DECOMMISSIONING PLANNING FOR SASKATCHEWAN'S POTASH MINES

Kenneth W. Reid [1]
Mark N. Getzlaf, P.Eng [2]

[1]Windsong Environmental Consulting
4100 45 St. South
Cranbrook, B.C.
V1C 7A1

[2]PotashCorp
122 1st Ave. South
Saskatoon, Sk.
S7K 7G3

ABSTRACT

Saskatchewan's potash producing companies are now in the process of developing decommissioning and reclamation (D&R) plans for potash mines which were in operation many years before these plans were required by provincial regulations. The major problem is to develop a plan for the extensive piles of potash tails now stored on the surface in tails management areas. There are many features of potash mining which are unique to the mining industry. These include mining operations, refining processes, waste characteristics, waste management techniques, mine life, land tenure, public concern, pre-mining environment, and environmental risks. The D&R techniques commonly employed for tails have been considered for use on potash tails piles and have been found to be unsuitable. Potash operations in other jurisdictions have not decommissioned tails piles to a standard which would be acceptable in Saskatchewan. Since there are no precedents to use as a guide, the Saskatchewan industry and regulatory agency have cooperated in developing a novel approach to D&R planning. Because of the features unique to the industry and because of the fundamental differences between the regulatory agency and the industry about the magnitude of the risk inherent to potash tails, early in the process, it was agreed to assess the acceptability of various D&R proposals through a decision process which employed cost benefit analysis. Another area of disagreement between the parties was resolved by developing and using contaminant transport models to predict the subsurface movement of brine from the waste management areas through a multilayered environment, a unique problem requiring a unique approach. The D&R planning process being employed for potash mines in Saskatchewan has been formalized through the development of a flow diagram which is being followed to arrive at a solution acceptable to all parties.

PRODUCTION AND MANAGEMENT OF POTASH WASTES

Although other minerals are sometimes called "potash", in Canada, the term is used to describe the mineral sylvite, potassium chloride (KCl). This mineral is refined from sylvinite, an ore consisting of 30-40% KCl, 50-50% common salt (NaCl) and 1-8% insolubles (insols) in the form of clay, silt, sand, and dolomite. Much of the southern quarter of Saskatchewan is underlain by horizontal beds of sylvinite at a depth of about 1000 m. (Fig 1). This mineral was deposited in the form of a series of evaporates from ancient seas.

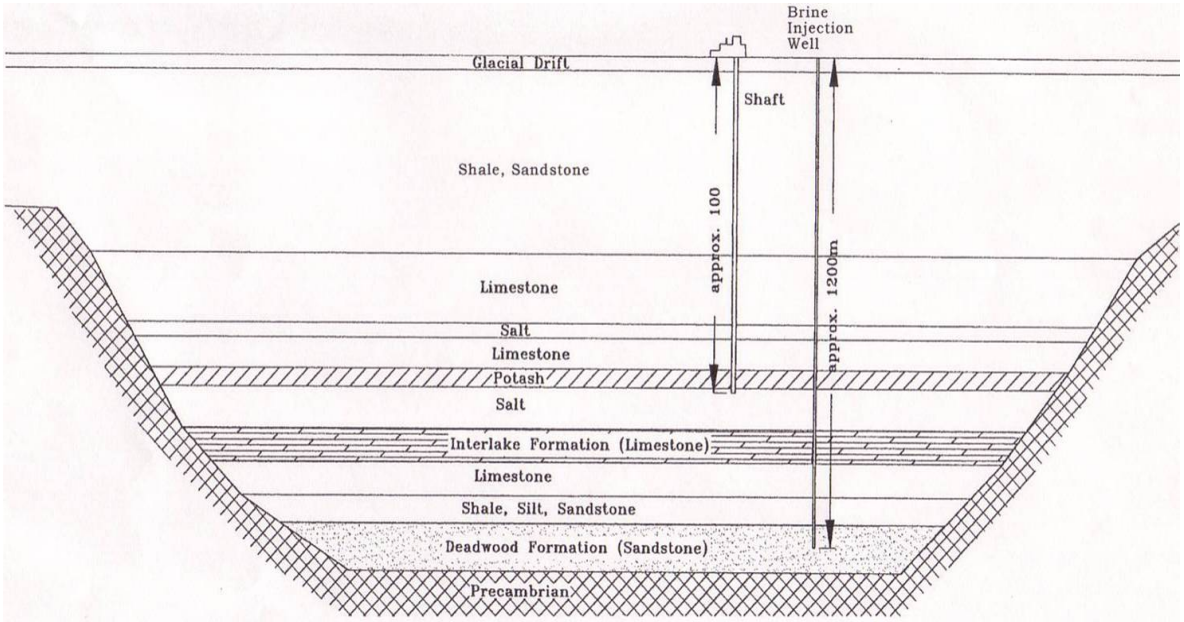

Figure 1. Potash Mining and Brine Injection Formations in Saskatchewan

There are ten potash mines in Saskatchewan (Fig 2). Of these, two are solution mines and eight are conventional. A solution mine extracts ore by dissolving it in hot water pumped from the surface into the formation, recovering the resulting brine and separating potash from salt by selective precipitation in ponds or crystallisers. In Saskatchewan, a conventional potash mine removes ore from the formation with the use of mining machines which are essentially boring devices. The extracted ore is hoisted, ground, slurried in brine and processed to remove the insols. Crystallization and/or floatation processes are used to separate NaCl (salt tails) from the potash. Insols are concentrated in a thickener before being discharged. Salt tails are debrined on a filter and slurried with reclaim brine before being pumped to the tails management area. (TMA). The insol stream may either be combined with the salt tails or may be pumped separately to the TMA. A simplified, typical flow sheet for a conventional mine is shown in (Fig.3).

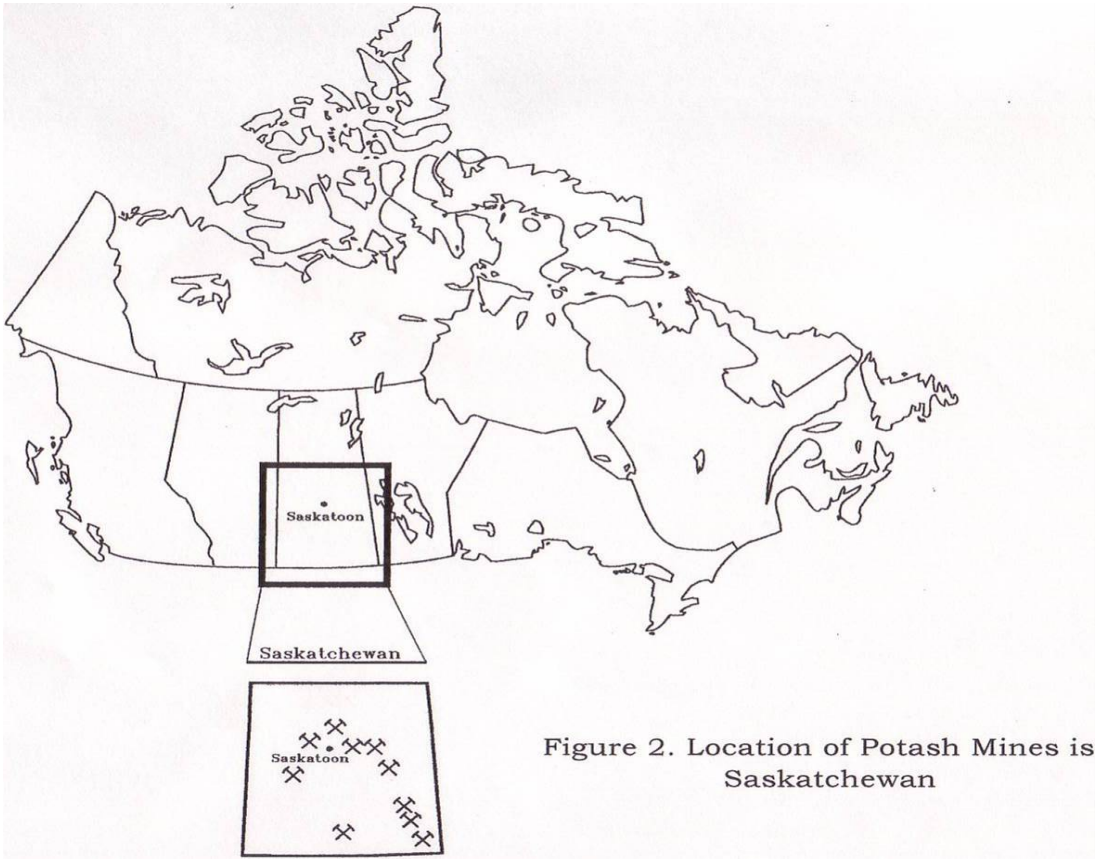

Figure 2. Location of Potash Mines is Saskatchewan

In the TMA, the salt tails slurry is pumped to the top of the tails storage pile upon which is it sphigotted (Fig.4). These piles cover the largest portion of the TMA and are up to 65 m high and 200 ha in area. The piles are in the shape of a wedge with side and back slopes of 30-40 degrees and a long slope of about 2 degrees. The coarser material settles on the upper portion of the piles where the slope is steeper, while the finer particles settle on the lower, flatter part of the slope. Where insols have been combined with salt tails, they settle at the toe of the pile where the slope is essentially flat. If insols have been discharged as a separate stream, they are pumped to a pond where they are impounded.

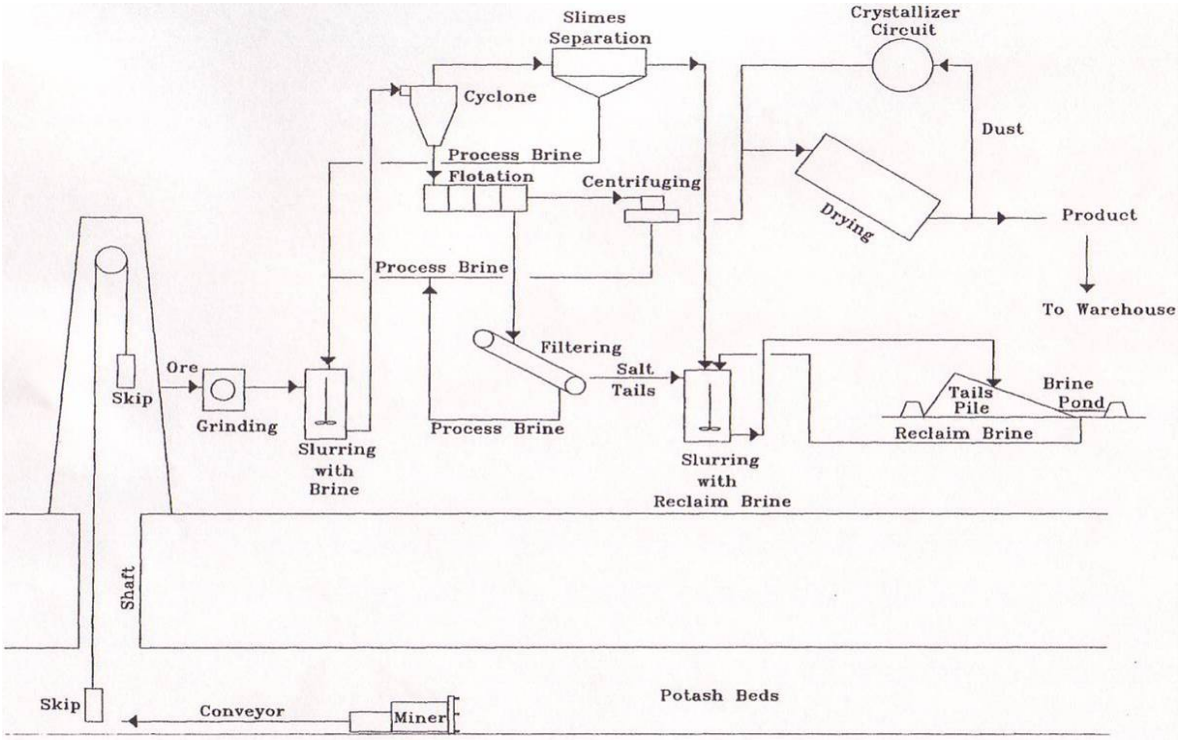

Figure 3. Simplfied Potash Production
Flowsheet for
Saskatchewan Mines

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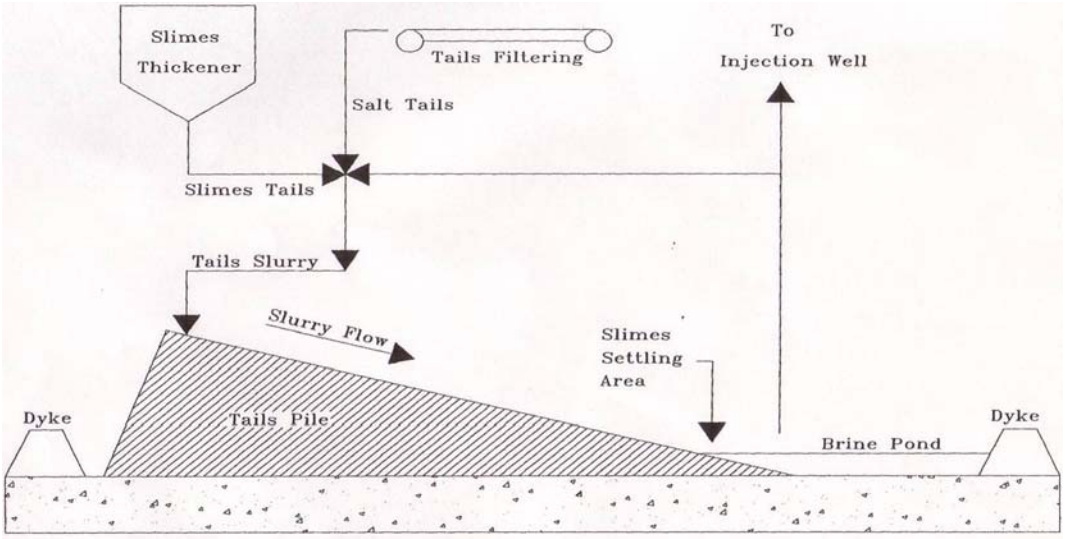

Figure 4. Solid and Liquid Waste Management Practices at
Conventional Potash Mines in Saskatchewan

The TMA is surrounded by dykes and, usually, one or more types of sub-surface seepage containment systems (Fig. 5). Brine used to transport the tails is contained in these areas along with brine formed from precipitation falling on the tails pile and run off from the mine site. This storage creates ponds usually less than 3m deep but with an area of up to 150 ha. Stored brine is reclaimed to slurry tails and for make up in the process. Although the potash refining process is designed as a closed circuit, and although evaporation exceeds precipitation in Saskatchewan, excess waste brine is produced which requires disposal. This is accomplished by injecting the excess brine into deep, naturally saline formations (Fig 1). There are no discharges to surface waters.

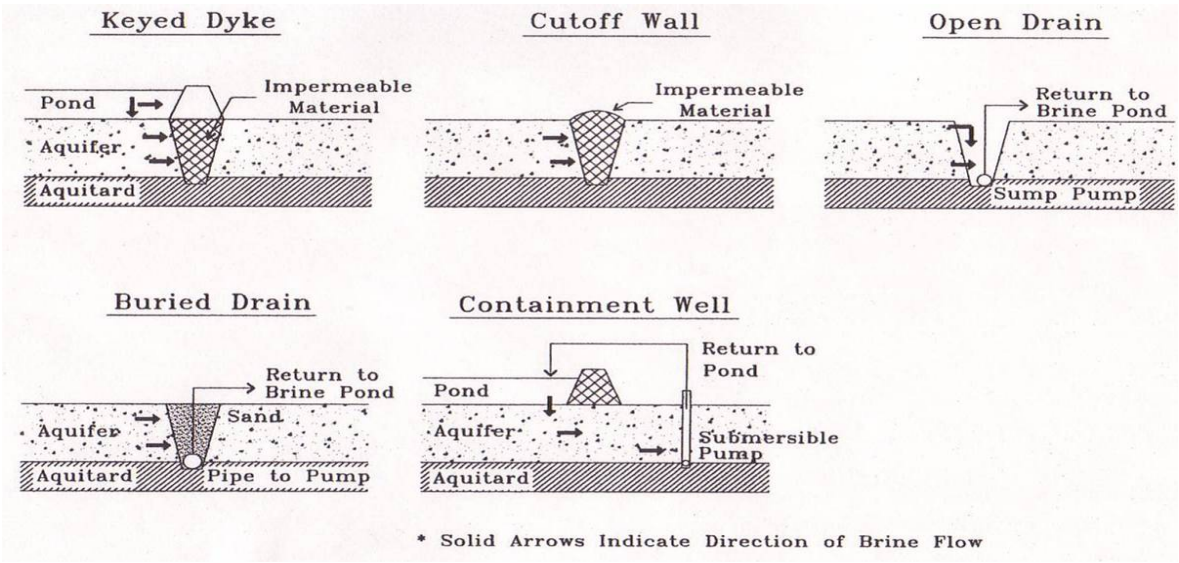

Fig 5. Brine Containment Techniques Employed by the Saskatchewan Potash Industry

ENVIRONMENTAL CONCERNS OF POTASH MINING

The reagents and wastes of potash mining are neither persistent, bioaccumulative nor chronically toxic. However, potash waste is a concern because it is predominantly salt, a material which, when present in high concentration, is detrimental to plant and aquatic life. The objective for potash operators both during the operating life and after mine closure is to prevent salt from leaving the TMA. Soon after deposition, salt tails drain to form a rock-like mass. Providing attention is paid to pile stability issues, containment of this solid material is not difficult. However, the TMA also contains large volumes of salt in the form of brine. Some of this brine enters the TMA with the solid salt tails but, in addition, large volumes of brine can be produced by precipitation falling on the tails pile. Containment of this aqueous phase salt is much more problematic than containment of the solid phase. One or more aquifers typically underlie brine ponds in Saskatchewan where ground water is a valuable resource. The major environmental concern of potash mines in Saskatchewan both during their operating lives and for the decommissioned site is to minimize the transport of brine from the waste management area through the underlying aquifers to locations where it can unacceptably impact environmental receptors.

DECOMMISSIONING REQUIREMENTS AND PRECEDENTS

Potash mining has been practiced in Saskatchewan since the late 1950's. At that time, no jurisdiction in the world required a decommissioning and reclamation (D&R) plan for potash operations and limited thought was given to D&R in the 1950's and 1960's when most of the Saskatchewan potash mines where being planned. Indeed, most mines of any sort planned in that period did not give much attention to D&R requirements. However, most hard rock mines have a life of less than 20 years and mines planned in the period before D&R plans were required to develop these plans when they were being closed. Mines planned in the 1970's and later required a decommissioning plan as a condition of approval. Saskatchewan potash mines are projected to have a very long life and were not even close to closure in the 1970's when D&R plans began to be a standard requirement for new mines. In 1993, the Province of Saskatchewan amended its Mineral Industry Environmental Protection Regulations to include the requirement for submission of D&R plans for all existing mines by 1997 and the provision of financial assurances for those plans by 1998. There was also the requirement for revising plans and financial assurances, if necessary, every five years.

The potash industry complied with this requirement although the 1997 plans submitted contained many uncertainties for several reasons. There were no precedents which could be used for guidance. No potash operation in the world had been decommissioned to a standard acceptable in Saskatchewan. In fact, few potash mines even had D&R plans for the tails pile, which is the major D&R concern in Saskatchewan. The hard rock mining industry had little experience useable by the potash industry. None of the procedures employed to decommission tails in the hard rock mining industry were found to be suitable for potash. In contrast to other types of mines, potash operations are located in marginal agricultural areas where the company generally owns all the land within at least a kilometre of the mine site, a buffer usually containing all the land at risk of being impacted by mining operations. Little of the land on the mine site was in natural condition before mining.

There were also no validated tools available to make realistic projections. Existing long-term projections of sub surface brine transport were doubtful because the behaviour of saturated brine in the subsurface was unknown. Where doubt existed, the regulatory agency assumed the worst case while the industry assumed a case believed to be more realistic.

The very long projected life of the mine made planning difficult. What were realistic technical and economic assumptions for periods about a hundred years in the future, the earliest predicted date for mine closure?

After much negotiation, lasting several years, the regulatory agency accepted the plans submitted in 1997 as interim plans conditional upon the industry developing better substantiated plans by 2005.

PROCEDURE ADOPTED FOR D&R PLAN REVISION

The industry and the regulatory agency agreed early that a co-operative approach was most likely to be successful. A steering group consisting of senior executives from both industry and government

was established to set policy for a committee of technical personnel from both organizations. The committee was charged with developing and implementing a procedure which would result in a decommissioning plan acceptable to both parties being ready by July 2005. The committee believes the procedure outlined below will successfully address the requirements.

A method for making projections which accommodates the long life of the mine was developed after much discussion. It was recognized that the major uncertainty in the distant future lay with the TMA. To avoid having to predict the volume of tails generated in the next 100 years, how it would be managed and what it would cost then to dispose of the material, it was decided to restrict the plan to the production and service facilities and to the existing TMA. Each mine has a finite TMA capable of holding a finite amount of waste. Before the area can be expanded, approval of the regulatory agency is required. The current decommissioning plan will cover the period from the time the existing TMA area is full until it is decommissioned. Any expansions of the TMA will require a separate decommissioning plan for the new area.

An agreement to use a cost benefit approach for assessing alternative plans was one of the major accomplishments of the committee. This reflects the reality that the choice will be between alternative uses, after site closure, for land which was marginal agricultural land at the time mining commenced. It also reflects the fact that the potash industry has a major economic impact in a province with relatively little heavy industry and whose economy is subject to major stresses when climatic conditions and world markets detrimentally impact agriculture.

Another major accomplishment was an agreement to use an objective, systematic approach to developing an acceptable D&R plan. This was considered necessary to eliminate the biases inherent in the participants. It was agreed to use the flowsheet shown in Fig. 6 to guide the selection of the best alternative. This flowsheet combines environmental impact assessment procedures with those of decision analysis. In addition, at least two plans will be compared and the one with the best cost/benefit ratio selected as the preferred plan. One of these plans will be the base case which is a plan to which each mine has committed and which each mine considers as adequately addressing all requirements. This plan is then compared to a plan which contains features resulting in less environmental impact and greater costs than the base case.

If the cost/benefit analysis shows the enhanced plan to be superior, then it becomes the base case and it in turn is compared to a further enhanced plan. This process stops when the enhanced plan is shown to have a cost benefit ratio inferior to the base case. Generally, the base case D&R plan at each mine calls for sealing of the shafts, demolition and removal of the service and production facilities, recontouring and revegetation of the site and maintenance of brine and salt containment facilities until all salt in the TMA has been removed or stabalilized. Salt tails present at closure would be dissolved in the water used to produce potash and in the naturally occurring precipitation followed by injecting the resulting brine to deep geological formations. The intended use of the mine site after D&R would be wildlife habitat.

Two other unique approaches were employed. One of these involves the valuation of the impacted environment and it is critical to the valid application of the process as well as being probably the most contentious aspect. This subject will not be discussed here since it is covered in another paper in these proceedings.

The second unique approach was projecting the subsurface transport of brine. This also was critical because this route was found to be the only one potentially allowing brine to impact off site receptors. Detailed knowledge of the subsurface conditions at each mine was a laborious pre-requisite for this task. Then a model which had the basic ability to handle a dense aqueous fluid had to be modified and hundreds of model runs were required to calibrate and validate the models for each mine. Fortunately, there were over 30 years of groundwater monitoring data available for use in this task.

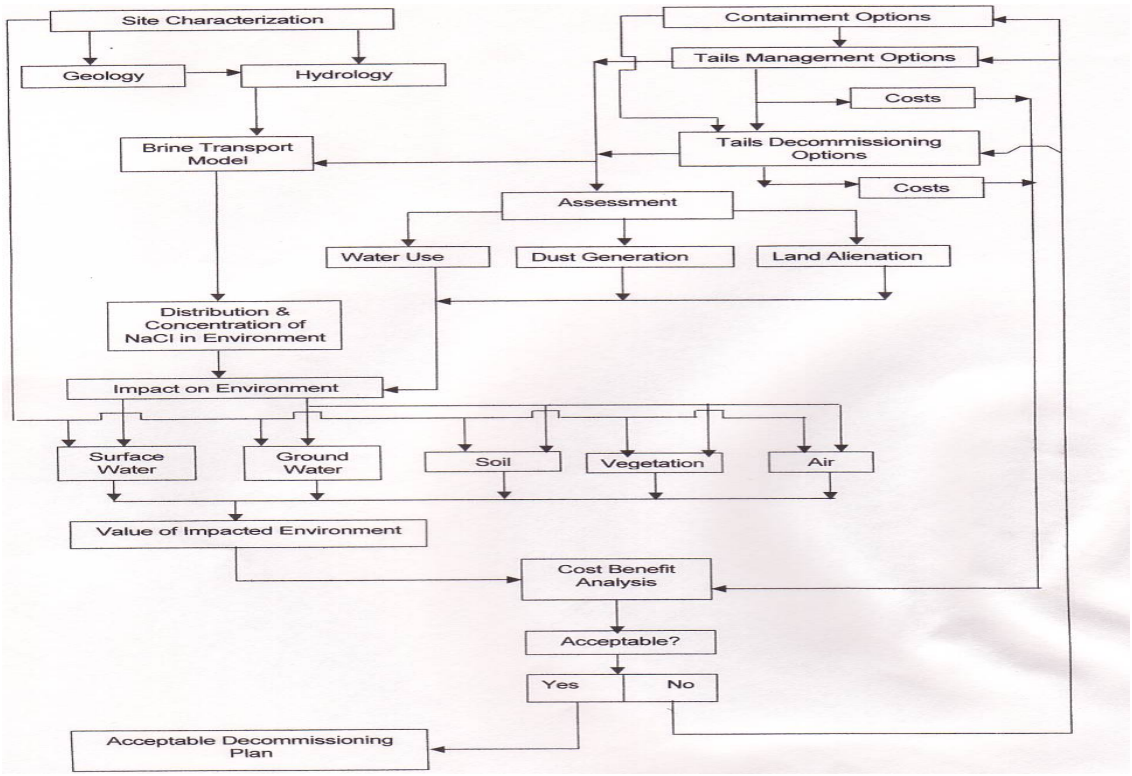

Figure 6. Process Flowsheet for Decommissioning a Saskatchewan Potash Mine

A full description of the development and use of this model must await the authorship of a person who has the specialized knowledge required. However, there were some interesting observations made during the construction and use of the model. One of these is the overriding importance of the density of the brine relative to groundwater. Because of its density, brine does not mix with groundwater in the flat, slow moving aquifers common to Saskatchewan. Ground water gradient is less important to brine transport than the configuration of the bottom of the aquitard. Brine will move up gradient if the aquitard's bottom slopes in that direction. The weight of the trails pile pushes brine laterally in the subsurface but beyond the influence of pile, the direction of flow is downward not

laterally. Generally, the brine does not move far in the subsurface, even in the long term. The usual pattern observed is a bulb lying on the bedrock under the waste management area.

CONCLUSION

In most cases, sub surface brine is not projected to move off the company owned land nor to rise to the surface. The impact is then restricted to the potential use of groundwater on this land. In those few cases where brine is projected to move further, the best enhancement to the base case appears to be upgrading the sub surface brine containment system.

Using the process and procedures described above, revised D&R plans for the potash industry in Saskatchewan are now in the analysis and compilation process. It is believed that the result will be plans which will protect the environment and the industry.