CALCULATION OF VOLUMES (CUT AND FILL)

www.geodis-ale.com

Technical Note

1. Foreword

The software ALE Advanced Land Editor is used by civil engineers, geologist and surveyors to perform the detail design of roads, open-pit mining, dams, garbage dumps, land rehabilitation, civil general design and so on. The program engine performs the complete land design and automatically makes the calculation of the cut and fill volumes inside a bounded area.

The computation of digging and filling volumes may be performed by two different methods.

a) Cross Sections

b) Prisms

The result of the calculation, the detail report, the cross sections and the contour map are all available in real time.

If requested, ALE automatically modifies the project to balance the cut and fill volumes.

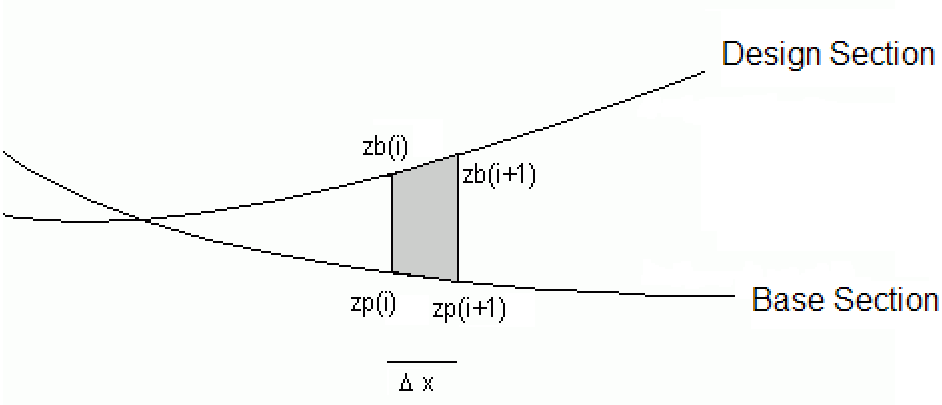
The purpose of this technical note is to describe the two computation methods and identify the key parameters for the accuracy (paragraphs 2 and 3).

A test case performed by ALE with high quality parameters is discussed in paragraph 4.

Final conclusions are reported in the last paragraph 5.

2. Cross Sections Method

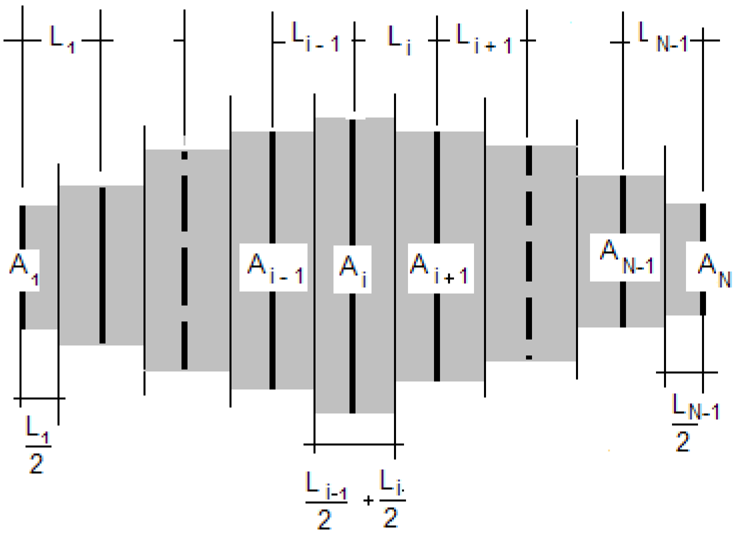
A group of parallel section are drawn in such a way to cover the area to be evaluated.
The surface between the design profile and the base profile is evaluated for each section.
The filling area and digging surface per section are not summed but set apart.
In order to evaluate the surfaces, ALE splits the surface in stripes and for each stripe evaluates the surface of the trapezium as in the next figure.
The sum of the strip surfaces gives the cut and fill surfaces of the section.



The total digging and filling volumes are calculated by multiplying the digging and filling surface of each section for an appropriate distance as in the next figure.
For the generic surface A_i :

$$A_i\ (L_{i-1} + L_i) / 2$$

You can see that the first and last section have a missing term.



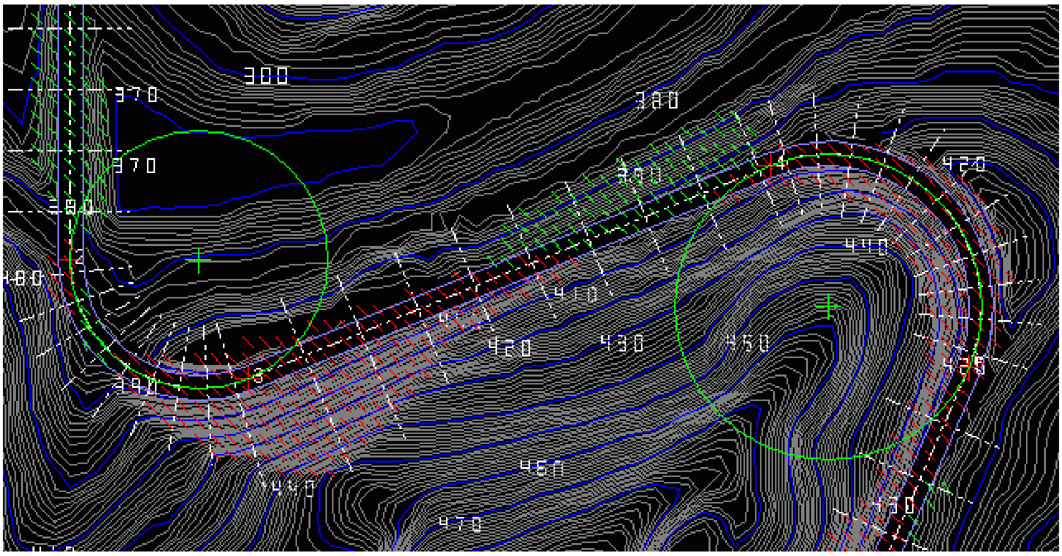
Note that you can get the same result by summing the terms

$$L_i\ (A_i + A_{i+1}) /2$$

The accuracy of the calculation is related to
a) the number of stripes
b) the number of sections
c) the shape of the ground
d) the orientation of the parallel sections

In the case of a road the cross sections are not parallel but are oriented in a direction perpendicular to the axis of the road. This procedure introduces other causes of error in the bends. It is advisable to evaluate the bends with a large number of short sections.
If this is not possible, it is better to utilize the prism method described in the next

paragraph.



A technical report generally includes information to understand the calculation.

CALCULATION OF VOLUMES

File : C:\Documents and Settings\Tutone\Documenti\Ale4-Casi Esempio\Modeler\punti+spiano+scavo equilibrio sc-rin.mod
Base surface: Base surface
Design surface :Digging
Number of sections = 30

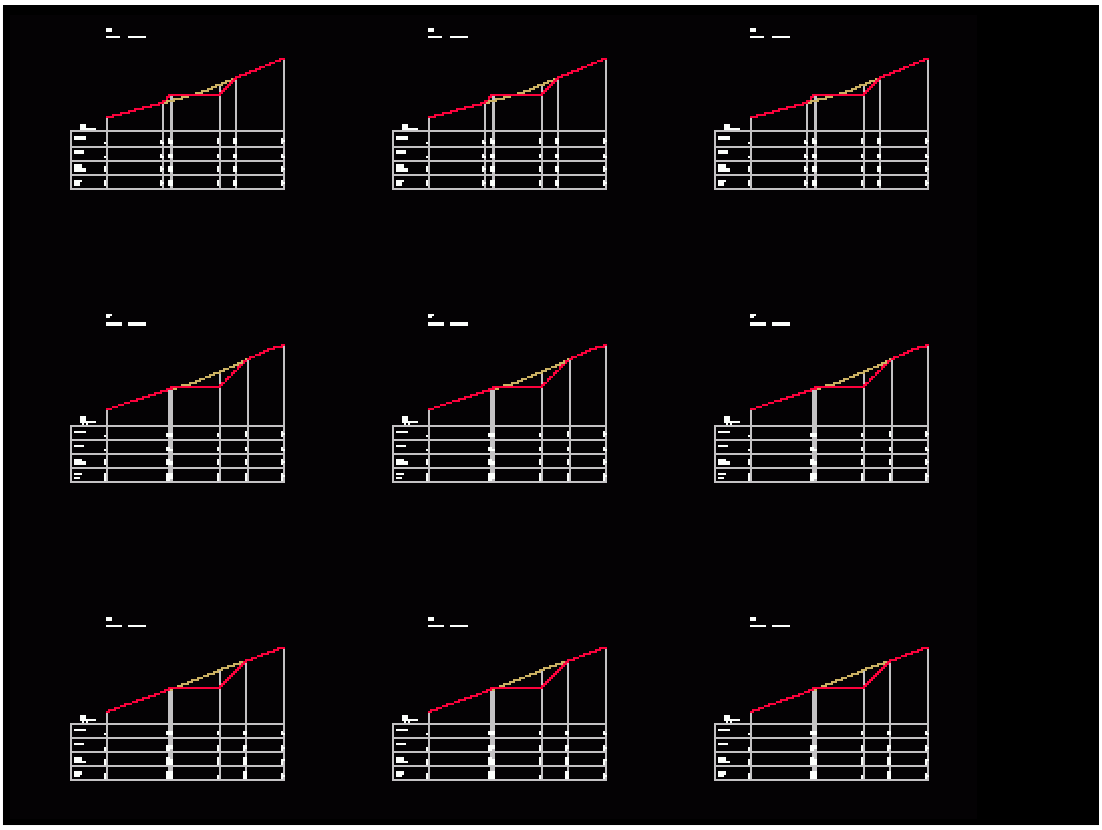
LEGEND:
N = Number of the section in the group"
Sd = Digging surface between the base profile
and the design profile [m2]
Sf = Filling surface between the base profile
and the design profile [m2]
L = Distance to be associated to each section [m
Vd = Digging volume = Sd x L [m3]
Vf = Filling volume = Sf x L [m3]
N = number of the section in the group
Ss = Digging surface between trhe base profile and the design profile [m2]
Sr = Filling surface between the base profile and the design profile [m2]
L = Distance to be assiciated to the section [m]
Sc = Digging volumes [m3]for each section
Ri = Filling volumes [m3] for each section

N	Ss	Sr	L	Sc	Ri
1	0.6	6.2	3.5	2.1	21.9
2	0	12	7	0	84.9
3	0	14.4	7	0	101.3
4	0	13	7	0	91.8
5	0.2	9.7	7	1.5	68.3
6	1	6.1	7	6.8	42.7
7	2.8	3.1	9.4	25.9	29.3
8	2	3.5	9.8	19.5	34.2
9	2.9	1.9	7.8	22.3	14.8
10	2.4	2.3	7.8	19	17.5
11	3.8	1.6	7.4	28	11.7
12	2.6	2.3	7	18.3	15.9
13	1.2	3.9	7	8.1	27.8
14	0.5	5	7	3.7	35.5
15	1.3	3	7	9.1	21.3
16	3.4	1	7	23.6	7.3
17	6.6	0	7	46.4	0.2
18	8.5	0	7	59.9	0
19	5.8	0.2	7	40.8	1.5
20	3.3	1	6.9	22.6	7.1
21	1.3	2.7	6.5	8.2	17.3
22	0.7	4.9	6.1	4.2	30.2
23	0.8	4.7	6.1	5	28.7
24	1.7	3.4	8.1	13.7	27.3
25	4.5	1.2	8.6	38.3	10.2
26	6.6	0.6	7	46.6	3.9
27	7.6	0.7	7	53.7	4.9
28	6.5	1	7	46	7.2
29	4.2	2.4	8.3	34.7	19.6
30	2.4	2	8.3	19.8	17
31	2.1	1.5	7.1	14.5	10.7
32	2.7	2.1	7.1	18.8	15
33	3.2	2.4	7.5	24	17.9
34	0.8	4.6	7	5.9	32.2
35	0	12.1	6.1	0	73.5
36	0	21	6.1	0	127.8
37	0	29.3	6.1	0	178.2
38	0	27.6	6.1	0	168.2
39	0	20	6.1	0	121.6
40	0	12.7	6.1	0	77.5

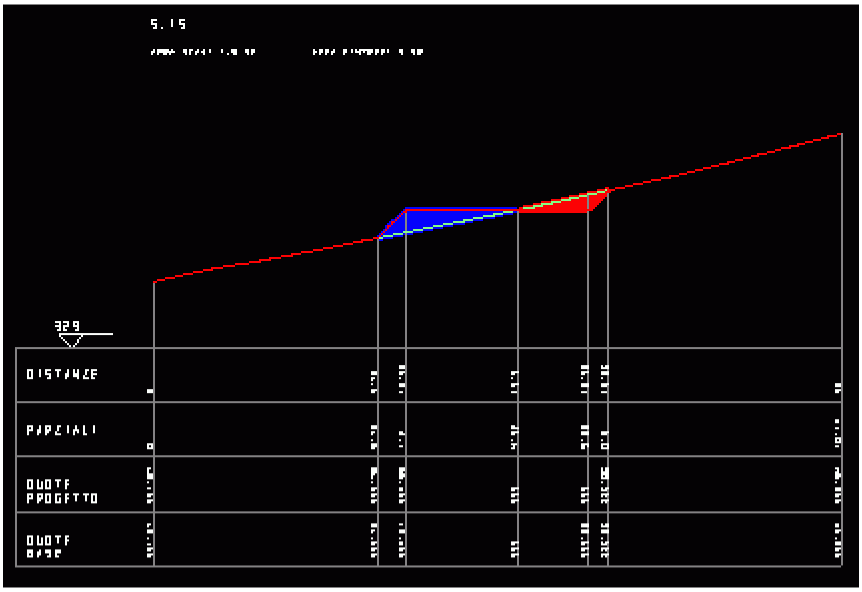
41	0.3	6.9	6.1	1.7	41.8
42	2.9	3.8	6.1	17.4	23.2
43	4.2	3.1	8.1	33.6	24.9
44	2.7	4.3	8.6	23.2	36.6
45	2	4.6	7	14	32.2
46	5.6	2.6	7	39.8	18.4
47	14.7	0.1	7	103.5	0.9
48	16.7	0.2	7	117.9	1.1
49	7.7	3.5	3.5	27	12.4

TOTAL DIGGING VOLUME = 1069.1 m3
TOTAL FILLIN G VOLUMEI = 1815.5 m3

The attached drawings include a topographic map and a complete set of sections.



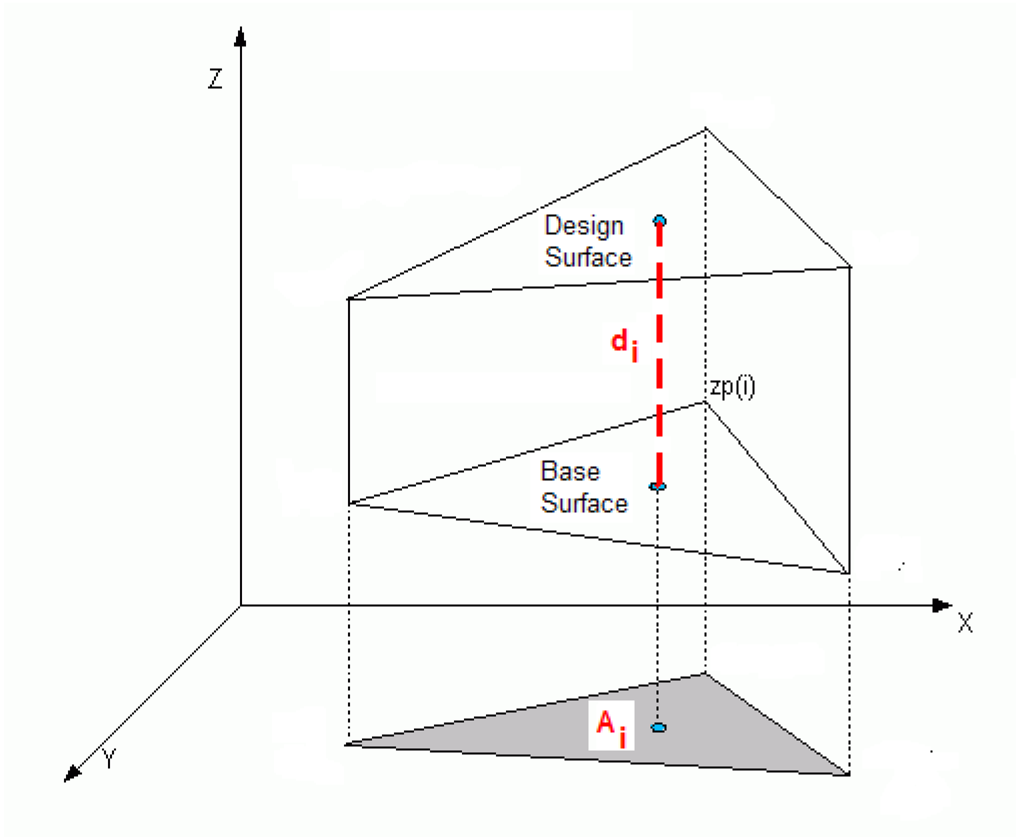
The cut and fill areas are printed on each section.



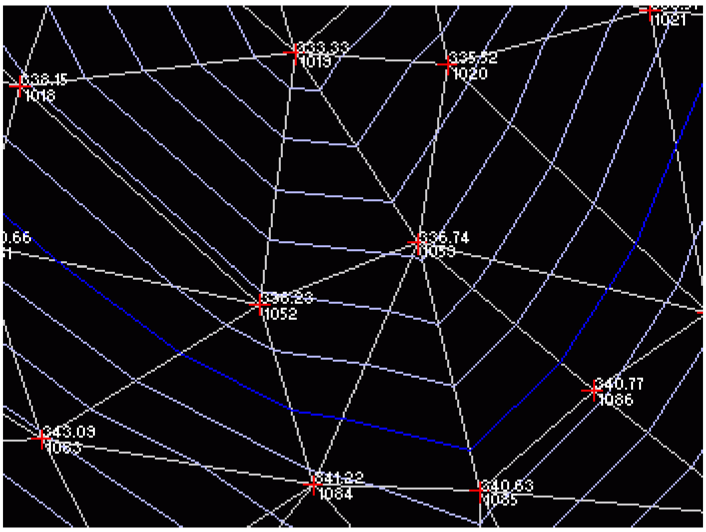
3. Prism method

The volume V_i of a right prism with triangular base may be calculated starting from the projection surface (grey area) A_i and the distance d_i between the centres of mass of the two triangles.

$$V_i = A_i \; d_i$$

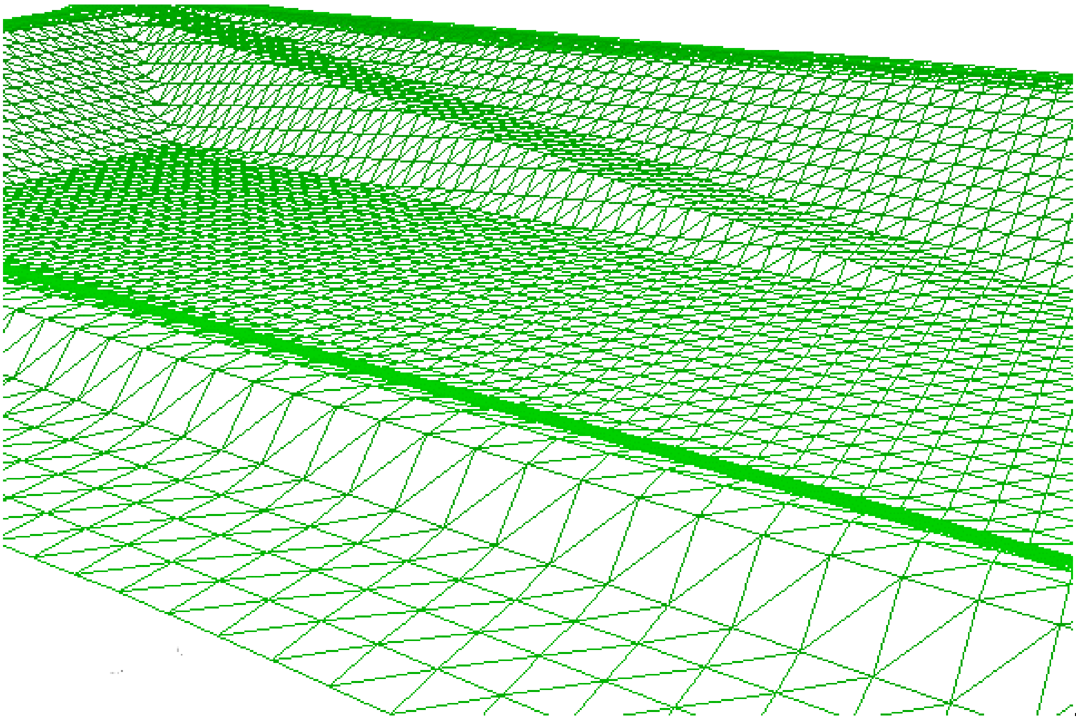


If the map is split in triangles, the total volume between the base surface and the design surface may be calculated by summing the volume of all the prisms.



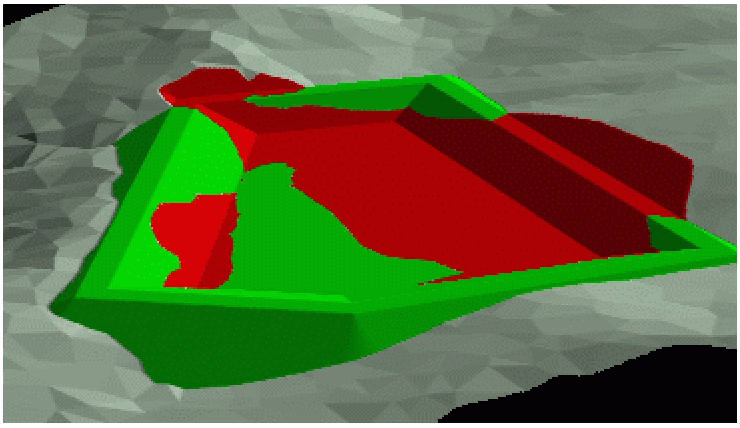
The accuracy of this calculation is related to the capability of the 3D model generated by this triangulation to represent the real shape and dimension of the ground.

The 3d representation often starts from a number of sparse points (x,y,z) and therefore the 3d model is as accurate as the original source of the information. However, if you want to represent accurately a ground after a modelling, you need such a large number of triangles that the matter takes an high technology form. The technical report of such a calculation is so large that often is omitted for pratical purpose

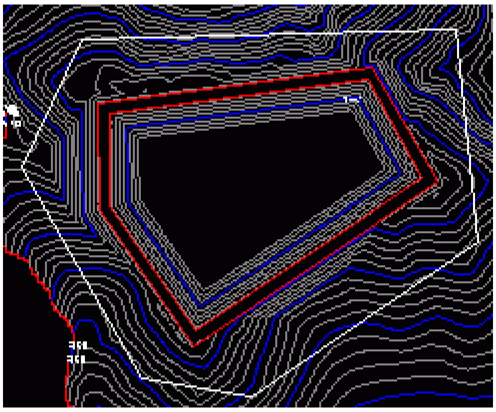


4. A test case performed by ALE Advanced Land Editor

ALE is an advanced hight technology engine and all the above problems are resolved with a mixture of easy and fast procedures for the operator and extremely accurate processes for the computer.
Therefore it is possible to check the degree of accuracy of each method and of each sensible parameter for each of your projects.
This paragraph contains a test case : a 350 m basin shown in the fist 3D picture of this note.
The digging and filling volumes have been automatically balanced.



The operator draws a closed polyline in a topographical survey map. He has a perfect knowledge of the area which has been excavated through change of contour lines and coloured theme chart.



Any volume calculation described in the following take 5-15 sec

a) <u>Prism method</u>

This calculation is shown first because the ALE procedure is so simple and accurate that the result takes the form of an absolute reference with no sensible parameter to be changed or discussed.
ALE automatically splits the area in 1000 x 1000 squares and each square is divided in 2 triangles (2 million triangle) regular triangles.
An square area of 500 m is so split in 50 cm squares which are sufficient to accurately represent the particulars of the project.
The digging and filling volumes calculated inside the boundary polyline are both

$$154{,}700 \ m^3$$

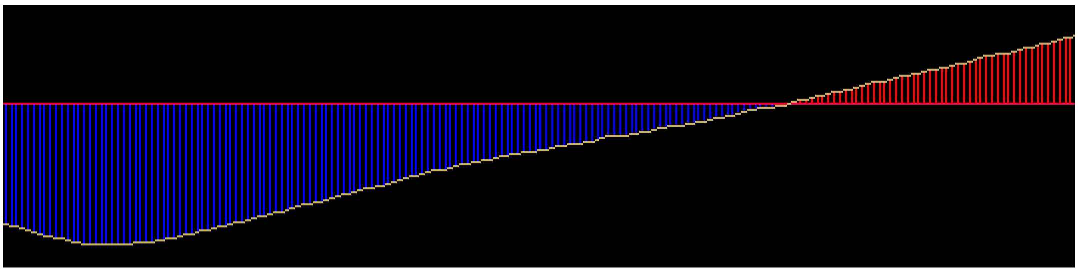
This volume has been assumed as reference zero to evaluate the accuracy of the cross section method.

b) <u>Cross sections method</u>

ALE generates automatically groups of parallel sections inside the boundary polyline with an assigned direction as shown in figure.

The sections are automatically developed and analysed one by one.

The cut and fill areas for each section are calculated by splitting in a fixed number of 600 stripes.

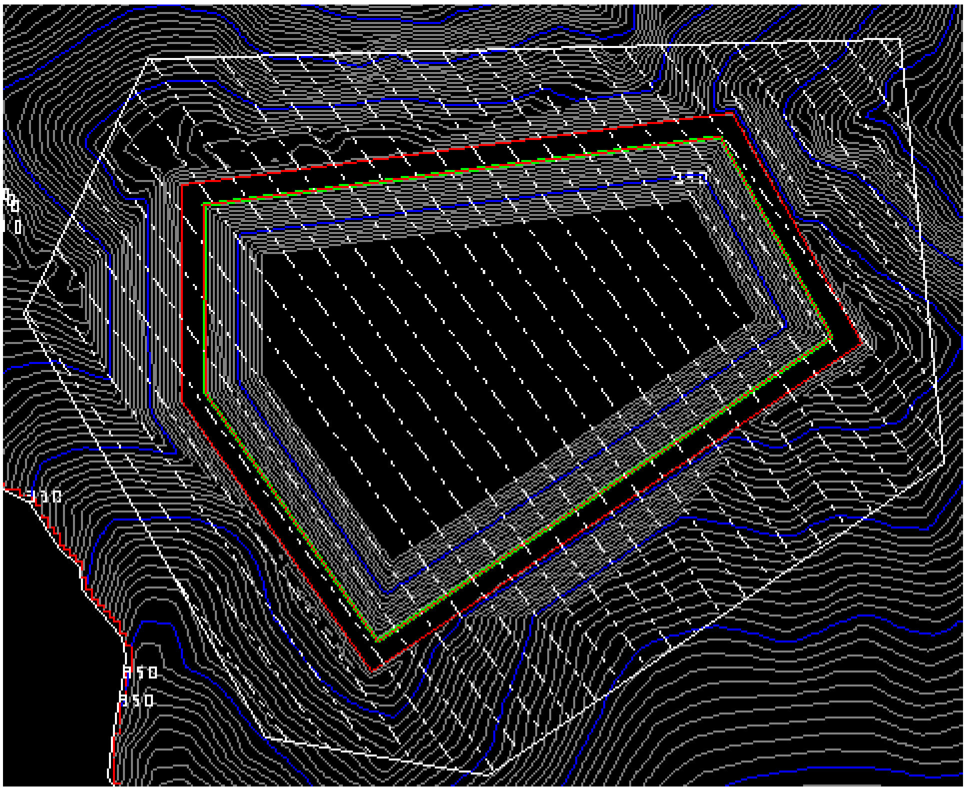


Such number of stripes is so hight with respect to the common practice that the evaluation of the surface has to be considered exact.
For this reason the number of stripes is not considered a sensible parameter for the accuracy of the calculation of the ALE volumes.

The maximum number of cross sections per group is 200, which is adequate for the roads but is large for the simple test case which was limited to 30..

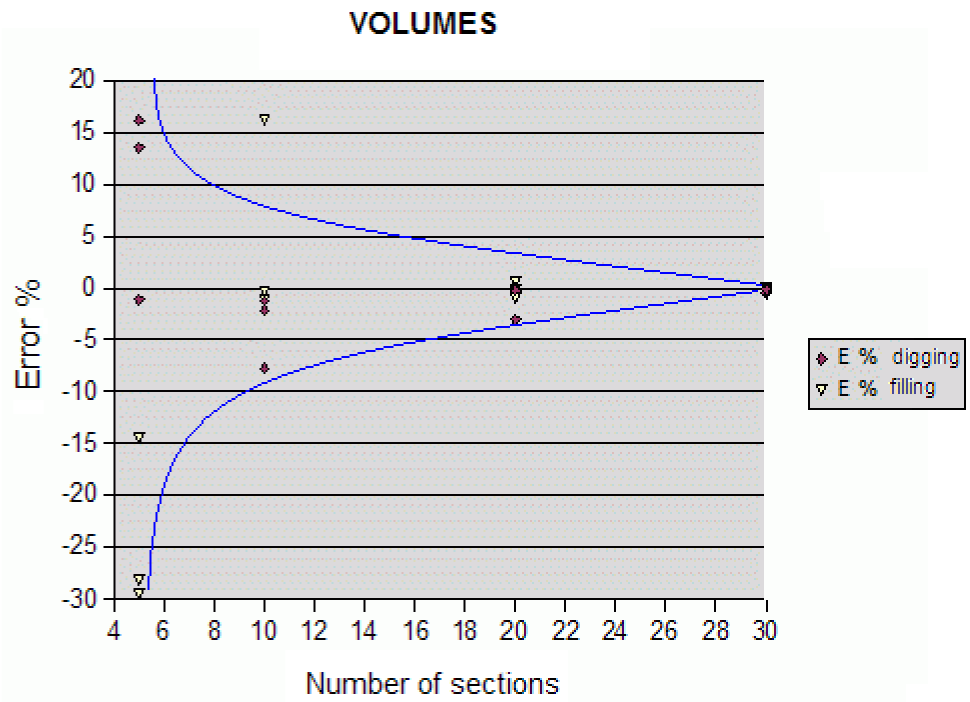
The time for such a calculation is about 8 seconds.

The technical report and drawings are available in real time.



The calculation was repeated changing the number of sections and the direction of the sections.
The results are reported in the next figure, where the volumes calculated by the prism method are assumed as zero reference of the errors.

As you see, the results are quite spread up to 20 sections and show an high level of accuracy at 30 sections, where practically the volumes are coincident with the prism method results.



5. Conclusions

1) The ALE prism method with 2 millions prism provides easily in a short time (15 sec) very accurate calculations of digging and filling volumes.

2) The cross section method is widely used because it provides short a short report and expressive drawings but it was demonstrated that, also for a simple test case, a number of 30 sections are necessary to provide a good accuracy.
This mean that the calculations of volumes using a small number of cross sections are normally wrong.
The number of necessary sections increases with the roads containing short ray bends.
ALE can perform calculations with to 200 cross sections per group, which are adequate in any circumstance.

3) There is no reason to accept projects with large errors and no check of the accuracy of the results because the high accuracy technology is available and easy to use.

4) ALE is an advanced engine. It provides two different methods to calculate volumes (cross section and prism) with negligible effort and negligible errors.
ALE gives the possibility of a simple cross check between 2 different technology evaluations and therefore increases the reliability of the project and the comfort of the designer.

5) The ALE engine may be tested in a few minutes by downloading the demo