'	Black Loam	
2.0'	Blue Clay & Sand	
2.5'	Blue Clay Wet & Soft	
4.5'	Loose Fine Gravel. Wet.	
6.0'	Probably Fine Gravel (Not cemented)	

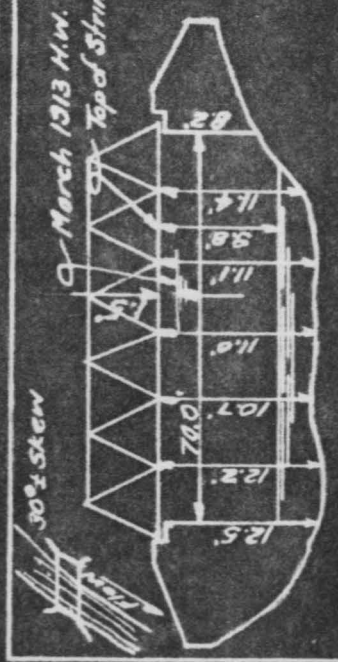
Post Hole Auger

⅝" Rod

TYPICAL WATERWAY

10/31/27 O.A.R.

COUNTY ROAD BRIDGE
1.3 Miles Downstream



Drainage Area about 3.5 sq. miles greater than at the proposed site.
Average Ordinate to top of stringers = 11.0'
Area below 1913 H.W. = (110-15) x 70.0 = 665 sq ft
Effective Area = 0.87 x 665 = 580 sq ft
J. C. KIRBY
Has lived ½ mile NE for 37 yrs. Structure could be slightly smaller. Water never gets over approaches.
Nov. H.W. in March 1913 as shown. 1923 1' lower.