

Loop the Loop with Opti-Cut & Four-D

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Introduction

Opti-Cut and Four-D are both tools to optimize the Net Present Value (NPV) of an open pit mining project. Four-D optimizes NPV looking at the shape/size of the open pit. Opti-Cut optimizes the return from mining the resource considering the mining, production and selling throughputs by changing the cut-off grades applied. This paper covers aspects of how these two tools can be used together. Four-D is perhaps like a large bolster used to rough out the basic form, while Opti-Cut is a fine chisel used to smooth out the rough edges and bring out the finer detail. A good sculptor will use both tools at the appropriate time.

Using Four-D and Opti-Cut together as a team, they are different tools requiring different skills and can produce a higher NPV for your open pit than using either program in isolation.

Simple Single Metal Example

To study the basic ideas we will use a simple single metal example. This is the Southern Mine area in the Legendary Valley (this is a simulated student data set from RMIT). It is a large epithermal gold deposit with classical high grade veins and breccia zone, but in addition has significant stringer and replacement mineralization in a favourable cherty lithology. The project thus has a good area of decent grade and also has a large tonnage of marginal grade material. To simplify the example we are not considering capital expenditure. We will use the following economic and mining constraints.

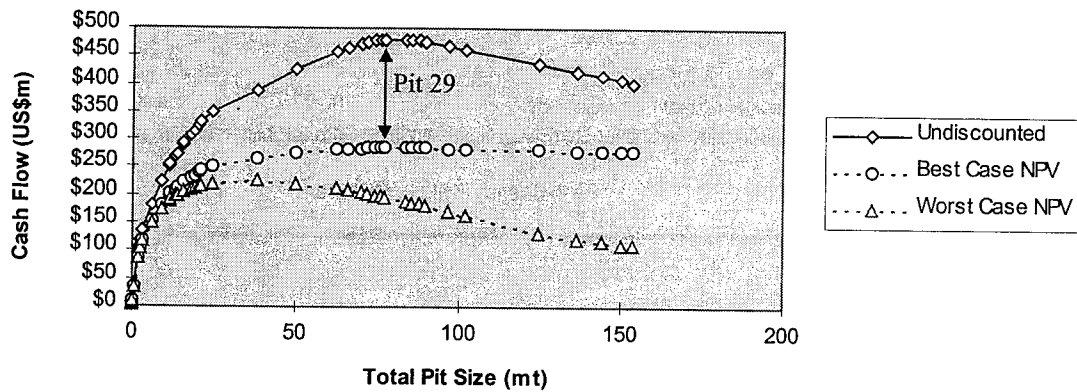
Summary of main design assumptions

Mining Cost	US \$1.20/t (of rock mined)
Gold Price	US \$11.25/g (roughly US \$350/oz)
Discount Rate ¹	15%
Processing Cost	US \$12.00/t (of ore processed)
Recovery	92.5%
Mining Capacity	7.5 m tpa
Milling Capacity	2.5 m tpa

This was optimized with Four-D and 40 shells were defined. The relationship between total pit size against value for each design shell was studied using FDAN, the Four-D analysis program. It is shown graphically overleaf.

¹ I have chosen to use a 15% discount rate throughout this paper as it emphasises the impact of the time value of money. Currently 10%, 7% or 5% discount rates are commonly used in Australia, where the economy is relatively stable, with low growth and low inflation. A higher discount rate is usually used to ensure safer returns in times/areas of greater economic risk, such as high inflation, and/or significant sovereign risk. Whilst high discount rates will produce a lower net present value for a project, they will favour having a greater return early in the project life (i.e. faster payback).

Graph of Value versus Size



We will select pit shell 29, which is optimal in both undiscounted cash flow and the “best case” schedule (i.e. mining from the inner most shell outwards a single shell at a time). A summary of the key results is shown below.

Summary of Pit 29

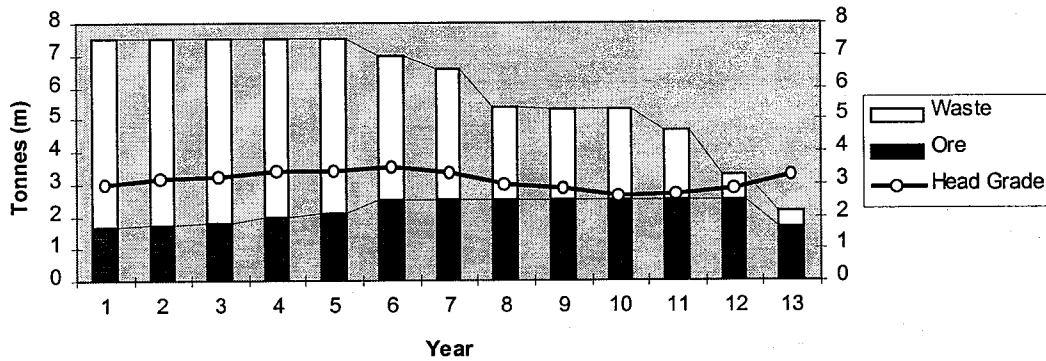
Total Rock	Total Ore	Head Grade Au (g/t)
77,174,125	28,506,600	3.08

	Cashflow	Life (years)
Undiscounted	US \$ 480 m	-
Worst NPV	US \$ 196 m	12.66
Best NPV	US \$ 286 m	13.06

Investigating the Mining and Milling Schedules

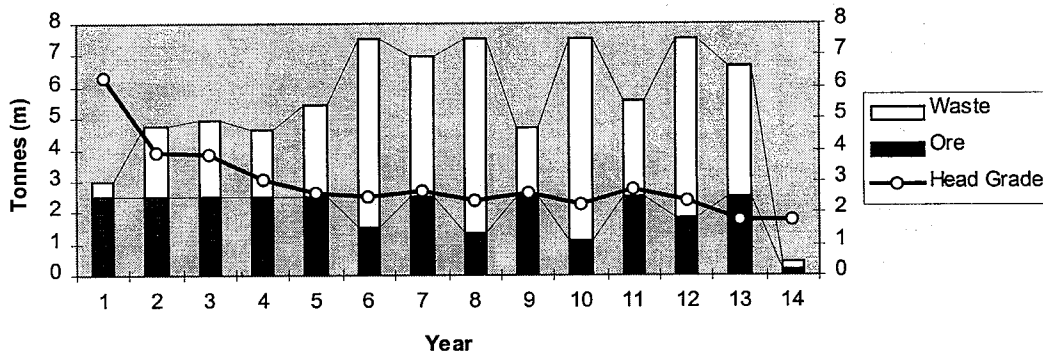
The worst case schedule is mining limited at the start of the project until period 6 when the mill becomes the controlling factor.

Worst Case Mining Schedule



The best case schedule manages to fill the mill in the early years and has better starting head grades.

Best Case Schedule



Both schedules suffer from periods of insufficient ore available to fill the mill.

We can generate Opti-Cut data when we specify only a single schedule (i.e. using only one of the worst, best or specific schedule options). This produces an economic text file and a sequence text file based on the defined FDAN schedule.

You need to have an Opti-Cut=Yes line in your system block of the FD.INI file, you will then be prompted during the FDAN run to also export the files required by Opti-Cut. Listing 1 in the appendix is a typical FDAN log files used to prepare the files for Opti-Cut. Listing 2 is an example of an Opti-Cut economic text file.

Trying to "High Grade" the Top Down Mining Plan

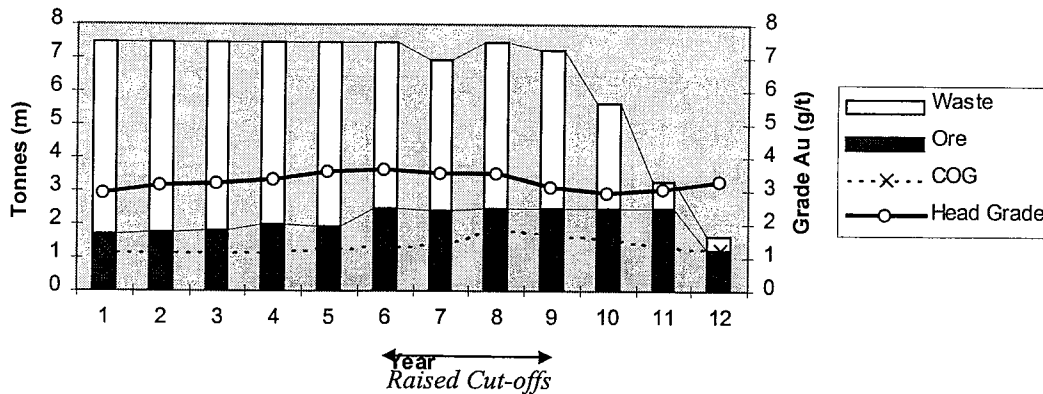
We can now use Opti-Cut to investigate the impact of increasing cut-off grades above the marginal break even of 1.15 g/t. The so-called worst case is simple to design and schedule. The full pit is mined and each bench must be fully removed before the mining commences on the next lower bench. In our example, even though the average strip ratio is only 1:3 and our proposed mining capacity is 3 times our milling rate, the early years see the mill under-utilized while waiting for the waste to be stripped.

Example summary for an Opti-Cut cashflow report

Period	Process Element	Rock	Metal Units Input	Process Tonnes	Strip /Feed Grade	Optimal Element Cut-off	Costs and Income Cash Flow	NPV Discounted Cash Flow
	Rock			77174125	2.04		-92608950	-45457937
	MILL	ORE		25354897			-304258769	-131984323
		GOLD	83439178		3.29		868288949	376714128
	Internal rate of return %				N/A			
	Total number of years				11.50		471421230	199271867

NOTE: Comparing the above results with those based on marginal Cut-offs, (Total number of years 12.68, discounted NPV 195758047) shows that the Opti-Cut method gives an improvement in NPV of 1.8 % This amounts to an increase in NPV for this project of 3513820

Worst Case Schedule & Opti-Cut Cut-off Grades



It is only in the later years that Opti-Cut can make much improvement and it does this by raising the cut-off grade (COG) in years 8, 9, 10 and 11. This shortens the mine life slightly but the full mill and higher grades do give a 1.8 % improvement in present value. Sub-grade material mined during this time is unfortunately thrown away², but trying to mill this material would have displaced better grade ore and this delay would have cost some potential revenue. (The delay cost is \$3.5 million in today's dollar terms.)

² This is sometimes called **High Grading**, since only the highest grade ore is taken. However the term must be used cautiously as it is also often used to describe situations where the remaining mining sequence is made uneconomic, or sterilized, because the "eyes have been picked out" of the best ore. The term thus has "rape and pillage" connotations to many. Clearly this is not the case with the Opti-Cut result, so I will only use the term "high grading" in quotes when I am referring to an Opti-Cut schedule.

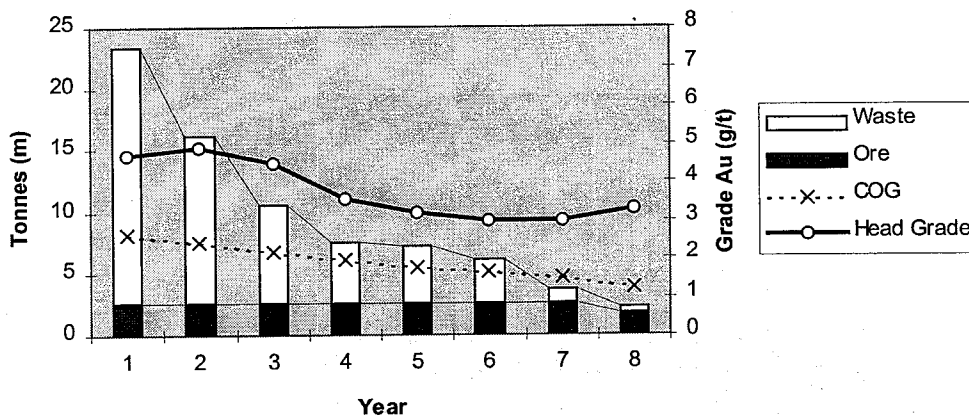
Removing the Mining Limit

If we have read and absorbed the wisdom in Ken Lane's book, we will know the classic method to improve the schedules is to completely fill the mill at all times and this is most easily achieved by removing the limit on mining capacity.

Period	Process Element	Rock	Metal Units Input	Process Tonnes	Strip /Feed Grade	Optimal Element Cut-off	Costs and Income Cash Flow	NPV Cash Flow
	Rock			77174125	3.01		-92608950	-62770504
	MILL	ORE		19267895			-231214745	-131746507
		GOLD	72516379		3.76		754623564	454056834
		Internal rate of return %			N/A			
		Total number of years			7.71		430799869	259539823

NOTE: Comparing the above results with those based on marginal Cut-offs, (Total number of years 11.41, discounted NPV 224905287) shows that the Opti-Cut method gives an improvement in NPV of 15.4 % This amounts to an increase in NPV for this project of 34634537

Opti-Cut Schedule with No Mining Limit



This is a great improvement in the present value. The mine life is substantially shorter but the mill is always full and the head grade nicely declines with time.

However, our Managing Director doesn't want a plan where we are committed to going flat out mining at close to 25 million tonnes per annum in year one, and then having the fleet hanging around doing very little after year three. If we cannot convince him to use contractors, we must obey his 7.5 million tonnes per annum mining limit.

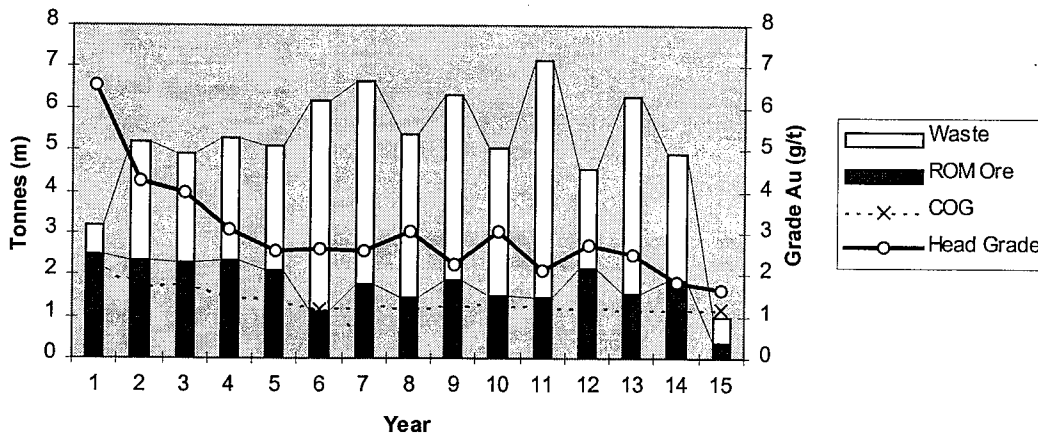
Can the Best Case be Improved?

The best case schedule involves starting mining in the innermost design shell, mining this out and then moving on to the next shell. This makes considerable sense economically because mining starts in the highest grade and lowest stripping pits, which have the highest profit. However such a sequence is normally impractical since the Four-D shells can be as thin as a single block in width, making access and manoeuvring mining equipment difficult or impossible. Ignoring the practical problems for the moment, let us see if Opti-Cut can improve the present value of the best case schedule.

Period	Process Element	Rock	Metal Units Input	Process Tonnes	Strip /Feed Grade	Optimal Element Cut-off	Costs and Income Cash Flow	NPV Discounted Cash Flow
	Rock MILL	ORE		77174125	1.89		-92608950	-35640016
				26720072			-320640865	-139558990
			GOLD 85463644		3.20		889356041	459464958
			Internal rate of return %		N/A			
			Total number of years		14.17		476106226	284265953

NOTE: Comparing the above results with those based on marginal Cut-offs, (Total number of years 14.61, discounted NPV 281362146) shows that the Opti-Cut method gives an improvement in NPV of 1.0 % This amounts to an increase in NPV for this project of 2903806

Best Case Schedule with Optimized Cut-off Grades



In simple terms the present value is improved by only 1%, around \$2.9m, in percentage terms this increase is only about half of that achieved by optimizing the cut-off grades for the worst case. The mill is seldom fully utilized during the last two thirds of the mine life, which has been extended.³ The small improvement is brought about by getting a better head grade in the first four years. So the improvement realized by using Opti-Cut seems to depend on the sequence it is given. This is a very important point which we need to investigate further.

³ The reasons for the longer mine life are discussed later under the topic **Differences between Four-D and Opti-Cut**. This somewhat surprising result has occurred because there are many very small mining increments and Opti-Cut must satisfy its constraints for each increment, whereas FDAN only has to satisfy them over a whole period (a year in this case).

Bringing in a Low Grade Stockpile

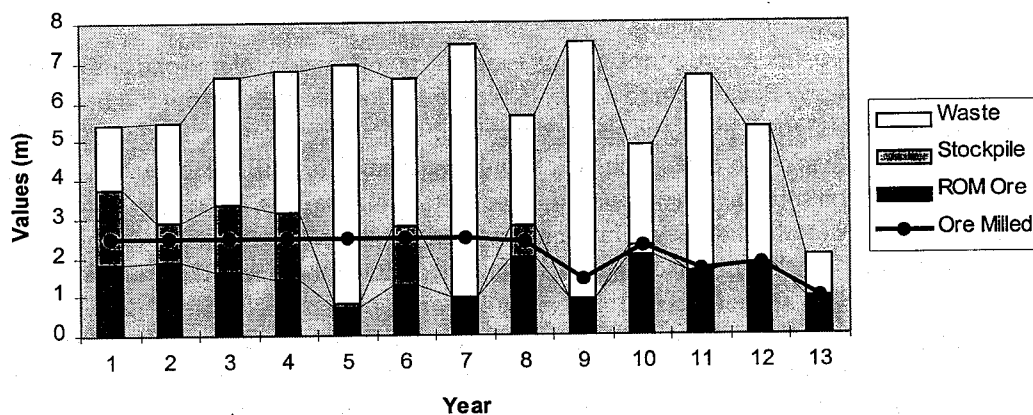
Using a stockpile to smooth over “stripping hurdles”⁴ simply involves adding a few lines to the economic text file.

```
SP ORE 0 0.80
SPD Gold R 100
SPD Gold I 1.23
```

The SP line firstly defines the type of rock to be stockpiled (ORE in our case), the initial stockpile size and a material rehandling cost. The two SPD line define recovery of metal from the stockpile (100% in our example) and a minimum cut-off to send to the stockpile which can be computed so as to pay for both processing and rehandling.

$$\text{Low Grade Stockpile Cut Off} = \frac{\text{Processing Cost} + \text{Rehandling}}{\text{Price} \times \text{Recovery}}$$

Best Case Schedule with Opti-Cut Cut-offs & Stockpile



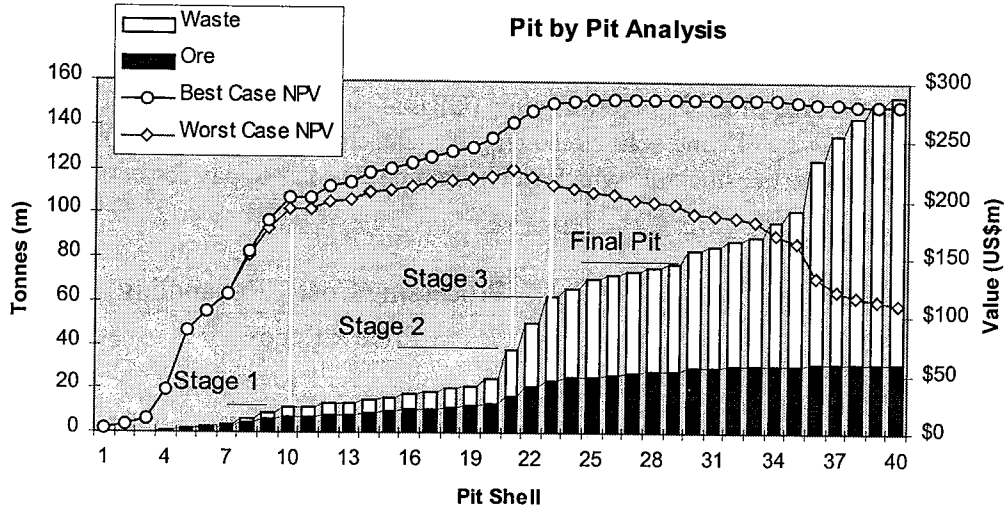
The shaded bars show the ore mined and the heavy line shows the ore milled. The extra low grade ore stockpiled in years 1 to 4 is almost sufficient to carry us through the lean years 5 and 7.

What we need to try now is to bring forward some waste stripping to avoid the “stripping hurdles”. This can be achieved by having fewer and larger slices as we move out from the inner pit shells and start work on stripping outer slices before completing the inner shell. This form of incremental mining is usually called cut-back or pushback.

⁴ “Stripping hurdles” refers to periods of very high strip ratios, where the amount of waste to be removed is so large that only a small amount of ore can be mined and this is not sufficient to satisfy the mill capacity.

Using Pushbacks

Four-D allows us to select specific shells to act as pushbacks and then define the number of benches which an inner pushback can advance before the next pushback can be started.



Selecting the best shells for pushbacks requires a wide range of practical considerations and is beyond a full explanation here. I will limit my discussion to a simple “first pass” guess at selecting the best shells. We know that pit 29 will be the final design. This contains approximately 80 million tonnes of rock to be mined and we would like to have four pushbacks, so each pushback should be around 20 million tonnes. Looking at the above graph, we can see that an even tonnage spread would force us to pick shells in the range 20 to 23, since there is a very significant increase in total pit tonnage through this range.⁵ We also see that as the pit design gets bigger, the net present value (NPV) increases, but this increase is not smooth and there are some bumps and hollows. By selecting pit shells at shoulders (Pit 10 is a good example), it is clear that this pit increment is more profitable than slightly smaller pits and only just less profitable than the next higher pit. It makes economic sense to select pit shells at shoulders wherever possible. In our example we must compromise between these two simple approaches and pick shells 10, 21, 23 and 29. Some further experimentation can be carried out to determine a suitable lag/lead interval between pushbacks. The four benches used in our example will represent 80 metres.

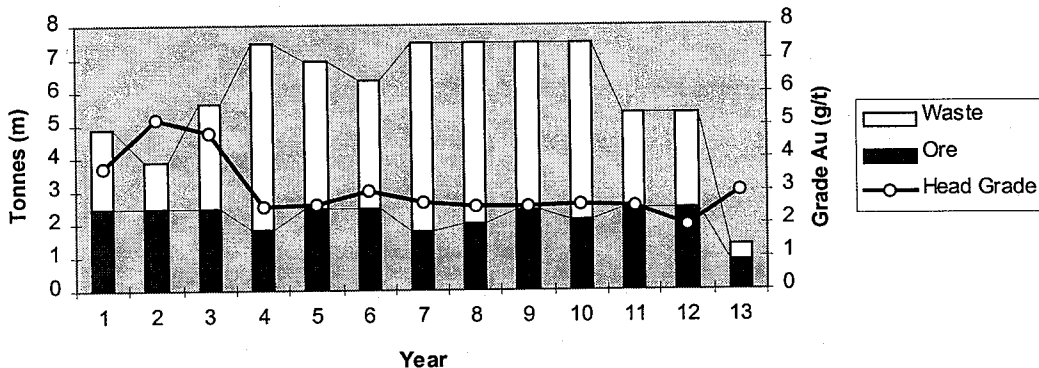
These are defined in the FDAN as follows

```

Specified_schedule?      y
Push-Backs               10 21 23 29
Lag                       4
    
```

⁵ Four-D and Four-X both have the ability to design more “infill” shells for specific “metal cost of mining” or “revenue ratio” values. In extreme cases such as this, you may wish to design a few more shells just to help scheduling. These shells probably add nothing in terms of improving sensitivity analysis and they will make the optimization slower, but may give you a wider choice for selecting shells for pushbacks.

Pushback Schedule



This has achieved the desired goal of bringing a reasonable amount of waste stripping forward but the mill is still not running at full capacity for much of the latter part of the mine life.

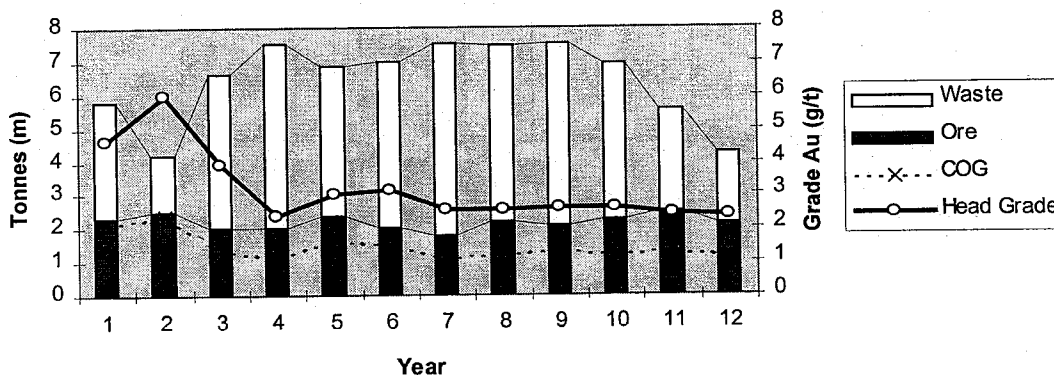
Refining the sequence

We can again evaluate the new sequence using Opti-Cut in an attempt to “high grade” and alternatively stockpile sub-grade.

Period	Process Element	Rock	Metal Units Input	Process Tonnes	Strip /Feed Grade	Optimal Element Cut-off	Costs and Income Cash Flow	NPV Discounted Cash Flow
	Rock			77174125	1.96		-92608950	-41262302
	MILL ORE			26106095			-313273136	-142631920
	GOLD		84393513		3.23		878219992	454398849
	Internal rate of return %				N/A			
	Total number of years				11.85		472337906	270504627

NOTE: Comparing the above results with those based on marginal Cut-offs, (Total number of years 12.56, discounted NPV 264077907) shows that the Opti-Cut method gives an improvement in NPV of 2.4 % This amounts to an increase in NPV for this project of 6426720

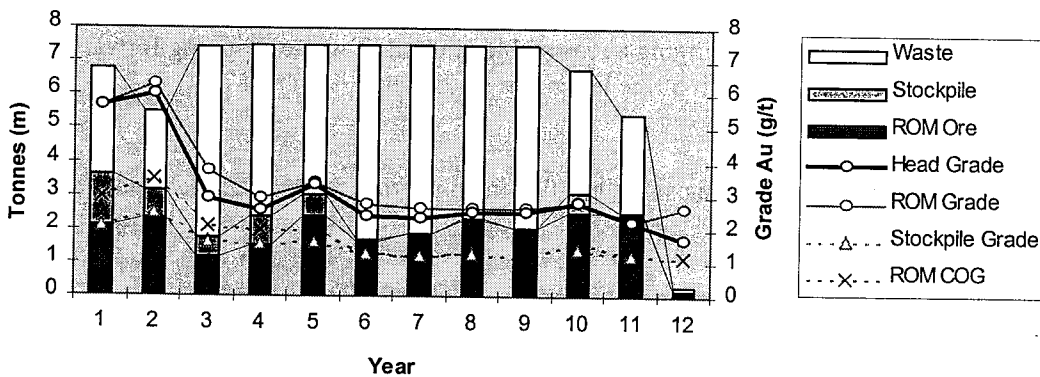
Pushback Schedule with Opti-Cut



Period	Process Element	Rock	Metal Units Input	Process Tonnes	Strip /Feed Grade	Optimal Element Cut-off	Costs and Income Cash Flow	NPV Discounted Cash Flow
Rock				77174125	2.43		-92608950	-43794982
MILL	ORE			27729298			-332751577	-154063456
	GOLD		86979288		3.14		905128216	479658957
	Stockpile additions			5202728				
	Stockpile deductions			5202728			-4162182	-1991871
	Internal rate of return %				N/A			
	Total number of years				11.33		475605507	279808648

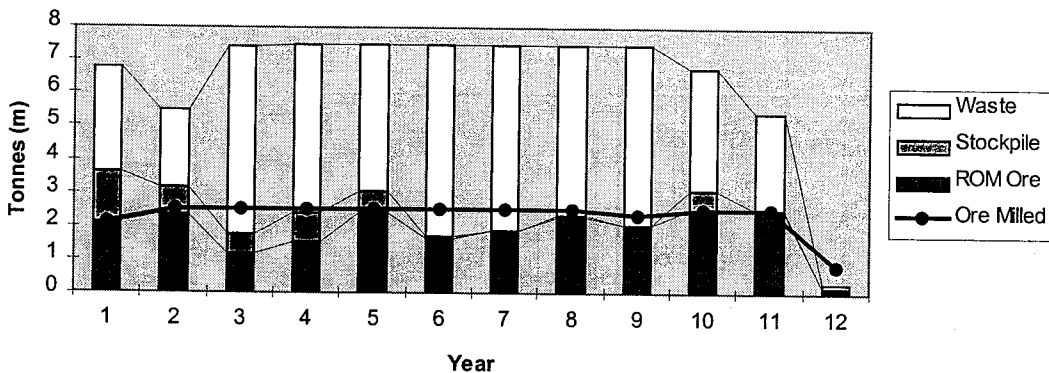
NOTE: Comparing the above results with those based on marginal Cut-offs, (Total number of years 12.56, discounted NPV 264077907) shows that the Opti-Cut method gives an improvement in NPV of 6.0 % This amounts to an increase in NPV for this project of 15730742

Pushback Schedule with Opti-Cut Cut-offs & Stockpile



A truly amazing thing has now occurred. Opti-Cut has balanced out both mining and processing (see graph below) within the physical constraints and has done this as well as improving the present value by 6%, a very respectable \$15.7 million. This is an important feature of Opti-Cut. When it is given a good sequence it can yield better improvements in the present value and will tend to balance mining and milling.

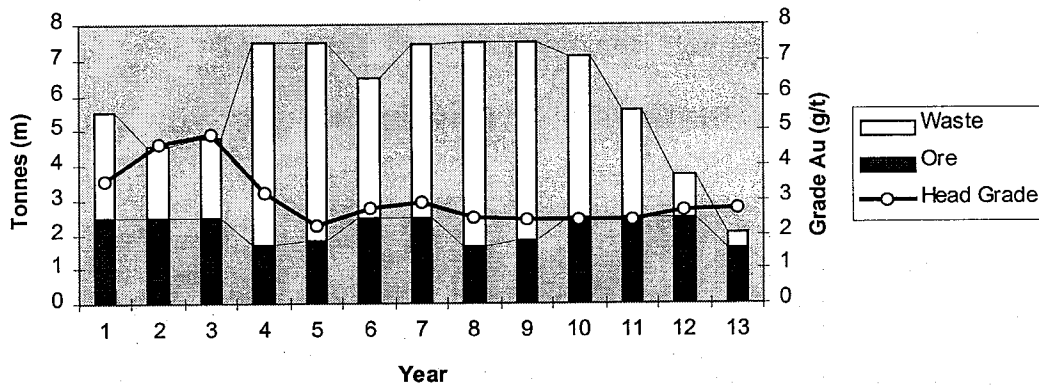
Pushback Schedule with Opti-Cut Cut-offs & Stockpile



Practical Mining Widths and Access Considerations

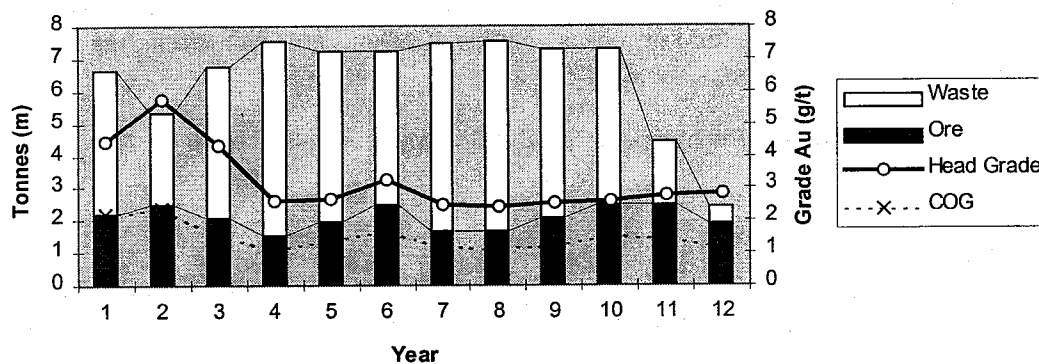
Largely due to constant user requests, Whittle Programming has developed a simple utility program FXMW to take care of the geometric requirements of minimum mining widths when developing a pushback and ensuring contiguous access to each section. After running the program, we get a new results file with only four shells. The present value of this new pit is approximately \$253 million, so these practical constraints impose a cost of approximately \$12 million in today's dollar terms.

Practical Pushback Schedule



This sequence can again be exported to Opti-Cut and cut-offs optimized in a similar fashion to the previous steps.

Practical Pushback Schedule and "High Grading" with Opti-Cut

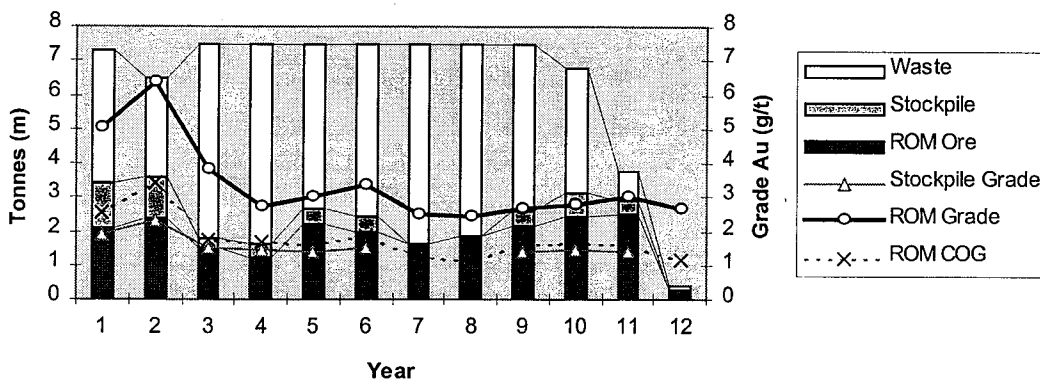


The mine life is again shortened and the head grades in earlier years are higher but the mill is still not filled at all times. Stockpiling can again be introduced to overcome this problem.

Period	Process Element	Rock	Metal Units Input	Strip Process Tonnes	Optimal /Feed Grade	Costs and Element Cut-off	NPV Income Discounted Cash Flow
	Rock			77174125	2.48		-92608950
	MILL	ORE		27811194			-333734328
		GOLD	87077626		3.13		906151542
		Stockpile additions		5646842			
		Stockpile deductions		5646842			-4517473
		Internal rate of return %			N/A		-1985995
		Total number of years			11.67		475290791
							269177319

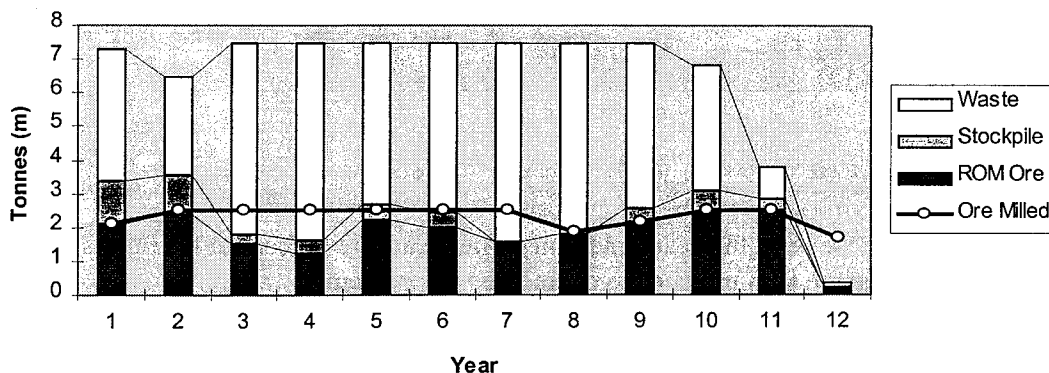
NOTE: Comparing the above results with those based on marginal Cut-offs, (Total number of years 12.90, discounted NPV 251578687) shows that the Opti-Cut method gives an improvement in NPV of 7.0 % This amounts to an increase in NPV for this project of 17598632

Practical Pushback Opti-Cut Schedule with Stockpile



Whilst this is now both practical and an excellent improvement, we have had to bring some waste stripping from the final pushback stage into the third pushback and this means we are again struggling for ore because of the limitations of the mining rate in years 8 and 9.

Practical Pushback & Opti-Cut Schedule with Stockpile



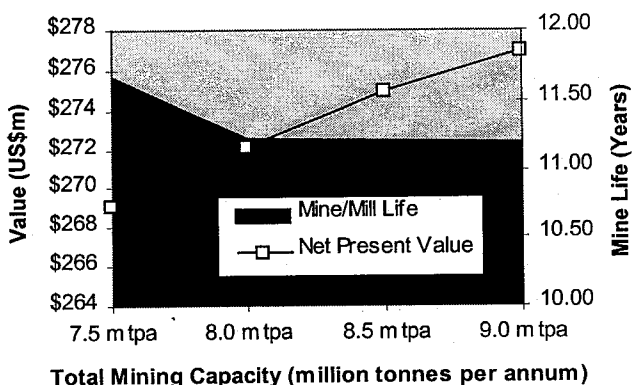
We can now again look at the mining rate with Opti-Cut to see if "tweaking" the mining capacity, by making small incremental changes, can have a reasonable return in terms of present value. In this case we will run with three additional increments of half a million tonnes each.

Effect of Small Incremental Changes in the Mining Capacity

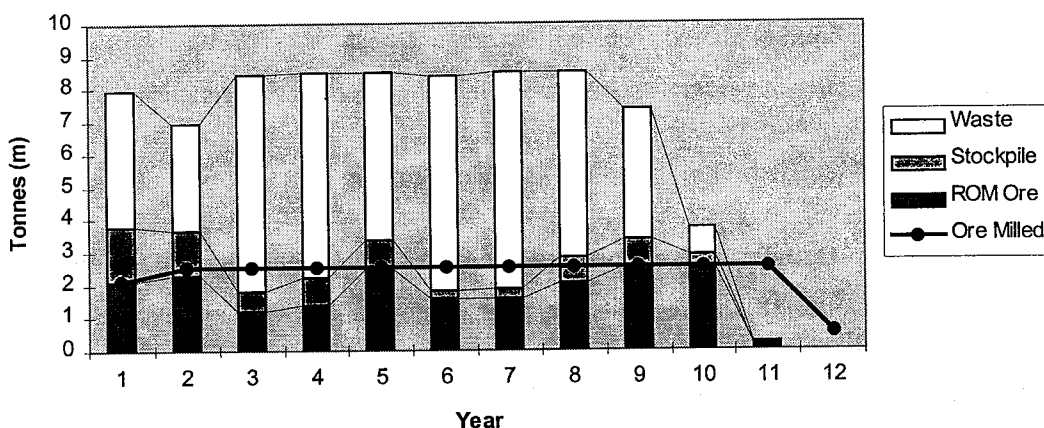
Limiting Mining Rate	Net Present Value	Mine/Mill Life
7.5 m tpa	269,177,319	11.67
8.0 m tpa	272,188,891	11.23
8.5 m tpa	275,015,733	11.21
9.0 m tpa	276,946,341	11.20

It is now a much easier task to convince the Managing Director that a small increase in mining capacity is justified. He can see that both the mill and mine are running at full productivity and, with his own style of quick back of the envelope guess-timation, he decides the 8.5 million tonnes per annum option is best. He is also impressed by our scheduling and is happy about an 11 year mine life.

Present Value, Mining Capacity and Mine Life



Practical Pushbacks with Stockpile & 8.5 m tpa Mining Rate



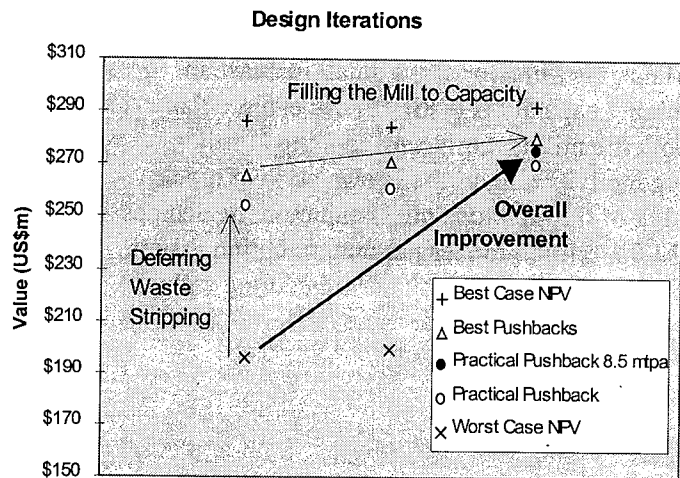
In our very simple single metal example, we have been able to significantly improve on a net present value of \$196 million for a straightforward top down mining sequence. A practical set of 4 pushbacks which obey mining width and access constraints together with a single low grade stockpile could make the project worth \$269 million. This is a staggering \$73 million or 37% increase. If we increase the mining capacity to 8.5 million tonnes per annum, we can improve the net present value to \$275 million, which is a \$79 million improvement or 40%. The pushback sequence has contributed around \$57 million and the cut-off optimization a further \$16 million and the "tweaking" of the mining rate a final \$6 million.

Summary of Iterations

	Four-D	Opti-Cut "High Grading"	Opti-Cut with stockpile
Practical Pushback 8.5 mtpa			\$275,015,733
Practical Pushback	\$253,308,636	\$259,903,271	\$269,177,319
Best Pushbacks	\$265,832,140	\$270,504,627	\$279,808,648
Best Case	\$286,000,000	\$284,265,953	\$292,031,567
Worst Case	\$196,000,000	\$199,271,867	\$201,081,195

An Iterative Procedure

What we can see from this example is a series of steps that can improve a project's net present value. The initial "optimal" pit can have a range of present values depending on both practical and theoretical aspects of the way in which it is exploited. Since we require a "practical" mining sequence, we may need to follow a set of looping steps which close in on the best result.



- 1) Run the required Four-D programs to design optimized pit shells.
- 2) Run FDAN, choose the optimal pit and prepare the worst and best case schedules.
- 3) When the difference in present value of their schedules is large, look for a sequence that will defer waste stripping down the mining sequence.
 - You may need to experiment with a range of shell and lag intervals, using a specific pushback sequence in FDAN.
- 4) Export your schedule to Opti-Cut and optimize cut-off grades, trying to always fill the mill.
 - Consider stockpiles, if you are limited by your mining capacity or have a large quantity of low grades material.
- 5) Review periods where the mill is not running at full capacity.
 - Can mining rate be changed?
 - Can waste mining be deferred or brought forward?
 - Would stockpiling help you avoid the shortage?
- 6) Make sure the pushback sequence is practical, in the sense that it obeys mining width and access constraints using FXMW, the new Mining Width Program.
 - Repeat steps 3), 4) & 5) as required.
- 7) If mining capacity is still occasionally a limiting factor, "tweak" mining throughput.
 - Try a set of small incremental steps to the mining rate.

The Four-D program FDAN is used to defer or bring forward mining. High early cash flows can be achieved by mining ore early and deferring waste till later in the sequence. Then Opti-Cut is employed to ensure a balanced mining and milling sequence that endeavours to keep the highest grade ore possible filling the mill. Finally stockpiles can be established to help overcome fluctuations in mill feed and ensure the maximum resource utilization.

Differences between Four-D and Opti-Cut

There are a number of differences that will become obvious when you move back and forth between Four-D and Opti-Cut. Firstly Opti-Cut generally computes a slightly lower NPV than the equivalent Four-D run. This can occur because of the discounting formulas used and/or the way Opti-Cut works within increments, whereas Four-D always works in whole periods.

Opti-Cut works out the scheduling limits and present value of each increment. In cases where there are many increments, it may become mill limited for some time and mining limited at other times.

Firstly it is important to check that both packages are using equivalent discounting methods, NPV discounting in Four-D and Mode 3 discounting in Opti-Cut.

1. In the Four-D INI file (FD.INI), check that the discount line in the system block is set to the NPV discounting method. The default discounting method in Four-D, called simple discounting, does not have an equivalent calculation in Opti-Cut.

```
[System]
Discount=NPV
```

2. In the Opti-Cut INI File (OC.INI), check that the discount mode line is either not present or is set to 3

```
[System]
DiscountMode=3
```

When the increments are small compared with the period length, we can expect some differences due to different capacity limitations used in each increment. Compressing the increments Sequence Text File can reduce the differences, but very large increments may reduce the effectiveness of Opti-Cut.

Conclusions

The iterative looping from FDAN to Opti-Cut, refining the FDAN scenario and back into Opti-Cut can have significant impact on how a resource is to be exploited and its net present value. In only four iterations we have achieved a substantial improvement.

Anyone used to the "linear programming" culture of Four-D, where hundreds of options are available and can be used with very little penalty in run time, may find setting up similar runs in Opti-Cut a little slow. Opti-Cut has to solve changes in constraints within each iteration and gauge the impact each change has on the full production sequence for the rest of mine life. There is a lot of detail required and each change to the sequence naturally changes the present value of the remaining resource.

Using Four-D's analysis program FDAN to help defer or bring forward mining, and then Opti-Cut to balance mining and milling sequence whilst keeping the highest head grade possible, may involve several iterations. Stockpiles can be used to overcome fluctuations in mill feed and ensure the maximum resource utilization.

References

- Lane K F, 1988 *The Economic Definition of Ore*, Mining Journal Books, London.
- Stewart D, 1991 *Aspects of Pit Optimization, Pit Design, Planning and Scheduling*. ACADS Conference on Computers in Mining.
- Stewart D & Tiver AG, 1995 *Adding \$Millions to Mine Value* Proceedings of Optimizing with Whittle Conference, Perth.
- Whittle J & Wharton C, 1995 *Optimizing Cut-off Grades* Proceedings of Optimizing with Whittle Conference, Perth.
- Wooller R, 1995 *Where Four-D Ends*, Proceedings of Optimizing with Whittle Conference, Perth.

Listings

The following listings of file contents are included to give a little more detail on key procedures used during the iterations of Four-D and Opti-Cut.

Listing 1 PBACKS.LOA An example FDAN Log File used to generate Opti-Cut files

```

PrintFile                #LVsmlc
ParametersFile           lvsml.par
ResultsFile              lvsml.res
Output_spreadsheet_data? y
SS_Definition_File      period
SS_Output_File          #lvsmlc
Run_Descn                Legendary Valley - Southern Mine Scoping & Scheduling
Example
Timecost_Ovr?           N
Initial_capital          0
COSTM                    1.2
PRICE                    11.25
PIT                      29
DISCOUNT                15
ROCK/L                   7.5m
MILL/L                   2.5m
METAL/L                  0
Modify_params?          N
Specified_schedule?     y
Push-Backs              10 21 23 29
Lag                      4
Worst_case?             n
Best_case?              n
OK?                     y
Another_request?        n
Full_print?             y
Opti-Cut?               y
Product_Name            Gold
SequenceTextFile        LVSM1c
EconomicTextFile        LVSM1c
Min-Seq?                n
  
```

Listing 2 NPV.SSD (prepares grand total summaries of each pit) An example of a Spreadsheet Definition used with FDAN to create the Size versus Value and Pit by Pit Analysis Graphs

```

GRA PIT/PI ROCK/TG WASTE MILL/TI MILL/GI
GRA OPVALUE/CW OPVALUE/DW OPVALUE/DB
  
```

Listing 3 PERIOD.SSD An example of a Spreadsheet Definition used to prepare Four-D Schedule Graphs

```

PER CASE PERIOD ROCK/TG WASTE Mill/TI Mill/GI
PER OPVALUE/CP OPVALUE/DP STRIP
  
```


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Listing 4 LVSM1C.ETX An example of Economic Text File generated by Four-D for use with Opti-Cut

ECO Legendary Valley - Southern Mine Scoping & Scheduling Example
 ! Results file was: lvsml.res
 ! These are the costs used for the FDAN run.

```

TV      0
PL     12
TC     A 0
DI              15.0
PR Gold      P      11.25
CU Gold              0.01

RO ORE        M      1.2
RO WASTE      M      1.2
MT MILL       ORE              12.0000
MTP Gold      R              92.5000
TL ROCK       A      7500000.0
TL MILL       A      2500000.0

MF DPRS       0
MF DPRL       0
MF DPPS       0
MF DPPL       0
MF DPVS       2
MF DPVL       0
  
```

Listing 5 LVSM1CS.ETX An example of Economic Text File, including a stockpile

ECO Legendary Valley - Southern Mine Scoping & Scheduling Example
 ! Results file was: lvsml.res
 ! These are the costs used for the FDAN run.

```

TV      0
PL     12
TC     A 0
DI              15.0
PR Gold      P      11.25
CU Gold              0.01

RO ORE        M      1.2
RO WASTE      M      1.2
MT MILL       ORE              12.0000
MTP Gold      R              92.5000
TL ROCK       A      7500000.0
TL MILL       A      2500000.0

MF DPRS       0
MF DPRL       0
MF DPPS       0
MF DPPL       0
MF DPVS       2
MF DPVL       0
  
```

```

!include Stockpile
SP ORE 0 0.80
SPD Gold R 100
SPD Gold I 1.23
  
```

Listing 6 PER-NSP.SSD An example of a Spreadsheet Definition used to prepare Opti-Cut Schedule graphs without stockpiles

```
PER PERIOD ROCK/TG WASTE STRIP
PER MILL/TI MILL.ORE.GOLD/GI MILL.ORE.GOLD/CO
PER VALUE/C VALUE/CD
```

Listing 7 PER-SP.SSD An example of a Spreadsheet Definition used to prepare Opti-Cut Schedule graphs with a stockpile

```
PER PERIOD ROCK/TG WASTE STRIP
PER MILL/TI MILL.ORE.GOLD/GI MILL.ORE.GOLD/CO
PER SP_1/TT SP_1.GOLD/GT SP_1/TS SP_1.GOLD/GS SP_1/TF SP_1.GOLD/GF
PER VALUE/C VALUE/CD
```