

CHAPTER 7

EARTHWORK COMPUTATIONS

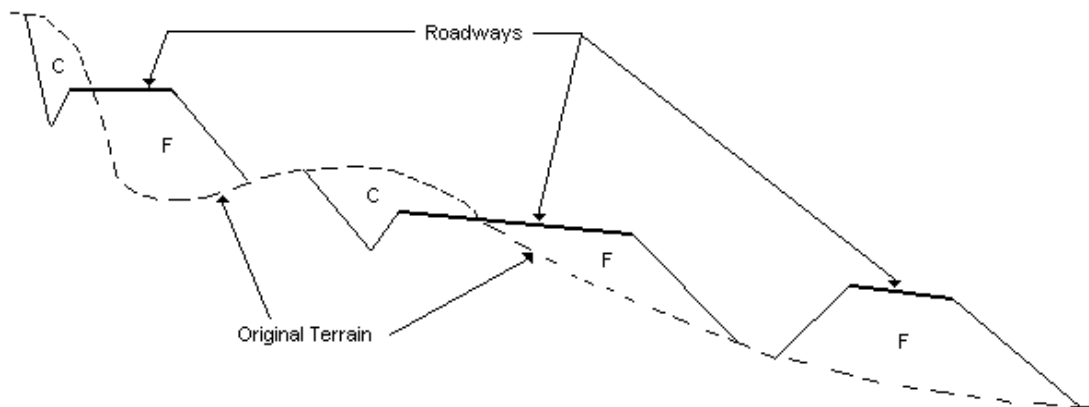
Earthwork computations are based on the design cross sections generated in the design process and cut and fill end areas computed and stored by that process. Additional required and optional data is needed for the earthwork computations. This data is discussed below under Earthwork Parameters. When subsurface data is provided, end areas for each material in cut are computed and used as a basis for volumes. A compaction factor can be specified for each material, and volumes and mass ordinates will be computed accordingly.

EARTHWORK PARAMETERS

The earthwork parameters, such as compaction factors, added quantities, and forced balance stations, are used in computing the earthwork quantities for the designed roadways. These parameters are entered along with the other design data.

These parameters are necessary in the compilation of earthwork volumes, mass ordinates and haul computations. Although these data are not strictly design data, they are entered and stored along with design data because the designer may then want to modify volume computation parameters and make new alternate volume computations. New volume parameter data may be entered at any time.

The design process, which creates design cross sections, as discussed in the previous Chapter, computes cut and fill end areas for each roadway at each original terrain cross section, as illustrated here.



These end areas are maintained in the cross section file for the appropriate baseline until the design is changed. They are available for volume computations using any combination of design roadways associated with the baseline. The volume computations are made by roadway between each terrain cross section and quantities thus computed are accumulated by roadway. This process provides considerable versatility in analyzing quantities.

Compaction Factors

A compaction factor is a characteristic assigned to a specific earth material which indicates how, and to what extent, its volume will change when that material, after having been cut from the original ground, is compacted as fill material. This characteristic is expressed as the ratio of a given volume of this material, in its original ground state, divided by the volume that same material would occupy when compacted as fill. Compaction factors produce an adjusted fill or cut volume to be used in computing earthwork volumes and mass ordinates.

The compaction factors are applied when computing volumes. Volumes are computed separately for each roadway, and the appropriate compaction factor is selected and applied. Then these individual roadway volumes are summed to compute the design cross section volume.

Forced Balance Stations

Forced balance data causes the mass ordinate to be zero at specified stations. This allows the designer to force balances on individual roadways at such places as bridges, overpasses or borrow sources. If excavated material cannot be hauled across a river because the bridge is not built, a forced balance point entered at the beginning station of the bridge would give the correct haul quantities.

Added Quantities

Added cut or fill quantities may be specified at a point or distributed. This feature provides the ability to add or subtract cut or fill from the quantities computed from the cross sections. The designer can use this feature to compensate for borrow or waste, for stockpiling materials from the roadway, and other such uses. Positive or negative cut values are added algebraically to the mass ordinate. A compaction factor can be entered for application to added quantities.

The amount of dead haul for an added quantity may be computed by entering the haul distance. Free haul is not used in determining dead haul for an added quantity. Haul computations are discussed later.

VOLUME CALCULATIONS AND MASS ORDINATES

Volume calculations are made using the average end area method and distances along each roadway alignment. For a particular baseline, volume computations may be done for individual roadways, combinations of roadways, or the entire design, and may extend through any baseline station limits. Each volume calculation request generates volume calculations through the limits specified by the user by accessing the appropriate baseline cross section file to get the end area per station (established during the design process) and then determining the volume using the volume parameters entered with the design data. A mass ordinate file is created as the volumes are calculated. Any design exceptions in the stationing are taken into account in the volume calculations. Corrections for horizontal curvature may be applied to the volume computation as desired.

HAUL CALCULATIONS

Haul calculations are made using the mass ordinates generated by the volume calculations and the free haul distance. The designer may request a printer or digital haul plot which are illustrated in Figures 7-1 and 7-2.

The amount of dead haul for an added quantity are computed by using the haul distance entered for the quantity. The dead haul is computed as shown here.

Single Station

$$\text{HAUL} = \text{Added Quantity} \times \text{Haul Distance} \times \text{Shrink/Swell Factor}$$

Range of Stations

$$\text{HAUL} = \text{Added Quantity} \times \text{Haul Distance} \times \text{Shrink/Swell Factor} \times \text{Station Range}$$

WHERE Station Range = To Station - From Station (taking station equations into account)

The amount of dead haul for added quantities will be indicated on the haul plots and be included in haul quantities for each balance.

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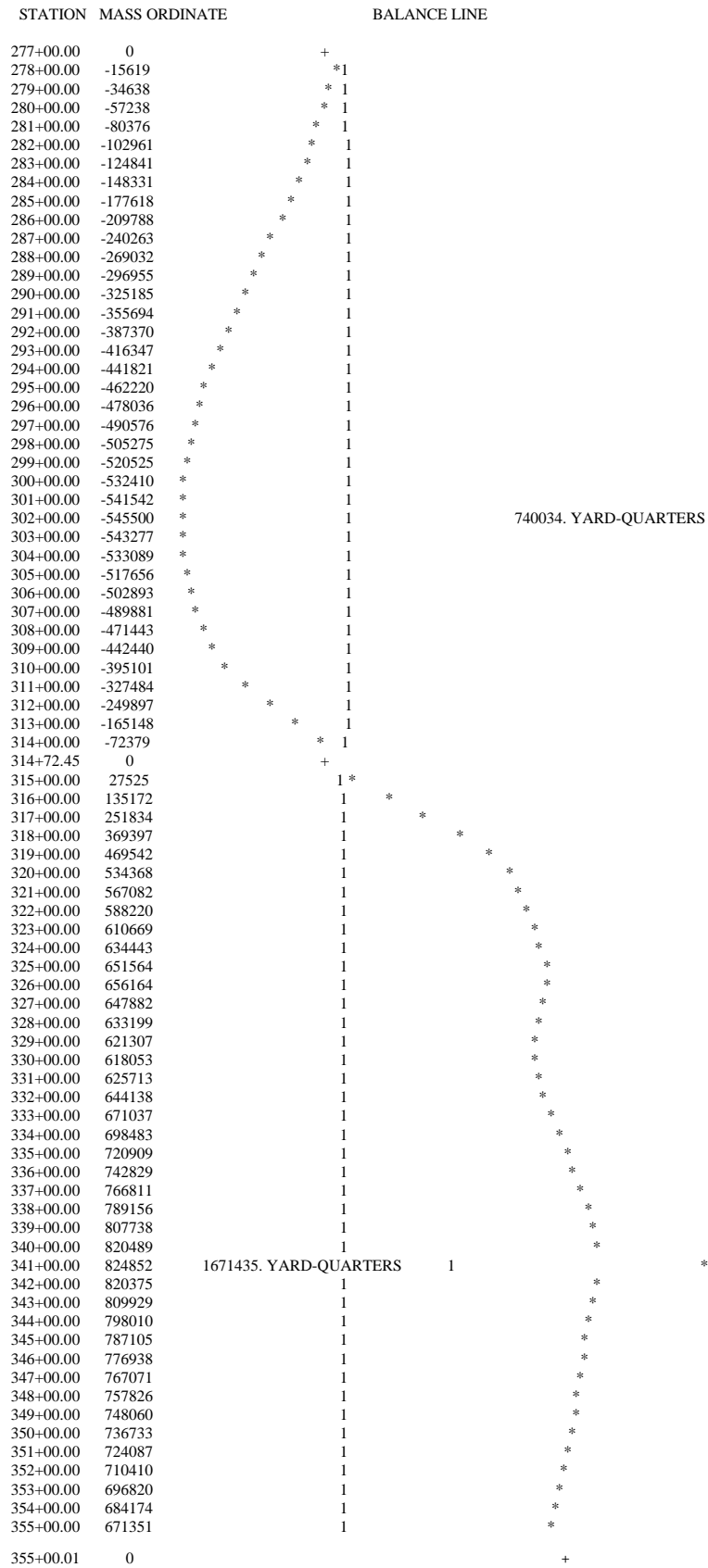


Figure 7-1 - Printer Haul Plot

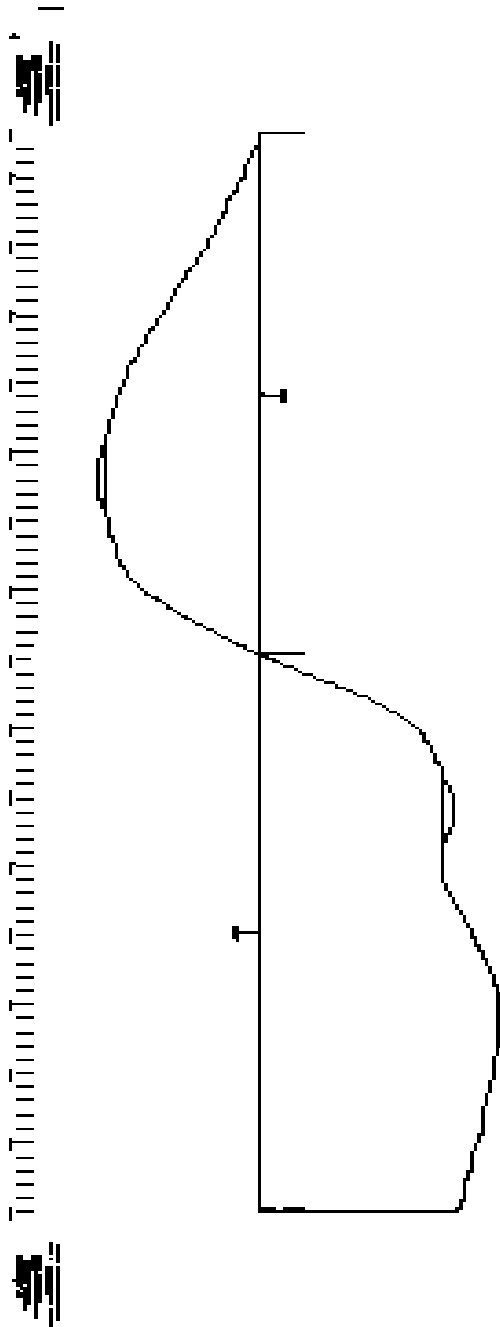


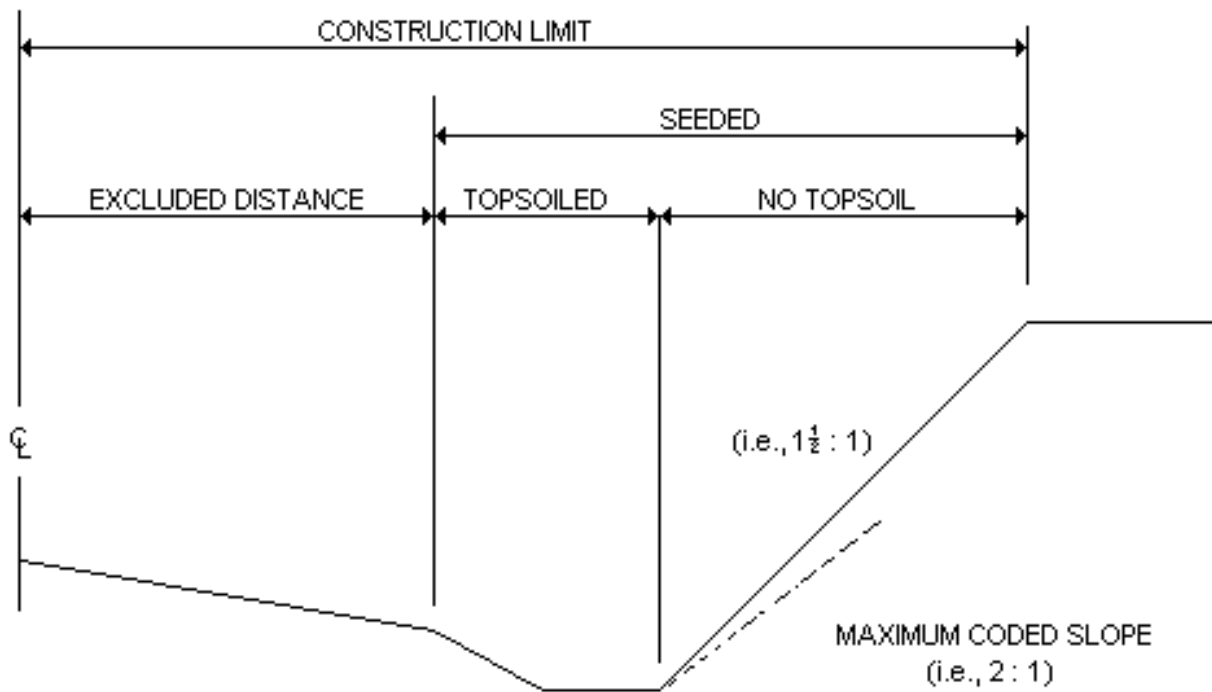
Figure 7-2 - Digital Haul Plot

CONSTRUCTION STAKING

A construction staking report may be requested for any roadway which has been designed. The designer may specify the limits of the report and indicate that it is to be referenced to any of six reference hubs. The report will give point code, elevation, cut or fill from the hub, and distance from the hub for each point associated with the roadway. Hub data must have been entered. Hub data entered without elevations will be referenced to the terrain elevation at the hub location.

TOPSOIL PLACEMENT AND SEEDING

The designer may request computing of topsoil placement volumes and seeding areas for a roadway as illustrated here.



The topsoil placement volumes computed are the amounts needed to cover the areas disturbed by construction from a specified distance left and right of the roadway centerline to the slope stake. The topsoil depth and maximum slope ratio for placing topsoil are required input. The seeding areas are for all slopes from a specified distance left and right of the roadway centerline to the slope stake.

EARTHWORK COMPUTATION REQUESTS

Requests for volume and haul computations and reports may be combined with design requests and completed at the same time. They may also be made later in various combinations. It is possible to look at roadways separately, or in combinations, for staged construction. Earthwork requests include:

- Beginning and ending baseline stations
- Applicable roadways
- Free haul distance, if applicable
- Output options
 - Construction staking
 - Auxiliary listings
 - Staking detail
 - Toe-of-slope
 - Design cross section
 - Profile grade
 - Widening

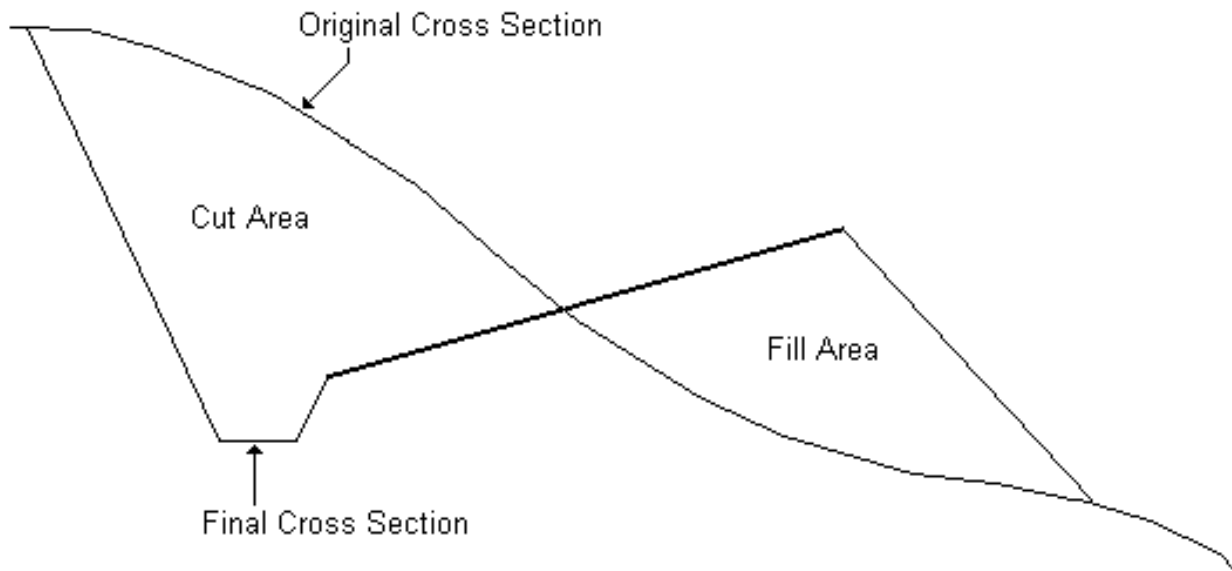
FINAL VOLUMES

Final earthwork volumes can also be computed and reported. They represent the volume of cut and fill between terrain (original ground) cross sections and final (as-built) cross sections. Final cross sections are entered and stored by the same methods as those used for original cross sections. They are stored in a separate file. The table below shows the data required for final quantities.

<u>Data</u>	<u>Function</u>
Force Balance Stations	Define the locations of balance stations
Volume Exceptions	Define the limits of volume exceptions
Added Quantities	Define the amount and locations of added cut or fill
Compaction Factors	Define compaction factors
Final Volume & Haul Request	Produce volume computations, haul calculations and haul plot

METHOD OF FINAL VOLUME COMPUTATION

The designer needs to have a basic understanding of how data is combined to obtain this report. For a final volume request, IGrds first computes the cut and fill end areas defined by the original and final cross section for each station in the file within the limits of the request.



Any terrain station on the selected baseline which does not contain an original and final cross section is skipped. (These stations are not used.) Volume calculations are made using the distance along the terrain centerline (baseline) and the average end area method. Any volume exceptions or added quantities in the stationing are taken into account in the volumes calculations. A final earthwork quantities list is produced. Note that the compaction factor is equal to one if compaction factors are not entered.

If balance stations are entered, the final earthwork quantities list is produced twice. The first list contains the total cut, fill, and added quantities volumes between the balance points. This list contains a mass ordinate based on a compaction factor of one. A compaction factor is then computed between each set of balance points by dividing the accumulated cut by the accumulated fill. IGrds produces a final volumes parameter list. The second volume computation is then performed using the calculated compaction factors, added quantities, and exceptions to compute and tabulate a second list of volumes for each cross section station. Requests for haul calculations and plots can only be made when final volumes are requested. The haul calculations are performed using the mass ordinates from the second final earthwork quantity list.

EARTHWORK COMPUTATION REPORTS

The earthwork computation processes make use of the design and original cross sections or final and original cross sections to make numerous computations and to produce extensive reports, including:

- Compaction Factor Data Listing
- Forced Balance Design Data Listing
- Added Quantity Design Data Listing
- Right-of-Way and Maximum Slope Intercept*
- Earthwork Quantity Listing
- Haul Quantity Report
- Haul Diagram - Printer Plot
- Construction Staking Report
- Widening Report*
- Toe of Slope Plot
- Design Cross Section List*
- Profile Grade List*
- Auxiliary Slope Stake List
- Topsoil Placement and Seeding Report
- Surface Removal and Template Subcut Quantities by Material Type
- Adjacent Roadway Segment Rollover Check

*Design results at each design station

PAVEMENT STRUCTURE QUANTITIES

This capability provides for the calculation of quantities of pavement structure materials within IGrds using user-defined criteria. In essence, the user defines the thickness and material between ridgeline limits (with offsets) for each component of the pavement structure for a particular design roadway over a station range, and requests pavement structure quantity calculations be performed. The quantities are reported by roadway, station and material with summaries in a fashion similar to the current earthwork quantities report. The process is strictly non-graphical; no pavement structure layers are displayable. The specific capabilities are discussed in Appendix P.

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