

# The Construction of a Zoned Embankment Dam in Indonesia

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**Summary** This paper documents the construction of a 30m high water storage dam at the Bukit Sentul Project in West Java, Indonesia. The author was extensively involved in the design phase of Dam L2 and spent a subsequent six month period in Indonesia for the construction of the embankment. This paper discusses the major technical and engineering issues which arose, as well as focusing on the more practical aspects of living, working and managing a project in a foreign country.

## 1. INTRODUCTION

Dam L2 is an "off-stream" storage, and carries a curved road alignment on its crest, which dictated the final dam location. The L2 embankment was designed as a zoned earth/soft rockfill embankment with a central clay core. Geotechnical investigation and design were carried out through the latter part of 1994, with construction taking place from April to December 1995.

During the design phase the author undertook stability, seepage and seismic risk analysis, before travelling to Indonesia to take up the position of Laboratory Manager late in June 1995. This position provided much experience in construction supervision, and in September a reduction in site personnel resulted in the author's duties being extended to include the role of Site Engineer.

The specific aspects of engineering supervision included the excavation of foundations which exhibited unusually rapid deterioration upon exposure, the construction and placement of the extensive filter/seepage collection system and the quality control of material selection, compaction and testing for the ten separate zones incorporated into the embankment.

Some of the more practical issues encountered centred on the problems inherent with understanding and adapting to a different culture and working environment, such as the initial training of laboratory staff, the establishment of satisfactory standards and practices, and the continual liaison with the client and contractors.

## 2. PROJECT BACKGROUND

The Bukit Sentul Project is a US\$500M privately funded residential and resort development situated 40 km south of Jakarta in the hills surrounding the city of Bogor. Bukit Sentul could be described as a "satellite city" for affluent Indonesians, a development trend popular at the moment in South-East Asian countries with rapidly emerging economies.

The project contains a number of housing precincts, a hotel complex, high quality golf course and country club, as well as associated water supply, sewerage and transport infrastructure.

Major components of the water supply infrastructure include pumping stations set up on the nearby Citereup River, two water storage dams; L1 and L2, and a treatment plant. The original intention was to construct the two dams simultaneously, but project finances and other constraints did not allow this to occur. Dam L2 is the slightly smaller of the two, with a capacity of 400 megalitres and a maximum crest height of almost 30 metres. Its design function was to store water for golf course irrigation and to provide a temporary supply for potable water treatment.

The road on the crest and the proximity of residential subdivisions to both abutments meant that conventional spillways could not be used, so a "glory-hole" type spillway tower and outlet culvert was incorporated into the design, together with an increased freeboard. The General Arrangement of Dam L2 is depicted in Figure 1.

To this day, construction of Dam L1 has not been completed. Its original purpose was to store water for supply to a treatment plant located over the downstream toe of the embankment. This plant was, at the time urgently required, and the author was subsequently involved in the construction of the downstream toe and treatment plant platform immediately after completion of Dam L2. This work took a further two months.

### 2.1 Site Topography

The Dam L2 site is located within the prestigious 'Northridge' subdivision area, in a relatively narrow "V" shaped valley. Prior to clearing the area was covered with low trees and dense undergrowth. There were signs of previous cultivation in small alluvial flats adjacent to the water course. Both abutments are located on relatively steep slopes, as is the rim of virtually the entire impounded area.

### 2.2 Site Geology

The site is underlain by the Tertiary Jatilihur Formation, comprising marl, claystone and clay shale, with quartz sandstone intercalations. Where fresh, the formation is a blue-grey colour, but is generally weathered to a brownish flaky rock. Residual deposits are only a few metres deep, occurring as a yellow-brown

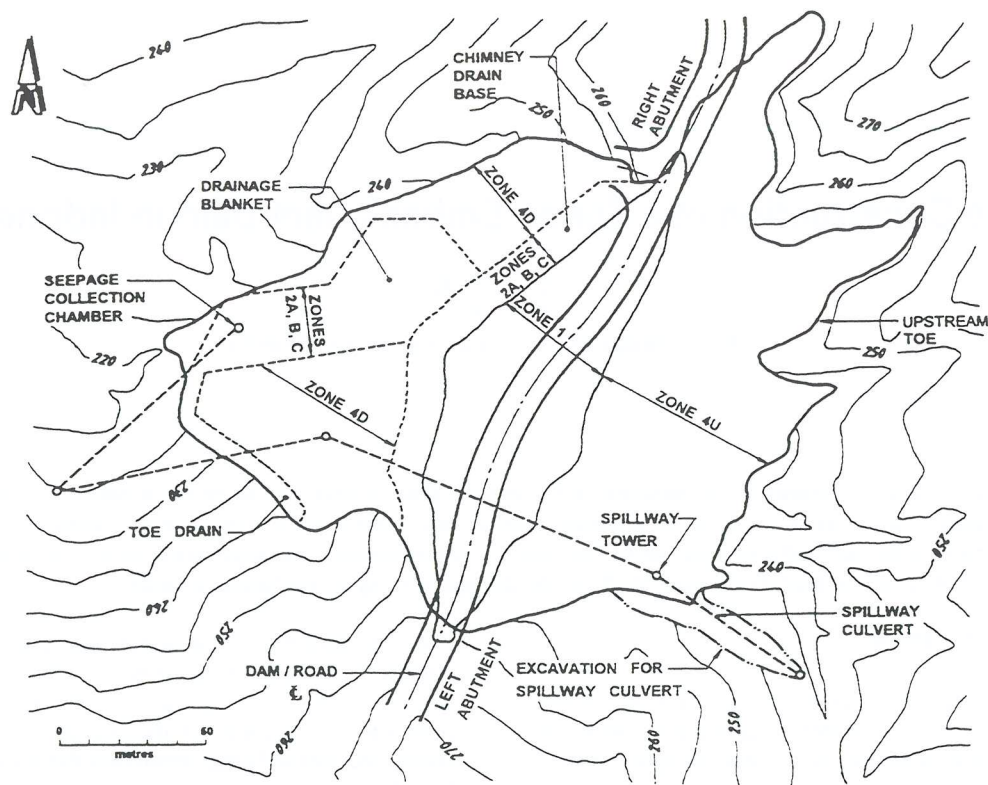


Figure 1 Dam L2 - General Arrangement

clay. The formation is generally steeply inclined and has been folded about east-west striking fold axes, with a dip to the north.

Over parts of the site (particularly the abutment slopes), the Jatilihur Formation rocks are overlain by a relatively thin (1 to 3 metres) mantle of red-brown halloysitic clays, considered to represent weathered younger Quaternary volcanics.

Zones of surficial alluvium of Recent/Quaternary origin exist along alluvial terraces in the river valleys. These include clay, silt, sand and gravel, mostly of volcanic origin.

### 2.3 Site Investigation

The site investigation was limited by terrain and access difficulties, and comprised four boreholes on the centerline, supplemented by test pits. Potential borrow areas were evaluated by test pits.

## 3. EMBANKMENT DESIGN

As with most embankments, the profile adopted for Dam L2 was governed by material availability. The client had planned to construct the dam coincident with major subdivisional works on the plateaus immediately north and east of the site, and these locations were set aside as embankment material borrow sources. Following investigation and testing of material properties, it was deemed that the clays and underlying claystone from these excavations would be suited to a zoned earth/soft rockfill embankment profile, and the typical section shown in Figure 2 was adopted.

### 3.1 Embankment Zoning

The central **Zone 1** Core consists of compacted medium to high

plasticity clay. Extensive laboratory testing indicated that both the "upper" volcanic clay and the "lower" residual clay were suitable for use. It was revealed during the site investigation that moisture contents of the clays fluctuated considerably on a seasonal basis, but were generally wet of optimum.

Given the likelihood of the wet season encroaching on the construction period, it was considered practical to approach design in a conservative manner. Hence, design proceeded for the central clay core on the basis of undrained shear strength, with no allowance made for the dissipation of pore pressures during construction. Stability limitations thus became the controlling factor, and are presented in the following section.

Based upon both laboratory and stability analyses, a minimum Dry Density Ratio of 93%(Standard) and moisture content range of 1% dry to 3% wet of optimum were specified. Notwithstanding this compliance criteria, it was also a requirement that the vane shear strength should not be less than 60 kPa.

A design permeability of  $k = 1 \times 10^{-9}$  m/sec was established for Zone 1 clay compacted in accordance with this specification. Shrinkage or cracking of the clay core was not considered to be a problem, based on the relatively flat 1:1 sides, and the thickness and low air voids content of the compacted Zone 4 rockfill shell.

Zone 2 materials form the downstream filter and drainage system. **Zone 2A** is clean, durable filter sand, and with an outer layer of geotextile forms the Chimney Drain. **Zone 2B** (nominal size 10mm) and **Zone 2C** (nominal size 20mm) are drainage materials consisting of screened gravels. These three materials together with geotextiles are incorporated in various "sandwich" arrangements to form the Chimney Drain Base, the Drainage Blanket and the Toe Drain.

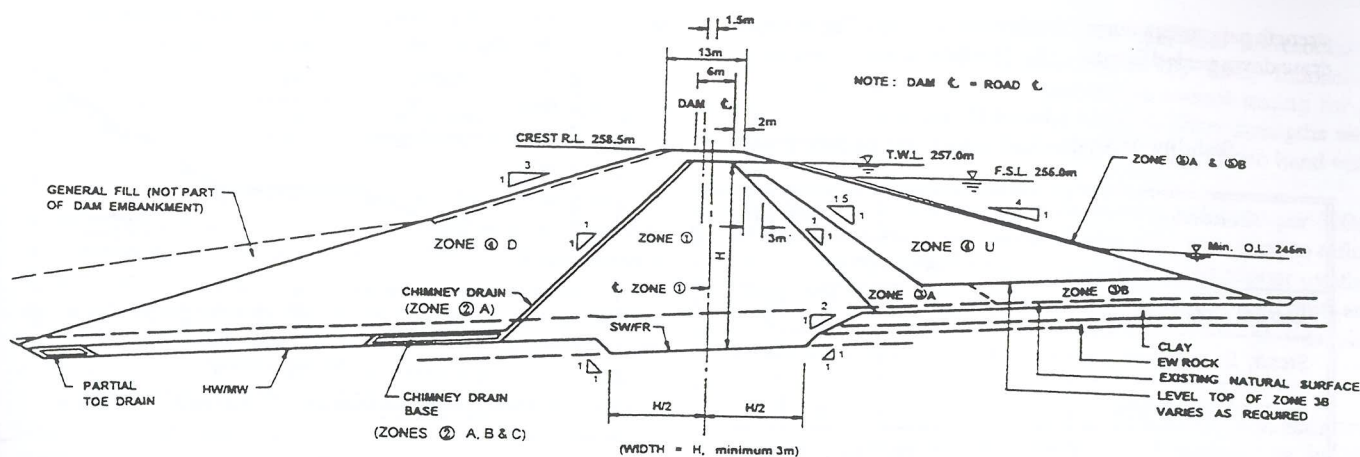


Figure 2 Dam L2 - Typical Cross Section

A Seepage Collection System comprising perforated collection pipes, concrete collection chamber and outfall pipe are located in the Blanket Drain at the downstream toe. This arrangement was necessary as the deep subdivisional fill over the downstream toe eliminated the option of conventional toe drains.

**Zone 3A** formed the upstream shoulder transition, and is made up of extremely to moderately weathered claystone compacted to a Dry Density Ratio of 95% (Standard) with moisture contents in the range 2% dry to 4% wet of optimum. **Zone 3B** consisted of similar material, and was incorporated into the floor of the upstream shoulder.

**Zone 4** slightly weathered to fresh claystone forms the upstream and downstream shoulders of the embankment. It was identified during site trial compactions that the fresh claystone forms a weak rockfill which breaks down under compaction to form a soil-like material. It was thus considered appropriate to use soil-type methodologies for fill placement and testing.

The claystone is not durable and was found to deteriorate rapidly upon exposure. When dried it cracks and shatters, and also exhibits pronounced slaking and softening in contact with water.

The shoulders were hence designed as soft rockfill, with a compacted Dry Density Ratio of 98% (Standard) and a maximum allowable air voids of 10%. This was primarily to minimise "collapse" settlements caused by the wetting up of loose, dry fill.

The upstream slope is protected by **Zone 5A** geotextile and **Zone 5B** volcanic rock rip-rap.

### 3.2 Embankment Stability

Embankment stability analyses were conducted on the maximum height section, as well as the critical topographic upstream and downstream sections. Three loading conditions were considered, namely:

- during construction
- steady state seepage during operating conditions
- rapid draw-down from full supply level (25 day and three month durations)

As the island of Java is seismically active the steady state

maximum height section was also analysed with a pseudo-static earthquake load. Existing seismicity data for the area were used to calculate horizontal acceleration versus Average Recurrence Interval (ARI). Each stability condition was then solved for " $a_{yield}$ ", the acceleration producing a Factor of Safety of 1.0 for a full depth failure surface passing through the crest.

Finite element modelling of pore water pressure dissipation in the clay fill was conducted using the computer program SEEP/W, to obtain pore pressures for use in rapid draw-down stability analyses. The embankment piezometric surfaces generated during these analyses were also used as the basis for the design of the downstream filters and drains.

Laboratory testing conducted during the site investigation phase provided a basis for the selection of the design parameters presented in Table I.

Table I  
Adopted Design Parameters

Unit Description	Strength Parameters				Bulk Density t/m <sup>3</sup>
	Steady State		During Construction		
	c' kPa	$\phi'$ deg	c <sub>u</sub> kPa	$\phi_u$ deg	
<b>Embankment -</b>					
Zone 1	0	31	50	5	1.85
Zone 3A	6	31	35	10	1.95
Zone 4	5	29	60	0	2.02
<b>Foundations -</b>			c <sub>r</sub>	$\phi_r$	
Surface Clay	5	20	0	12	1.85
HW - MW Rock	50	25	-	-	2.10
SW - Fr Rock	100	28	-	-	2.20

Critical Factors of Safety determined during the stability analysis are presented in Table II.

Upstream failures through the residual clay foundations were considered. The Zone 1 clay was assumed to exhibit undrained

strength parameters during earthquake loading. The critical rapid draw down period identified by SEEP/W was 25 days.

**Table II**  
Stability Analysis - Critical Factors of Safety

Condition	Downstream	Upstream
	Factor of Safety	
During Construction	1.71	1.30
Steady State Seepage	1.83	1.94
Rapid Draw Down	-	1.27
	$a_{yield}$ & equivalent ARI	
Seismic Steady State	0.24g   600	0.22g   450

#### 4. EMBANKMENT CONSTRUCTION

##### 4.1 Construction Progress and Timing

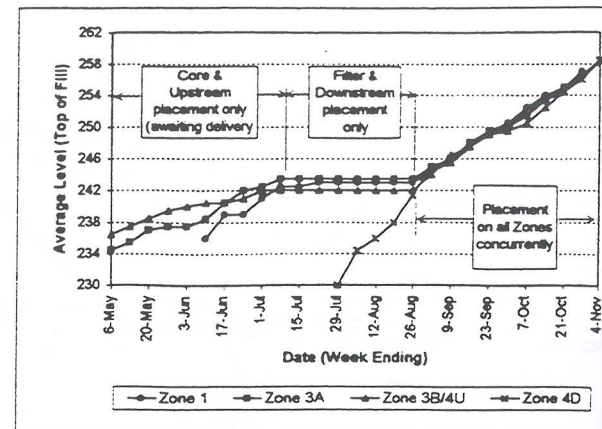
Construction of Dam L2 commenced with the clearing and stripping of topsoil in early April 1995. Actual fill placement began in early May and was practically completed in early November, a total period of approximately seven months. A total of 290,000 m<sup>3</sup> of fill was placed in this time.

The construction process is presented graphically in Figure 3. The construction time was of longer duration than originally forecast, and this can be attributed to three main factors:

- *Weather* - unseasonably wet weather during the normally drier months of April to August caused significant delays. This pattern continued into the wet season with consistent rain falling in the afternoons and evenings. Working days were shortened, with the first and last few hours of each day usually devoted to cleaning-up after a night's rain and then sealing-off in anticipation of the next.
- *Filter Material* - delays in provision of Zones 2B and 2C filter materials were a great concern during the first few months of construction, as evident in Figure 3. Random quality of materials, poor roads, long haulage distances and small, inappropriate trucks resulted in extremely slow delivery rates and the eventual postponement of all earthworks on the core and upstream shoulder for four weeks.
- *Abutment Foundations* - foundation conditions in the right (northern) abutment were poorer than expected, and subsequently required the excavation of greater quantities of unsuitable material than originally forecast. This often resulted in lengthy delays in the placement of the clay core (Zone 1).

##### 4.2 Foundation Preparation

The embankment design specified different types of surface preparation for the core trench, upstream and downstream



**Figure 3** Dam L2 - Progress of Raising

foundation areas. Soil condition / degree of weathering was as the basis for foundation stripping, as the variable subsurface conditions proved the depths encountered during the investigation to be indicative only. Stripped materials were incorporated into the embankment zones wherever practical. Works conducted in preparing the foundations, separated into three categories, can be summarised as follows:

*Type A (Upstream)* - the specification called for the stripping topsoil and the insitu compaction of the exposed clay. In practice however, the upstream ground consisted of a layer of very wet up to 2 metres thick over relatively thin zones of weathered rock. This clay was unsuitable as a foundation material and was subsequently removed. This resulted in the majority of upstream Zone 4 material being founded on moderately weathered claystone.

*Type B (Downstream)* - this type of preparation required removal of all soils and extremely weathered rock, exposing moderately weathered claystone. The claystone weathering profile was found to be very shallow, with layers of suitable moderate weathered material generally being too thin to be distinguished by excavation plant. Thus most of the downstream Zone 4 is founded on slightly weathered rock.

Although the actual Type A and B foundation works give the impression of an over-engineered design, they are in fact directly attributable to the limited coverage of the original investigation and the dryer conditions in which it was conducted.

*Type C (Core)* - Type C stripping beneath the Zone 1 core was slightly weathered to fresh claystone. After bulk excavation of weathered material, the surface was scraped with the bucket of a small excavator, hand cleaned and air blasted. Provided clay was placed within the next few hours a good surface was held, but longer exposure periods would result in rapid deterioration of the rock surface. Air blasting would then be required to be repeated whilst the total cleaning sequence was repeated in cases where the placement delay exceeded 24 hours. Deterioration after this time would generally take the form of extensive shrinkage cracking and fissuring such that lumps exceeding one kilogram could not be removed by hand.

Due to the variability of the weathering profile there were numerous places where it was not considered viable to complete

clay against the excavated and cleaned surface. Good rock was either therefore removed to provide a working area for compaction equipment, or alternatively dental concrete was poured. The biggest such problem, which was exacerbated by poor workmanship, was in the area of the spillway culvert.

The spillway culvert was constructed by a separate contractor prior to the commencement of embankment works. It was designed to be cast-in-situ, in a trench excavated into fresh rock. Subsequent excavation at the south abutment in the area adjacent to the spillway culvert showed that in some areas the culvert had not been built to specification. Fresh rock had generally not been encountered during trenching and, presumably as a result of excavation instability, the culvert had been constructed against formwork. The resulting gap was then backfilled with loose material. This formed a potential seepage path beneath the embankment, and it was necessary to remove some 180 m<sup>3</sup> of loose material and replace it with concrete. Constant supervision was then required during the preparing of foundations and placement of core material against the sides of the concrete culvert encasement.

#### 4.3 Zone 1 - Clay Core

During the Zone 1 construction, the two different medium to high plasticity clay types were utilised. The "lower" yellow residual clay type, sourced from various subdivisional works, was the primary source of core material during the early stages of construction, and was utilised in approximately 75% of the core.

During construction of the upper third of Zone 1 the reserves of "lower" clay became very limited, hence requiring the use of "upper" red-brown clay deposits. Being of volcanic origin, these contained many basalt floaters which had to be removed, usually by hand at the dam site.

Compactors and vibrating sheeps foot rollers proved to be the most efficient means of placement. Isolated or confined areas resulting from foundation preparation had their initial layers placed and compacted with a wheel-loader to avoid damage to the underlying rock foundations. In especially confined areas, such as adjacent to the spillway culvert, a whacker-packer was employed. Once all zones were at a consistent level, scrapers were used to increase placement efficiency.

As expected, most clay used was found to have a moisture content wet of optimum. The upper limit of the moisture content specification was removed during the final third of the core construction (provided all other requirements were met) to assist with the problem of increasing moisture content in the available materials as the wet season set-in. An analysis of post-construction consolidation settlements indicated that the impact of this relaxation would be negligible.

Ultimately, however, placement of the "upper" red clays had to be abandoned during the final 2 metres and "lower" yellow clay employed from a new source as moisture contents in the former were too high for required shear strengths to be obtained.

Quality control for the construction of Zone 1, as with all other zones, was the jurisdiction of the author, who determined the

timing and location of all tests, and supervised site laboratory practices. The laboratory was staffed by three Indonesian technicians, who undertook compaction control testing for all earthworks using the Hilf Rapid Method. Shear strengths were determined at each Zone 1 test location using a Pilcon hand vane.

The specified testing frequency for Zone 1 was 1 test per 500m<sup>3</sup> of fill, but this frequency was ultimately almost doubled to reflect the smaller representative lots placed as a result of poor weather conditions. Compliance testing comprising Atterberg Limits and Soil Particle Density (the latter also for Zone 4) was also conducted at a nominal rate of one per week.

The distribution of Zone 1 compaction control testing is presented in Figure 4. The density ratio histogram indicates that, of the 348 tests conducted, only 19 results fell below 92%, hence requiring recompaction and retesting. The variable field moisture contents are demonstrated in the second histogram. It can, however, be seen that only 12% of results fell outside the original specification.

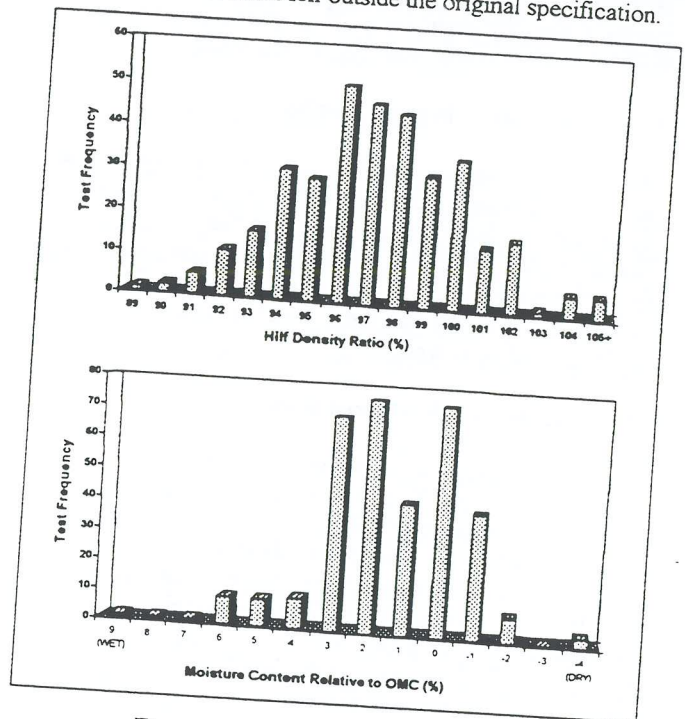


Figure 4 Zone 1 Compaction Control

#### 4.4 Zone 2 - Filters and Drains

##### 4.4.1 Zone 2A - Sand

This Zone consisted of fine to medium silica sand and was obtained off-site from a number of processed natural sand suppliers. Selection methods and quality control were based on the specification particle size distribution, with sampling and laboratory testing being carried out upon delivery as supplier quality control was poor. Very fine sand was often encountered and many of the initial deliveries had to be rejected.

Zone 2A was required in the Chimney Drain, the Chimney Drain Base and the Blanket Drain and as such required two main methods of placement. The chimney drain was placed in lifts of approximately 500 mm, with levels kept uniform with adjacent

Zones 4D and 1 for the majority of placement. Contamination was kept to a minimum by the geotextile layer and by hand removal of clay prior to subsequent lifts. Compaction was by lateral passes of the vibrating smooth drum roller. The Chimney Drain Base and Blanket Drain was placed in single lift horizontal layers with a wheel-loader, spread generally by hand and compacted with the smooth drum roller.

#### 4.4.2 Zone 2B/2C - Crushed Rock Aggregate

Initially, these zones were to consist of washed river gravels obtained on site. However, project politics resulted in these gravels becoming unavailable, resulting in the filters being redesigned, using crushed rock aggregates from various quarries around West Java. The primary quality concern was with regard to consistency of supply, with samples presented for testing often bearing little resemblance to delivered material. The most common problem was crusher-dust and the apparent inability of suppliers to remove it from the aggregate. This was particularly the case with the finer Zone 2B material, resulting in much material being rejected, often simply on a visual basis.

#### 4.4.3 Seepage Collection Chamber

The seepage collection chamber, together with the 8 collector pipes, was constructed 2.5 m higher than originally designed. The reason for this change in elevation was that unseasonably wet weather during foundation preparation and construction of the downstream toe forced the contractor to build-up Zone 4D to a level higher than the existing creek invert in order to eliminate the continual ponding of water.

#### 4.5 Zone 3A - Weathered Rockfill

This shoulder transition zone consisted of extremely and highly weathered claystone. Dam abutment excavations did at times produce material suitable for Zone 3A, and this was incorporated into the dam whenever practicable. Material selection was on the basis of visual inspection, as a broad range of material types were considered to be within the specification parameters. Placement was generally in conjunction with the two adjacent zones so that "soft spots" would not occur at the interfaces due to insufficient compaction across the zone boundaries.

#### 4.6 Zone 4 - SW/Fresh Rockfill

This Zone made up the upstream and downstream shells of the dam. The majority of material was borrowed from Northridge roadworks whilst all suitable rock from the dam foundation excavations was also recovered and utilised.

The high degree of variability in rock size and strength made compaction requirements very difficult to assess and various placement methods were experimented with during the early stages of construction. The breaking-up of individual rocks was often very time consuming, but it was found that a Caterpillar 825 compactor working in tandem with a bulldozer provided the most efficient results. Once the rock was sufficiently crushed, the vibrating sheeps-foot rollers proved effective in completing the layer to the specified compaction standard. Resultant particle sizes were predominantly gravel-sized or smaller, and hence air voids

compliance was generally always achieved. Quality control centred on the maintenance of adequate layer thicknesses, with many rock fragments being of greater size than the required layer depth. Rain was also a concern, as an uncompleted layer subjected to a heavy downpour often resulted in waterlogging and the need for subsequent material removal.

#### 4.7 Zone 5 - Upstream Slope Protection

The upstream slope protection consisted of Zone 5A and Zone 5B. "Zone" 5A was Bidim A29 geotextile which formed the base layer for the rip-rap, and Zone 5B was the rip-rap itself. It was made up of the basalt floaters which occur in the "upper" clays in abundant quantities throughout Northridge. All such stones removed from the Zone 1 clay were stock-piled at the upstream toe of the dam for use as rip-rap. The material was hand-broken to manageable sizes and hand placed over the underlying geotextile in several layers to ensure adequate coverage.

### 5. EMBANKMENT MONITORING

Seven vibrating wire piezometers were installed in various locations in the dam embankment. Five of the piezometers were installed at RL 240 m; three in Zone 1, one in Zone 3A and one in Zone 4U. The two remaining piezometers were installed in Zone 4U at RL 247 m.

As the dam design had proceeded on the basis of undrained parameters, the main purpose of the piezometers was to provide data which would be of assistance in the design and construction of the considerably larger Dam L1.

The build-up of pore pressures within the embankment were monitored by reading each piezometer and recording its associated depth of fill twice a week. The piezometers in Zone 4U showed little fluctuation due to the depth of rockfill above them; instead their fluctuations reflected rainfall patterns. Zone 1, and to a lesser extent Zone 3A showed a steady, almost linear increase in pore pressure with depth of fill, which was not unexpected, given the wet placement conditions. This increase can be seen for the Zone 1 piezometers in Figure 5. These results indicate the pore pressure parameter,  $r_u > 0.5$ , which retrospectively justifies the design based on undrained strength. Note also how pressures began to level out upon completion of fill placement.

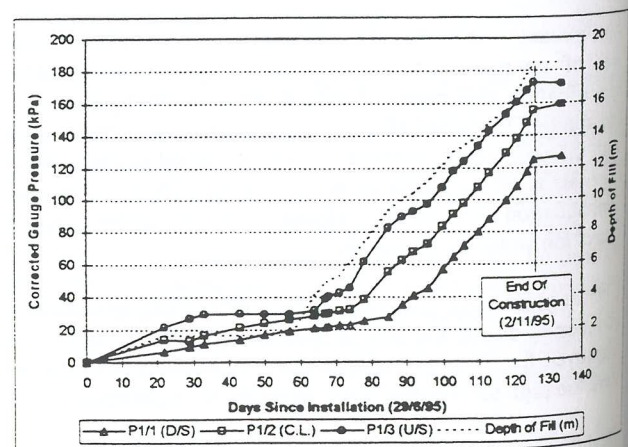


Figure 5 Zone 1 Piezometer Readings During Construction

## 6. PRACTICAL PROJECT ISSUES

As can be expected, supervising a construction project such as this in a developing Asian country results in a range of practical issues not usually encountered in Australia. Even the day to day issues which are normally expected to arise take on a new context when combined with different cultures, work ethics and languages.

### 6.1 Standards and Practices

The first major issue confronting the supervision team was the establishment of satisfactory standards and practices. Laboratory personnel supplied by the contractor were found to be excellent workers, but despite their basic understanding of testing procedures, quality control aspects of their work was initially lacking. However, once required standards were implemented, the staff demonstrated a sound willingness to learn, such that by the third construction month supervision could be lessened appreciably.

A similar situation was encountered with the construction personnel. The contractor was an Australian-Indonesian joint venture, with predominantly Australian management. Plant operators and foremen were all Indonesians, however, whose work practices and standards were found to vary considerably. This was found to be easily overcome, mainly due to the Indonesian worker's ability to put potential ego conflicts aside and their strict adherence to project hierarchies. The expatriate engineer is generally awarded the highest respect, and procedural suggestions and directives were usually eagerly implemented.

One of the biggest challenges facing the expatriate engineer is in adapting to construction practices still based largely on manual labour. Maintenance of machinery in Indonesia is generally considered optional, and man-power is cheap and abundantly available. Teams of village men and children would be on site daily for manual tasks such as foundation preparation, filter material placement, rock removal from the clay core and rip-rap breaking and placement.

Quarried material suppliers do not generally own tip trucks, so a common site would often be up to a dozen trucks encircling the filter material stockpiles, each with 10 to 15 shovel-armed Indonesians unloading by hand.

### 6.2 The Site Engineer - Client Relationship

The client filled their many levels of management predominantly with Indonesians, as well as a scattering of expatriates. During the course of the project the author liaised with many staff members of different nationalities, enabling an assessment of the various managerial styles to be made.

The Indonesian Manager, after demonstrating an initial period of caution regarding the new "foreign" site engineer, would generally

prefer to step back from the decision making process, hence requiring a much more broadly based site supervisory role to be filled. This would often involve direct liaison with contractor management on specific issues, and subsequently reporting back, often on a daily basis to the project manager.

### 6.3 Tropical Weather Patterns

Although a vague awareness of the influence tropical weather has on large construction projects was gained during the design phase, the author was quite unprepared for the scale of the impact on construction methods and productivity. A warning period for imminent rain of at least thirty minutes was essential in order to complete compaction of all working layers, and to form and seal a self-shedding profile. Local knowledge was one's greatest asset, especially during periods of unseasonably early wet weather. Wet season rainfall was somewhat more predictable, but could nevertheless be devastating in its intensity. During the early stages of construction of the Dam L1 treatment plant platform in January, 420mm of rain was received over a seven day period, engulfing stranded plant in up to four metres of water.

### 6.4 Living in a Foreign Country

Probably the most challenging and ultimately rewarding aspects of the project was learning to adapt to a whole new way of life. Little can be done to prepare the inexperienced traveller, other than to ensure that a language dictionary and malaria tablets are packed. Communication was not the hurdle initially expected; a basic understanding of the Indonesian language proved sufficient when combined with the varying degrees of English familiarity expressed by most locals.

Residence was initially in a hotel in the small city of Bogor, hence requiring a 30 minute drive to site. The Indonesian way of driving is certainly 'different', and driving ones' self was made all the more interesting by frequent break-downs and flat tyres.

Exposure to the predominantly Muslim culture was another valuable experience as its effect on day to day life is all-encompassing. The suspension of work five times a day for prayer sessions was at first frustrating, especially on occasions when wet weather was closing in.

It could in fact be concluded that the experiences gained in life-skills throughout the period of the project were equally as valuable as those of a technical nature.

## 7. ACKNOWLEDGEMENT

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