ENGINEERING GEOLOGY AND SOILS ENGINEERING IN THE DEVELOPMENT OF THE CANNON MINE

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INTRODUCTION

The Cannon Mine in Wenatchee, Washington was brought into production in July 1985 by Asamera Minerals (US) Inc. Development of the mine involved a number of geotechnical facilities:

- A reinforced earth retaining wall;
- A cut for the millsite;
- Foundations for the mill; and
- A major tailings impoundment.

All geotechnical work, from initial site exploration to final construction, took about two years. This is a relatively short time for work with a value of up to $20 million; involving moving about 3.0 million cubic meters of soils and rock, a complex site geology, and construction in an environmentally sensitive area adjacent to a populous town.

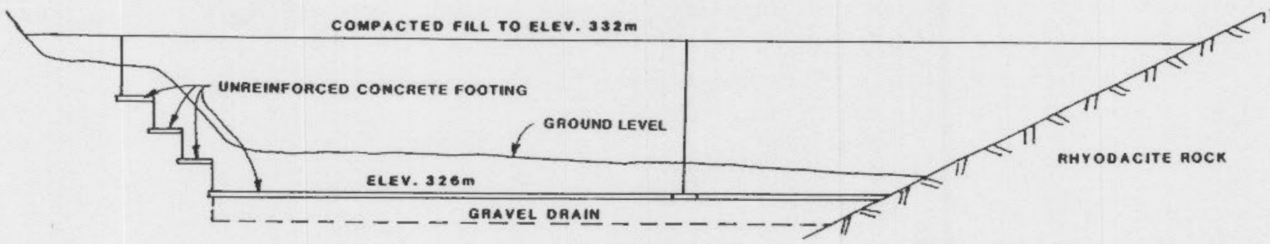
That this was possible, is attributable to the attitude of the owner: an attitude that included a concern for environmental factors, a strong organization backed by a determination to develop the property, and a willingness to accept a geotechnical approach based on the philosophy of Peck's Observational Method.

In essence, the Observational Method involves only sufficient exploration to define general geological and geotechnical parameters, a design based on likely conditions, a plan to deal with possible deviations from anticipated conditions, and observations of actual conditions and adjustment to these.

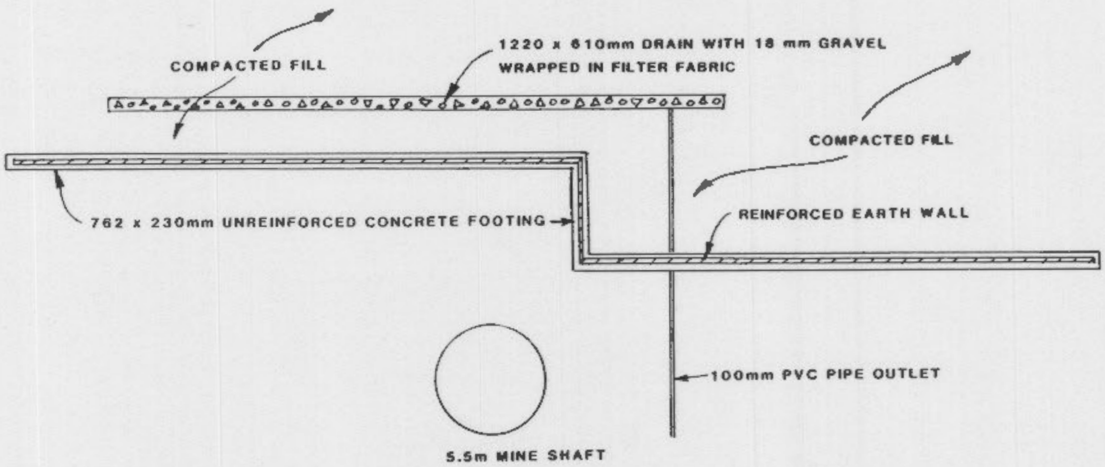
This approach forms the basis of the work done at the mine as described below.

THE REINFORCED EARTH WALL

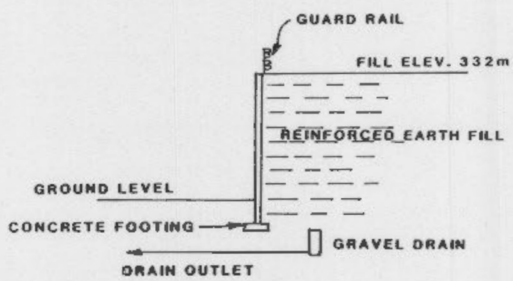
Figure 1 shows the layout and cross section of the reinforced earth



LONG SECTION OF WALL FROM INSIDE FILL AREA



LAYOUT OF REINFORCED EARTH WALL



SECTION THROUGH WALL

FIGURE 1. LAYOUT AND SECTIONS OF REINFORCED EARTH RETAINING WALL

retaining wall constructed above the shaft to support fill forming part of the millsite platform.

Site investigation for that facility involved on borehole in which SPT tests were done every 1.5 m. This showed interbedded medium dense silts, sands, and gravels to 15 m depth. This was sufficient to confirm the viability of a reinforced earth wall.

Construction involved removing overburden soil to expose bedrock on the flanks of the wall, exposing the soils beneath the topsoil, and excavating a trench for the drain behind the wall. On the basis of the data as exposed during construction, the layout of the wall was finalized, the drain layout altered to deal with observed seeps, and the backfill material chosen.

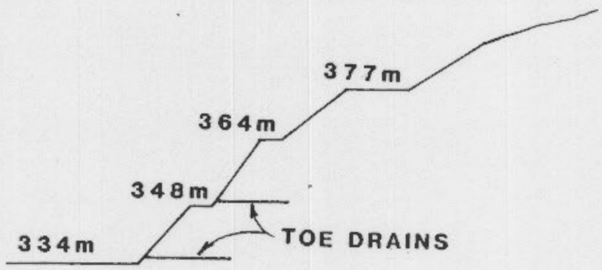
THE MILLSITE CUT

Figure 2 shows a generalized layout of the millsite cut and a cross section through the cut.

Exploration involved three rotary core holes. Core was logged. Rock exposed in road cuts at the site was examined. Detailed discussions with mine geologists who were familiar with the geology of the ore zone about 200 m below and just adjacent to the site, enabled us to compile a reasonable picture of conditions likely to be encountered at the site.

This work indicated that the cuts would be into mudstones, sandstones, and perlite, but it was not possible to define the exact extent or proper distribution of the various lithological sequences.

Excavation of the 400,000 cubic meters took one month. Each day the material excavated was examined. The sandstones were stockpiled for tailings embankment construction. Other materials were used to level a valley above the property; the level platforms are now used to store the multitude of equipment and material associated with the mine.



CROSS SECTION A-A THROUGH MILLSITE CUT

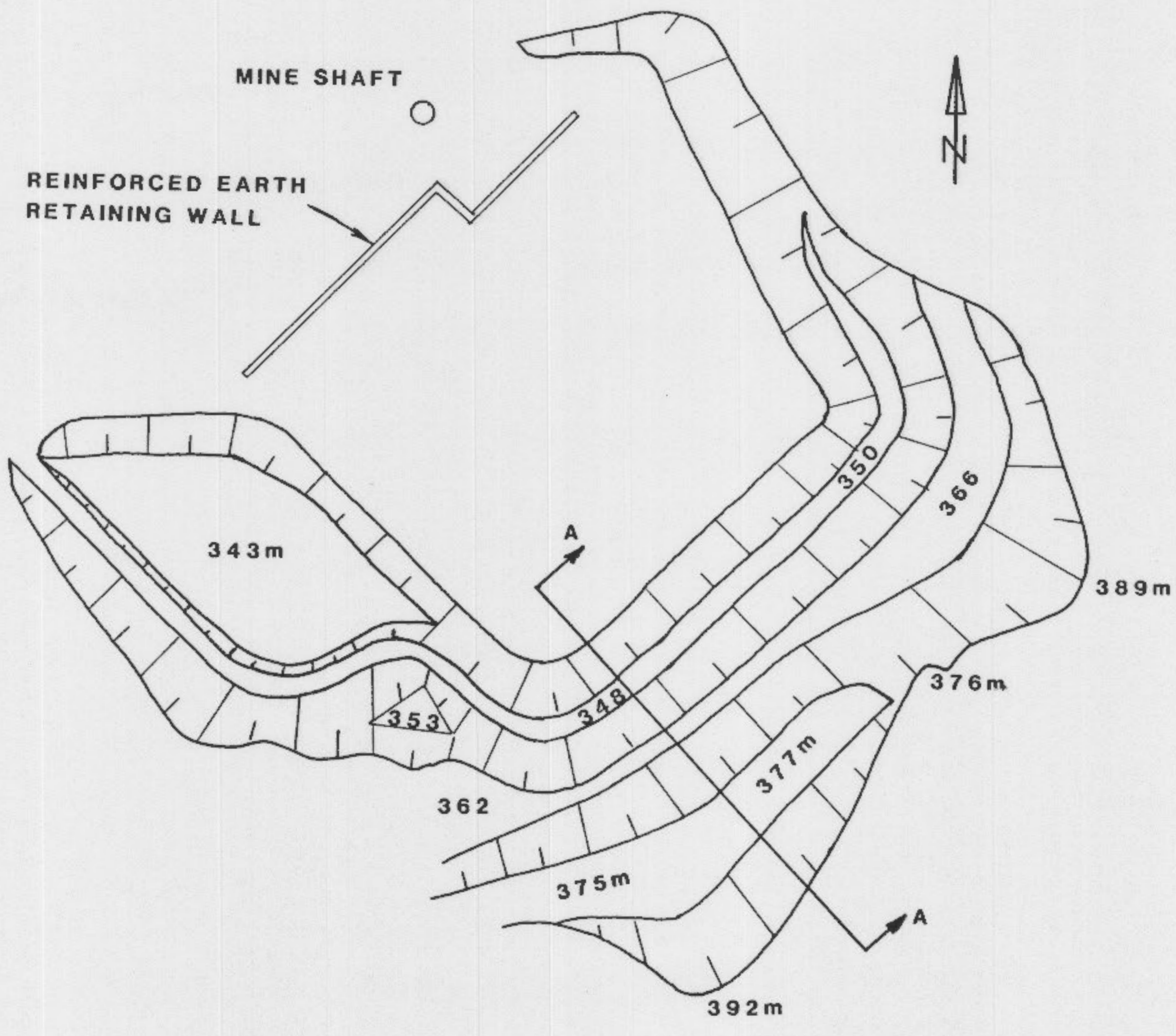


FIGURE 2. GENERAL LAYOUT OF MILLSITE CUT

Also examined each day were the materials in the cut slopes. On the basis of the material exposed by excavation, we steepened the lower portions of the cut, hence the wide top bench. Slope protection was installed at a number of places in the mudstone: wiremesh over the face and anchored back with 1.5 m anchors (we must note that this has not proved successful - the mudstones have slid and pulled out the anchors).

Where seeps were noted, toe drains holes were installed. These consist of 20 m long 50 mm slotted PVC pipes wrapped in geotextile.

FOUNDATIONS FOR THE MILL

The holes drilled to define the millsite geology and rocks of the mill site cut were positioned to explore conditions where the heaviest mill equipment is located. The holes indicated that competent materials adequate for the foundation bearing pressures could be anticipated. There was concern, however, that slaking and rapid deterioration could occur when the mudstones were exposed. To avoid this, construction was planned to cover the foundation rocks with concrete as soon after excavation as possible.

The rock exposed for the foundations was solid, hard sandstone. Concrete was placed within 24 hours of exposure.

THE TAILINGS EMBANKMENT

Figure 3 shows the cross section of the embankment. Site investigation involved eight boreholes from which core was obtained. Limited seismic refraction lines were done. The geology of the area was defined from the drilling, examination of exposures in road cuts, and definition of regional geology.

This showed that the site was characterized by interbedded sandstones and siltstones, that had been faulted before being covered by mass waste basalts. A loess deposit covered the basalts. The base of the valley where the embankment was constructed was filled with up to 25 m of alluvial silts, sands, and gravels.

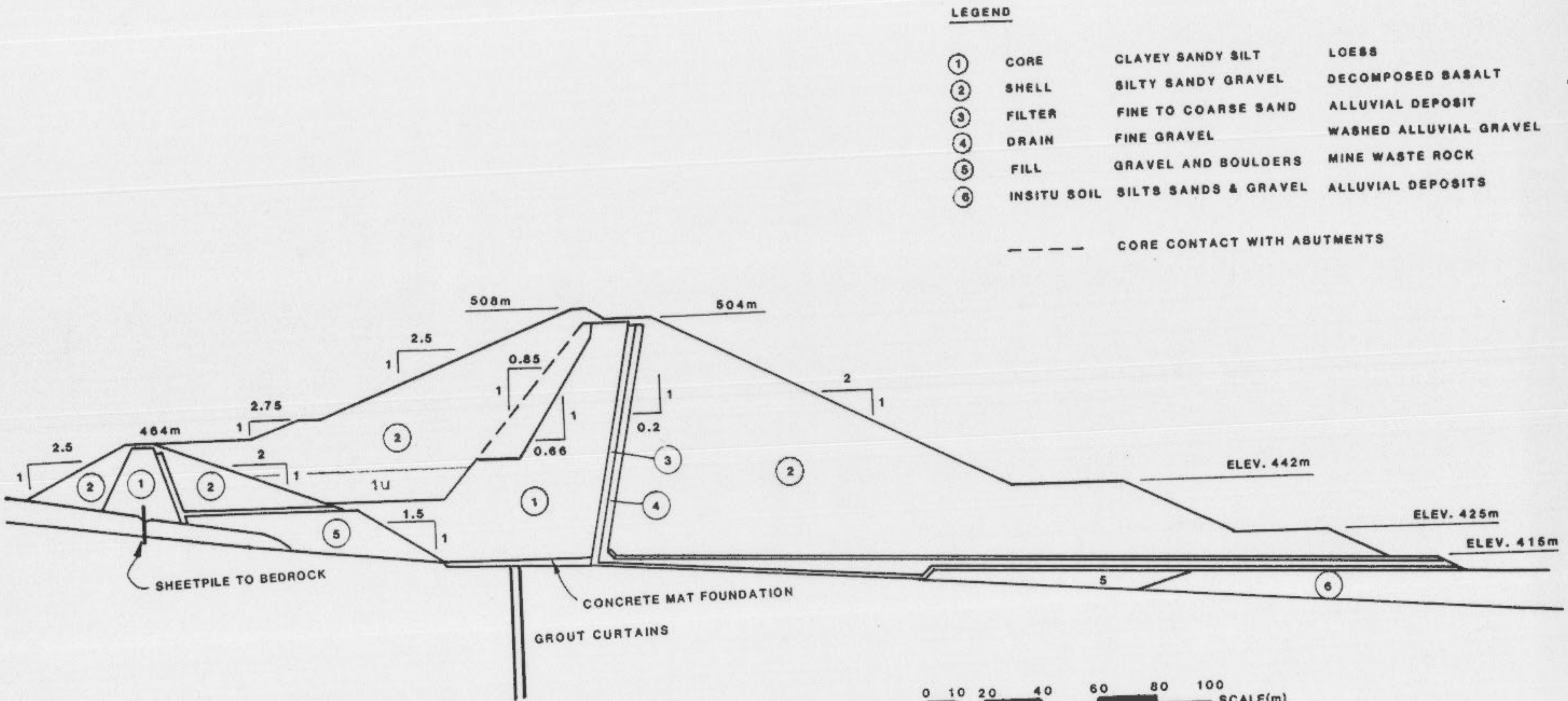


FIGURE 3. FINAL CROSS SECTION OF EMBANKMENT AS BUILT

Figure 4 shows the initial cross section of the embankment defined at the design and bidding stage. During construction, the following conditions were encountered which lead to the changes of design indicated. These are the reasons for changing the embankment cross section from that shown in Figure 4 to that shown in Figure 3:

- Deep soft alluvial soils at the upstream toe: The cofferdam was constructed on these sediments with sheet piles for seepage control and a rock toe to bedrock for stability;
- Thick colluvium, deep valley alluvium, and instability of the overburden at the toe of the embankment: The planned excavation to bedrock at the toe was not completed. Instead, berms were built over the in situ soil to provide the required stability;
- A deep ravine at the base of the valley: Concrete fill was placed at the base of the ravine and the abutment side slopes excavated to an overall slope of one to one;
- The bedrock topography in the core area: The core was steepened in the core area to better accommodate the actual topography encountered; and
- Friable foundation bedrock beneath the downstream shell: A layer of filler sand was placed over these rocks to control potential piping through friable sandstones and shattered and jointed siltstones.

Numerous changes were made in the borrow areas to find and use suitable materials. For a time, a material generally finer than anticipated was encountered in the borrow pit. Rather than waste this material, we flattened the upstream slope for about 10 m to create conditions conducive to stability.

DISCUSSION

Concern for economics prompted a relatively lean exploration

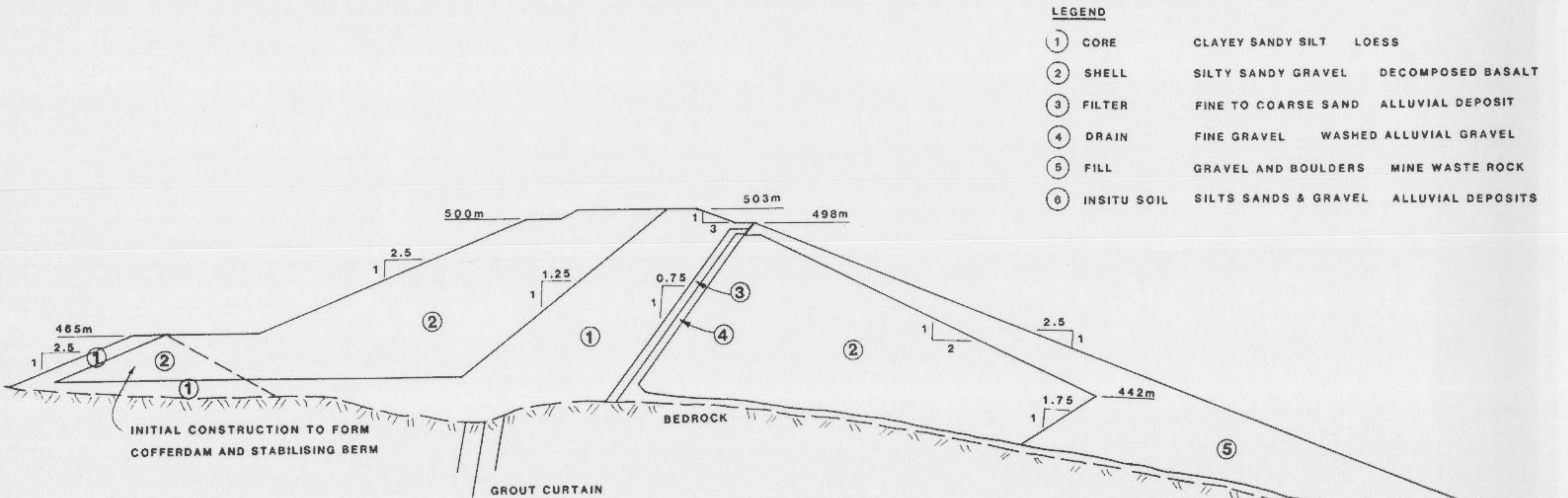


FIGURE 4. INITIAL CROSS SECTION OF EMBANKMENT AT BIDDING STAGE

program for the geotechnical facilities at the Cannon Mine - the exploration costs were about one and a half percent of the value of the work undertaken. To balance this, the engineers who did the exploration and design work were on site during construction. They were able to update their knowledge and understanding of the geology, and soils and rocks at the site as excavation and construction proceeded.

The mine developer was amenable to the many changes in the design that were made during construction as a result of observed conditions. Indeed the developer had accepted this because during the exploration stage the nature, operation, and potential advantages of the Observational Method had been explained to him.

At times during construction, some people considered that the numerous changes were leading to increased costs. A study done to evaluate this, showed that to the contrary, a significant sum of money was saved by using this approach. The cost of the normal amount of initial work was not incurred usually, about five percent of construction costs. While budget was not necessarily provided for all construction involved, all money spent on construction would have had to be spent even if the need to do so had been identified earlier. In all cases, work was done at bid rates for similar operations or at time and materials rates. Moreover, because the accepted approach was to make changes to adjust to actual conditions, we were able to make many adjustments which lead to significant savings. If a rigid approach to construction had been the order of the day, a number of aspects of construction would simply have been completed without thought given as to the need for or efficacy of such work.

CONCLUSIONS

This paper has explored the thesis that economic and rapid design and construction are possible when limited site investigation is augmented by an understanding of the engineering geology of the site and the likely behavior of available construction materials. We have shown that an essential part of this approach is an acceptance by the developer that change will be made during construction to adapt to conditions actually encountered, and to adopt this approach it is necessary to have on site people who are familiar with design requirements, the design itself, the soils and geology of the site, and who are able and empowered to make design changes considered necessary.

These ideas have been explored by way of a description of the geotechnical work done at the Cannon Mine. We have described how the design of a retaining wall, millsite cuts, and the tailing embankment were adjusted during construction to better fit actual site conditions.

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