No.

# THE FOLLOW-UP STUDY
# ON
# THE REHABILITATION OF
# HYDROPOWER STATIONS IN THE
# KELANI RIVER BASIN
# FOR
# HYDROPOWER OPTIMIZATION
# IN
# SRI LANKA

# FINAL REPORT
# Vol. II
# APPENDIX

**JULY 2005**

**JAPAN INTERNATIONAL COOPERATION AGENCY**
**ECONOMIC DEVELOPMENT DEPARTMENT**

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# Appendix

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# *APPENDIX A*

# *MAINTENANCE AND INSPECTION MANUAL FOR CIVIL STRUCTURE*

# *APPENDIX A-1*
# *GEOLOGICAL INVESTIGATIONS*

# 1. ASSUMED GEOLOGICAL PROBLEMS AND ADDITIONAL INVESTIGATIONS

The problems to be studied in terms of geology are as follows.

・Assumed collapse of tunnel walls at Wimalasurendra Power Station
・Water leakage and slope instability around the surge tank of New Laxapana Power Station
・Slope instability around Polpitiya Power Station
・Instability of the slope behind Polpitiya Power Station

To study the above assumed problems, the additional investigations shown in Table 1.1 was carried out from October, 2004 to March, 2005.

**Table 1.1 Additional Investigations**

| Name of Power Station | Structure | Infered geolpgical problem | Investigation: Inspection of tunnel inside | Investigation: Topographic survey | Investigation: Geoogical mapping | Investigation: Water quality test | Investigation: Mesurement of discharge volume |
|---|---|---|---|---|---|---|---|
| Wimalasurendra | Headrace Tunnel | collapse | yes | | | 1set | |
| New Lavapana | Surge Tank and surroundings | leakage ans slope stability | | 20ha | 20ha | 1set | 1set |
| Polpitiya | Intake and surroundings | slope stability | | 6ha | 6ha | | |
| | Slope behind Power Station | slope stability | | 10ha | 10ha | | |

# 2. THE HEADRACE TUNNEL OF WIMALASURENDRA POWER STATION

Some problems such as collapsing walls had been a concern in the headrace tunnel of Wimalasurendra because mad water was observed at the outlet of the power station. Accordingly, the Study Team conducted the investigation with CEB, when the headrace tunnel was dewatered at the end of February 2005.

Consequently, only several small wall collapses of were detected. However, there are no serious damages caused by geologically weak zones.

The small collapses have been repaired by CEB during the dewatering period.

# 3. AROUND THE SURGE TANK OF NEW LAXAPANA POWER STATION

## 3.1 General

There are many water springs on the slopes around the surge tank of New Laxapana Power Station. The history of these springs is as follows.

・There were small springs on the slope above the tarred road away from the valve house.

・It is reported that with the excavation of the tunnel, the springs on the valve house slope had dried up.

- They reappeared only a few years after filling the tunnel. Since then, there has been an increase in the number of springs.

- After slow dewatering of the Head race tunnel in Feb-March1998, the springs on the slope area around the valve house dried up, and reappeared a few hours after of the start of tunnel filling.

- At present, seepage water from a cluster of springs by the roadside is routed through pipes for domestic use by the villagers living on the lower slopes.

The above information clearly indicates that the water of the springs around the surge tank are from the waterway of the New Laxapana Power Station.

To study the effect of the springs on slope stability, a topographical survey, geological mapping, water quality test and measurement of discharge of small streams were carried out.

### 3.2 Topography and Geology

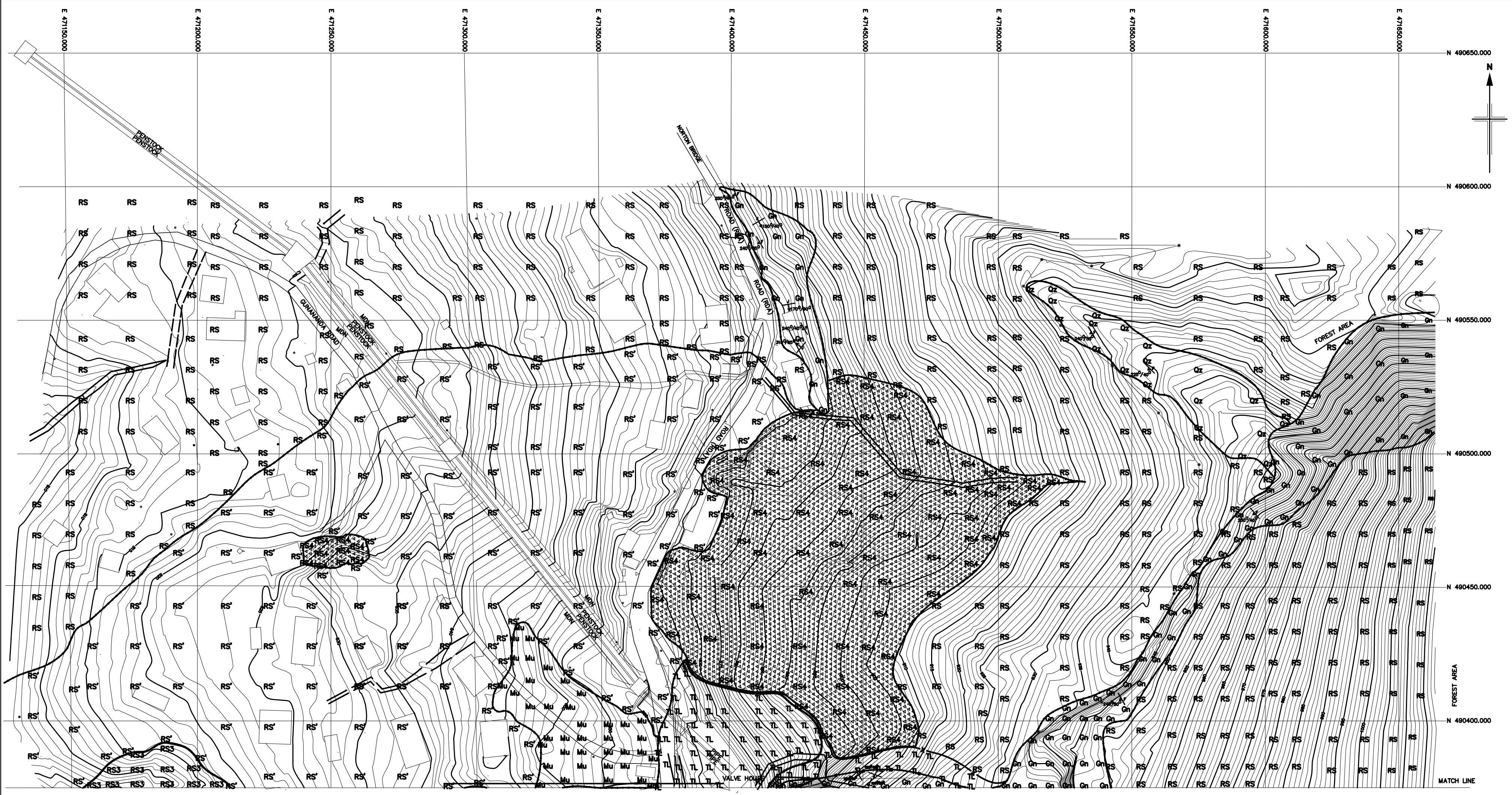
The slopes around the surge tank incline west at an average of 30 degrees. Limited outcrops are observed along the cliffs extending in the NE-SW direction. The surge tank is upslope of the cliffs and the penstocks lie on the gentle slope of less than 15 degrees below them. A paved road traverses at the elevation around 860 m, just below the valve house of the penstock, where completely weathered or moderately weathered rock could be seen on the road cut.

Geological mapping around the surge tank was carried out in January and February, 2005, and provided the geological map of Figure 3.1.

Bedrock is composed of charnockitic gneiss, charnockite and quartzite. The dip angle of foliation of bed rock varies from 30 – 50 degrees which is about the same or steeper than the slopes. The dip direction of foliation falls in a narrow band from 220 – 250 degrees which are somewhat oblique to the downslope direction.

Overburden material was divided into ten categories as shown in Table 3.1, based on the type of material and nature of surface conditions.

Within the mapped area some manmade fill also can be seen. This fill is made of the rock material that came from the excavation of tunnel and adits of the New Laxapana hydropower project. Estimated age of occurrence of slips forming debris material is tabulated in that table.




## LEGEND

**BEDROCK**

| | |
|---|---|
| Gn | GNEISSIC ROCK. (UNDIFFERENTIATED, MAINLY CHARNOKITIC GNEISS.) |
| Qz | QUARTZITE. |

**OVERBURDEN**

| | |
|---|---|
| RS | RESIDUAL SOIL.<br>REDDISH BROWN CLAYEY SANDS & SANDY CLAYS WITH GRAVEL.THICKNESS 0.5–2m.<br>WHERE SOIL LAYER IS THIN UNDER LYING BEDROCK DAYLIGHTS.<br>AT PLACES LARGE ANGULAR BLOCKS OF (UPTO 7m.)<br>SLIGHTLY DECOMPOSED GNEISSIC BEDROCK APPER ON SURFACE. |
| RS' | AREA COVERED WITH OLD LAND SLIDE DEBRIS.<br>MATERIAL CONSISTS OF YELLOWISH TO REDDISH BROWN CLAYEY SAND WITH GRAVEL.<br>1–2m. ANGULAR TO SUB-ROUNDED BOULDERS ARE EMBEDED IN SOIL MATRIX.<br>AMOUNT OF BOULDERS VARY. |
| RS3 | AREA COVERED WITH SECONDARY LANDSLIDE DEBRIS.<br>MATERIAL IS MADE OF YELLOWISH TO REDDISH BROWN CLAYEYEY SAND AND<br>SANDY CLAYS MIXED WITH BOULDERS PREDOMINENTLY OF SIZES LESS THAN 1m. |
| RS4 | VARY LARGE ROCK SLIP DEBRIS.<br>MATERIAL PREDOMINENTLY MADE UP OF EXTRA LARGE ANGULAR BOULDERS OF FRESH GNEISSIC ROCK.<br>(SOME BLOCKS EXCEED 20m.) |
| BL | BOULDERES LYING ON THE STREAM BEDS.<br>MATERIAL CONSISTS OF SUB-ANGULAR TO SUB-ROUNDED BOULDERS OF GNEISSIC ROCKS.<br>THEIR RANGE FROM 0.5–4m. |
| BL2 | YELLOWISH TO REDDISH BROWN SANDY CLAY WITH EMBEDED BOULDERS. (1–2m.) |
| TL | TALUS<br>ROCK MATERIAL DERIVED FROM ROCKY CLIFF FACE.<br>MATERIAL IS MADE UP OF BOULDERS OF SIZE OF 0.5–1.5m.<br>SOIL FRACTION MADE UP MAINLY OF CLAYEY GRAVEL.MATERIAL ABOUT 20/–30/. |
| Ms | MARSY AREA COVERED WITH THIN CLAY LAYER.<br>BROWN SILTY PLASTIC CLAY CONTAINS SOME GRAVEL. THICKNESS 0.2–0.3m. (UNDERLAIN BY EARTH SLIP DEBRIS. ) |
| Db | SMALL ACTIVE SECONDARY SLIDES IN DEBRIS MATERIAL. |
| Mu | MAN – MADE FILL.<br>MADE UP OF ROCK MATERIAL EXCAVATED FROM TUNNEL & PENSTOCK ADIT.<br>SIZE OF ROCK FRAGMENTS 0.1–0.5m, MAINLY GNEISSIC ROCK AND SOME CRYSTALLINE LIMESTONE. |

BOUNDARY BETWEEN ROCK TYPES OR CATEGORIES OF OVERBURDEN.

TOP OF SCARP FACE FORMED BY EXPOSED BEDROCK.

LANDSLIDE SCAR.

TENSION CRACK ON SOIL

5L/Mnt. SPRING.

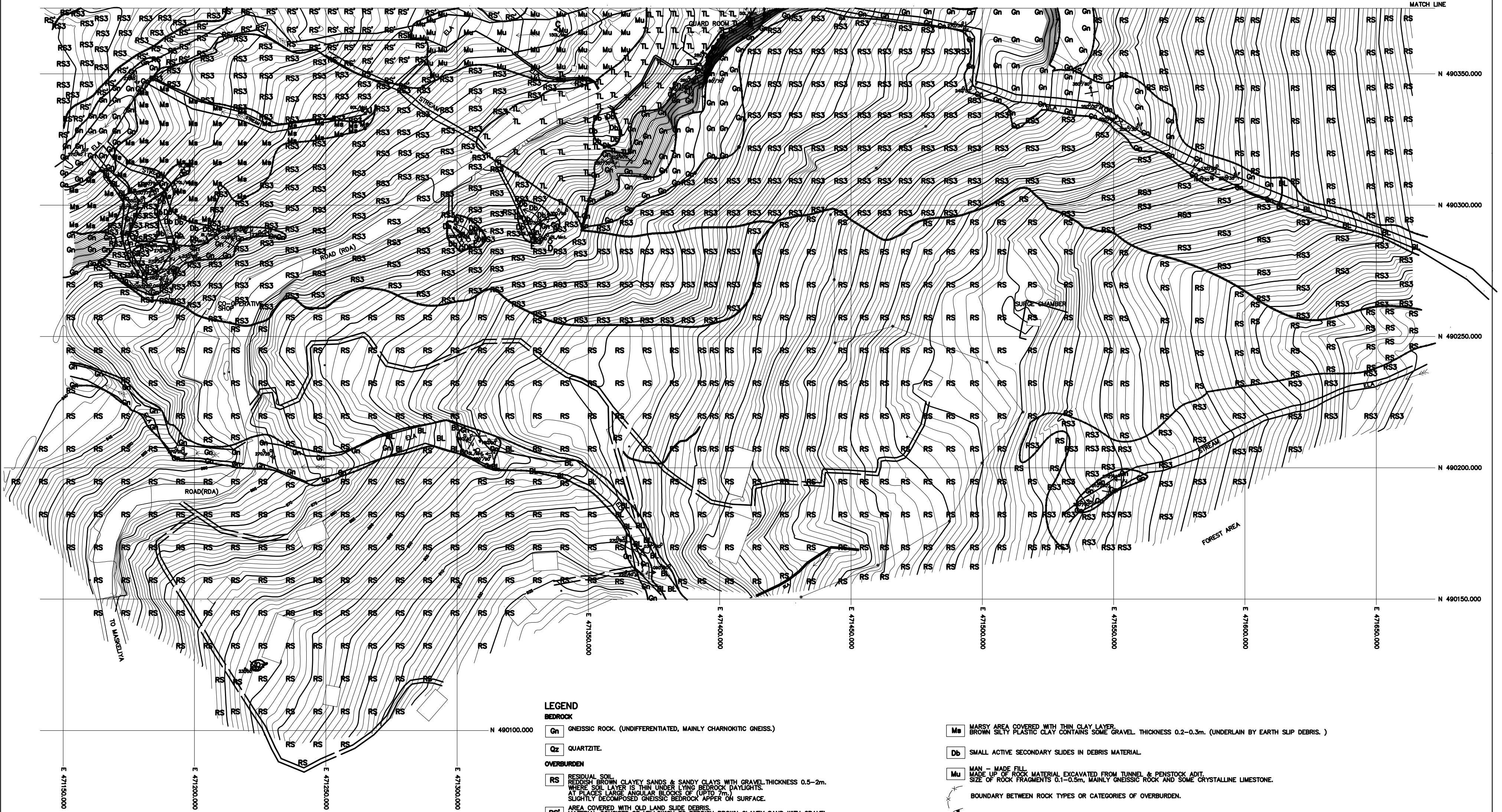
DIP DIRECTION / DIP OF FOLIATION (000/00) — F: FOLIATION OF BEDROCK.

FJ: FOLIATION JOINT.

J: JOINT.

Figure 3.1 Geo Map (New Laxapana – 1)

| | | | |
|---|---|---|---|
| JICA STUDY TEAM<br>J – Power<br>(ELECTRIC POWER DEVELOPMENT CO., LTD) | | | |
| INVESTIGATION WORKS FOR THE FOLLOW-UP STUDY ON HYDROPOWER STATIONS IN THE KELANI RIVER BASIN FOR HYDROPOWER OPTIMIZATION IN SRI LANKA<br>GEOLOGICAL MAP<br>NEW LAXAPANA SURGE SHAFT AND SURROUNDING AREA<br>(SHEET 01 OF 02) | | | |
| DESD: ..........<br>DRWN: .......... | CHKD: ..........<br>SUBT: .......... | RECOMMENDED | APPROVED DGM (WR) |
| CENTRAL ENGINEERING CONSULTANCY BUREAU,<br>415, BAUDHALOKA MAWATHA,<br>COLOMBO 7 – SRI LANKA. | SCALE: 1:500 | DATE: FEBRUARY 2005 | A0 |
| | DRG. No. 647/IN/03/01 | | REV. |

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BOUNDARY BETWEEN ROCK TYPES OR CATEGORIES OF OVERBURDEN.

TOP OF SCARP FACE FORMED BY EXPOSED BEDROCK.

LANDSLIDE SCAR.

TENSION CRACK ON SOIL

SPRING. (5L/Mnt.)

DIP DIRECTION / DIP OF FOLIATION (000/00) — FOLIATION OF BEDROCK.

FOLIATION JOINT.

JOINT.

Figure 3.2 Geo Map (New Laxapana – 2)

| | | | |
|---|---|---|---|
| JICA STUDY TEAM<br>J – Power<br>(ELECTRIC POWER DEVELOPMENT CO., LTD) | | | |
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| DESD: ..........<br>DRWN: .......... | CHKD: ..........<br>SUBT: .......... | RECOMMENDED | APPROVED DGM (WR) |
| CENTRAL ENGINEERING CONSULTANCY BUREAU,<br>415, BAUDHALOKA MAWATHA,<br>COLOMBO 7 – SRI LANKA. | SCALE: 1:500 | DATE: FEBRUARY 2005 | A0 |
| | DRG. No. 647/IN/03/02 | | REV. |

**Table 3.1 Details of Formations of Overburden**

| Type of Formation | Average Thickness (m) | Interpreted Age of Last Event (yrs.) | Ground Stability |
|---|---|---|---|
| RS | 1-20 | In situ material | Stable |
| RS' | 5-10 | More than 75 | Stable |
| RS4 | 10-15 | More than 75 | Stable |
| BL2 | 1-5 | More than 50 | Unstable |
| TL | 2-6 | After RS2 | Unstable |
| RS3 | 5-7 | 1944 | Unstable |
| MU | 2-5 | About 35 | Stable |
| MS | <1 | 5-8 | Unstable |
| Db | 2-5 | 1-5 | Unstable |
| BL | 1-3 | 1-5 | Unstable |

## 3.3 Springs

Eleven springs were found on the slopes around the surge tank. They are shown in Table 3.2. Many of them are springing through joints of the bed rock. Their total discharge is 730 L/min, and the largest is 150 L/min. The discharge of the stream that gathers spring waters, measured by V notches, was about 240 L/sec (14400 L/min). The poor discharge of other streams indicate that most of the stream water is leaked from the waterway. The amount of leakage from the waterway is much larger than that measured at the springs.

**Table 3.2 Location and Nature of Springs**

| Location of Spring | Outflow L/min | Formation /Nature of Spring | Behavior with time (Monitoring Period 2 months: August –Sep 2005) |
|---|---|---|---|
| A | 50 | Clear water, through open joint in Gneissic rock | Continuous: No significant change in flow |
| B | 150 | Clear water, through open joint in Gneissic rock | * Flow changes with the operation of valve house |
| C | 150 | Clear water, a hole about 4-cm in diameter appearing under a tree root. Area filled with tunnel muck | Continuous: No significant change in flow |
| D | 5 | Clear water, through hole in soil | Continuous: No significant change in flow |
| E | 25 | Clear water, through open joint in Gneissic rock | * Flow changes with the operation of valve house |
| F | 40 | Clear water, through hole in debris material of earth slip | Continuous: No significant change in flow |
| G | 100 | Clear water, through hole in debris material of earth slip | Continuous: No significant change in flow |
| H | 20 | Clear water, through open joint in Gneissic rock | Continuous: No significant change in flow |
| I | 40 | Clear water, through open joint in Gneissic rock | Continuous: No significant change in flow |
| J | 80 | Clear water, through hole in debris material of earth slip | Continuous: No significant change in flow |
| K | 70 | Clear water, through hole in debris material of earth slip | Continuous: No significant change in flow |

Water quality was investigated to confirm the origin of the spring and stream water.

Water samples of the waterway were collected from the intake, surge tank, and outlet of the New Laxapana plant. Samples of springs and streams were also collected around the surge tank. The following physical and chemical qualities were measured and analyzed.

- Electrical conductivity
- Suspended solids
- pH
- Temperature
- Dominant ions (Na+, K+, Ca2+, Mg2+, Fe2+, Mn2+, Cl-, SO42-, Total alkalinity)

The results of the water quality investigation are shown in Table 3.3.

Electrical conductivity of water of the waterway is 20μS (NWL – 1, NWL – 2). That of springs and streams around or downslope of the surge tank is 10 to 20μS. Streams distant from the waterway are less than 10μS (Figure 3.3 and Figure 3.4). Electrical conductivity indicates that the water of springs and streams around or downslope of the surge tank resemble to or contain much water of the waterway.

Chemical quality is shown in pattern diagram in Figure 3.5. This diagram is shown in milligram equivalent per litter, which is obtained by dividing concentration of ion by the equivalent weight of that ion. Judging from patterns in this diagram and location of water samples, waters collected at this time are divided in 4 chemical quality groups. Their distribution is shown in Figure 3.6 and Figure 3.7.

- Group A ( shown in red in Figures): Rich in Ca2+
- Group B ( shown in yellow in Figures): Rich in Ca2+ and rich in Cl-
- Group C ( shown in yellow in Figures): Poor in Ca2+ and rich in Cl-
- Group D ( shown in yellow in Figures): Poor in Ca2+ and poor in Cl-

Group A is the same or almost the same as the water of the waterway. Group C is quite different from Group A and likely to be water traveling underground for a long time. Group B seems to be a mixture of Group A and Group C. Group D resembles rain water. (NLW – 20 is rain water. But its ion concentration is higher than usual rainwater. This sample may contain contaminated materials.)

Water leaked from the tunnel belongs to Group A. NLW - 10, NLW – 12 and NLW – 14 are spring water and belong to Group A. Stream waters near the road such as NLW – 6 and NLW – 7 are mostly composed of leaked water. Downstream, stream waters belong to Group B except NLW – 8, which belongs to Group A indicating the presence of a large amount of leaked water in the stream.

The volume of the leakage water around the surge tank of New Laxapana is roughly estimated as below. NLW-2, NLW-18 and NLW-8 is used as water in the tunnel, surface water and stream water respectively.

A: Ion oncentration in tunnel water
B: Ion concentration in surface water
C: Ion concentration in stream water
Qa: Volume of leakage from tunnel
Qb: Volume of surface water
Qc: Volume of stream water

For Ion amount $A \times Qa + B \times Gb = C\ Qc$
For volume $Qa + Qb = Qc$

$Qa = Qc \times (B – C) / (B – A)$

$(B – C) / (B – A)$ indicates the rate of leakage.

$(B – C) / (B – A)$ of each ion is shown below.

| | |
|---|---|
| $Ca^{2+}$ | 1 |
| $Na^{+}$ | 2/3 |
| $K^{+}$ | 4/5 |
| $Cl^{-}$ | 0 |
| $SO4^{2-}$ | 1 |

The rates of leakage water shown by the above ions are more than 2/3 except $Cl^{-}$. Because the observed discharges of the other streams are very small, the rate of leakage water is estimated almost 100% or more than 80%.

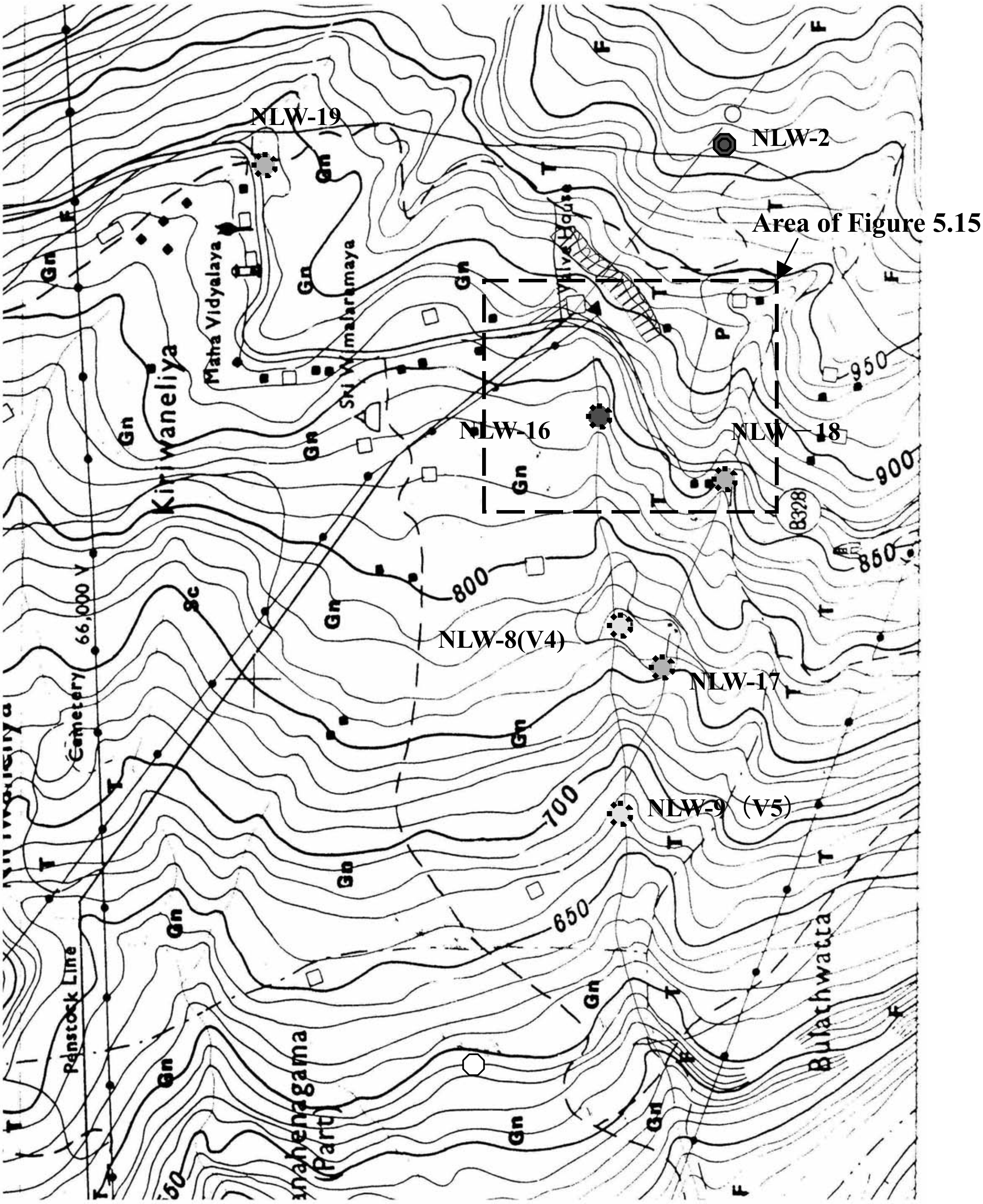
## Table 3.3 Water Quality Test Results

**Area A**

| Sample No. | | NLW-1 | NLW-2 | NLW-3 | NLW-4 | NLW-5* | NLW-6 | NLW-7 | NLW-8 | NLW-9 | NLW-10 | NLW-11 | NLW-12 | NLW-13 | NLW-14 | NLW-15 | NLW-16 | NLW-17 | NLW-18 | NLW-19 | NLW-20 | NLW-21** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Locality | | Reservoir near intake of New Laxapana Power Plant | Surge shaft of Laxapana Power Plant | Masukeliya river just upstream of Laxapana Power Plant | Outlet of Laxapana Power Plant | Stream at V1 notch | Stream at V2 notch | Stream at V3 notch | Stream at V4 notch | Stream at V5 notch | Spring just below the cliff | Guided water at the roadside | Guided water at the roadside | Spring from the wall to the NE of valve house | Spring from the outlet of penstock tunnel | Spring below the cliff to the SW of valve house | Large spring downstream of V2 | Just downstream of the waterfall of Seegra Ela | Stream of Seegra Ela beside the road | Stream beside the road | Rain water near Laxapana Power Plant | |
| pH | | 6.33 | 6.19 | 6.84 | 6.35 | | 7.11 | 7.00 | 7.08 | 7.13 | 6.29 | 7.24 | 6.72 | 6.86 | 6.34 | 7.17 | 6.48 | 6.90 | 7.00 | 6.63 | 6.39 | 6.15 |
| EC | μs/cm | 20 | 20 | 20 | 19 | | 18 | 20 | 18 | 18 | 19 | 17 | 26 | 15 | 20 | 17 | 20 | 8 | 8 | 9 | 19 | 19 |
| $Na^{+}$ | ppm | 4.0 | 4.5 | 5.2 | 3.8 | | 3.5 | 4.0 | 4.0 | 3.5 | 4.0 | 3.5 | 3.5 | 3.5 | 3.5 | 4.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.9 | 3.5 |
| (1e=23g) | me/l | 0.2 | 0.2 | 0.2 | 0.2 | | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 |
| $K^{+}$ | ppm | 1.7 | 1.5 | 1.5 | 1.2 | | 1.1 | 1.3 | 1.3 | 1.2 | 1.2 | 1.1 | 1.3 | 0.9 | 1.2 | 1.2 | 1.2 | 0.6 | 0.5 | 0.4 | 1.3 | 1.2 |
| (1e=39g) | me/l | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $Na^{+}+K^{+}$ | me/l | 0.2 | 0.2 | 0.3 | 0.2 | | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 |
| $Ca^{2+}$ | ppm | 8 | 6 | 8 | 10 | | 8 | 8 | 6 | 8 | 8 | 4 | 12 | 4 | 8 | 8 | 8 | 4 | 2 | 4 | 18 | 8 |
| (1e=20g) | me/l | 0.4 | 0.3 | 0.4 | 0.5 | | 0.4 | 0.4 | 0.3 | 0.4 | 0.4 | 0.2 | 0.6 | 0.2 | 0.4 | 0.4 | 0.4 | 0.2 | 0.1 | 0.2 | 0.9 | 0.4 |
| $Mg^{2+}$ | ppm | 2 | 4 | 4 | 2 | | 4 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 4 | 2 |
| (1e=12 g) | me/l | 0.2 | 0.3 | 0.3 | 0.2 | | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.2 |
| $Fe^{2+}$ | ppm | <0.1 | <0.1 | <0.1 | <0.1 | | <0.1 | 0.1 | 0.1 | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 0.1 | <0.1 |
| (1e=28g) | me/l | | | | | | | 0.00 | 0.00 | 0.00 | | | | | | | | | | | 0.00 | |
| $Mn^{2+}$ | ppm | <0.05 | <0.05 | <0.05 | <0.05 | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| (1e=27.5g) | me/l | | | | | | | | | | | | | | | | | | | | | |
| Cation | | 0.78 | 0.87 | 1.00 | 0.86 | | 0.91 | 0.78 | 0.68 | 0.75 | 0.77 | 0.55 | 0.95 | 0.54 | 0.75 | 0.77 | 0.77 | 0.51 | 0.41 | 0.67 | 1.44 | 0.75 |
| $Cl^{-}$ | ppm | 5.7 | 5.7 | 7.1 | 8.5 | | 5.7 | 5.7 | 2.8 | 8.5 | 6.0 | 8.5 | 5.7 | 8.5 | 5.7 | 8.5 | 7.1 | 11.0 | 2.8 | 2.8 | 4.3 | 5.7 |
| (1e=17.5g) | me/l | 0.3 | 0.3 | 0.4 | 0.5 | | 0.3 | 0.3 | 0.2 | 0.5 | 0.3 | 0.5 | 0.3 | 0.5 | 0.3 | 0.5 | 0.4 | 0.6 | 0.2 | 0.2 | 0.2 | 0.3 |
| $SO_4^{2-}$ | ppm | 1.4 | 0.6 | 1.0 | 0.4 | | 0.3 | 0.5 | 0.6 | 1.2 | 0.6 | 1.0 | 1.2 | 1.1 | 0.2 | 0.5 | 0.7 | 1.1 | 1.1 | 0.6 | 0.3 | 0.6 |
| (1e=48g) | me/l | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $HCO_3^{-}$ | | | | | | | | | | | | | | | | | | | | | | |
| | me/l | 0.4 | 0.5 | 0.6 | 0.4 | | 0.6 | 0.4 | 0.5 | 0.2 | 0.4 | 0.0 | 0.6 | 0.0 | 0.4 | 0.3 | 0.4 | (0.1) | 0.2 | 0.5 | 1.2 | 0.4 |
| Total Alkalinity | ppm | 6 | 10 | 10 | 8 | | 12 | 10 | 6 | 8 | 8 | 6 | 14 | 10 | 8 | 6 | 8 | 6 | 4 | 6 | 18 | 8 |
| SS | ppm | 9.2 | 13.2 | 10.0 | 7.6 | | 21.6 | 2.0 | 1.6 | 2.4 | 7.6 | 5.6 | 2.4 | 8.0 | 2.0 | 5.2 | 8.0 | 9.6 | 19.2 | 1.6 | 30.0 | 17.6 |

* Water is not available at the location

** Water sampled from a new location (spring) just downstream of the corporative shop between NLW-16 and NLW-18




| | | | |
|---|---|---|---|
| | Stream | NLW-1 | Name of location |
| | Spring | | Electrical conductivity ＞20 μ S |
| | | | Electrical conductivity 10 -20 μ S |
| | Shaft | | Electrical conductivity ＜10 μ S |

**Figure 3.3　Electrical conductivity**

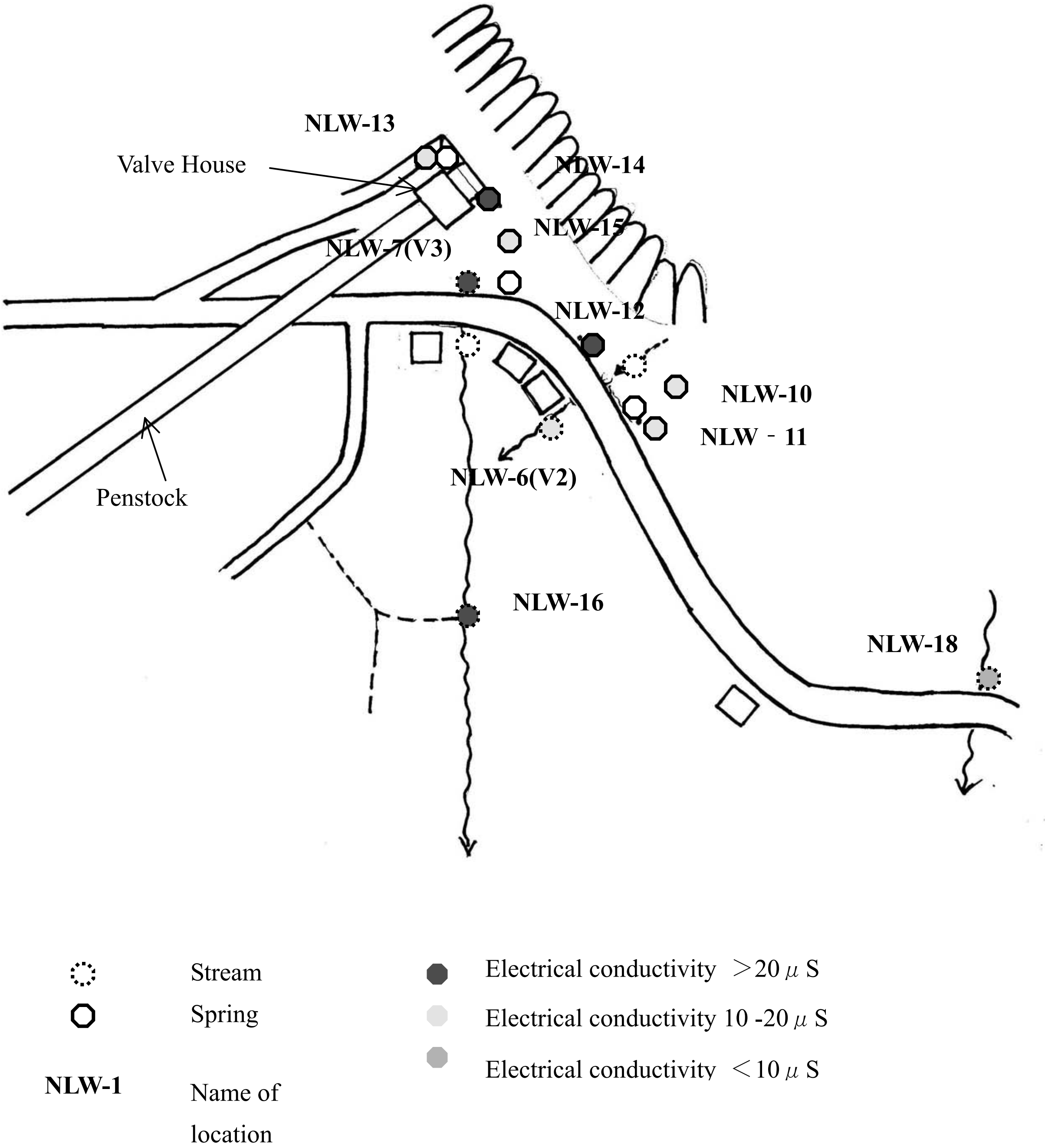



**Figure 3.4 Electrical Conductivity**

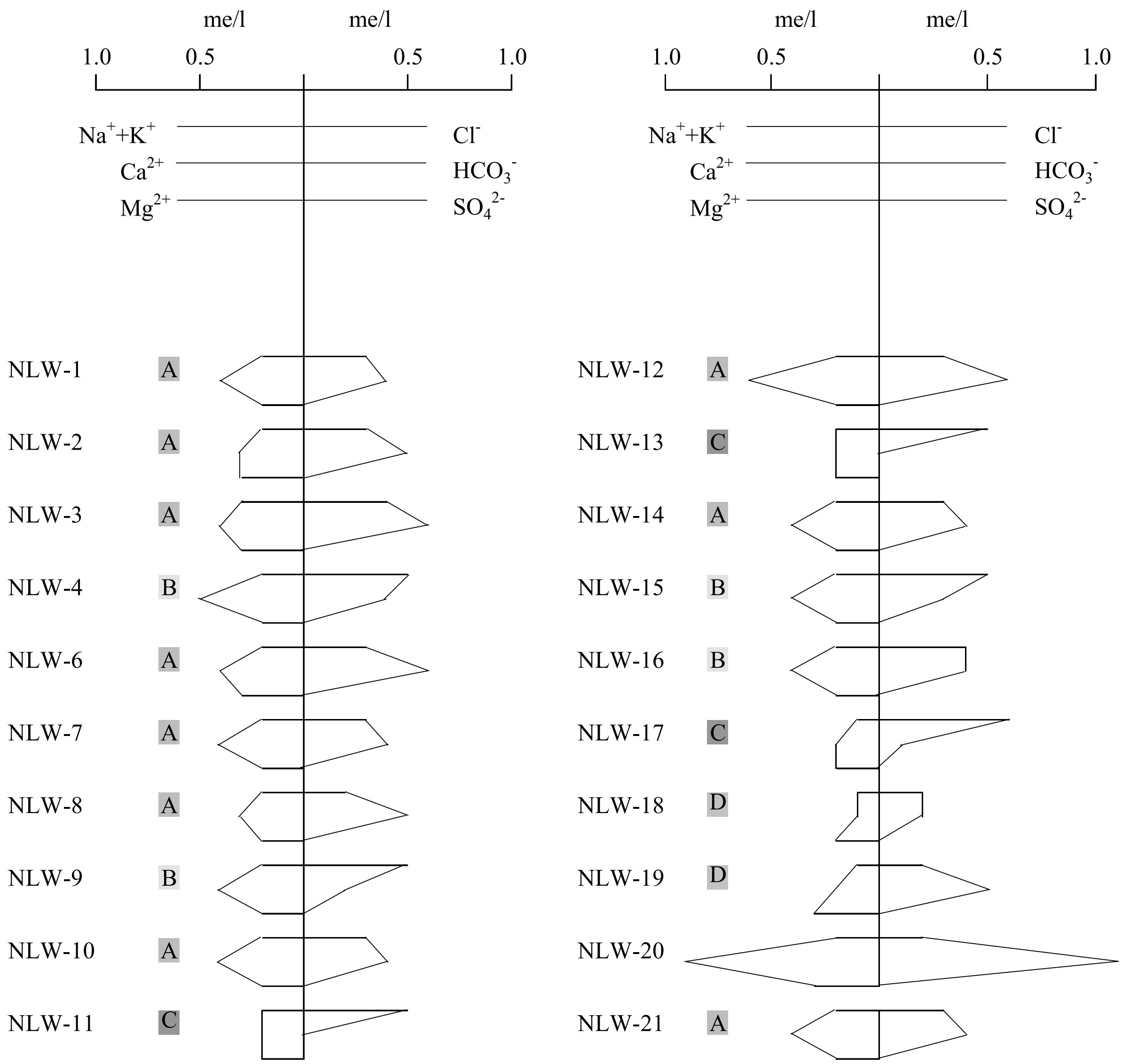
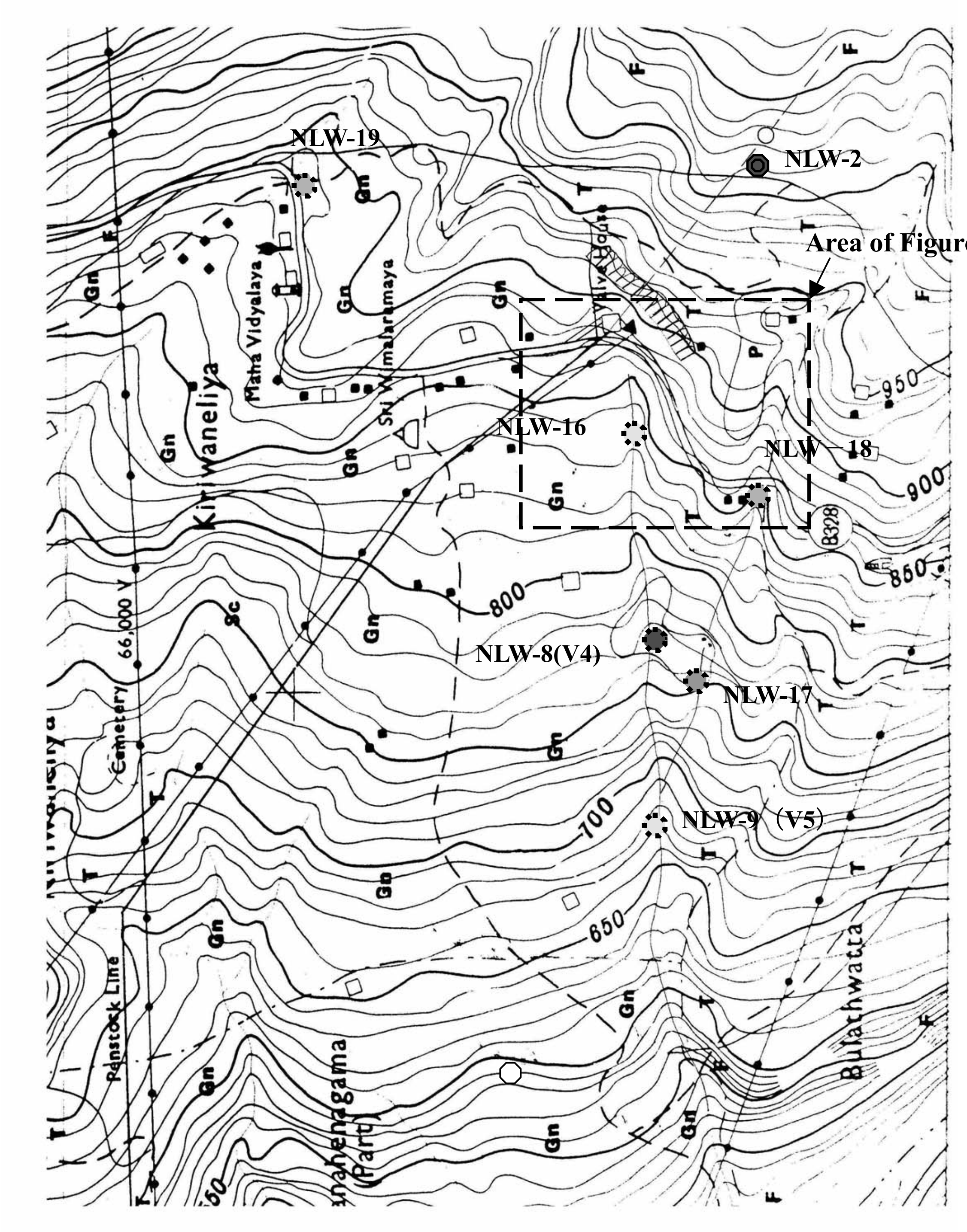



**Figure 3.5 Water Quality by Hexadiagram**




Stream

Spring

Shaft

$Ca^{+}$ rich

$Ca^{+}$ rich and $Cl^{-}$ rich

$Ca^{+}$ poor and $Cl^{-}$ rich

$Ca^{+}$ poor and $Cl^{-}$ poor

NLW-1 Name of location

**Figure 3.6 Water Quality**

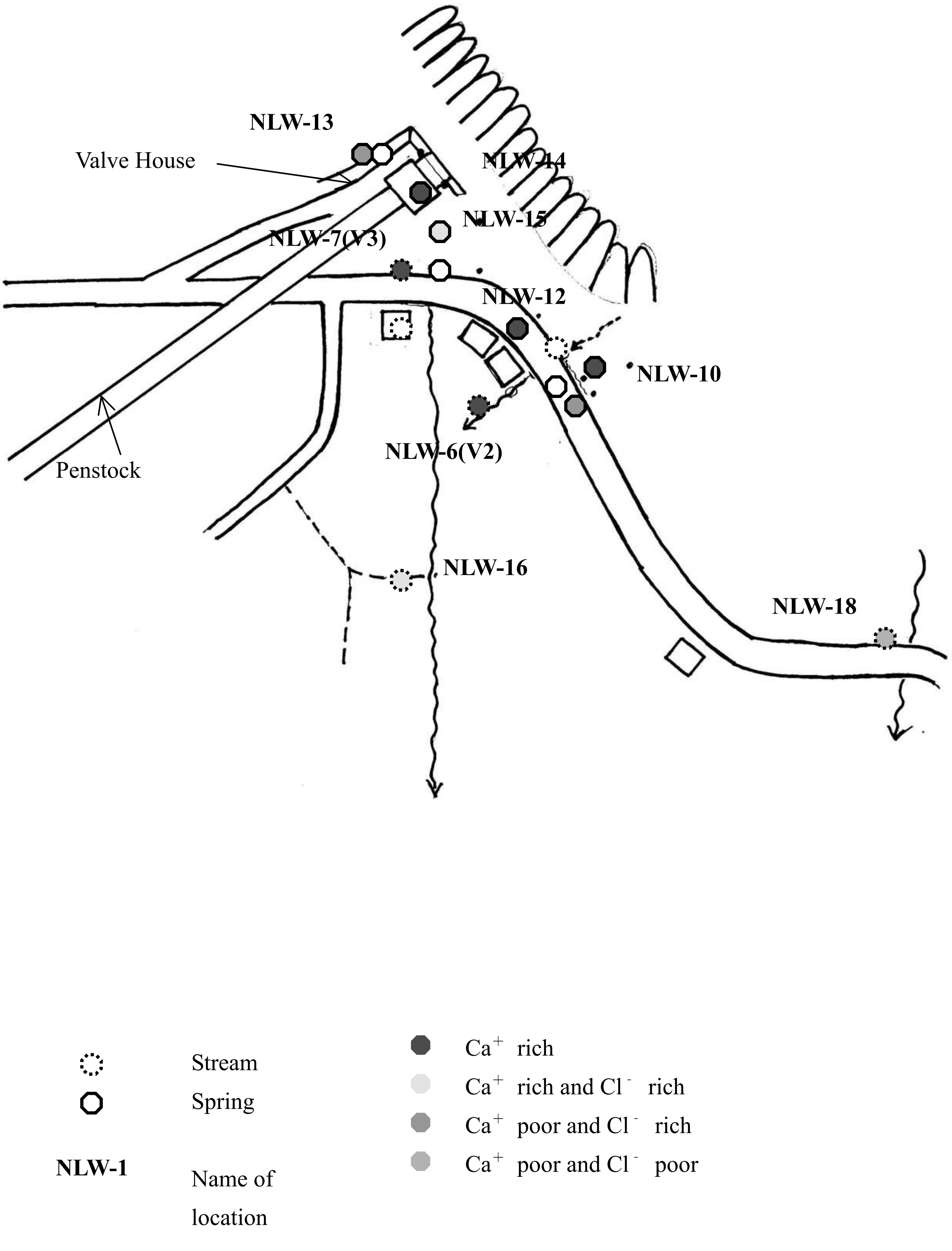



**Figure 3.7 Water Quality**