ADVANCED EARTHWORK WITH GEOPAK

1 Earthwork Overview

In order to compute earthwork, GEOPAK requires:

- MicroStation cross section design file
- GEOPAK coordinate geometry database file (.gpk) if the baseline used to generate the cross sections has station equations
- *Earthwork Input file (required for CFLHD method)*

1.1 *Simplified Process*

The GEOPAK earthwork computation process can be simplified into three basic steps. The basic steps are:

- Find an enclosed area
- Determine the centroid of the area
- Determine the material type of the area

GEOPAK computes earthwork *(using the Average End Area Method)* by reading and interpreting the MicroStation design files containing proposed and existing ground cross sections. This approach affords the user maximum flexibility in that it is irrelevant whether the cross section elements were created entirely by GEOPAK or were created or modified using generic MicroStation commands. GEOPAK can compute earthwork volumes from any reasonable graphical representation of a cross section.

These graphical cross sections can be very simple to compute only cut/fill quantities or very complex cross sections including several types of unsuitable or removable materials and several fill material types. *(There is no limit to the number of existing or proposed soil types.)*

GEOPAK is extremely flexible when computing earthwork, utilizing several types of excavation and fill, many functional classifications, numerous material types, (known as soil types), and different shrink/expansion factors. In order to tell the software how to compute earthwork, a thorough understanding of these concepts is mandatory.

1.2 *Adjustments for Horizontal Curvature*

Earthwork volumes are calculated by averaging end areas and then multiplying these averaged areas by the distance between two successive cross sections as measured along the baseline. If the bulk of the cross section areas are located predominantly to either the left or the right of the baseline, as in a detour, an error occurs in the volume calculations for all non-tangential portions of the baseline. This error can be negligible or substantial depending on the degree of baseline curvature as well as the degree to which cross section areas are offset about the baseline.

These types of errors can be optionally accounted for via specification of the "centroid" adjustment keywords. These keywords can be placed immediately before the process earthwork for baseline = ... statement. The option invokes a procedure that adjusts volumes based upon the lateral offset between the centroid of cross section end areas and the baseline. This procedure involves the following steps:

- A centroid is calculated for each cross section
- An offset between the centroid and the baseline is computed for each cross section
- Between two successive cross sections, the individual centroid offsets are averaged. A concentric chain offset by this averaged distance is then calculated and the longitudinal distance along this chain between the two patterns is determined.
- The resultant volume is then determined by multiplying end areas by the adjusted longitudinal length along the concentric chain.

2 Excavation Types

Several types of excavation are supported in GEOPAK. The three main types include:

- **Common excavation** - excavation volumes that are not backfilled with an earthwork material. This includes the excavation required for cut sections as well as for pavement thickness, shoulder thickness, etc.
- **Subgrade excavation** - excavation volumes that are backfilled with an earthwork material. (*Below proposed finish grade)*
- **Subsoil excavation** - excavation required to remove unsuitable material either 1) down to the bottom of the proposed template or 2) down to the bottom of the unsuitable material layer in cases where excavation limits are defined.

These excavation types are not specified by the user but are determined by the software. However, there are cases where material is placed in subgrade excavation when it should be classified as common. An example is a layer of topsoil added to the proposed side slopes in a cut section. In order to "override" the software and force the material into common excavation, the keywords common excavation only should be added after proposed undercut.

3 Embankment Types

In addition to the excavation types, GEOPAK determines where fill material is required. The user does not specify where embankment is required as GEOPAK determines it from the graphic elements in the MicroStation cross section design file. GEOPAK does not have various types of fill similar to the various types of excavation; however, the user does have control of the various types of material used for embankment.

4 Functional Classes or "Class" and Soil Types

All computed earthwork areas/volumes are identified by a functional class and a soil type. The class and type for a specific material are used to control how quantities are reported

4.1 *Functional Classes*

Functional classes - are set by the designer and identify the function or purpose of the cross section element. GEOPAK supports six different classes. Within each class there can be multiple soil types.

In order to compute basic earthwork, two functional classes are required. They are:

- **Proposed Finished Grade –** Must connect to another proposed finished grade element or to existing ground. Must also connect to existing ground an even number of times and a minimum of two places in each cross section.
- **Existing Ground –** is a line string or connection of elements that are the bases for all earthwork volumes.

The soil types specified with the proposed finish grade and existing ground classes are important as they are used as the default fill material and default excavation material.

The Federal Lands Highway standards for Existing Ground and Proposed Finish Grade are:

Existing Ground Line soil type = RdwyExc roadway exc mult factor = 1.00 subsoil exc mult factor = 1.00 fill mult factor = 1.00 type = line, line_string lvname = x_e_ground_xs co = 8	Proposed Finish Grade soil type = Embankment /* RdwyExc - WFL*/ roadway exc mult factor = 1.00 subsoil exc mult factor = 1.00 fill mult factor = 1.00 type = line lvname = x_p_cutslope, etc, etc…. co = 0,1,15,29,40,42,…

The other supported functional classes that are not required are:

- **Proposed Undercut -** are used to define any proposed component which is not part of the finished grade. This includes undercuts, proposed topsoil placement, or aggregate quantities. Although the proposed undercut is used to define undercuts or subcuts, it is important to remember that the soil type is not the material being removed, but what the area will be backfilled with. The material being removed is computed in the default excavation unless it is an existing suitable or unsuitable material. The multiplication factor is again optional, and defaults to one. The roadway and subsoil excavation factors may also be utilized. The element symbology must specify a unique layer of material for each soil type and all proposed undercuts must tie to another proposed undercut or proposed finish grade, not to existing ground.
- **Existing Suitable –** is material removed **only** if its excavation is needed to build the proposed design. (Example: if existing pavement is an "Existing Suitable" and a proposed cross section is entirely in fill, the pavement will not be removed.)
- **Existing Unsuitable –** is material that is removed, if within the excavation limits regardless if its excavation is needed to build the proposed design. (Example: if existing pavement is an "Existing Unsuitable" and a proposed cross section is entirely in fill, the pavement will be removed.)
- **Excavation Limit –** *(no soil type needed)*

Common misconceptions:

- *"Unsuitable" means unused, wasted or disposed*
- *"Existing suitable" means material that is used.*
- *Removed = disposed*

4.2 *Soil Types*

The soil type nomenclature is what determines if a material is used or reused.

With each functional class, additional project-specific information must be supplied in order for GEOPAK to compute the quantities. This information required to compute quantities includes: Soil Type, Search Criteria and Shrink/Swell Factors.

Soil Type – is extremely important as it dictates what materials are re-used and which materials are not. The soil type variable is nothing more than a "name" for the material and is used for reporting purposes. The name of the soil type is created by the designer and the number of types is unlimited.

Search Criteria – are the element attributes or parameters (level, color, linestyle, weight) that define and provide uniqueness to a specified material.

Shrink/Swell – or "multiplication factor" is the specified value of how much a volume will increase or decrease once removed or placed and can be specified for each material type. The value is expresses as a decimal percentage with the default value (1.0) equaling no shrink or swell. (Example: a material that swells 5% would have a Shrink/Swell value of 1.05. If not specified, GEOPAK defaults the missing factor to 1. If the material type is used in several classifications, (such as topsoil in both existing unsuitable and proposed undercut), the factors must be identical in each classification.

In some cases, it is desirable to omit some materials from the mass ordinate. Multiplication factor = 0 is supported in GEOPAK, and will keep the material out of the mass ordinate for existing suitables and unsuitables, which accrue their own mass ordinates. However, the easiest method for Proposed Undercuts is the activation of the **Do Not Include in Mass Ordinate** toggle or command.

4.3 *Procedure – Summary*

Below are the procedures for creating/adding and earthwork item to a project via the Project Manager and with an input file.

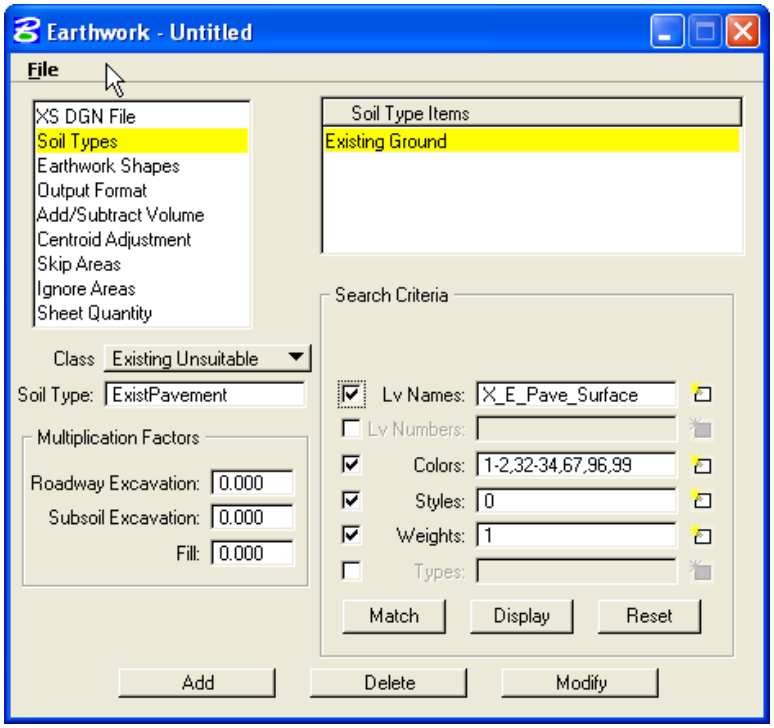
4.3.2 Through Project Manager:

As the Earthwork – Soils Type dialog has numerous fields; it is prudent to review the procedure for populating the dialog. As a minimum, the Existing Ground and Proposed Finished Grade must be defined. However, Soil Type Items can be defined in any order.
The steps to add an item are as follows (note they can be done in any order as long as the dialog is populated before **Add** is clicked.):

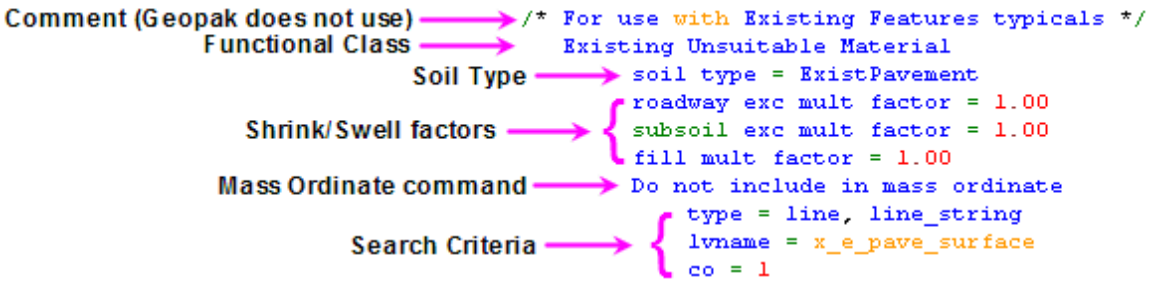
1 Select the **Class**, which determines the rest of the dialog settings. For example, select Existing Ground.
2 Key in the **Soil Type**, utilizing NO spaces between characters.
3 Set **Multiplication Factors** if a value other than one is desired.
4 Define the desired element symbology, utilized as many parameters as required to provide uniqueness to the specified material. Note the display in Criteria Status.
5 Click **Add**. The item is added to the Soil Type Items list box.

To modify an Item, simply highlight the item in list box, which populates the dialog. Change the desired field, then click **Modify**. To delete an Item, highlight the item in the list box, then click **Delete**.

GEOPAK supports an unlimited number of Proposed Undercuts and Existing Suitables and Unsuitables, if they have unique element symbology. Continue to add items, in any order, watching for the slight changes in the Search Criteria options based on the selected class. When the eighth item is added, scroll bars and arrows automatically appear to the right of the Soil Type Items list box for easier viewing.



4.3.3 Through Input File:



5 Earthwork Shapes

When the Draw Earthwork Shapes toggle\command is active, the earthwork shapes are drawn with color fill attributes. When the Fill toggle is active on the View Attributes dialog, color filled complex shapes are displayed.

The shapes either can be drawn in a single color or various colors can be assigned to various types of cut and fill. When the **Stratify Shape Color** is not active, the actual color corresponds to the color defined for the plot parameters.

Variations in color between various cut and fill options are achieved with the **Stratify Shape Color** toggle active. Color assignments initialize at zero, regardless of the color listed in the plot parameters of the write earthwork shapes. However, the specified level is utilized for drawing the complex shapes. In the first material type, color 0 is assigned

to excavation areas, while color 1 is assigned to fill. Color stratification for the various types of excavation is not supported. For the next material, color 2 is assigned for excavation, while color 3 is utilized for fill. Note the pattern that all excavation colors are even, while all fill colors are odd. The next pair of colors (4 and 5) is assigned to. Note that colors are assigned on the basis of material type, not functional classification. Therefore, TOPSOIL is assigned colors, even though it is an existing unsuitable. When TOPSOIL is encountered as a proposed undercut, no colors are assigned, as the material was already assigned colors 4 and 5 in its first occurrence in the dialog under existing unsuitable.

Combination areas, those which involve both cut and backfilling utilize the fill color, and ignore the cut color.

6 Output Formats

6.1 *Output Format*

Three classifications of excavation volumes are listed on standard GEOPAK earthwork outputs: common, subgrade, and subsoil. In certain design instances, the designer does not require these distinctions. Hence, the Output Format dialog can be utilized to combine various quantities. Any combination of the three classifications of excavation volumes can be formulated. Options include:

- Common Exc, Subgrade Exc, Subsoil Exc, and Fill
- Excavation (Common and Subgrade), Subsoil Exc, and Fill
- Excavation (Common and Subsoil), Subgrade Exc, and Fill
- Excavation (Subgrade and Subsoil), Common Exc, and Fill
- Excavation (all types) and Fill

6.2 *Calculate Only Between Excavation Limits*

Another option is **Calculate Only Between Excavation Limits.** In this case, the use of excavation limits is to demarcate earthwork processing. This is extremely useful in projects where earthwork is staged or separate quantities for each roadway in a multiple alignment is necessary. When activated, ALL earthwork calculations are limited to within user-defined excavation limits, not just existing removals.

6.3 *Accumulate Adjust Volume Column*

Another option within the Output Format dialog is **Accumulate Adjust Volume Column**. When activated, an additional column is added to the earthwork report, where the adjusted volume of each excavation and fill for each material is cumulatively totaled. Note this toggle may be activated simultaneously with the **Accumulate Unadjust Volume Column**, in which case, two columns are added to the report. In the report fragment below, the Accumulated Adjusted Volumes of the first section are all zero, to match the Adjusted Volumes.

6.4 *Accumulate Unadjust Volume Column*

Another option within the Output Format is **Accumulate Unadjust Volume Column**. When activated, an additional column is added to the earthwork report, where the unadjusted volume of each excavation and fill for each material is cumulatively totaled. Note this toggle may be activated simultaneously with the **Accumulate Adjust Volume Column**, in which case, two columns are added to the report. In the report fragment below, the Accumulated Unadjusted Volumes of the first section are all zero, to match the Unadjusted Volumes.

7 Earthwork Report

The earthwork report consists of four major parts:

- Individual cross section quantities
- Grand Total Summary
- Balance Point Summary (Included only if there are balance points)
- Centroid Adjustment Summary (Included only if the centroid adjustment option is active.)

7.1 *Station Quantities*

As seen on the fragment below, each station is listed in numerical order (including regions), regardless of the order in the cross section design file. Then for each material type, (our example only has one) each type of excavation and fill is listed, followed by the end areas in master units (either square feet or meters). Then unadjusted and adjusted volumes follow. Note that the volumes listed are from the previous section to the current section, so the first section will have no volumes. In the fragment below, station 639+00 has no volumes as it is the first section of our earthwork run. At station 640+00, the common excavation volume of 3463 cubic yards is computed utilizing the average end area between 639+00 and 640+00. The last two columns are the multiplication factor used to generate the adjusted volumes from the unadjusted volumes, and the mass ordinate, which is the cumulative total of the adjusted volumes.

Station	Material Name	End Areas (sq. ft.)	Unadjusted Volumes (cu. yd.)	Adjusted Volumes (cu. yd.)	Mult Factor	Mass Ordinate
639+00.00	A2&A3					
	Common Exc	1075.93	0	0	1.00	
	Subgrade Exc	0.00	0	0	1.00	
	Subsoil Exc	0.00	0	0	1.00	
	Fill	3973.53	0	0	1.00	0
640+00.00	A2&A3					
	Common Exc	793.93	3463	3463	1.00	
	Subgrade Exc	0.00	0	0	1.00	
	Subsoil Exc	0.00	0	0	1.00	
	Fill	3796.16	14388	14388	1.00	-10925

7.2 *Grand Summary Totals*

After the individual cross section entries, there is a Grand Summary Totals as depicted below. This lists each material name followed by each type of excavation and embankment, and its adjusted and unadjusted volumes. Since each material can only have one set of multiplication factors, these are listed after the volumes.