

Chapter Seven presents guidance for the design of New and Reconstructed projects; design guidance for 3R projects is provided in Chapter Seventeen.

Chapter Seven

Earthwork

The following items **are not** earthwork items; **do not** include these items in your grading quantities:

- Shoulder Construction (Surfacing pay item, see Chapter Eight: Surfacing, Section 4.C, of this manual)
- Median Construction (Surfacing pay item, see EXHIBIT 4.27 and the Standard Specifications for Highway Construction (*Spec Book*), Ref. 7.1, Section 308) (<https://dot.nebraska.gov/media/g4qp4y0d/2017-specbook.pdf>)
- Excavation for Box Culverts (Culverts pay item, see Section 702 of the *Spec Book*, Ref. 7.1, and Chapter One: Drainage, Section 8.R, of the Drainage Design and Erosion Control Manual (*Drainage Manual*), Ref. 7.2, <https://dot.nebraska.gov/media/qhubv1ji/d-chap-one-drainage.pdf>)
- Excavation for Culvert Pipes and Headwalls (Culverts pay item, see Section 702 of the *Spec Book*, Ref. 7.1, and Chapter One: Drainage, Section 8.R, of the *Drainage Manual*, Ref. 7.2)
- Excavation for Structures (e.g. abutments, piers, bents; see Section 702 of the *Spec Book*, Ref. 7.1)

1. EARTHWORK

Earthwork is composed of two main components, excavation and embankment. Excavation is the amount of material that must be "cut" to construct the proposed roadway, ditches, channels, entrances, and other associated components. Embankment is the amount of material that must be "filled" to construct the proposed roadway and its associated components.

Projects in rural areas should be designed to produce balanced earthwork; the excavation should equal the embankment as adjusted by the balance factor (See Section 1.A.1 of this chapter). Grade adjustments are the generally preferred method used to balance the earthwork. The approximate change in the elevation of a vertical PI required to produce a given volume of material can be computed using the formula found in EXHIBIT 7.1. When it is not possible, or practicable, to balance the earthwork, provisions must be made to borrow or waste material as necessary (See Section 1.B of this chapter).

Adjustments to the project grading must be weighed against impacts to environmentally sensitive areas, safety criteria, possible aesthetic damage, and maintenance problems in these areas. Changes to the horizontal and/or vertical alignments as described in the approved environmental (NEPA) document shall be submitted to the **Environmental Section** in the **Project Development Division (PDD)** for review.

In urban areas, other considerations (e.g. limiting right-of-way impacts and matching elevations of existing development) may have a higher priority than balancing the earthwork.

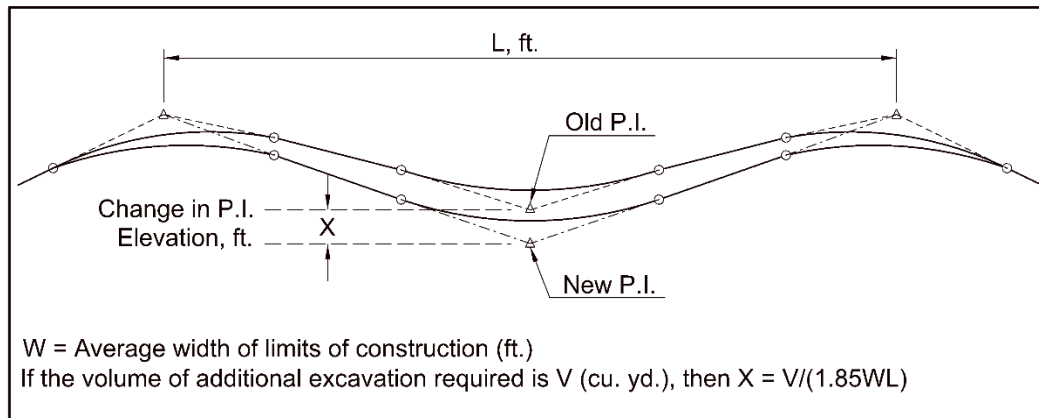


Exhibit 7.1 Earthwork Computation Formula

1.A Computations

Earthwork computations are used to determine pay quantities and to verify final calculations in the field. There are a variety of computer programs available for earthwork computations. Although the methods may vary, the basic approach is the same; the following data is entered into the program:

- Cross-sections of the existing terrain
- The horizontal and vertical alignments
- The design cross-sections
- Surface of the existing terrain

Utilizing this data, the computer program will:

- Compute cross-section end areas of cut and fill
- Compute volumes of excavation and embankment
- Establish balance points and perform an earthwork distribution analysis
- The computer software can also do surface to surface calculations of excavation and embankment (e.g. for roundabout intersections, interchanges, wetlands)

Earthwork does not begin or end at the projects' beginning and end stations, the roadway designer should transition the earthwork from a no grading section to the full grading section. The transition will establish L.O.C.s to determine if right-of-way or construction easements are required, if there are any environmental and/or utility impacts and will improve the earthwork totals. This transition length may be as little as 0.01 foot but should not exceed 200 feet.

1.A.1 Balance Factors

Earthwork is balanced when the amount of available excavation equals the amount of embankment required after compaction. When soil is excavated, hauled, and compacted into an embankment the final volume of the compacted soil is usually less than when it is in its natural state. This difference in volume is defined as shrinkage. When rock is excavated, broken, and placed into an embankment it will occupy more space than rock in solid form due to the increase in void spaces. This increase in volume is known as swell. Balance factors are multipliers applied to the embankment volumes to adjust for the shrinkage or swell of the fill material. The balance factor also accounts for loss of material during haul and for ancillary construction items such as driveway construction. In most cases one balance factor is used for an entire project; an average balance factor must therefore be determined for the various materials encountered over the length of the project. Balance factors should be discussed with the **District Engineer (DE)** on the plan-in-hand field inspection, based on previous similar projects and individual design experience. The **Materials and Research Division (M&R)** may also be consulted for recommendations.

1.A.2 Distribution Analysis

Distribution analysis calculates the accumulation of excavation obtained and embankment required, Station by Station, over the length of a project. Distribution analysis helps the designer to determine if the earthwork is going to be balanced, borrowed, or wasted.

When the adjusted embankment required exceeds the amount of excavation available, borrow is required from borrow pits.

Waste occurs when the amount of available excavation exceeds the amount of needed embankment. The leftover material must be disposed of at approved waste sites or it may be used for shoulder construction (shoulder construction **is not** a part of the earthwork, it is a surfacing item and is paid for by the station, see Chapter Eight: Surfacing, Section 4.C, of this manual).

It should be determined at the plan-in-hand field inspection whether a project will be balanced with material from the right-of-way, using borrow, or if it will be necessary to waste excess material.

Considerations in determining if balanced earthwork is practicable for a given project include:

- Right-of-way limitations
- Impacts to environmentally sensitive areas and other environmental considerations
- Archaeological and historical considerations
- Matching existing elevations at cross roads, bridges, railroad crossings, etc.
- The availability and quality of borrow sites within the vicinity of the project
- The availability of waste sites within the vicinity of the project
- Would balancing the earthwork require crossing bridges or going through towns with earth hauling equipment

Information regarding the distribution of earthwork is required for the project; the following information must be provided in the distribution analysis for each station:

- End areas in sq. ft. of excavation and embankment
- Accumulated volume of excavation
- Accumulated volume of embankment
- Added quantities for intersections, large driveways, etc.
- Balance factor(s)
- Mass ordinate

The above information, together with the identification of approximate balance points, is considered adequate. Mass diagrams are not generally plotted for the project plans. The computer program provides a summary of the earthwork distribution analysis.

The following guidelines should be used when performing the earthwork distribution analysis:

1. Desirable balance lengths should be between one half mile and one mile in length, the preferred length is one mile.
2. Short balances of 300 feet or less should not be shown on the plans but should be shown as part of a combined larger balance.
3. For rural projects constructed under traffic, earthwork distribution analysis for the left and right sides of the roadway will be computed separately, for information only, so the contractor knows how much material must be hauled across traffic.
4. The earthwork should balance at bridges, railroad crossings, major highway intersections, both sides of towns, rivers or major streams, or other natural breaks.
5. When a project includes phasing, an earthwork analysis should be developed and quantities shown on plans, for information only, for each phase of construction (See Section 2 of this chapter).
6. The volume of existing pavement to be wasted or salvaged will be eliminated from the excavation and filling the void caused by the removal of the pavement will be included in the embankment in the earthwork run (See [EXHIBIT 7.2](#) and Section 1.C of this chapter).

Note:

In calculating the earthwork quantities, a nine inch depth void representing the existing pavement removal has been accounted for in both excavation and embankment.

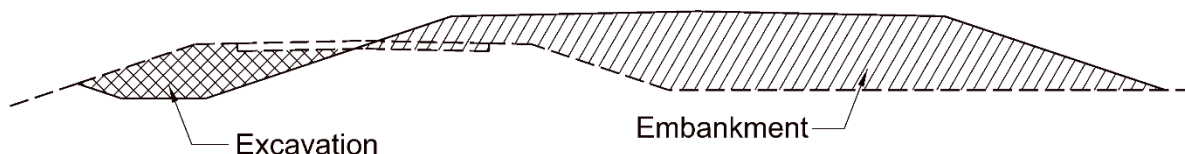


Exhibit 7.2 Existing Pavement Removal in Earthwork

7. Earthwork in urban areas should be paid for as either "Excavation Established Quantity" or "Earthwork Measured in Embankment" (See Section 5.E of this chapter). Earthwork will not usually be balanced for urban projects.
8. Earthwork quantities for temporary roads may be determined using established quantities where the temporary road material is put in as embankment and removed as excavation specified for the temporary road. Earthwork quantities for temporary roads may also be incorporated in the roadway earthwork if the designer includes the temporary road structure in the computer input.

1.A.2.a Haul Considerations

Haul is the distance excavated material is moved from the location where the material is obtained to the location where the material is to be deposited; haul distances should be kept to a minimum. When a distribution analysis is performed, the following questions should be considered:

1. Is waste available from the other side of the road?
2. Is waste available from adjacent balances?
3. Is borrow available?
4. Can the balance points be adjusted?

1.A.3 Moisture Content

The moisture content of the soil placed in the embankment at the time of compaction must be within the moisture range designated in the Soils and Situation Report (See Section 7.A.3 of this chapter). When the moisture content of the soil is not within the acceptable range, either water must be added to the soil or the soil must be aerated. When calculating grading item quantities, EXHIBIT 7.3 should be used to estimate the amount of water which must be applied to obtain the optimum moisture content. EXHIBIT 7.3 is based on excavation quantities; adjustments are required when paying for the quantity "Earthwork Measured in Embankment" (See Section 5.A of this chapter).

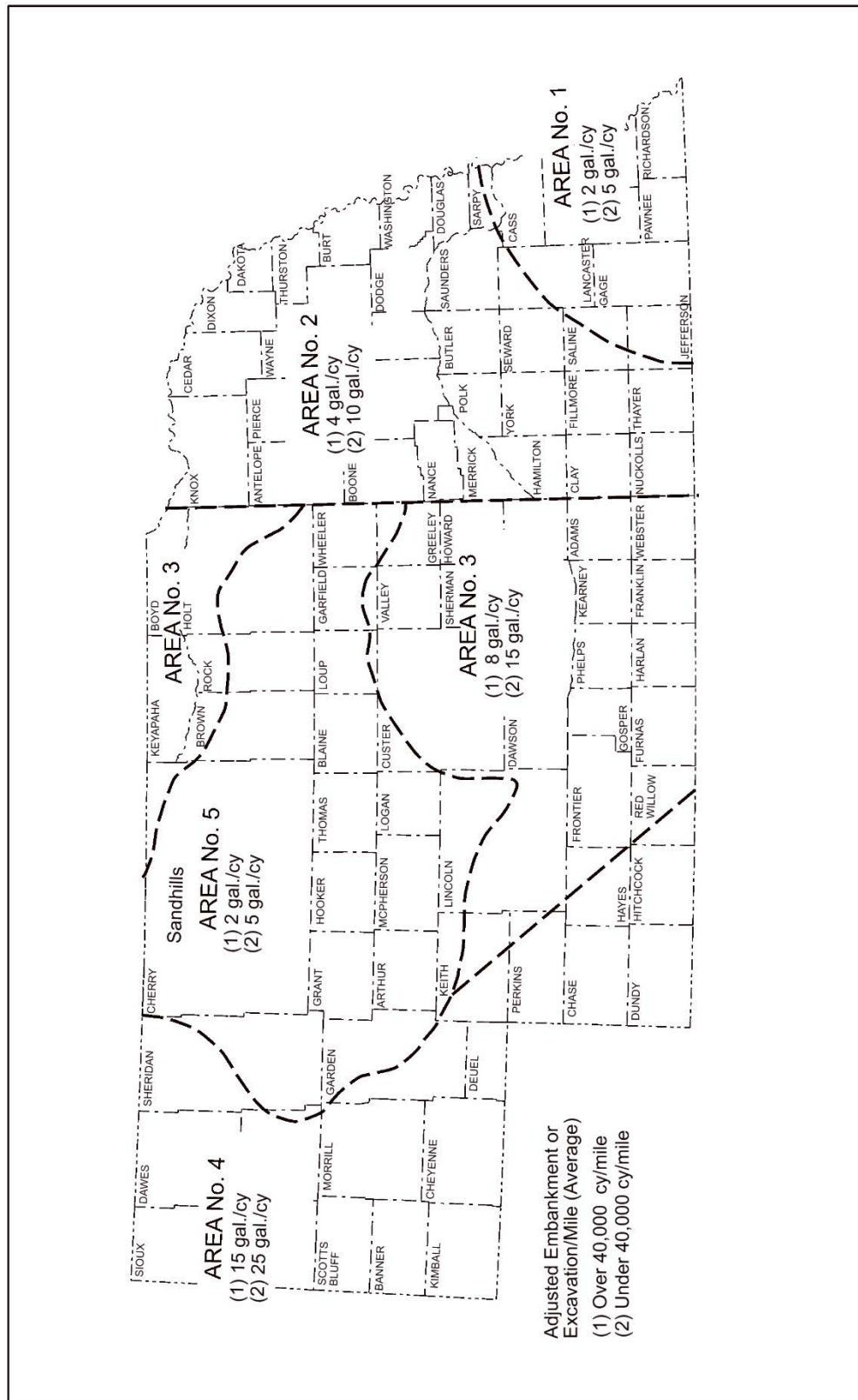


Exhibit 7.3 Map for Estimating Water Needed for Compaction

1.B Borrow Pits and Waste Sites

Borrow pits are sources of approved material required for the construction of embankments or other earthwork requirements on the project (e.g. earth dikes).

Waste sites are areas established for the disposal of excess excavation.

The following items should be considered for borrow pits and waste sites on New and Reconstructed projects:

1. The options available to balance the project or reduce borrow and/or waste.
2. When the use of borrow pits and/or waste sites is required, locations should be discussed on the plan-in-hand field inspection.
3. Costs may be held to a minimum by obtaining borrow from wetland mitigation sites to be built with the project, existing borrow pits, snow control areas, etc.
4. Locations for borrow and waste sites should be finalized before Roadway Design Details plans (Clarity Task 5508) are transmitted to **Right-of-Way Design (ROW)**.
5. Borrow pits and waste sites require clearance for historical and environmental impacts. If there are changes to these sites after the R.O.W. Appraisal Plans have been designed, the roadway designer will notify the **State Historical Preservation Officer** and the **Environmental Section Manager** in **PDD** (See Chapter Thirteen: Planning and Project Development, Section 5, of this manual).
6. If state-owned land is used for a borrow pit, restoration of the site is required. See Section 208 of the *Spec Book* (Ref. 7.1).

1.B.1 **Alternatives to Providing Borrow or Waste Sites**

1.B.1.a **Borrow Alternatives**

1. Daylighting: Daylighting is the flattening of the roadway backslope so that it intersects the natural ground at a lower elevation than the normal backslope (See Chapter Six: The Typical Roadway Cross-Section, Section 10.H, of this manual).
2. Ditch Widening: If adequate right-of-way is available, ditches may be widened to provide additional excavation. When ditch widening is used it should be uniform in cross-section and consistent in application, with gradual transitions between ditch widths.
3. Flattening Backslopes: If adequate right-of-way is available, backslopes on ditches may be flattened from 1:3 up to 1:4 to gain additional excavation. As with ditch widening, backslope flattening should be uniform in cross-section and consistent in application, with gradual transitions between slope changes.
4. Special Ditches: A special ditch is a ditch that varies in slope or depth from the standard ditch shown on the typical cross-section (See Chapter Six: The Typical Roadway Cross-Section, Section 10.B, of this manual). If adequate right-of-way is available, special ditches may be designed to increase the available excavation as well as to provide better drainage.
5. Modify Alignments: The horizontal and vertical alignments may be adjusted to eliminate or reduce the need for borrow. Changes to the alignments as described in the approved environmental (NEPA) document shall be submitted to the **Environmental Section** in the **PDD** for review.

1.B.1.b Waste Alternatives

1. Flattening Foreslopes: If adequate right-of-way is available, foreslopes may be flattened from 1:6 up to 1:10 to eliminate or reduce the need to waste material. Flattened foreslopes should be uniform in cross-section and consistent in application, with gradual transitions between changes in slopes. The designer should keep additional right-of-way to a minimum.
2. Fill Low Areas: Additional excavation may be placed in low areas outside of the construction limits and within the right-of-way, provided that the fill does not adversely affect environmentally sensitive areas, drainage, or aesthetic conditions.
3. Modify Alignments: The horizontal and vertical alignments may be adjusted to eliminate or reduce the amount of waste. Changes to the alignments as described in the approved environmental (NEPA) document shall be submitted to the **Environmental Section** in **PDD** for review.

1.C Removal of Existing Surfacing

“Removal” is generally a pay item when surfacing material is to be salvaged (See Chapter Eight: Surfacing, Section 5.B, of this manual for further information).

1.C.1 Rural Projects

On full grading projects the existing asphaltic concrete (asphalt) surface will normally be salvaged; existing Portland Cement Concrete (concrete) surfacing may be salvaged. The roadway designer should check with **M&R** during “Roadway Design” (Clarity Task 5350) to determine the location, depth, width, and length of the material that is to be salvaged. The preliminary cross-sections should reflect the void left by the existing surface that is to be removed. The removal of this material will be paid for directly as a separate pay item.

If the existing surfacing is asphalt and will not be salvaged, this surfacing may be disposed of in the outer slopes of the embankment, one foot below the finished shoulders and foreslope, after review by the **Location Studies Unit** in **PDD** (See Chapter Thirteen: Planning and Project Development, Section 5.H.1, of this manual). No deductions to the earthwork quantities are required for the volume occupied by this surfacing and no direct payment will be made for the removal. For additional information see the *Spec Book* (Ref. 7.1).

If the existing concrete surfacing is to be removed, the roadway designer should deduct the volume occupied by this surfacing in computing the earthwork balance and the removal should be paid for directly (See EXHIBIT 7.2). If the concrete is to be removed, crushed, and replaced as foundation course, the removal is subsidiary to the “Crushed Concrete Foundation Course” pay item as long as the crushed concrete is only used for the foundation course.

When less than three feet of embankment is to be placed over an existing concrete pavement or base course, the existing surfacing will be removed and paid for directly. If there is to be over three feet of embankment placed on top of existing concrete surfacing, the concrete will be broken into approximately four foot by four foot square pieces and left in place. The pay item “Breaking Pavement” will be defined by a special provision and is paid for by the sq. yd.

1.C.2 Urban Projects

Normally there is no place to bury existing surface material on urban projects, therefore removal is usually specified. In this case the roadway designer should deduct the volume occupied by this surfacing in computing the earthwork and the removal should be paid for directly.

Alternatively, asphalt may be milled and salvaged. In this case, it is paid for as milling and the quantity is deducted from the earthwork.

If the project covers both rural and urban areas, the plans will show the limits of asphalt removal to be paid for (urban areas) and the limits of asphalt removal which is subsidiary to excavation (rural areas).

2. STAGED CONSTRUCTION/PHASING

For projects with phased construction (e.g. Interstate, freeway, and expressway projects), a distribution analysis shall be done for each separate phase of construction (See Section 1.A.2 of this chapter). Cross-section cut and fill areas should reflect the staged construction and should correspond with the distribution analysis performed. The cross-sections will show earthwork quantities for each phase of construction and the General Information Sheet (See Chapter Eleven: Highway Plans Assembly, Section 4.G, of this manual) should show the earthwork quantities in tabular form for each phase of construction. A phased project may include both borrow, as new lanes are constructed, and waste earthwork at the finish of the project (See Section 1.B of this chapter). The distribution analysis for the phased construction is for information only, unless the quantities are “Established Quantities” (See Section 4.B of this chapter). Although it is the roadway designer's responsibility to provide reasonable phasing, demonstrating that construction is possible, the actual construction phasing is left to the discretion of the contractor with the approval of the **Project Engineer**. For additional information see Chapter Fourteen: Traffic, Section 6, of this manual.

When a project requires more than one construction season, cover crop seeding will be calculated for each phase of construction. The General Information Sheet will show the quantity of cover crop seeding required for each phase (See the *Drainage Manual* (Ref. 7.2), Chapter Two: Erosion and Sediment Control, Section 5.B).

3. MISCELLANEOUS EARTHWORK CONSIDERATIONS

3.A Bridge Replaced with a Box Culvert

The excavation for the box culvert is the responsibility of the culvert contractor and will not be included in the roadway grading. The roadway grading will include the earthwork required to bridge the channel and bring the roadway to finish grade, minus the box volume and the backfill required to bring the box excavation to the existing channel section (See [EXHIBIT 7.4](#)). For additional information on box culvert excavation, see the *Drainage Manual* (Ref. 7.2), Chapter One: Drainage, Section 8R.

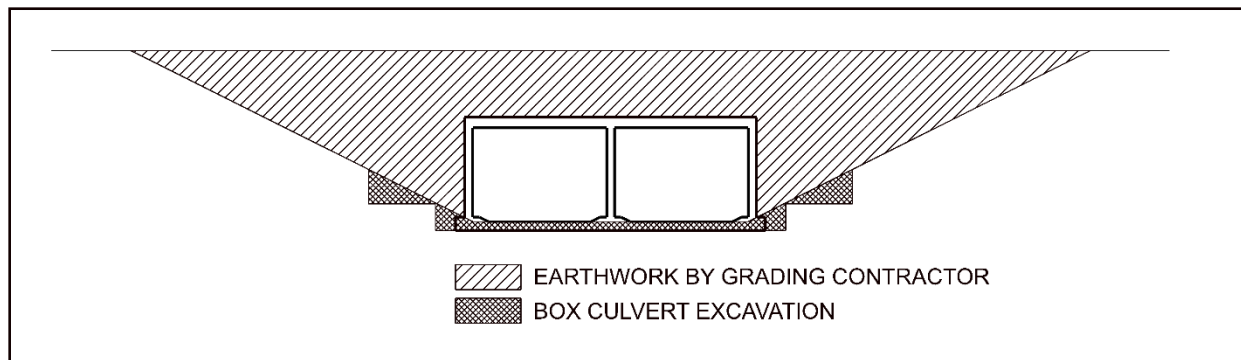


Exhibit 7.4 Earthwork at a Bridge Replaced with a Box Culvert

3.B Unsuitable Materials

Unsuitable materials are inappropriate for use in the embankment. They include rock, organic muck, or foreign objects such as garbage, car bodies, etc. The Soil and Situation Report will list the location, type of material, and treatments for the unsuitable material identified on the project. If unsuitable material is unexpectedly encountered by the contractor, a change order (a written order to the contractor covering changes in the contract) will be required to treat the unsuitable material (See Chapter Thirteen: Planning and Project Development; Section 5.H, of this manual for additional information).

3.C Contaminated Soils

See Chapter Thirteen: Planning and Project Development, Section 5.H.3, of this manual.

3.D Need for Additional Cross-Sections

Additional embankment and grading may be required at such locations as at the installation of guardrail or at mailbox turnouts. This earthwork will be calculated and included in the roadway earthwork quantities. There are also locations where the embankment and grading will not be included in the roadway quantities, such as railroad crossings and bridge exceptions. Additional cross-sections at these locations not only improve the earthwork calculations but further define the project L.O.C.s. Locations where additional cross-sections may be warranted include, but are not limited to:

- **Guardrail Grading:** At the break sections of the grading; for additional information see the guardrail grading details shown on plans 1700, 1710, and 1711 in the “Design Guides” section of the Standard/Special Plans Book (Standard Plans) (Ref. 7.3) ([Standard/Special Plans Manual - NDOT](#))
- **Mailbox Turnouts:** At the break sections of the grading (See EXHIBIT 7.5)
- **Intersections and Commercial Driveways:** At the edge of the earth shoulders for the side streets, the centerline of the intersection, and at the intersection returns on the mainline (See EXHIBIT 7.6)
- **Culverts and Culvert Extensions:** Down the flow line of the culvert
- **Special Ditches:** At the beginning and end stations and at any changes in ditch grade
- **Bridge Exceptions:** At the centerline of the bridge abutments (mainline earthwork will not be computed between the abutments)
- **Railroad Crossing Exceptions:** At the railroad crossing surfacing (earthwork will not be computed at the railroad crossing, see Chapter Ten: Miscellaneous Design Issues, Section 1.A, of this manual)
- **Survey Transitions:** At a break in the survey or the juncture of two surveys
- **Changes in terrain:** Where the grading transitions from cut to fill or visa-versa
- **Curves:** The PC and PT of non-superelevated curves and at the normal crown, adverse crown removed, reverse crown, and full superelevation sections of superelevated curves

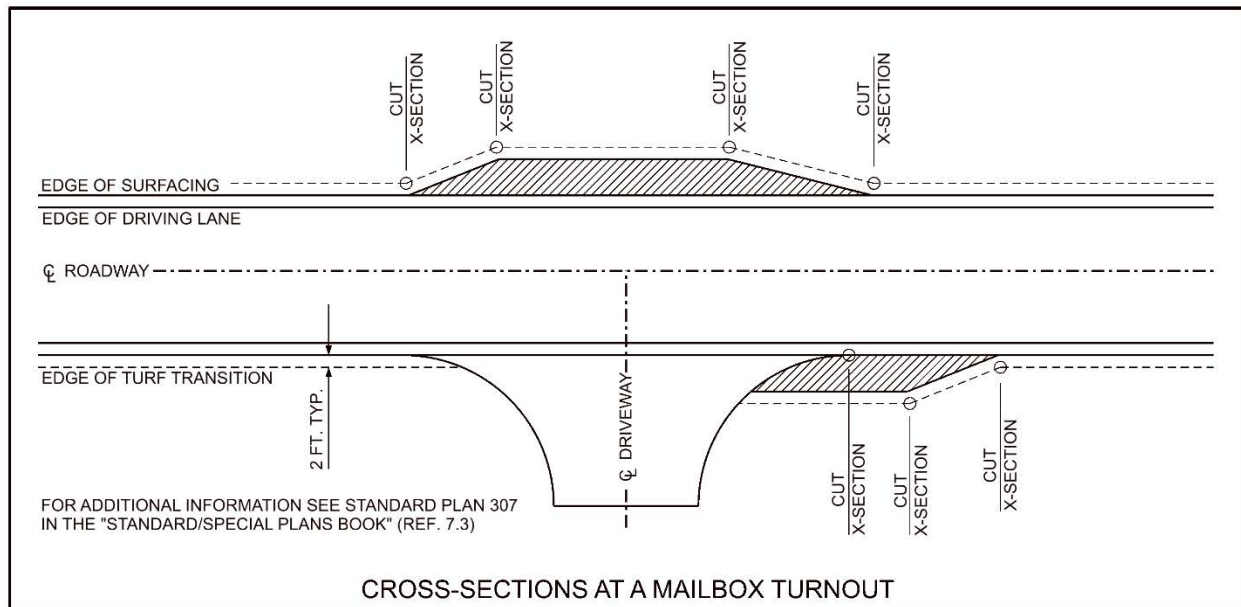


Exhibit 7.5 Additional Cross-Sections at a Mailbox Turnout

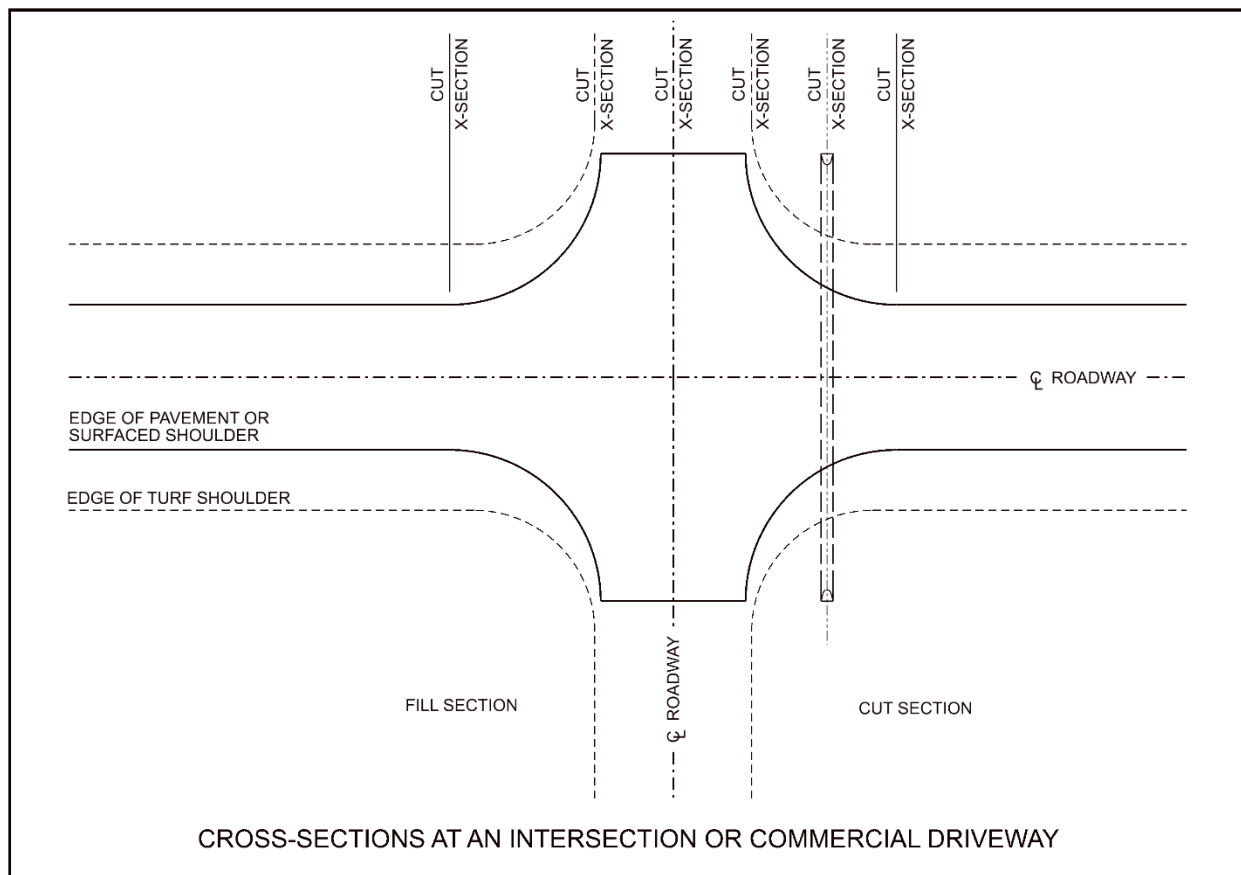


Exhibit 7.6 Additional Cross-Sections at an Intersection or Commercial Driveway

3.E Shear Lines

Shear lines are used for calculating earthwork volumes at intersections where side road alignments connect with the mainline alignment and at interchanges with ramps. Earthwork volumes are calculated along the mainline to a set distance from the centerline, assuming that the earthwork has a vertical line at that location (See EXHIBIT 7.7). Earthwork is then computed for the area outside of the shear line along the side road or ramp alignment. Shear lines may also be used at other locations where irregular excavations or embankments may be caused by channel changes, access roads, etc.

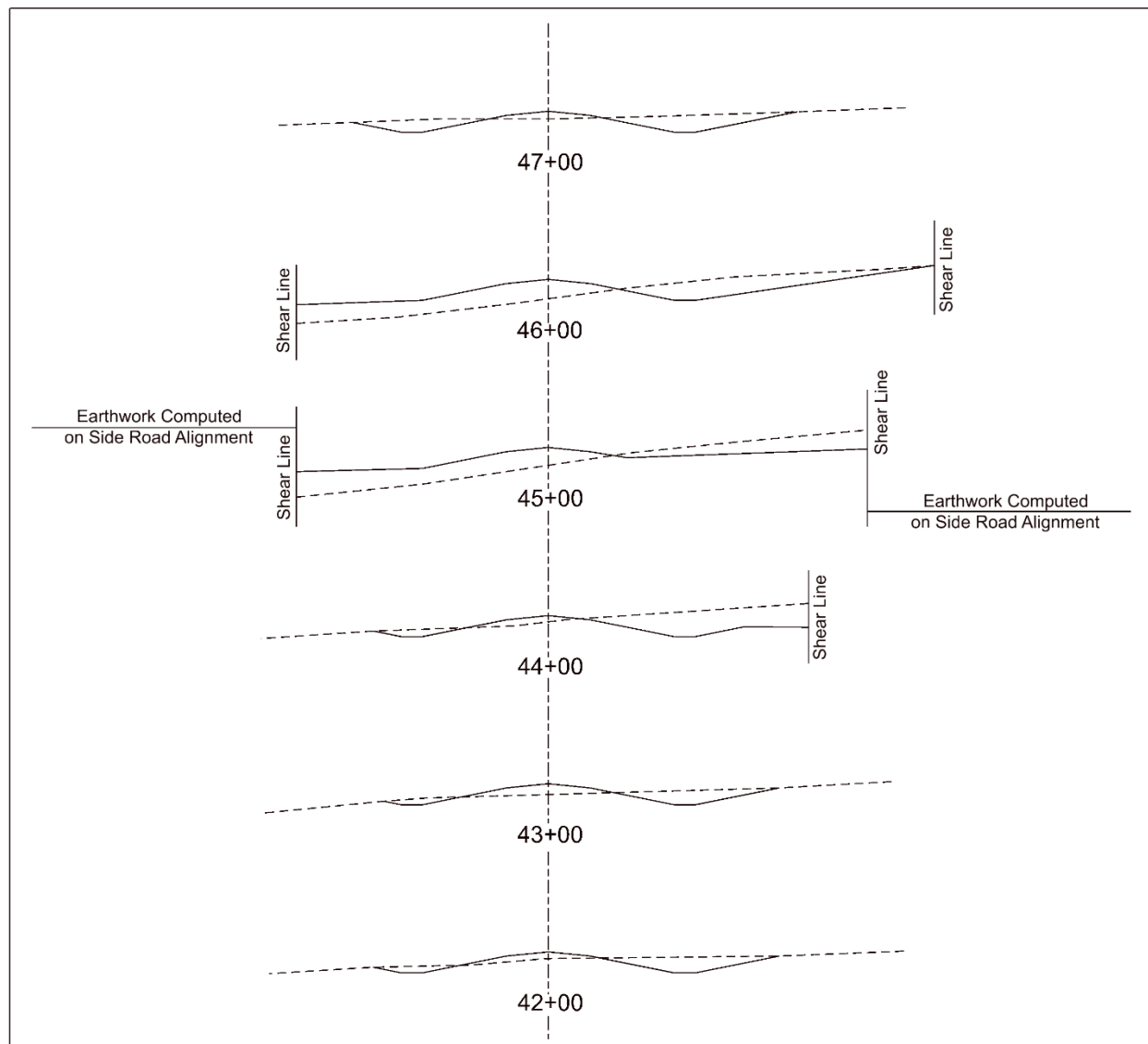


Exhibit 7.7a Shear Lines (Cross-Section)

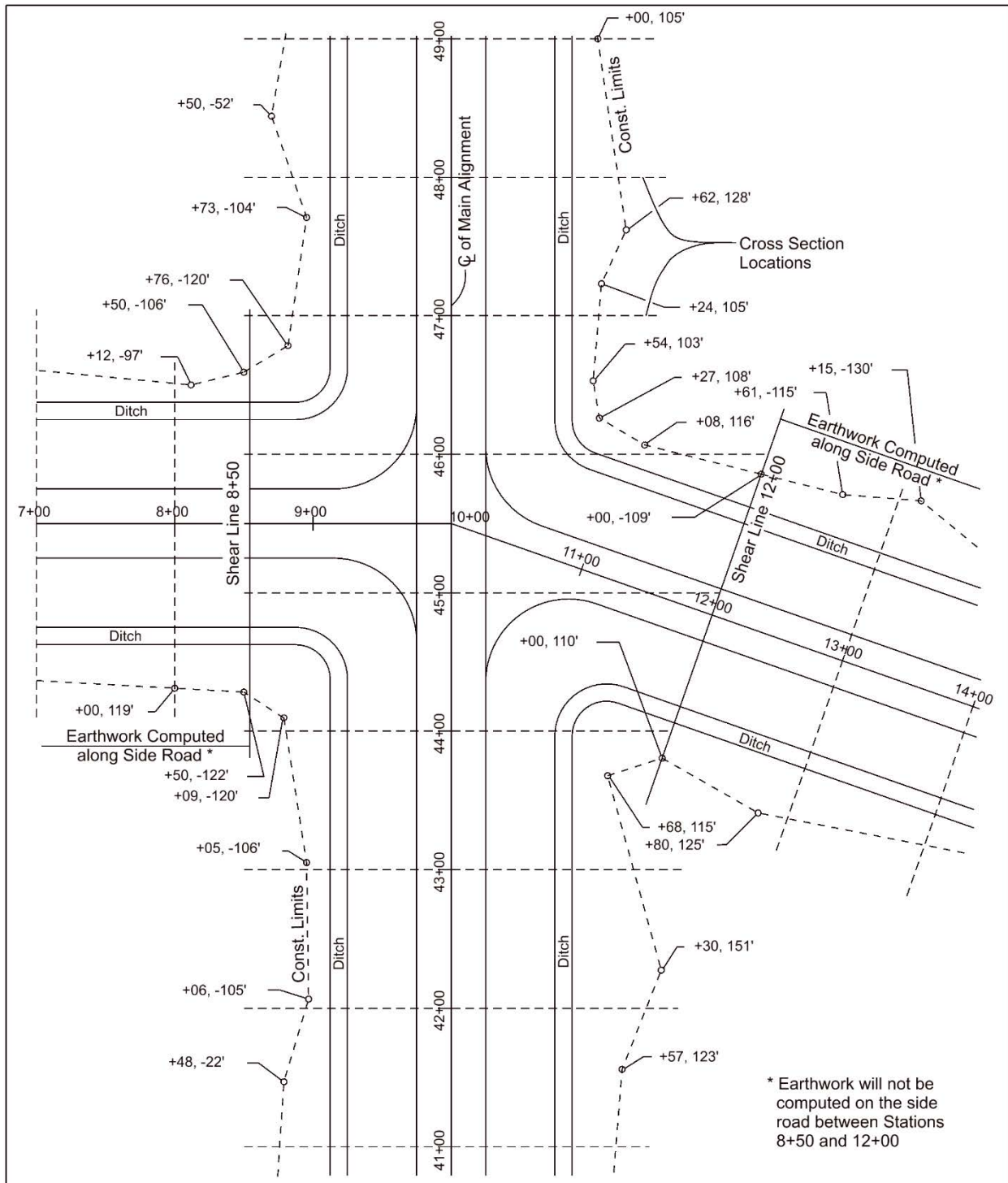


Exhibit 7.7b Shear Lines at an Intersection (Plan)



4. METHODS OF PAYMENT

For additional information, see the *Spec Book* (Ref. 7.1).

4.A “Excavation” and “Excavation-Borrow”

“Excavation” and “Excavation-Borrow” are the preferred methods of earthwork payment on projects with large quantities, generally grading projects which average more than 5,000 cu. yds. per mile. On major grading projects where the earthwork is paid for as “Excavation” and where borrow must be furnished, the excavation quantity within the right-of-way and the easements will be calculated separately from the borrow. A separate pay item, “Excavation-Borrow”, will be used for the borrow. The quantities for these pay items will be measured in the field and then calculated for payment.

4.B “Established Quantities”

Sometimes it is difficult to determine in the field the quantity of earthwork performed. In these situations, the earthwork should be paid for as an “Established Quantity”, which is determined by **Roadway Design** from the cross-sections. “Established Quantity” may be used for either excavation or embankment. This method of payment is most often used for urban roadway projects, for rural projects with low volumes of earthwork, and for temporary roadways. Point projects and projects with less than 5,000 cu. yd. of excavation or embankment per mile should be paid for as “Established Quantity”. In the Omaha area and on urban projects where the contractor will be required to furnish borrow the earthwork pay item will be an “Established Quantity”, with no separate pay item for contractor furnished borrow.

4.B.1 “Earthwork Measured in Embankment” and “Excavation (Established Quantity)”

“Earthwork Measured in Embankment” is typically used on projects that have embankment only or on projects that are mostly embankment with very little excavation (more fill than cut) or on minor or miscellaneous projects. “Earthwork Measured in Embankment” is paid for according to the embankment measured from the cross-sections. It does not include excavation nor is it adjusted by a balance factor. When earthwork is measured in embankment and there is a substantial anticipated settlement, consideration should be given to furnishing soil information or allowing additional quantities for the settlement. On projects involving embankments constructed with granular material obtained from river borrow pits, dewatered borrow areas, etc. the earthwork should be paid for as “Earthwork Measured in Embankment”, with no separate pay item for contractor-furnished borrow.

“Excavation (Established Quantity)” (more cut than fill) is paid for according to the measured excavation from the cross-sections. A balance factor is included if there is calculated embankment.

4.C Roadway Grading

For roadways constructed with only a typical section and without survey, the appropriate pay item is “Roadway Grading”. “Roadway Grading” consists of the furnishing, excavating, loading, hauling, placing, compacting, and finishing of the materials necessary for the completion of the roadway, including its embankments, intersections, driveways, and approaches as shown on the plans. For further information, see the *Spec Book* (Ref. 7.1), Section 206.

4.D Driveways and Field Entrances

Earthwork required for driveway and field entrance construction will be handled according to the pay item, as shown below:

1. **“Excavation” or “Excavation-Borrow”**: The designer will not calculate the earthwork required to build small driveways (i.e. a driveway that does not require the creation of a profile and/or is not commercial-size) and field entrances; the contractor will be paid for additional excavation as it is measured on the project.
2. **“Earthwork Measured in Embankment” or “Excavation (Established Quantity)”**: The earthwork required to build small driveways and field entrances will be included in the earthwork quantities.

4.E Subsidiary Earthwork

Subsidiary earthwork is earthwork that is not paid for directly but is included in other earthwork or other construction items, such as:

- On small urban projects (e.g. curb ramps, rebuild curb, build sidewalk/multi-use trail) with small amounts of earthwork, earthwork is made subsidiary. A special provision may be required.
- The construction of small earth dikes is subsidiary to the pay item “Excavation”.
- Earthwork for the construction of larger earth dikes should be calculated as “Earthwork Measured in Embankment” where no balance factor is considered, or they may be built as roadway embankment from a borrow pit, which will be paid for as “Excavation Borrow”.

5. EXAMPLE CALCULATIONS

In this section different situations are described related to computing embankment and excavation quantities for highway projects. EXHIBIT 7.8 summarizes the grading items for the examples.

Types of Quantities	Case 1 Embankment (Fill Only)	Case 2 Unbalanced - Mostly Embankment	Case 3 Balanced - Considerable Borrow	Case 4 Balanced - No Borrow	Case 5A Urban - More Excavation than Embank.	Case 5B Rural - More Excavation than Embank.
Excavation			31,830 cy	176,415 cy		
Excavation- Borrow			144,585 cy			
Excavation (Established Quantity)					10,000 cy	3,889 cy
Earthwork Measured in Embankment	38,110 cy	11,915 cy				
Water Applied, Mgal.	743	161	4,410	4,410	44	8

Exhibit 7.8 Example Grading Pay Items

ADDITIONAL REQUIREMENTS FOR EARTHWORK CALCULATIONS
ITEM 1: If an informational sheet is supplied with the plans showing a borrow pit where the contractor can obtain the embankment (optional or required pit), cross-sections should be provided showing the desired drainage and the computations made to reflect the available quantity.
ITEM 2: When earthwork is measured in embankment and there is a substantial anticipated subsidence, consideration should be given to furnishing soil information or allowing additional quantities for settlement such as surcharge on top of the fill.
ITEM 3: On projects involving embankments constructed with granular material obtained from river borrow pits, dewatered borrow areas, etc., whether borrow is state- or contractor- furnished, the earthwork should also be paid as "Earthwork Measured in Embankment." No separate pay item is required for contractor-furnished borrow.
ITEM 4: Post construction cross-sections will be taken and the excavation to be paid for will be the material actually removed, measured by volume in its original position.
ITEM 5: Pre- and post-construction cross-sections will be taken on borrow pits to determine the actual quantity of borrow.
ITEM 6: Balance points should be shown on the Plan and Profile Sheets or the General Information Sheets.
ITEM 7: Post-construction cross-sections will not be taken; the contractor will only be paid for the quantity that is shown in the plans. No balance factor will ever be applied for "Earthwork Measured in Embankment" but will be applied for "Excavation (Established Quantity)".
ITEM 8: The volume of existing concrete/asphalt pavement removal will be considered in all earthwork computations. See Section 1.C of this chapter for discussion of removal of existing surfacing.
ITEM 9: On a project where the earthwork is measured in embankment, the earthwork for the construction of driveways and field entrances must be included in the earthwork totals.

Exhibit 7.9 Additional Requirements for Earthwork Calculations

5.A Case 1: Embankment (Fill) Only

Many bridge and shoulder widening projects have only a fill quantity. No excavation is required for the roadway. Borrow will be required.

Given: An existing rural two-lane highway with six foot shoulders on level terrain in Buffalo County is to be improved to a two-lane highway with 10 foot shoulders for five miles. The highway is in fill for the full length of the project with 38,110 cu. yds. of embankment calculated. At the plan-in-hand review it was determined that the balance factor should be 1.30. Determine the earthwork quantity for payment and the amount of water needed.

Station to Station		Excavation Available (cy)	Earthwork Measured in Embankment (cy)
0 + 00	75 + 00	0	10,975
75 + 00	150 + 00	0	11,310
150 + 00	225 + 00	0	11,780
225 + 00	264 + 00	0	4,045
Total		0	38,110

Exhibit 7.10 Earthwork Quantities - Case 1

The pay items will be:

- Earthwork Measured in Embankment
- Water Applied

Solution: The earthwork quantity and pay item will be 38,110 cu. yds. of "Earthwork Measured in Embankment." It is the measured volume of embankment on the cross-sections and **is not** multiplied by the balance factor to obtain the pay item quantity, (Earthwork analysis is run at a 1.00 balance factor when paying for "Earthwork Measured in Embankment"). It is an established quantity and is not verified by field personnel after construction.

Water may be required in the compaction process to attain the proper density in the new embankment. To determine the quantity of water that needs to be applied for compaction, the measured volume of embankment must be adjusted for shrinkage by multiplying it by the balance factor since [EXHIBIT 7.3](#) is based on excavation quantities (for "Embankment", the balance factor established at the PIH will be used when calculating "Water Applied").

$$38,110 \text{ cu. yds.} \times 1.30 = 49,543 \text{ cu. yds.}$$

The quantity of water that needs to be applied is determined by multiplying the adjusted volume of embankment by the number of gallons of water per cu. yd. as indicated in [EXHIBIT 7.3](#) for the area in which the project is located. For this example, Buffalo County is in Area 3 and the project averages less than 40,000 cu. yds. of excavation per mile. The rate at which water should be applied for compaction is 15 gal. of water per cu. yd. of embankment:

$$49,543 \text{ cu. yds.} \times 15 \text{ gal./cu. yd.} = 743,145 \text{ gal. (call 743 Mgal.) (1 Mgal. equal 1000 gallons).}$$

According to the specifications, the contractor is paid for the quantity of "Earthwork Measured in Embankment" as shown on the plans (38,110 cu. yds.) and the quantity of "Water Applied" in Mgal. (743 Mgal.).

The following standard note should be shown on the plans:

STANDARD NOTE 12
THE CONTRACTOR WILL BE REQUIRED TO FURNISH BORROW.

EXHIBIT 7.10 shows a typical earthwork table that should be included on the plans. See items 2, 3, 7 and 8 in EXHIBIT 7.9 for additional information pertaining to this example.

5.B Case 2: Unbalanced - Mostly Embankment

Some major projects have the majority of the earthwork in fill and just a small cut quantity. This may occur on projects that involve adding a lane to an existing road.

Given: An existing rural two-lane highway on mostly level terrain in Madison County is to be improved to a four-lane highway with a median. The project begins at Sta. 1+00 and ends at Sta. 72+89. There is a major crossroad at Sta. 27+32, a stream crossing at Sta. 57+15, and the city limits at Sta. 68+40. At the plan-in-hand review it was determined that the balance factor should be 1.35.

Given the earthwork quantities in EXHIBIT 7.11, determine balance points for distribution analysis, the earthwork quantities for payment and the amount of water needed.

The pay items will be:

- Earthwork Measured in Embankment
- Water Applied

Solution: For this example, balance points should be at the following locations:

- Sta. 27+32 - cross road
- Sta. 57+15 - stream crossing
- Sta. 68+40 - city limits.

Since these balance points occur at intervals of approximately 0.5 mile, no intermediate balance points are needed.

Station to Station		Excavation Available (cy)	Earthwork Measured in Embankment (cy)
1+00	27+32	1,050	3,520
27+32	57+15	500	5,340
57+15	68+40	0	2,640
68+40	72+89	0	415
Total		1,550	11,915

Exhibit 7.11 Earthwork Quantities - Case 2

The pay item will be 11,915 cu. yds. of "Earthwork Measured in Embankment" of which 1,550 cu. yds. will be excavated as shown on cross-sections (See Case 1, which explains "Earthwork Measured in Embankment" in greater detail).

For the amount of water that needs to be applied for compaction, the embankment quantity needs to be adjusted for shrinkage by multiplying it by the balance factor:

$$11,915 \text{ cu. yds.} \times 1.35 = 16,085 \text{ cu. yds.}$$

The quantity of water that needs to be applied is determined by multiplying the adjusted volume of embankment by the number of gallons of water per cu. yd. as indicated in [EXHIBIT 7.3](#) for the area in which the project is located. For this example, Madison County is in Area 2 and the project averages less than 40,000 cu. yds. per mile of excavation. The rate at which water should be applied for compaction is 10 gallons of water per cu. yd. of embankment:

$$16,085 \text{ cu. yds.} \times 10 \text{ gal./cu. yd.} = 160,850 \text{ gal. (call 161 Mgal.)}$$

In this case, the following standard note should be shown on the plans:

STANDARD NOTE 12
THE CONTRACTOR WILL BE REQUIRED TO FURNISH BORROW.

[EXHIBIT 7.11](#) shows an example of an earthwork table that should be included on the plans. See items 2, 3, 7 and 8 in [EXHIBIT 7.9](#) for additional information pertaining to this example.

5.B.1 Case 2A: More Embankment than Excavation in Urban Areas

Use the procedures outlined in Section 5.B above.

5.C Case 3: Considerable Borrow

Often on major grading projects, such as adding lanes to an existing highway, the earthwork is paid as excavation even though a considerable amount of borrow is required to complete the project.

Given: An existing two-lane highway in Cheyenne County is to be widened to a four-lane highway. The project begins at Sta. 100+00 and ends at Sta. 497+00. There is a side road at Sta. 363+00 and improvements along the side road run from Sta. 3001+00 to Sta. 3077+00. There are no other side road crossings or major stream crossings. At the plan-in-hand inspection it was determined that the balance factor should be 1.45. Given the earthwork quantities in [EXHIBIT 7.12](#) (Excavation = 31,830 cu. yd., Embankment = 121,665 cu. yd.), determine the balance points for the distribution analysis, the earthwork quantities for payment, and the amount of water needed.

The pay items will be:

- Excavation
- Excavation Borrow
- Water Applied

Solution: For this example, balance points should be at the location of the side road and approximately every mile between the start and the side road and between the side road and the end:

- Sta. 152+00
- Sta. 204+00
- Sta. 257+00
- Sta. 310+00
- Sta. 363+00 - side road
- Sta. 416+00
- Sta. 467+00

1. The measured excavation is 31,830 cu. yds. and will be paid for as "Excavation".
2. Since there is more embankment than excavation available, borrow is necessary and is calculated by subtracting the excavation from the adjusted embankment. For the adjusted embankment volume, multiply the measured embankment by the balance factor:

$$121,665 \text{ cu. yds.} \times 1.45 = 176,415 \text{ cu. yds.}$$

Then subtract the measured excavation from the adjusted embankment:

$$176,415 \text{ cu. yds.} - 31,830 \text{ cu. yds.} = 144,585 \text{ cu. yds.}$$

The quantity and pay item will be 144,585 cu. yds. of "Excavation-Borrow."

The quantity of water that needs to be applied is determined by multiplying the adjusted volume of embankment by the number of gallons of water per cu. yd. as indicated by [EXHIBIT 7.3](#) for the area the project is located. For this example, Cheyenne County is in Area 4 and the project averages less than 40,000 cu. yds. of excavation per mile. The rate at which water should be applied for compaction is 25 gal./cu. yd. of embankment:

$$176,415 \text{ cu. yds.} \times 25 \text{ gal./cu. yd.} = 4,410,375 \text{ gal. (call 4,410 Mgal.)}$$

In this situation post-construction roadway cross-sections will be taken and the excavation to be paid for will be the material actually removed, measured by the cu. yd., in its original position. Also pre- and post-construction cross-sections will be taken on the borrow pit to determine the actual quantity of borrow used. Pay items in Case 3 will be "Excavation" and "Excavation Borrow."

The standard note that should appear on the plans for this situation is:

STANDARD NOTE 12
THE CONTRACTOR WILL BE REQUIRED TO FURNISH BORROW.

[EXHIBIT 7.12](#) shows an example of an earthwork table that should be included on the plans. See items 1, 4, 5, 6 and 8 in [EXHIBIT 7.9](#) for additional information pertaining to this example situation.

Earthwork					
Station to Station		Excavation (cy)	Excavation - Borrow (cy)	Embankment (cy)	Balance Factor
100+00	152+00	745	11,405	8,380	1.45
152+00	204+00	1,635	20,775	15,455	1.45
204+00	257+00	495	16,870	11,975	1.45
257+00	310+00	2,275	14,420	11,515	1.45
310+00	363+00	8,345	24,085	22,365	1.45
363+00	416+00	3,710	22,940	18,380	1.45
416+00	467+00	13,155	17,750	21,315	1.45
467+00	497+00	1,455	12,670	9,740	1.45
3001+00	3077+00	15	3,670	2,540	1.45
Total		31,830	144,585	121,665	

Exhibit 7.12 Earthwork Quantities - Case 3

5.D Case 4: Balanced - No Borrow

A balanced project with no borrow occurs when the material excavated from within the limits of the section is sufficient to construct embankments to the designed grade.

Given: The same existing highway, improvements and conditions as in Case 3 except that the earthwork quantities are those shown in EXHIBIT 7.13, determine the earthwork quantities and pay items.

Earthwork				
Station to Station		Excavation (cy)	Embankment (cy)	Balance Factor
100+00	152+00	12,150	8,380	1.45
152+00	204+00	22,410	15,455	1.45
204+00	257+00	17,365	11,975	1.45
257+00	310+00	16,695	11,515	1.45
310+00	363+00	32,430	22,365	1.45
363+00	416+00	26,650	18,380	1.45
416+00	467+00	30,905	21,315	1.45
467+00	497+00	14,125	9,740	1.45
3001+00	3077+00	3,685	2,540	1.45
Total		176,415	121,665	

Exhibit 7.13 Earthwork Quantities - Case 4

The pay items will be:

- Excavation
- Water Applied

Solution: Adjust the embankment volume for shrinkage by multiplying it by the balance factor:

$$121,665 \text{ cu. yds.} \times 1.45 = 176,415 \text{ cu. yds.}$$

Since the adjusted embankment volume is equal to the measured excavation quantity, the earthwork is balanced, additional excavation is not needed and no borrow is required; therefore, the only earthwork quantity and pay item will be 176,415 cu. yds. of "Excavation." The quantity of "Water Applied" in this example is 4,410 Mgal., similar to the quantities calculated in case 3.

The standard note that should appear on the plans for this situation is:

STANDARD NOTE 13
THE CONTRACTOR WILL NOT BE REQUIRED TO FURNISH BORROW.

EXHIBIT 7.13 shows an example of an earthwork table that should be included on the plans. See items 4, 6, and 8 in EXHIBIT 7.9 for additional information pertaining to this example.

It should be noted that balance points for this example were shown at one-mile stations for simplicity. For actual projects, the designer should refer to the mass ordinate in the distribution analysis to determine locations of natural balances (See Section 1.A.2 of this chapter).

5.E Case 5: Excavation or Embankment in Urban Areas and on Rural Projects with Low Volumes of Earthwork

5.E.1 Case 5A: More Excavation than Embankment in Urban Areas

In urban areas, where it is often difficult to determine the quantity of earthwork performed because of curb/gutter and driveways, the earthwork will be paid for as "Excavation (Established Quantity)" or "Earthwork Measured in Embankment." For additional information see Section 4.B of this chapter.

Given: An existing four-lane urban highway is being widened to six lanes in Douglas County. The project begins at Sta. 1+00 and ends at Sta. 55+00. At the plan-in-hand inspection it was determined that the balance factor should be 1.45. Given the information in EXHIBIT 7.14, determine earthwork quantities, pay items and the water that should be applied.

Station to Station		Balance Factor	Excavation (Established Quantity) (cy)	Embankment (cy)	Waste (cy)
1+00	55+00	1.45	10,000	3,000	5,650
Total			10,000	3,000	5,650

Exhibit 7.14 Earthwork Quantities - Case 5A

The pay items will be:

- Excavation (Established Quantity)
- Water Applied

Solution: For the adjusted embankment, multiply the measured embankment by the balance factor:

$$3,000 \text{ cu. yds.} \times 1.45 = 4,350 \text{ cu. yds.}$$

Since the adjusted embankment is less than the measured excavation, the quantity and pay item will be 10,000 cu. yds. of "Excavation (Established Quantity)." There will be no cross-sections taken in the field to verify this quantity. There will be waste, the amount of which will be determined by subtracting the adjusted embankment from the excavation:

$$10,000 \text{ cu. yds.} - 4,350 \text{ cu. yds.} = 5,650 \text{ cu. yds. of waste.}$$

The quantity of water that needs to be applied is determined by multiplying the adjusted volume of embankment by the number of gallons of water per cu. yd. as indicated in [EXHIBIT 7.3](#) for the area in which the project is located. For this example, Douglas County is in Area 2 and the project averages less than 40,000 cu. yds. of excavation per mile. The rate at which water should be applied for compaction is 10 gallons of water per cu. yd. of embankment:

$$4,350 \text{ cu. yds.} \times 10 \text{ gal./cu. yd.} = 43,500 \text{ gal. (call 44 Mgal.)}$$

The following notes should be shown on the plans:

STANDARD NOTE 13

THE CONTRACTOR WILL NOT BE REQUIRED TO FURNISH BORROW.

STANDARD NOTE 14

THE CONTRACTOR WILL BE REQUIRED TO FURNISH WASTE AREAS FOR EXCESS.

See item 8 in [EXHIBIT 7.9](#) for additional information pertaining to this example.

5.E.2 Case 5B: More Excavation than Embankment on a Rural Project with Low Volumes of Earthwork

On some rural projects with low volumes of earthwork it is desirable to use an established quantity pay item, either "Earthwork Measured in Embankment", or "Excavation Established Quantity". For additional information see Section 4.B of this chapter.

Given: An existing bridge on a two-lane rural roadway in Pawnee county is being removed and replaced. The new bridge will be approximately one-foot lower than the old bridge and the roadway profile will be lowered to match the new bridge. The project begins at Sta. 102+00 and ends at Sta. 110+40. At the plan-in-hand inspection it was determined that the balance factor should be 1.40. Given the information in [EXHIBIT 7.15](#), determine earthwork quantities, pay items and the water that should be applied.

Station To Station	Balance Factor	Excavation (Established Quantity) (cy)	Embankment (cy)	Waste (cy)
102+00 110+40	1.4	3,889	1,159	2,266
Total	1.4	3,889	1,159	2,266

Exhibit 7.15 Earthwork Quantities – Case 5B

The pay items will be:

- Excavation (Established Quantity)
- Water Applied

Solution: For the adjusted embankment, multiply the measured embankment by the balance factor:

$$1,159 \text{ cu. yds.} \times 1.40 = 1,623 \text{ cu. yds.}$$

Since the adjusted embankment is less than the measured excavation, the quantity and pay item will be 3,889 cu. yds. of "Excavation (Established Quantity)." There will be no cross sections taken in the field to verify this quantity. There will be waste, the amount of which will be determined by subtracting the adjusted embankment from the excavation:

$$3,889 \text{ cu. yds.} - 1,623 \text{ cu. yds.} = 2,266 \text{ cu. yds. of waste.}$$

The quantity of water that needs to be applied is determined by multiplying the adjusted volume of embankment by the number of gallons of water per cu. yd. as indicated in [EXHIBIT 7.3](#) for the area in which the project is located. For this example, Pawnee Country is in Area 1 and the project averages less than 40,000 cu. yds. of excavation per mile. The rate at which water should be applied for compaction is 5 gallons of water per cu. yd. of embankment.

$$1,623 \text{ cu. yds.} \times 5 \text{ gal./cu. yd.} = 8,115 \text{ gal (call 8 Mgal)}$$

The following notes should be shown on the plans:

STANDARD NOTE 13
THE CONTRACTOR WILL NOT BE REQUIRED TO FURNISH BORROW.

STANDARD NOTE 14
THE CONTRACTOR WILL BE REQUIRED TO FURNISH WASTE AREAS FOR EXCESS.

See item 8 in [EXHIBIT 7.9](#) for additional information pertaining to this example.

6. REVIEWING EARTHWORK COMPUTATIONS AND CROSS-SECTIONS

The following checks should be made on the earthwork computations and roadway cross-sections:

- **Design Phase (Activity 5300):** The **Roadway Design Unit Head (Unit Head)** should review the earthwork checklist with the roadway designer
- **Environmental Approval Phase (Activity 5400):** The **Unit Head** and designer should review the earthwork checklist and note changes from the plan-in-hand plans
- **Plan Details Phase (Activity 5500):** The **Unit Head** and designer should check the earthwork and cross-sections before transmitting plans to **ROW**
- **Plan Package Phase (Activity 5700):** The **Unit Head** and the designer should check:
 1. The computer generated earthwork output.
 2. The earthwork data sheets.
 3. The final cross-sections.
- **Begin Construction Phase (Activity 5900):** the designer should check the field books

See [EXHIBIT 7.16](#) for the Earthwork Checklist.

7. FINALIZING ROADWAY EARTHWORK FOR PAYMENT

After the project is completed, the **District** will perform a final surface shots survey. The final surface shots are sent to the **Final Review Section in Construction**, who will request that the survey be loaded into GeoPak, along with the preliminary project survey. Once this has been accomplished, the **Final Review Section** will inform the **Roadway Design Support Units ADE** that the GeoPak file is available. The **Support Units ADE** will assign a designer to calculate the roadway earthwork quantities based on whether the project was in-house or a consultant project and designer availability (the cross-sections for final earthwork computations should be cut at the same locations as the project design). When the final earthwork computations are finished, the designer will send them to the **Final Review Section in Construction**. These computations should be accomplished in a timely manner, they are necessary to close out the project and to make final payment to the contractor.

Existing Surfacing - Will it be removed, salvaged, or incorporated in the fill? Check with **M&R** and the **DCE** about payment for stockpiling and salvaging.

Undercut (Determination of Subgrade Elevation) - Account for surfacing, foundation course or soil aggregate base course. Compensate for shoulder material if necessary.

Balance Factor - Verify with **DE** or **PIH** report. Try to balance every mile.

Subgrade Slope on Shoulders - Same slope as driving lanes on full grading projects.

Subgrade on Superelevated Section - Verify against appropriate standard plan. Does the shoulder have a maximum 7% rollover?

Transitions to Superelevation - Does the roadway and shoulder superelevate properly - check transition distances.

Design Exceptions at Bridges - Does earthwork taper from abutment to flow line as designed by the bridge designer?

Roadway Cross-Sections - Are the slope break points at the appropriate locations?

Special Ditches – Shown on P&P sheets? When the ditch bottom is lower than the normal hinge point, verify that the 1:6 foreslope continues to the hinge point, and then breaks to a 1:4 or 1:3 at the required distance from centerline.

Intersections & Driveways - 1:6 transverse slopes within the clear zone? Do the foreslopes correspond to the criteria shown in the Typical X-Sections (*Standard Plans*, Ref. 7.3) “Rural Intersections and Driveways”). Pipe lengths match driveway slopes?

Guardrail Locations - Shoulder slope continued to two feet behind the surfacing and five feet beyond the last post. Transition the earthwork behind the guardrail from foreslope to bridge design.

Dikes - Are intercepting dikes shown on the cross-sections and sloped at 1:6 facing traffic within the clear zone, 1:10 within a median? (Normally, embankment required for a dike is not multiplied by the balance factor).

Phasing – Show on cross-sections and earthwork for each phase.

Temporary Drainage – Check drainage for each phase.

Detours, Temporary Roads - Will grading for temporary roads or detours be required?

Borrow/Waste Areas - Are these areas to be delineated or is it the contractor’s responsibility if borrow is along the project.

Channel Changes - Determine if excavation should be included with the total excavation or split out as “channel excavation”; this is determined on a case-by-case basis.

Surcharges/Settlement - Check with **M&R Geotechnical Engineer**.

Shoulder Construction/Urban Areas - Do the cross-sections show the shoulder construction according to policy?

Exhibit 7.16 Earthwork Checklist

8. SOIL, SUBGRADE, AND SITUATION REPORTS

The soil, subgrade, and materials surveys prepared by **M&R** provide pertinent information to be used in the following aspects of highway design:

- Location of the grade line, both vertically and horizontally
- Location and selection of borrow material for fills and subgrade treatment
- Design and location of ditches and underdrains
- Design of the roadway section
- Need for subgrade treatment and type of treatment required
- Location of local sources of construction material
- Selection of the surfacing type and its design (See Chapter Eight: Surfacing, Section 1, of this manual)

8.A Soil Survey/Soil and Situation Report

8.A.1 Soil Survey

A soil survey is usually performed with the Roadway Design plans (Clarity Task 5350). The survey usually consists of the research of soils maps, aerial photographs, geology reports and condition reports, preliminary field reconnaissance of the project, previous project reports, soil borings in areas of excavation and embankment, and recordings of water table locations. Laboratory soil tests are made on the samples taken and results are tabulated.

The soil survey will research the soil profile, soil horizons and the uniformity of the profile throughout the project, soil compaction and other soils characteristics by station, the water table condition, and other concerns such as underground wet zones. **M&R** uses the following criteria to determine the minimum finished grade elevation above the expected high water table:

- Four feet above the expected high water table if the entire profile is sand
- Seven feet above the expected high water table if there is to be silt-clay within four feet of the finished grade elevation

8.A.2 Preliminary Soil and Situation Report

If the soil survey reveals a condition that may present problems for the design or construction of a project, a Preliminary Soils and Situation Report is submitted to the **Roadway Design Division**. The preliminary report usually addresses water table concerns. It may include locations of usable quantities of sand in a silt-clay region or locations of borrow pits. Settlement and unsuitable material issues may also be addressed. Unless there is a big cut or fill, a preliminary report is not normally sent to **Roadway Design**.

8.A.3 Soil and Situation Report

The Soil and Situation Report presents the results of the soil survey in a standardized format. It includes the following:

- The location and length of the project
- The topography and drainage situation
- The water table
- The geology of the project area
- Soil horizons and formations
- Soil descriptions, including engineering characteristics
- Recommendations for subgrade treatments
- Compaction requirements

If selective handling of excavated materials is planned for the project, recommendations for the handling are also included. Selective handling is generally restricted to five cases:

1. To produce embankment sections of uniform material (e.g. all silt-clay soils or all sandy materials in the upper embankment)
2. To place materials suitable for use in a bituminous sand base course in the upper subgrade
3. To place highly undesirable materials at depth or in the outer slopes of the embankment
4. To place select materials over heavy clay materials to reduce moisture problems
5. To use select granular materials in lieu of a foundation course on Portland cement concrete pavement projects

The Soil and Situation Report will divide the project, if necessary, into sections of one or more balances according to soil type or other factors. A detailed discussion of soil materials to be excavated is then developed for each section. The selective soil placement notes reflect the surfacing plans for the project. The soil survey may also identify locations for possible sources of shoulder material, topsoil to support subsequent vegetation or soil binder material. It is the responsibility of the designer to verify that the recommendations of the Soil and Situation Report, and the resulting design, are detailed on the project plan sheets.

8.B Subgrade Survey/Subgrade and Situation Report

8.B.1 Subgrade Survey

The subgrade survey is conducted on previously graded roads for which rigid or flexible pavement is being designed. Its principal objectives are:

- To sectionalize the project according to the type of soil in the upper subgrade
- To locate and explore portions of the project where the subgrade may be of questionable stability due to springs, seepage or wet zones
- To evaluate gravel windrow or crust which may have been placed or developed under traffic with temporary gravel surfacing or clay surfacing
- To obtain a check on the conditions resulting from the selective placement required by the grading plans

8.B.2 Subgrade and Situation Report

The Subgrade and Situation Report is prepared for those projects where there is substantial time between grading and the preparation of paving plans (e.g. grading for future turn lanes). Whenever grading and paving are let in the same contract, the design of the base and surface courses is based on information obtained from the soil survey.

The Subgrade and Situation Report usually contains the following:

- A description of the existing surface conditions
- The proposed construction
- The foundation course requirements
- The existing topography and pedology
- A description of and recommendations for the surface and subsurface drainage
- Compaction requirements
- Subgrade distress
- Embankment and/or slope stability problems

The compaction requirements list will be added to the plans.

8.C Embankment Foundation Report

In known areas of poor foundation soils, a field investigation of foundation soils is made by the **Soils Mechanics Unit** of **M&R** to develop recommendations to minimize settlement and slope stability problems. An Embankment Foundation Report is submitted to the **Roadway Design Division** to advise of possible adverse conditions and to recommend possible remedies. The two most common solutions to correct settlement problems are:

- Construct surcharges to speed up settlement (See Section 8.C.1 of this chapter)
- Delay paving until settlement has reached a satisfactory level

Other possible corrective measures include:

- Use of temporary bituminous paving until settlement has reached a satisfactory level, when permanent paving may be placed
- Excavation of unsuitable material
- Use of vertical sand drains to speed settlement
- Lower the height of the fill
- Realign the road to avoid the unsuitable area
- Bridging over the unsuitable area

To correct embankment stability problems during and after grading construction, several possible solutions are available (See the Earthwork Engineering Guide, Ref. 7.5):

- Require special compaction of the embankment material (e.g. higher minimum density and lower maximum moisture content)
- Flatten side slopes of the embankment from 1:3 to 1:5
- Build berms
- Staged construction, the process of bringing fill up to maximum height in several stages over a period of time (usually two or more years)
- Excavate unsuitable material
- Lower the height of the fill
- Realign the road
- Bridging
- A combination of the above (e.g. special compaction and stage construction)

The recommendations contained in the Embankment Foundation Report, and the resulting design, will be detailed on the project plan sheets.

8.C.1 Settlement Surcharge

When embankment is placed on existing ground the weight of the embankment may cause the existing ground to settle and thus the embankment will also settle. An excess of embankment may be placed to overcome the effects of settlement. The Embankment Foundation Report will usually indicate when additional embankment is necessary. The designer will coordinate the design of the project in areas of embankment settlement with the **Soils Engineer** in **M&R**.

9. REFERENCES

- 7.1 Nebraska Department of Transportation, Standard Specifications for Highway Construction (*Spec Book*), 2017.
(<https://dot.nebraska.gov/media/g4gp4y0d/2017-specbook.pdf>)
- 7.2 Nebraska Department of Transportation, Drainage Design and Erosion Control Manual (*Drainage Manual*), Current Edition. ([Roadway Design Manuals - NDOT](#))
- 7.3 Nebraska Department of Transportation, Standard/Special Plan Book (*Standard Plans*), Current Edition. ([Standard/Special Plans Manual - NDOT](#))
- 7.4 Nebraska Department of Transportation, Design Process Outline (*DPO*), Current Edition. ([Design Process Outline](#))
- 7.5 Nebraska Department of Transportation, Earthwork Engineering Guide, 1990.

