THE CANNON MINE TAILINGS IMPOUNDMENT: A CASE HISTORY

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ABSTRACT

This is a case history. This is the story (history) of the design, construction, operation, and closure of the Cannon Mine Tailings Impoundment in Wenatchee, Washington. The Cannon Mine was a gold mine that opened in the early 1980s just to the southwest of Wenatchee, WA. The tailings impoundment included an initial 100-m high rock-fill embankment, diversion channels, and hydraulically discharged tailings. With time the embankment was increased to 140-m high. The impoundment was operated successfully for the life of the mine, and when mining stopped, the impoundment was reclaimed. Today the reclaimed site is fully integrated into the surroundings and an example of mining that can be successfully undertaken close to urban areas.

INTRODUCTION

The Cannon Mine, Wenatchee, WA was a joint venture project between Asamera Minerals (U.S.) Inc. and Breakwater Resources. The impoundment was constructed in the early 1980s, operated for a decade, and then reclaimed. This is the story of the impoundment from the perspective of the authors who designed the impoundment, were on site for most of its construction, and ultimately were involved in the reclamation of the impoundment.

THE IMPOUNDMENT SITE

The tailings impoundment site is to the southwest of the mine which is southwest of Wenatchee, Washington. The site was selected after a formal site selection study that included consideration of: health & safety (the potential for constructing a safe facility); economic (capital, operating, and reclamation cost); environmental impact (area of the impoundment and length of tailings delivery pipeline); socio-economic consideration (current land use); and public attitude (visibility and perceived public concerns.)

The selected site was close to the mill, significantly impacted by prior silica mining, screened by the surrounding hills, and characterized by suitable bedrock. Significant disadvantages of the site included the need to pump tailings against a head of up to 200 m and its location upgradient of houses in the town of Wenatchee, WA.

The bedrock at the impoundment site was primarily Wenatchee rocks including interbedded sandstones and siltstones varying in thickness from 10 mm to six meters. Bedrock was covered by a variable thickness of soil that was stripped prior to construction of the embankment. On the crest of the hills adjacent to the site were thick deposits of Columbia River Basalt that was quarried to construct the rockfill shells of the embankment. Pleistocene windblown clayey, silty sand was obtained at a borrow site also close to the impoundment and this material was used in the core of the embankment.

THE EMBANKMENT

Initially the impoundment embankment was designed to rise to a height of approximately 100m. The cross section includes a low permeability core, drains, and rock-fill outer shells. A grout curtain was installed beneath the core. (Figures of the layout of the impoundment, and the details of the embankment are in the references and are not repeated here.)

The core and the primary drains are founded on the bedrock that underlies the entire site. The upstream and downstream toes are founded on the materials that filled the gully at the base of the valley.

An inclined core was adopted in order to provide for staged construction of the embankment and to enhance performance during operation.

The filters and drains are three-meters wide. This width was chosen to facilitate placement and as a conservative seepage control feature. The filter material is a fine to coarse sand. The gradation was chosen so that the sand retains even a slurry of the core material; thus the filter was able to prevent piping of soil due to normal seepage through the core and to hold back any material dislodged into potential cracks in the core.

The downstream and upstream shells are of compacted, decomposed basalt. The downstream slope is two horizontal to one vertical. The average angle of friction of the basalt is about 37^o, hence the factor of safety of the downstream slope is at least 1.5.

The upstream slope is 2.5 horizontal to one vertical. This slope was set on the basis of stability analyses which included consideration of excess pore pressure in the core and blanket (i.e., u=0.3 and the angle of friction being about twenty-five degrees.

In the course of operation, the embankment was raised three times to an ultimate height of 140 m. All raises were by the centerline method. The raises continued with the same zonation as established in the initial construction.

The final raise serves as the flood detention berm to this day. In the final raise no filter zone was necessary. The core and downstream slope in the final raise were steepened relative to the initial embankment geometry and subsequent raises.

Temporary CMP pipe spillways installed through the dam were replaced with a permanent open-cut channel spillway on the south abutment.

CONSTRUCTION

About 2.3 million cubic meters of soil and rock were placed in about nine months in 1984 and 1985 to form the embankment.

But first, we had to strip and excavate about 650,00 cubic meters of topsoil and colluvium; this was achieved with six CAT 623 scrapers in four months of two 10-hours shifts per day. Overburden removal started at the top of the left abutment. Materials were moved with a bulldozer. The colluvium was pushed down the slope to form a bench. Once the bench was wide enough to traverse, scrapers picked up the colluvium and deposited in waste piles downstream of the embankment. The abutment in the shell area was cleared of soil and loose rock. The specifications called for “machine cleaning”.

Foundation excavation was done before the winter snow. As a result of inadequate overburden removal and degradation of the rocks during the winter, further foundation cleaning was done during fill placement the following year. An area three meters ahead of the fill was cleaned with a backhoe or a slope board. Generally the rock thus exposed was competent and substantially free of loose pieces that could be removed by hand.

The specifications called for hand-cleaning of the core area. Shovels and air hoses were used to clean the foundation bedrock over the core area. Where the rock in the core area was loose, excessively fractured, or very rough because of friable sandstone or shattered siltstone, mortar or shotcrete was applied.

Numerous benches and distinct changes of profile were encountered up the abutment. The edges of the benches were trimmed so that the following requirement was generally met: the angle between two straight edges about 300 mm apart should be no more than 20^o.

The upstream and downstream toes are founded on the materials that filled the gully at the base of the valley. This fill was excavated and removed beneath the greater part of the embankment core as it was found to be deep (up to 15 m) and of soft, compressible clays and silt. Such excavation was, however, difficult and expensive. It was easy to establish that a better approach at the toe was to construct a toe dike or berm on the in situ gully fill.

A grout curtain was installed beneath the core. It consisted of two lines of holes about three meters apart. On average, tertiary boreholes were required for satisfactory closure (limited grout take) and sometimes quaternary holes were required. The average hole spacing was about one meter and the hole depths increase from 12 m at the crest to a maximum depth of about 50 m beneath the highest part of the embankment.

Placement and quality control of the embankment materials other than the shell basalt was straightforward and in accordance with standard practice. The basalt however, being a rockfill, called for special attention: specifications called for a minimum of four passes of the specified roller and a density no less than 98 percent of ASTM D698. Test pads of the basalt were placed and the effects of compaction were monitored. In particular, considerable work was done to establish correlation between variations in the gradation and quality of the basalt, the lift thickness, the number of passes of the compactor, and the resulting settlement and density of the fill. These data were subsequently used to monitor and control basalt placement.

The core of the embankment is compacted clayey, silty loess. It was compacted in 150-mm layers to at least 98 percent ASTM D698 at a moisture content between two percent dry of optimum to one percent wet of optimum; this was done to avoid the generation of excess pore pressure. A zone of core materials at one to three percent wet of optimum and at least 600-mm thick was placed against the abutments in order to enhance contact by molding the soil into the irregular surface of the rock.

OPERATION

Deposition of tailings began in mid-July 1985. Tailings were pumped to the impoundment as a slurry and discharged from spigots along and some way upstream from the crest. Deposition was generally managed to form thin layers of tailings each of which was sun-dried to the extent possible. And so over the years the impoundment was filled. Just one point of interest: the design water balance which was generally achieved. No flood bedeviled the impoundment and no discharge of excess water occurred.

RECLAMATION

By 2004, the impoundment had been closed and reclaimed. It was by then the topic of symposia and Powerpoint presentations easily accessed via Google on the internet. One such presentation (Rothberg et al.) tells us that the impoundment covers 14 hectares, has a 104-m high embankment with a 335-m long crest and contains between four and five million tonnes of tailings.

This same presentation tells us that the impoundment retains its high hazard designation as more than one-hundred homes are at risk.

The cover is also described. It reportedly consists of—from the bottom up:

- Geotextile support layer
- 750 mm well-graded sand and gravel
- 300 mm of topsoil
- Vegetation.

The 4.6-m wide open-cut spillway serves as the permanent emergency overflow structure for post-closure. The 300-m long channel is unlined but is founded in competent Wenatchee Formation sedimentary rock of the south abutment. The final 6.5-meters of embankment height along with the spillway serve as a flood detention and routing facility that can completely store the small to moderate storm events and safely route extreme flood events up to and including the 72-hour probable maximum flood (PMF) with a 20-year snowpack melt.

Operational seepage and groundwater interflow beneath the dam was estimated at a cumulative nominal flow rate of 1.3 to 1.6 liters per second at site closure. Most of the flow component, based on chemistry signatures, is from natural groundwater sources. To mitigate the presence of some mineralization byproducts generated by reactive components in the tailings particles and from mobilization of the associated pore fluids, passive treatment cells were installed at the dam toe area. Constituents characteristically found in the seepage include sodium, chloride, elevated pH, TDS and trace metals.

These passive treatment cells, collectively referred to as the wetland treatment system, function in a truly passive manner and discharge the treated seepage back into Dry Gulch just below the embankment. Three ponds, each nominally 0.2 hectare in size, were constructed to treat the seepage flow from the tailings facility and operate in series. The first two cells incorporate both aerobic and anaerobic capabilities based on the direction of inflow to the cell (either from above or below). The third cell is a simple aerobic cell, or polishing pond. The wetland cells, nominally 2 meters in total depth, were populated primarily with cattails and bulrushes. The wetland treatment system was completed and commissioned in September 1996.

We are told that by 2001 county and state-held bonds were released and that in 2003 the impoundment (or at least those who undertook its closure) was/were the recipient(s) of the Washington Department of Natural Resources "Recognition for Reclamation Award."

PERSONNEL & PERSONAL

In that this paper is a case history, we include as follows some history about the people who worked on the initial phases of the construction of the embankment. Many more than we could write about here contributed. Those mentioned below are noted because of the technical contributions they made.

The authors of this paper worked for Steffen Robertson and Kirsten during the seminal phases of design and construction of the Cannon Mine Tailings Impoundment. We thank our many colleagues from SRK past and present who helped and contributed to its success.

Gary Bates was the Asamera project manager. It is he who kept us under control and focused on success. He spent countless hours with us pouring over engineering reports as we tried to explain our concepts to those who were writing the project Environmental Impact Statement. We wanted more in the EIS; they want the essence and less. Gary always found the right balance and the EIS was a success. His personal, hands-on, day-to-day involvement with the details fo the impoundment design and construction were the key to its success.

John Toften was Asamera's chief mining engineer in day-to-day charge of embankment construction. He was a large German mining engineer. The first day I met him, I presented to him the SRK budget for site characterizations. John looked me in the eye and said: "Jack, here we are miners. We are used to going into the ground and then deciding how to proceed and adjust. You cannot spend all this money drilling. Rather you come to site for a year and do the engineering as we move the soil and rock for you." And that is just what I did. For nearly two years I was on site every day observing, testing, and designing as we went. It was John who forced me to and worked with me as I implemented the Observational Method in geotechnical engineering. To him as a miner it was a normal way to proceed. To me it was an honored approach in geotechnical engineering that I was forced to implement in practice in real time application.

Syd Hillis was the design peer reviewer. He highlighted how a good peer reviewer operates. He would spend the day looking at the rocks, feeling the soil, counting the passes, and examining the results we produced in a small on-site soils laboratory. Then we would review the day's findings. He always came up with profound insight and practical solutions and details. He knew every detail, asked penetrating questions until we were all satisfied with the answers. He brought his vast experience at earth days world-wide to our table and never let us do less than the best.

Don Moore was Asamera's process engineer. He and our Adrian Smith dealt with the chemical and geochemical issues. We reference one of their papers on the topic. They too focused on testing, facts, and practical approaches. They worked in concert with the geotechnical engineers and thus we succeeded. .

We do not know the many others who must have come after us as we moved on to other places and interests. They operated the impoundment and ultimately reclaimed it. To them our credits and plea: tell us more.

CONCLUSIONS

When we were designing and building the Cannon Mine Tailings Impoundment, we thought of the work as routine. And time has proven that for there are now many more, much larger and higher impoundments world-wide.

Yet, to-date, the embankment is still one of the highest in Washington State, and has stood the test of some time.

We are honored to have been given the chance to work on this project, which we submit is a testament to the fact that mines can be developed, operated, and closed in close proximity to urban centers.

REFERENCES

Breitenbach, A. "Rockfill for Mines." At http://www.infomine.com/publications/docs/E-Book_Rockfill_for_Mines.pdf

Caldwell, J., Sluder, T., Crews, T. "Engineering Geology and Soils Engineering in the Development of the Cannon Mine Tailings Impoundment" http://www.infomine.com/publications/docs/Caldwell1986b.pdf

Caldwell, J., Thatcher, J., Kiel, J. "Environmental Geotechnical Considerations in the Design of the Cannon Mine Tailings Impoundment. http://www.infomine.com/publications/docs/Caldwell.pdf

Caldwell, J., Hillis, S., Hutchinson, I. "The Design of the Cannon Mine Tailings Impoundment. http://www.infomine.com/publications/docs/Caldwell1985d.pdf

Caldwell, J., Moore, D., Hutchison, I., Sluder, T. "Design and construction outlined of the Cannon mine tailings impoundment." Mining Engineering August 1986. At SME OneMine. http://www.onemine.org

Caldwell, J., Moore, D., Smith, A. "Impoundment for Cyanided Tailings—Case History of the Cannon Mine Project." http://www.infomine.com/publications/docs/Caldwell1984a.pdf

Caldwell, J., Hillis, S., Crews, T. "Construction of the Embankment for the Cannon Mine Tailings Impoundment." http://www.infomine.com/publications/docs/Caldwell1985a.pdf

Cannon Mine Asamera Minerals (US) Inc and Breakwater Resources Ltd. Website at http://www.geocities.com/cannon_mine/

Pincock Allen & Holt, 2000. Permit Termination Request & Summary Technical Data Review, Cannon Mine Project, Wenatchee, Washington.

Steffen Robertson & Kirsten, 1994. Cannon Mine Tailings Impoundment Reclamation Plan, April 1994.

Rothberg Tamburini Winsor "Cannon Mine Tailings Closure" UNR Mining Life-Cycle Center Tailings Closure Workshop. Elko Nevada. June 8-9, 2004 at http://www.unr.edu/mines/mlc/conf_workshops/tailings/Elko_8.pdf