MISSION AIRSTRIP SERVICES

Improving airstrip safety for missionary pilots.

302 Beverly Rd, Newark, DE 19711 Phone/Fax 302-368-0427 **www.airstrips.us**

MAS donates the following supplies and services to Christian flying missions:

A. Supplies: Runway end markers, edge markers, windsocks, tie-downs, geofabric drains, visual approach slope indicator boards, alignment strobes, and utility shelters.

B. Designs to minimize earthwork for existing and proposed airstrips, prepared from terrain data submitted by the pilot.

C. Surveying and construction services, when work at several neighboring airstrips justifies travel cost.

- Runway extensions, grading improvements
- Grading for surface drainage
- Subsurface drain installation
- Flight path and runway clearing

Supplies and services are provided each year as long as funding remains in a charitable gift fund. Use the **REQUEST FORM**.

1-05

DESCRIPTIONS

A. SUPPLIES

1. Runway end markers *For visibility from the air*.

20x50' bright orange UV-resistant woven polyethylene film. Typical life 5-10 years. Stretch the four edges into shallow trenches and backfill, beyond ends of airstrip. Planes can accidentally touch down on them without damage.

2. Runway edge markers *For visibility on the ground*.

5'x20', the same material.

3. Wind socks *For wind direction and speed*.

27"x6.5" dia. windsock, aluminum mast 33" to 54".
See www.sportyscatalogs.com.

4. Screw anchor tie-downs *For safety in gusts*.

Portable tie-down anchor kit. 3 steel screw anchors & three-15' braided nylon ropes. See www.sportyscatalogs.com.

5. Geofabric drains *To reduce soft spots after rains*.

1" thick 6" wide by 100' roll of plastic strip drain. Rigid PVC waffle core enclosed in polypropylene filter fabric. Better drawdown of water than pipe and less costly to install (requires only a slit trench). Akwadrain strip. See www.americanwick.com.

6. Geofilter cloth *To wrap perforated pipe or stone drains*.

3' by 100' rolls, 5 oz/sq.yd.

7. Visual approach slope indicator boards *To correct for slope illusions*.

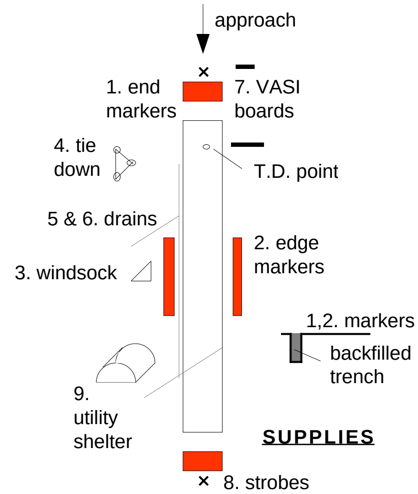
Contrasting bright orange and green 2' by 8' by 1/4" expanded high density rigid PVC boards bolted to 1.5" PVC pipe posts. Or make your own from local materials.

8. Alignment strobes *For emergency landings at dusk*.

Low intensity solar cell-charged strobe lights at each end of runway operated remotely with one of five VHF frequencies, or manually. Includes two strobes, solar panel, and cabinet housing batteries, controls, and circuit board. Do not depend upon without ground backup such as vehicle headlights or an alternative landing site.
See www.8wing.trenton.dnd.ca/8accs/equip/redas.htm.

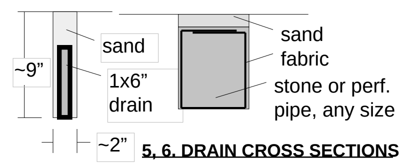
9. Multi-use re-locatable utility shelters *For plane maintenance, medical clinic, work team housing, storage, or other uses*.

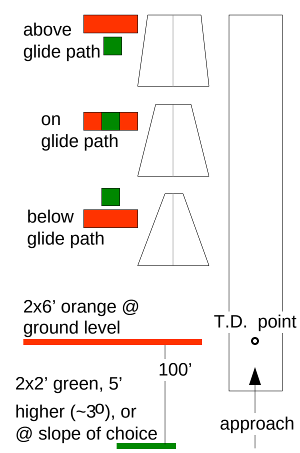
8'x12' to 30'x40' (hangar size) with covers for air visibility. See **www.pan.cc** for details and for **REQUEST FORM**.



3. Windsocks

4. Tie-downs





7. VASI BOARDS

9. SHELTERS

B. DESIGNS

1. Runway profile & approach designs *To eliminate approach obstructions and runway bounders or improve grades*.

The design minimizes your earthwork cost while satisfying MAF (APPENDIX 1), local, or other airstrip profile and cross section specifications.

A profile is plotted from terrain data submitted by the pilot. MAS ships laser survey equipment on loan, if required. Alternative runway extensions and grade improvements are plotted, showing the volume of earthwork for each. The pilot or missionary decides which improvements to make and in what sequence.

Centerline ground profile and finished grade are shown. Finished grade is selected to (1) meet MAF grade specifications, (2) minimize cut and fill volume, (3) balance cut and fill, and (4) minimize haul distances to reduce construction cost. Grading volumes, cut and fill balance points, and haul directions and distances are shown. Our report simplifies stage construction and facilitates design changes.

For new airstrip location studies, reconnoiter a candidate site and send us the terrain data. We will apply the runway design program to provide a minimum earthwork solution to meet your local runway specifications, or MAF's. Cross sections and surface drainage grading options are shown, with accompanying earthwork volumes. We strive to balance airstrip safety with privacy and serenity of adjacent land uses, to best meet community needs with least disturbance to natural terrain.

2. Emergency landing locations *To add emergency landing sites to your GPS*.

In jungles or mountains the initial search for emergency landings is usually more efficient from photos than from over-flights, especially for sites off of usual flight paths. Satellite images are provided (Landsat-7, Spin-2, IRRS, SPOT, Orbimage, or IKONOS, depending on availability and cost at your coordinates) between any two airstrips you designate, showing potential emergency landing sites, based on analysis of geomorphology, ground cover, access to visible salvage routes by land or water, etc. Sent by e-mail or as 8"x8" photos. Make low passes over the sites to evaluate them. Enter those desired into your GPS for emergency use.

C. CONSTRUCTION SERVICES

1. Runway extensions, surface grading, repairs of soft spots and bounders

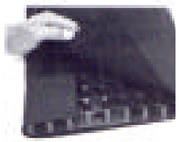
Volume of earthwork will depend on availability of earth moving equipment which can be moved to the airstrip and/or amount of hand tools and hand labor available.

2. Grading for surface drainage See example cross section.

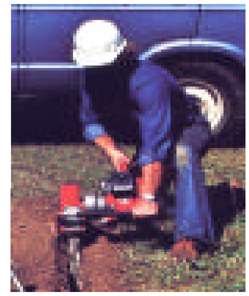
3. Subsurface drain installation Geo-fabric drains may be used for runway cross drains and small lateral drains.

4. Flight path clearing, runway mowing Performed only with other runway work.

Subdrain installation



AKWADRAINä and fittings



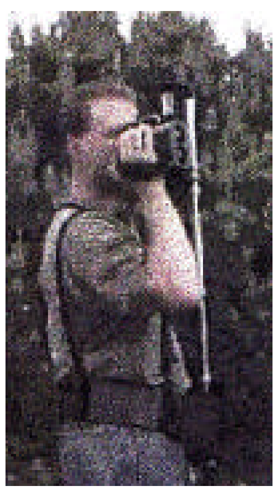
Trencher

TERRAIN SURVEY

Purpose. The purpose of the survey is to provide xyz coordinates of ground points, particularly at changes in slope, which we can download to produce a terrain model for finding the airstrip profile which minimizes earthwork. Typically 100 to 300 points will be recorded up to 50' each side of the airstrip centerline and 200' or more beyond each end.

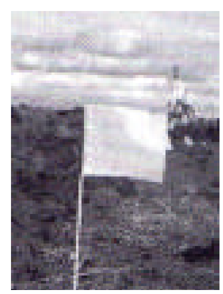
Equipment. Two persons can do this with an inexpensive contractor's level, rod, and tape or measuring wheel, which you might rent locally. But if you prefer, we will ship on loan a laser meter, with data logger and instructions, which allows work by a single person, setting up at one or more points on the centerline and shooting distance, inclination, and azimuth to each ground point (recorded automatically) from which we construct the digital terrain model (DTM).
We air ship the laser, useable by anyone, for a $500 deposit, returned to you within 24 hours after receiving it back undamaged, within 30 days of shipping. After 30 days, we charge $40 per day, and may deduct for any significant damage. 30 days allows time for airstrip surveying (typically under 2 days for one person) plus shipping both directions, and permits us to recycle the laser to other users. The laser is rugged, but should be insured for $5,000 against loss when returned to us. The package also includes flagging tape, orange flags on 12" wire stems, and a flag driving pole with instructions.

Impulse laser and field case.



Hip pod mounting.

Staff and bi-pod mounting.



Survey flag.

Soil penetrometer.

Surveying equipment (see www.lasertech.com)

Minimize your work. Do the least work you can. You might possibly eye-ball the airstrip in with little or no surveying. If you begin construction and become discouraged by the labor required for earthwork, just send us the current terrain data, and we will optimize earthwork from that point on. If you send us incomplete or inaccurate terrain data, you will still receive a design that will satisfy MAF (or other) specs. But it will not be as close to a minimum earthwork design as if based on more accurate terrain data. We will also collect terrain data for you, if several airstrips can be scheduled in one region to justify our travel cost.

Survey steps:

1. Locate the airstrip centerline.
2. Log xyz coordinates for the terrain map.
3. Log xyz coordinates of any obstacles in approach/departure zones.

1. Locate center line. Set a flag on the centerline at each end of the runway. Drive a stake adjacent to each flag to serve as a reference point until construction is finished. Set two more flags up to 200' beyond the runway ends, aligning each with the two end flags. If needed, hold a plumb bob at arm's length to align on the two end flags.

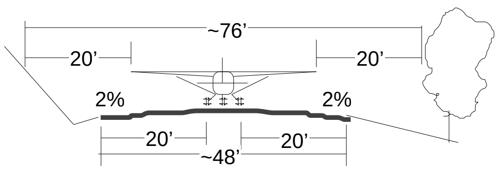
2. Log terrain data points. Set up the laser anywhere on the centerline, as observed by aligning on the two flags at one end, and log the distance, inclination, and azimuth to the four end flags and to points at breaks in slope within the previously-defined area. It may be necessary to choose two or more laser setups to see the whole area, and also because larger inclination angles enable greater accuracy of earthwork volumes.

Your investment in survey time will produce a more accurate terrain model if you set the flags at sharp changes in slope (100 flags included), and improve locations before sighting on them, or add others later to fill in gaps. The program uses the TIN (triangulated irregular network) method. It models terrain as planar triangles drawn between every three neighboring survey points. After a preliminary setting of flags, try to visualize the error in earthwork volume by not adding intermediate flags, and add any where you think they're needed. Identify any features to be avoided or left undisturbed: vegetative cover, bedrock, or other.

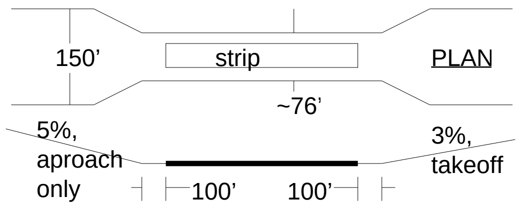
3. Approach/departure obstacles

The sketch shows MAF-specified obstacle-free approach and takeoff zones. At most sites visual absence of obstacles can simply be recorded, or one can make a sweep from the end of runway with the laser set at 5° for approach or 3° for takeoff, to ascertain that no obstacles project above the glide or climb slope surfaces. Otherwise any obstacles beyond the airstrip ends or planned airstrip extensions can be located with the laser in the same manner as for the ground xyz coordinates.

This description has been for a laser survey. Different survey instruments will dictate different methods. If a contractor's level and leveling rod are used, it is easier to set flags at intervals of 100' or so along the centerline and take level readings at points on the right angle cross section to each flag. See www.delorme.com for an economical gps alternative with post processing.



MINIMUM WIDTHS



REQUIRED AIR SPACE

EARTHWORK CALCULATIONS

Missionary airstrips are built with limited labor, equipment, and financing. If clearing and grubbing are manageable, minimizing earthwork is often the critical factor in whether an airstrip can be built, or extended to handle larger planes.

Earthwork is also the activity where a little engineering can save the most labor. Since earthwork is your major construction cost, our major effort is to minimize it.

We download the terrain data you collect in the data logger to our optimization program, which minimizes earthwork by the steps listed in APPENDIX 3.

If alignment is not already established by an existing airstrip, and you are doubtful which alignment will require the least earthwork, extend your terrain data farther to each side. We will compare earthwork requirements for different alignments within the boundaries of data which you provide.

Dramatic earthwork reductions (90% or more) can sometimes be obtained by slight lateral shifts and/or reorientation, particularly on side-hill sites. Improvements can be made in a matter of minutes with the terrain model which are time-consuming or impossible to detect by on-site inspections. Part of the problem is the need to account for terrain variations across the width of airstrip. The optimization program adjusts PI coordinates within the specified design constraints iteratively until the reduction in earthwork between two successive trials falls below a prescribed amount.

DATA RETURNED TO YOU by email or hard copy, to perform grading:

1. Contour map of initial and finished grades, showing cut/fill depths.
2. Centerline profile, showing balanced cut and fill volumes and boundaries and haul directions.
3. Cross sections at 200' intervals or less, showing elevations.

This data enables all staking for field grading. Slope stake lines (top of cut and toe of fill) are displayed. We break the project into two or more construction stages, showing the earthwork volume for each, with the greatest improvement per unit of labor in the first stage, so that landings can be made before all specs are satisfied, if the pilot or regional flight program director so directs.

CONSTRUCTION

Survey.

1. Set centerline stakes and runway edge stakes at points where finished grade crosses existing terrain, indicating changes from cut to fill (shown on our plan view).
2. Set a few stakes along each side indicating the boundaries of cut and fill (shown by the break in contour lines on our plan view). Distances from centerline to slope stakes (where side slopes meet natural ground surface) are shown every 100' on the plan, or scale your own distances from the plan at intermediate points. Alternatively, set offset stakes 10' beyond, so they will not be disturbed during cut and fill operations.
3. As earthwork proceeds, occasionally take rough level readings at any selected points to determine additional depth of cut or fill required. Any type of builder's hand level and a pipe or pole with an adhesive-backed rod tape works well for this. First place the rod at your toes to record your eye level, then proceed with the readings. A builder's hand level and adhesive-backed rod tape are included with the laser we ship, for you to keep and use for construction surveys after returning the laser. Also included is a spring-loaded pocket soil penetrometer with

instructions for determining suitable soil hardness for safety against aircraft nosing over. Use it on clayey soils after rains.

Grading equipment. Obtain what is possible at your location, such as:

1. Shovels and wheel barrels or carts.
2. A walking rototiller with grader blade, as used by landscapers.
3. Small garden tractor with tiller and grader blade.

Any hand- or tractor-drawn harrow or drag board, and a vibratory plate or roller compactor may be useful. Or do any necessary re-grading after a few years of settlement.

Construction practices:

1. Remove thick and highly organic top soil in areas to be filled, to minimize having to re-grade due to settlement. Keep large quantities of organic matter out of fill material, for the same reason.
2. If grading will take many weeks, consider filling near the centerline initially, so it can settle first with time and with rains.
3. Stretch twine across nails in stakes 3" to 6" above final grade to provide a guide to final leveling or harrowing in cut and fill. The finished contour map gives the necessary information for grading a rounded crown without breaking slope at the centerline.
4. Include a turn-around at the end opposite the approach end(s).

Even if the design indicates almost a balance of cut and fill volumes, you will have to either waste some, or borrow some. Factors causing this difference include the assumption of 1.05 swell of soil moved from cut to fill and the difference between actual terrain and the TIN model used for calculations.

Soft spots can be improved by:

1. Replacing with more granular material, raising grade, or adding sub-drains, all of which improve drainage.
2. Harrowing or raking in cement and compacting, or planting native grasses to establish dense root mats, both of which harden the surface.

Add any utility buildings (see **www.pan.cc**, "Construction")

NEW AIRSTRIP SITE SELECTION

There is no substitute for an experienced missionary or short-field pilot examining satellite or aerial photos or stereo pairs, making low over-flights, or walking the site. In addition to the MAF airstrip specifications (APPENDIX 1), here are some criteria for selecting a new site. Add your own requirements to this list and prioritize them for your situation.

Site selection

Away from populated areas, especially the departure path, for noise and safety

Away from high obstacles
Where there are minimal land ownership complications
Absence of abrupt grade changes, to reduce earthwork
Clear visibility of surroundings, for people and animals near the runway
Economical to provide adequate drainage
General proximity to mass center of population to be served
Proximity to other transportation modes; water, vehicle trails, etc.
High, flat terrain is generally preferred, such as a level river terrace where soil is well-drained and where approach and departure paths can be directed over a stream or unoccupied area. Elevated sites also have less fog. Sandy or gravelly soils are more economically drained.
Orient into prevailing winds, other factors permitting.
We can suggest sites based on satellite photos if you wish. Give us a map or sketch with coordinates of the area within which you want us to search.

Any photos of your project are much appreciated, before, during, or after construction.

MISSIONARY AIRSTRIP SERVICES
Robert Nicholls, 302 Beverly Rd, Newark, DE 19711 Phone/Fax 302-368-0427   **www.pan.cc**

APPENDIX 1. MAF (U.S.) NEW AIRSTRIP CONSTRUCTION STANDARDS, 1989

Slope after touchdown point (first 300'):	less than 15%
Bounders, a max. of:	5" rise in 50'
Rate of change in slope (first 500'), max. of:	1.5% per 100'
Airstrip width for excursions right & left of center:	20'
Side slope, max. of:	2%
Approach-only paths less than:	5%
Departure paths less than:	3%
Visual approach slope indicator:	If > 4% runway slope, or other illusions
Airstrip boundaries defined with markers at:	75% & 50%
Wind indicator:	Yes
Responsible caretaker & reporting method:	Yes
Airstrip length determined by either takeoff length or landing length, whichever is greater for the design aircraft, at gross wt., with alt., temp., slope, & surface correction factors.	
Additional cleared area may be required to observe animals or people where they are not adequately controlled by fences or by persons.	

APPENDIX 2. DECISION CHART

Modify this list for your own use. It suggests a decision sequence.

Topics to consider

New airstrip?

- Site selected?
- To be selected?

Existing airstrip?

- Extension?
- Grading?
- Drainage?
  - Surface?
  - Subsurface?
- Airstrip marking?
- Windsock?
- Utility building?
- Clear approach obstacles?
- Others? Name:______________

Emergency landing sites?

Provide coordinates of strips flown between.

Preliminary approvals

Land use granted?

Flying organization agrees to serve?

National and local government approvals?

Survey

Provide own terrain survey?

- Need MAS survey equipment loan?
- Or use other equipment?

Need surveyor?

Approvals of design submitted,

from same agencies, above.

If phase construction is used, minimum phase for landing approval by each agency.

Construction decision

Not worth trying?

Worth trying only with MAS help?

Worth trying with other const. resources?

APPENDIX 3. COST REDUCTION EXAMPLE

Earthwork relationships

Graphs A to D illustrate what happens with earthwork. Graph A is the profile. Graphs B to D are successive integrations of earthwork volumes with respect to distance along the profile. Therefore the area of each graph becomes the ordinate value of the next, and the ordinate value becomes the slope of the next. That is, the steepest points on each plot occur at the peak ordinate values on the previous plot, and the maximum values correspond to the zero crossings on the previous plot, as shown by the vertical dashed lines. The slight misalignments between Graphs B and C are due to the fact that volumes are calculated by 100' station increments rather than as a continuous function. Graph C is the "Mass haul diagram", the one most used to minimize earthwork cost. The units of measurement are tabulated below Graph D. We seek the following improvements to Graphs A to D:

Graph	**A**	**B**	**C**	**D**
Name	**Profile**	**Earthwork**	**Mass haul**	**Integrated haul**
To balance cut & fill	Eye-ball equal areas above and below diamonds, accounting for vertical curves.	Make the sums of positive areas and negative areas equal.	Set the terminal ordinate equal to zero.	
To minimize cut & fill	Plot the profile as close to the diamonds as possible.	Minimize the sum of fill (positive) areas and of cut (negative) areas.	Reduce the peak ordinate values, both cut and fill.	
To minimize haul	Try to make the profile cross from cut to fill at short intervals.	Make the zero crossings between cut and fill as frequent as possible.	Minimize the total of all areas (+ and -).	Keep the terminal ordinate as small as possible.*

* A zero terminal ordinate in Graph D would indicate zero haul.

<u>Search algorithm</u>

Various algorithms with different advantages are used to minimize earthwork. This one focuses first on balancing cuts and fills, then minimizing volumes while maintaining an approximate balance, and finally on minimizing mass haul. The iterations in each phase tend to also improve the objectives of the other two phases.

<u>1. Select the centerline alignment</u>. The earthwork program plots finished grade elevations for which cut area exactly balances fill area at each cross section (diamonds in profile view, Graph A). Notice that, depending on the terrain cross section shape, the diamonds may have to be slightly above or below centerline terrain elevation in order to balance that cross section's cut and fill areas.

<u>2. Plot eight or fewer tangents</u> (3 are shown) passing as closely through the balanced cut-fill cross section diamonds as possible. These lines could be plotted using a least squares or polynomial fitting method, but plotting by eye is about as accurate. If the finished grade could pass through all diamonds, there would be zero earthwork.

<u>3. Test to see that MAF specs (APPENDIX 1) are satisfied</u>, ie. profile slope less than 15% in the first 300', and change in slope less than 1.5% per 100' in the first 500'. The first requirement is simply entered as a program constraint. To check the second requirement, sum the absolute values of grade changes at each PI within the first 500' of profile. If the sum exceeds 7.5%, flatten slopes or eliminate PIs to satisfy.

From here on iterative adjustments are made in PI elevations to (a) balance cut and fill volumes, (b) minimize cut and fill volumes, and (c) minimize haul (cu.yd.-stations).

Balance earthwork

4. Calculate the earthwork. Test whether the terminal ordinate in the mass diagram C, labeled a, is in cut or fill. If in fill, reduce the largest Vf, volume of fill, in C by lowering a PI lying within the corresponding fill an arbitrary amount, such as 1 ft. If ordinate a is in cut, reduce the largest Vc volume similarly by raising the appropriate PI.

5. Recalculate the earthwork. If the terminal ordinate in C is still in fill, repeat, using the appropriate PI, which may be the same or different one. Similarly if the terminal ordinate is now in cut.

Minimize earthwork volumes Iterations 4 and 5 seek balanced earthwork, with reductions in total volume and haul being coincidental.

6. After iterations 4 and 5 reduce the terminal ordinate to 20% (an adjustable limit) of its initial value, continue to minimize earthwork volumes by adjusting PI elevations in both cut and fill simultaneously, using the similar criteria of largest Vf and largest Vc in Graph C.

Minimize mass haul

7. This step corresponds to reducing the terminal ordinate in Graph D, meaning reduce the steepest slopes in D, i.e. reduce the largest ordinate values of Vf and Vc in Graph C. After the total Vc has been reduced to 20% (an adjustable limit) of its initial value, reduce mass haul, by reducing the largest adjacent Vc and Vf values in Graph C approximately equally, to maintain balance while reducing total mass haul.

Various alternative decision criteria and calculation refinements can be made to this algorithm. They are omitted here for simplicity.

Example

The design uses parabolic vertical curves to the middle of tangents to provide long smooth transitions, and uses a 48' cross section with 2% side slopes, and cut slopes to allow 20' excursions left and right of center for both wheels and wing tips (see Cross Section, page 5).
The aim is to (a) balance cut and fill, (b) minimize cut and fill, and (c) minimize haul (the sum of all cut volumes times their respective haul distances). Haul is in station-yards (one cu.yd. hauled 100'), i.e. the product of distance between centers of gravity of equal adjacent volumes in cut and fill (stations) times the associated volume in cut (cu.yd.).
The program plots cut and fill between each pair of stations and the mass diagram, an accumulation of cut and fill volumes, starting at the left end of the airstrip. Our goal is to make the totals of cut and fill areas on Graph B as small as possible, equal to each other (to balance earthwork), and crossing the zero line as frequently as possible (to minimize haul distances).

After each new profile and mass diagram are plotted the process is repeated until successive reductions in (a) difference in cut and fill, (b) total cut, and (c) maximum distance between crossing points all fall within some specified limit, such as 5% reduction in each over the last two iterations, representing a point of diminishing return for the computational time in successive iterations. This is then accepted as the final design profile.
Actual earthwork will differ slightly because the terrain model will not be precise and the choice of a 1.05 swell factor may be slightly in error.

It may also be cheaper to take fill from a nearby borrow pit than to haul it a longer distance from a cut. This will modify the mass diagram, and also allow one to shorten other haul distances on the job. Use of borrow pits is based on economic haul limit: L = B/H

where L = economic haul limit, in 100' stations,

B = borrow cost, $/cu.yd.,

H = haul cost, $/cu.yd./sta.

You will need to evaluate the cost advantage of using borrow pits based on their availability at your particular site. A ridge can often be shaved off closest to the point of need for excess fill. Excess cut can be wasted in any suitable manner.

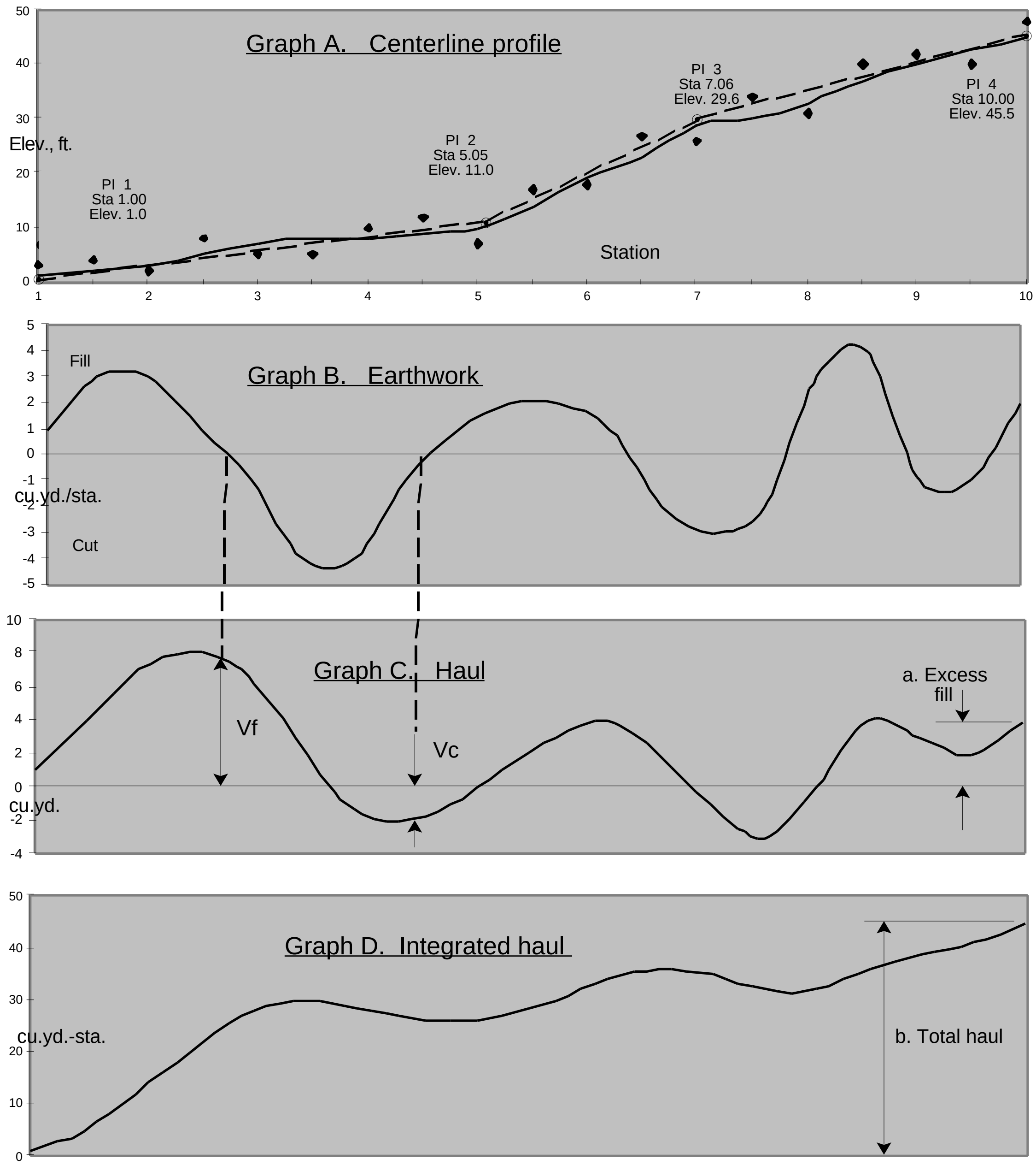
Figures 1 to 4 show typical results obtained with Simple Road, the highway design software written by Chris Baker, Creative Engineering, Wilston Qld, Australia (see **www.createng.com.au**).

Fig. 1 is a plan view of a 1145' side-hill airstrip having a maximum grade of about 14%, showing finished grade contours. Fig. 2 shows the plan and profile. Rill marks on the plan view show cut and fill widths. The profile view shows natural and finished surface elevations, cut and fill depths and volumes, percent grades, and lengths of vertical curves. Fig. 3 shows the typical cross section and the section at Station 11 as an example. Fig. 4 shows the mass diagram and tabulated cut and fill volumes. Drainage design, stage construction phases, etc. are not shown.

Here are the reductions in volume and haul after 7 iterations of the above procedure.

	cu.yd. of cut	**cu.yd. of fill**	**Haul, cu.yd.-stations**
Best first guess	19354	15214	138
7th iteration	4654	4260	22
% reduction	76%	72%	84%

This result was obtained with just two vertical curves. It can be improved with more. The small ratio of haul to cut and fill volumes is due to the side hill location; most haul being from one side of strip to the other instead of along the length of strip.



UNITS OF MEASUREMENT

Graph	**Slope**	**Ordinate**	**Area**
A.Profile	-	-	-
B.Earthwork	cu.yd./sta.^{2}	cu.yd./sta.	cu.yd.
C.Mass haul	cu.yd./sta.	cu.yd.	cu.yd.-sta.
D.Integrated haul	cu.yd.	cu.yd.-sta.	cu.yd.-sta.^{2}

Cost items are shaded.

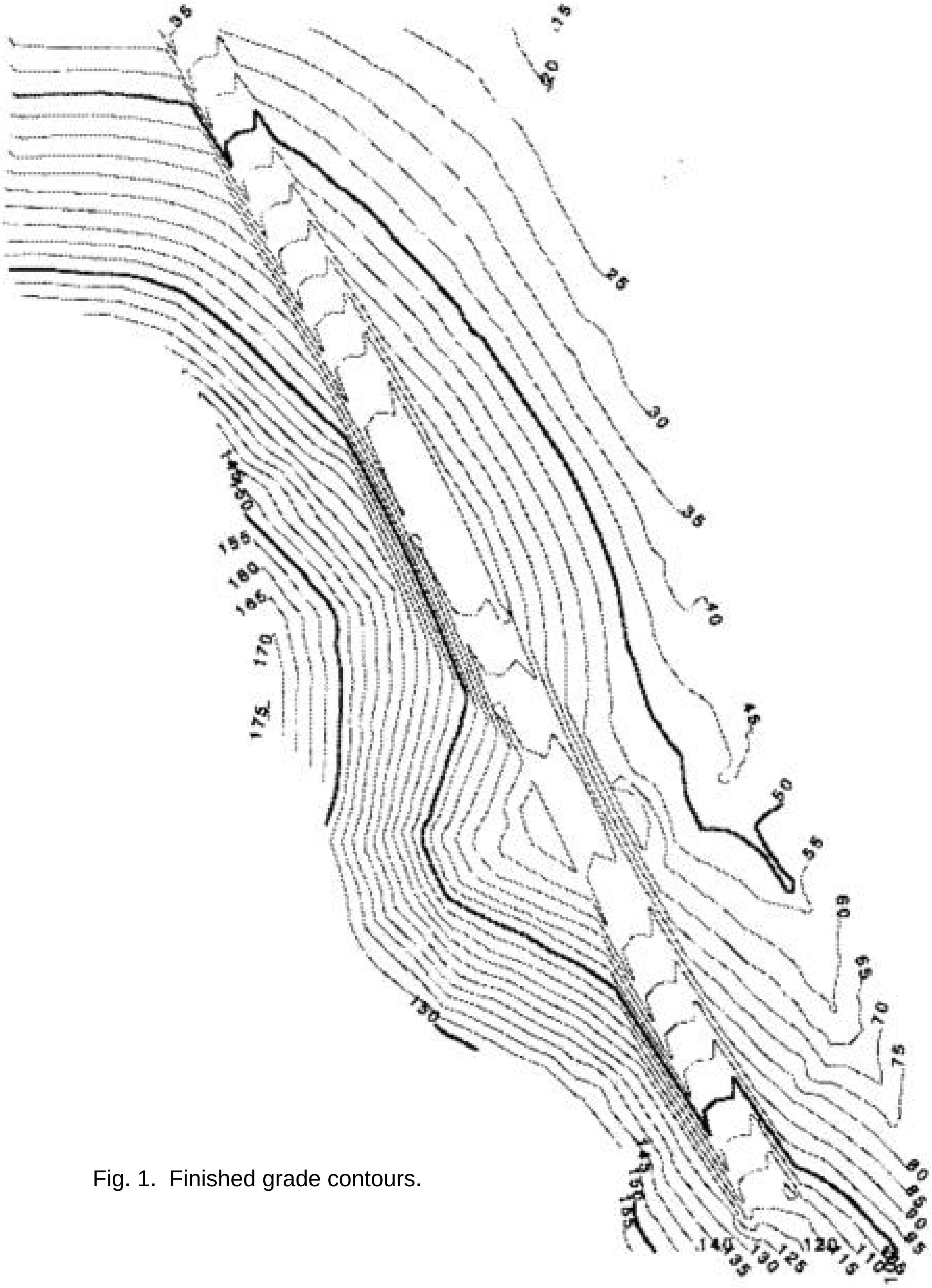


Fig. 1. Finished grade contours.

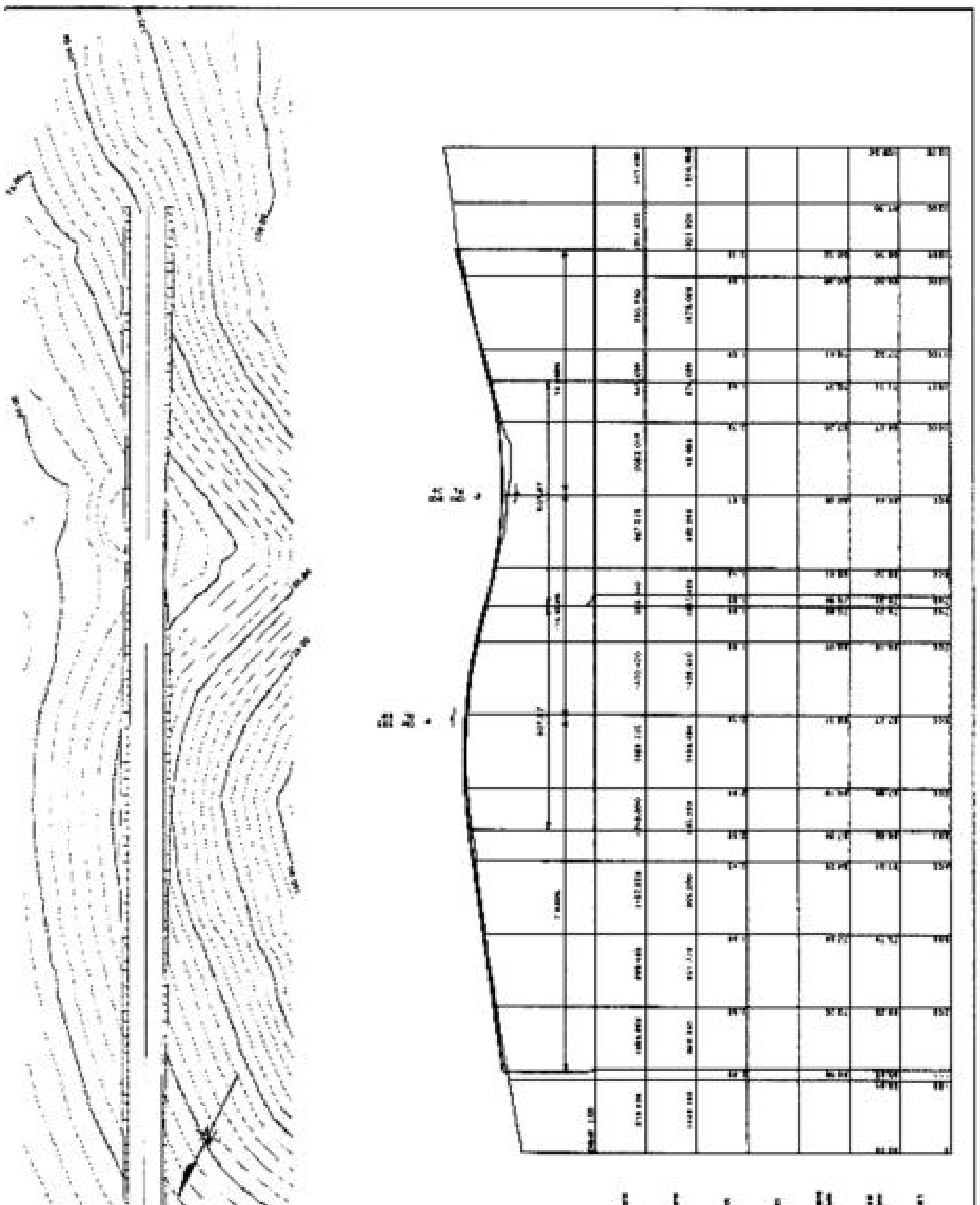


Fig. 2. Plan and profile.

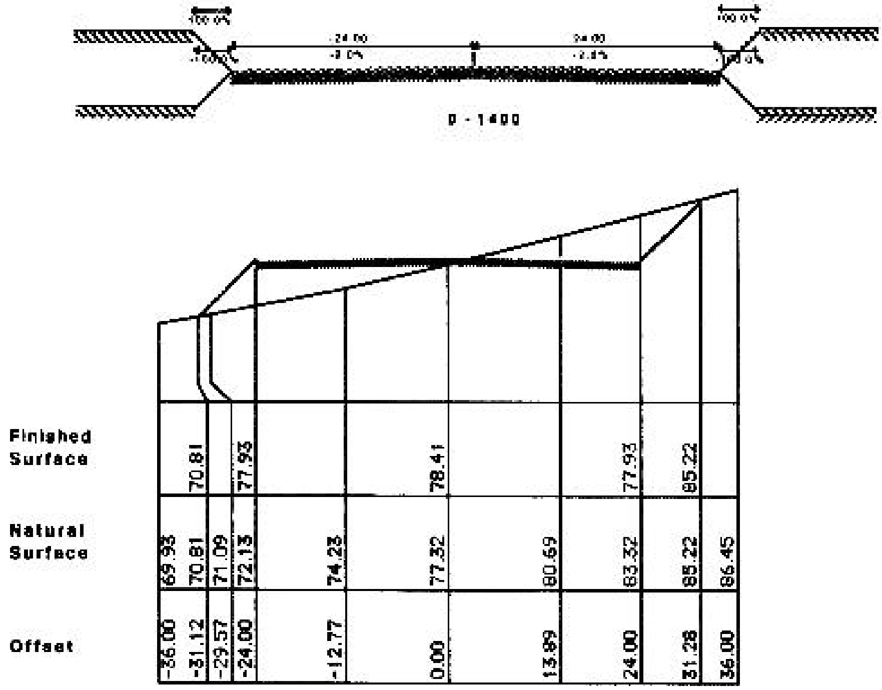
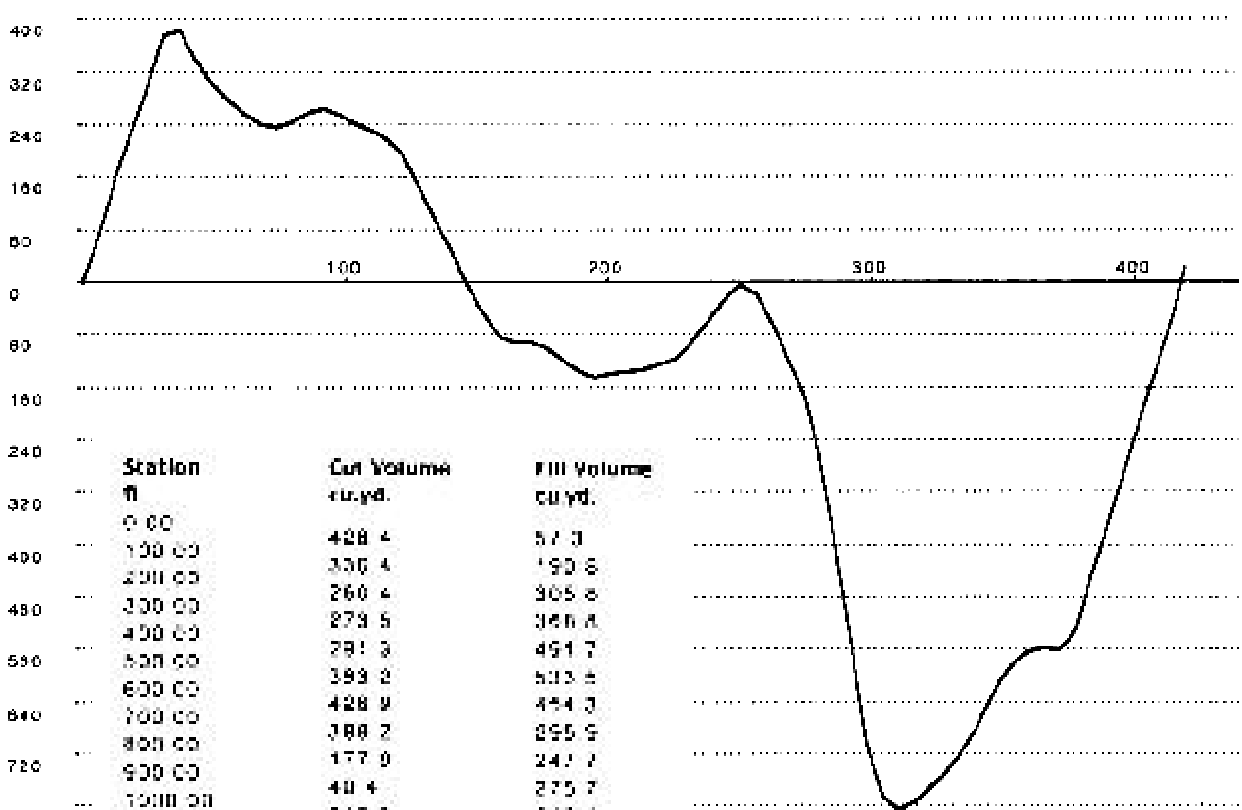


Fig. 3. Typical cross section and section at Station 11.



Station ft	Cut Volume cu.yd.	Fill Volume cu.yd.
0.00		
100.00	428.4	57.0
200.00	330.4	190.6
300.00	260.4	305.6
400.00	273.5	360.8
500.00	281.3	491.7
600.00	393.2	503.4
700.00	428.9	454.0
800.00	388.2	295.9
900.00	177.0	247.7
1000.00	40.4	275.7
1100.00	245.0	249.4
1200.00	415.4	321.8
1300.00	522.4	314.7
1370.00	470.7	153.9
Total	4454.1	4269.4

Fig. 4. Mass diagram and cut/fill quantities.