

# EARTHWORK

Calculating and Quantifying



Delaware Department of Transportation

September 8, 2011

## **Project Excavations / Material Source for Embankment**

There are many operations that are performed throughout the construction stages of a project that require excavation, which becomes a material source for embankment, for the completion of work. Examples of these operations are the removal of topsoil, preparation of the roadway subgrade, placement of drainage infrastructure, etc.

To ensure that all project excavation has been properly accounted for as a potential for embankment it is necessary to understand how each of the construction operation specifications deals with excavation, and account for these excavations in a uniform and consistent manner.

Some of the major construction operations that require project excavation include, but are not limited to:

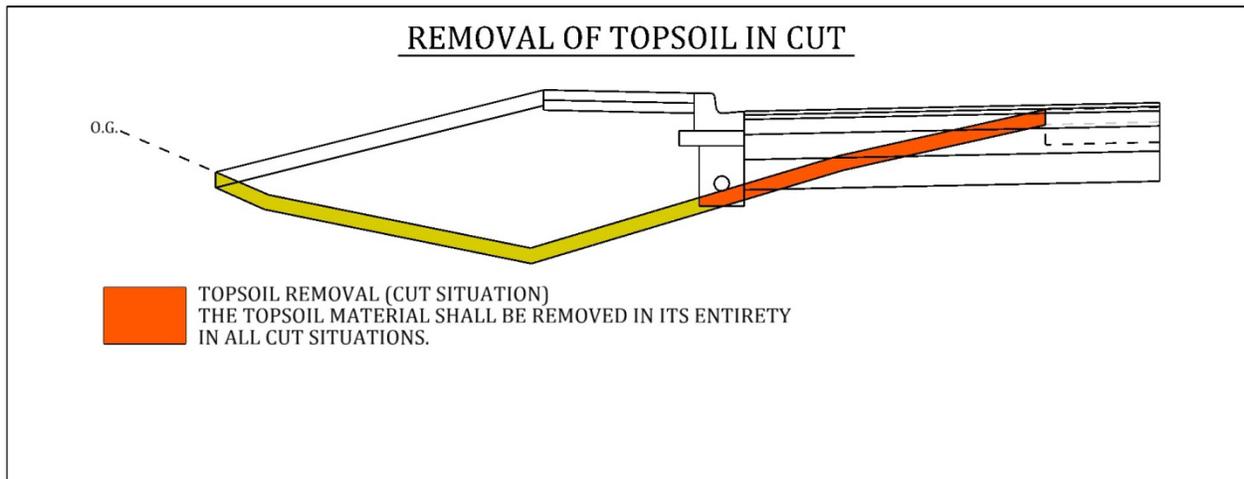
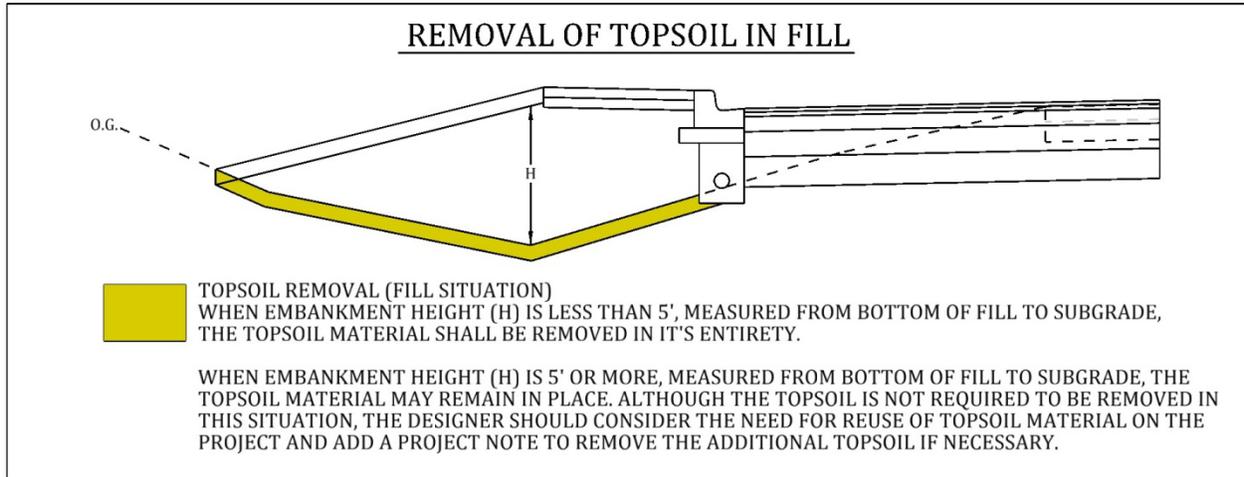
- Topsoil Removal
- Root Mat Removal
- Removal of Rock
- Undercutting
- Structure Installations
- Underdrain Installations
- Drainage Pipe Installations
- Curb and/or Curb and Gutter Installations
- Pole Base Installations
- Removal of PCC Pavement, Curb and Sidewalk
- Stormwater Management Pond Creation

This document will discuss each of these operations and how the specifications account for the quantification and payment of excavation.

## Topsoil Removal

As per Section 202.03c of the Standard Specifications, topsoil shall be removed in its entirety from all cut sections and from fill sections where embankment heights are less than 5' when measured from bottom of fill to the subgrade.

The removal of topsoil as defined above shall be paid for under item 202000 – Excavation and Embankment. The actual depth of topsoil removed shall be determined from soil boring information.



## **Root Mat Removal**

As per Section 201.05 of the Standard Specifications, the removal of project root mat is included under item 201000 – Clearing and Grubbing and should not be included under item 202000 – Excavation and Embankment.

The depth of root mat removed is determined as per Section 201.05, which is listed below.

**Section 201.05** - *In areas where excavation is to be made, the ground shall be cleared of all living or dead trees, stumps, brush, or other objectionable material. All embedded stumps, root mats, etc., shall be removed to a depth of not less than 2' below the subgrade or slope surfaces. All depressions made below the subgrade or slope surfaces by the removal of stumps or roots shall be backfilled with approved material and compacted as directed.*

*In areas where embankment is to be made 5' or more in depth, where depth is measured from the bottom of the fill to the subgrade, trees and stumps shall be cut off as close to the ground as is practicable, but not to exceed 6" above the ground surface. In the area from the toe of the embankment slope to 5' inside the embankment, all trees, stumps, roots, brush, root mat, and debris shall be removed.*

*In areas where embankment is to be made less than 5' in depth, all trees, stumps, roots, brush, root mat, and debris shall be removed, grubbed, or blasted from the ground, in their entirety. Root mat shall be removed to the following depths unless otherwise indicated in the Contract:*

- a) Forested areas (within tree line shown on the Plans): 2'*
- b) Scrub wooded areas: 1'*
- c) Field areas: vegetation only*

### **Designer Note:**

The density of wooded areas typically varies over the project area. The designer should consider these variations when determining the amount of root mat to be removed and accounted for under item 201000 – Clearing and Grubbing.

As per Section 201.10 of the Standard Specifications, the price and payment will constitute full compensation for replacement of suitable material that was cleared and grubbed; for furnishing and compacting approved fill material to fill all depressions; and for all labor, equipment tools and incidentals required to complete this work. Depending on the scope, size and location of the project the amount of suitable material required to fill the depressions left after the root mat material has been removed can be significant. As an aide to the contractor, for item 201000 – Clearing and Grubbing lump sum bid preparation purposes, the amount of suitable material required to fill all depressions shall be quantified on the Earthwork Summary Chart.

## **Removal of Rock**

As per Section 205.01 of the Standard Specifications, the removal of bedrock and ledgerock for the roadway that cannot be accomplished without either blasting or using rippers is included under item 205000 – Rock Excavation for Roadway and should not be included under item 202000 – Excavation and Embankment.

### **Designer Note:**

It is important to note that no payment will be made for rock excavated from depths in excess of 12” below the subgrade as per Section 205.06. Also, no payment will be made for backfilling areas from the bottom of the excavation to 12” below the subgrade. It is also important to note that the material generated by this excavation operation needs to be included in the Earthwork Summary Chart to determine the overall amount of material that is available for embankment and or backfill operations.

## **Undercutting**

As per Section 212.01 of the Standard Specifications, the excavation required to correct unstable subgrades and embankment foundations is included under item 212000 – Undercut Excavation, and should not be included under item 202000 – Excavation and Embankment.

If the soil boring data identifies large areas requiring undercut excavation, the engineer may choose to modify the proposed pavement box section and include the excavation required for those areas as part of item 202000 – Excavation and Embankment.

### **Designer Note:**

As per Section 202.11, item 202000 – Excavation and Embankment allows for the quantification and payment for undercutting operations, provided that item 212000 Undercut Excavation is not included as a Contract Bid item.

If undercutting is included under item 202000 – Excavation and Embankment, this quantity will be paid at the rate of 150% of the unit price for 202000 and should be reflected in the engineer’s quantity calculations and estimate. A project note should also be considered to notify the contractor and construction inspector that undercuts are to be quantified and paid for under item 202000 – Excavation and Embankment.

As per Section 212.08 of the Standard Specifications, the material used for backfilling undercut areas will be paid under applicable Sections. Typically, in cases where undercutting is performed in dry conditions, the material used for backfilling undercut areas is Borrow, Type A. In cases where undercutting is performed in wet conditions, the material used for backfilling undercut areas is Borrow, Type B. In either case, the material used for backfilling the undercutting operation shall be accounted for in the Earthwork Summary Chart.

## **Structure Installations**

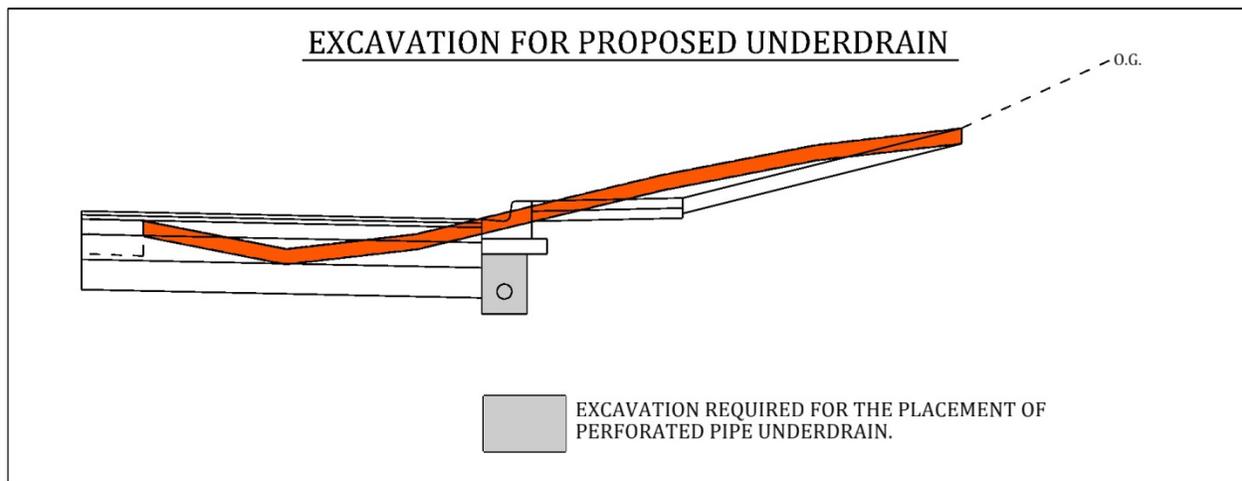
As per Section 207.01 of the Standard Specifications, the excavation required for the construction of box and pipe culverts, pipe headwalls, bridge structures, bridge approach slabs and other structures is included under item 207000 – Excavation and Backfilling for Structures, and should not be included under item 202000 – Excavation and Embankment.

### **Designer Note:**

It is important to note that if the material generated by this excavation operation is not used for backfilling purposes in and around the structure, then it needs to be included in the Earthwork Summary Chart to determine the overall amount of material that is available for embankment and or backfilling operations elsewhere on the project.

## **Underdrain Installations**

As per Section 715.09 of the Standard Specifications, the excavation required to place the proposed perforated pipe underdrain is included under the specific perforated pipe underdrain item that is being constructed, and should not be included under item 202000 – Excavation and Embankment.



### **Designer Note:**

It is important to note that the material generated by this excavation operation needs to be included in the Earthwork Summary Chart to determine the overall amount of material that is available for embankment and or backfilling operations.

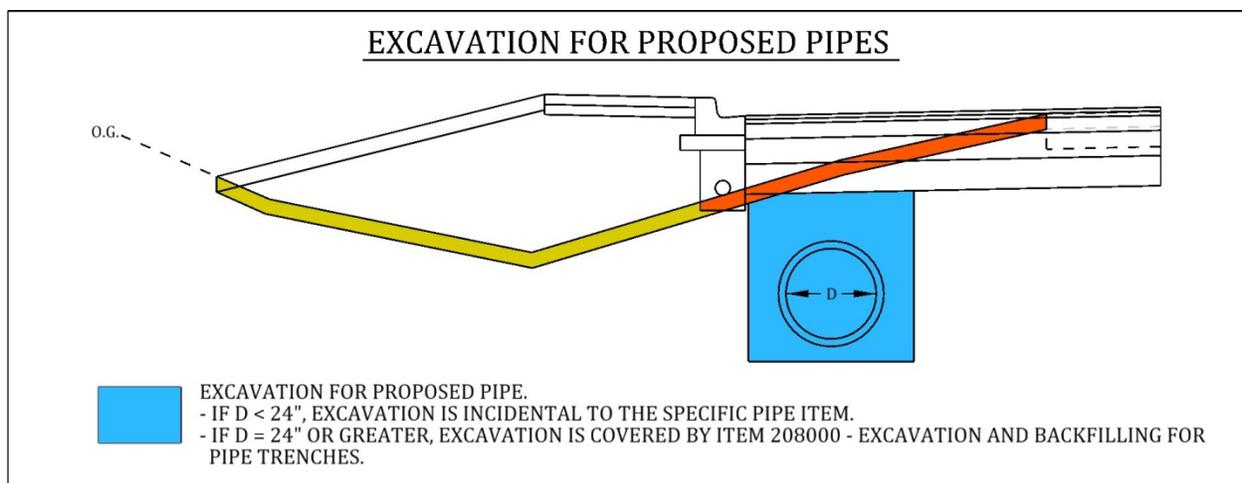
## Drainage Pipe Installations

As per Sections 612.11 and 614.11 of the Standard Specifications, the excavation required to place proposed reinforced concrete pipes or corrugated pipes is accounted for in the following manner:

- Pipe inside diameter < 24" – Excavation is included under the specific pipe item that is being installed.
- Pipe inside diameter = 24" or greater - Excavation is included under item 208000 – Excavation and Backfilling for Pipe Trenches.

In both cases, excavation for proposed pipes should not be included under item 202000 – Excavation and Embankment.

As per Section 208.05 of the Supplemental Standard Specifications, the quantity of excavation and backfilling for pipe trenches will be measured as the volume of excavation included between a line from the bottom of plan excavation to the bottom of the pipe at the time of pipe placement, and a normal horizontal measurement of pipe dimension plus 18" on each side of the pipe, unless otherwise noted on the Plans.



### Designer Note:

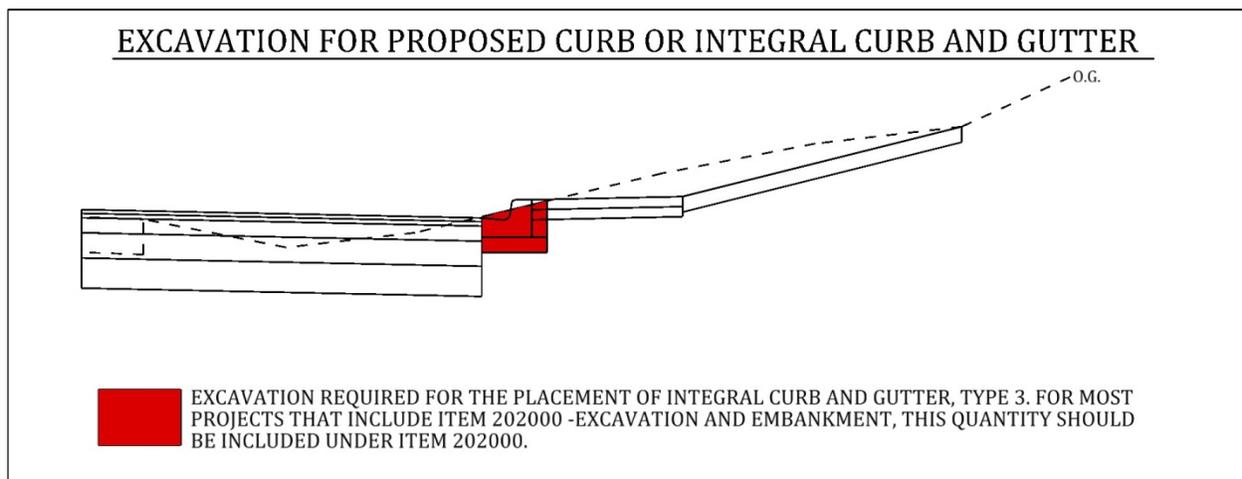
It is important to note that the material generated by this excavation operation needs to be included in the Earthwork Summary to determine the overall amount of material that is available for embankment and or backfilling operations.

## **Curb and/or Curb and Gutter Installations**

As per Section 701.15 of the Supplemental Standard Specifications, the excavation for the proposed curb or integral curb and gutter is included under the specific curb or integral curb and gutter item that is being constructed, and should not be included under item 202000 – Excavation and Embankment, UNLESS it has been accounted for in the excavation for the roadway box.

### **Designer Note:**

In projects where there is a large amount of earthmoving operations, it is recommended that the excavation for proposed curb and/or integral curb and gutter be included in the quantity calculated for item 202000 – Excavation and Embankment and should be clearly noted in the quantity calculations for the project. **In this instance, a project note should be added to the plans indicating that the excavation for curb and/or curb and gutter is included in item 202000 – Excavation and Embankment.**



### **Designer Note:**

It is important to note that the material generated by this excavation operation needs to be included in the Earthwork Summary to determine the overall amount of material that is available for embankment and or backfilling operations.

## **Excavation for Proposed Pole Bases**

As per Section 746.05 of the Standard Specifications, the excavation required for the construction of Pole Base Types 1, 2, 2A, 2B, 3, 3A, 3B, 4, 5, and 6 is included under the specific pole base item that is being constructed and should not be included under item 202000 – Excavation and Embankment.

### **Designer Note:**

It is important to note that the material generated by this excavation operation needs to be included in the Earthwork Summary to determine the overall amount of material that is available for embankment and or backfilling operations.

## **Removal of PCC Pavement, Curb and Sidewalk**

As per Section 758.01 of the Standard Specifications, the removal of existing Portland Cement Concrete (PCC) pavement, curb and sidewalk is included under item 758000 - Removal of Existing Portland Cement Concrete Pavement, Curb and Sidewalk and should not be included under item 202000 – Excavation and Embankment.

### **Designer Note:**

If after the Portland Cement Concrete Pavement, Curb and Sidewalk has been removed, and there is still material that needs to be removed to construct the proposed roadway, then that material excavation shall be included under item 202000 – Excavation and Embankment.

## **Stormwater Management Pond Creation**

As per Section 271.08 of the Standard Specifications, the excavation required for the construction of the storm water management pond, foundation cutoff trench, reservoir and emergency spillway is included under item 271000 – Stormwater Management Pond and should not be included under item 202000 – Excavation and Embankment.

### **Designer Note:**

It is important to note that the excess material generated by this excavation operation needs to be included in the Earthwork Summary Chart to determine the overall amount of material that is available for embankment and or backfilling operations elsewhere on the project.

## **Incidental Excavations**

The specifications for all project items should be reviewed to determine if excavation is required as part of their method of construction and verify how the quantification and payment for any items requiring excavation is addressed for those items.

## **Earthwork Summary**

Section 202.10 of the Standard Specifications states that the quantity of excavation included under item 202000 – Excavation and Embankment will be measured by the cubic yard. The volume will be computed by the method of average end areas and will be measured by cross sections taken at regular intervals and at breaks in grade.

DelDOT typically prepares cross sections at fifty foot (50') intervals (coincident with the +00 and +50 stations), as well as at key event points along the roadway alignment such as cardinal points and drainage structure locations. To accurately determine the total amount of roadway excavation it may be necessary to create cross sections at tighter interval spacing near intersections, driveways and pavement width transition areas.

The key component to calculating accurate excavation quantities is the amount of care and detail that has been placed in developing the roadway model, specifically the bottom surface of the entire roadway model. For it is this surface that will be compared to the original ground surface (or topsoil stripping surface) when computing excavation and embankment quantities.

On larger scale projects involving a detailed multi-phase approach to constructing the final product, it may be necessary to calculate and quantify excavation quantities on a phase by phase basis to ensure that material is available when it is required for construction.

As an aid to account for earthwork quantities in a uniform and consistent manner for all DelDOT projects, the Department of Transportation has developed a Microsoft Excel template for the quantification and presentation of earthwork quantities, entitled "Earthwork Summary Chart".

The "Earthwork Summary Chart" shall be displayed on the "Notes" sheet within the Construction Plan set, and shall include the phase by phase summary if so required for the project.

## Earthwork Summary Chart

<b>Excavation – Item 202000</b>	
EX01: From Cross Sections / Models (+)	This value reflects the volume calculated by comparing the bottom of the proposed roadway template surface to the existing surface, using the average end-area method. The roadway template surface includes the pavement structure, curbs and/or curbs and gutter, underdrains, sidewalks, tie-in slopes, etc.
EX02 : Bituminous Pavement Removed in Fill Sections (+)	This value reflects the volume of bituminous pavement that is required to be removed when it is within 3' of the final grade or under the pavement structure if the subgrade is more than 3' from the final grade. See Section 202.05a for more detailed information regarding the treatment of existing paved surfaces.
EX03 : Topsoil Removed Under Fill Sections (+)	This value reflects the volume of topsoil removed in fill sections where the fill height is less than 5' when measured from the bottom of the fill to the subgrade.
EX04 : Topsoil Placed in Cut Sections (+)	This value reflects the volume of earth excavated for the placement of topsoil in cut sections. <b>This value is equal to ZERO if the bottom of the proposed roadway template surface that was generated already includes the required topsoil depth.</b>
EX05 : Root Mat Removed (-) <b>(Note: This line item is included here as an estimated quantity to aid the contractor as they prepare their bid price for item 201000 – Clearing and Grubbing.</b>	This value reflects the amount of root mat material that was removed under item 201000 - Clearing and Grubbing in sections where the embankment height is less than 5' measured from the existing ground to the finished slope or subgrade. See Section 201.05 for more detailed information regarding the treatment of root mat material, including the various depths of required removal based on field conditions (Ex: Forested Areas, Scrub Wooded Areas, Field Areas)
EX06 : Curb and/or Curb and Gutter Excavation (-)	This value reflects the amount of excavation required to construct the proposed curb and/or curb and gutters. <b>This value is equal to ZERO if the bottom of the proposed roadway template surface that was generated already includes the required curb excavation.</b>
EX07 : Underdrain Excavation (-)	This value reflects the amount of excavation required to construct the proposed underdrain for the project. <b>This value is equal to ZERO if the bottom of the proposed roadway template surface that was generated already includes the required underdrain excavation.</b>
EX08 : Rock Excavation (-)	This value reflects the amount of rock that was removed under item 205000 - Rock Excavation for Roadway. See Section 205.01 for more detailed information regarding the types of material (disintegrated rock, broken stone, etc.) that should not be included under item 205000.
EX09 : Removal of PCC Pavement, Curbs, Sidewalks, Etc. (-)	This value reflects the amount of PCC pavements, curbs, curbs & gutter, sidewalk, etc. that has been removed under item 758000 - Removal of Existing Portland Cement Concrete Pavement, Curb, Sidewalk, Etc. See Section 202.05a for more detailed information regarding the treatment of existing paved surfaces.
<b>EXTOTAL : Total Excavation</b>	<b>This value reflects the total excavation. (EXTOTAL = EX01 + EX02 + EX03 + EX04 – EX05 - EX06 - EX07 - EX08 - EX09)</b>

## Earthwork Summary Chart (Continued)

<b>Stormwater Management Pond Excavation – Item 271000</b>	
SWEX01 : From Cross Sections / Models (+)	This value reflects the volume calculated by comparing the bottom of the proposed stormwater management pond surface to the existing surface, using the average end-area method. The stormwater management pond bottom surface includes the pond basin, foundation cutoff trench, reservoir and emergency spillway.
SWEX02 : Topsoil Removed Under Fill Sections (+)	This value reflects the volume of topsoil removed in fill sections where the fill height is less than 5' when measured from the bottom of the fill to the bottom of the stormwater management facility.
SWEX03 : Topsoil Placed in Cut Sections (+)	This value reflects the volume of earth excavated for the placement of topsoil in cut sections. <b>This value is equal to ZERO if the bottom surface of the proposed stormwater management facility that was generated already includes the required topsoil depth.</b>
SWEX04 : Root Mat Removed (-) <b>(Note: This line item is included here as an estimated quantity to aid the contractor as they prepare their bid price for item 201000 – Clearing and Grubbing.</b>	This value reflects the amount of root mat material that was removed under item 201000 - Clearing and Grubbing in sections where the embankment height is less than 5' measured from the bottom of fill to the existing ground. See Section 201.05 for more detailed information regarding the treatment of root mat material, including the various depths of required removal based on field conditions (Ex: Forested Areas, Scrub Wooded Areas, Field Areas)
SWEX05 : Rock Excavation (-)	This value reflects the amount of rock that was removed under item 205000 - Rock Excavation for Roadway. See Section 205.01 for more detailed information regarding the types of material (disintegrated rock, broken stone, etc.) that should not be included under item 205000.
<b>SWEXTOTAL : Total Stormwater Management Pond Excavation</b>	<b>This value reflects the total stormwater management pond excavation. (SWEXTOTAL = SWEX01 + SWEX02 + SWEX03 - SWEX04 - SWX05)</b>

## Earthwork Summary Chart (Continued)

<b>Excavation Available For Embankment</b>	
EXTOTAL : Total Excavation (+) [Item 202000]	This value reflects the total excavation (EXTOTAL) calculated under the "Excavation - Item 202000" section.
SWEXTOTAL : Total Stormwater Management Pond Excavation (+) [Item 271000]	This value reflects the total excavation excess (SWEXTOTAL) calculated under the "Stormwater Management Pond Excavation - Item 271000" section.
AVEX01 : Excavation and Backfilling for Structures (+) [Item 207000]	This value reflects the total excess material that is available for embankment purposes, that was generated from the excavation operations involving structures. (Ex: Box and pipe culverts, pipe headwalls, bridge structures, bridge approach slabs, etc.)
AVEX02 : Excavation and Backfilling for Pipe Trenches (+) [Item 208000 + Pipes < 24" in Diameter]	This value reflects the total excess material that is available for embankment purposes, that was generated from the excavation operations involving pipes regardless of pipe size.
AVEX03 : Channel Excavation (+) [Item 203000]	This value reflects the total excavation generated from the operations involving channels. (Ex: Widening and deepening existing stream channels and waterways, reconstructing channel and stream configurations, shaping and finishing channels and stream beds, etc.)
AVEX04 : Excavation from Lateral or Longitudinal Ditching (+) [Item 714000]	This value reflects the total excavation generated from the operations involving the creation of either lateral or longitudinal ditching.  <b>NOTE: This item is not typically used since most ditching excavation has already been accounted for under item 202000.</b>
AVEX05 : Excavation From Curb and/or Curb and Gutter (-)	This value reflects the total excavation generated from the operations involving the installation of curb and/or curb and gutter. <b>NOTE: Depending on whether or not the proposed roadway template includes this excavation or not, this quantity may have already been accounted for under item 202000.</b>
AVEX06 : Excavation from Underdrains (+) [Item 71500X]	This value reflects the total excavation generated from the operations involving the installation of underdrains. <b>NOTE: Depending on whether or not the proposed roadway template includes this excavation or not, this quantity may have already been accounted for under item 202000.</b>
AVEX07 : Miscellaneous Excavations (+)	This value reflects the miscellaneous project excavations that have not been accounted for in other lines above.
AVEX08 : Topsoil Removed in Cut and/or Fill Sections (-)	This value reflects the quantity of actual topsoil excavated from cut and/or fill sections. This value should be equal to item EX03 plus any topsoil that was salvaged under item EX01 in the "Excavation - Item 202000" section.
AVEX09 : Topsoil Removed in Cut and/or Fill Sections for Stormwater Management Ponds (-)	This value reflects the quantity of actual topsoil excavated from cut and/or fill sections. This value should be equal to any topsoil that was salvaged under item SWEX01 in the "Stormwater Management Pond Excavation - Item 271000" section.
AVEX10 : Unsuitable Materials (-)	This value reflects the amount of excavated material that has been determined to be unsuitable material and not reusable for other embankment or fill operations within the project.
<b>AVEXTOTAL : Total Excavation Available for Embankment</b>	<b>This value reflects the total excavation available for embankment. (AVEXTOTAL = EXTOTAL + SWEXTOTAL + AVEX01 + AVEX02 + AVEX03 + AVEX04 + AVEX05 + AVEX06 + AVEX07 - AVEX08 - AVEX09 - AVEX10)</b>

## Earthwork Summary Chart (Continued)

<b>Embankment and Borrow, Type 'F' Required</b>	
EMRF01 : From Cross Sections / Model (+) [Embankment Required Below Subgrade or Capping]	This value reflects the total quantity of material required below the subgrade or capping layer of the pavement box as well as the quantity of material that may be required in the construction of the Stormwater Management Ponds (Pond, berms, etc.)
EMRF02 : Topsoil Removed Under Fill (+)	This value reflects the quantity of borrow material that is required to fill voids created by the removal of topsoil.
EMRF03 : Root Mat Removed Under Fill (+)	This value reflects the quantity of borrow material that is required to fill voids created by the removal of root mat material.
EMRF04 : Unsuitable Material Removed Under Fill (+) <b>(Note: This line item is included here as an estimated quantity to aid the contractor as they prepare their bid price for item 201000 - Clearing and Grubbing.</b>	This value reflects the quantity of borrow material that is required to fill voids created by the removal of unsuitable materials.
EMRF05 : PCC Removed Under Fill (+)	This value reflects the quantity of borrow material that is required to fill voids created by the removal of PCC pavements, curbs, sidewalks in fill sections.
EMRF06 : Bituminous Pavement Removed Under Fill (+)	This value reflects the quantity of borrow material that is required to fill voids created by the removal of bituminous pavements in fill sections.
EMRF07 : Topsoil to be Placed in Fill (+)	This value reflects the quantity of borrow material that is required to fill voids underneath the proposed topsoil that will be placed in fill sections.
EMRF08 : Subtotal of Embankment and Borrow, Type 'F' Required	This value reflects the subtotal of embankment and borrow, type 'F' required. (EMRF08 = EMRF01 + EMRF02 + EMRF03 + EMRF04 + EMRF05 + EMRF06 + EMRF07)
EMRF09 : Compaction Factor to be Applied to the Subtotal (EMRF08)	This value reflects the compaction factor to be applied to the subtotal (EMRF08). This factor is typically between 0.15 and 0.20, and shall not exceed 0.25.
<b>EMRFTOTAL : Total Embankment and Borrow, Type 'F' Required</b>	<b>This value reflects the total embankment and Borrow, Type 'F' Required. (EMRFTOTAL = EMRF08 +(EMRF08 x EMRF09))</b>

## Earthwork Summary Chart (Continued)

<b>Topsoil Summary</b>	
TOP01 : Topsoil Salvaged from Cut Sections (+)	This value reflects the total quantity of topsoil that has been salvaged from cut sections.
TOP02 : Topsoil Salvaged from Fill Sections (+)	This value reflects the total quantity of topsoil that has been salvaged from fill sections.
TOP03 : Topsoil Salvaged from Stormwater Management Ponds (+)	This value reflects the total quantity of topsoil that has been salvaged from stormwater management pond locations. This value should be equal to the value calculated for item AVEX07.
TOP04 : Topsoil Required (-)	This value reflects the total quantity of topsoil required for the project.
<b>TOPTOTAL : Total Topsoil</b>	<b>This value reflects the total topsoil available. (TOPTOTAL = TOP01 + TOP02 + TOP03 - TOP04)</b>

<b>Material Balance</b>	
Borrow, Type 'A'	This value reflects the quantity of material that is either in need, or in excess for the project.
Borrow, Type 'B'	This value reflects the quantity of material that is either in need, or in excess for the project.
Borrow, Type 'C'	This value reflects the quantity of material that is either in need, or in excess for the project.
Borrow, Type 'F'	This value reflects the quantity of material that is either in need, or in excess for the project.
Topsoil	This value reflects the quantity of material that is either in need, or in excess for the project.
Unsuitable Material	This value reflects the quantity of material that is unsuitable.