CHAPTER 7

GEOLOGY

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Chapter 7 Geology

7.1 Outline of the Geology of the Project Area

Sri Lanka is an island country lying near to the east coast of the south India. The shape of the island is like a drop which extends 435 km in north-south direction and 240 km in east-west direction. The center part of the island is a mountain area called the Central Highlands which has an average height of 1,000 m to 2,000 m at the hilltops. The other areas are low planes surrounding the mountain area on all sides of the island. The Victoria project is situated in the Mahaweli river which rises in the south part of the Central Highlands around Nuwara Eliya. The Mahaweli river flows to the north from Nuwara Eliya until the north part of the Central Highlands near Kandy. Then the Mahaweli river bends to the east and meanders through the mountains till the east border of the Central Highlands near Mahiyangana. The Victoria project area is located in 20 km south-east of Kandy where the Mahaweli river flows to the south-east direction down to the Randenigala reservoir. Then the Mahaweli river flows to the east down to Mahiyangana and then bends to the north, flows in the low plane, and finally discharges into the Koddiya bay.

According to a treatise named “The Geology of Sri Lanka (Ceylon)” (P.G. Cooray, 1984), the basement rock of Sri Lanka is composed mainly of Precambrian high-grade metamorphic rocks and numerous small dykes and veins which have intruded into the high-grade metamorphic rocks at various times between Precambrian and Tertiary eras. These basement rocks are divided into three tectonic provinces. The first one is called the Highland-Complex which lies longitudinally in the middle of the island including the Central Highlands. The second one is the Vijayan-Complex (eastern Vijayan-Complex) which lies in the eastern part of the island, and the last one is the Wanni-Complex (western Vijayan-Complex) which lies in the western part of the island. In addition, the tertiary sedimentary rocks overlies unconformably on an eroded basement of Wanni-Complex along the north-west coast of the island. The Victoria project area is in the Highland-Complex province.

Based on the construction reports and geological drawings of the existing Victoria Hydropower Station, the basement rock of Victoria project area is composed of certain kinds of Precambrian high-grade metamorphic rocks as described in details in **7.3**. Generally these rocks distribute alternately with some foldings and nearly parallel to the Mahaweli river.

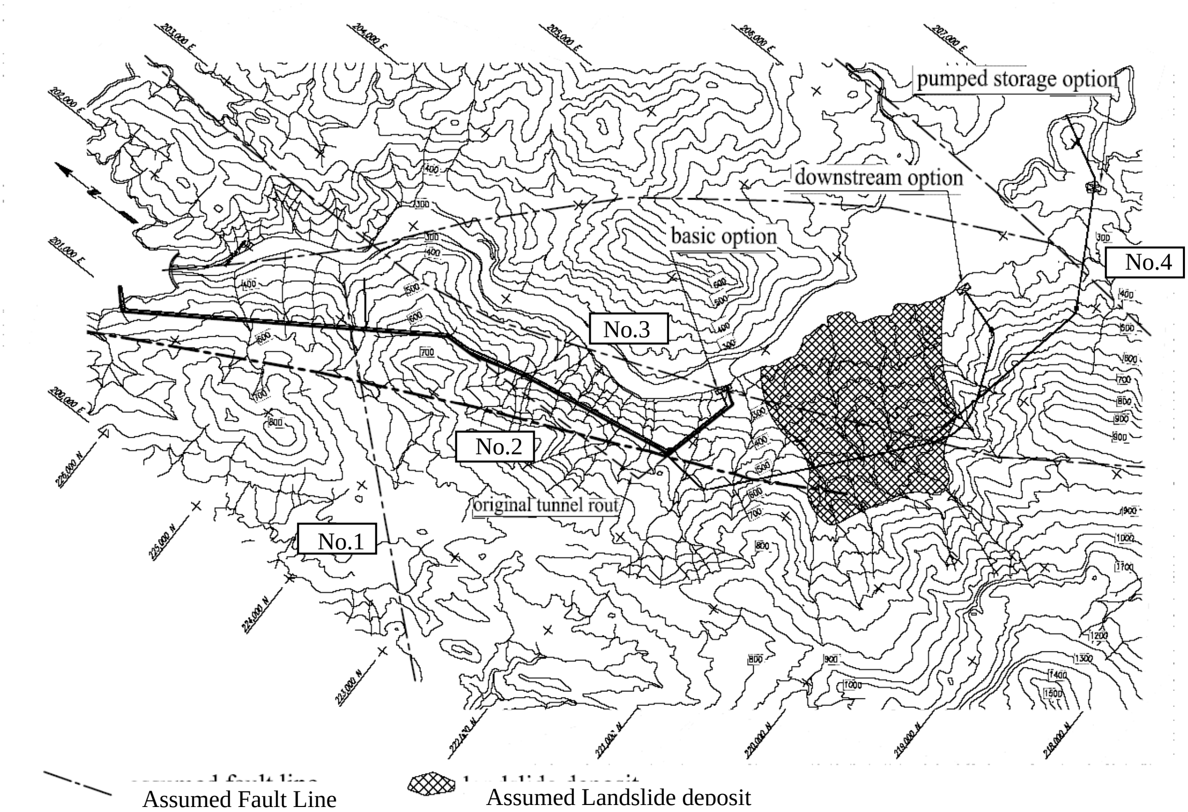
7.2 Outline of the Site Geology of the Three Alternative Options

As mentioned in Section **6.1**, CEB considered the three alternative options such as the basic option in which the new powerhouse is to be constructed adjacent to the existing powerhouse, the downstream option in which the powerhouse is located downstream of the existing powerhouse, and the pumped storage option in which the Victoria reservoir functions as the upper reservoir and the Randenigala reservoir functions as the lower reservoir. Remarkable geological phenomena which need attentions around the expansion project area are the faults shown in the 1:100,000 geologic map issued by the Geological Survey and Mines Bureau of Sri Lanka (GSMB) and a deposit zone identified by the site reconnaissance carried out by Study Team.

Five faults distribute in the expansion project area as shown in **Figure 7.2-1**. Most of them can be identified with the actual sheared zones encountered during the previous construction, so the geotechnical conditions of them are almost clear already. Four of the five faults are supposed to encounter at the expansion options. The size of each fault and relative locations between the each alternative option and faults are shown in **Table 7.2-1**. The No.2 fault running near the surge chamber is the worst and fatal among them. Hence, the existing tunnel alignment was revised in order to avoid the No.2 fault during the construction stage. The No.2 fault should be taken into account in the selection of optimal expansion option.

A large amount of deposits which extends around 1 km wide in river flow direction and around 2 km long in the perpendicular of the river flow direction was identified on the right bank downstream of the Victoria powerhouse. It seems to be made from old landslides or collapses of bank slopes. The rock cover of the new tunnel around the deposits zone would be thin and the weathered zone under the deposits might be deep because they have been escaping from erosion. The information of width and depth of both deposit zone and weathered zone is necessary for designing the tunnel alignment.

Although the basic option avoids encountering both No.2 fault and the deposits zone, the downstream option and the pumped storage option have a large risk of encountering them at their tunnel alignment. If one of the two options is selected, geological investigations and study of countermeasures for such bad geology are necessary. Hence, the basic option is recommended in order to avoid such geological risks.



Assumed Fault Line   Assumed Landslide deposit

Source: Fault: Refer to Sri Lanka 1:10,000 Geology, Geological Survey and Mines Bureau of Sri Lanka
Landslide deposit: Based on the site reconnaissance during the Study

Figure 7.2-1 Main Geological Structure of Project Area

Table 7.2-1 Main Geological Structure and Alternative Options

Main Geological Structure		No.1 Fault	No.2 Fault (Fatal)	No.3 Fault	No.4 Fault	Landslide deposit
Size (thickness of sheared zone)		2-3m	10m	5m	unknown	1km×2km
Existing Power Station		○	— / (○) Original Route	○ Powerhouse	—	—
Options	Basic Option	○	—	○ Powerhouse	—	—
	Downstream Option	○	○	○	—	○
	Pumped Storage Option	○	○	○	○	○

○ *: encounter*
— *: not encounter*

7.3 Site Geology of the Basic Option

This section shows the detailed geology of the basic option which is the selected option among the three expansion options as mentioned in Section **6.1**. As facilities of the basic option are to be located adjacent to the existing facilities, the basement rock conditions will be very similar to those of the existing facilities.

The detailed design report on existing power station could not be found during the Study, but useful documents of construction works for the existing facilities were found in the first site survey, such as the geotechnical report on the tunnel, the construction report on the powerhouse, and many drawings (geological plans, geological sections, 12 sheets of geotechnical records of the tunnel, support works, grouting works, and so on). Especially, the 12 sheets of geotechnical records of the tunnel show the 5.6 km long continuous geotechnical conditions, which cover almost of all the area of the basic option. Geotechnical Evaluation on the new facilities was carried out based on such records of geology, support works, and grouting works.

7.3.1 Waterway

(1) Topography

Each part of the waterway such as the intake, the headrace tunnel (length 5.6 km, elevation 350-270 m), the surge tank and the penstock is located on the right bank of the Mahaweli river. The ridgeline of the right bank is at 600 to 700 m in elevation, and the riverbed is on 230 to 350 m in elevation. The inclination of the slope is about 30 to 40 degrees around the project area. The rock cover of the new tunnel is about 150 m or more in the most part. The minimum rock cover portion except both portals is around [1]Ch. 2,000 m under a tributary valley near the existing adit, where the rock cover is slightly less than 100 m. And the rock cover of the downstream side of Ch. 3,500 m is 100 to 150 m, and 120 m at the surge tank. The new tunnel is located on the river side of the existing tunnel, therefore the rock cover is about 50 m smaller than that of existing tunnel.

(2) Geology

The geologic plan of project area is shown in **Figure 7.3.1-3** and **Drawing 003** (each "**Drawing**" is attached in Section **9.8**). The basement rock of waterway alignment is composed of Precambrian high-grade metamorphic rocks such as Gneiss (Garnetiferous-Quartz-Gneiss, Quartz-Biotite-Gneiss, Biotite-Gneiss), Guranulite, Quartzite, Crystalline Limestone (Marble). The thickness of each layer of Gneisses, Guranulite, and Quartzite varies several cm to several 10 m and appears in turns, therefore each layer of them can not be shown in the figure, but the alternation zones and their main component rocks are shown in the figure. While, four layers of Quartzite and one layer of Crystalline Limestone are shown in the figure, because they distribute widely and have peculiar rock characteristics. The strike of the foliation in these metamorphic rocks varies NW-SE to NNW-SSE from the dam site to the powerhouse site, nearly parallel to the meandering of the Mahaweli river. The syncline of the foliation lies along the riverbed. Hence, the foliation dips downward to the riverbed from the both banks. Basically, the dip of foliation of the right bank on which the exiting power facilities are located varies 15° at the riverside to 40° at the upper slope. Sometimes

[1] "Ch. 2000 m" means the horizontal distance at the point of 2000 m from the upstream portal along the tunnel alignment.

the irregular dip variations occur due to the minor foldings and due to the presence of displaced blocks of rocks.

The basement rock is covered by overburden or talus deposits. The highly weathered zone assumed to be muddy or sandy distributes about 1 m in depth from the ground surface, and under it another zone with 2 to 10 m deep is moderately weathered zone which is assumed to be loose brocks of rocks. Below them there should be a mixture zone of fresh rock and slightly weathered rock of which the joint faces are oxidized. The ratio of slightly weathered rock becomes smaller when it comes deeper.

As mentioned in Section **7.2**, the five faults distribute in the expansion project area, however only two of them will be concerned to the basic option. The No.1 fault of which sheared zone is 2 to 3 m wide is the only one which runs across the new tunnel alignment. When it appeared at the existing tunnel, typical supports were installed and the tunnel was stabilized without any trouble. The No.1 fault is assumed to encounter around Ch. 2,050 m of the new tunnel.

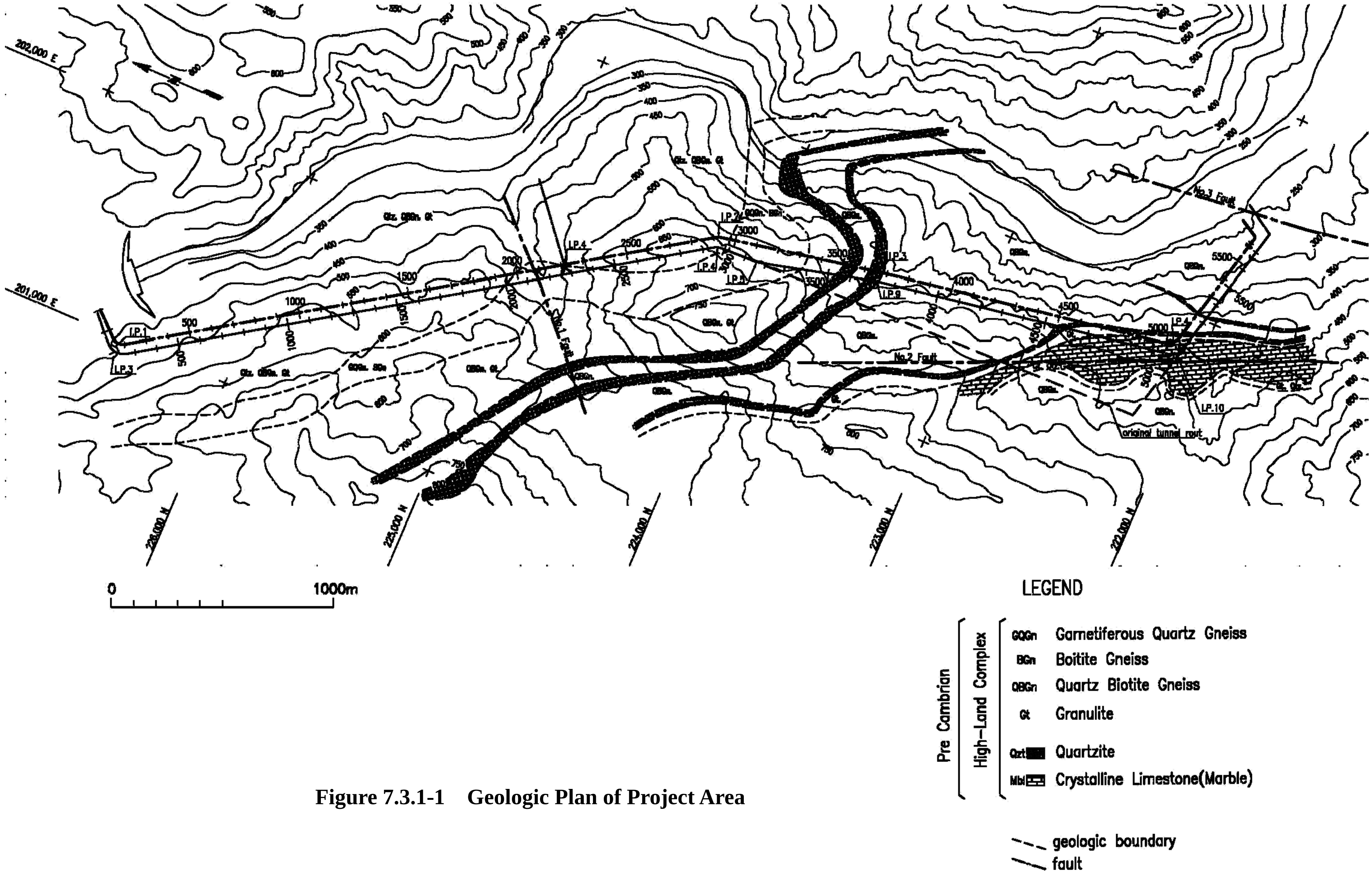


Figure 7.3.1-1 Geologic Plan of Project Area

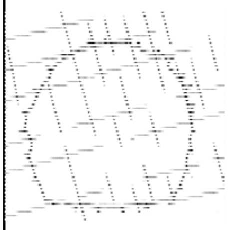
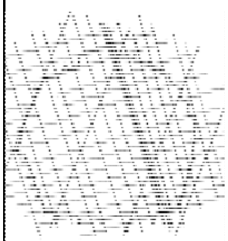
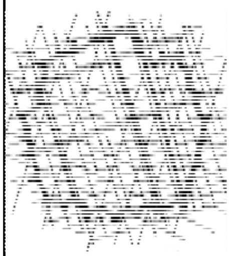
(3) Geotechnical Evaluation

The geotechnical condition of the basement rock of the basic option is expected to be basically good, because every high-grade metamorphic rock which distributes in the area is essentially hard and the joints are widely spaced, and any deep weathering zone or geothermal alteration zone has not been recognized. Although some weak rock zones such as faulted zone or highly jointed zone were recognized, all of them are not fatal and they will not cause any trouble to the construction works.

The geotechnical feature of each metamorphic rock is as follows: i) Gneiss, Granulite, and Quartzite are occasionally highly jointed along the foliation plane and the orientation which is perpendicular to the foliation. Such joints set rarely forms isolated blocks of rock at the wall, but the joints hardly slip if they are tightly pressured in the ground. When the blocks are formed in the loosen ground like faulted zone or weathered zone, the joints may open and the blocks are easy to slip down. ii) Both biotite layers in the Gneiss and mica layers in the Quartzite sometimes perform as slippery planes and tend to cause the instability of the blocks. iii) Crystalline Limestone is considered to be rarely jointed and basically in good condition. However, thin Crystalline Limestone layer which are included in other kind of rocks are sometimes associated with mica and got weathered selectively. Such weathered mica and Crystalline Limestone layer tends to cause the instability of the tunnel wall.

The geotechnical condition of basement rock is estimated to be almost good, but weak rock zones may distribute in some limited areas. Therefore, the basement rock should be classified by its geotechnical conditions so as to consider their suitable rock support patterns. In the Study, the rock mass classification established during the previous construction works seems suitable to the new project, because the geotechnical records of the previous construction works can be easily referred to for the new project. The rock mass classification is called “Rock Type” during the previous construction works and it is shown in **Table 7.3.1-1**. The basement rock is classified into the four types, ranging from the best rock showing as Type I to the worst rock indicating as Type IV. The Type IV corresponds to the condition of No.2 fault mentioned in **7.2**, so the Type IV did not appear to the existing tunnel after the revision and will not appear in the new tunnel.

Table 7.3.1-1 Rock Type

	Tipical face	Geology	Profile	Support type	Typical support cycle
TYPE I		Rock is fresh or slightly altered, joints are generally widely spaced and rough	The profile is generally very good with little or no overbreak. More than 70% of half barrels are left. No instability except isolated blocks bounded by unfavourable joints	Only occasional spot bolting is required.	N.A.
TYPE II		Rock is fresh or slightly altered and well jointed, with a small proportion of clay-filled or slickensided joints. Isolated zones of sheared material of the order of 0.5m wide may occur. This condition would be typical of isolated zones poorer rock within otherwise high quality rock, or may be associated with the margin of faulted zones below.	The profie bcomes irregular and controlled by joints. Between 20% to 80% of half barrels are left. Limited ravelling of blocks and loosening of the rock around the tunnel occurs.	Pattern rock bolts to be installed, with occasional mesh and shotcrete in shattered zones.	All support to be installed in cycle.
TYPE III		The majority of the rock is moderatery altered and well jointed with slickensided and clay-filled joints. There are multiple zones of sheared and altered material of the order of 0.5m in width. This condition would be typical of minor faults and the peripheral parts of major faults.	Profile becomes very irregular with overbreak controlled by joints. Less than 20% of half barrels are left. Considerable ravelling occurs, leading to substantial collapses if unsupported.	Immadiate support with shotcrete, mesh and pattern rock bolts to be installed. If rock conditions deteriorate towards TYPE Ⅳ, spiling may be required. Spacing of bolts and spiles estimated from the spacing of the critical joint set: Rock Bolts: 3 times the width of the blocks formed by the critical joint sets. Spiles: Less than 3 times the width of the blocks formed by the critical joint sets	A typical cycle would be as follows: 1. Blast possively using a reduced round length. 2. Inspect face and, If required, shotcrete prior to mucking. 3. Muck 4. Apply shotcrete if not already done. 5. Install bolts and mesh. 6. Apply a second layer of shotcrete. 7. Drill and Blast.
TYPE IV		The rock is predominantly highly altered, and/or there is a predominance of joint infilling. All rock is closely jointed or sheared. This condition would be typical of the central part of a major fault.	Profile is very irregular and unstable. Immadiate support is required to prevent major collapse.	Immediate support using ribs, or shotcrete, mesh and dowels to be installed. Spiling may be required. Spacing of bolts and spiles as for TYPE III.	A typical cycle would be as far TYPE III except the round length would be greatly reduced or hand excavation carried out, and if ribs were used, these would be erected immadiately and shotcrete applied between them.

(from Contract no.2-tunnel Report on geotechnical conditions, Central Consultancy Bureau, 1983)

1) Existing Tunnel

Records of previous construction works such as rock names, rock types, groundwater inflows, supports, and grouting are put together in the geologic profile of the existing tunnel shown in **Figure 7.3.1-2** and **Drawing 004** so as to estimate the geotechnical condition along the existing tunnel. The basement rock mass of the existing tunnel is mainly composed of the Type I rock. The rest consists of the Types II or III rock which corresponds to the sections where the minor faults concentrate or the sections where certain joints caused the instabilities of tunnel wall. Such weak sections are separated and tagged as “poor zone” for the convenience of estimation where the weak sections may appear in the new tunnel. The identified poor zones and the details of their composed weak sections are shown in **Table**

7.3.1-2 (1) and **Table 7.3.1-2 (2)**. The poor zones are separated by frequency and predominant orientation of minor faults, and also the appearance of groundwater inflows. The groundwater inflows occurred in these poor zones, Quartzite zones, and the weathered zones of both portals. The total length and average progress of each rock type of the existing tunnel are shown in **Table 7.3.1-3**.

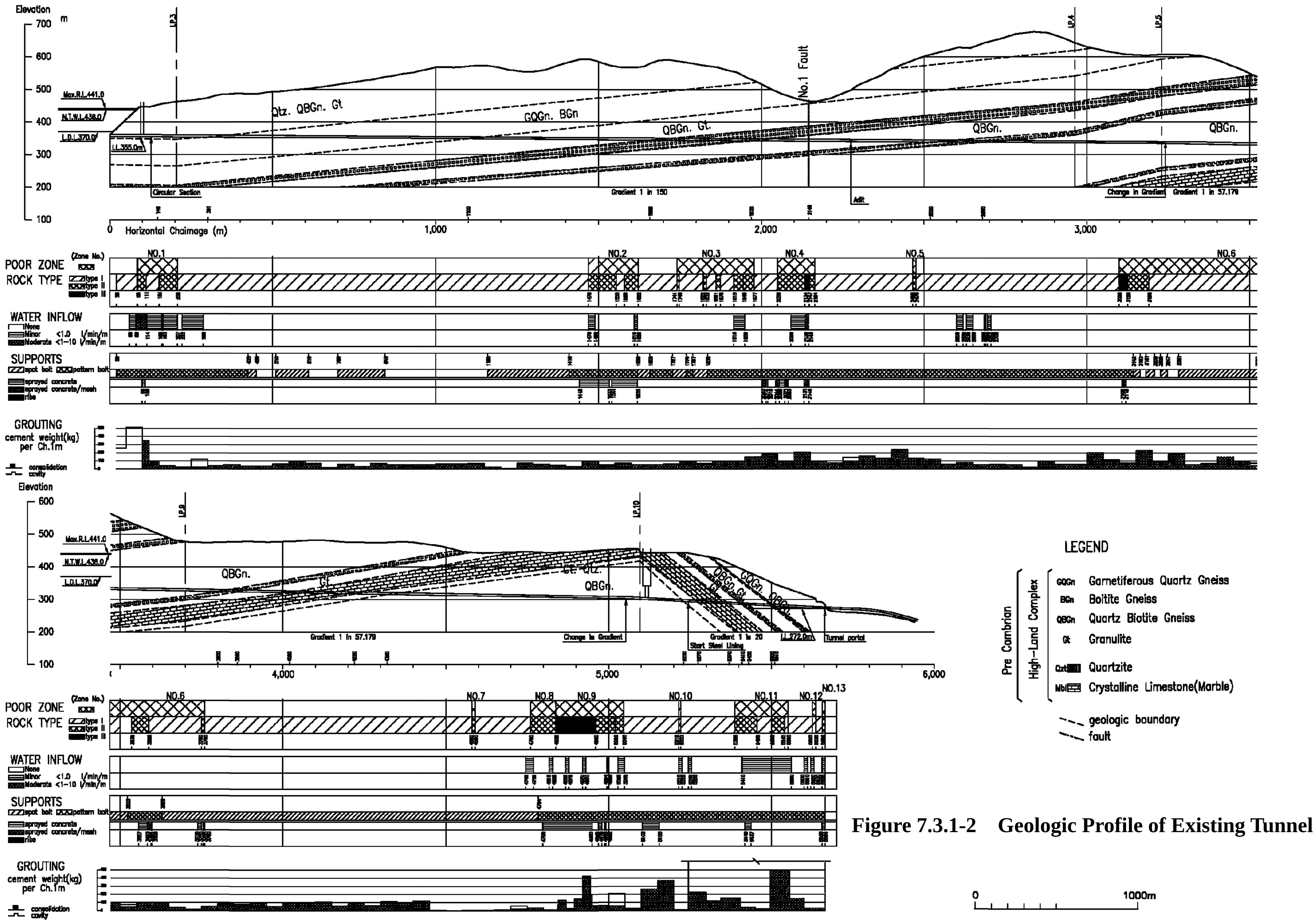


Figure 7.3.1-2 Geologic Profile of Existing Tunnel

Table 7.3.1-2 (1) Poor Zone Encountered along Existing Tunnel (1/2)

Zone no.	General condition							Details of the weak rock parts					
	Ch. (m) existing	Width(m)	Rock Type (%)			Geology	Assumed orientation	Ch. (m)	Width(m)	Rock Type	Trouble	Geological condition	Support installed
			I	II	III								
1	85 - 208	123	32.5	67.5	0.0	Granulite /Quartzite	pararell to the foliation	85 - 111	26	II	N/A	A jointed rock zone associated with smooth beddings, and minor cavitated zones.	3m pattern bolts
								151 - 208	57	II	N/A	A jointed rock zone associated with smooth beddings.	3m pattern bolts
2	1,470 - 1,622	152	16.4	83.6	0.0	Granulite	perpendicular to the foliation	1,470 - 1,555	85	II	N/A	A jointed rock zone associated with slickensided steep joints, and some smooth beddings.	3m pattern bolts 50mm shotcrete
								1,580 - 1,622	42	I-II	N/A	A jointed rock zone associated with minor faults.	3m pattern bolts 50mm shotcrete
3	1,741 - 1,977	236	60.6	39.4	0.0	Quartzite	perpendicular to the foliation	1,741 - 1,748	7	I-II	N/A	A jointed rock zone associated with a minor fault.	3m spot bolts
								1,822 - 1,832	10	I-II	N/A	A jointed rock zone associated with a minor fault and slickensided steep joints.	3m pattern bolts
								1,861 - 1,875	14	I-II	N/A	A jointed rock zone associated with minor faults.	3m pattern bolts
								1,915 - 1,945	30	II	N/A	Series of minor faults associated with minor fructured zones.	3m pattern bolts
								1,945 - 1,977	32	I-II	N/A	A jointed rock zone associated with some slickensided steep joints.	3m pattern bolts
4	2,050 - 2,164	114	0.0	88.6	11.4	Gneiss	perpendicular to the foliation	2,050 - 2,134	84	II	rock fall (sliding on a bedded plane)	A jointed rock zone associated with a series of minor faults and slickensided steep joints. A rock fall occurred at tunnel crown Ch.2,071-2,083m.	3m pattern bolts partly 50mm shotcrete partly 1m spacing ribs and backfilled concrete
								2,134 - 2,147	13	III	N/A	A jointed rock zone associated with a fault(2-3m width) and sheared and broken materials. Groundwater inflow of 100 L/m was recorded.	3m pattern bolts 2m long tensioned rock bolts 100mm shotcrete with weld mesh
								2,147 - 2,164	17	II	N/A	A jointed rock zone associated with a series of minor faults and slickensided steep joints.	3m pattern bolts
5	2,465 - 2,475	10	0.0	100.0	0.0	Gneiss	perpendicular to the foliation	2,465 - 2,475	10	II	N/A	A jointed rock zone associated with smooth beddings and steep joints.	3m pattern bolts
6	3,098 - 3,760	662	76.6	19.3	4.1	Gneiss	pararell to the foliation	3,098 - 3,125	27	III	Unstable rock (sliding along a minor fault)	An unstable zone associated with a fault(0.5m width) consisted of sheared and broken rock fragments.	100mm shotcrete with weld mesh 4m pattern bolts supports were installed immediately
								3,125 - 3,190	65	II	N/A	A jointed rock zone associated with shuttered rock.	3m spot bolts
								3,535 - 3,588	53	II	N/A	A jointed rock zone associated with shattered rock and a sheared bedding.	3m pattern bolts 50mm shotcrete
								3,730 - 3,750	20	I	N/A	A thin band of moderately weathered micaceous Crystalline Limestone.	3m pattern bolts 50mm shotcrete
								3,750 - 3,760	10	II	N/A	A thin band of moderately weathered micaceous Crystalline Limestone lying behind the tunnel crown.	3m pattern bolts 50mm shotcrete
7	4,580 - 4,590	10	0.0	100.0	0.0	Gneiss	pararell to the foliation	4,580 - 4,590	10	II	N/A	A jointed rock zone associated with a minor fault.	3m pattern bolts

Table 7.3.1-2 (2) Poor Zone Encountered along Existing Tunnel (2/2)

Zone no.	General condition							Details of the weak rock parts					
	Ch. (m) existing	Width(m)	Rock Type (%) I	Rock Type (%) II	Rock Type (%) III	Geology	Assumed orientation	Ch. (m)	Width(m)	Rock Type	Trouble	Geological condition	Support installed
8	4,760 - 4,838	78	0.0	100.0	0.0	Gneiss	diagonally across the foliation	4,760 - 4,838	78	II	N/A	A jointed rock zone associated with minor faults, steep slickensided joints and smooth beddings.	3m pattern bolts 4m long tensioned rock bolts 100mm shotcrete with weld mesh
9	4,838 - 5,046	208	0.0	41.3	58.7	Gneiss	perpendicular to the foliation	4,838 - 4,960	122	III	rock fall (sliding alog minor faults)	A shattered zone associated with a series of minor faults. A rock fall of 25m^3 occurred around Ch.4,923m from the west shoulder of the tunnnel.	4m pattern bolts 50-100mm shotcrete
								4,960 - 5,020	60	II	N/A	A jointed rock zone associated with shattered rock.	3m pattern bolts
								5,020 - 5,046	26	II	N/A	A jointed rock zone associated with a minor fault and steep slickensided joints.	3m pattern bolts
10	5,215 - 5,222	7	0.0	100.0	0.0	Gneiss	perpendicular to the foliation	5,215 - 5,222	7	I-II	N/A	There is a minor fault	3m pattern bolts
11	5,388 - 5,550	162	25.9	74.1	0.0	Granulite Quartzite	pararell to the foliation	5,388 - 5,418	30	I-II	N/A	A jointed rock zone	3m pattern bolts
								5,418 - 5,438	20	II	N/A	A jointed rock zone associated with a minor sheared zone and a micacious Crystalline Limestone layer.	3m pattern bolts 50mm shotcrete with weld mesh
								5,438 - 5,468	30	I-II	N/A	A jointed rock zone associated with a micacious Crystalline Limestone layer.	3m pattern bolts
								5,500 - 5,530	30	I-II	N/A	A jointed rock zone	3m pattern bolts
								5,530 - 5,540	10	II	N/A	There is a thick micacious Crystalline Limestone layer.	3m pattern bolts
								5,540 - 5,550	10	I	Major ground water inflow (fissure)	A ground water inflow of 50-100L/m and back pressure 0.25-0.45MPa(2.5-4.5bar) was recorded in the probe hohes. 15tons of cement were injected.	3m pattern bolts
12	5,625 - 5,635	10	100.0	0.0	0.0	Gneiss	pararell to the foliation	5,625 - 5,635	10	I	rock fall (sliding along a sheared zone), Major ground water inflow	There is a broken and sheared zone (<1m width) associated with clay, which contributed to the formation of weadges and blocks. A groundwater inflow of 50-60 L/m was recorded at this zone.	3m pattern bolts 4m long tensioned rock bolts 50mm shotcrete with weld mesh ribs
13	5,655 - 5,664	9	0.0	100.0	0.0	Gneiss	pararell to the slope	5,655 - 5,664	9	II	Unstable rock (sliding on bedded planes)	A weathered and jointed rock zone associated with smooth beddings and slickensided steep joints.	3m pattern bolts 50mm shotcrete ribs

Table 7.3.1-3 Total Length and Average Progress of Each Rock Type of Existing Tunnel

	Total length in existing tunnel (m)	Percentage (%)	Average progress (m/week)	Support Installed
Type I	4,650	82.1	39.6	> Occasional spot bolts
Type II	852	15.0	15.9	> 3m long pattern rock bolts > 50mm shotcrete with or without mesh
Type III	162	2.9	5.1	> 3-4m long pattern rock bolts > Occasional 4m spiles > 50-100m shotcrete with mesh
Type IV	0	0.0	N.A.	N.A.

(based on Contract no.2-tunnel Report on geotechnical conditions, Central Consultancy Bureau, 1983)

2) New Tunnel

The geotechnical condition of the new tunnel is assumed to be similar to that of the existing tunnel. However, the actual sections where the geologic items such as geology, poor zones appear in the new tunnel will be shifted along their boundaries. Hence, the actual sections where they appear are estimated as follows: i) First, draw the geological items which are encountered along the existing tunnel into the geologic horizontal section shown in **Figure 7.3.1-3** and **Drawing 003**. ii) Then extend their boundaries along the orientations which are assumed in the record of the existing tunnel and find the crossing points of the new tunnel. iii) Estimate the assumed sections where each geological item will appear.

The sections where minor groundwater inflows may occur are assumed to be the same sections of poor zones, quartzite zones, and the weathered zone at the portal. And the sections where major groundwater inflows may occur are assumed to be the same sections of weathered zone at the portal, No.1 fault zone, and Crystalline Limestone zones. The Crystalline Limestone is assumed to be good rock condition but still remains the possibility of existence of unpredictable cavities because of its soluble nature.

The assumed sections of geological items such as rock name, poor zone, rock type, and groundwater inflow are put together in the geologic profile of the new tunnel shown in **Figure 7.3.1-4** and **Drawing 005**. The details of the assumed condition of each poor zone are shown in **Table 7.3.1-4**. The details of the assumed sections where ground water inflow may occur are shown in **Table 7.3.1-5**.

When the tunnel excavation reaches to the poor zone, the tunnel wall would be stabilized with the adequate supports pattern of its rock type. The major groundwater inflows which assumed to appear in the new tunnel may not be fatal to the excavation works, but the impact to the existing wells or valleys should be considered. The probe drilling in the sections where major ground water inflows are suspected to appear may foresee the possibility of major ground water inflows and the pre-grouting in the zone will decrease impacts caused by tunnel excavation.

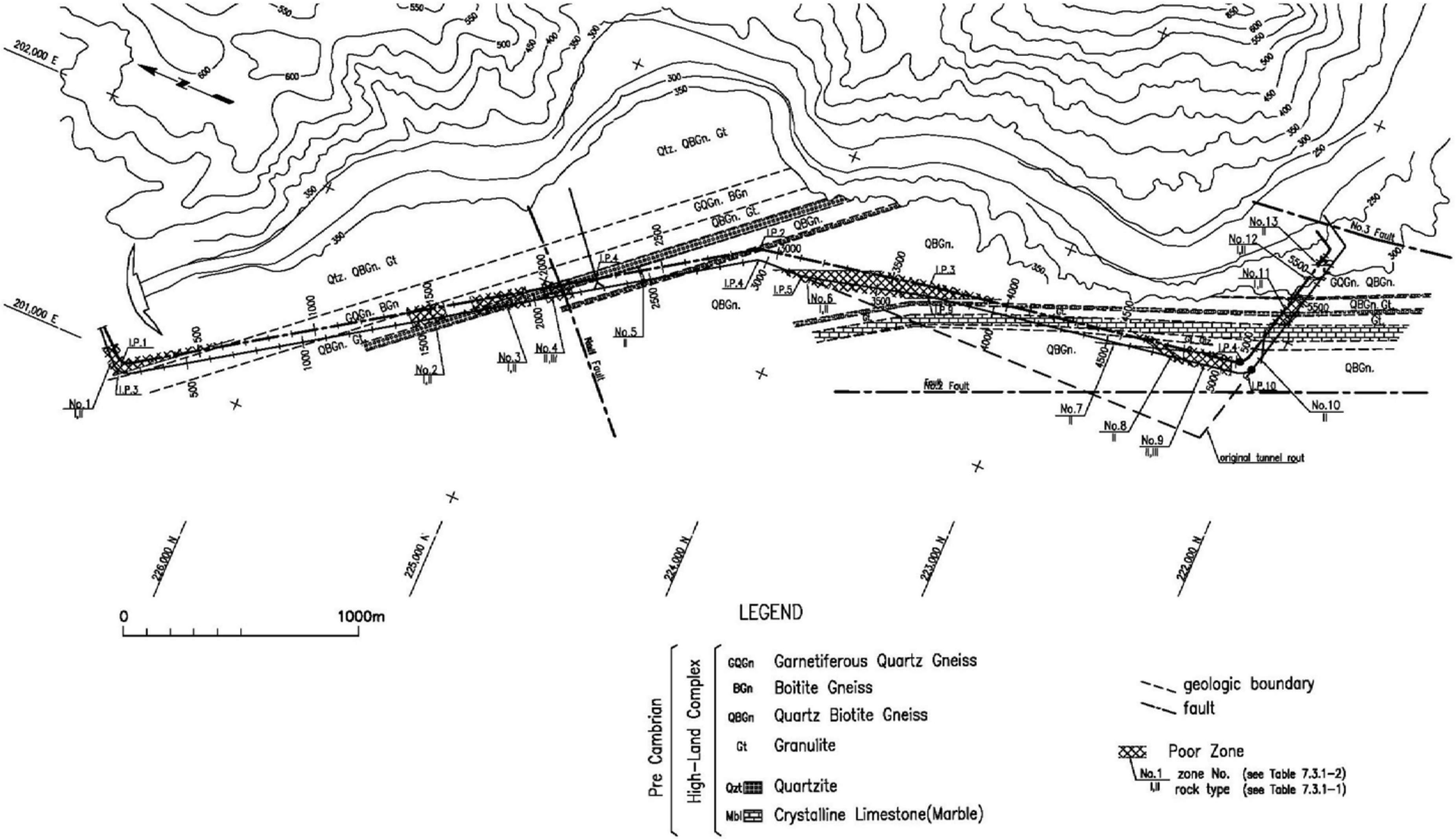


Figure 7.3.1-3 Geologic Horizontal Section at Tunnel Level

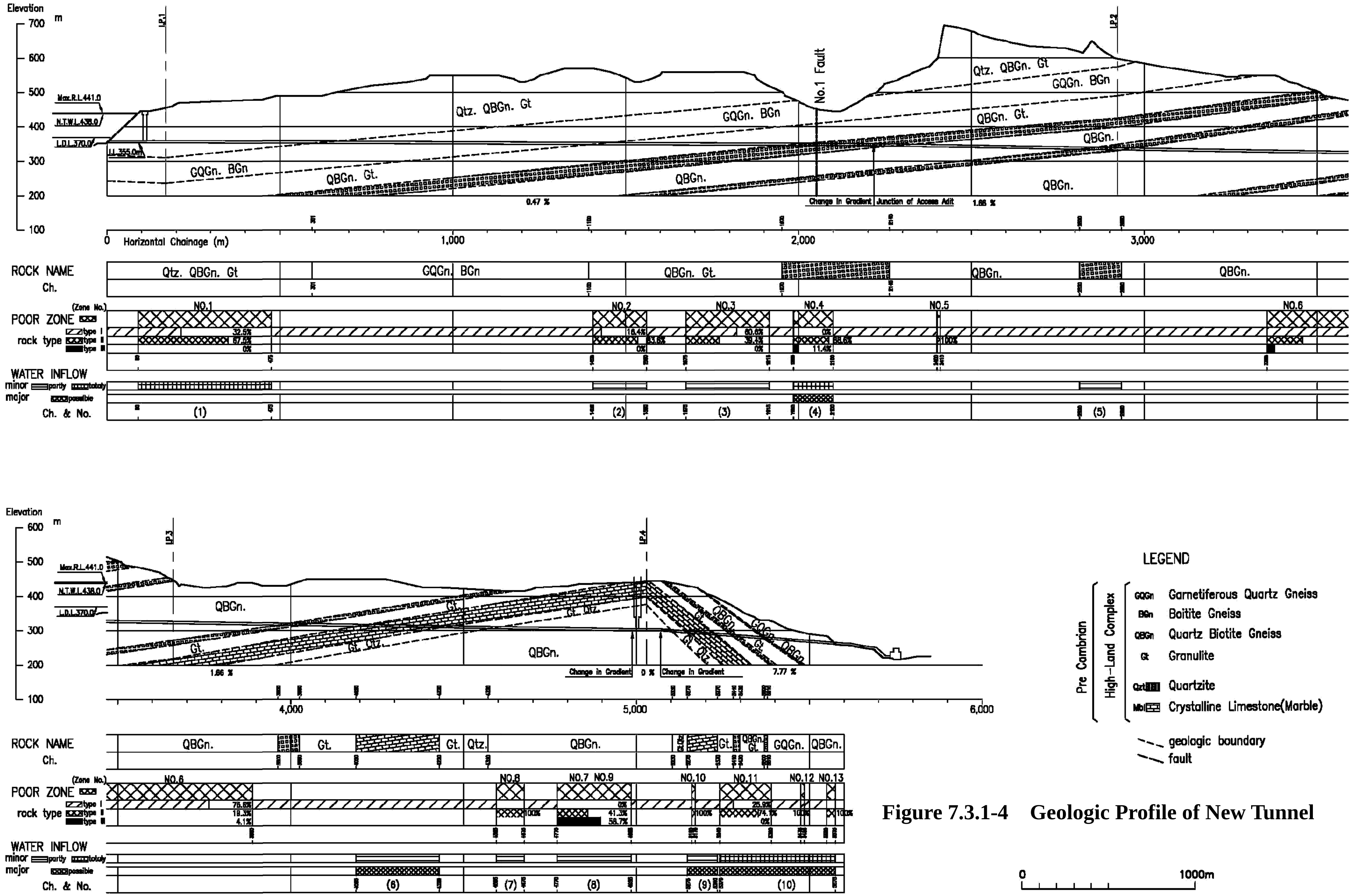


Figure 7.3.1-4 Geologic Profile of New Tunnel

Table 7.3.1-4 Assumed Sections where Poor Zones will be Encountered along the New Tunnel

Zone No.	Ch. (m) new tunnel	Width(m)	Assumed condition									
			Rock Type						Geology	Orientation	Geological condition	Support items
			I		II		III					
			%	m	%	m	%	m				
1	90 - 475	385	32.5	125	67.5	260	0.0	0	Granulite /Quartzite	pararell to the foliation	There will be some jointed rock zones associated with smooth beddings and merely minor cavitated zones.	3m pattern bolts
2	1,405 - 1,560	155	16.4	25	83.6	130	0.0	0	Granulite	perpendicular to the foliation	There will be some jointed rock zones associated with smooth beddings, slickensided steep joints and minor faults.	3m pattern bolts partly 50mm shotcrete
3	1,675 - 1,915	240	60.6	145	39.4	95	0.0	0	Granulite	perpendicular to the foliation	There will be some jointed rock zones associated with slickensided steep joints and minor faults.	3m pattern bolts
4	1,985 - 2,100	115	0.0	0	88.6	102	11.4	13	Quartzite	perpendicular to the foliation	A jointed rock zone associated with a series of minor faults and slickensided steep joints.	3m pattern bolts partly 50-100mm shotcrete partly ribs
5	2,400 - 2,410	10	0.0	0	100.0	10	0.0	0	Gneiss	perpendicular to the foliation	A jointed rock zone associated with smooth beddings and steep joints.	3m pattern bolts
6	3,355 - 3,890	535	76.6	410	19.3	103	4.1	22	Gneiss	pararell to the foliation	There will be some jointed rock zones associated with shattered rock, sheared beddings and weathered micaceous Limestone layers.	3m pattern bolts partly 50mm shotcrete partly 100mm shotcrete with weld mesh
8	4,595 - 4,675	80	0.0	0	100.0	80	0.0	0	Gneiss	diagonally across the foliation	A jointed rock zone associated with minor faults, steep slickensided joints and smooth beddings.	3m pattern bolts 4m long tensioned rock bolts 100mm shotcrete with weld mesh
7,9	4,770 - 4,985	215	0.0	0	41.3	89	58.7	126	Gneiss	perpendicular to the foliation	A shattered zone associated with a series of minor faults and steep slickensided joints	4m pattern bolts partly 50-100mm shotcrete
10	5,160 - 5,170	10	0.0	0	100.0	10	0.0	0	Gneiss	perpendicular to the foliation	A minor fault	3m pattern bolts
11	5,240 - 5,390	150	25.9	39	74.1	111	0.0	0	Granulite Quartzite	pararell to the foliation	There will be some jointed rock zones associated with a minor sheared zone and micacious Limestone layers.	3m pattern bolts partly 50mm shotcrete with weld mesh
12	5,475 - 5,485	10	100.0	10	0.0	0	0.0	0	Gneiss	pararell to the foliation	A broken and sheared zone associated with clay, which will contribut to the formation of weadges and blocks. Much groundwater inflow may appear.	3m pattern bolts partly 4m long tensioned rock bolts partly 50mm shotcrete with weld mesh partly ribs
13	5,550 - 5,575	25	0.0	0	100.0	25	0.0	0	Gneiss	pararell to the slope	A weathered and jointed rock zone associated with smooth beddings and slickensided steep joints.	3m pattern bolts 50mm shotcrete ribs

Table 7.3.1-5
Assumed Sections where Ground Water Inflows will be Encountered along the New Tunnel

secton No.	Assumed condition					
	CH. (m) new tunnel	Width (m)	Geology	Geological condition	possibility of groundwater inflow	
					minor groundwater inflow	major groundwater inflow
(1)	120 - 475	355	Granulite /Quartzite	This section corresponds to the identified poor zone 1(see table 7.3.1-4).	Minor ground water inflow may occur along most of the section.	Major water inflow may not occur.
(2)	1,405 - 1,560	155	Granulite	This section corresponds to the identified poor zone 2(see table 7.3.1-4).	Minor ground water inflow may occur partly.	Major water inflow may not occur.
(3)	1,675 - 1,915	240	Granulite	This section corresponds to the identified poor zone 3(see table 7.3.1-4).	Minor ground water inflow may occur partly.	Major water inflow may not occur.
(4)	1,985 - 2,100	115	Quartzite	This section corresponds to the identified poor zone 4(see table 7.3.1-4). There is the most obvious minor fault crossing this section.	Minor ground water inflow may occur along most of the section.	Major water inflow might occur at the minor fault zone.
(5)	2,520 - 2,680	160	Quartzite	This section corresponds to the exposure of a Quatzite band.	Minor ground water inflow may occur partly.	Major water inflow may not occur.
(6)	4,020 - 4,220	200	Crystalline limestone	This section corresponds to the exposure of a Crystalline Limestone band.	The Crystalline Limestone band appears dry at the existing tunnel.	There still remains the possibility of existence of cavities and major ground water inflow because of the soluble nature of the rock.
(7)	4,595 - 4,675	80	Gneiss	This section corresponds to the identified poor zone 8(see table 7.3.1-4).	Minor ground water inflow may occur partly.	Major water inflow may not occur.
(8)	4,770 - 4,985	215	Gneiss	This section corresponds to the identified poor zone 9(see table 7.3.1-4).	Minor ground water inflow may occur partly.	Major water inflow may not occur.
(9)	5,275 - 5,370	95	Crystalline limestone	This section corresponds to the exposure of a Crystalline Limestone band.	The Crystalline Limestone band appears dry at the existing tunnel.	There still remains the possibility of existence of cavities and major ground water inflow because of the soluble nature of the rock.
(10)	5,240 - 5,575	335	Gneiss	This section corresponds to the identified poor zone 11,12,13(see table 7.3.1-4).	Minor ground water inflow may occur along most of the section.	Major water inflow might occur at weahered joints and open beddings.

3) Surge Tank

The geologic profiles of the new surge tank are shown in **Figure 7.3.1-5** and **Drawing 005**. The location of the new surge tank is about 60 m north of the existing surge tank, and the direction in which the new surge tank is located from the existing surge tank is roughly parallel to the strike of geologic boundary. Therefore, the geotechnical condition can be expected to be similar to existing surge tank. The basement rock is composed of Crystalline Limestone at the upper part, the alternated zone of Quartzite and Granulite at the middle part, and Gneiss (Quartz-Biotite-Gneiss) at the deeper part. The geotechnical condition is expected to be good, but some isolated blocks of rocks may appear at the wall. Such blocks will be stabilized by the adequate spot boltings. The core drillings are recommended to be carried out during the detailed design stage in order to certify the boundaries of geology and weathered zones. Furthermore, permeable testing in the borehole is desirable in order to find water passes which would cause major groundwater inflows and lowering of water level of wells around there.

The pre-grouting in the water passes during construction may prevent the outbreak of the ground water inflows, and such measures during construction will decrease impact caused shaft excavation.

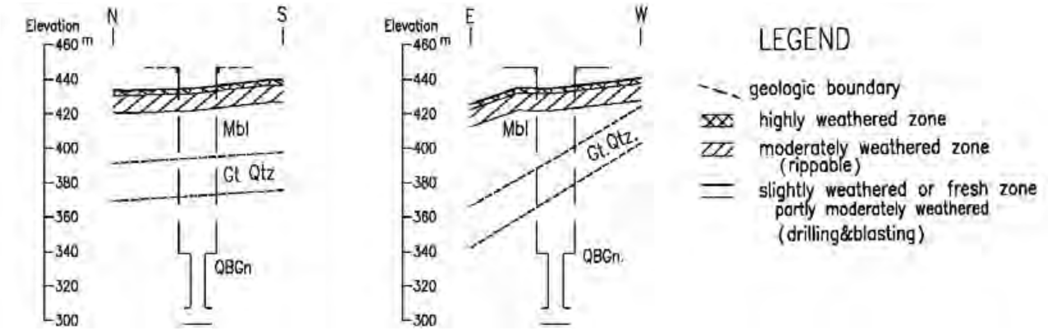


Figure 7.3.1-5 Geologic Profile of New Surge Tank

4) Surface Type Penstock

The geologic profiles of the new penstock are shown in **Figure 7.3.1-6** and **Drawing 006**. The surface portion of the penstock is situated on the slope between the downstream portal about on 270 m in elevation and the powerhouse about on 230 m in elevation. The basement rock of the slope is mainly composed of Gneiss (Garnetiferous-Quartz-Gneiss), of which foliation is nearly parallel to the slope inclination, and the biotite layers which are included in Gneiss tend to become slippery planes when they are in the weathered zone. Due to such biotite layers and a small fault, a slip of about 100 m^3 of material occurred during the previous construction. It is necessary to pay attention to the appearance of instable blocks during excavating in the weathered zone, and to install the adequate rock bolts when it appears.

The core drillings at the anchors are recommended to be carried out during the detailed design stage in order to certify the boundaries of weathered zones.

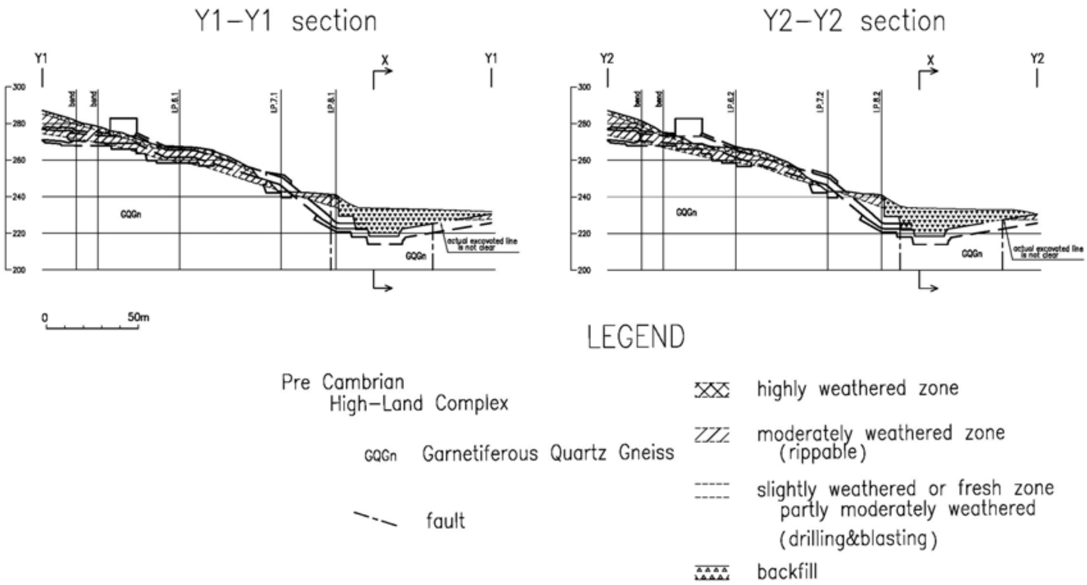


Figure 7.3.1-6 Geologic Profile of New Penstock

7.3.2 Powerhouse

The geologic section of powerhouse is shown in **Figure 7.3.2-1** and **Drawing 006**. The powerhouse is situated on the gentle slope near the riverbed. The basement rock of the new powerhouse was already excavated during the previous construction works. According to the construction report on the powerhouse, the basement rock is composed of Gneiss (Garnetiferous-Quartz-Gneiss, Quartz-Biotite-Gneiss). The weathered zone was already removed, and the fresh zone and slightly weathered zone are exposed on the foundation surface. There are two parallel fault zones at the powerhouse foundation which are striking NNW-SSE and considered to be the No.3 fault shown in **Figure 7.2-1**. The western fault is associated with 1 to 2 m wide shear zone, and the eastern fault is associated with 5 m wide shear zone. The strict positions of them are not clear but if they appear at the new powerhouse foundation, substitute concrete for the sheared zone would keep the foundation bearing. The gently dipping foliation beds and steep joints tend to form 0.5 m to 2 m blocks, which might cause overbreaks on the horizontal foundation surfaces. Foliation beds and joints on the already excavated foundation surface may have loosened because over 20 years have passed after excavation. The actual excavated shape is not clear, therefore the shape should be confirmed during the construction stage.

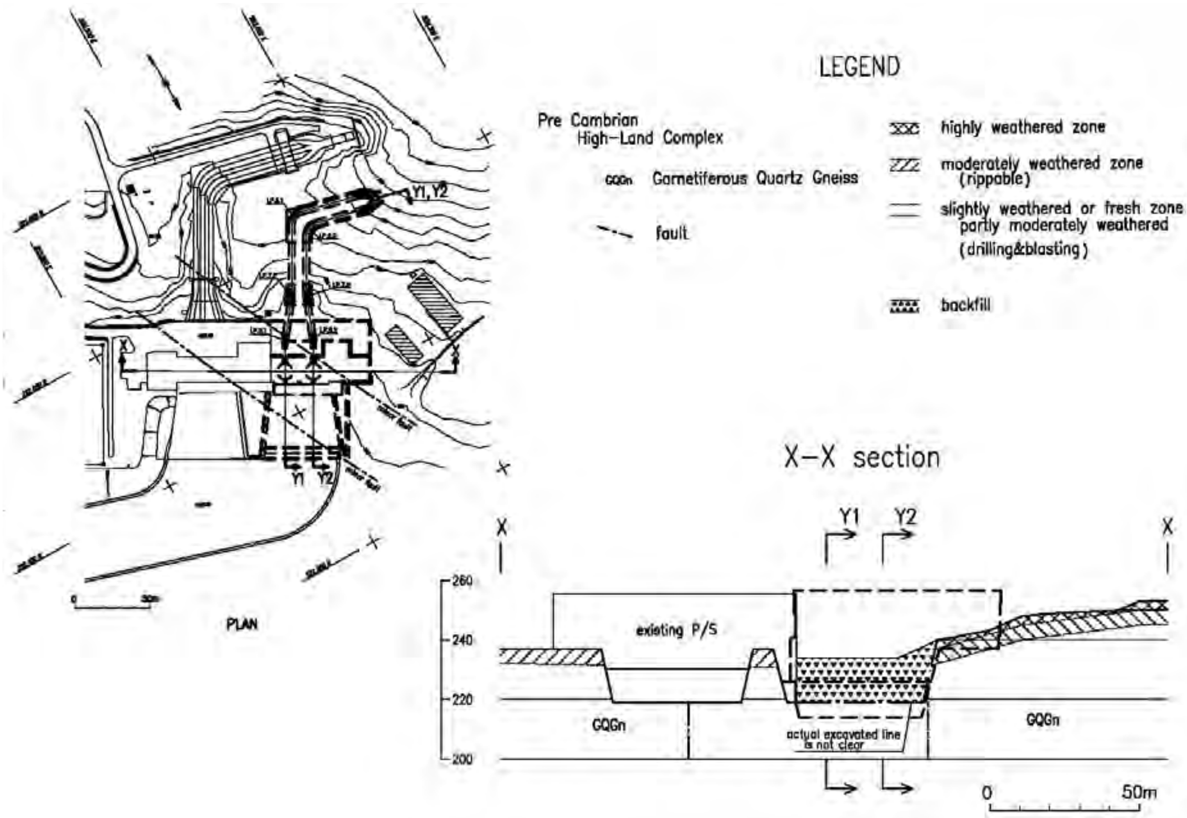


Figure 7.3.2-1 Geologic Section of Powerhouse

7.4 Construction Material

The quarry site used during the previous construction works is located 1 km downstream of the dam site. Coarse and fine aggregates were produced by using materials taken from the quarry site during the previous construction. Most of the rock had been already excavated. As mentioned in Chapter **10**, fresh rock obtained from the tunnel excavation is considered for the aggregates.

According to the construction report on the powerhouse, a half portion of fine aggregates were obtained from river sand which distributed in limited area of the Mahaweli river. But there is not much sand in the river now. The sedimentation of the Victoria reservoir is little, and the sedimentation of the upstream part of the Randenigala reservoir is mainly composed of sandy mud which is too powdery to produce fine aggregate. As mentioned in Section **10.1.3**, the river sand at the tributary valley located 5 km upstream from the CEB's tunnel office has a possibility for use.