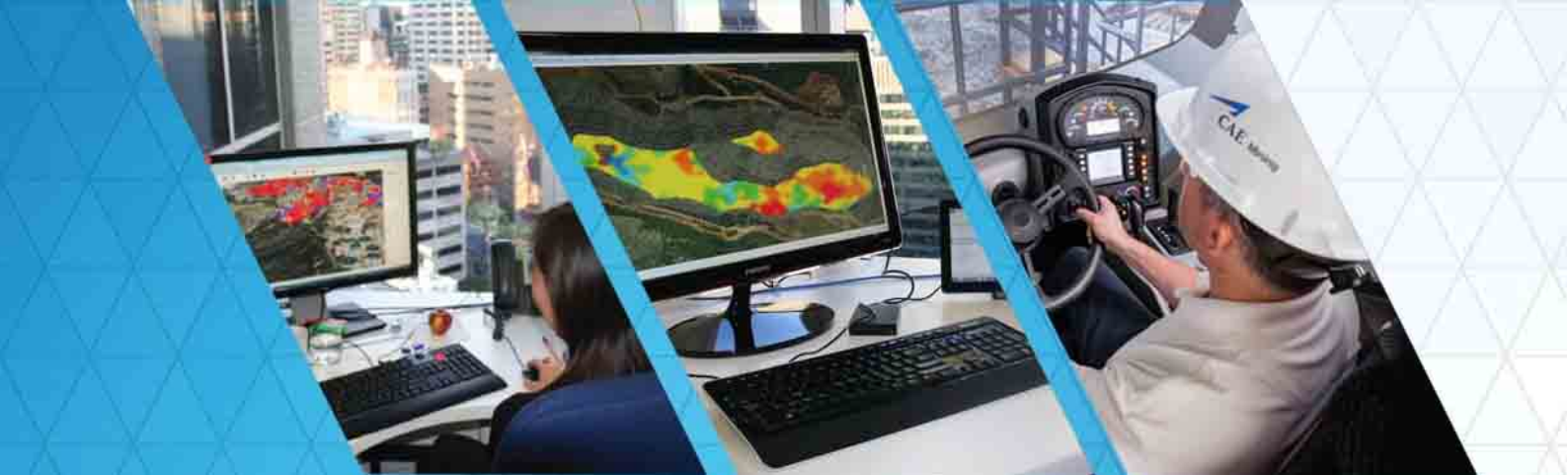


# Studio 3



## Open Pit Design User Guide



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## EXECUTIVE SUMMARY

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There are many approaches to the task of surface mine design, and like other functions within Studio 3, there is no fixed way in which you are forced to complete your design work. Rather, there are many general and specific tools for designing both surface mines, dumps and other types of surface excavations.

Designing an open pit is an iterative process involving consideration of many design criteria, constraints and objectives. There is no single way to design a pit - every engineer does it slightly differently. The objective of this user guide is to show in detail how to use the various design tools in Studio 3 to create a detailed pit design.

# 1 OVERVIEW

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## Purpose of this document

This document introduces Studio 3's open pit design tools and explains not only what they do but in what situation(s) they should be used.

## Prerequisites

You will need to have a basic understanding of Studio 3's Design Window string creation/modification tools. (Studio 3 Introductory Geology Training Manual)

- You understand the concepts underpinning Studio 3 data display, including sheets, overlays and objects. (Studio 3 Introductory Geology Training Manual)
- You understand the basic real-world requirements of open pit mining, with regards to pit design.
- You will have a good understanding of Studio 3's string and wireframe editing commands.

## Acronyms and Abbreviations

The following acronyms are used in this document:

Acronym	Description
OP	Open Pit
DTM	Digital Terrain Model
WF	Wireframe
RL	Reduced Level (Spot Level)

## More information

For more information on Studio 3's open pit design facilities, consult your online Help, and in particular, the Studio 3 Open Pit Tutorial (select **Help | Tutorials | Open Pit Tutorial** from the Studio 3 interface).

## 2 FIRST PRINCIPLES

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**There is no definitive way to design an open pit.**

**Studio 3** provides many tools for designing pits, dumps and other types of surface excavations. This introduction will identify some of these tools and suggest an approach to pit design.

Before you can start a detailed pit design you need to have some idea of the existing surface topography, the extent and nature of the orebody and the economic or ultimate pit limit of the mine.

There are several ways to do this depending on what information you have available and also how you prefer to do your design.

In this section, the basic aspects of open pit mine design are described, to give you some idea of how Studio 3 matches real-world pit design requirements.

### Existing Surface Topography

There are two ways to represent surface topography; with an orebody model or a surface wireframe.

#### Block Model

Because **Studio 3** allows fully variable sub-celling of blocks in a block model the surface topography can be reasonably accurately represented using model cells. As the position of the design screen is moved up and down the model cells are displayed for each elevation. Near the surface the model cells start to disappear indicating areas which are above topography.

An advantage of this method is that the orebody model can be queried and colored according to grade ranges, rock types and other parameters.

#### Wireframe

A surface wireframe or digital terrain model (DTM) can be created using surface contours and/or level points. Not only will this precisely locate the surface topography in any view but can easily be displayed in the **Visualizer** to assist with conceptual designs.

A surface wireframes can be displayed as slices in the design window by turning on wireframe slices.

#### Contours

It is also possible to use actual surface contour strings. However, this is not generally recommended as the surface contours may become confused with the pit design contours.

## Extent and Nature of Orebody

The extent and nature of the orebody is best represented by an orebody block model or wireframe.

### Block Model

There are several techniques that can be used to create models in Studio 3. The ability to constrain the generation of cells within wireframes or perimeters along with sub-celling gives an accurate representation of the orebody. The orebody model can be queried and colored by grade ranges, rock types and other parameters.

### Wireframe

Another way of representing the orebody is by a solid wireframe. This can be generated by linking perimeters representing sectional or plan interpretation. These wireframes can be viewed easily in the **Visualizer** window. Wireframes can also be displayed as slices in the Design Window.

## Economic or Ultimate Pit Limit

The limits of the surface mine can be represented by a block model, wireframe or strings. Typically these limits will have been determined from a financial analysis using techniques such as Lerchs-Grossmann nested pits or floating cone pit optimization.

There may also be other over-riding constraints placed on the design such as limited surface access, drainage problems or lease boundaries. These limits need to be stored within the computer so that they can be viewed during the design. Applications such as CAE Mining's **NPV Scheduler** allow this information to be applied, resulting in an optimal extraction sequence and pushback schedule that will take these limiting factors into account, and also copes with multi-mine situations, stockpiling and large volume material allocation/distribution requirements.

*Contact your CAE Mining Representative for more information on NPV Scheduler*

### Block Model

The most convenient way to view one or many optimum pit shell limits is to assign the cells within a block model with the PIT code from the optimization.

The output from a pit optimization is generally a series of model cells contained within the pit. While these model cells can be loaded directly into the **Design** window it is far more convenient to merge them with the original model thus flagging the model cells inside the pit. The pit cells may also be coded by the *phase* or *pushback* within the pit.

Once the orebody and optimum pit models are combined, the new combined model can be viewed in the **Design** window. Filters can be used to display any pit outline or individual stages showing how the pit expansion will progress.

### Contours

Pit contour strings can be quickly generated around the cells within the optimized pit using the **BLKPER** process.

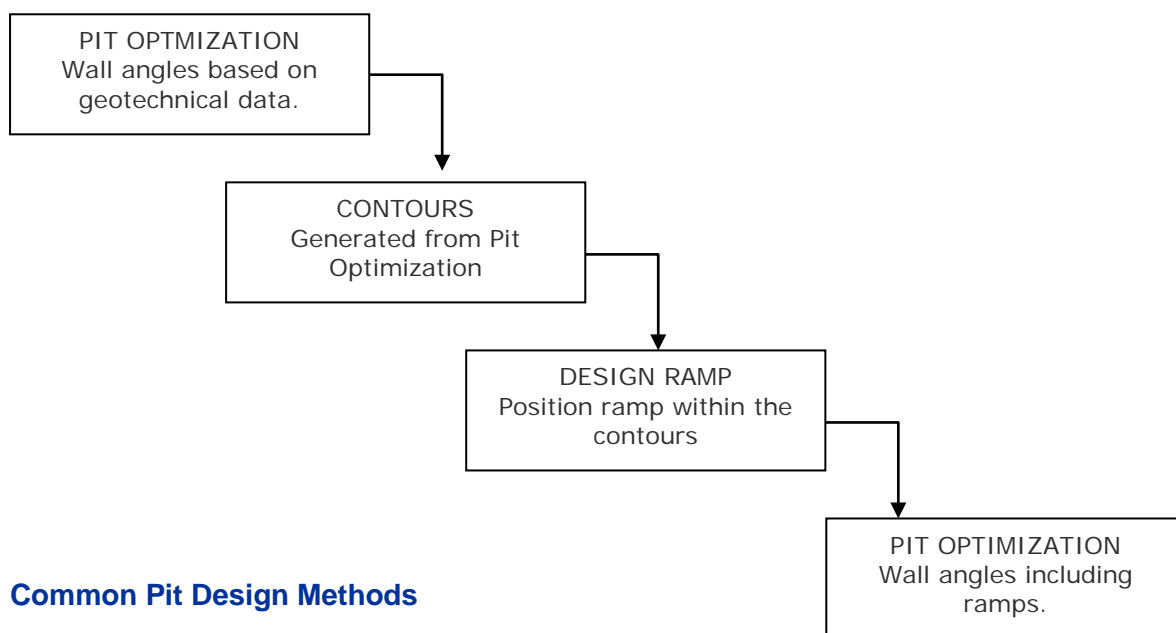
When contouring the model it is necessary to decide whether the mid-bench, top of bench or bench toe is required depending on how the design will be created.

### Estimating Pit Wall Angles

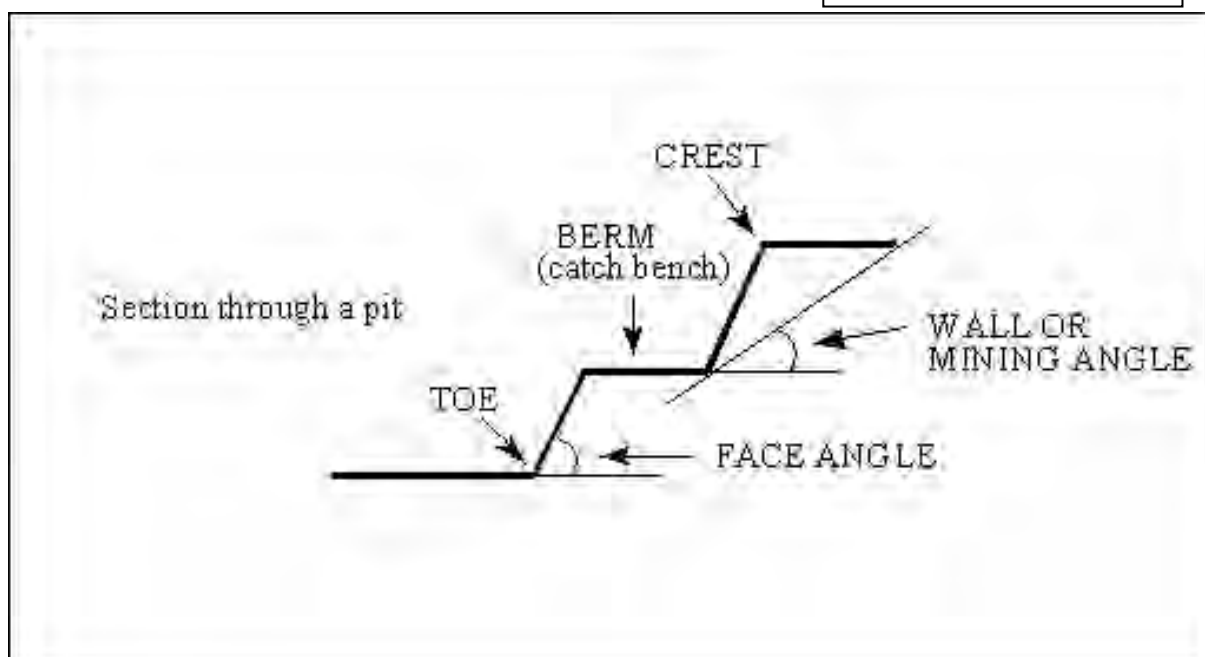
When using optimization methods it is necessary to define the wall angles for the resulting pit. Normally, these angles are influenced by two components; the *geotechnical stability* and the *location of ramps in the pit walls*.

For new deposits, the geotechnical aspect of the wall angles can be estimated based on the *rock types* and *interpreted joint sets and faulting*. When considering ramps however, it is difficult to predict their placement in the pit until after the size of the pit has been determined according to economic conditions.

The following flow chart outlines the steps used to assist in the determination of appropriate wall angles.



### Common Pit Design Methods



There are four basic methods of creating a detailed pit design in Studio 3.

### **Toe + Ramp + Crest Design**

The Toe + Ramp + Crest method involves designing the pit on a bench by bench basis often starting from the lowest bench and working upwards. The toe string is created, the ramp is inserted and finally the crest strings are added. This method builds ramps that include access to the berms and it can be applied working either from the bottom up or the top down.

### **Toe + Ramp Design**

This method involves creating all the toe and ramp strings first and then adding in the crest strings later. This method is quicker than the Toe + Ramp + Crest approach and it yields a continuous ramp with no offsets. You must, however, complete the pit design in the same session of Studio 3 and the pit can only be designed from the bottom upwards.

### **Contour Design**

The third technique involves inserting a ramp and crest strings into an existing set of toe strings. These toe strings are typically created by generating contours around an optimum pit shell block model.












### **Automated Pit Design (QUICKPIT)**

The **QUICKPIT** process is designed to speed up open pit design, and access existing Studio 3 tools in an efficient way. **QUICKPIT** enables an iterative design process whereby the design of a pit can be altered (ramp positions, gradients, berms etc.) to find the best results

### 3 COMMON PIT DESIGN COMMANDS

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Some of the more commonly-used commands specific to open pit design are summarised in the table below although you should note that this does not represent an exhaustive list. All open pit commands can be found in the **Applications | Open Pit** menu from any data window of Studio 3:

Menu Command	Quick Key	Toolbar Icon	Description
<b>Road Segment</b>	rseg		Creates a road (Ramp) segment up or down from a contour string to a defined target RL.
<b>Road Contour</b>	rcon		Builds a contour string by projecting another string a set distance. Connections to adjoining Road Segments will be maintained if this command is used in sequence with the <b>Road Segment</b> command.
<b>Road Berm</b>	rbe		Creates a berm string offset a fixed distance from a toe or crest contour.
<b>Set Face Angle</b>	fng		Set a fixed face angle that is used by the Road Segment, Road Contour and Project String commands.
<b>Set Berm Width</b>	sbw		Set a fixed berm width which is used by the Road Berm command.
<b>New Rosette</b>	nr		Creates a new rosette.
<b>Delete Rosette</b>	dro		Deletes a rosette.
<b>Use Rosettes</b>	tur		Use rosettes to define projection angles instead of the hard coded values.
<b>String to Road</b>	stro		Builds a road outline string from a single road design string.
<b>Road Between Contours</b>	rbc		Builds a single road design string between two contour strings.
<b>Road from Contour</b>	rfc		Builds a single road design string starting from a point on an existing contour string.
<b>Road Line</b>	rli		creates a three-dimensional road edge around a supplied road centreline string, that also honours supplied elevation and gradient parameters.

In the following chapter these commands are explained in the context in which they would normally be used, starting with how mine road strings are generated. They will also be referred to throughout the remainder of the guide. It is advisable to give yourself time to become familiar with these commands before starting on an open pit design.

In Studio 3, the foundation for road design is a string object. Roads can be created using a variety of different methods, including along digitized strings, added in between strings, snapping to contour positions or other known points, and by projecting an existing string (for

example, a toe string) whilst honouring pit face angles. The actual method(s) chosen will depend on the context. For example, in some cases, it may be result from knowing key requirements, and generating roads (ramps) so they satisfy these requirements (for example, between different elevations, at an optimum incline and with a minimum angle according to limiting factors such as haulage capability and required face angles).

**Studio 3** provides a host of string design tools, and these are always available to open pit designers, however, they are not all described in detail in this guide (the best resource for this information would be *Studio 3 Introductory Tutorial*, the *Studio 3 Introductory Geology Training Manual*, or your online Help file); this section focuses on those commands that are explicitly related to open pit design.



Many commonly-used open pit commands can be found on a dedicated toolbar. From the menu choose **Applications | Open Pit | Open Pit Toolbar**; the toolbar will be displayed and you can drag it to a convenient location (or dock it with the other toolbars if you find it easier to use like this).

## Road Design Commands

The following commands are related to the construction of haul road strings and resulting roads in Studio 3:

### Road Segment

**Road Segment** allows you to create a road outline from a string using a specified gradient and width. Please note, **a plan view must be selected** prior to running the **create-road-segment command**.

You can access this command:

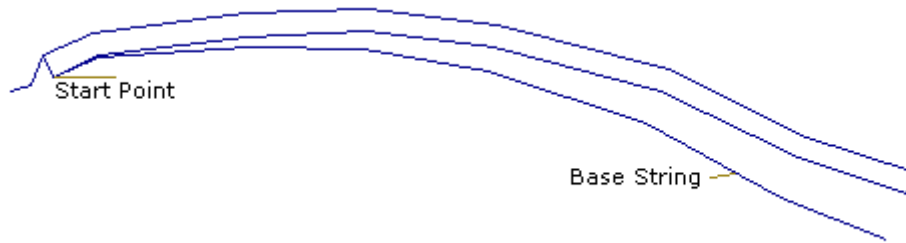
- from the **Open Pit** toolbar,
- the menu system (**Applications | Open Pit | Road Segment**),
- entering the instruction 'create-road-segment' into the Studio 3 command line or;
- by typing the 'rseg' quick key combination.

Initially, you are asked to point with the cursor to the start of the road – all points selected must be on the selected string. If there is no selected string you are asked to select one.

You are then asked to indicate the direction of the road using the cursor. Depending upon the progress of the design you may be asked to indicate the high side of the selected string. Prompts are then given for the elevation at which the road outline must end, the road width, and the road gradient.

Like other, similar, open pit commands, **create-road-segment** uses the *default face angle* (also known as the 'batter' angle) setting to construct a road line. It also makes use of the default berm width. Either of these settings can be changed at any time during mine design.

- The default face angle can be specified by selecting **Applications | Open Pit | Set Face Angle**
- The default berm width can be set by selecting **Applications | Open Pit | Set Berm Width**



Once your default pit design settings have been made (or you're happy to accept the existing defaults), select the Road Segment command. The general procedure to add a new road segment is then as follows:

1. If not already in a plan view, select one (you could type '1' then click inside the **Design** window, select the *Plan* view option and click **OK**. This command must be run in a plan view.
2. A 'base' string, if not selected before running the command, must be selected now. This is the string from which the new road will be projected.
3. Once a base string has been selected, you will be shown the **Road Segment** dialog. This dialog will request three settings:
  - A *gradient %*
  - The *width* of the road to be created
  - The *target elevation* of the road (also known as the 'RL' value - see the note below)
4. You will then be asked to enter the start point of the road, followed by the general direction, resulting in a new ramp being created, complete with entry point.

You may find yourself using this command regularly in open pit design, as it automates the process of generating individual road segments to known elevations.

#### **"Reduced Level"**



This term, and its acronym 'RL', are used to represent the height above specified datum level of a surveyed point or design point such as the target elevation of a road.

Two related commands also exist to make the creation of new road segments easier; **create-road-segment-in** and **create-road-segment-out**.

These commands are not available through the standard Studio 3 menu system, but can be accessed by typing the appropriate command name into the Command line, or by using the 'rsei' (in) or 'rseo' (out) commands.

The major difference between these commands and the standard **Road Segment** command is that you will only need to define the direction of the road, and the three settings outlined above. The 'high' side of the string in question is then determined automatically based on whichever command was selected.

### Road Contour

The **Road Contour** menu option (which runs the Studio 3 **create-road-contour** command) is used to define a new contour string, projected from the original, based on the supplied values for face angle and target elevation. A string will be projected upwards or downwards (selected interactively) at the default face (batter) angle until the target elevation is reached. This new contour string will connect correctly to the end of the previous Road Segment if one has just been created. Remember, the default face angle can be specified by selecting **Applications | Open Pit | Set Face Angle**. This is set to 60 degrees by default.

*As with the Road Segment command (see the previous section), a plan view must be selected before attempting this command.*

To create a new road contour, you will need to access the command. To do this:

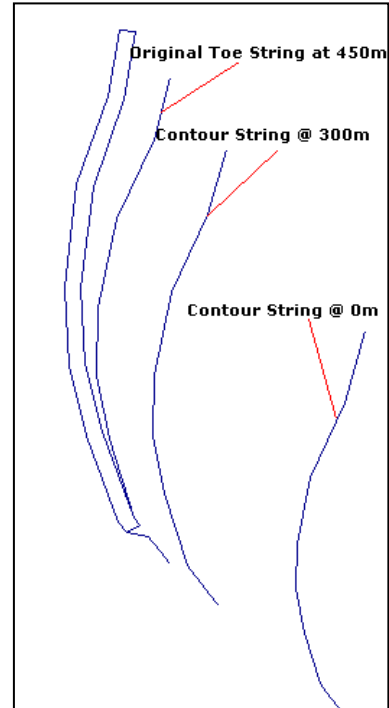
- Select **Applications | Open Pit | Road Contour**
- Type 'create-road-contour' into the Studio 3 command line
- Use the quick key combination 'rcon'.


When running, you will be asked to select a string (unless one was selected before the command was run). You are then shown the **Create Contour** dialog, in which you are asked to enter a target elevation (sometimes referred to as the 'RL' in other Studio 3 dialogs).

Two variations on this command exist: **create-contour-down** and **create-contour-up**. These commands are almost identical to the main command, although projection will always be attempted to high side or low side of the selected string.

### Road Berm

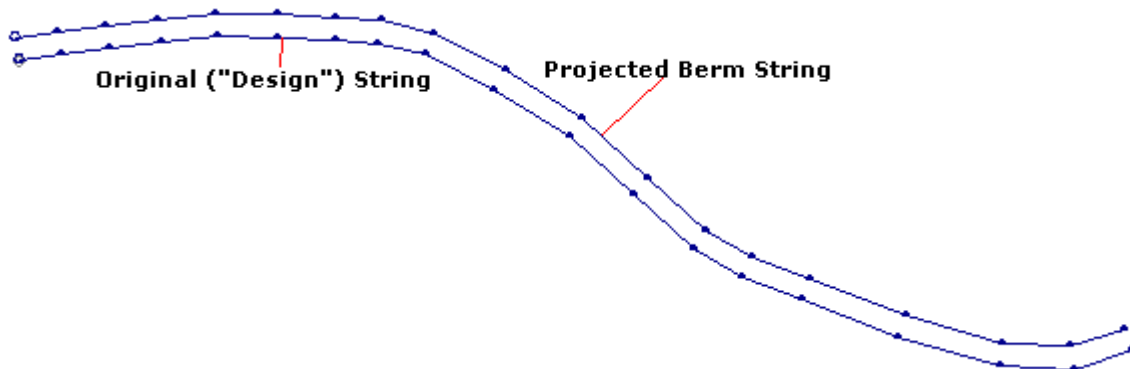
This command projects a string horizontally by the default berm width to create a new string. With this command, a new string is created at the same elevation (Z value) as the selected original which can be any existing string but will usually be a crest or toe string.



 **"Design Strings"**  
Many of Studio 3's open pit tools make use of the concept of a 'design string'. The

term is used to refer to a string object that is used as a basis to construct other lines. These strings can be maintained after use (and, indeed, may form part of the final pit design) or they can be removed as required.

The current berm width is always utilized with this command, and as mentioned previously, you can change this setting (**Applications | Open Pit | Set Berm Width**). Note that when the berm width is changed, any strings created with the previous setting are unaffected – only new projected strings will be created according to the new offset value.



With this command, a new string is created to construct the berm, and these strings are independently controllable if required – once created, there is no other association between the two strings other than any global changes to the display of the object to which they belong (changes to that object's current overlay display format, for example).

### String to Road

You can also design road strings in a more 'manual' way by turning any digitized string into a road. The first step in generating a road along a predefined path is to first digitize the path using a single string. This technique is commonly used when designing a pit using the Contour method.

Once you are satisfied with the design line, you can use the **String to Road** command to generate the road outline around it.

This command is accessed in one of the following ways:

- Select **Applications | Open Pit | Road Layout Tools | String to Road**.
- Enter 'string-to-road' into the Studio 3 command line.
- Use the quick-key combination 'stro'.

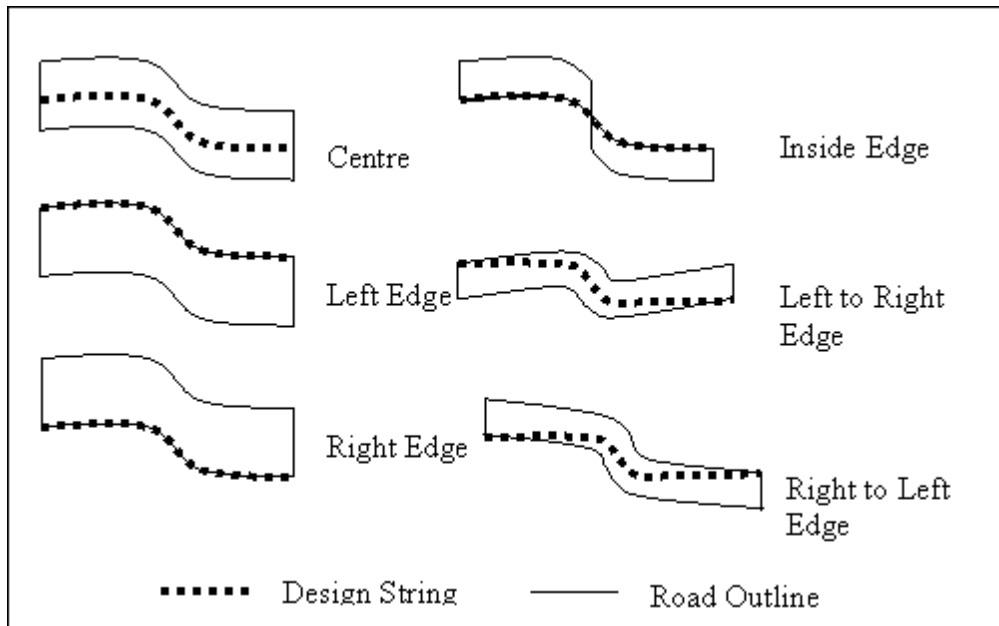
This command is used to generate the road outline around an initial ('design') string. The road width can be varied from one end to the other and the position of the design string in relation to the resulting road can be selected from the following options.

### Inside Edge

Should be used when assigning gradients based on the inside edge of the road. The best results are achieved when the design string segments are kept long.

### Left to Right or Right to Left Edge

This should be used for placing single ramp segments from the toe of one bench to the crest of the bench above, or crest to toe if going down one bench.



The general procedure for generating a road string in this way is as follows:

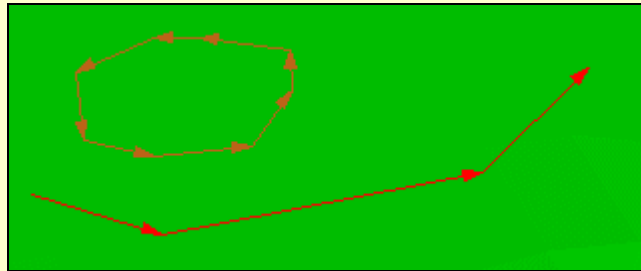
1. On selecting this command you are asked to specify whether the original design string (to be selected) will be kept after road creation, or whether it will be removed. Select **Yes** to delete the string or **No** to keep it. If you are unsure, it is recommended that you maintain the design string.
2. You are asked to specify how the design string is treated using the **String to Road Control** dialog. The options are:
  - **C** - as a Centre line.
  - **L** - as the Left edge of the road.
  - **R** - as the Right edge of the road.
  - **I** - as the Inside edge of the road.
  - **LR** - to run from the Left to the Right of the road.
  - **RL** - to run from the Right to the Left of the road.
3. You are then asked to enter the width of the road at the start and the end using the **Road Width** dialog. Add the width details and click **OK**.
4. The currently selected string is converted to a road of the specified settings.

The terms 'start' and 'end', when referring to a road, are related to the direction of the underlying data. This direction is determined by the order of the vertices in the string data (each point has a number). If you are digitized a road string, the direction will be the order in which the points were digitized, however, if you are importing linear data, to be represented as roads, the order may not be known. One way of determining this direction is to format the display of string(s) to show aligned arrow symbols. To do this:

1. Select **Format | Display**.
2. Select a string overlay from the list, and select the *Symbols* tab.
3. Enable *Fixed* symbols and select the 'Filled Arrow Head' symbol from the drop-down list.
4. Ensure the Point along lines check box is selected.
5. Apply this overlay to the Design window.



The resulting image will show the direction of each closed or open line, e.g.:



In all cases, the **String to Road** command will smooth the outside edge of the road to prevent it from creating unrealistic elongated corners.

The gradient of a string can be varied by snapping points onto other objects on the screen, varying the gradient using the **Smooth Gradient** or **Reset Gradient** commands (**Design | Condition** menu) or by assigning a precise point elevation using the status panel.

If you want the road to follow a terrain use the **Project to Wireframe** (**Design | Project** menu) command to drop the string vertically onto the wireframe surface.

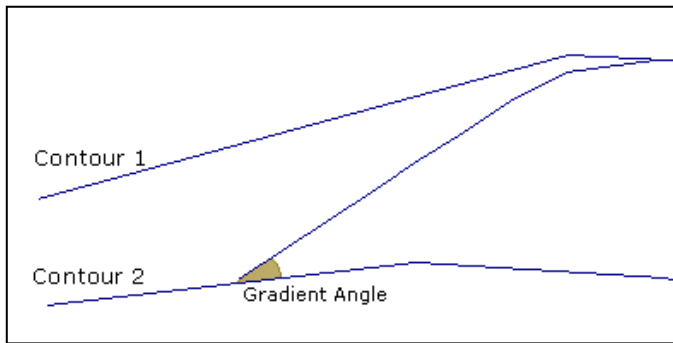
In all cases the **String to Road** command will smooth the outside edge of the road to prevent it from creating unrealistic elongated corners.

### Road Between Contours

Another option exists for open pit designers; to create a road between two topographical contours. In this situation, when the elevation and direction of contours are known, the **Road Between Contours** command is available from the **Applications | Open Pit | Road Layout Tools** sub menu.

Selecting this command initiates Studio 3's **road-design-string-pair** command (the relevance of which will be explained shortly).

To use this command, you will need to know the following information in advance:



- The contours, between which, a new road string is to be generated
- The required gradient of the new road
- The starting position of the road
- The basic direction of the road

You can change the default face angle by selecting **Design | Project | Set Projection Angle** and entering a new setting, in degrees.

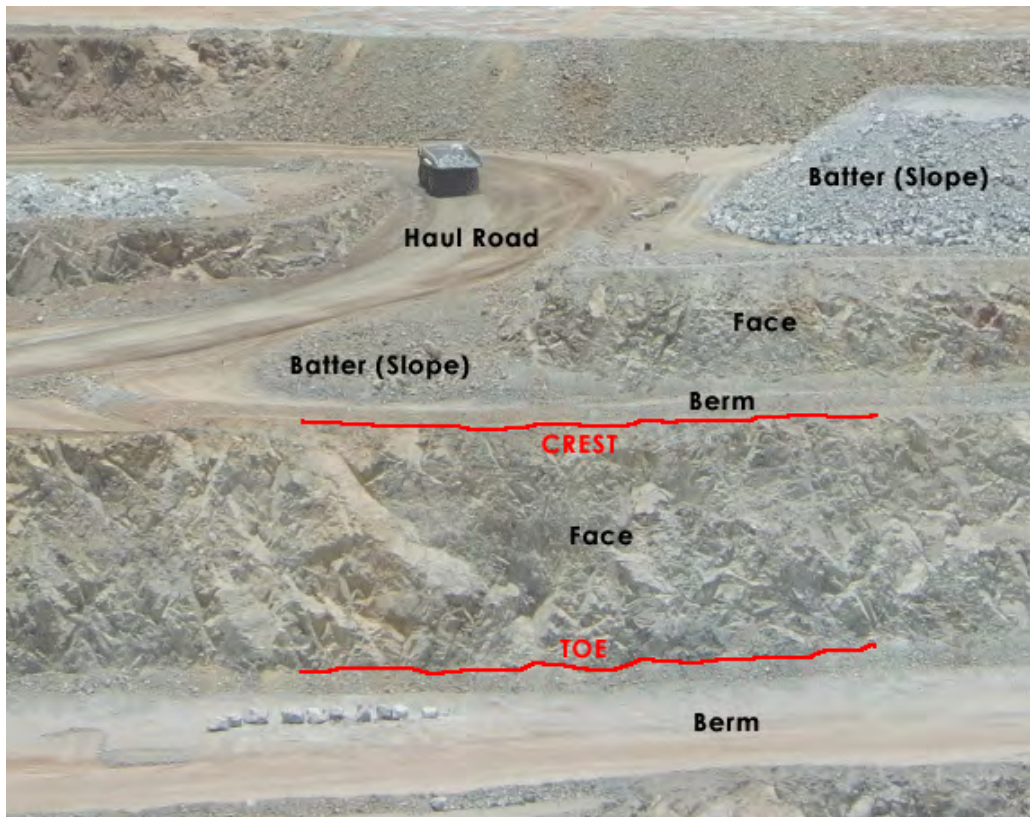
After running the command, the general procedure for creating a string between two contours is as follows:

1. First, you are then asked to select the *start point* of the road.
2. Next, define the second (*target*) string using the mouse. The selection of the second string also defines the *direction* of the road string.
3. A new string is generated. As mentioned above, the face angle generated between the new road design string and the contour perimeters is determined by the default face angle and how the face angle is being controlled.



Successful pit design involves using the right combination of digitizing and manipulation commands. For example, the road string generated by **road-design-string-pair** can be easily converted to a road outline using the **string-to-road** command (as described in the previous section).

## 4 CONTROLLING WALL ANGLES



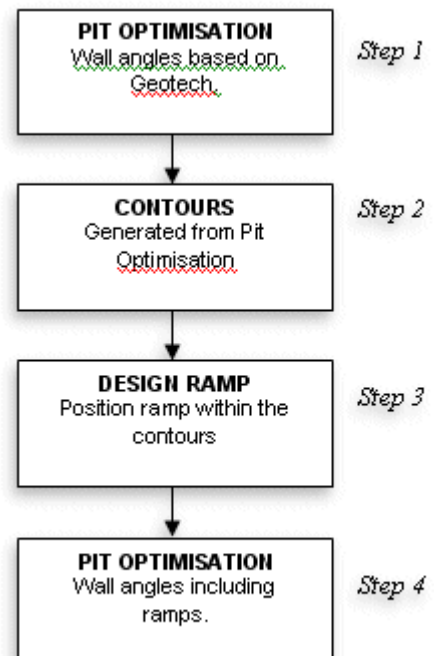
When using optimisation methods you will need to define the wall angles for the resulting pit. Normally these angles are influenced by two components; the *geotechnical stability* and the *location of ramps in the pit walls*.

For new deposits, the geotechnical aspect of the wall angles can be estimated based on the rock types and interpreted joint sets and faulting. When considering ramps however, it is difficult to predict their placement in the pit until after you have determined how big the pit will be.

The flow chart shown on the right outlines the steps you should use to assist in the determination of appropriate wall angles. These steps in more detail:

1. You should first perform a pit optimisation using only the geotechnical wall angles.
2. The resulting pit is then contoured in Studio 3 and the contours saved as strings.
3. The next step is to position the ramps within the contours.

To do this; load the contour strings into Studio 3 and use the **road-between-**



**contours** function found in the **Applications | Open pit | Road Layout Tools** menu. Set the desired ramp gradient and then select the top (or bottom) contour of the optimised pit. Select the next contours in sequence going down (or up) until you have generated a ramp string covering the full depth of the pit. Depending on the geometry of the pit you may also wish to include switchbacks or multiple ramps. With the **road-between-contours** command you can quickly try several different ramping options to determine the best solution. When you have chosen the final ramp record its position in the pit and use that information to update the wall angles put into the optimisation process.

4. Now when you perform the pit optimisation the wall angles will more closely reflect reality.

Once optimum default angles and widths have been deduced, and before starting a pit design, it is necessary to set up some control parameters:

### Wall Angles and Berm (Catch Bench) Widths

There are several ways in which wall angles can be defined around a pit design. The method used will depend on the complexity of the design.

The default angle for all string projections within Studio 3 is 60°. This can be altered using the command **Applications | Open Pit | Set Face Angle**.

For a *Toe-ramp* design this angle should be set to the *toe-to-toe* angle between the design benches. For a *toe-ramp-crest* design this angle is set to the actual face angle. Once set this angle will be applied to all directions within the pit.

The default berm width is 2.5m this can be changed using the command **Applications | Open Pit | Set Berm Width**.

More control over projection angles can be applied within the pit in several ways.

### Controlling Wall Angles with a Block Model

Slope angles may be controlled automatically by rock type, degree of weathering or any other attribute within the block model. This is achieved by creating a numeric *SLOPE* field in the block model and assigning each cell a slope value (in degrees). The easiest way to assign this value is by using the command **EXTRA**.

After loading the model file into the Design window select the command **Applications | Open Pit | Use model file**. When a string is projected, the points of the string that lie within a model cell will have the projection angle stored in the *SLOPE* field assigned to the adjacent segments.

Note that if the wall angles vary greatly from cell to cell and the strings contain many points the resultant projected string will be jagged. This option is best used for changing wall angles with depth, e.g. through near horizontal weathering or oxidation zones.

### Using Rosettes

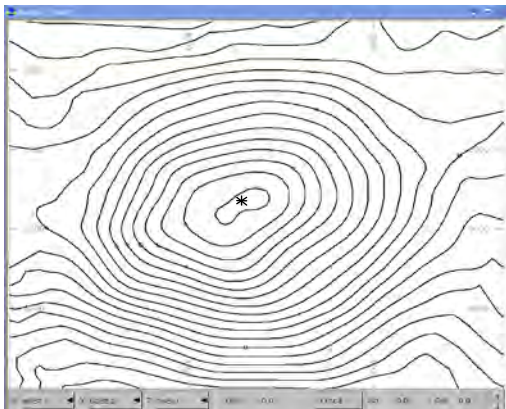
For the greatest degree of control over face angles and berm widths "rosettes" should be used. A rosette is a 3-D point in space which is associated with user defined face angles and berm widths. Each rosette controls the parameters for a specified minimum and

maximum elevation range. Outside the range of influence of the rosette the global settings take effect.

When creating a rosette it is necessary to define the minimum and maximum elevations of influence. A series of azimuths with associated projection angles and berm widths must then be entered. String segments which face this azimuth will use these settings.

Segments which lie between two defined azimuths will have their projection settings interpreted. For example, if an angle  $50^\circ$  at azimuth  $30^\circ$  and an angle of  $60^\circ$  at azimuth  $120^\circ$  are defined then wall segments at azimuth  $90^\circ$  will use an angle of  $55^\circ$ . If only one azimuth is specified then the associated parameters will be applied to all azimuths.

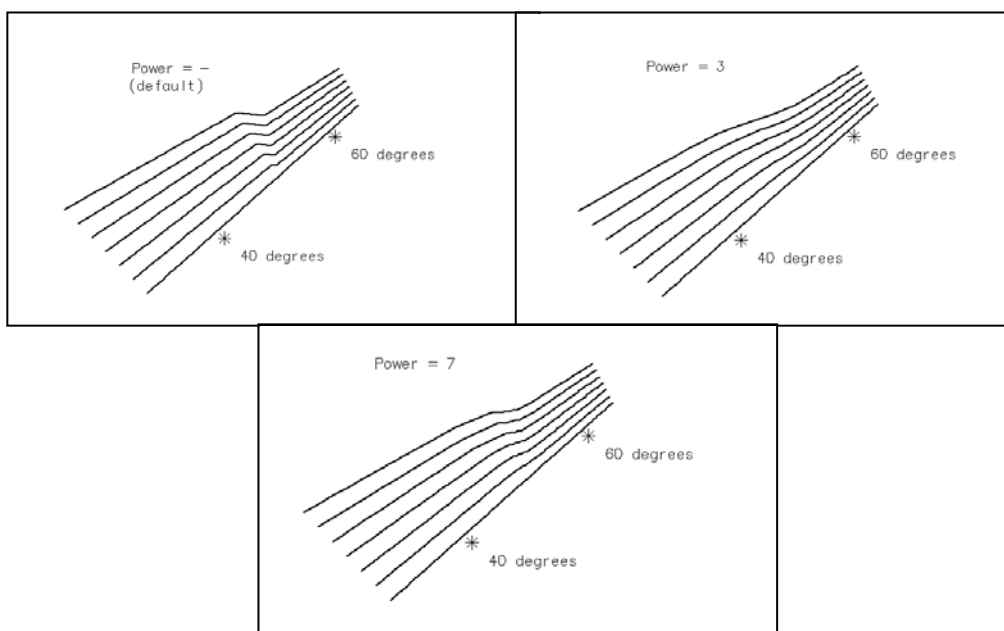
For most cases the location of the rosette will not be important. For convenience, place it near the centre of the proposed design.



If two or more rosettes are used for the same vertical interval where they are placed becomes important.

Multiple rosettes are useful when it is necessary to be able to control local conditions within the pit. For example, if one section of a long wall has a weaker dyke material passing through it, or different jointing sets, then it may have to be shallower than the adjacent section of wall even though they are both projected in the same direction.

To set angles locally place a rosette near the section of wall that is to be controlled. When the string is projected the projection angles for each segment will be interpolated from the nearest rosette. The influence of each rosette is controlled by setting the **Applications | Open Pit | Set rosette power**. The values vary from 1 to 9. Lower values give smoother transitions while higher values give more abrupt changes.



*The Impact of Changing a Rosette's Power*

The previous image captures the effects of altering the rosette power. They show face contours after projection using the two rosettes represented by asterisks. The rosette on the left uses a face angle of 40°, the rosette on the right uses a face angle of 60°.

All rosettes created are written to a file and therefore it is only necessary to define the design parameters once. In order to use a saved rosette, simply open the file.

There are several functions under the **Applications | Open Pit** menu that allow you to query, delete and use rosettes.

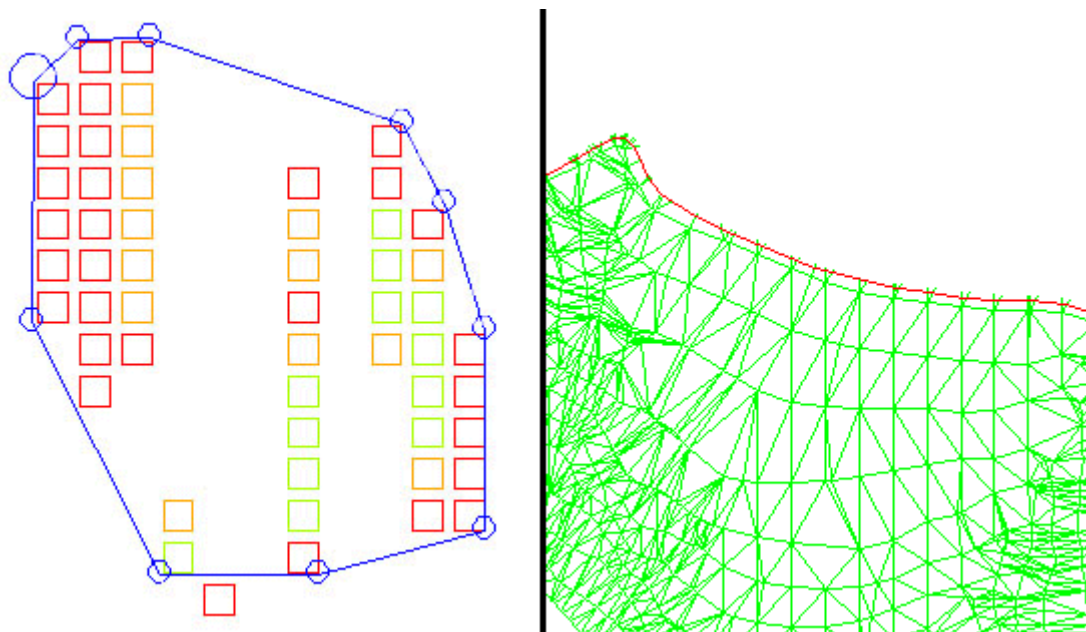
## 5 DETAILED PIT DESIGN

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Once you have determined the final limits of your pit you can start to create a detailed pit design with toes, crests and ramps.

### Using a Block Model or Orebody Wireframe as a Guide

A wireframe of the optimum pit or a view of the geological block model will, most likely, be used as a guide when editing contours created by the open pit design tools.



Using the various data clipping and viewplane controls in Studio 3, you can view a slice of an optimum pit wireframe (such as that output by an external scheduling package such as NPV Scheduler, for example) or a model, at a particular bench, and use this view as a guide for designing pit contours. As Studio 3 allows individual object data to be represented by individual overlays, it is a simple process to set up the most practical data view, minimizing the impact of designing a 3D construct on a 2D screen.

Full details of how to load/import data objects into your project are given in the Studio 3 online Help and the Introductory Geology Training Manual. These sources also provide information on how to adjust overlay settings, and viewplane positions so as to control how a section of each object can be viewed. A summary of this information is shown below:

1. Ensure your project contains all relevant 'guide' objects that are relevant to your open pit design, e.g. a wireframe orebody, or block model. These items must be loaded into memory if they are to be drawn in the **Design** window.
2. It is recommended that initial pit design is performed using a plan view; press '1' on the keyboard and click anywhere in the Design window. Select the *Plan* option and click **OK**.
3. Select **View | Zoom | Zoom All Data**. Unless you have previously set the loaded objects to be viewed in another fashion, or have specified clipping limits previously, all data should be viewable, regardless of its position in relation to the viewplane.

4. Enable data clipping by first **View | Use Primary Clipping**. Clipping is an essential tool for pit designers as it can be used to restrict the display of data without removing it from memory.
5. For the next step, you will need to know some details about your overall pit geometry. For example, if you wish to view only data that is within a certain distance of the pit base, allowing you to draw a pit base line in a 'bottom-up' design, you will need to know the at which Z plane to draw this line, before creating benches upwards. Alternatively, if you are producing a design from the top downwards, a view of the topographical contour strings or wireframe would be useful in order to design the most applicable upper crest string. Once this location data is known, you can then set your viewplane (**View | Viewplane | Custom...**) and clipping limits (**View | Set Clipping Limits**) accordingly.
6. With your view of the supporting objects set up, you can now design reference strings as required for your design.

### Bottom-up or Top-down?

You have the choice of designing from *bottom up* or *top down*. The choice depends on your constraints:

- If you are designing a pit near existing infrastructure then you may need to ensure that the ramp exits the pit at a precise location. In this case a *top down* design is best. The drawback of this method is that as you go deeper in the pit you will be more limited in how the ramp is located.
- If the ramp exit position is not a major concern then you should do a *bottom up* design. In this way you can optimise the positioning of your ramps to get the best ore extraction and lowest stripping ratio.

The techniques and tools used in either case are identical. This manual will be generic in its description of procedures, however, some screen shots may display the results of a particular approach.

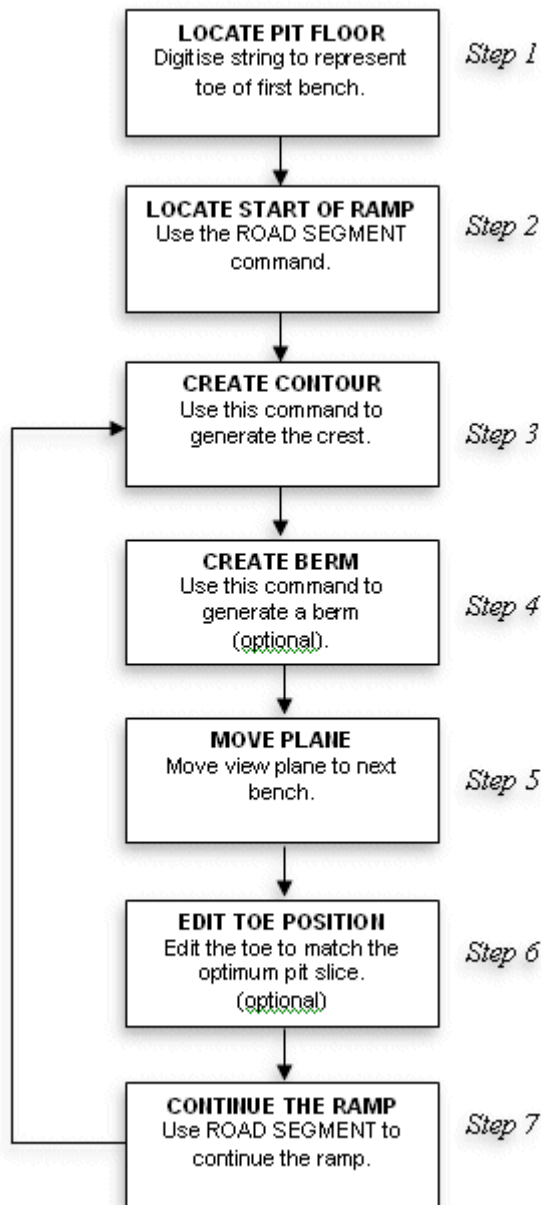
Using a combination of the available open pit design tools (as described in Chapter 3), you will have to determine which overall *method* of pit design you are going to adopt. The various pit design methods (*Toe+Ramp+Crest*, *Contour* etc. – see Chapter 2) are each suitable for a variety of scenarios, and in the following chapters these techniques are explained in more detail. It is likely that a single pit design may rely on more than one approach, so it may be necessary to use the *Toe+Ramp+Crest* design for certain areas of the pit, and adopt a contour design for other benches.

This choice will depend on the real-world constraints that are associated with the design in question, including technological limitations (equipment turning radius, maximum inclines, minimum berm width etc.) or topographical limitations. The following sections outline, in principle, how each method should be tackled.

# 6 THE TOE + RAMP + CREST METHOD

## Method Introduction

In a Toe+Ramp+Crest design, presuming that a 'bottom-up' approach is being adopted, the first task is to define the pit base as a single closed string. This string will form the 'core' from which all benches at higher elevations will be devised.



Once a pit base has been created, the first ramp, contour and berm can be digitized, using the available open pit tools.

After the creation of each new bench, the view plane is lifted up to commence design of the next bench. For this reason, when specifying clipping limits for use during open pit design, it is often useful to set the front and back clipping limits so that they encompass the current bench, and the previous one. You may also wish to set them so that a total of 3 benches can be viewed, providing reference lines for the previous and next bench.

Your choice of view is completely up to you, and will most likely depend on the complexity and structure of the pit in question. The recommended approach, however, is to display *only* the data you *need* to see to create an effective mine design, and organize your data so that overlays can be enabled and disabled to show different aspects of your design and construction objects (you may, for example, filter your block model so that only values above a predetermined cutoff grade are in view).

When designing a bottom-up pit, pit structures are created in the order of *toe-ramp-crest-berm-toe* until all benches are as required.

Throughout the design process, more complicated editing can be performed, either using the proprietary string editing tools (to move strings, move points, condition strings

etc.) or more dedicated open pit commands such as the Ramp Segment command to create a switchback, for example.

This section gives a generalized overview of the process of creating an open pit design with the Toe + Ramp + Crest method. For a tutorial, based on the Studio 3 Demonstration Data Set, select **Help | Tutorials | Open Pit Tutorial** from your Studio 3 menu.

## Toe + Ramp + Crest General Procedure

The following procedure outlines the stages that are commonly worked through in order to create a Toe + Ramp + Crest design. These instructions are generic, and relate to a recommended usage of open pit tools. You can achieve similar effects using other design tools but the process is likely to be more time-consuming than that shown:

### The Base String and First Bench

1. Set the default face angle (**Applications | Open Pit | Set Face Angle**) and berm width (**Applications | Open Pit | Set Berm Width**) for your new design. The default settings are 60 degrees and 4.5 meters. You can change this setting at any time during pit design without affecting any previously created pit strings.
2. Load all supporting files, e.g. any relevant block model, orebody wireframe and/or topography data to make your design work easier.
3. Navigate to an appropriate plan view, and apply clipping limits to your data so that you can see only the data that is relevant for the initial string. Assuming a bottom-up design, this would be the pit base string. The **Move Plane** commands (**View | Move Plane Backwards** or **Forwards**) are useful when in a plan view as they will allow the current viewplane to be positioned accurately whilst maintain the current clipping limits (**View | Set Clipping Limits**).



Clipping limits will not be applied to the **Design** window view until clipping is applied. To enable (or disable) clipping, select **View | Primary clipping**.

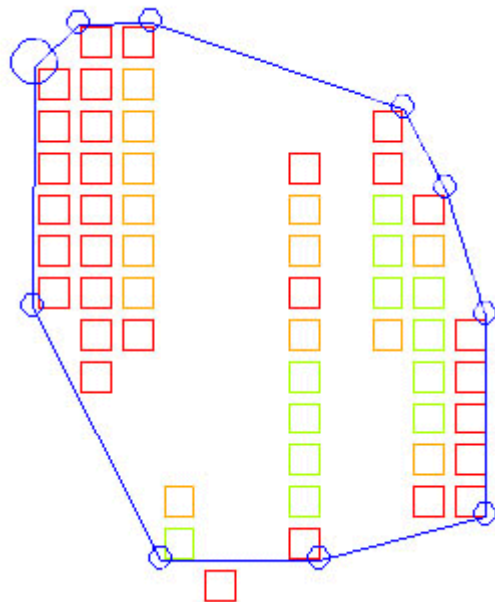
4. Digitize the initial string, using a view of the relevant data objects (e.g. block model section). At this stage, it is a good idea to save this string to a Datamine file for future reference (**Data | Save | All Strings**).

Note that this string must be closed (you can quickly close a new string by snapping the final digitized point – with a right-click – to the position of the first point).

5. Create the first road segment. Select the **create-road-segment** command (either from the open pit design toolbar or **Applications | Open Pit | Road Segment**).

You may, at this step, be requested to point to the 'high side of the string'. If this prompt is shown, click on the outside of the outline string (the side where strings of higher elevation will be created).

6. Edit the new road string as required, using the standard string editing tools but you should take care not to erase the point at which the road string meets the initial (toe) string.

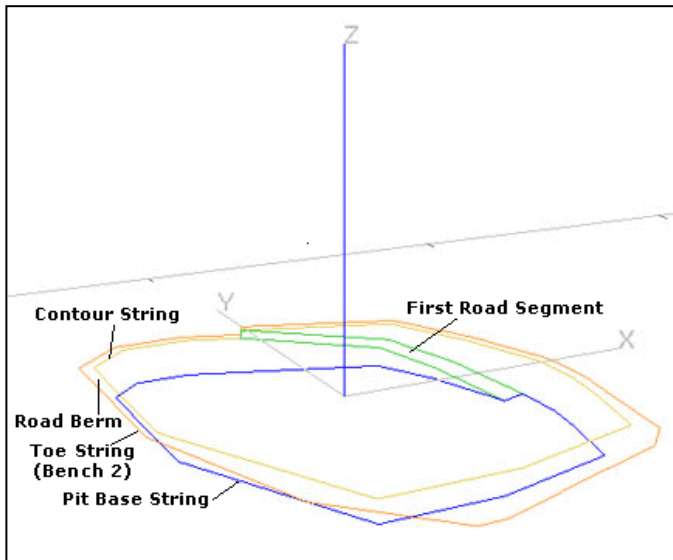


7. You will need to enter a road gradient percentage, a road width and a target elevation (also known as 'RL').

Normally this is the toe elevation of the next bench in which you want to insert a berm (catch bench). If you forget to enter a new value here no ramp will be created. Also, do not enter an elevation that causes the ramp to wrap around the full pit more than once.

8. Create the crest and toe strings using the **create-road-contour** command (select **Applications | Open Pit | Road Contour**). You will need to specify the bench elevation (this is the height of the first 'step' running around and above the pit base).
9. Once a contour string has been defined, you can now add your road berm with the **create-road-berm** command (**Applications | Open Pit | Road Berm**). You will need to click to the outside of the contour string (the 'crest') defined in step 7.
10. The string created by this command becomes the toe string for the next bench.

At this stage, you have created the basic components for your pit floor, rising to the first bench position. You can edit any of the lines using the available digitizing and modification tools (move points, insert points, smooth strings etc.) before continuing, or



return at a later stage to make the necessary amendments. In reality, it is likely that you will do both but please remember not to delete any of the points where the road segments meet the toe or crest strings.

The **Visualizer** window view, shown on the left, is often a useful way of checking your design's progress, and can make it easier to spot areas that may need attention.

You can also enable a view of your block model or orebody in the **Visualizer** to put your design in

true geological context (in the Visualizer, select **Format | Visualizer Settings**).

## The Second Bench

Once you have created the initial pit strings, you can start to design the next bench:

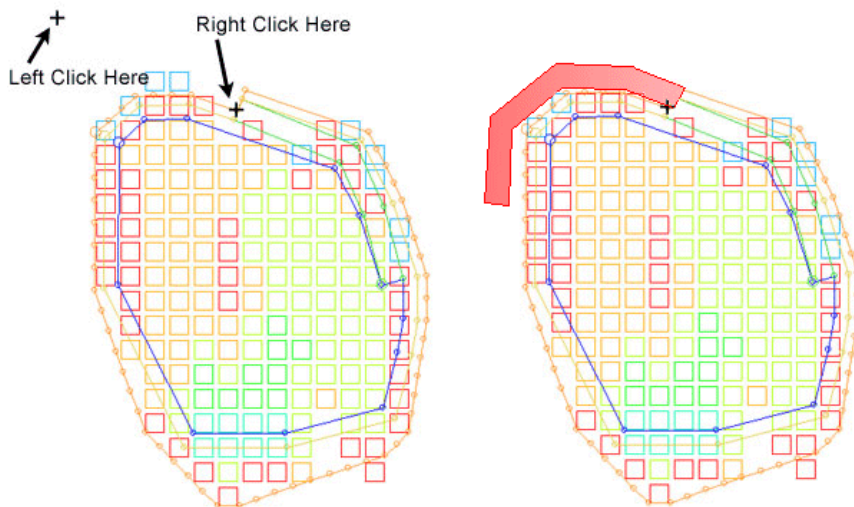
When creating subsequent benches, it is important to click in the correct location when creating new road segments, switchbacks and contours. This is to ensure that the integrity of your haul route design is maintained. The following procedure outlines the general method for your bench design above the pit floor:

1. With the initial pit design work in a plan view, in the Design window, select the **create-road-segment** command. Specify a road gradient (the 'steepness' of the road to the crest of the next bench), a road width and a target elevation (if designing from the base upwards, this will be a higher elevation than that specified for the

previous bench). The new road segment will be projected at the specified gradient until it reaches the target elevation.

If you wish, you may locate the next ramp segment at a different location from the last segment. To do this; locate the new ramp start point on the existing toe string. As this will be the start of a new ramp you may need to edit the toe string after the ramp is generated to smooth out the string offset at the starting position.

To place the new road, you should snap (right-click) to the inner corner point of the current bench's toe string, where the previous road segment ends. Then, you will need to specify which direction around the pit the road will be constructed (this time with a left-click). For example, the image below shows a section through a simple geological block model at the 20m elevation.



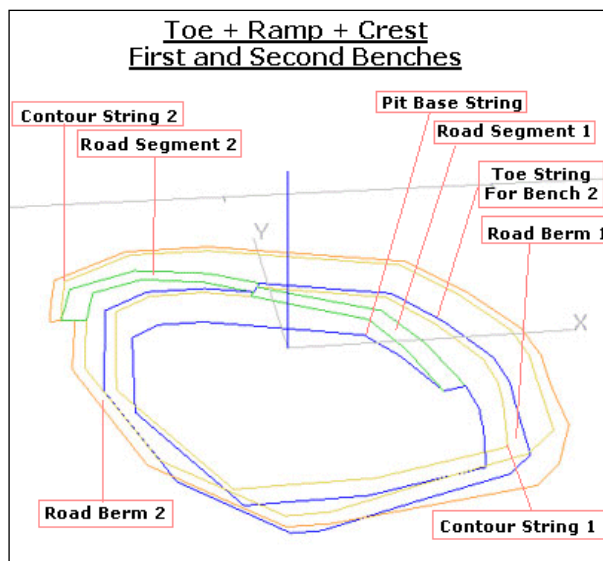
If you want the ramp to align with the previous segment you must position your cursor on the end of the existing ramp and “snap” to the *inside* corner to locate your new ramp start point. Make sure that the ramp direction is given as the same as the previous segment otherwise the new section will not create a proper turn. If you want to have a switchback for the next ramp segment the starting position you select should be the *outside* corner of the last ramp. The ramp direction is then the opposite of the last segment.

A pit base string has been designed, and a ramp projected to the 20m elevation at 20 degrees. A contour string and road berm have also been applied at this level. The requirement is for the new road segment to be placed in an anticlockwise direction.

2. Next, stipulate the position of the next road contour, by specifying an elevation for the new string.
3. Specify a new road berm. This will create the toe string for the third bench.
4. Edit the new string(s) as required.

You now have a pit base, with a road rising to the first bench, and geometry for the second bench including a continued haul route. Note how the angles of the pit are derived from the default setting (**Applications | Open Pit | Set Face Angle**). As before, the **Visualizer** window is useful for visualizing the progress of your pit.

You can now continue the design of your pit using the procedure above to introduce all subsequent benches, creating the necessary features as you go (creating a switchback for example, as described in Chapter 10).



## Completing Your Design

Make sure that you move your screen position to the new bench so that you can see where the topography is located. Keep projecting benches until you have gone completely above the existing topography.

You can modify your design strings later to remove any portions above the topography. If your ramp has already reached the surface then you need only create the remaining toe and crest strings.

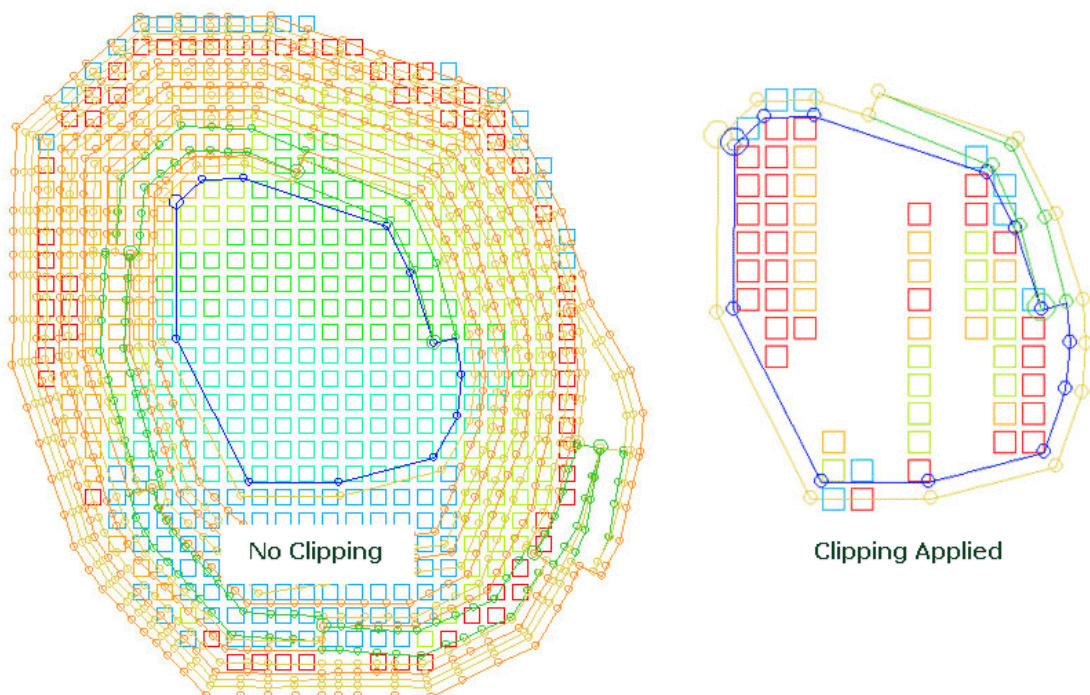
As you progress through your design you should save your strings to new files often. This will let you more easily re-trace your steps, should you wish to undo some of your

design, and also will protect you from losing data should the computer fail for some reason.

## The Importance of Clipping Data

It is recommended that you update your viewplane settings as you progress, in order to keep the important data in view.

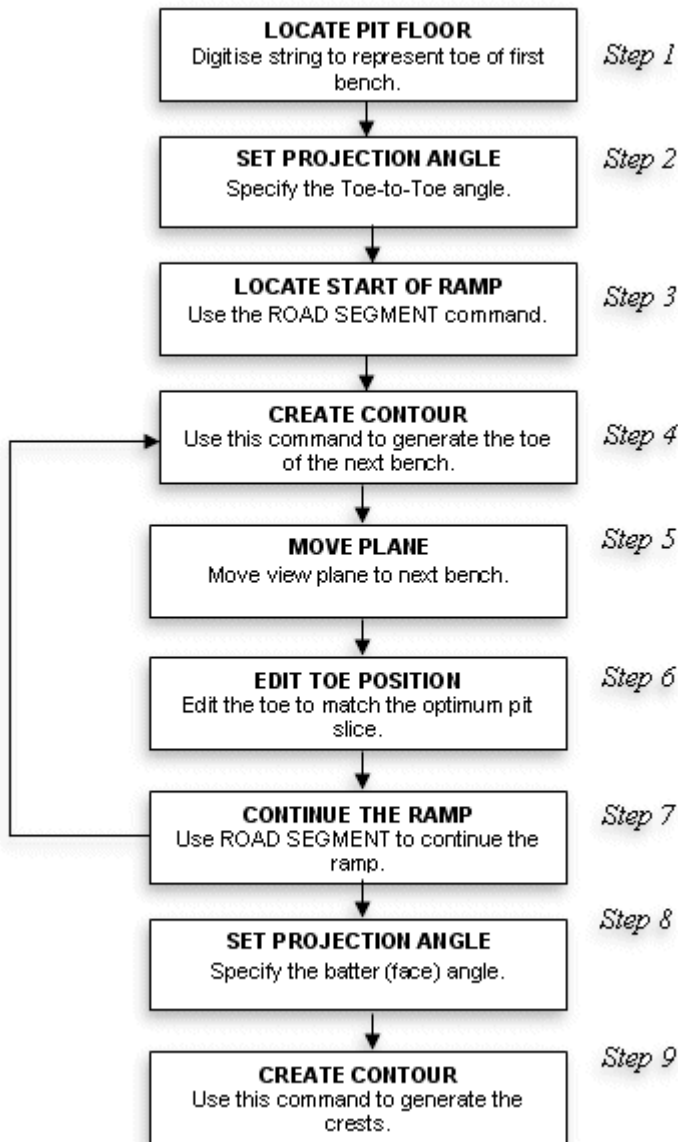
Selecting individual strings for manipulation in the left-hand view would be more problematic than in a clipped view.



# 7 THE TOE + RAMP METHOD

## Method Introduction

An alternative method for creating a pit design in Studio 3 is to use only the ramp and toe strings, inserting the crests later. The advantage of this method is that it is quicker and requires less work to modify because you are dealing with fewer strings. It also creates ramp segments which are not offset on each bench. The disadvantage is that it is only a practical method for a bottom-up design.



The essential difference between this and the Toe + Crest + Ramp design is that the string projection angle is set to the toe-to-toe angle instead of the face angle.

The flow chart shown on the left outlines the steps involved for a Toe + Ramp design.

Steps 1 to 7 are essentially the same as for the 'Toe + Crest + Ramp' method, explained in the previous chapter. These identical steps are not duplicated in this chapter.

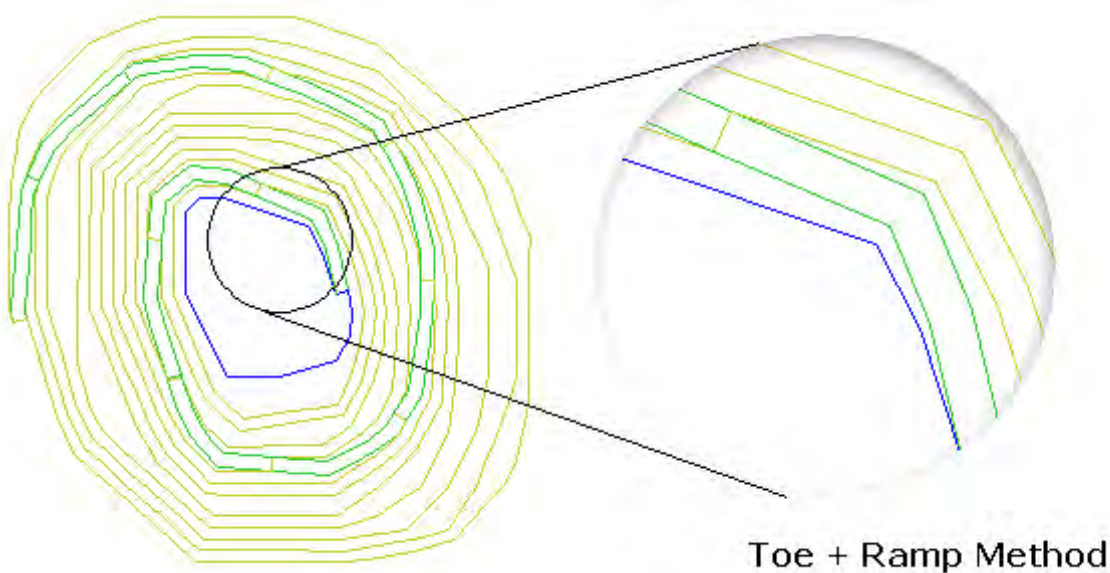
The additional step of specifying a toe-to-toe angle is typical with this method and when you contour the next bench that contour becomes the *toe* instead of the *crest*. Note that you do *not* create a berm with this method.

Once an initial pit base has been designed, the series of benches are defined using the contour/edit toe/road segment /contour process until the desired pit height is reached (remember, this is a bottom-up method). Once this has been done, the face angle is defined, and the contour (crest) strings for each bench are then created individually, using the **create-road-contour** command, as shown in the following procedure:

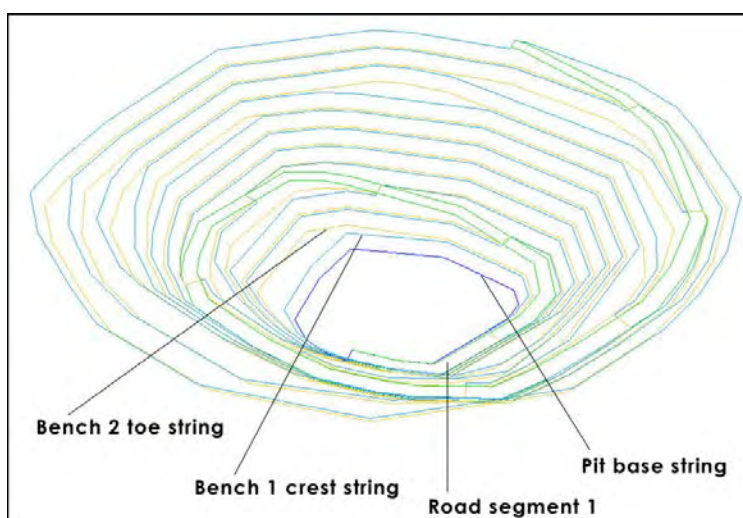
## Toe + Ramp Method General Procedure

1. Complete the pit base and first bench as shown in the previous chapter (see "The Base String and First Bench"). Stop this procedure just before creating the road berm, as this is not required for this method.

2. With the first road string and contour in place, continue to create the second bench. As in the previous step, create the contour, move the viewplane, edit the toe position as required to match the optimal pit shape and then continue the ramp. When you contour this bench, the contour string becomes the toe of the next bench instead of the crest. Without a berm, pit walls are defined without crests until the final stages.
3. When the desired magnitude of pit has been achieved, you will need to decide on a suitable face angle (one which will give the desired face profile). Before creating the crests for this design, set the default face angle by selecting **Applications | Open Pit | Set Face Angle**.
4. Now select the first toe string (*not* the pit base, but the toe string of the second bench) in the pit design then select the **create-road-contour** command (**Applications | Open Pit | Road Contour**). Studio 3 will remember which bench that string was contoured to and you need only press the <Enter> key. A crest string will then be projected up to the next bench. This crest will also merge in with the ramp.



The remainder of the Toe + Ramp design is then completed by selecting successively higher toe strings, and creating a new crest string at the next bench elevation. This will automatically create the necessary berms at each bench level.

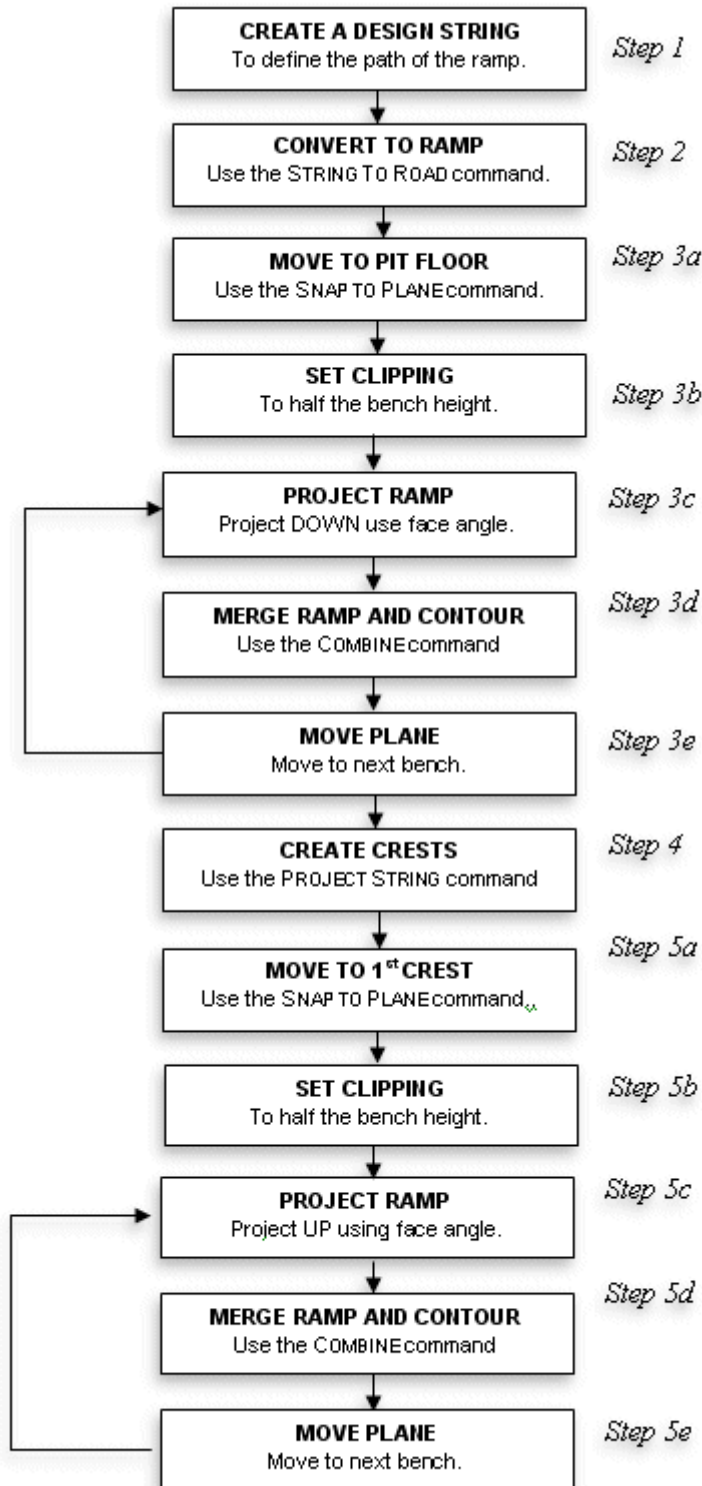


Using this method, it is important to remember that the crest strings are created by projecting the individual toe strings based on the face angle, not the wall angle.

You may also find it easier to distinguish between toe strings and the newly created crest strings if you change the default color for the crest strings (from the menu bar choose **Applications | Open Pit | Set Colours | Contour**).

## 8 THE CONTOUR METHOD

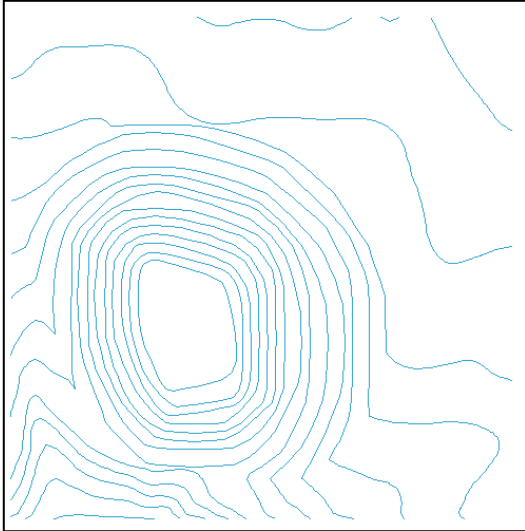
The third main technique for doing a detailed pit design in Studio 3 involves inserting a ramp into an existing set of optimum pit contour strings. While the techniques used here are similar to those in the previous methods, different tools are used.



The flowchart on the right shows the general process undertaken to create an open pit design using the contour method. At first glance, it may appear overly complicated when compared to, say, a Toe + Ramp design, but in reality the work involved is very similar. This method is, as the name suggests, ideal for creating a pit design within a set of known pit contours, allowing you to fit the necessary ramps and crests into the existing design model.

To begin your contour pit design, your pit contour strings must represent the toes of each bench. If they are currently mid-bench contours you can create the toe contours by:

1. Setting the string projection angle to the batter (face) angle. This is done by selecting **Design | Project | Set Projection Angle**. This runs the **Projection Face Angle** dialog. Enter the same value as you would set for a default face angle.
2. Then, using the **Project String** command in the same sub-menu, project each contour string down to the bench floor. Erase the original contours and save the new ones to a new file.
3. Your pit design now includes pit contour strings representing the toes of each bench.



The first step in the contour design is to load the actual contours into the **Design** window. These strings represent the base upon which you will be designing a practical design.

These contour strings are typically created by generating contours around an optimum pit shell block model. This operation is performed as a separate task and supplied for finalizing the design using the contour method.

To create a set of contours yourself, simply load the relevant geological model, and, using the viewplane adjustment techniques explained with the Toe + Ramp + Crest method, generate a set of strings either from the top-down, or bottom-up. You should then save these strings as a separate

file (why? Because the base contours can then be reused for alternative design work at a later stage).

### Contour Method General Procedures

Once contour strings have been loaded / imported, the following procedures can be followed to insert the necessary items to complete the design:

#### Road String Design Between Contours

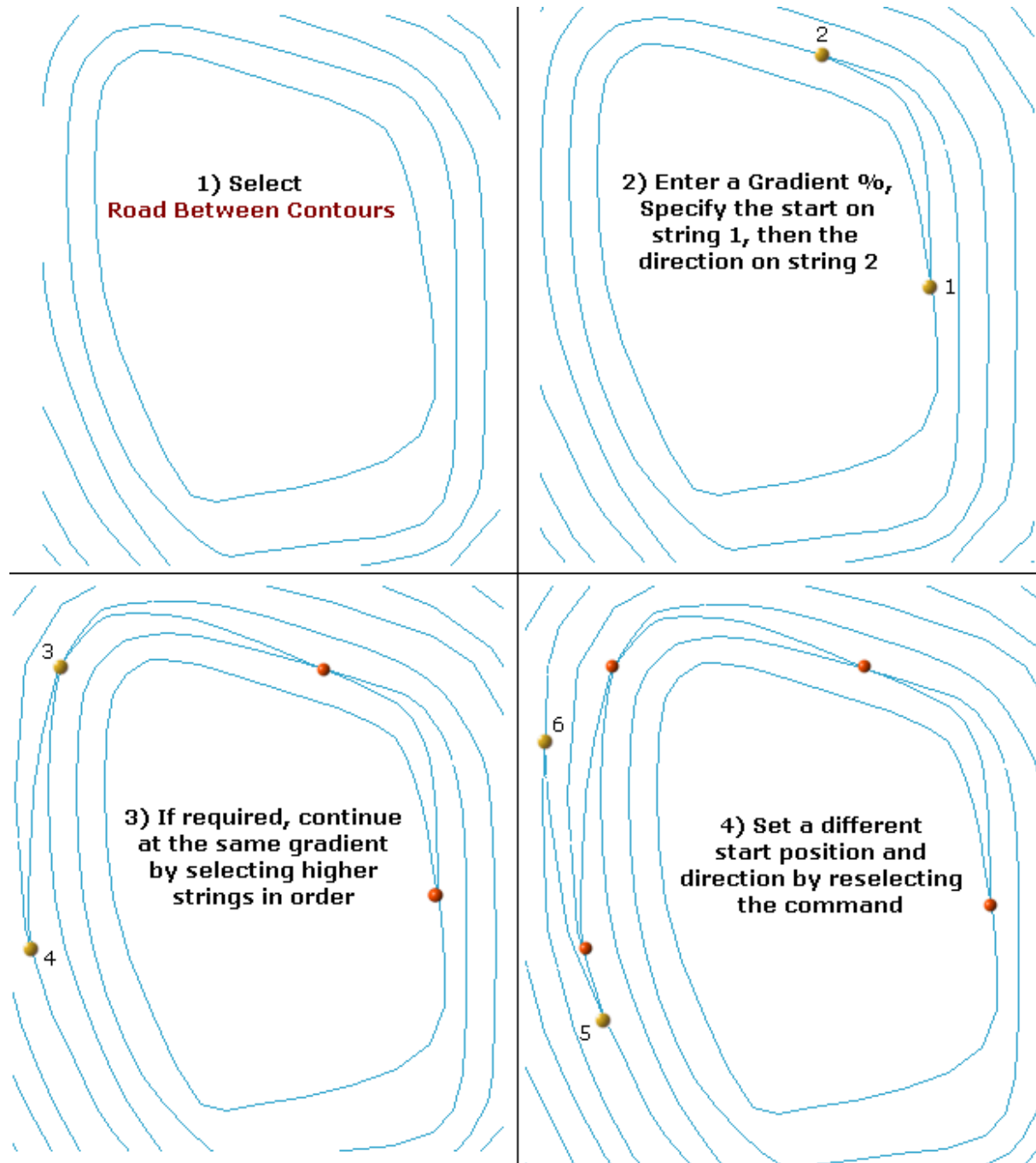
1. To locate a ramp within the contours, the **road-design-string-pair** command is used. This command is synonymous with the **Road Between Contours** menu entry found under the **Applications | Open Pit | Road Layout** Tools menu.
2. Once you have entered the required road gradient select the first contour string at the ramp start position.
3. Next, select the second contour string roughly at the position you want the ramp to be positioned. A single string will then be generated between the two contours. Continue selecting sequential contours to create the full ramp extending to the top (or bottom) of the pit.
4. If you want to change the starting position of a ramp segment select the **Ramp Between Contours** command again and pick the new ramp position followed by the subsequent contours. You do not have to re-select the command in order to change the direction of a road, for example, you can create an *anticlockwise* road and then change to a *clockwise* direction for the next contour. Re-selection is only required if a new start position is required, different to that of the terminal point of the previous road string.

The road strings that are generated in this way will honor the specified gradient, and be positioned in between the two selected contours, curved as required to maintain it. As with all open pit design methods, it is not possible to automatically generate a road string so that it ends at a predetermined position on the next bench elevation – road strings are generated according to the real-world requirements of mining operations, such as the maximum incline that a haul truck can drive along safely.

If you wish, you can adopt a mixture of top-down and bottom-up designing to ensure all requirements are met. You may have a design requirement for the final ramp string to end within a specified distance of a particular stockpile location, for example. In this situation, a

bottom-up design could be amended at the final bench to top-down, selecting the pit crest string before the next contour downwards. Road gradients are then maintained, and these will be merged with the contour strings in the next step.

As a summary of the road string creation concept for this method (note that a bottom-up method is demonstrated):

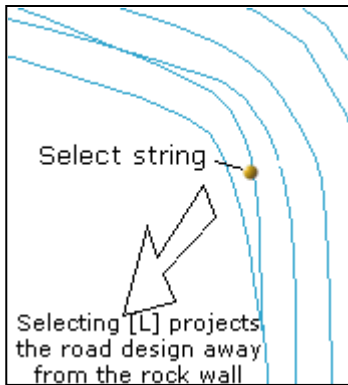


*A final word about road strings*, if you have created a road string consisting of multiple segments (by successively selecting higher or lower contours whilst in the same 'command' process) this string will be treated as a single entity, even if it spans more than one contour. This is particularly important when defining the width of the road(s) as specified in the **String to Road** command, explained in detail in the following section, as you can only define the start and end width of roads with this command.

## Converting Road Strings to Roads

Once you have inserted the ramp design string into the pit you can then convert it to a ramp using the **String to Road** command:

1. Select the **String to Road** command from **Applications | Open Pit | Road Layout Tools**.
2. You will be asked to select a string to act as a design string. Select any road design string.
3. You will now be asked what you want to do with the original design string when the road has been constructed. You can choose to delete the string (select **Yes**) or to keep the string (select **No**) after the command has been run.
4. After selecting the design string you will be prompted for whether this string represents the centreline, left hand edge, right hand edge, inner edge or crosses from the left to right or right to left edge.

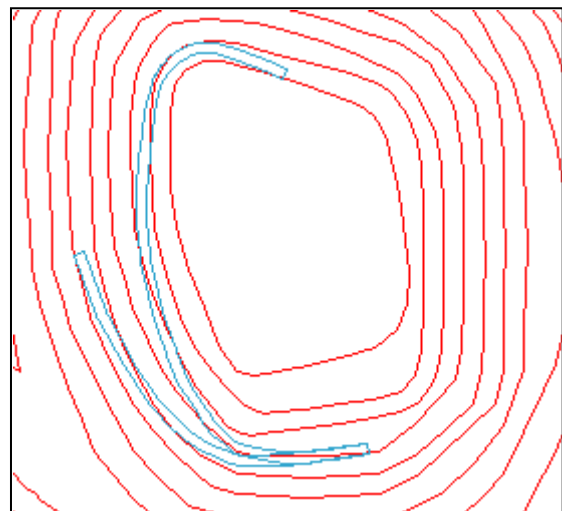


You should select the option which causes the ramp edge to project inside the pit. For example, with a ramp string extending up the pit wall, the side furthest from the rock wall would be chosen for converting it to a ramp.

If you have accounted for the ramps when setting the wall angles in your pit optimisation then projecting the ramps inside the pit will not affect the optimum pit shell.

*(see Chapter 3 for more information on common road creation and editing commands, including an overview of how design lines can be managed).*

5. The next step is to specify the road width and the start and end of the road. When this is done, click **OK** to create your new road. Note that there is no need to select the road string afterwards (in fact, doing so would have unwanted results).
6. If you simply wish to apply the same settings to all roads in your pit, select each design string to become a road and the command will be applied to each successive selection.
7. If you need to change the width or gradient settings for a particular road, or you have completed road creation, you will need to click the **Cancel** button in the top left of the display area to end this mode, and reselect the **String to Road** command if required.



When all ramps have been generated, the next step is to complete the contour design by merging these constructions with the contours.

## Merging the Ramp Strings with the Contours

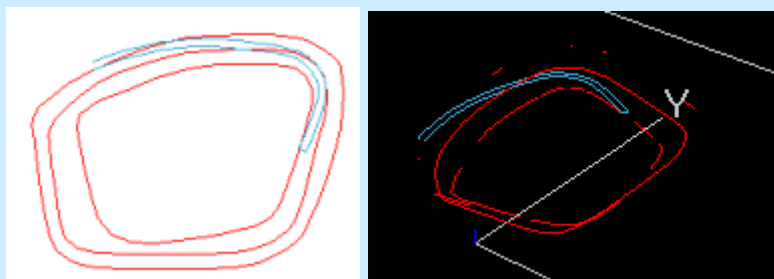
When your contour design has the required number and alignment of ramps, you will need to adjust the toe positions to account for the inserted ramp.

When performing this task, you can make things a lot easier by setting the viewplane to clip unwanted data from view:

1. Choose **View | Set Viewplane | Snap to** (or type the quick command 'stpl' and snap (right click) on any point in the crest of the first bench (remember that this is the *second* contour up from the base of the pit). The viewplane is now at the same elevation as the first bench. If clipping is disabled, you won't see any affect on the screen display at this point.
2. If clipping is disabled, choose **View | Set Clipping Limits** ('scl') to set the near and far clipping to half the bench height. For a bench at, say, 20 meters above the pit floor, you would set the view plane to show 15 meters behind and 15 meters in front of the viewplane (you will need to disable both *Infinite* check boxes to do this) Setting these limits will automatically enabled clipping.
3. You can disable/enable clipping at any time by selecting **View | Apply Clipping**.



Clipping can also be applied to the Visualizer view – when you have applied clipping in the Design window, go to the Visualizer and right-click the display area to **select Options | Clipping On**. You will need to update the visualizer display to see the clipped data:



4. The task now is to adjust the toe position to account for the inserted ramp. To solve this you need to determine where the toe would lie if the edges of the ramp were projected at the face angle to the next bench elevation, up or down. This can be done very easily using the **Project String** command. Choose **Applications | Open Pit | Road Layout Tools | Project String**:

For example, consider a ramp starting at elevation 1350m and going up ten metres to 1360m. The first step is to ensure that the string projection angle is set to the face angle. In this case, you would select the **Project String** command and choose a [D] (downward) projection to elevation 1350m. You would need to pick the ramp outline string on the high side. In this instance, because we want the string to project down and outwards we select a point inside of the ramp outline.

In this example, you would see a new outline string created around the ramp and lying on the 1350 bench floor at this point. The only section of this new string which is of importance is that which lies within the original pit outline. This represents the updated toe position resulting from the ramp.

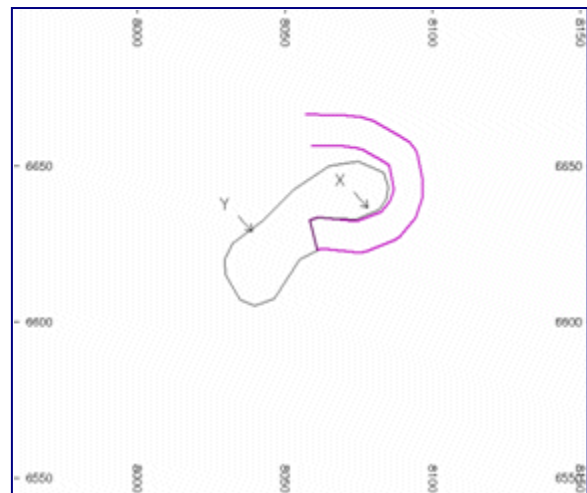


You should now see a new outline string created around the ramp and lying on the 1350m bench floor. If the original ramp outline is very long the new projection may be rather complex.

The only section of this new string which is of importance to you is that which lies within the original pit outline. This represents the update toe position resulting from the ramp.

- To update the original outline select the **Combine** string command (**Design | String Tools**) and pick a portion of the original toe.

It is important that the point you choose (e.g. **X** in the image on the right) does *not* lie in the area you want to remove i.e. under or behind the new ramp on this bench. Next pick the projected ramp string somewhere inside of the pit (e.g. **Y** in the image on the right). The two strings will then be merged producing a single outline showing the new pit toe line.

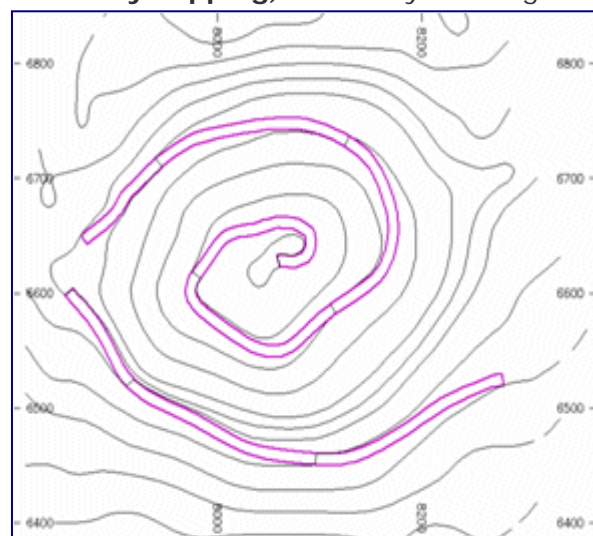


- Next, adjust your view to the next bench and repeat the exercise, this time projecting up or down to the next bench floor.
- Repeat steps 1 to 6 until you have processed every bench in your pit. When you are finished turn off the clipping (**View | Use Primary Clipping**) to check your design.

The pit should now have a correctly merged ramp.

Using the **Design** window and **Visualiser** check for small segments of strings which may have been left over from the automatic crossover removal and string combining.

The easiest way to remove these is to highlight the offending item with a left-click, followed by the <Delete> button. Confirm your removal in each case.



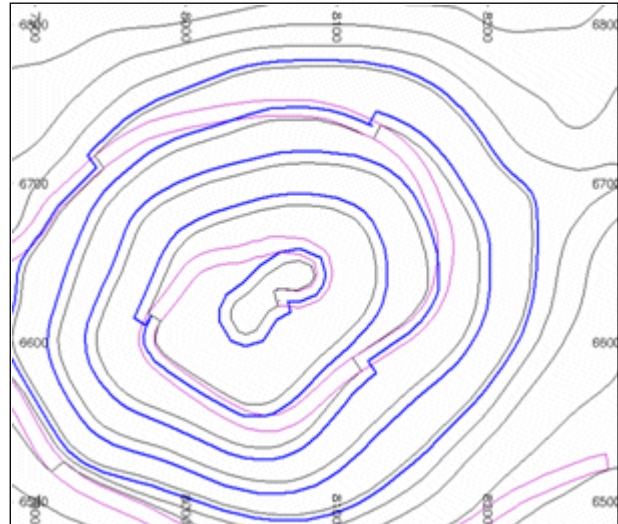


If you choose the centreline when converting the string to road the steps you need to follow are similar except that you will have to generate *two* contours on each bench to complete the ramp merge. This is because the projected contours will now only merge with one for the front half and another for the back half.

8. You must now create the crest contours. This is done by selecting the Project String command (**Design | Project | Project String**).

Using the 'relative' option ('R') click just outside each toe contour. You may find it easier to zoom in (**View | Zoom | Zoom In**) so you can be sure that you are projecting the correct string.

9. Now merge the ramp in with the crest contours. To do this:

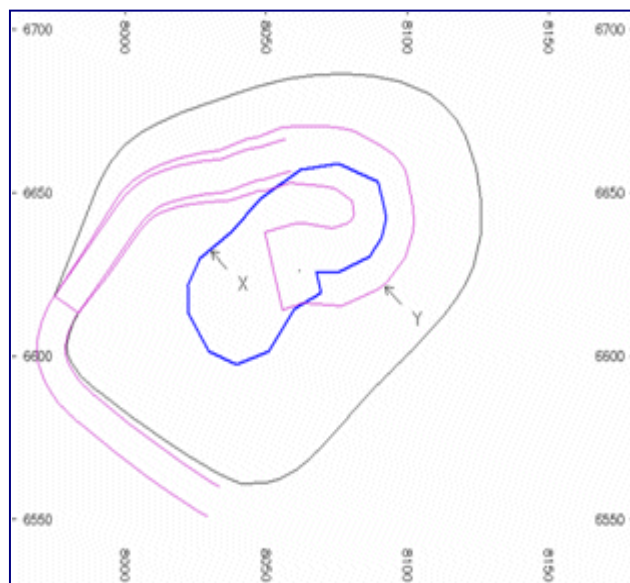


- a. Move your screen position to the first bench.
- b. To make the display clearer set the near and far display clipping to half the bench height. You should now see only the pit contour for this bench.
- c. You must now adjust the crest position to account for the ramp. This is done in a similar way in which the toe contours were merged except this time you should project the ramp string **UP** to the crest elevation.

For example, consider a ramp starting at 1350 and going up ten metres to 1360. The first step is to ensure that the string projection angle is set to the batter angle.

Once that is done select the **Project String** command and choose an *Upward* projection to elevation 1360.

You need to pick the ramp outline string on the high side. In this instance because we want to string to project up and inwards we select a point *outside* of the ramp outline (note how this particular step is the opposite of the similar step in the previous section).

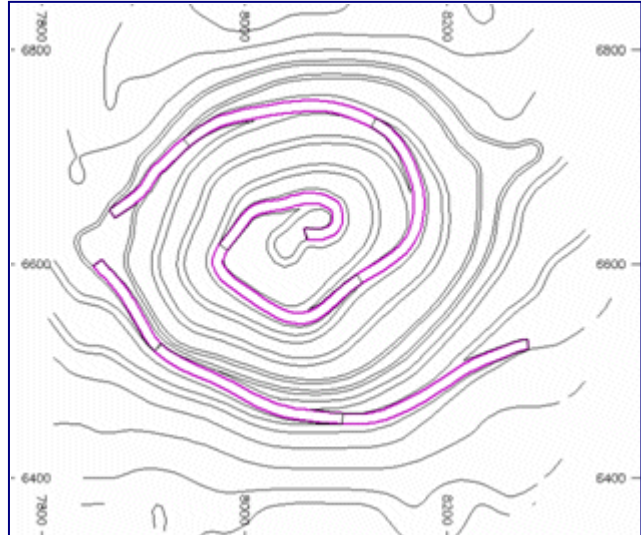


- d. You should see a new outline string created around the ramp and lying on the crest contour. The only section of this new string which is of importance is

that which lies outside the original pit outline. This represents the updated crest position resulting from the ramp.

- e. To update the original outline select the **Combine String** command to create the new crest contour. It is important to select the two parts of the string you wish to keep (e.g. X and Y in the image on the previous page). The two strings will be merged producing a single outline showing the new pit crest line.

10. Adjust your view to the next bench and repeat steps 9d and 9e, this time projecting up to the next crest.
11. Continue in this way (repeating steps 9 and 10, above) until you have processed each bench in the pit. When you are finished turn off the clipping to check your design.

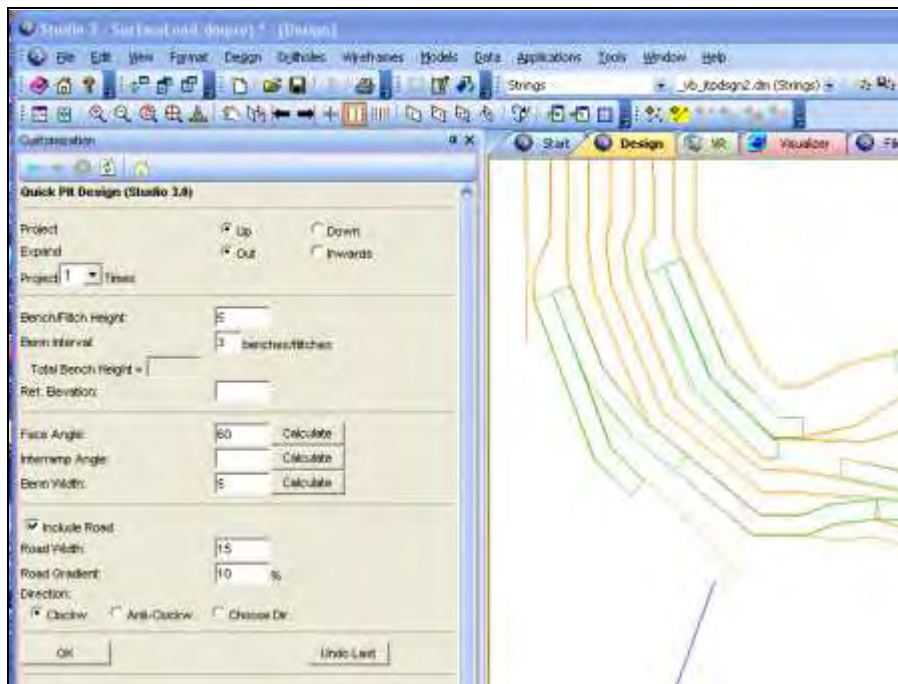


# QUICKPIT – RAPID PIT DEVELOPMENT

Studio 3's **QUICKPIT** process is designed to speed up open pit design, and access existing tools in an efficient way.

**QUICKPIT** enables an iterative design process whereby the design of a pit can be altered (ramp positions, gradients, berms etc.) to find the best results. The process is run from the menu, **Applications | Open Pit | Open Pit Design Utility**. Alternatively, you can type 'quickpit' into the Studio 3 command line.

When **QUICKPIT** starts, a dialog is displayed in the Studio 3 **Customization** window (where all Studio 3 script interfaces are displayed).



*QUICKPIT Displayed in the Studio 3 Customization Window*

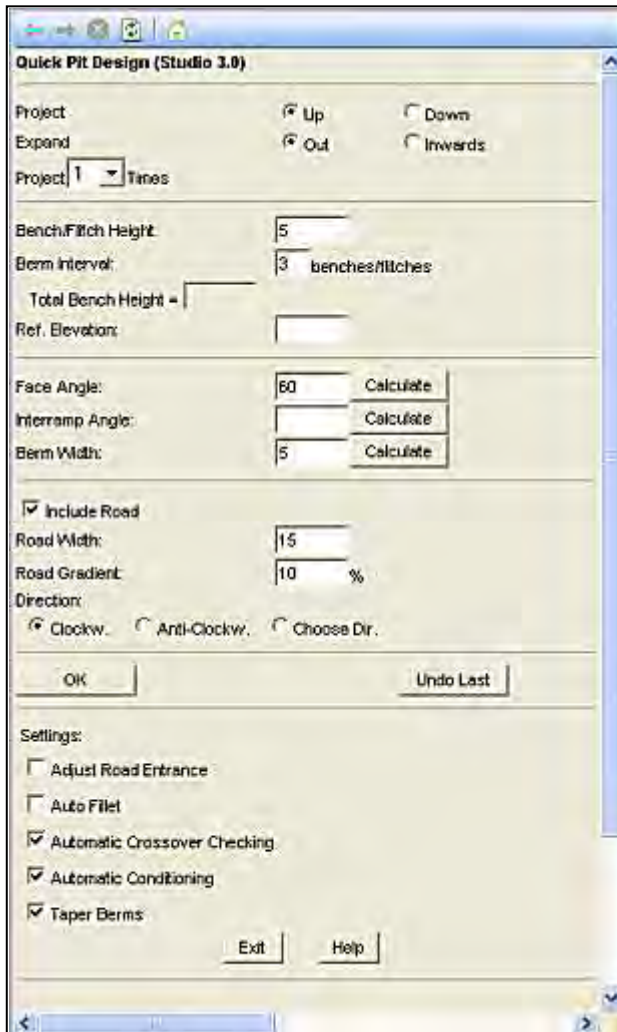
Added functionality to the existing tools includes the tapering of berms where they meet the road. This greatly improves pit designs and minimizes the need for manual adjustments while designing.

The process ensures that there are few overlaps where road segments start and end. This means the generation of a DTM of the pit is quicker.

## Golden Rules for Using Quickpit

- Always start with a closed string which can represent the bottom or the top of the pit. Relative to that string, you can carry out multiple projections that build the pit.
- If something goes wrong, click on the "undo last" button to reload the pit as it was before you ran the last command.

## The QUICKPIT Dialog



The QUICKPIT dialog

The **QUICKPIT** command is a Studio 3 'super-process', providing access to many useful open pit design tools using a simple interface. It is designed to automate as much of the pit design process as possible using the **QUICKPIT** dialog's fields:

### QUICKPIT fields

**Project:** it is possible to project up or down from the closed string. The default is to project strings up and out from the original closed string, the initial string. You can project a string a set number of times.

**Expand:** you can expand the pit inwards or outwards from the initial closed string.

**Bench / Flitch Height:** if benches are mined in stages, the number entered here is the height of each stage (flitch or sub-bench).

**Berm Interval:** the number entered here is the number of flitches or sub-benches per bench.

**Total Bench Height:** this value is calculated automatically, it is the product of the berm interval and the bench \ flitch height.

**Ref. Elevation:** this is the elevation from which the berms start, it is the elevation of the first berm.

**Face Angle:** this is the angle in degrees of each bench face, the default is 60.

**Interramp Angle:** this is the angle (from the horizontal) of a line that is drawn from bench toe to bench toe.

**Berm Width:** the width of a berm. NOTE: For the settings: Face angle, Interramp angle and Berm width. The user enters values for two settings and the third is calculated when the Calculate button is pressed.

**Include Road:** if this check box is selected a haulroad will be included in the pit design as it is projected. The user will be prompted to select the start point of the ramp.

**Road Width:** the width of the haulroad.

**Road Gradient:** the angle of the road as a percentage.

**Direction:** this controls the direction of the road around the pit. If the clockwise (clockw.) or anticlockwise (anti-clockw.) option is selected the road will continue in this direction for each projection. At the end of a series of projections the direction can be changed to include a

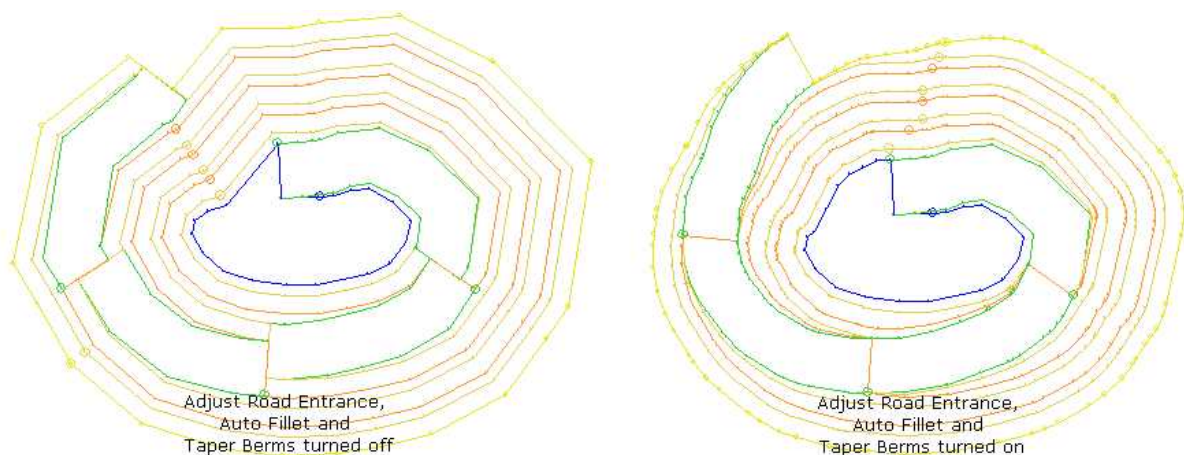
switchback. If the choose direction (Choose dir.) option is selected the user will have to decide the direction of the road for each projection.

### Settings:

- **Adjust Road Entrance:** gives the entrance of a road a constant width (See images below).
- **Auto Fillet:** with an angular closed initial string, the pit generated can be unrealistic. This option adds extra points on a projected string to give a more rounded projection (See images below).
- **Automatic Crossover Checking:** checks for and removes any crossovers.
- **Taper Berms:** this option should be selected when access to a bench is not required as the berm is tapered to a point at the road.

### QUICKPIT Settings Example

The image shown below has the settings, Adjust Road Entrance, Auto Fillet and Taper Berms turned off. The image on the right has these settings active:



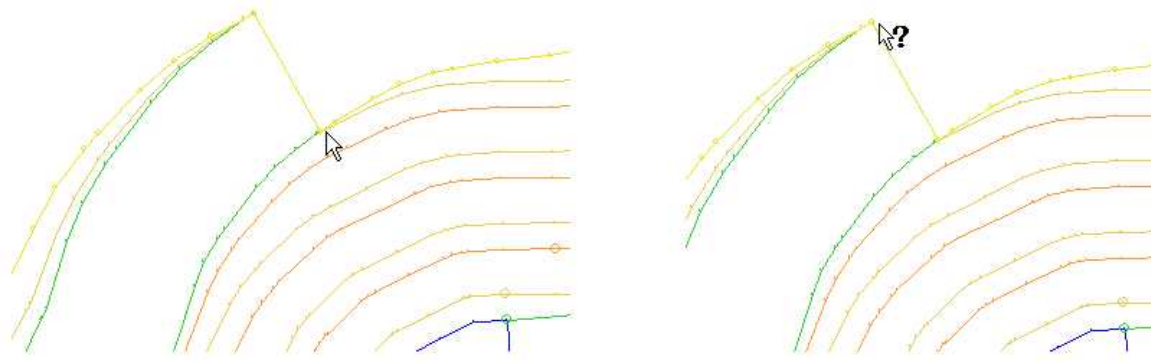
### Guidance for generating an open pit

It is advisable to project a few benches at a time, if there is a problem with the design it is simpler to rectify. If something does go wrong, zoom into the area of the problem, it may reveal a point that needs editing.

### Guidance for generating a switchback

To continue a road you must select the start point. If you want the road to continue in the same direction you must select the inside corner point of the last section of the road (image on the left, below).

To create a switchback (change the direction of the road) you must select the opposite direction, the base string (the last projected string) and select the outside corner point of the last section of the road (image on the right, below).



### **QUICKPIT rosettes and block models**

Instead of specifying the berm width and face angle, you can use a rosette or block model to control projection as described in Chapter 3.

## 9 INSERTING RAMPS INTO A PIT FACE

The pit design methods detailed in the previous sections show you how to insert a ramp along the face of a pit design. Often, you will need to insert a ramp which lies *perpendicular* to the pit face, or projecting into the pit cavity at a specific angle, such as when creating the final exit point of the pit.

In this section, ramps are classified into two groups, those having a 'constant gradient' and those with 'varying gradients'. This section describes the general procedures for completing both types of ramp design.

To create these structures in your pit design, you will need to use a combination of tools already described; **Project String**, **String to Road** (varying gradients) and **Combine String**, along with commands that are new to this section; **Road Line** (constant gradient only) and **String Trace**.

The first step in designing the ramp is to digitise a string which identifies the path of the ramp. The string need not be at any particular elevation or gradient as it will only be used as a guide; strings will be projected upwards or downwards to the correct elevation as required.

The flowchart on the right outlines the basic steps necessary for creating a non-aligned ramp.

### The Road Line Command

The procedure for inserting ramps with constant and varying gradients is very similar, with the only difference being the selection of either **Road Line** (constant) or **String to Road** (varying) commands at the key stages.

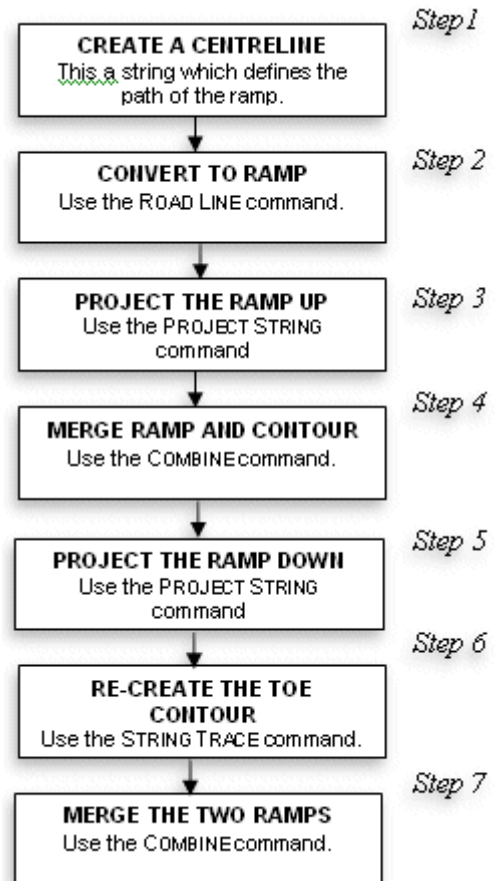
The **Road Line** command is available from the Studio 3 menu system (**Applications | Open Pit**), by typing the quick key combination 'rli' or by entering **create-road-line** into the command line (you can also initiate it from the **Pit Design** toolbar).

The **create-road-line** command is used to create a three-dimensional road edge around a supplied road centreline string, that also honours supplied elevation and gradient parameters.

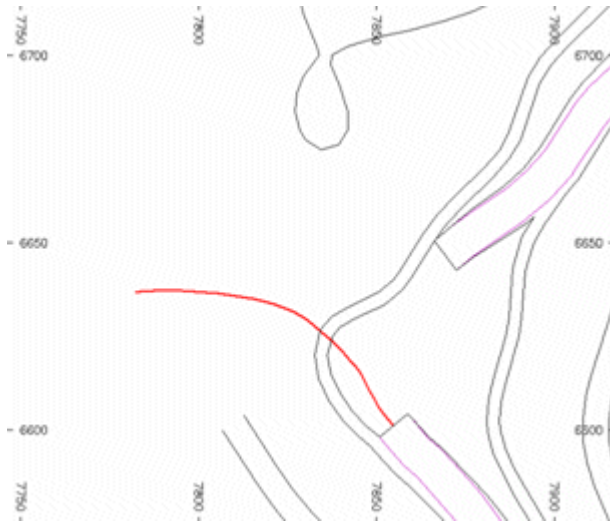
You will be requested to identify the required centre line string, if it is not already current. Then you need to define the road width, and two of the three prompted parameters for road gradient, start and end elevation. For example, if the start and end elevations are supplied, then the gradient will be calculated from the plan length of the centreline and these elevation values.

### Ramp Insertion General Procedure

The procedure below will highlight the requirement for an alternative command selection where relevant:



1. Before you start, make sure your **Command** window, and **Command Line** toolbar are both in view. If not, you can enable these items using the **View | Customization** options.
2. Regardless of the type of ramp being created, the first step is to introduce a design string into your open pit that represents the centre of the path of the new ramp, or a section of it, e.g.:

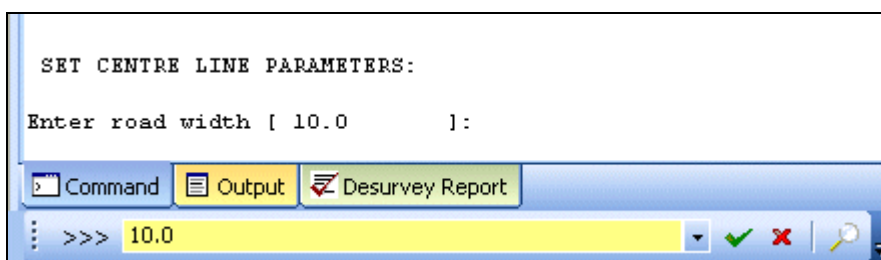


Next, switch to a plan view of your data (this is required to run the following commands)

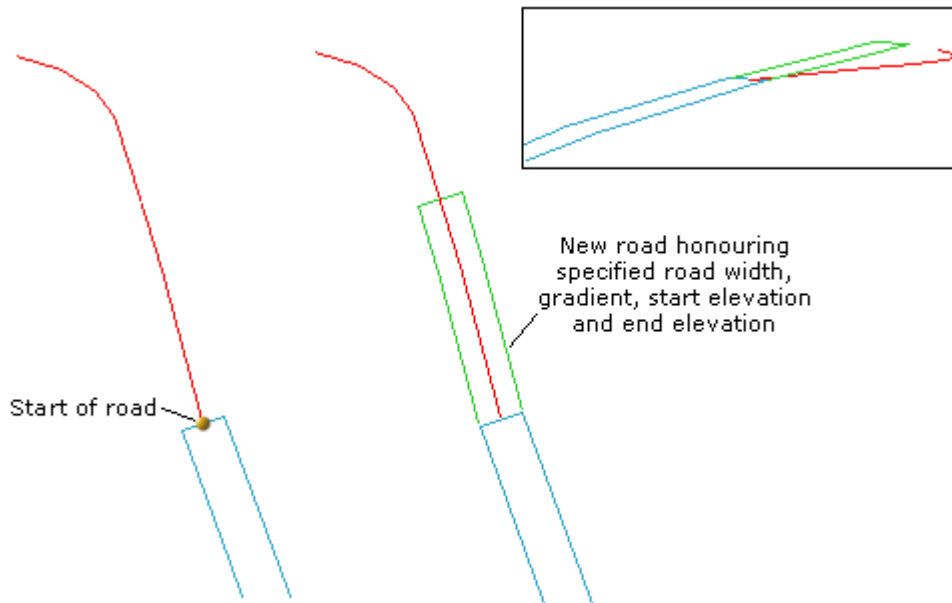
3. The next stage depends on the type of ramp being created:

#### ***Constant Gradient Ramps:***

When the required string has been created, edited and conditioned, select **Applications | Open Pit | Road Line** and you will be prompted for the road *width*, *gradient*, *start level* and *end level*. This information needs to be entered into the Studio 3 command line, e.g.:



How you answer these prompts controls how the ramp is created. If you enter values for all prompts, a 3D ramp will be generated along the path string and will stop when the specified end elevation is achieved. If the ramp reaches the end of the string without arriving at the desired elevation it will continue beyond the end of the sting, following the direction of the last string segment.



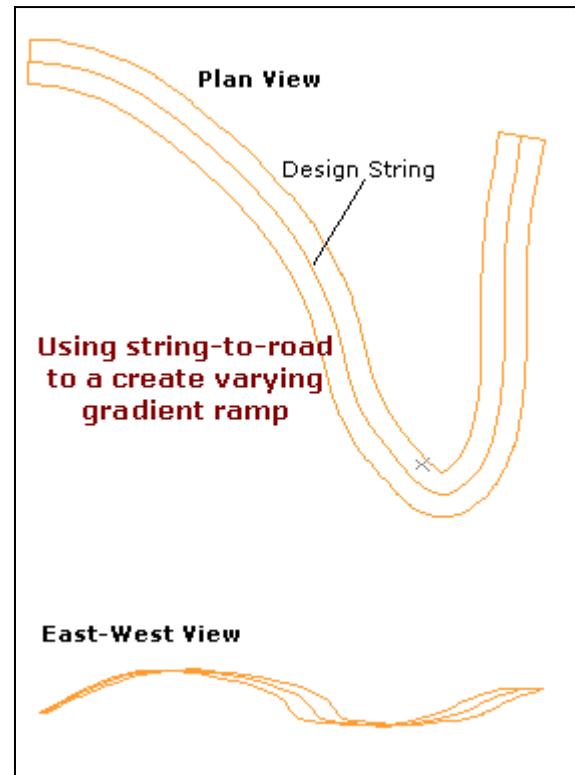
The Road Line command and (inset) a 3D view of the same data

### Varying Gradient Ramps:

When the required string has been created, edited and conditioned (and, of course, following the required gradients), select **Applications | Open Pit | Road Layout Tools | String to Road**. If you want to keep the original string, select **No** at the prompt, otherwise select **Yes**.

You will then be asked for an alignment instruction. You can see more information about the options available for this command in Chapter 3. Select how you want your road to align with the original (design) string.

Note that you cannot specify a start or end target elevation with this command, although you can force points to known elevations by either snapping to known points, projecting to a wireframe etc. before creating the road string.



2. Once you have created an initial ramp, you can repeat the process to introduce as many independent ramp strings as required. For example, you may wish to merge a second ramp with the first, by designing another string.

The **Road Line** command (constant gradient only) can also calculate the road gradient or end elevation of the ramp. To do this you answer those prompts you want to control and enter a minus sign ('-') for the one you want calculated.

When Studio 3 encounters an undefined value here (represented by a minus sign) it is forced to calculate this value based on the other defined parameters and the length of the string. For example, if you enter values for both the ramp start elevation and

gradient then enter "minus" (-) for the gradient, Studio 3 will generate a ramp to the end of the string.

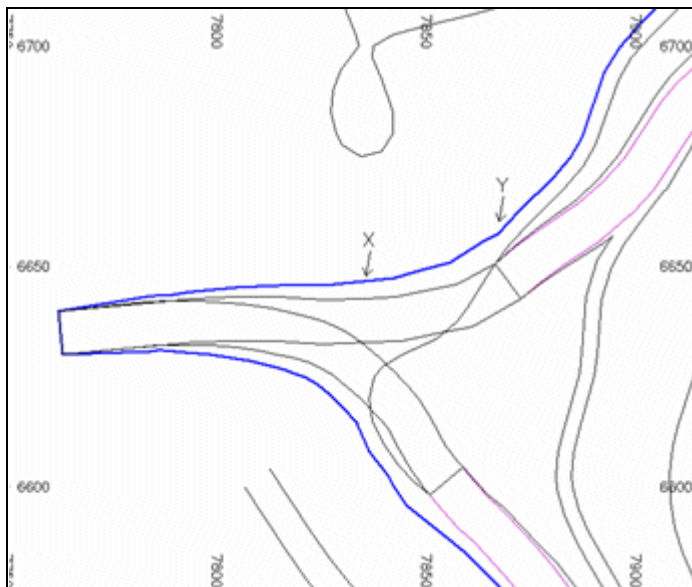
The elevation of the ramp at the end point will be calculated. Similarly, if you enter both the start and end elevations the ramp will be generated from one end of the string to the other. In this case the gradient of the ramp will be calculated.

3. Once you have positioned the ramp outline string where you want it you must merge it into the existing wall by projecting the ramp up to the relevant crest or toe contour string. This is achieved using the **Project String** command, as explained in the previous sections.

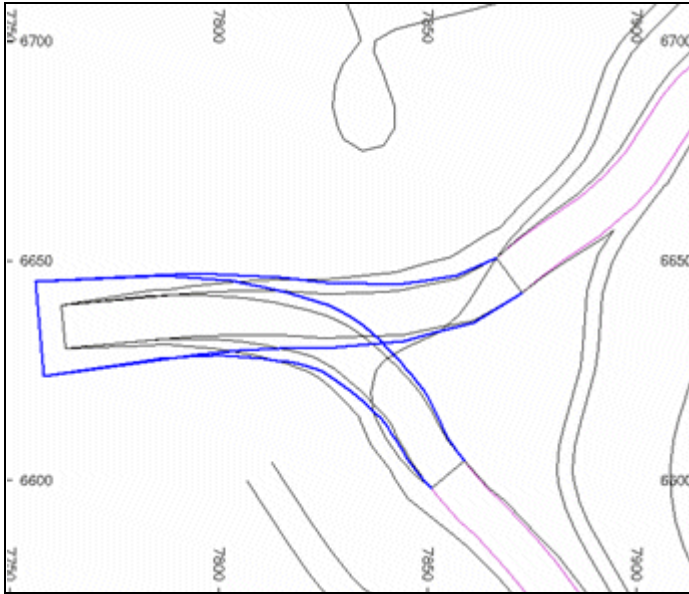
Project String can be found in the menu system under Design | Project | Project String. Note that this command relies on the currently defined projection angle – which is likely to be the same as the default face angle.

4. You may wish to merge these new strings into the existing pit strings, using the **Combine** string command (**Design | String Tools | Combine** – as shown in the Contour design method overview in the previous chapter).

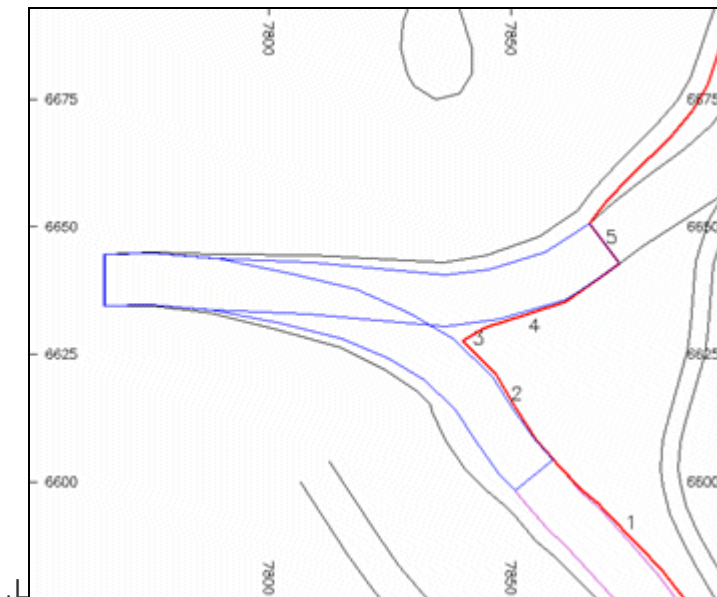
The strings labelled X and Y in the above image are shown after combining in the image below:



5. The next step is to project the ramp downwards to the toe contour using the **Project String** command.

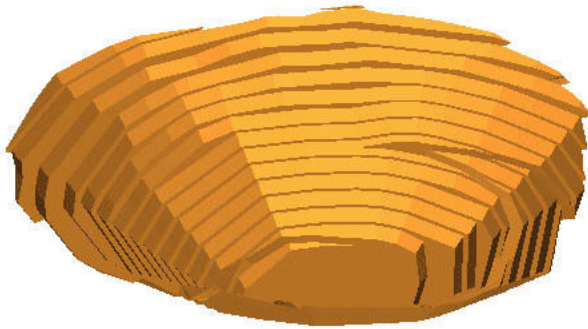


- Next create the new toe contour. This is best done using the **String Trace** command. This command allows you to digitise string data around the geometry of another string. (you could also use the **Combine** command). The numbers below indicate, as an example, road segments chosen to re-create a contour:



- Finally, merge the two ramp strings using the **Combine** command.

## 10 CREATING A DIGITAL TERRAIN MODEL



When you have completed a full pit design you can quickly calculate the reserves within it by building a Digital Terrain Model (DTM) of your pit design strings.

You will find the tools you need for this in the **Wireframes | Interactive DTM Creation** menu.

Before making the DTM set the outermost string of the pit as an outer boundary (**Wireframes | Interactive DTM**

**Creation | Select Outer Limit**); this will prevent triangle surfaces from being created outside the pit. Finally, select the **Make DTM** command, select the object(s) to form the new model and click **OK**. It's always good at this point to load the wireframed pit design into the **Visualiser** window and check your design.

DTM calculation optionally uses limit strings, maximum separation and tolerance settings that have been set by other commands.



If a filter is set on the strings, it will be used. No filter can be set on the optional points file. The toggle switch command **dtm-limit-include-switch** controls whether the actual data points in any limit strings are used to form part of the DTM. If not, they are used just to define plan boundaries using their X and Y coordinates. You are also asked to assign a value for numeric attribute fields to the DTM. Thus each DTM created can be given a specific colour. The attribute values for the DTM are not taken from the strings. The DTM, together any other current wireframe data, may then be saved using the command **write-wf-data**.

If everything appears correct return to the **Design** window and verify your wireframe command by selecting **Wireframes | Verify**.



**Creating a DTM in conjunction with specifying point separation values:** to triangulate data where the maximum segment length needs to be reduced, you can speed up the DTM creation operation by conditioning strings as required beforehand.

### Merging your DTM with the Topography

It is often useful to see your pit design in context, showing the level of the surrounding topography and trimming data where it sits above the surface. There are several ways of achieving this in Studio 3, but the method described below is a good 'all purpose' way of created a merged pit/topography.

1. The first step is to load the topography wireframe that is relevant to your pit design.
2. From the menu bar choose **Wireframes | Interactive DTM Creation | Make the DTM**, select a color and click **OK**. This action creates the basic DTM (untrimmed). See the previous section for more information on the DTM creation process.

3. A New Wireframe object will appear in the **Loaded Data** Window. Right-click on this object and choose **Data | Save As**. Give this file a suitable name (it may be a good idea to highlight the fact that the object is in a 'raw' state).

4. The next step is to create a string where the topography file intersects with your new pit design. Choose **Wireframes | Boolean Operations | Strings from Intersections**.

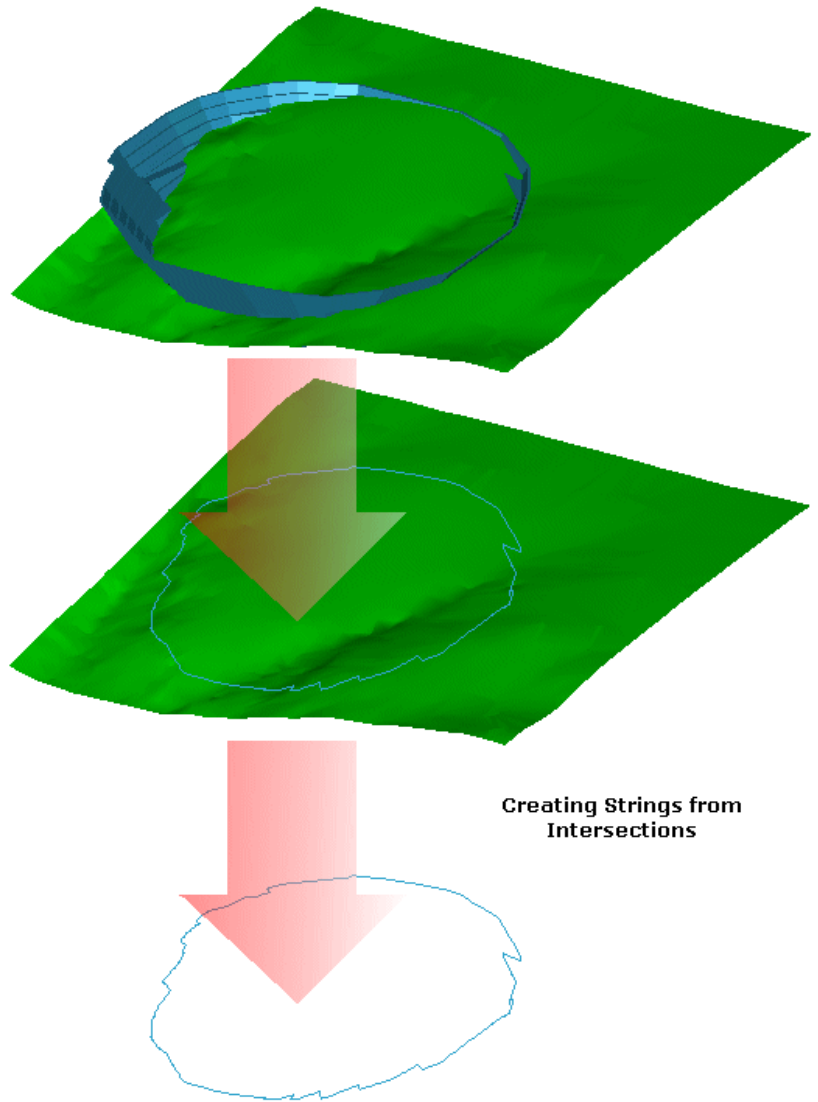
5. In the **Strings from Intersections** dialog, you will need to select both the topography wireframe and the newly-created DTM file (you can do this by interactive selection or by selecting the names of the relevant objects from the drop-down lists. It is not important which object is selected from which list.

Click **OK** to create a new string object (which will appear in the **Loaded Data** toolbar).

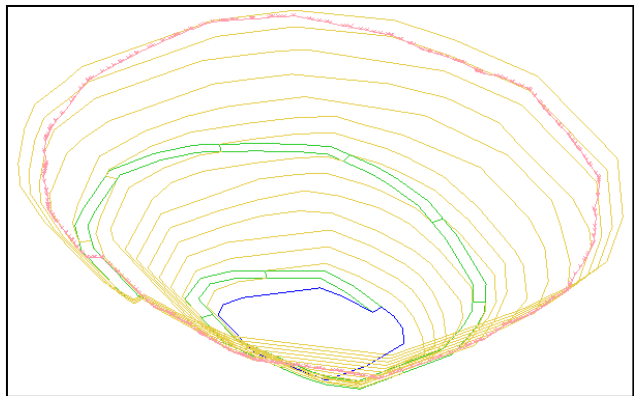
6. Save the new intersection string by selecting the string with a left click, then right-clicking in the **Design** window and choosing **Save | Single String** (you can achieve the same effect with the **Loaded Data** control bar – right-click the new string object's description and select **Data | Save As...**).

7. At this stage, it is recommended to 'condition' the intersection string. Conditioning will result in the string being comprised of chord lengths not exceeding a maximum length and/or angle. This exercise will help to create a more accurate (i.e. containing more data) intersection string that, when used to trim the pit wireframe, will produce a more realistic result. To condition a string:

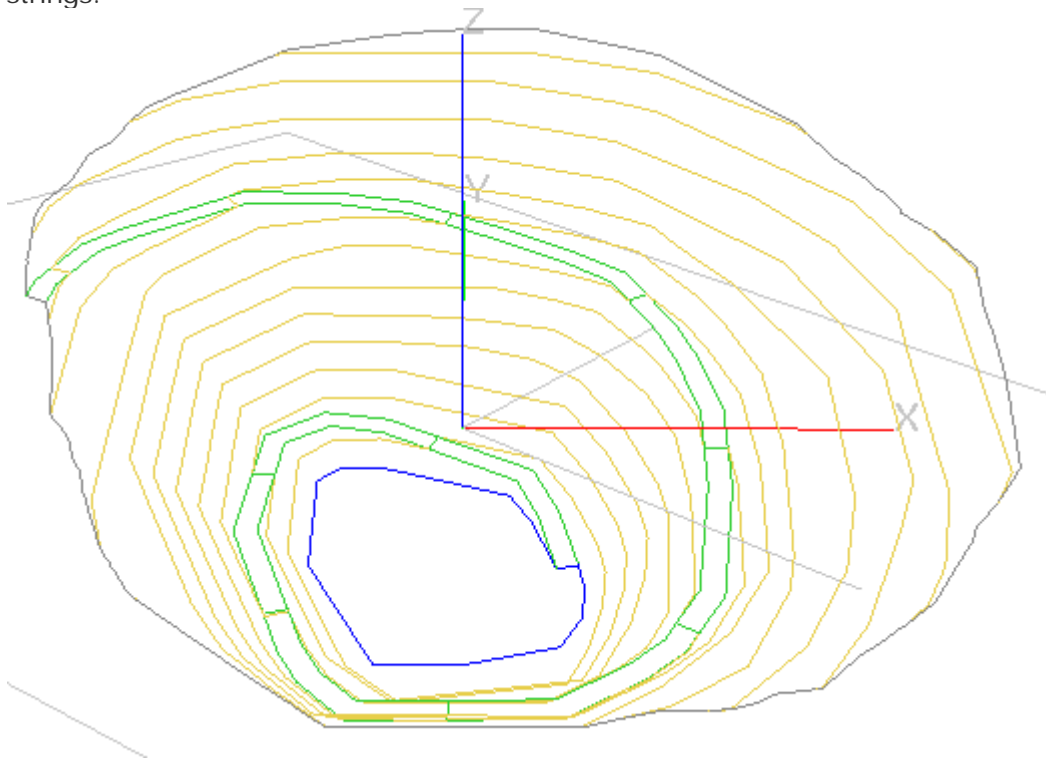
- a. Choose **Design | Open/Close | Close** or type the quick command clo to ensure the string is closed.
- b. Choose **Design | Condition | Condition string**.
- c. Type a maximum chord length. This is the maximum length of individual string segments. A lower setting will result in more string segments (and points). Higher settings will result in a lower resolution string.



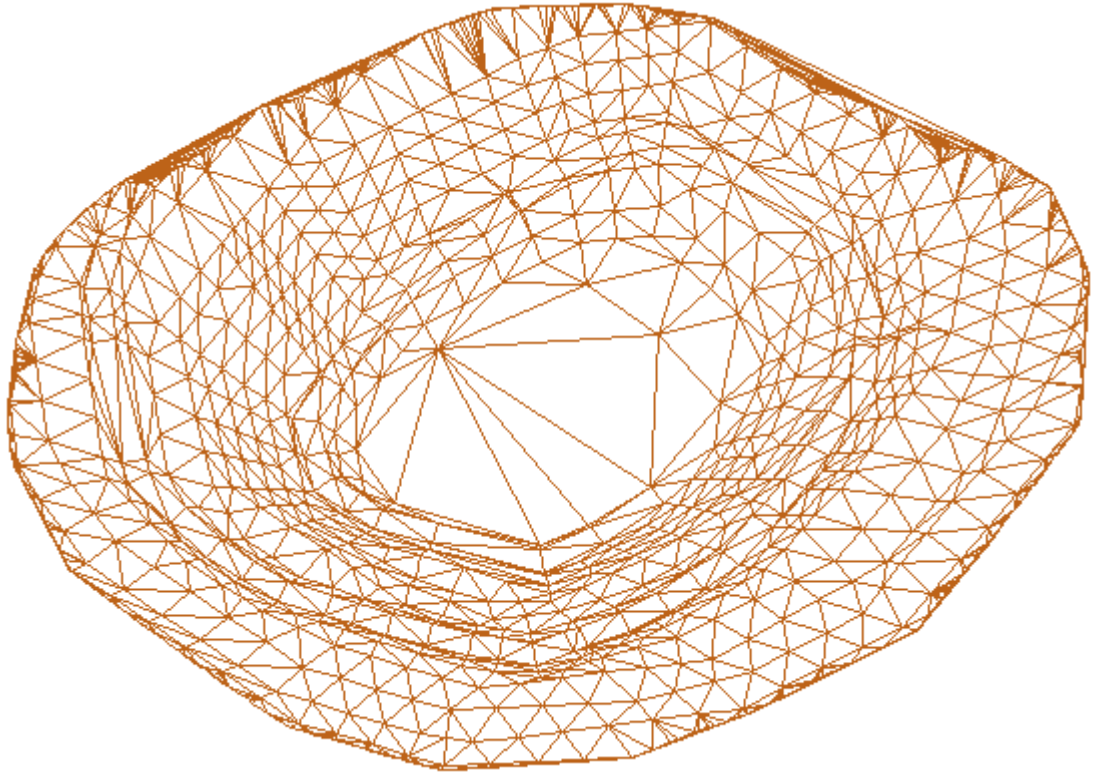
- d. Type a minimum chord length value. This will prevent the number of string segments from being disproportionately high. This value cannot be higher than the maximum value, and if the difference between minimum and maximum is small, less variation in chord length will be permitted.
  - e. Type a minimum angle value. This determines the minimum permitted angle between chord segments. Setting this value to a high value will increase the number of chord segments around tighter curves
  - f. Choose **Design | Condition | Trim Crossovers** to remove any loops.
  - g. Choose **Data | Save | All Strings** or type the quick command 'wa' to save the conditioned string to a file.
8. Once a conditioned string is in memory, you can use it to trim your pit design strings (note that it is the string object that is trimmed with this procedure, not the new DTM). Using the Sheets control bar, switch off all overlays other than those relating to your pit strings object and the intersection string. Redraw the display.



9. Select **Design | String Tools | Clip to Perimeter**.
10. If the conditioned perimeter string is not already selected (highlighted), you will need to select it once with a left click. Next, click outside of the clipping string to trim the pit design strings.

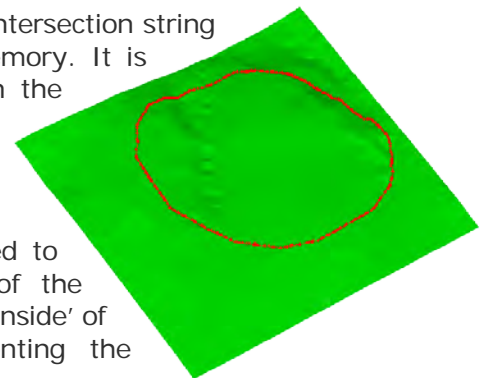


11. Next, you need to create a DTM of the clipped pit strings. This is the same procedure as outlined in step 2 – select **Wireframes | Interactive DTM Creation | Make DTM** and make sure the object containing the clipped pit strings is selected. Click **OK** and select a color. Click **OK** again to create the new, trimmed DTM, e.g.:



12. The final stage is to ‘chop a hole’ in the topography and draw it with the trimmed pit DTM. Studio 3 offers several methods for doing this, but the simplest is to simply project an existing string onto a wireframe surface, and remove the data that is contained within. This option also offers the possibility of verifying your wireframe data beforehand. This particular method utilises the **Split by String** command:

- a. Make sure your wireframe topography and intersection string (as created in step 7) are loaded into memory. It is recommended that they are also drawn in the Design window, although this is not essential.



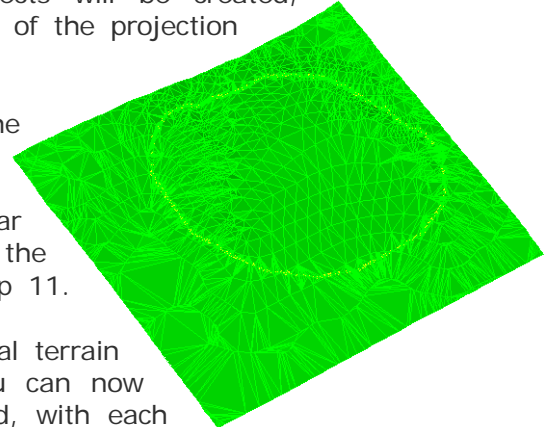
The loaded intersections string can be used to create two distinct objects as a result of the following command – one representing the ‘inside’ of the clipping perimeter and one representing the ‘outside’.

- b. Before you attempt a wireframe split, **you must ensure the string to be used for clipping is selected before accessing the command.**
- c. Select the menu option **Wireframes | Plane Operations | Split by String**. The Split by String dialog appears. You will need to select the topography object from the drop-down list, and for this procedure, no other changes are

required. You could, if you wished, define the direction that a string is projected from the other settings, but as the intersection string is already aligned with the topography and no projection is necessary, this isn't needed for this procedure.

- d. Decide whether you wish to verify the wireframe to be 'chopped' by either clearing or selecting the Verify check box. Verification will cause the operation to take longer, but will highlight potential areas of concern (crossovers, duplicate vertices etc.). If you are confident that the integrity of your topography is satisfactory, you can clear this check box.
- e. Click **OK**. After a short delay, two objects will be created, representing the data found on either side of the projection string.

Using the **Sheets** control bar , disable the view of all overlays that represent all loaded objects apart from the 'outside' data object created in the above step (this will be clear from the automatically generated name) and the trimmed pit design DTM as created in step 11.

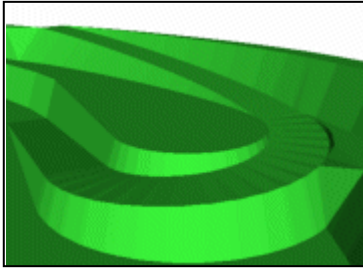


Redrawing the display will show both digital terrain models, aligned at the pit boundary. You can now enhance the view of this data as required, with each object (pit and topography) being independently controllable.

Studio 3's object-based approach allows legends and display formats to be set independently for all overlays of all objects. This means that you can not only represent different objects using the most suitable method for the object(s) in question, but you can also show multiple representations of objects (in the Design window) using different approaches.

Studio 3 has a wealth of pit design options, and the methods outlined above represent the most common methods only.

## 11 SWITCHBACKS AND TURN RADII



Two common utility methods used when designing open pits include the creation of a switchback that honours a minimum turning radius. This is generally stipulated by mine equipment capabilities.

In simple terms, a switchback is a zigzag arrangement of a mine road for surmounting the grade of a steep slope wall of a surface or open-pit mine.

### Creating a Switchback

Switchbacks are recognised by a sharp change in direction of road over a relatively short area. A switchback is created by the selection of a contrary direction when specifying an extension to an existing ramp. To create a switchback:

1. Choose **Applications | Open Pit | Road Segment**.

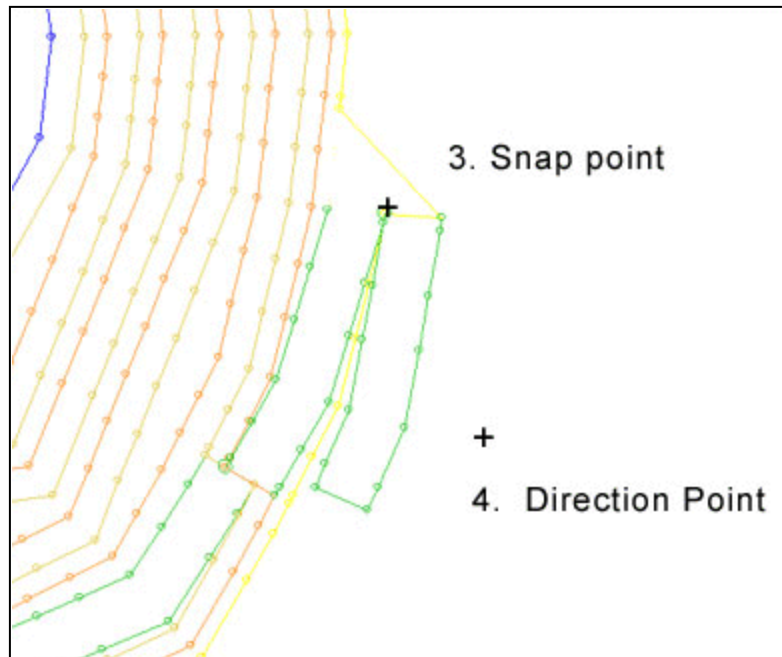
2. Type a road gradient .

3. Type a road width.

4. Type the target elevation.

5. Snap to a point on the target contour string where you wish to start the road (this time select the outermost point on the road. Indicated by point 3 on the diagram).

6. Click another point to indicate the direction you want the road to take (see diagram).



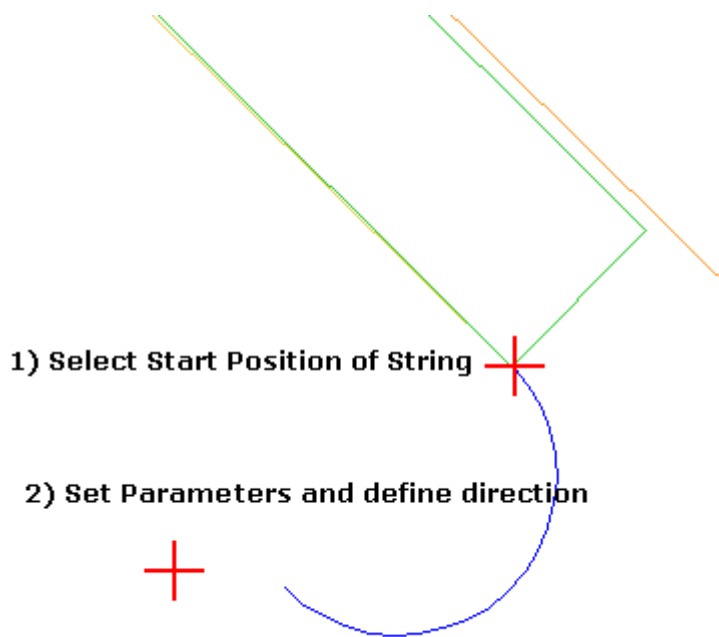
7. The next step is to edit the newly-created contour string so that it has a more practical shape.

### Setting a Minimum Turn Radius

When designing road switchbacks you will often need to specify a ramp with a fixed radius of curvature. To do this you will need to use the **New Road String** command (**Applications | Open Pit | Road Layout Tools | New Road String**).

After selecting **New Road String** you will be asked to position the start point of the ramp. Use the cursor to snap onto the end of the existing ramp which defines the **INSIDE OF THE TURN**. You are then prompted to enter the starting azimuth (or accept the default value) and the gradient of the new string.

Next, you are asked for the radius of the turn and finally the type of turn. Normally you would select a (H)alf turn for a switchback. Finally, you are again requested to select a point on the screen using your cursor to indicate the direction of the turn. Once this is done the inner curve is generated, honouring the minimum radius specified.



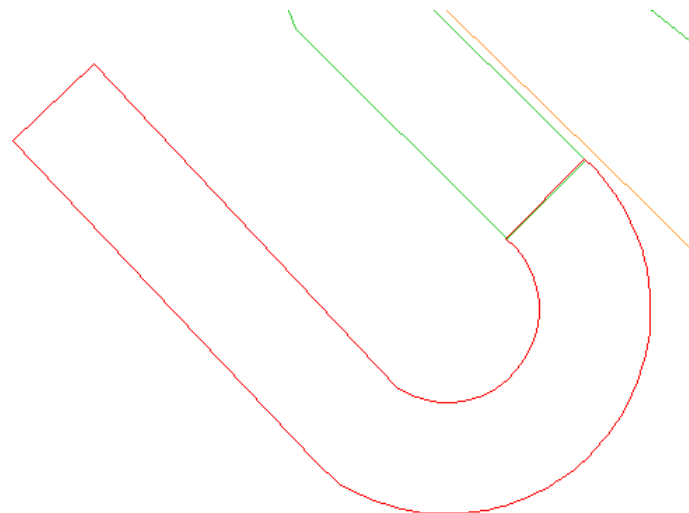
There are several ways to continue your new road string, for example, you could digitize a new string using the same command, but this time a straight road segment can be created by entering '-' at the prompt for a turning radius (why? to ensure that a new, straight line segment is generated whilst honouring the specified azimuth).

When a new road segment is created, you can use the **Connect String** command (**Design | String Tools | Connect**) to ensure the inside edge of the road is continuous.

When a switchback design string has been created, the next step is to convert it to a road using the **String to Road** command already discussed.

As you have designed the string around the inside of the curve, this needs to be specified when defining the alignment of the design string, which, as it is going to be replaced in the same position with a road string, can be safely deleted during the **String to Road** command.

You now need to create a toe contour for this new ramp segment. Use the Query Point (**Design | Query | Point**) command to find out the elevation at the end of the ramp. You can then use the **Project String** command to generate a contour at this elevation.



Next, use the general string editing functions to erase the part of the ramp that occurs below the bench. Using the **Project String** command you should now create a new toe string for the pit wall at the correct elevation.

Use the COMBINE command to merge the ramp curve and the toe string. To make a practical design, you may be required to do some string editing at the switchback.

The next step is to create a crest string using the **Project String** command and projecting the toe string up to the crest elevation and use the **Combine** command to merge the ramp with the crest string.

As a summary of the previous process:

1



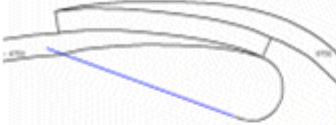
**Design Initial Ramp**

2



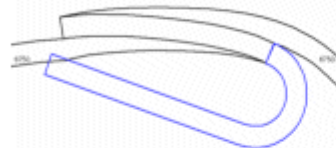
**Create Insert Curve**

3



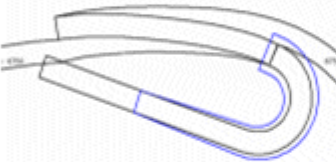
**Extend and Connect**

4



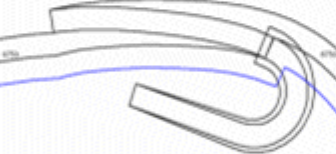
**Convert Extension to Road**

5



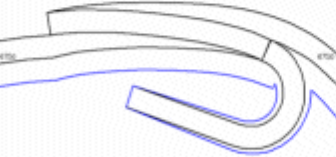
**Create Toe Contour**

6



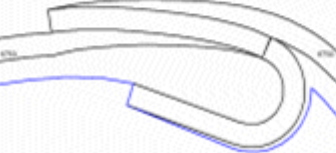
**Edit Ramp**

7



**Merge Ramp Curve and Toe String**

8



**Edit Switchback**

9



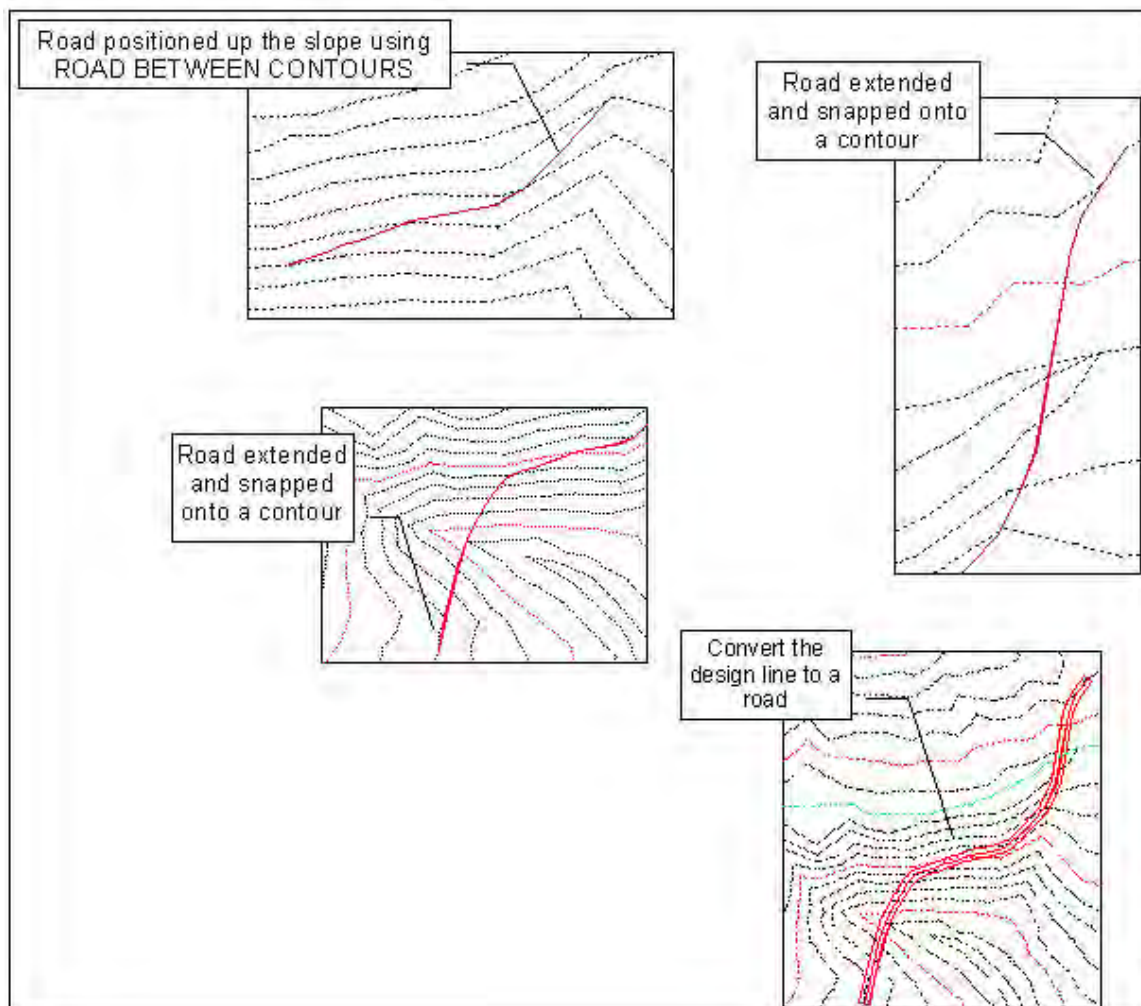
**Create a Crest**

## 12 CUT AND FILL VOLUMES

When designing roads over uneven terrain you will often need to determine the amount of cut and fill associated with them. The pit design tools in conjunction with the wireframe tools allow you to do this.

Before you can begin you will need to wireframe the original topography and save it to file. The next step is to locate the position of your road on the topography. When designing the road it is simpler to work with the road centreline and then convert it to a 3D road later using the **String to Road** command.

Various tools within Studio 3 will be helpful for positioning the road including **Create Ramp String**, **Smooth Gradient**, **Set Gradient** and **Project to Wireframe**. If you are designing a road which travels up the face of a slope, and you have the surface contour strings loaded into memory, you can use the **Road Between Contours** function to set the correct position and gradient.



### Calculating a Cut Volume

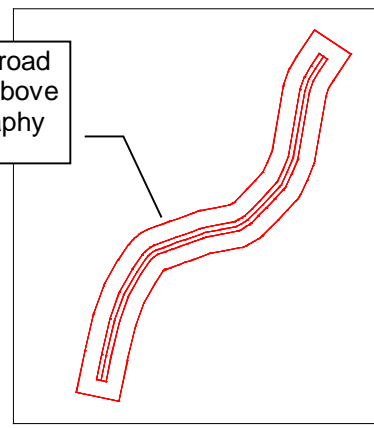
To determine the volume of material removed from the road excavation you will need to project the road outline string UP to some position completely above the existing topography.

Prior to projecting the string set the projection angle to the desired angle for the material face.

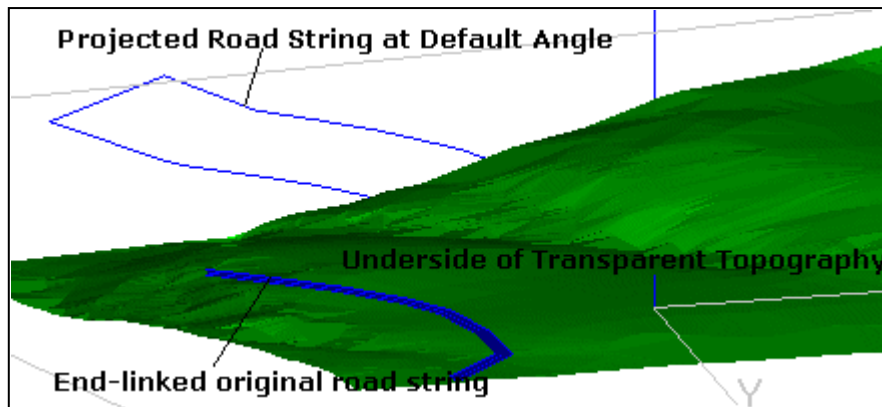
Note that, at this stage, the original road design string is still displayed.

Using the **Project String** command select a (R)elative projection and enter a positive distance. After the new outline is generated make sure to load it into the **Visualizer** window and check that it is completely above the topography. If not, you will have to erase the string and recreate it.

Project the road outline UP above the topography



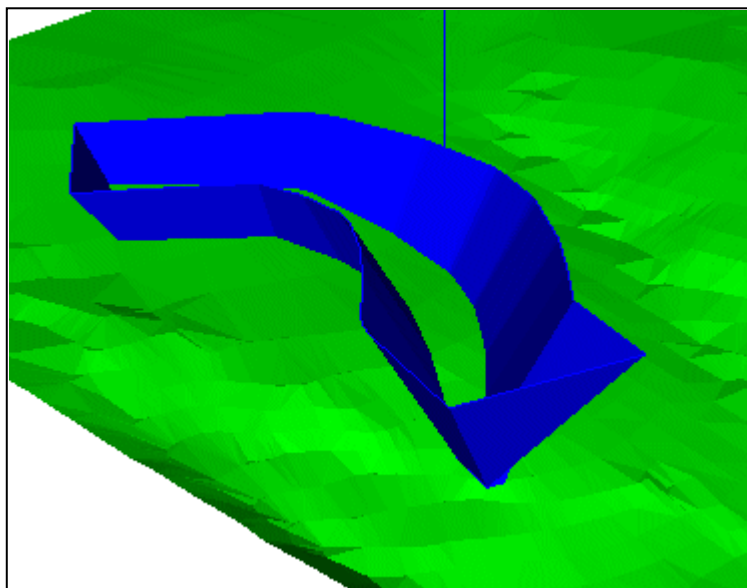
The wireframe object to create should resemble a trench, forming an enclosed base, and side walls. Note that there is no top surface to this object. Before you create a wireframed version of your original road string, it is wise to create a separate object, and set it as the current wireframe, to store your new wireframe data. To do this, create a new wireframe object using the **Current Object** toolbar – this will automatically set the new object as 'current'.



An easy way to create an enclosed wireframe from a closed string entity is to use the **End Link** command. Select **Wireframes | Linking | End Link** and select the original road string (not the projected, larger string, nor the original design string). This will create a flat road 3D plane in the position of

the road string, as shown in the **Visualizer** image shown above.

Next, to create the cutout walls, you will need to link the original road string and the projected string, this time, using the **Link Strings** command (in the same **Linking** sub-menu).



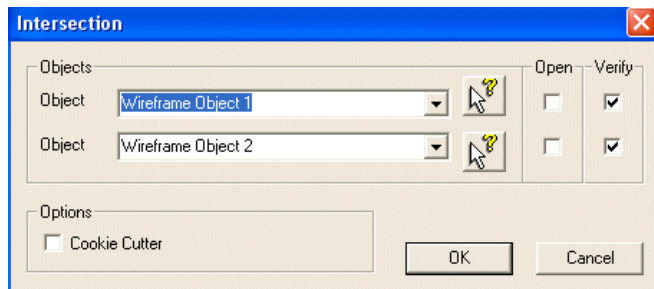
Save your wireframe to a new file for later use (e.g. right-click the new wireframe object in the **Loaded Data** control bar and save it as a separate .dm file. When you do this, the name shown will be updated.

Then, load (or re-display) the topography wireframe in Studio 3, where it can be visualized with the 'trench' wireframe. An example is shown on the left.

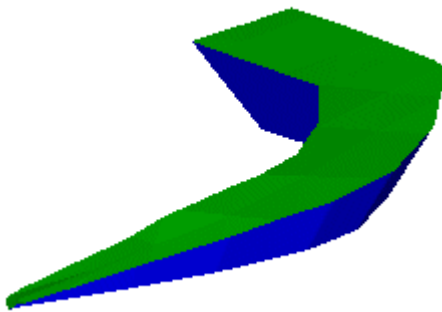
The remaining procedure

involves creating a solid of the material that you wish to 'remove' from the virtual topography. You can then measure this *cut volume*.

Fortunately, Studio 3 provides a quick way of working out this volume, using one of the Boolean operations – **Intersection**. A wireframe intersection, in Boolean terms, is used to create a new, single wireframe from two precursors, representing the common volume of the two components. To perform a wireframe intersection, you will need to make sure that both wireframe objects exist in memory (i.e. they are shown in the **Loaded Data** control bar as separate objects). Then, selecting **Wireframes | Boolean Operations | Intersection** opens the **Wireframe Intersection** dialog as shown on the right.



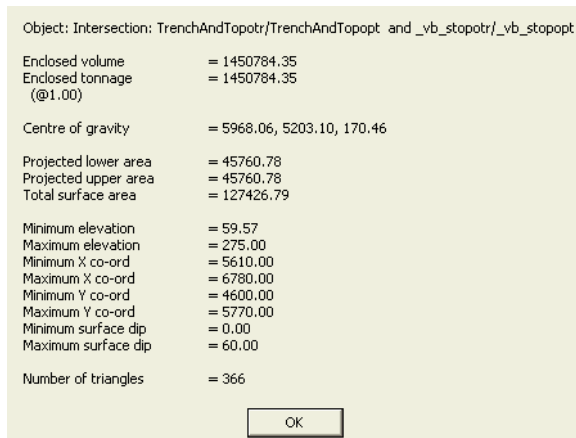
Providing two distinct wireframe objects (in your case, the newly-created 'trench' object and the wireframe topography file) are selected for objects 1 and 2 respectively. **This order is important** – when performing Boolean operations, the results that occur will often be the total opposite of what you require if objects are not specified in order. To resolve this situation, ask yourself the following question when using Boolean operations; *What volume am I looking for?* If the volume is part of object ABC, make sure that it is selected as object 1, and ensure object 2 is the wireframe to be used to modify object ABC's volume in some way.



If you wish to check your wireframe(s) for potential faults (crossovers, duplicate faces etc.), you elect to Verify the selected object(s) beforehand. This will extend the length of time to create the new object. For more information on Studio 3's boolean functions, including **Intersection**, please refer to your online Help.

Click **OK** to perform an intersection. A new object is created in memory, the description of which will start with 'Intersection:'. To view the cut volume object, disable all overlays in the Sheets control bar (Design folder) apart from the newly-created intersection object. You should now see the volume of the material to be removed. You can also show this in the **Visualizer** window.

intersection object. You should now see the volume of the material to be removed. You can



To show the volume of this object, select **Wireframe | Calculate Volume**. This will run one of Studio 3's automatic reports, and show a dialog highlighting the enclosed volume/tonnages, as well as other useful information such as the overall surface area, the data extents etc.

At this stage, it is a good idea to save your project, and when requested, save the intersection object to a file (at present, it will only exist in memory, and if you do not save it, it will no longer be available after the

session is stopped).

## Calculating a Fill Volume

It is also possible to determine a Fill Volume, in a very similar manner to that already described. The creation of the 'cutout' would, most likely, be performed by creating a cutout area, as a road string or other closed string either above, or directly onto, the surface of a topography, then projecting this string downwards to create a lower limit.

The creation of the resulting trench, and the production of an intersection object, would be achieved as shown in the previous exercise for creating a cut volume.

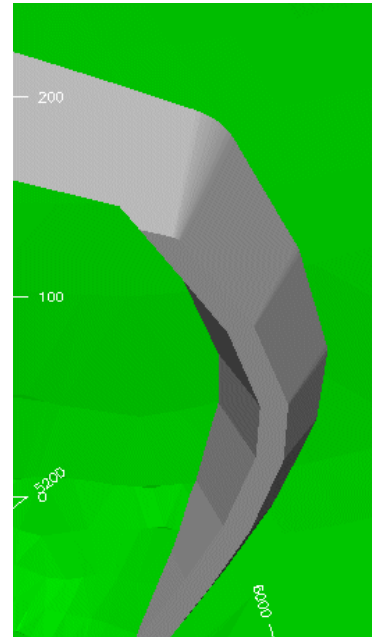
## Viewing the 'Excavated' Topography

Once a cut and/or fill volume have been generated, you can view the resulting topography after the cut/fill has been performed.

As the required view of the topography is effectively the 'opposite' of a cut or fill volume, you can generate the required view using the same **Intersection** command, but in this case, you would select the topography as object 1 (this is the object volume that is to be displayed/modified) and the full cutout volume (that is, the object created from the original road string, and the projected string) would be selected as object 2.

Studio 3's wireframing operations are based on strict logic, and as such, you can apply Boolean and plane operations in a relatively freeform manner. As each operation creates a new object, you are never in danger of corrupting your original data. When you are finished, you can save your project and elect to save only useful resulting objects.

For more information on Boolean operations in Studio 3, please consult your online Help.



## Appendix A: CONTROLLING STRING CROSSOVERS

When projecting strings up or down it is possible that complex strings will generate some segments which contain crossovers or loops. These crossovers can cause problems for subsequent string projecting as well as other tasks such as wireframing and evaluation. Therefore it is important that you remove crossovers as soon as they become apparent.

The easiest way to remove crossovers is to ensure that the system checks for crossovers and handles them accordingly. The `remove-string-crossovers` can be used to manually remove crossover areas after strings with these qualities are generated.

Another alternative is to set the **check-crossover-switch** system switch (by typing it into the **Studio 3** command line or by selecting the **Applications | Open Pit | Road Layout Tools | Crossover Check Switch** menu option). If turned on, pit design commands that generate new strings will automatically check those new strings for crossovers and remove them.

The key to using this function is to understand how it finds crossovers; the function needs to know which point is not in any loop. It gets this information by examining *where* on the string you clicked the cursor for your projection. This portion of the string is then assumed to be valid and not in any loop. To ensure that the crossover removal is done properly you need to select the strings at a point which is away from any tight corners or unlikely to cross another projected segment. If you find that your projected string disappears, leaving only the loops, then you should select **Edit | Undo String Edit** and re-project the string by picking another point along the string.

Another, related command is **check-for-crossovers** – this command checks for faces that intersect, but are not adjoining. When found, a new object is created containing strings made up from the edges formed by the intersections.

To manually remove crossovers in existing strings you can use the **Trim Crossovers** command (**Design | Condition | Trim Crossovers**). It works in the same way as the automatic version and so the point along the string at which you select it is important; select a segment on part of the string that is to be retained. Any crossovers (closed-over loops) in the string will be eliminated, by removing those string vertices on the loop formed by each crossover. A new point will be created at the original intersection point of each former loop. The position and shape of these crossovers, and hence the action of this command, depends on the orientation of the current view plane.



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