Mine Dewatering

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ABSTRACT

Mine Dewatering for reoccupation of a flooded mine requires rehabilitation and recommissioning of shaft and some level functions to provide safe efficient access, services and logistics, as well as securing connections with all exposed workings. The objective is the earliest secure reoccupation of the target depth horizon for minimum water pumping, consistent with an appropriate investment and optimum schedule of operating inputs to the dewatering, redevelopment, services and consolidation processes. Strategy must focus on recommissioning of relevant functions in the shaft and at stage pumping horizons, advance of logistics close to pumping and rehabilitation, management of the secured exposed workings. The progress must be systematic, sustained and integrated, and must be secured against risk and uncertainty. There must be a strategic capability to respond effectively, and manage interruptions to processes, conditions requiring higher or different resources, and contingencies which affect schedule, budget or risk profile for the continuing programme. Planning must aim to reduce or contain risk or uncertainty elements and contingencies, limit interruption frequency and severity, identify and provide the capability for efficient responses. It is appropriate to model and simulate the reoccupation analogous to a mine initial development production programme. Only minor changes to relationships and relativities of models for Capital works, Operations (Production and Development) and Services/Logistics are needed but the model for management of workings is more relevant than that for depleted workings in an operating mine because of the water and other transfers. An important difference is the unsteady state of Operations which requires probabilistic modelling of availability and utilization of equipment and processes.

1.0 PLANNING OF DEWATERING

1.1 The Planning Analogy With Mine Development

Reoccupation of a deep flooded mine workings is at least as complex, demanding and risk prone at a major sink, equip, develop project. It can also be as costly on a time basis, and usually the major critical element of a larger programme. It deserves more thorough planning than is generally provided.

The model structure of Mine Development readily adapts and extends to simulate dewatering. This is a model where an optimum production (the objective in Mine Planning) is constrained by Development and logistics/services advance. Development and logistics advance are likewise dependent on Investment level in works, etc,. both initial and incremental, while the productivity of input factors (work, consumables, power) within processes of Production, Development etc. are similarly dependent of investment levels in each function.

1.2 Background

1.2.1 Antipathy To Dewatering Projects

Antipathy is a consequence of poor cost and time performance and management exasperation with the chaotic image of crises and contingencies. The poor performance results from deficient or non-existent planning philosophy. The attitude is often that since there are uncertainties, unknowns, breakdowns, blockages, "contingencies", a mine reoccupation dewatering can't be planned, budgetted, scheduled. The lack of strategy, and management plan and under capitalization make this attitude self-fulfilling.

Planning must extend to probabilistic elements such as interruptions and address uncertainties. The recommissioning of functions within exposed workings, the advance of logistics and services, the establishment and commissioning of stage pump stations, consolidation and management of workings are integral to the task.

1.2.2 Geohydraulics

Geohydraulic advice is frequently not sought or used (it is taken as a benediction!). Better terms of reference, a coherent plan and appropriate budget are needed. The geohydrology needs to expand below the near surface influence zone surrounding the workings. The product must be relevant to the task of dewatering the mine, generate estimates of inflow independant of that based on the apparent historical pumping rate and reconcile the geohydrology with the interpretations of mine and structural geologists.

Even the best hard rock geohydraulic models need major modification for each geological circumstance. Accounting must be made for the slow drainage from upper workings. Infiltration into exposed workings is not all transferred down to shaft. The management plan may continuously, cyclically or intermittently transfer flows above water line to stage sumps, other storage or separate ejection systems. This requires a more complex infiltration model.

Monitoring and Review of the model must continue to completion of task. Calculated infiltration often peaks early in the competent rock zone where geological aquifers are unloading under relatively low pressure and the porous upper levels are drying out. Repressurization of a geological acquifer during a long pumping interruption or due to some external influence may cause bulkheads, plugged boreholes and drainage retarding stope fronts to fail catastrophically.

1.3 Towards A Better Way

1.3.1 Philosophy

In dewatering it is important to:

- develop a plan from concepts which reflect philosophy, criteria, conditions, and to know the source and magnitude of limitations and uncertainties

- have a strategy based on this plan and secured against the limitations, uncertainties etc.

rather than depend on reactive and short range tactical ("horseback" initiatives to address interruptions, contingencies, blow outs in input schedules (equating to a process output).

It follows that:

- a model based simulation is a necessary planning tool

- the models should (need) have similar precision and confidence levels

- by analogy with planning a new mine the precision and confidence of Investment and Operating models should equal or better those of the "Resource" models for standing water and infiltration.

An appropriate dewatering plan is much more dependant on a formal modelling (not necessarily mathematical) than most mine development planning. The relationships are less easily visualised, time base is shorter and many parameters do not have accepted empirical values. Some functions can only be modelled by investing in sufficient capacity to respond appropriately.

1.3.2 Criteria

The relevant criteria of an action or proposal are:

Risk (size, direction, source of risk how measured).
Certainty and Confidence
Efficiency and how gauged
Productivity of items of infrastructure, equipment
Productivity of inputs (labour, power etc.).
Safety

The decision/selection process needs to be:

- Robust
- Valid
- Reliable etc.

The time frame in dewatering, especially in conditions of high risk and uncertainty, is short and the risk profile quickly turns adverse.

1.3.3 Strategy

Sustained progress which does not stall from internal constraints and is not readily stalled or reversed by external forces requires:

- identification, location and quantification of known, probable and potential forces and conditions.
- reliable, robust, functional integration of both sequential and parallel activities
- adequate response capability to progress the work schedule through heightened uncertainty and risk to restore status to normal
- the capacity to implement uncertainty and risk conditioned ideals.

1.3.4 Structure

The Mine Development to Production Model is an appropriate, easily adapted and generally familiar model for dewatering.

1.3.5 Broader Participation

Coherent, documented planning permits a broader participation and management understanding.

2.0 PLANNING

2.1 A Conceptual Planning Model for Dewatering

1. The operation may be described by a set of sequential or parallel processes and functions which effect:

   - the water depletion and delivery;
   - development (defined as removal of obstructions and redevelopment of exposed workings);
   - logistics and services extension;
   - stage establishment;
   - management of workings and conditions.

2. Infrastructure, logistics, ordnance (equipment), installations and establishment are planned with adequate investment to effect these functions and processes efficiently, provide a positive risk profile and optimum productivity of inputs.

3. Processes are described by schedule of output/input equations where the input factors reflect the efficiency, productivity and unit costs. There is a limited range of solutions to production and development functions. The value in the range reflects philosophy, criteria and investment level per function.

4. The flow of water production is modelled as a sequence of processes from infiltration, transfers and inventory storage via pumping and the rising mains, through lift stage storage(s) to the mine exit. This causes a stope draw down increment and exposes workings for development.

5. The work to recommission each metre is never completely known. The policy can only be to invest sufficiently in access and materials handling, safety, communications and logistics for the task so that labour efficiency and productivity are maximised whatever the magnitude or complexity of task.

   If there is no work to be done (which is rare as service/ladder/counter-weight compartments are usually a mess) the progress (checking) can approach 20 metres per shift, but where work is substantial, 5 metres per day can be scheduled comfortably if labour is adequately supported.

6. The advance of logistics requires labour, durables, minor consumables, availability of power. It may require varying amounts of miner, timberman, trades labour but much of the work is in restricted circumstances. Productivity requires a maximum investment for all materials handling functions and for fixing work in small compartments.

7. Major permanent stages are usually 150m - 300m vertical interval but the constraints on power, weight of advancing column (usually in a haulage compartment) and need to limit occupation of haulage compartment may require intermediate stations. The special circumstances of the upper levels (protracted drainage, dirty water), the management of blockages and difficulty in establishing adequate sump, clarification, mud capacity on some levels may require an irregular vertical spacing.

   As with logistics, an adequate response capacity is needed to optimize output. Typically this means capacity to support some rapid and efficient mining and construction activities preceding the installations work.

8. The rehabilitation of a limited schedule of the mine workings beyond the shaft, consolidation, management and maintenance of all mine workings, help secure against uncertainty, risk in the subsequent schedule and contingencies.

9. The management of workings function expands to:

   - keep the underground infrastructure functioning efficiently;
   - deliver the inputs to processes (labour, consumables);
   - remove secondary outputs (waste, mud, water);
   - preserve operating environment (ventilation, etc.).

10. Planning must model the Interruptions to the processes and Contingencies, which by deploying resources increase the risk to processes. In a lengthy interruption, for example, mine storage capacity progressively reduces as retardations fill and overflow. Bulkheads, borehole plugs etc. may fail. The capacity to recover lost advance, development etc. is situation specific, time and depth dependent. A sequential accumulation of net downtime, both operating and maintenance may occur. Redevelopment activities may increase and lose their limited independence from interaction with the production equation.

2.2 Criteria

1. The efficiency of the reoccupation by dewatering is determined by:

   - the availability and utilization of the pumping ordnance, the latter being especially significant where there are blockages and multiple stages to be established

   - the time overrun beyond optimum hours which decreases the productivity of infrastructure, logistics etc.

   - the inputs other than power (i.e. labour, maintenance, consumables) required to maintain availability and utilization of pumping ordnance i.e. to maintain progress

   - the overrun of power and other consumed inputs when more than optimum water is pumped.

2. A sustained Dewatering Redevelopment is dependant not only on capacity for production of water which exposes development to be rehabilitated, but the capacity to:

   - advance logistics to provide the "inputs" to the processes (of water production and exposure of development) and to

   - deliver the capability to expediently deal with interruptions and contingencies both within the production process and the rehabilitation process

   - develop and commission appropriate stage installations

   - manage transfers of water, waste products and conditions within recovered workings.

3. The optimum plan i.e. minimum risk, maximum confidence level is when the confidence in the performance of the operation and equipment exceeds that in the water inventory and infiltration models.

2.3 Simulation

Simulation consists of iterating (cycling) for a cyclically incremented number of shaft pump stages, of appropriate power and head per stage, through a sequence of balance points (sumps) and processes (infiltration, transfers, pumping and pipeline delivery using a model for availability/utilization as switch (or clock) and the pipeline as an accumulator of output values until minimum flowrate, or the "make" during interruption equals half the resumed pumping rate or until maximum column weight or maximum power is reached or advance equals development rate.

The rising main is the "accumulator" of the work output, the advance (i.e. it grows in length), the delivered quantity, the incremental (pump) operating time and the pump delivery rate. It also communicates a (parameter) value for total head back to the pump and contains the alarms for delivery rate (high and low), head (high only), weight of water column.

Experience shows that although the unit pumping rate is determined by pump power the time to reach objective is determined by interruptions to pumping due to:

- non utilization (and to a lesser extent under utilization)
- unavailability of shaft pump (even with standby, the response time lengthens)

The major cause of non-utilization and an underlying cause of unavailability is slow progress in redeveloping the shaft compartments to permit:

- advance of logistics
- capacity to respond to interruptions
- capacity to expediently consolidate and equip stages for pumping and to upgrade power substations

Initialization for simulation

- maximum advance equal target redevelopment rate
- power voltage to pump which determines maximum power thus stages
- pump specific speed
- pump stage power, head, flow rate
- maximum/minimum flow rates
- initial rising main diameter (150mm - 250mm usually)
- weight of full column per metre

3.0 CONCEPTUAL MODELS OF THE PRODUCTION PROCESSES

3.1 Depletion of Standing Water From Inventory

The simplest inventory model expresses the estimated (water filled) void per depth unit advanced.

The model should:

- highlight significant changes in the volume per metre advance e.g. reduced extent of mining lower levels with little stoping
- detail the upper levels better where:
  * formation water storage and transmissivity are greater
  * more "void" may be partly filled
  * drainage from workings may be slower
  * there are more openings to surface
  * the mined extent may be greatest
  * more water is dirty and contains slimes

The model needs to be constantly reconciled with observations: water pumped, advance loss rate and changes in other models.

3.2 Infiltration, Seeping etc.

The models should:

- support separate estimates for water "make" from infiltration below water line and from infiltration, seepage, drainage and managed release in the "compartments" above water line
- expand geological and geohydraulic contribution to enhancing infiltration models to reflect the distribution of infiltration
- support initiatives for managing transfers, isolation of potential recharge, depressurization, retardation
- support planning for the management of the mine void above water line especially the security and consolidation at each level.

4.0 PLAN DEVELOPMENT

4.1 Simulation Conditions

The pilot simulation is qualified by arbitary selection of:

- development rate
- power (voltage and kw)
- weight of column (in haulage compartment between stages)
- the availability/utilization model

and the definition of a potential crisis when resumed pumping is less than double infiltration plus transfer rate.

4.2 (Re)Development Constraint

The premise is that investment (and organisation) of the function can be increased to provide an adequate rate may only be valid over a limited range and usually depends on the ability to recommission almost full scale service and mullock handling capacity in the main compartments (which may conflict with use for shaft pump) and/or the consolidation and management plan for workings (due to the amount of rubbish, spoil, stores, standby capacity to be managed).

The simulation needs a CPM/PERT type schedule study.

4.3 Development (Blockages)

There are a number of types of blockages:

- collar collapse (sometimes with head works etc.)
- stage in shaft
- conveyance etc.

and the location and nature depends on the history:

- late stage tributers (mine part flooded)
- salvage of head works
- recent vandalism, bushfire etc.

even during preparation (the writer's crew once burnt a head frame down) or during dewatering:

- loading pocket collapse
- brattice, stage, ladder bolts oxidize rapidly

There are also partial blockages

- detached, snaking skids, pipes, cables, pump shaft
- service compartment a mess while haulages are clear

The water above a blockage may require separate pumping.

The strategy must include good research and reconnaissance, anticipation, modelling of potential cases, simulation of extended interruption, escalation of dirty water transfers, etc.

The capabilities required are:

- mixed (soft or hard) mullock and other waste handling
- efficient timber pulling and handling
- cutting timber, pipe, cable
- pumping pulps.

4.4 Power

Reclassification of 1000V as medium voltage (Queensland) has important consequences for Australian dewatering and should generally permit a more flexible choice of stage locations than is possible with 415V distribution without the difficulties associated with 3.3KV.

4.5 Weight of Column

The weight affects not only the design of support (in the haulage) but determines severity of water hammer.

4.6 Availability/Utilization

The model needs to cover:

- the influence of recognition (of problem), reaction etc.
- the dominance of electrical problems from motor, cable glands, starter etc. The importance of continued tests, metering, protection, alarms.
- a protracted interruption
- underutilization due to low stage sump capacity
- the establishment of stages

4.7 Critical Zone

The definition of a critical zone as insufficient marginal pumping capacity needs to be expanded to accomodate initiatives within the Management of Workings for:

- directing transfers of above water infiltration to stage stations
- separate ejection (with or without mud)
- cyclic release of water
- drying out by ventilation
- depressurization

4.8 Plan for Management of Workings

Planning cannot focus only on the zone around shaft stations. Ventilation, continuing drainage, storage or transfer of mud, wet solids, wastes, safety etc. require a plan for management of workings e.g. lateral water flows towards shafts must be intercepted as they may accumulate to exceed capacity of any water rings that can be recommissioned in the shaft. An appropriate model is a faster version of the progressive close down of depleted workings in an operating mine which needs to keep ventilation, drain holes, mud and water pump stations to remain commissioned. In dewatering the organisation of these workings into compartments may make important positive contributions to dewatering e.g. ventilation may remove some tens of tonnes of water per day, transfer of infiltration and drainage directly to stage stations or surface, or temporary retardation may reduce demand on the shaft pumps when at maximum head or "down".

The typical partition or compartment has boundaries which may be controlled such that isolated and separate management is possible for a time e.g.:

- upper infiltration and "dirty" zone,
- "Transition" transfer-via-stope zone.