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VALUATION OF POTASH RESERVES AT THE WASTE INSTALLATION PILOT PLANT

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ABSTRACT

Monte Carlo simulation was used in conjunction with several random walk price and cost models to value potash reserves at the Waste Installation Pilot Plant (WIPP) site near Carlsbad, New Mexico. Selection of market price and product processing cost models is the critical issue discussed in this paper. Key issues and inputs to the thirty five year simulation are briefly discussed. Results for one type of potash found in the WIPP region are presented. Present value distributions for revenues from potash operations and estimated cash flows to a single firm conducting potash extraction were generated using several price/cost model combinations. A simple Wiener process was selected for annual potash market prices, and processing costs were generated using random draws from a uniform distribution. The rationale for selection of this model combination is discussed.

1 OVERVIEW

The Waste Installation Pilot Plant (WIPP) is located in Eddy County, Southeastern New Mexico near the town of Carlsbad. Projected as an underground burial area for low level radioactive waste, the WIPP site has been in various stages of completion for the last twenty years. As part of the process of activating the site, personnel from the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) evaluated oil, gas and two types of potash reserves in the area (NMBMMR, 1995). The primary end product use for Eddy County potash is agricultural fertilizer.

More specifically, resources within the sixteen square mile WIPP site, a one mile buffer zone (known as the "additional area") around the site and the two combined areas were assessed. NMBMMR provided mineral reserve estimates that were used in the value estimation process. The concern in this paper is description of the process, results and sensitivity analysis associated with evaluation of combined assessed potassium chloride (KCl) reserves within the WIPP and additional area. If WIPP indeed opens and begins storing waste, all mineral resources within the combined area are assumed to be inaccessible. Thus the need for valuation of the mineral resources at the site.

The policy implications of both this study and the overall NMBMMR effort are potentially very significant. Although mining as a whole is declining in New Mexico, the industry still provides some of the highest wage jobs in the state and is the employment sector with the highest average wages. Southeastern New Mexico, with (among other minerals) potash and oil and gas resources, is an area of the state that is very sensitive to changes in the mining industry and its economic climate. Potash operators have been in the area since the 1920s. Oil and gas producers are enjoying something of a resurgence in the area, and the issue of mining access to public lands has been the cause of some conflict between regional oil and potash producers.

Potash mining in the Eddy County area is conducted underground. Burrowing machines extract the raw ore, which is processed into potash product on site. Several operators are currently mining in the vicinity of the WIPP site. For this study, it was assumed that potash mining within the combined area would begin one year after a decision to *not* open WIPP. No new development costs are directly associated with this scenario. All costs associated with mining WIPP area potash are included in the per-ton rate obtained by NMBMMR consultants from area operators.

Data presented here represent results from 1560 simulation runs each. An individual simulation run consists of a 35 year sequence of data resulting from randomly generated annual prices and costs in conjunction with NMBMMR-provided mineral extraction data. These simulations were conducted using Microsoft Excel on a personal computer with a 133Hz Pentium processor and 16 megabytes (mb) of RAM. The main simulation models each occupy about 10 mb of memory.

A discount rate of 15% was used as the base case for evaluation of potash resources, which was and is a point of some controversy. This issue is discussed below.

Operation cash flow net present values (NPV) were calculated from the perspective of a single firm. They represent the average of the present values of all the cash flows associated with each simulation run.

Total expected revenue present values (PV) were calculated as an indication of the overall worth of KCl deposits. Revenue values are also expected present values, as they are the average of the expected present values generated by each simulation run. Bureau of Land Management (BLM) specifications were used to determine mining variables which in turn impacted estimates of the tonnages of various grades of KCl present and the raw material tonnage required for a given level of market demand. The full potash valuation analysis is available in Anselmo (1996).

2 ISSUES AND ASSUMPTIONS

KCl reserve estimates for the WIPP area were provided by consultants and specialists at the New Mexico Bureau of Mines and Mineral Resources, and the simulation model was constructed. Key model inputs, in addition to reserve data, included the discount rate, annual potash production level, market price of the resource, the unit cost of extraction, and tax and royalty rates. Development of a method to anticipate future market prices and operating costs for potash was a key issue. Time units were years, and the time frame simulated was 1995-2030.

Forecasting in cases like this is as much an inexact art as a science, particularly when the forecasting horizon is thirty five years. Thus, although historical prices for Eddy County potash were modeled using time series methods, a simulation approach was used to value these resources. Annual market prices and costs were simulated using several random walk methodologies (Karlin and Taylor, 1975), which are discussed below. Depletion was calculated using the standard percentage methodology, which may be found in Stermole and Stermole (1993).

Key assumptions and features associated with the potash cash flows used in the simulation include:

All calculations are performed from 1 January 1995. KCl extraction activity is treated as a capital project that was evaluated from 1 January 1995 and undertaken beginning 1 January 1996. The decision to go forward with any potash mining and development venture was considered from the perspective of 1 January 1995.

Revenues were treated as if realized monthly, and taxes and royalties were treated as if they are paid on a quarterly basis.

The Monte Carlo simulations generated numbers for each year for the present market value of the reserves and the present value of the total cash flow for each simulation run. As is standard practice in financial analysis (Levy and Sarnat, 1994), cash flows attributable to the decision to mine potash are the sum of income after taxes, depreciation and depletion less annual investment (in this case, the annual investment is zero). Data were also generated for expected present values for severance taxes, state and corporate taxes and royalties. These may be found in Anselmo (1996). We briefly discuss tax and royalty issues below because of their effect on expected cash flows.

2.1 Discount Rate

Results presented here are associated with a 15% nominal discount rate. 15% was also used in the last major analysis of WIPP mineral reserves (Weisner, Lemons and Coppa, 1980). Estimation of discount rates for risky investment projects (the perspective taken in this study was one of viewing potash exploration activity as a risky investment project) is generally a difficult and (potentially) inexact process. Though there is detailed knowledge regarding the location and grade of potash deposits in the area, there is some uncertainty regarding the future market price of potash products. Along with the long time horizon, price uncertainty may be considered a major source of potash mining operation risk.

The 15% rate used in the results presented above is reasonable in light of the short and long-term market uncertainties faced by potash producers (Searls, 1992). Although the development risk associated with potash deposits in the WIPP area is low, there is market price risk that is faced by operators. Extensive KCl (also known as sylvite) deposits in various stages of development exist around the world. Further, any investment situation as long-term in duration as a potash mining operation faces considerable interest rate risk - the risk that more favorable return opportunities will arise over the life of a project.

A precise discount rate for different firms operating in the WIPP area is difficult to estimate (particularly in the absence of debt/equity ratio and other data for said firms). So, although pinpointing a discount rate for a 35 year project is quite risky in and of itself, current levels of activity in the region and market factors point to a 15% nominal discount rate as a reasonable estimate for Carlsbad area potash operations.

2.2 Annual Production Levels

Because potash is mined in a linear fashion over many years, present value-based analyses of the viability of potash operations will be controversial because large future cash flows are severely discounted. Market demand is a major factor impacting annual production levels. In the original study, 450,000 tons of KCl was obtained as a reasonable average annual demand figure from area operators. Product output levels of 600,000 and 1,000,000 tons (annual demand) were also used to assess the sensitivity of the original analysis to annual market demand. At the time this sensitivity analysis was conducted, we were interested only in the sensitivity of the base case results to increases in annual production levels.

Increasing annual demand levels results, as one might expect, in higher expected values for the relevant variables. The key is whether assuming a particular level of market demand is appropriate. Demand for KCl as a major component of fertilizer is far from certain at any level, a point which is discussed further below.

2.3 Market Prices

Annual prices and mining costs per ton for sylvite (KCl) were generated using random walk methods. Two types of random walk processes and a Geometric Brownian Motion model were used. Historical, confidential Eddy County sylvite prices were analyzed using time series techniques to show that these historical prices may be modeled as a random process. However, the amount of available Eddy County data was limited, which precluded the use of a time series model to actually estimate thirty five years of future market prices. A national KCl price index covering 1965-1993 was provided by the NMBMMR. Historical Eddy County potash prices tracked the index. However, a limited number of years of Eddy County prices were available and the prices and index figures were not the same. An estimate for the end of 1994 market price was obtained from area operators (and later verified as reasonable), and was used as the 1995 market price and the point of departure for the price simulations.

As with other commodities, the weak-form market efficiency assumption is appropriate here, which partially justifies the use of Markov processes. The independence of year-to-year price changes assumption is not as evidently congruous, but in the longer term (over a 35 year period, for instance) it probably holds. The third key assumption is that annual price changes are normally distributed. Based on the analysis of historical annual price data conducted for this study, we cannot refute this assumption. The trouble with this assumption is that very large price (and cost) swings are possible. In fact, negative prices and costs are theoretically possible. However, since all data reported are the result of 1560 simulation runs, potential negative price (and cost) impacts in individual simulation runs are negated.

Individual price paths have a tendency to wander and vary considerably. However, the number of runs conducted resulted in a average KCl price and cost figures for all price/cost models considered that were nearly identical to the time zero price and cost. Price and cost standard deviations depended on the model used. Annual changes in potash prices (as measured using Eddy County KCl data and the 1965-1993 national KCl index) exhibit a 4% average nominal return and a 0% average real return. These averages were essentially the same regardless of whether a geometric or arithmetic mean was computed.

2.4 Operating Costs

After much discussion (in the absence of historical data), the uncertainty associated with annual operating costs was expressed as plus or minus 10% of the previous year's per ton operating cost. Thus, a uniform distribution was initially used for annual per-ton operating cost, with the mean for any one year the cost generated for the previous year. All non capital annual costs were aggregated into the operating cost figures provided by consultants and area operators.

As noted above, the average, inflation adjusted change in the analyzed historical potash prices was zero. Although mine productivity (in terms of tons produced per potash mine worker) has been essentially flat since 1965 (*Economic Report of the President*, 1994), area operators have expressed confidence in their abilities to offset the effects of inflation on operating costs in both the near and distant future.

2.5 Taxes and Royalties

The state of New Mexico assesses severance taxes on revenues attributable to minerals extracted within the state. Rather than attempt to predict factors which might contribute to alterations in the severance tax rate, a rate of 1.25% (based on current tax law) of potash revenues was used for the study period. A royalty rate of 2.5% of revenues, provided as a current estimate by experts in this area, was used in the simulations for similar reasons.

Capital investment and other tax incentives that mining companies may periodically receive from political entities were likewise ignored in this work. In addition to presenting a major limited data prediction problem, consideration of tax incentives would involve acquisition of additional proprietary data from area producer firms. An average corporate tax rate of 34% was therefore used.

All taxable income is assumed to be New Mexico income for state tax purposes. New Mexico tax rates are 4.8% of taxable income under \$500,000, \$24,000 plus 6.4% of the excess over \$500,000 for amounts between \$500,000 and \$1,000,000 and \$56,000 plus 7.6% of the excess over \$1,000,000 for taxable income over \$1,000,000.

Of course, the key here is that the expected tax values generated in this study represent expected opportunity losses to the various governmental entities under the specified mining and development circumstances if WIPP comes on line. These numbers were also essential in computation of expected annual cash flows.

3 MODELS AND OUTPUT

3.1 Models

A Monte Carlo sampling method was used to generate random walk price and mining cost data for the time period 1995-2030, and three price/cost models were used in this evaluation. Model 1 is a version of a simple Wiener price process combined with a Monte Carlo method for operating costs that is based on information provided by area potash firms. This was used as the base case for several reasons. First, historical operating cost data of any kind are proprietary and were unavailable. Second, limited and inconsistent data made price variance estimation difficult. Third, firms did indicate to NMBMMR consultants that annual per-ton operating costs tended to be between 90% and 110% of the previous year's per-ton cost.

We define P_t and C_t as per ton price and cost in year t, respectively. z_t is a normally distributed random variable with mean 0 and standard deviation 1 that is generated using random numbers in the simulation runs (this value is estimated as the sum of twelve uniform [0,1] random variables minus 6) and σ denotes standard deviation. Random variable y_t is uniformly distributed on the [0,1] interval, and is generated using the RAND() comment in Excel. Price/cost model 1 is written as follows:

$$P_t = P_{t-1} + z_t\sqrt{t}$$
$$C_t = .9C_{t-1} + .2y_tC_{t-1} \qquad (1)$$

In model 2, where P_0 (\$75/ton) and C_0 (\$18/ton) are the time zero market price and per-ton processing cost, both prices and costs were analyzed using Wiener processes, as shown below:

$$P_t = P_0 + z_t\sqrt{t}$$
$$C_t = C_0 + z_t\sqrt{t} \qquad (2)$$

Geometric Brownian Motion is often used to assess commodity prices (Dixit and Pindyck, 1994). In order to compute parameters for the price component of model 3, which were also used in the cost component, real returns on Eddy County (and the national index) KCl prices were calculated. The real return over the time period for which we had data was 0 with a standard deviation of about .167. Model 3 therefore had no mean coefficient, as follows:

$$P_t = P_{t-1} + z_t\sigma_P P_{t-1}$$
$$C_t = C_{t-1} + z_t\sigma_C C_{t-1} \qquad (3)$$

Although estimates for σ_P were obtained from the limited data, estimates of σ_C were unavailable. In the absence of historical cost data, $\sigma_C = \sigma_P$ was assumed. Two values for price and cost standard deviation were used in valuation simulations, .167 and .085. As noted above, the first value represents the standard deviation of the limited Eddy County KCl price data that were available.

3.2 Output

Key variables were the expected present value of KCl potash revenues and the expected net present value of cash flows to a single (imaginary) firm from potash operations in the WIPP area. As expected, these values did not vary according to the model used. Distribution standard deviations did vary considerably with the model used. Expected present values E(PV) and expected net present values E(NPV) and their standard deviations (noted as SD) are summarized below in Table 1 for the base production case of 450,000 tons per year. For model 3a, the standard deviation used was .167; it was .085 for 3b. Note that although expected values are all in the \$193 million range, estimate standard deviations vary considerably. In addition to the potential profitability of potash operations, a major concern throughout this process was the variability of all estimates.

Table 1: Base Case PV and NPV Results

Model	E(PV)	SD(PV)	E(NPV)	SD(NPV)
1	$193m	10m	52m	14m
2	193m	1.4m	52m	4.6m
3a	197m	72m	50m	68m
3b	192m	32m	51m	32m

Additional data for the Table 1 expected values are provided below in Tables 2 and 3. In Table 2, in which revenue data are provided (and in subsequent tables), Max and Min refer to the maximum and minimum values obtained, Med refers to the data median and Skew refers to skewness. Numbers in all Tables are rounded off.

Table 2: Additional Base Case Revenue Data

Model	Max	Min	Med	Skew
1	225m	161m	193m	-.045
2	197m	188m	193m	-.034
3a	651m	54m	187m	1.23
3b	307m	111m	190m	.41

Table 3 contains distribution data for the expected present value of cash flows to a single mining operation from combined area potash operations.

Table 3: Additional Base Case Cash Flow Data

Model	Max	Min	Med	Skew
1	90m	-14m	66m	-.338
2	67m	36m	52m	.006
3a	362m	-270m	49m	.02
3b	152m	-46m	51m	.015

Sensitivity analysis was conducted with respect to annual production levels. Tables 4 and 5 contain E(PV), E(NVP) and standard deviations for production levels of 600,000 and 1,000,000 tons per year respectively.

Table 4: 600,000 Tons Annual Production

Model	E(PV)	SD(PV)	E(NPV)	SD(NPV)
1	$257m	13m	65m	19m
2	257m	1.9m	66m	6.1m
3a	257m	91m	63m	90m
3b	257m	45m	66m	42m

Table 5: 1,000,000 Tons Annual Production

Model	E(PV)	SD(PV)	E(NPV)	SD(NPV)
1	$424m	22m	94m	33m
2	424m	3m	94m	11m
3a	428m	146m	90m	148m
3b	427m	80m	92m	80m

The models provided essentially consistent estimates for expected present values for total revenues and cash flows over the thirty five year life of the hypothetical mining project. Model selection for the final estimate is a critical issue, though, as examination of the divergent standard deviations for each estimate suggests.

Although expected present and net present values were the "bottom line" concern for most interested parties, standard deviations vary considerably across models. Model 1 was the base case. There is no evidence that any interested parties (it was necessary throughout this process to receive and consider input from any and all interested individuals and groups) are interested in either minimum or maximum variance price/cost models. This, combined with data availability and accuracy, supports the use of model 1 as the model to use for WIPP site KCl valuation analysis.

Only model 2 produced results indicating no chance of the mining operation having a negative net present value. However, the low variance associated with model 2 estimates also preclude statements about the upside potential of potash operations. The high variances associated with model 3 estimates could cause a risk averse firm to avoid WIPP area potash mining altogether. Furthermore, the uncertainty associated with model 3 variance estimates makes use of that model difficult to justify.

4 DISCUSSION

From a KCl valuation perspective, a major decision impacting the analysis once input variables are specified was price/cost model selection. The concern here has been examination of the effects of alternate models on the variance of some of the relevant simulation output data. This is a critical issue because the expectations derived from the three models under different production scenarios are close in value. The notion that model 1 is the appropriate base case model is supported by the data and circumstances surrounding this project; a major objective of this study was assessment of the validity of model 1 as the base model. As may be seen in Tables 1, 4 and 5, expected present values for the assessed variables are comparable across models. Distribution variability depends on the model selected, which makes the variance of each estimate a key variable - along with the data availability issue discussed above - in model selection.

Choice of a discount rate is also made a subjective decision because Eddy County area potash operators are either subsidiaries of large corporations or privately held entities. In either instance, firm information that would aid in the use of a conventional process (Copeland, Koller and Murrin, 1990) to determine an appropriate discount rate was unavailable. However, there was (and is) no shortage of macro-level data to aid in the discount rate decision.

There is little doubt that global demand for food, fueled by both the large and expanding global population and the rapid industrialization occurring in areas where much of the world's population lives will be increasing for the foreseeable future. Demand for food will not decline in the near or distant future unless a global catastrophe occurs. However, as Searls (1992) notes, near term demand for potash products as food-producing fertilizer is far from certain.

The random walk methods used in this study do not allow for any drastic year to year planned upward (or downward) non-random movements in these commodities prices and operating costs. This is a conservative approach that is based on several factors which impact the national and global demand for fertilizer. Farm productivity in the United States has been increasing slowly but steadily since 1965 along with the use of agricultural inputs. However, the use of agricultural inputs relative to all other inputs to the overall in the United States agricultural process (such as labor and capital equipment such as farm machinery) has remained steady since 1985 (*Economic Report of the President to Congress*, 1994). Stable domestic demand for potash based fertilizer products is a likely feature of the potash market for the (at least) near future. Searls (1992) notes that future demand increases are likely to come from outside the U.S.

Although the world population is rapidly increasing, passage of international and regional treaties such as the General Agreement on Tariffs and Trade (GATT) and the North American Free Trade Agreement (NAFTA) may have a negative impact on agriculture subsidies around the world. Stabilization or rolling back of agricultural subsidies in countries such as Japan may have a stabilizing (or, in the short term, negative) impact on global demand for potash based fertilizer products. Certainly, the near future for potash prices (despite the historical upward trend in per ton product prices) is uncertain; the more distant future is uncertain by definition.

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