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# Appendix 1. Member List of the Study Team

**1st Field Investigation**

**Official Member**

1. ***Team Leader : Yoshiki Oomura***
   Senior Advisor, JICA

2. ***Coordinator : Tsutomu Suzuki***
   Project Monitoring and Coordination Division, Grant Aid Management Department, JICA

**Consultants Member**

3. ***Chief of Consultant Team/Water Supply Planning : Takemasa Mamiya***
   *Nihon Suido Consultants, Overseas Services Department*

4. ***Water Supply Facility Design Engineer : Shinkichi Kobayashi***
   *Nihon Suido Consultants, Overseas Services Department*

5. ***Waterworks Management Expert : Hiroyasu Saito***
   *Nihon Suido Consultants, Overseas Services Department*

6. ***Hydrogeologist : Seimi Mochizuki***
   Wacos Japan

7. ***Geophysical Prospecting Specialist : Shigemi Kimura***
   Mitsui Mineral Development Engineering

8. ***Procurement Specialist/Cost Estimator : Isamu Sato***
   *Nihon Suido Consultants, Overseas Services Department*

**2nd Field Investigation**

**Consultants Member**

1. ***Water Supply Facility Design Engineer : Shinkichi Kobayashi***
   *Nihon Suido Consultants, Overseas Services Department*

2. ***Geophysical Prospecting Specialist : Shigemi Kimura***
   Mitsui Mineral Development Engineering

**Draft Final Explanation Mission**

**Official Member**

1. ***Team Leader : Yoshiki Oomura***
   Senior Advisor, JICA

2. ***Grant Aid : Yoshihiko Sato***
   Grant Aid Division, Economic Cooperation Bureau, Ministry of Foreign Affairs

**3.** ***Coordinator : Junko Uno***
First Project Management Division, Grant Aid Management Department, JICA

**Consultants Member**

***4. Chief of Consultant Team/Water Supply Planning : Takemasa Mamiya***
*Nihon Suido Consultants, Overseas Services Department*

***5. Water Supply Facility Design Engineer : Shinkichi Kobayashi***
*Nihon Suido Consultants, Overseas Services Department*

# Appendix 2. Study Schedule

## 1st Field Investigation

| | | | Official Study Team | Consultants Study Team | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Chief of Consultant Team／Water Supply Planning | Water Supply Facility Design Engineer | Waterworks Management Expert | Hydrogeologist | Geophysical Prospecting Specialist | Procurement Specialist ／Cost Estimator |
| | | | Mr.Y.Omura, Mr.T.Suzuki | Mr.T.Mamiya | Mr.S.Kobyashi | Mr.H.Saito | Mr.S.Mochizuki | Mr.S.Kimura | Mr.I.Sato |
| 1 | 08/28/00 | Mon | Travel -> Colombo | | | | | | |
| 2 | 08/29/00 | Tue | Courtesy call JICA, Japanese Embassy, NWSDB | | | | | | |
| 3 | 08/30/00 | Wed | Discussion with NWSDB on IC/R, Travel ->Nuwara Eliya | | | | | | |
| 4 | 08/31/00 | Thu | Discussion with Nuwara Eliya Waterworks, Site Investigation | | | | | | |
| 5 | 09/01/00 | Fri | Site Investigation | | | | Travel -> Colombo | | |
| 6 | 09/02/00 | Sat | Inner Meeting | Preparation of Office Space | | | Travel -> Nuwara Eliya | | |
| 7 | 09/03/00 | Sun | Travel -> Colombo | | | | Preparation of Office Space | | |
| 8 | 09/04/00 | Mon | Discusiion with NWSDB | | | | Discussion with Nuwara Eliya Waterworks | | |
| 9 | 09/05/00 | Tue | Singing on Minutes of Discussion | | | | Hydrological Investigation, Geophysicl Prospecting | | Discussion with Nuwara Eliya Waterworks |
| 10 | 09/06/00 | Wed | Report to JICA Office and Japanese Embassy | | | | Hydrological Investigation, Geophysicl Prospecting | | Discussion with Nuwara Eliya Waterworks |
| 11 | 09/07/00 | Thu | Return to Japan | Travel -> Nuwara Eliya | | | Hydrological Investigation, Geophysicl Prospecting | | Discussion with Nuwara Eliya Waterworks |
| 12 | 09/08/00 | Fri | | Discussion with Nuwara Eliya Waterworks | | | Hydrological Investigation, Geophysicl Prospecting | | Preparation for Household Survey |
| 13 | 09/09/00 | Sat | | Data Processing | | | | | |
| 14 | 09/10/00 | Sun | | Team meeting | | | | | |
| 15 | 09/11/00 | Mon | | Discussion with Nuwara Eliya Local Government and organizations concerned | | | Hydrological Investigation, Geophysicl Prospecting | | Household Survey |
| 16 | 09/12/00 | Tue | | Discussion with Nuwara Eliya Local Government and organizations concerned | | | Hydrological Investigation, Geophysicl Prospecting | | Household Survey |
| 17 | 09/13/00 | Wed | | Site Investigation | | Discussion with Nuwara Eliya Local Government and organizations | Hydrological Investigation, Geophysicl Prospecting | | Household Survey |
| 18 | 09/14/00 | Thu | | Site Investigation | | Discussion with Nuwara Eliya Local Government and organizations | Hydrological Investigation, Geophysicl Prospecting | | Household Survey |
| 19 | 09/15/00 | Fri | | Site Investigation | | Discussion with Nuwara Eliya Local Government and organizations | Hydrological Investigation, Geophysicl Prospecting | | Household Survey |
| 20 | 09/16/00 | Sat | | Data Processing | | | | | |
| 21 | 09/17/00 | Sun | | Team meeting | | | | | |
| 22 | 09/18/00 | Mon | | Site Investigation | | Discussion with Nuwara Eliya Local Government and organizations | Hydrological Investigation, Geophysicl Prospecting | | Household Survey |
| 23 | 09/19/00 | Tue | | Site Investigation | | Discussion with Nuwara Eliya Local Government and organizations | Hydrological Investigation, Geophysicl Prospecting | | Household Survey |
| 24 | 09/20/00 | Wed | | Site Investigation | | Discussion with Nuwara Eliya Local Government and organizations | Hydrological Investigation, Geophysicl Prospecting | | Household Survey |
| 25 | 09/21/00 | Thu | | Site Investigation | | Discussion with Nuwara Eliya Local Government and organizations | Hydrological Investigation, Geophysicl Prospecting | | Household Survey |
| 26 | 09/22/00 | Fri | | Site Investigation | | Discussion with Nuwara Eliya Local Government and organizations | Hydrological Investigation, Geophysicl Prospecting | | Household Survey |
| 27 | 09/23/00 | Sat | | Data Processing | | | | | |
| 28 | 09/24/00 | Sun | | Team meeting | | | | | |
| 29 | 09/25/00 | Mon | | Site Investigation | | Discussion with Nuwara Eliya Local Government and organizations | Hydrological Investigation, Geophysicl Prospecting | | Cost Data Collection |
| 30 | 09/26/00 | Tue | | Site Investigation | | Discussion with Nuwara Eliya Local Government and organizations | Hydrological Investigation, Geophysicl Prospecting | | Cost Data Collection |
| 31 | 09/27/00 | Wed | | Site Investigation | | Discussion with Nuwara Eliya Local Government and organizations | Hydrological Investigation, Geophysicl Prospecting | | Cost Data Collection |
| 32 | 09/28/00 | Thu | | Discussion with Nuwara Eliya Waterworks | | | Hydrological Investigation, Geophysicl Prospecting | | Contractor's Capability Survey |
| 33 | 09/29/00 | Fri | | Discussion with Nuwara Eliya Waterworks | | | Hydrological Investigation | Travel -> Colombo | Contractor's Capability Survey |

## 2nd Field Investigation

| | | | Water Supply Facility Design Engineer | Geophysical Prospecting Specialist |
|---|---|---|---|---|
| | | | **Mr.S.Kobyashi** | **Mr.S.Kimura** |
| 1 | 02/15/01 | Thu | Travel Tokyo -> Colombo | |
| 2 | 02/16/01 | Fri | Courtesy call JICA, Japanese Embassy, Meeting with NWSDB | |
| 3 | 02/17/01 | Sat | Meeting and Contract signing with Sub-Contractor for Test Boring | |
| 4 | 02/18/01 | Sun | Travel Colombo -> Nuwara Eliya | |
| 5 | 02/19/01 | Mon | Meeting with Nuwara Eliya Municipal Council | |
| 6 | 02/20/01 | Tue | Setting up for Test Boring | |
| 7 | 02/21/01 | Wed | Start Test Boring | |
| 8 | 02/22/01 | Thu | Supervise Test Boring | |
| 9 | 02/23/01 | Fri | Discussion with Nuwara Eliya Municipal Counc | Supervise Test Boring, Conduct Well Logging, Conduct Air-lifting Test,Conduct Permeability Test, and Data Analysis |
| 10 | 02/24/01 | Sat | Travel Nuwara Elilya -> Colombo | |
| 11 | 02/25/01 | Sun | | |
| 12 | 02/26/01 | Mon | Travel Colombo -> Tokyo | |
| 13 | 02/27/01 | Tue | | |
| 14 | 02/28/01 | Wed | | |
| 15 | 03/01/01 | Thu | | |
| 16 | 03/02/01 | Fri | | |
| 17 | 03/03/01 | Sat | | |
| 18 | 03/04/01 | Sun | | |
| 19 | 03/05/01 | Mon | | |
| 20 | 03/06/01 | Tue | | |
| 21 | 03/07/01 | Wed | | |
| 22 | 03/08/01 | Thu | | |
| 23 | 03/09/01 | Fri | | |
| 24 | 03/10/01 | Sat | | |
| 25 | 03/11/01 | Sun | | |
| 26 | 03/12/01 | Mon | | |
| 27 | 03/13/01 | Tue | | |
| 28 | 03/14/01 | Wed | | |
| 29 | 03/15/01 | Thu | | |
| 30 | 03/16/01 | Fri | | |
| 31 | 03/17/01 | Sat | | |
| 32 | 03/18/01 | Sun | | |
| 33 | 03/19/01 | Mon | | |
| 34 | 03/20/01 | Tue | | |
| 35 | 03/21/01 | Wed | | |
| 36 | 03/22/01 | Thu | | |
| 37 | 03/23/01 | Fri | | |
| 38 | 03/24/01 | Sat | | |
| 39 | 03/25/01 | Sun | | |
| 40 | 03/26/01 | Mon | | |
| 41 | 03/27/01 | Tue | | |
| 42 | 03/28/01 | Wed | | |
| 43 | 03/29/01 | Thu | | |
| 44 | 03/30/01 | Fri | | |
| 45 | 03/31/01 | Sat | | |
| 46 | 04/01/01 | Sun | | |
| 47 | 04/02/01 | Mon | | |
| 48 | 04/03/01 | Tue | | |
| 49 | 04/04/01 | Wed | | |
| 50 | 04/05/01 | Thu | | |
| 51 | 04/06/01 | Fri | | Discussion with Nuwara Eliya Municipal |
| 52 | 04/07/01 | Sat | | |
| 53 | 04/08/01 | Sun | | |
| 54 | 04/09/01 | Mon | | Travel Nuwara Elilya -> Colombo |
| 55 | 04/10/01 | Tue | | Courtesy call JICA, Japanese Embassy, Meeting with NWSDB |
| 56 | 04/11/01 | Wed | | Travel Colombo -> Tokyo |

**Draft Final Explanation Mission**

| | | Official Member | | Consultants Member | | Official |
|---|---|---|---|---|---|---|
| | | Y. Oomura | J. Uno | T. Mamiya | S. Kobayashi | H. Satou |
| 1 | 12-Jun-01 | Hanoi->Bangkok->Colombo | Tokyo->Singapore->Colombo | | | |
| 2 | 13-Jun-01 | Courtesy Call to the Embassy of Japan in Sri Lanka<br>Meeting with JICA Sri Lanka Office<br>Courtesy Call to Ministry of Urban Development, Construction and Public Utilities<br>Courtesy Call to National Water Supply & Drainage Board (NWSDB) | | | | |
| 3 | 14-Jun-01 | Discussion with NWSDB, Colombo ->Nuwara Eliya | | | | Meeting with Embassy of Japan in Sri Lanka, JICA Sri Lanka Office, Colombo->Nuwara Eliya |
| 4 | 15-Jun-01 | Site Survey, Discussion with Nuwara Eliya Municipal Council | | | | Site Survey, Nuwara Eliya->Colombo |
| 5 | 16-Jun-01 | Discussion with Nuwara Eliya Municipal Council | | | | Colombo->Bangkok->Dhaka |
| 6 | 17-Jun-01 | Site Survey | | | | |
| 7 | 18-Jun-01 | Nuwara Eliya->Kandy, Discussion with NWSDB Kandy, Kandy->Colombo | | | | |
| 8 | 19-Jun-01 | Discussion with NWSDB | | | | |
| 9 | 20-Jun-01 | Discussion with NWSDB | | | | |
| 10 | 21-Jun-01 | Sign on the Minutes of Meeting, Report to the Embassy of Japan in Sri Lanka and JICA Sri Lanka Office | | | | |
| 11 | 22-Jun-01 | Colombo->Singapore->Tokyo | | Discussion with JBIC Consultants on JBIC Road Rehabilitation Project | | |
| 12 | 23-Jun-01 | | | Data collection for cost estimates | | |
| 13 | 24-Jun-01 | | | Data collection for cost estimates | | |
| 14 | 25-Jun-01 | | | Discussion with NWSDB | | |
| 15 | 26-Jun-01 | | | Colombo->Singapore->Tokyo | | |

# Appendix 3. List of Parties Concerned in Sri Lanka

**Ministry of Finance & Planning, Department of External Resources**

| | |
|---|---|
| J. H. Jayamaha | Director, Japan Division |
| Sujatha Cooray | Director, Japan Division |

**Ministry of Urban Development, Construction, and Public Utilities**

| | |
|---|---|
| Ananda S. Gunasekera | Secretary |

**National Water Supply & Drainage Board**

| | |
|---|---|
| N. S. K. N. de Silva | Chairman |
| H. B. Jayaratne | Vice Chairman |
| Hirokatsu Asakawa | JICA Expert |
| D. N. J. Ferdinando | Assistant General Manager (Japan Project Unit) |
| K. M. N. S. Fernando | Additional General Manager (Planning & Design) |
| M. K. Bandara | Assistant General Manager (Planning & Design) |
| T. P. Lamabadusooriya | Deputy General Manager (Planning & Design) |
| P. H. Sarath Gamini | Project Director of Greater kandy Project |
| D. U. Sumanasekera | Assistant General Manager (Development), Kyandy |
| W. M. S. K. Menikdiwek | Chief Engineer (Planning & Design), Kyandy |
| H. D. G. Dharmapala | Assistant Engineer (Planning & Design), Kyandy |

**Nuwara Eliya Municipal Council**

| | |
|---|---|
| A. W. D. Bandula Seneviratne J. P. U. M. | Mayor |
| H. E. L. S. Chandrasoma | Superintendent of Works/Waterworks |
| B. N. Karnathilake | Technical Officer/Waterworks |
| Ajith Bandara | Technical Officer/Waterworks |
| Makiko Tani | JOCV |

**Road Development Authority**

| | |
|---|---|
| T. A. Karunaratne | Technical Officer |

**Urban Development Authority, Nuwara Eliya**

| | |
|---|---|
| W. M. S. Wijeretna | Deputy Director |

**Ministry of Health of Central Provice**

| | |
|---|---|
| Dr. Athwlan Wijeniniglu | Divisional Director of Health Services |

**Agricultural Research Station**

| | |
|---|---|
| Mangalika Nugaliyadde | Director |

# Appendix 4. Minutes of Discussions

## 1. Minutes of Discussion on Inception Meeting

# Minutes of Discussions
# on
# The Basic Design Study
# on
# The Project for Improvement of Nuwara Eliya Water Supply
# in
# The Democratic Socialist Republic of Sri Lanka

In response to a request from the Government of the Democratic Socialist Republic of Sri Lanka (hereinafter referred to as 'Sri Lanka'), the Government of Japan decided to conduct a Basic Design Study on the Project for Improvement of Nuwara Eliya Water Supply (hereinafter referred to as "the Project"), and entrusted the study to Japan International Cooperation Agency (hereinafter referred to as 'JICA').

JICA sent to Sri Lanka the Basic Design Study Team (hereinafter referred to as 'the Team'), which is headed by Mr. Yoshiki Omura, Senior Advisor, and is scheduled to stay in the country from the 29th August to the 4th October 2000.

The Team held a series of discussions with the concerned officials of the Government of Sri Lanka and conducted a field survey at the study area.

In the course of discussions and field survey, both parties confirmed the main items described on the attached sheets. The Team will proceed to further work and prepare the Basic Design Study Report.

Colombo, 6th September 2000

Yoshiki Omura
Leader
Basic Design Study Team
Japan International Cooperation Agency

J.H.J. Jayamaha
Director (Japan Division)
Department of External Resources
Ministry of Finance & Planning

Ananda S. Gunasekera
Secretatary
Ministry of Urban Development, Housing and Construction

N.S.K.N. de Silva, Dr.
Chairman
National Water Supply & Drainage Board
Ministry of Urban Development, Housing and Construction

## ATTACHMENT

### 1. Objective of the Project

The objective of the Project is to improve the water supply services in Nuwara Eliya in order to make safe and stable water supply for the residents.

### 2. Responsible and Implementing Organization

Responsible organization:

Ministry of Urban Development, Housing and Construction

Implementing organization:

National Water Supply & Drainage Board

### 3. Site of the Project

The site of the Project is Nuwara Eliya as shown in Annex-1 (page 5).

### 4. Items requested by the Government of Sri Lanka

After discussions with the Team, the items described in Annex-2 (page 6) were finally requested by the Sri Lanka side. JICA will assess the appropriateness of the request and will report the findings to the Government of Japan.

### 5. Japan's Grant Aid Programme

The Sri Lanka side has understood the system and characteristics of Japan's Grant Aid Programme as described by the Team shown in Annex-3 (page 7).

### 6. Necessary measures to be taken by the Sri Lanka side

The Sri Lanka side will take the necessary measures, as described in Annex-4, for smooth implementation of the Project on condition that the Japanese Grant Aid is extended.

### 7. Further Schedule of the Study

a. The consultant members of the Team will proceed the further study in Sri Lanka until 4th October 2000.

b. JICA will prepare the Basic Design Study Report in English and dispatch a mission in order to explain its contents in (or around) January 2001.

c. In case the contents of the report are accepted in principle by the Government of Sri Lanka, JICA will complete the final report and send it to the Sri Lanka side by April 2001.

## 8. Other relevant issues

### a. Exclusion of sanitation improvement component from the Study

The Team explained, and the Sri Lanka side agreed that the sanitation improvement component was excluded from the scope of work of the Study due to its capital investment scale although the Government of Sri Lanka originally requested implementation of the sanitation component.

### b. Necessity of countermeasures for mitigation of negative environmental impact

The Team explained the Japanese Government's concern that development of water supply system would eventually increase volume of wastewater, which might cause significant problems to environment in Nuwara Eliya. The Team explained, and the Sri Lanka side understood that the Government of Japan might renounce implementation of the water supply development project subject to evaluation of seriousness of the negative environmental impact caused by the increase of wastewater and of possible countermeasures to mitigate the negative impact. Therefore, both parties recognized it would be indispensable for the implementation of the Project that the Government of Sri Lanka made the best effort to take action for environmental impact mitigation. The Sri Lanka side requested, and the Team agreed that the Study would recommend, to mitigate environmental impact, possible countermeasures against increasing wastewater.

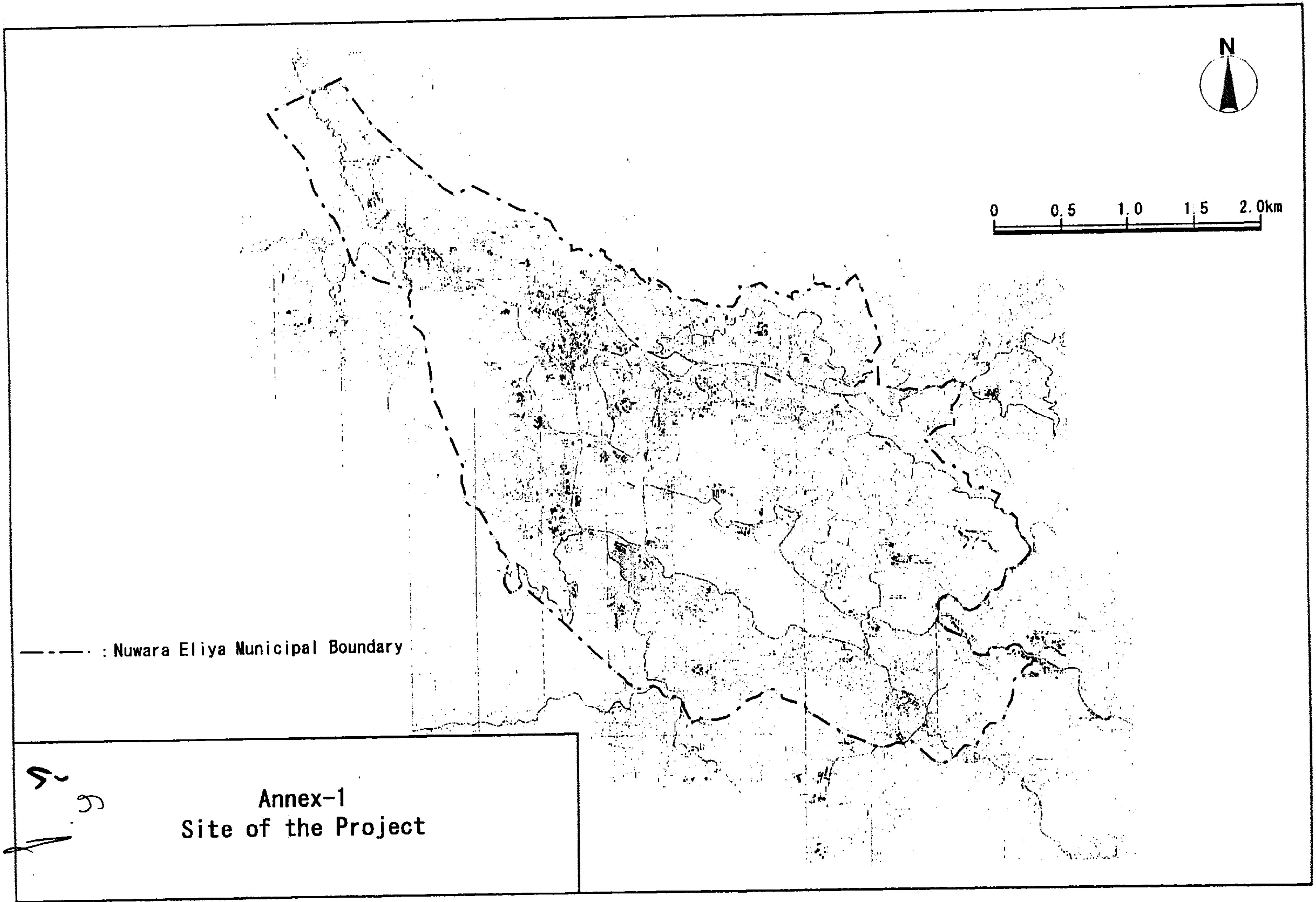
In view of management, the Team referred to strengthening the existing municipal waterworks department and sound management of water supply undertaking, which would be indispensable not only for water supply but also for the future development of sustainable sewage system in Nuwara Eliya.

### c. New housing area in Gemunupura

The Mayor of Nuwara Eliya Municipal Council requested inclusion of Gemunupura, where newly developed housing area of about 150 households was located. The Team agreed to conduct evaluation and to include the area into the Project if technical and financial feasibilities were confirmed.

**d. Exemption or reimbursement of taxes and government formalities related to the Project**

The Team explained that the taxes including customs duties and the Goods and Service Tax (GST), related to the Project should be either exempted or reimbursed by the Government of Sri Lanka. The Team requested, and the Sri Lanka side agreed that the Sri Lanka side would coordinate authorities concerned and will inform the Team which organizations will have responsibility and the government formalities and procedures required for project implementation by the end of September 2000.




Annex-1
Site of the Project

## Annex-2 List of Requested Items

| Facility | Item | Specifications | Unit | Quantity |
|---|---|---|---|---|
| Groundwater Development | Total capacity approx. 7,000 m3/day | | | |
| | Wells | 150 m | location | 7 |
| | Pumps | 1,000m3/day x 58m x 15kW | set | 8 |
| | Electrical System | | set | 7 |
| | Pump House | 10m2 | location | 7 |
| Raw Water Transmission | Pipes | PVC ϕ 160 mm | m | 1,240 |
| | Pump House | | location | 2 |
| | Pumps | 5,000m3/day x 68m | unit | 2 |
| | | 1,900m3/day x 63m | unit | 2 |
| | Electrical System | | set | 2 |
| | Pump House | 25m2 | location | 2 |
| Clear Water Transmission | Pipes | PVC ϕ 110 mm (Surface Water) | m | 2,867 |
| | | PVC ϕ 225 mm (Groundwater) | m | 700 |
| | | DCI ϕ 250 mm (Surface Water) | m | 3,545 |
| | | DCI ϕ 300 mm (Groundwater) | m | 4,320 |
| | | Total | m | 11,432 |
| | Pumps | 600m3/day x 25m | unit | 1 |
| | | 690m3/day x 25m | unit | 1 |
| | | 920m3/day x 85m | unit | 1 |
| | Pump House | 4m2 | location | 3 |
| | Electrical System | | set | 3 |
| Disinfection | Chlorinator | | set | 3 |
| | Chlorinator House | 10m2 | location | 3 |
| Distribution | Reservoirs | 100 m3 (Old water field) | nos | 1 |
| | | 220 m3 (Pedro) | nos | 1 |
| | | 200 m3 (Unique View) | nos | 1 |
| | | 140 m3 (Vijithapura) | nos | 1 |
| | | 470 m3 (Low area 2) | nos | 1 |
| | | Total | nos | 5 |
| | Pipes | PVC ϕ 63 mm | m | 50 |
| | | PVC ϕ 75 mm | m | 1,460 |
| | | PVC ϕ 110 mm | m | 1,839 |
| | | PVC ϕ 160 mm | m | 1,828 |
| | | PVC ϕ 225 mm | m | 1,760 |
| | | DCI ϕ 300 mm | m | 2,069 |
| | | Total | m | 9,006 |
| Non Revenue Water Reduction | Preparation of Non Revenue Water reduction programme including provision of bulk flow meters. | | | |

***Note :*** ***Requested items (items, specifications, and quantities) shown in the table above are subject to change based on the Study results.***

## Annex-3 Japan's Grant Aid Programme

### 1. Grant Aid Procedures

a. Japan's Grant Aid Program is executed through the following procedures.

| | |
|---|---|
| ・Application | (A request made by the recipient country) |
| ・Study | (Basic Design Study conducted by JICA) |
| ・Appraisal & Approval | (Appraisal by the Government of Japan and Approval by the Cabinet of Japan) |
| ・Determination of Implementation | (Exchange of Notes between the Governments of Japan and the recipient country) |

b. Firstly, the application or request for a Grant Aid project submitted by a recipient country is examined by the Government of Japan (the Ministry of Foreign Affairs) to determine whether or not it is eligible for Grant Aid. If the request is deemed appropriate, the Government of Japan assigns JICA (Japan International Cooperation Agency) to conduct a study on the request.

Secondly, JICA conducts the study (Basic Design Study) using (a) Japanese consulting firm(s).

Thirdly, the Government of Japan appraises the project to see whether or not it is suitable for Japan's Grant Aid Programme, based on the Basic Design Study Report prepared by JICA, and the results are then submitted to the Cabinet for an approval.

Fourthly, the project, once approved by the Cabinet, becomes official with the Exchange of Notes signed by the Governments of Japan and recipient country.

Finally, for the implementation of the project, JICA will assists the recipient country in such matters as preparing tenders, contract and so on.

### 2. Basic Design Study

a. Contents of the study

The aim of the Basic Design Study (hereafter referred to as "the Study") conducted by JICA on a requested project (hereafter referred to as "the Project") is to provide a basic document necessary for the appraisal of the Project by the Government of Japan. The contents of the Study are as follows:

a) Confirmation of the background, objectives, and benefits of the Project and also institutional capacity of agencies concerned of the recipient country necessary for the Project's implementation.

b) Evaluation of the appropriateness of the Project to be implemented under the Grant Aid Scheme from a technical, social and economic point of view.

c) Confirmation of items agreed on by both parties concerning the basic concept of the Project.

d) Preparation of a basic design of the Project.

e) Estimation of costs of the Project.
The contents of the original request are not necessarily approved in their initial form as the contents of the Grant Aid project. The Basic Design of the Project is confirmed considering the guidelines of the Japan's Grant Aid Scheme.

The Government of Japan requests the Government of the recipient country to take whatever measures are necessary to ensure its self-reliance in the implementation of the Project. Such measures must be guaranteed even though they may fall outside of the jurisdiction of the organization in the recipient country actually implementing the Project. Therefore, the implementation of the Project is confirmed by all relevant organizations of the recipient country through the Minutes of Discussions.

b. Selection of Consultants

For smooth implementation of the Study, JICA uses (a) registered consultant firm(s). JICA select (a) firm(s) based on proposals submitted by interested firms. The firm(s) selected carry(ies) out a Basic Design Study and write(s) a report, based upon terms of reference set by JICA.

The consultant firm(s) used for the Study is(are) recommended by JICA to the recipient country to also work on the Project's implementation after the Exchange of Notes, in order to maintain technical consistency.

### 3. Japan's Grant Aid Scheme

a. Grant Aid

The Grant Aid Programme provides a recipient country with non-reimbursable funds to procure the facilities, equipment and services (engineering services and transportation of the products, etc.) for economic and social development of the country under principles in accordance with the relevant laws and regulations of Japan. Grant Aid is not supplied through the donation of materials as such.

b. Exchange of Notes (E/N)

Japan's Grant Aid is extended in accordance with the Notes exchanged by the two Governments concerned, in which the objectives of the Project, period of execution, conditions and amount of the Grant Aid, etc., are confirmed.

c. Period

"The period of the Grant Aid" means the one fiscal year which the Cabinet approves the Project for. Within the fiscal year, all procedures such as exchanging of the Notes, concluding contracts with (a) consultant firm(s) and (a) contractor(s) and final payment to them must be completed.

However, in case of delays in delivery, installation or construction due to unforeseen factors such as weather, the period of the Grant Aid can be further extended for a maximum of one fiscal year at most by mutual agreement between the two Governments.

d. Purchase of the Products and or Services

Under the Grant Aid, in principle, Japanese products and services including transport or those of the recipient country are to be purchased.

When the two Governments deem it necessary, the Grant Aid may be used for the purchase of the products or services of a third country.

However, the prime contractors, namely, consulting, constructing and procurement firms, are limited to "Japanese nationals". (The term "Japanese nationals" means persons of Japanese nationality or Japanese corporations controlled by persons of Japanese nationality.)

e. Necessity of "Verification"

The Government of recipient country or its designated authority will conclude contracts denominated in Japanese yen with Japanese nationals. Those contracts shall be verified by the Government of Japan. This "Verification" is deemed necessary to secure accountability to Japanese taxpayers.

f. Undertakings required of the Government of the Recipient Country
(As described in Annex-4, page 11)

g. Proper Use

The recipient country is required to maintain and use the facilities constructed and the equipment purchased under the Grant Aid properly and effectively and to assign staff necessary for this operation and maintenance as well as to bear all the expenses other than those covered by the Grant Aid.

h. Re-export

The products purchased under the Grant Aid should not be re-exported from the recipient country.

i. Banking Arrangements (B/A)

a) The Government of the recipient country or its designated authority should open an account in the name of the Government of the recipient country in an authorized bank in Japan (hereinafter referred to as "the Bank"). The Government of Japan will execute the Grant Aid by making payments in Japanese yen to cover the obligations incurred by the Government of the recipient country or its designated authority under the Verified Contracts.

b) The payments will be made when payment requests are presented by the Bank to the Government of Japan under an authorization to pay issued by the Government of the recipient country or its designated authority.

## Annex-4 Necessary Measures to be taken by the Sri Lanka side

The following necessary measures should be taken by the Sri Lanka side on condition that the Grant Aid by the Government of Japan is extended to the Project:

1. To provide data and information necessary for the Project.
2. To prepare the land for the Project and secure the authority to build facilities.
3. To secure the water rights for ground water development in the project.
4. To provide proper access road to the Project area, if necessary.
5. To remove existing facilities, if necessary.
6. To bear commissions to the Bank for its banking services based upon the Banking Arrangement, namely the advising commission of the "Authorization to Pay" and payment commission.
7. To ensure prompt unloading, tax exemption, customs clearance at the port of disembarkation and prompt internal transportation therein of the materials and equipment for the Project purchased under the Grant Aid.
8. To provide warehouse for storage of spare parts and other equipment procured by the Project.
9. To undertake incidental outdoor works such as security of the sites, if necessary.
10. To exempt Japanese juridical and physical nationals engaged in the Project from customs duties, internal taxes and other fiscal levies which may be imposed in Sri Lanka with respect to the supply of the products and services under the verified contracts.
11. To accord Japanese nationals whose services may be required in connection with the supply of the products and the services under the verified contract such facilities as may be necessary for their entry into Sri Lanka and stay therein for the performance of their work in accordance with the relevant laws and regulations of Sri Lanka.
12. To provide necessary permissions, licenses and other authorizations for implementing the Project, if necessary.
13. To maintain and use properly and effectively the facilities constructed and the equipment provided under the Project.
14. To bear all the expenses, other than those to be borne by the Japan's Grant Aid within the scope of the Project.
15. To assign the necessary staff and secure the necessary budget for operation and maintenance of the equipment purchased under the Grant Aid.

## 2. Minutes of Discussion on Draft Final Explanation

# MINUTES OF DISCUSSIONS
# ON THE BASIC DESIGN STUDY ON
# THE PROJECT FOR IMPROVEMENT OF NUWARA ELIYA WATER SUPPLY
# IN THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA
# (EXPLANATION ON DRAFT FINAL REPORT)

In September 2000 and February 2001, the Japan International Cooperation Agency (hereinafter referred to as JICA) dispatched Basic Design Study Teams on THE PROJECT FOR IMPROVEMENT OF NUWARA ELIYA WATER SUPPLY (hereinafter referred to as the Project) to the Democratic Socialist Republic of Sri Lanka (hereinafter referred to as Sri Lanka), and through discussions, field surveys, and technical appraisal of the results in Japan, JICA prepared a draft report of the study.

In order to explain and to consult the components of the draft report, JICA sent to Sri Lanka the Draft Final Report Explanation Team (hereinafter referred to as the Team), which is headed by Mr. Yoshiki OMURA, Senior Advisor, JICA, from 13 June to 25 June 2001.

As a result of discussions, both parties confirmed the main items described on the attached sheets.

Colombo, 21 June 2001

Yoshiki Omura
Leader
Basic Design Study Team
Japan International Cooperation Agency
Japan

Sujatha Cooray
Director (Japan Division)
Department of External Resources
Ministry of Finance and Planning
Sri Lanka

Ananda S. Gunasekera
Secretary
Ministry of Urban Development,
Construction, and Public Utilities
Sri Lanka

H. B. Jayaratne
Vice Chairman
National Water Supply and Drainage Board
(NWSDB)
Sri Lanka

## ATTACHMENT

### 1. Components of the Draft Final Report

The Sri Lanka side agreed and accepted in principle the components of the draft of final report explained by the Team.

### 2. Japan's Grant Aid Scheme

The Sri Lanka side understood the Japan's Grant Aid Scheme and the necessary measures to be taken by the Government of Sri Lanka as explained by the Team and described in Annex-3 and Annex-4 of the Minutes of Discussions signed by both parties on 6 September, 2000.

### 3. Schedule of the Study

JICA will complete the final report in accordance with the confirmed items and send it to Sri Lanka by August 2001.

### 4. Other Relevant Issues

#### (1) Land acquisition

The Team expressed that it was indispensable to secure the land for construction of wells in the golf course. The Sri Lanka side explained that the Urban Development Authority (UDA), the landowner, and the Nuwara Eliya Golf Club, the operator of the golf course, agreed with drilling and construction of wells in writing. These letters are attached to these minutes in Annex – 1 together with a confirmation letter from the NWSDB. The Sri Lanka side confirmed that the Road Development Authority (RDA) had no objection to well construction in the golf course since four wells were located outside of RDA road reservation.

The Sri Lanka side stated that land acquisition for other facilities such as wells in Hawa Eliya, pump stations and distribution reservoirs were in progress and would be completed by November 2001.

## (2) Operation and Maintenance of Water Supply System

For the purpose of efficient management of water supply system improved by the Project, the Team recommended a new organization for Nuwara Eliya Municipal Waterworks. The Sri Lanka side expressed that they understood the recommendation and they would complete its organizational reform before completion of the Project. The Sri Lanka side through NWSDB would provide necessary technical assistance to Nuwara Eliya Municipal Waterworks during the initial operation period of duration one year minimum.

## (3) Mitigation of Negative Environmental Impact

The Team explained that the negative environmental impact caused by the increase of wastewater after the Project could be overcome by recommended countermeasures. The Team, therefore, expressed that it was indispensable to implement countermeasures identified in the Basic Design Study. The Sri Lanka side committed to take necessary measures to mitigate negative environmental impact.

## (4) Technical Issues

### a) Location of Groundwater Development Areas

The Sri Lanka side agreed with the proposed groundwater development plan, which had four wells in the golf course and five wells in Hawa Eliya. The Sri Lanka side requested that securing production capacities meeting the planned water demand should be deemed as completion of well construction. The Team explained that the groundwater development plan was carefully prepared based on and derived from the results of field investigation, test borings, and technical analysis, therefore, the Team considered the planned abstraction would be achieved if drilling were carefully carried out. Both parties agreed that the completion condition of well construction would be the number of wells constructed and tested as specified.

### b) Well Pump House and Method of Well Pump Control

The Sri Lanka side requested that well pump house should not be constructed for each well in golf course to minimize negative impacts of well pump houses to golf course landscape and one central well pump house should be constructed at one of four well construction sites. This well pump house would accommodate remote on-off switchboard for all four wells. The Team agreed to consider the request and modify the design accordingly if the modification was found technically sound and financially acceptable. The Sri Lanka side requested to provide automatic control devise for the well pump houses in Hawa Eliya. However, the Team rejected this request. Both parties agreed that individual well pump house and manual operation would be applied for wells in Hawa Eliya.

### c) Alternative Groundwater Transmission Pipeline Route

The Sri Lanka side requested to reroute groundwater transmission pipeline between the golf course and the Race Course junction well because of new road rehabilitation project, which would be implemented by the Road Development Authority (RDA).

As for the pipeline up to the Race Course, the Team agreed to reroute it along the roads facing the Municipal Council and Good Shepherd Girls School.

As for the pipeline along the Race Course, both sides agreed the following procedure:
At the commencement of the detailed design, both sides examine construction schedule of the RDA and the Project. If the subject pipe installation work of the Project is to be completed before the RDA project commencement in the section, the pipe alignment should be within the road as originally planned. If not, the alignment might be relocated into the Race Course premises as agreed by the Municipal Council.

The Team requested and the Sri Lanka side agreed that the project status, and design information such as planned road section, alignment, and construction schedule of the RDA project should be provided to the Team by the Sri Lanka side by June 25, 2001.

### d) Training for Meter Test Bench

The Team expressed that training should be provided to calibrate water meters using meter test bench which would be procured under the Project. The Sri Lanka side agreed that the training on the meter test bench for Nuwara Eliya Waterworks staff would be conducted at the NWSDB Colombo or Kandy upon arrival of the bench.

### e) Meter Replacement

The Team explained that 800 pieces of water meters would be procured under the Project for replacement of defective meters and replacement work should be implemented by Nuwara Eliya Waterworks. The Sri Lanka side agreed that meter should be replaced by the Waterworks and confirmed that the replacement would be completed within four months (ten meter replacements per day) from delivery of water meters to the Waterworks.

### f) Replacement of Service Connection

The Sri Lanka side requested to include replacement of old Galvanized Iron (GI) service connections and replacement of bundled connections. However, the Team rejected the request and recommended to utilize local budget for such work.

**g) Groundwater Surveillance**

The Sri Lanka side requested to conduct groundwater surveillance including drilling observation wells into the Project to confirm the planned groundwater abstraction would not adversely affect existing shallow wells. The Team replied that the surveillance should be conducted by the Sri Lanka side.

**h) Overseas Training**

The Sri Lanka side requested execution of overseas training in Japan for staff of Nuwara Eliya Waterworks and Kandy regional office of NWSDB, and the Team recommended official submission of the request concerning the training to the JICA Sri Lanka Office. The Team explained that not every project was allocated overseas training opportunity.

Annex - 1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தேசிய நீர் வழங்கல் வடிகாலமைப்பு சபை

**National Water Supply & Drainge Board**

Chairman TEL/FAX 634488 | Vice Chairman 635883 | Head Office 635281 - 3, 635247, 638999 | P. O. Box 14 | Mt. Lavinia

General Manager 636449 | Telex : 21482 NWSDB CE | Fax : 636449, 635999 | E-mail : nwsdb agc@sltnet.lk | Galle Road, Ratmalana, Sri lanka


07.06.2001

My No. AGM/JPU/G.K

Your No.

Mr. S. Kaiho,
Resident Representative,
JICA Sri Lanka

Dear Sir,

**NUWARA ELIYA WATER SUPPLY AUGMENTATION PROJECT**
**LAND FOR CONSTRUCTION OF BORE HOLES**

I wish to bring to your attention that the Urban Development Authority has principally agreed for the construction of bore holes at the Golf Course premises, as indicated in their letter dated 30.05.2001 (copy attached).

The JICA study team has tentatively located the bore holes on either side of the road way which runs across the Golf Course. UDA would grant formal approval for the specific location once it is finalized in consultation with the Road Development Authority and the Golf Club of Nuwara Eliya.

Thanking You,

Yours faithfully

NATIONAL WATER SUPPLY & DRAINAGE BOARD

S. Weeraratne
General Manager

CC: Secretary, M/UDC&PU

Annex - 1

නාගරික සංවර්ධන, ඉදිකිරීම් හා පොදු උපයෝගිතා අමාත්‍යාංශය
Ministry of Urban Development, Construction & Public Utilities

නාගරික සංවර්ධන අධිකාරිය
நகர அபிவிருத்தி அதிகாரசபை
Urban Development Authority

Telephone: 872913, 875916, 873447, 878817, 875920, 873840, 873910, 873644, 873031, 873662, 876330
Fax: 872637

6 & 7 Floors, Sethsiripaya, Battaramulla.

My No. 17/NE/6/9,
Urban Development Authority,
1/1 Mahamaya Mw,
Kandy.

May 30, 2001.

Project Director,
Greater Kandy Water Supply Project,
Getambe,
Peradeniya Road,
Kandy.

Dear Sir,

**Land for Construction of Bore-holes.**

This is further to my letter No. 17/NE/6/9 dated May 22, 2001 and discussion I had with you over the phone regarding the above.

The construction of Bore-holes as mentioned in your letter is principally accepted by the UDA. You may obtain approval from Road Development Authority Nuwara-Eliya and Golf Club of Nuwara-Eliya and forward to UDA Central Provincial Office, for obtaining clearance from the UDA.

Thanking you

Yours faithfully.

V. Arudchelvan,
Deputy Director,
UDA
Kandy.

cc : Deputy Director
UDA/Nuwara-Eliya. - for your information & follow-up pl.

Arud/vr.

Annex - 1

Nuwara Eliya Golf Club

Our Ref.

Your Ref.

NUWARA ELIYA
SRI LANKA

TELEPHONE No: 052-21835
Fax: 052-34360

13th June, 2001

Mr.P.H.Sarath Gamini,
Act.Project Director,
Greater Kandy Water Supply Project,
National Water Supply & Drainage Board,
C/O Municipality,
Nuwara Eliya.

Dear Sir,

PERMISSION FOR CONSTRUCTION OF TEST BORE HOLES

Reference your letter RSC-C/JICA/99 dated 31st May 2001, followed up by messages from the Wor.the Mayor, Mr.Chandrasoma and Mr.Jayaratne of the U.D.A. we are please to approve of the drilling of four Bore Hole, as demartated on the Plan and pointed out today; as long as there is no damage or hindarance to the game of Golf.

The drilling of one Bore Hole has in fact already been done and marked No.4.

Yours faithfully,

Secretary.
(L.H.C.Tissera).

c.c. President - N.E.G.C ) as discussed.
Haputale Estate, )
Haputale. )

# Appendix 5. Cost Estimation Borne by the Recipient Country

## Cost of Land Acquisition

| Structure | Location | Area Required (m2) | Unit Cost (Rs/m2) | Cost (Rs.) |
|---|---|---|---|---|
| Well | Golf Course (for Race Course) | 20 | 5,000 | 100,000 |
| Well | Golf Course (for Race Course) | 20 | 5,000 | 100,000 |
| Well | Golf Course (for Race Course) | 20 | 5,000 | 100,000 |
| Well | Golf Course (for Race Course) | 50 | 5,000 | 250,000 |
| Well | Hawa Eliya (for Race Course) | 50 | 1,800 | 90,000 |
| Well | Hawa Eliya (for Race Course) | 50 | 1,800 | 90,000 |
| Well | Hawa Eliya | 50 | 1,800 | 90,000 |
| Well | Hawa Eliya | 50 | 3,000 | 150,000 |
| Well | Hawa Eliya | 50 | 5,000 | 250,000 |
| Junction Well | Haddon Hill road (Race Course) | 200 | 1,800 | 360,000 |
| Junction Well | Hawa Eliya | 300 | 1,800 | 540,000 |
| Booster Pump Station | Gemunupura | 110 | 1,800 | 198,000 |
| Booster Pump Station | Naseby | 50 | 1,940 | 97,000 |
| Reservoir | Old Water Field | 250 | 1,700 | 425,000 |
| Reservoir | Pedro | 170 | 1,500 | 255,000 |
| Reservoir | Naseby Tea Estate (Low Area 2) | 700 | 5,000 | 3,500,000 |
| Reservoir | Unique View | 140 | 5,000 | 700,000 |
| Reservoir | Gemunupura | 270 | 3,000 | 810,000 |
| Reservoir | Vijithapura | 150 | 5,000 | 750,000 |
| | **Total of Land Acquisition** | **2,700** | | **8,855,000** |

## Cost of Receiving Electrical Power

| Location | Power Required (kW) | Contract Fee (Rs.) | Cable Installatio (Rs.) | Cost (Rs.) |
|---|---|---|---|---|
| Wells in Hawa Eliya | 22 | 200,000 | 41,400 | 241,400 |
| Wells in Golf Course | 22 | 200,000 | 41,400 | 241,400 |
| Wells in Hawa Eliya | 16.5 | 200,000 | 41,400 | 241,400 |
| Transmission Pump Station (Low Area 2) | 90 | 675,000 | 41,400 | 716,400 |
| Booster Pump Station (Gemunupura) | 4.4 | 200,000 | 41,400 | 241,400 |
| Booster Pump Station (Naseby) | 7.4 | 200,000 | 41,400 | 241,400 |
| Transmission Pump Station (Race Course) | 170 | 675,000 | 41,400 | 716,400 |
| | **Total of Power Receiving Cost** | **2,350,000** | **289,800** | **2,639,800** |

Contract fee includes installation of transformer

## Cost of Defective Meter Replacement

| | | Quantity | Unit Cost (Rs.) | Cost (Rs.) |
|---|---|---|---|---|
| Meter Replacement | | 800 | 1,500 | 1,200,000 |

## Summary of Cost

| Description | Cost (Rs.) |
|---|---|
| Cost of Land Acquisition | 8,855,000 |
| Cost of Receiving Electrical Power | 2,639,800 |
| Cost of Defective Meter Replacement | 1,200,000 |
| **Total Cost Required** | **12,694,800** |

# Appendix 6. References



| No. | Title | Type | Original or Copy | Published by | Date of Publicaiton |
|---|---|---|---|---|---|
| 1 | Agricultural Statistics of Sri Lanka | Book | Copy | Department of Census and Statistics, Ministry of Finance and Planning | 1995 |
| 2 | Annual Health Bulletin 1998 | Book | Copy | Ministry of Health Sri Lanka | |
| 3 | Annual Report | Book | Copy | NWSDB | 1997 |
| 4 | Annual Report, RSC Central | Book | Copy | NWSDB | 1999 |
| 5 | Annual Report, RSC Central | Book | Copy | NWSDB | 1998 |
| 6 | Demographic Survey, Preliminary Release Based on Enumerator's Summaries | Book | Copy | Department of Census And Statistics, Ministry of Finance, Planning, Ethnic Affairs and National | 1994 |
| 7 | Design Manual D2,Urban Water Supply and Sanitation | Book | Copy | NWSDB | Mar-89 |
| 8 | Design Manual D3, Water Quality and Treatment | Book | Copy | NWSDB | Mar-89 |
| 9 | Development Plan Nuwara Eliya | Book | Copy | Urban Development Authority, Ministry of Housing And Urban | 1998 |
| 10 | Development Plan Nuwara Eliya ,Volume Ⅰ, Ⅱ | Book | Copy | Urban Development | Sep-99 |
| 11 | Fertilizer Recommendation and Seed Requirement | Book | Copy | | |
| 12 | Financial Statement,1998/1999 | Book | Copy | NWSDB | |
| 13 | Household income and Expenditure Survey 1995/96, Final Report | Book | Copy | Department of census and statistics Ministry | 2000 |
| 14 | Insecticides | Book | Copy | | |
| 15 | Investment Opportunities in The Central Province of Sri Lanka | Book | Copy | Ministry of Industries, Trade, Commerce & Tourism, Central Province-Sri lanka | Jul-00 |
| 16 | National Accounts of Sri Lanka | Book | Copy | Department of Census and Statistics, Ministry of Finance and Planning | 1998 |

| No. | Title | Type | Original or Copy | Published by | Date of Publicaiton |
|---|---|---|---|---|---|
| 17 | National Environmental Act, No. 47 of 1980 (Incorporating Amendment Act No:56 of 1988) | Book | Copy | Central Environmental Authority | 1989 |
| 18 | National PVC, Brief Technical Guide | Book | Copy | Central Industries Limited | |
| 19 | Nuwara Eliya Environmental Study,Environmental Assessment, Final Report ,Volume 1 | Book | Copy | Canadian International Development Agency | Feb-96 |
| 20 | Nuwara Eliya Environmental Study,Environmental Action Plan, Final Report ,Volume 2 | Book | Copy | Canadian International Development Agency | Feb-96 |
| 21 | Organization Chart of M.U.D.H.C. | Book | Copy | | |
| 22 | Past Water Supply Project by NWSDB,1994-1999 | Book | Copy | | |
| 23 | Public Investment Programme (1999-2004) | Book | Copy | | |
| 24 | Rates for 2000 | Book | Copy | NWSDB | Jun-00 |
| 25 | Recommendations for The Revision of The Cadre of The Nuwara Eliya Municipal Council | Book | Copy | Nippon Jogesuido Sekkei Co. Ltd. | Sep-00 |
| 26 | Report and Recommendation of The President to The Board of Directors on a Proposed Loan to The Democratic Socialist Republic of Sri Lanka for The Urban Development and Low-Income Housing (Sector) Project | Book | Copy | Asian Development Bank | Aug-98 |
| 27 | Sri Lanka Water Supply Sector Project, Loan No.1235SRI(SF), Summary Report on Controlling "UFW", Nuwara-Eliya W.S.S. | Book | Copy | Mott MacDonald Int. Ltd. ADB Water Supply Project | Mar-99 |
| 28 | Technical Information for The Planning and Installation of Rigid PVC | Book | Copy | St. Anthony's Industries Group | |
| 29 | The Gazette of The Democratic Socialist Republic of Sri Lanka | Book | Copy | Democratic Socialist Republic of Sri Lanka | Feb-90 |
| 30 | The Gazette of The Democratic Socialist Republic of Sri Lanka | Book | Copy | Democratic Socialist Republic of Sri Lanka | Jun-93 |
| 31 | The Gazette of the Democratic Socialist Republic of Sri Lanka | Book | Copy | Democratic Socialist Republic of Sri Lanka | May-96 |

# Appendix 7. Other Relevant Data

## Appendix 7-1 Comparison of Elevated Tank

### Comparison of Reservoirs

| Item | FRP Structure | Reinforced Concrete Structure |
|---|---|---|
| Procurement | Import from other counties<br>Panel Tank 7.0x8.0x2.5H | All materials are available at local.<br>Concrete is mixed at site. |
| Structure | Weight is lighter than concrete structure.<br>FRP material is superior in water tightness and corrosion resistance. | Structure becomes heavy. Careful attention should be paid to water tightness and protection from corrosion. |
| Construction | Materials are to be transported manually with small package and fabricated at the site.<br>Technical advice is required for fabrication.<br><br>Quality is reliable since it is produced in a factory.<br>Construction period is short (about 2 months.) | Construction work can be done by local workers but quality control should be carefully done to prevent leakage.<br><br>Construction period becomes long (about 4 months) since concrete should be cast manually at high place. |
| Maintenance | Maintenance is easy and requires low cost due to reliable quality and durability. | Maintenance is required when water leaks from cold joint and others. |
| Cost | Construction cost is high due to expensive material, marine transportation and supervision.<br><br>About 8,000,000 yen | Construction cost is higher than ordinary reinforced concrete structure due to high location and manual work.<br>About 3,500,000 yen |

### Comparison of the Tank Support Underneath

| Item | Steel-Frame Structure | Reinforced Concrete Structure |
|---|---|---|
| Procurement | Steel frame is to be fabricated at local factory considering assembling at site. | All materials are available at local.<br>Concrete is mixed at site. |
| Construction | Materials are to be transported manually with small package and assembled at the site by fastening bolts. Reinforcement is required to cope with buckle and other forces.<br><br>Construction period will be long because of the complicated assembling. (about 5 months). | Construction work can be done by local workers but careful quality control should be required.<br><br>Construction period becomes long (about 4 months) since concrete should be cast manually step by step. |
| Maintenance | Maintenance is required to prevent the rust at steel frame, bolts and other parts. | Painting is required to prevent rust at limited parts such as ladder. |
| Cost | Cost is a bit high due to assembling of steel frame and lots of bolts to be fastened. (about 6,000,000 Yen) | Construction cost is higher than ordinary reinforced concrete structure due to high location and manual work. (about 5,000,000 yen) |

Structural and topographical conditions for Pedro Reservoir are as follows:

Structural Condition

Reservoir Capacity : 130 m3
Height : 15 m (This figure might be modified a little after design completion)

Topographical Condition

Pedro Reservoir is located on the mountain behind the shopping centre. Small path for the residents should be used as the access road. All materials will be transported manually to the site since construction equipments and truck cannot reach to the site through the narrow path.

## Appendix 7-2 Comparison of Flow Meter

| Item \ Type | TURBINE TYPE | VERTICAL WOLTMANN TYPE |
|---|---|---|
| 1. Theory of Measurement | Turbine type flow meter is installed on pipeline. The rotation of an impeller, which is equipped along the flow direction, is transmitted through gears and magnet coupling and flow rate is indicated after figuring out by gear mechanism. | Same theory with Turbine type flow meter. A vane wheel axis is used as an impeller. |
| 2. Location of Installation | On a pipeline | On a pipeline |
| 3. Accuracy | ±2.0% | ±1.5% |
| 4. Meter Indication | Instantaneous flow rate, Accumulated flow rate | Accumulated flow rate |
| 5. Required straight pipe length | Upstream :5D, Downstream :3D | Upstream :5D, Downstream :3D |
| 6. Maintenance | Maintenance is easy though flow meter cannot used during inspection. | Same with Turbine Type |
| 7. Cost | Current flow type will be expensive | A bit cheaper than Turbine type |
| 8. Judgment | ○ | ◎ |

Flow meters which require electricity such as electromagnetic flow meter, supersonic flow meter and differential pressure type flow meter are omitted from the comparison table, considering the location of reservoirs where flow meters are to be installed.

## Appendix 7-3 Comparison of Chlorine Agent

| Item \ Type | LIQUEFIED CHORINE GAS | SODIUM HYPOCHLORITE | CALCIUM HYPOCHLORITE (BLEACHING POWDER) |
|---|---|---|---|
| 1. Character | Chlorine gas is liquefied and filled in a cylinder. It is a highly toxic chemical with a pungent smell and heavier than air. Quality is stable. | Sodium Hypochlorite is an strong alkaline and light yellow liquid. It is unstable when concentration of available chlorine is high. | Shape of Calcium Hypochlorite is a power, granule or tablet. It is a stable chemical. |
| 2. Concentration of effective chlorine. | nearly 100% | About 5% | About 35% |
| 3. Dosing method | Chlorine gas in a cylinder is dosed through ejector (Fig.-1) | Sodium Hypochlorite is dosed into a clear water reservoir by gravity. (Fig.-2) | Bleaching powder or granule is dissolved in water in a mixing tank and dosed by gravity. (Fig-3) |
| 4. Required Equipment | Cylinder, Dosing device, Ejector, Pipeline | Storage Tank, Pipeline | Mixing Tank, Manual Mixer, Pipeline |
| 5. Transportation and Storage | It is filled in 50 kg cylinder and transported by truck. It should be stored in a safety place keeping away from sunlight and moisture. | It is transported by tank lorry. It should be stored in a place like underground to keep away from sunlight and influence of temperature. It can not be stored for a long period. | It is packed in a bag and transported by truck or others. It should be stored in a dry, dark and cool place keeping out from inflammables. |
| 6. Handling | Easy | Easy | Easy |
| 8. Safety measures | Gas leak detectors and safety goods should be equipped to cope with leakage. | Dike is required around the tank to prevent leaked chlorine spreading. | Dike is required around the tank to prevent leaked chlorine spreading. |
| 9. Experience in Sri Lanka | Used in large scale water supply facilities. | No experience | Used in many small reservoirs. |
| 10. Cost | About 60Rs/kg | About 20Rs/Liter | About 35Rs/kg |
| 11. Comparison of Cost per effective chlorine (ratio) | 60 | 400 | 100 |
| 12. Applicability | Not applicable at reservoirs where chlorine cylinder can not be conveyed by truck | Not applicable at reservoirs where tank lorry can not be accessed. | Applicable at reservoirs where vehicles can not be accessed. Handling is easy. |
| 13. Judgement | ○ | △ | ◎ |

## Appendix 7-4 Comparison of Chlorine Dosing Facility

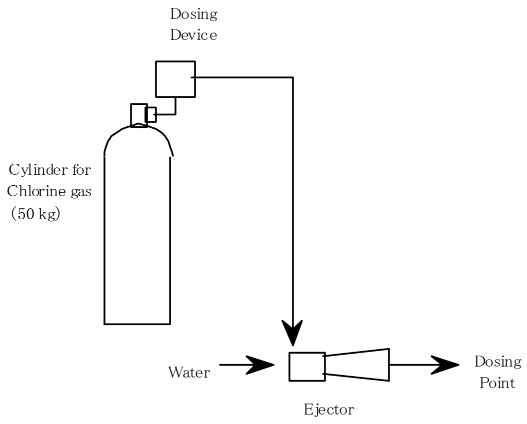



Fig.−1 Liquidfied Chlorine Gas

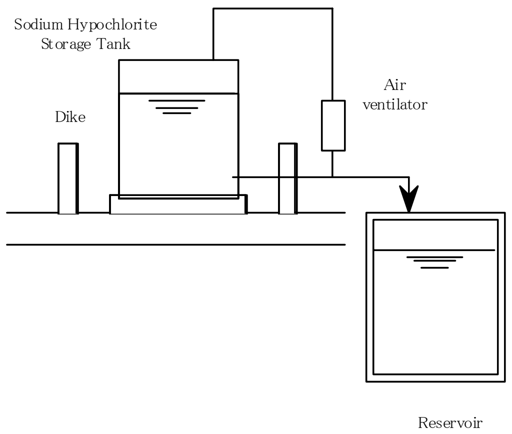



Fig.−2 Sodium Hypochlorite

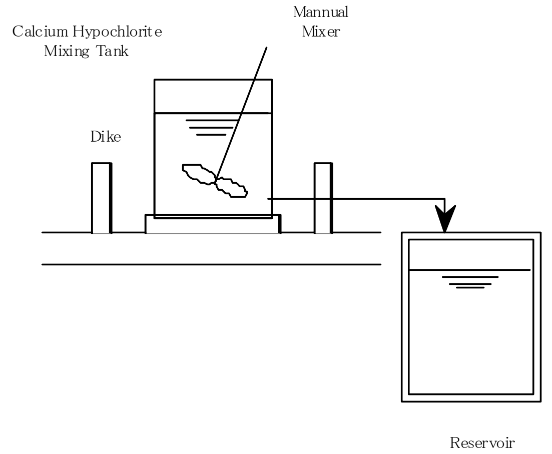
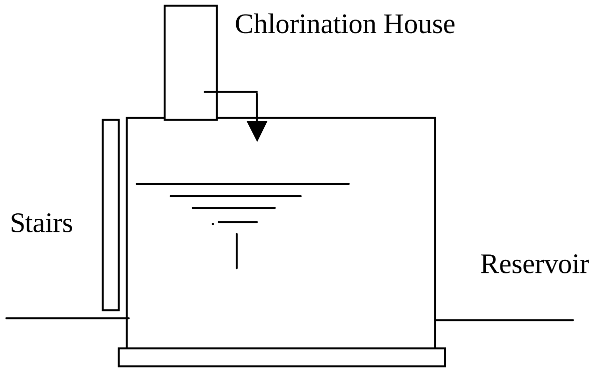



Fig.−3 Calcium Hypochlorite

## Appendix 7-5　　Arrangement of Chlorine House

### Calcium Hypochlorite Mixing Tank




**SIZE OF CHLORINE HOUSE**

| Reservoir | L | W | Floor Area (m2) | Remarks |
|---|---|---|---|---|
| Old Water Field ˋ | 3,500 | 2,000 | 7.0 | |
| Pedro (Elevated Tank)* | 3,500 | 2,000 | 7.0 | |
| Unique View | 4,000 | 2,500 | 10.0 | |
| Vijithapura | 3,500 | 2,000 | 7.0 | |
| Low Area 2 | 4,000 | 2,500 | 10.0 | |
| Gemunupura | 3,500 | 2,000 | 7.0 | |

＊　At Pedro a chlorination house is to be constructed near the reservoir since it is an elevated tank.

## Appendix 7-6 Comparison of Pipe Material

| Item / Type | DUCTILE CAST IROM PIPE (DCIP) | STEEL PIPE (SP) | PVC PIPE (PVC) |
|---|---|---|---|
| 1. Standard and diameter used for comparison | JIS G 5526・5527<br>φ75～φ2,600(K-Type)<br>φ75～φ2,000(Ｔ-Type) | JIS G 3443<br>φ80～φ3,000 | JIS K 6741<br>φ13～φ800 |
| ２.Mechanical Character<br>(1)Tensile Stress N/mm$^2$<br>(2)Extension %<br>(3)Bending Force N/mm$^2$ | More than 420<br>More than 10<br>More than 600(as reference) | More than 400<br>More than 18<br>More than 400 | More than 47 (20℃)<br>50～150<br>80～100 |
| 3. Safety<br>(1) External Pressure | DCIP can bear a high pressure due to large bending force. | Stiffness is inferior to DCIP since it is easier to bend due to larger extension and thinner pipe thickness. | Stiffness is less than DCIP and easier to bend.<br>(Elastic coefficient is about 1/60 of DCIP) |
| (2) Internal Pressure | DCIP can bear high pressure | SP can bear high pressure | PVC is not adequate for high pressure line. |
| ４.Joints<br>(1) Water Tightness | Good because of a watertight rubber ring between socket and spigot. | Good because of welding at the connection. | Good under normal condition. |
| (2) Expansion and Flexibility | No big pressure is expected on pipes during land movement because of easy expansion and flexibility. | No expansion and flexibility can be expected at welding joints. | Easy expansion and flexibility at RR joint though they cannot be expected at TS joints |
| (3) Against Thrust Force | Thrust blocks or reinforced joints are required at the fittings where pipe thrust forces are generated by un-balanced internal forces. | Welding Joints can work as reinforced joints. | Thrust blocks are required at the fittings where pipe thrust forces are generated by un-balanced internal forces. |
| (4) Pipe Installation at Soft Ground | ・Big stress will not occur on the pipes due to function of easy expansion and flexibility.<br>・For large sinkage, special fittings are required. | ・Big stress will occur on the pipes because function of easy expansion and flexibility cannot be expected.<br>・For large sinkage, special fittings are required. This place will become a week point due to concentration of displacement and force to the point. | At RR joints function of easy expansion and flexibility can be expected. Generally it is easier to install PVC pipes at soft ground because its weight is light. |
| (5) Earthquake Resistance | ・Good resistance can be expected due to easy expansion and flexibility at joints and strength of pipe body.<br>・Usage of special fittings improves the earthquake resistance | ・Usage of thicker pipes or expansion joints is required to cope with earthquake force. | ・For the pipes smaller than φ300, reinforced joints are used.<br>・For the pipes larger than φ350, no reinforced joints are available. (Pipe will come out during strong earthquake.) |
| 5. Difficulty in Installation<br>(1) Trench Excavation and Foundation | ・Deeper excavation is required at joints for tightening bolts. It is not necessary for T-type.<br>・Not special foundation is required in general. | ・Enough space is required at joints for welding.<br>・Sand bed is required. | Sand bed is required and compaction should be done well during backfill. |
| (2) Joints of Pipes | ・Jointing work can be done in a short period with simple tools.<br>・Small amount of water does not affect the jointing work and influence of weather condition and groundwater table is small.<br>・Alignment can be changed during installation due to flexibility at joints. | ・It takes time for welding and X-ray inspection.<br>・Skilled and qualified workers are required for welding.<br>・Influence of weather condition and groundwater table is big since dry condition is required for welding. | Jointing work is easy and can be done in a short period.<br>Adhesive is used at TS joints. |

| Item /Type | DUCTILE CAST IROM PIPE (DCIP) | STEEL PIPE (SP) | PVC PIPE (PVC) |
|---|---|---|---|
| (3) Backfilling and Compaction | ・ Excavated soil can be used for backfilling as far as it is not soft soil or corrosive soil.<br>・Compaction is easier than SP installation.<br>・ Affection to traffic is small since backfilling can be done just after jointing work. | ・ Backfilling with sand is required around the pipes and compaction should be done well.<br>・ Affection to traffic is big since it takes time for welding and painting at joints. | ・ Sand is required for backfilling and sufficient compaction should be done very well after removing debris and stones.<br>・ Affection to traffic is small since backfilling can be done just after jointing work. |
| (4) Transportation and Handling of Pipes | Handling is easy since DCIP is strong against shock though it is heavy. | Transportation and handling is easy since SP is lighter than DCIP. Attention is required for damage on pipe body by shocks. | Transportation and handling is easy since SP is lighter than DCIP. Special attention is required for damage on pipe body by shocks |
| 6.Durability<br>(1) Anti-corrosiveness | Superior to SP due to peculiar anti-corrosiveness of Ductile Cast Iron. | Inferior to DCIP | Good |
| (2) Prevention from Internal Corrosion | ・ Internal cement lining is good to prevent corrosion by alkali.<br>・ Cement lining is hard to be hurt and good adherence can be expected due to centrifugal force lining.<br>・ Internal surface of fittings is lined with powder epoxy, which has high anti-corrosiveness. | Internal surface of pipes is lined but lining at welding parts at the field is difficult especially for small diameter of pipes. | Good |
| (3) Prevention from External Corrosion | ・Synthetic resin is usually used for pipe coating.<br>・ At high corrosiveness soil, pipe is installed using polyethylene sleeve cover. | ・Multi-layer coating is usually done.<br>・ Pinholes will sometimes be developed by corrosion if pipe is installed without repairing damaged coating. | Good |
| (4)Anti-electric corrosiveness | ・ Electric corrosion is hard to occur since rubber rings at joints insulate the line.<br>・ Usage of Polyethylene sleeve improves the anti-electric corrosiveness. | ・ Pipeline is not insulated and it is easy to occur electric corrosion in certain conditions.<br>・ Several anti-electric corrosion methods are developed but there are problems in maintenance and cost. | Good |
| (5) Life Span (The Local Public Enterprise Law) | 40 years | 25 years | 25 years |

**（COST COMPARISON： October 2000 in Japan）**

① In Case of Diameter 200mm

| Pipe Material | Diameter x Length | Price/piece | Price per meter |
|---|---|---|---|
| Ductile Cast Iron Pipe (DCIP) | 200mm x 5m | ¥ 32,900 | ¥ 6,580 / m |
| Steel Pipe (SP) | 200mm x 5.5m | ¥ 49,600 | ¥ 9,048 / m |
| PVC Pipe (PVC) | 200mm x 5m | ¥ 18,880 | ¥ 3,776 / m |

② In Case of Diameter 300mm

| Pipe Material | Diameter x Length | Price/piece | Price per meter |
|---|---|---|---|
| Ductile Cast Iron Pipe (DCIP) | 300mm x 6m | ¥ 62,400 | ¥ 10,400 /m |
| Steel Pipe (SP) | 300mm x 5.5m | ¥ 80,200 | ¥ 14,581 /m |
| PVC Pipe (PVC) | 300mm x 5m | ¥ 41,600 | ¥ 8,320 /m |

## Appendix 7-7 Comparison of Well Pump

| Item \ Type | SUBMERGED MOTOR PUMP | VERTICAL-AXIS MULTI-STAGE TURBINE PUMP | HORIZONTAL SHAFT CENTRIFUGAL PUMP |
|---|---|---|---|
| 1. Structure | It is composed of pump, lifting pipe and effluent pipe at upper part. Motor is installed just below the pump and both are submerged. There is no mechanical parts above the ground. Middle shaft and middle bearing are unnecessary. | Motor and Frame is installed above the ground. Water is lifted by the power of motor which is transmitted by the shafts of motor and pump through thrust bearing. | Pump and shaft of electric motor are installed horizontally. Water is lifted by the centrifigual force of an impeller. |
| 2. Required Area for pumps | Small | Small | A bit larger than the others since a pump pit is required to place pump. |
| 3. Difficulty in installation | Easy since middle shaft is unnecessary and special technology is not required. | Easy | Easy |
| 4. Stability of operation against fluctuation of water table | Pump is operable even if groundwater table fluctuates. | Pump is operable even if groundwater table fluctuates. | Water cannot be lifted when fluctuation of groundwater table is big . |
| 5. Maintenance | Maintenance is easy though it requires to lift the pump and the motor above the ground for overhaul. | Overhaul of pumps is difficult due to complicated structure. Maintenance of motor is easy though it requires to lift the pump above the ground for overhaul. | Maintenance is easy. |
| 6. Experience | This pump is used for almost all well pumps. | This pump is used in few places. | This pump is used in few places as a well pump. |
| 7. Cost | — | Expensive compared with submerged motor pump. | Overall cost for pump facilities including civil structure such as pump pit is almost same with or higher than submerged motor pump though pump itself is cheaper. |
| 8. Judgement | ◎ | △ | △ |

**Appendix 7-8 Comparison of Transmission Pump**

| Type / Item | HORIZONTAL SHAFT CENTRIFUGAL PUMP | VERTICAL-AXIS DIAGONAL FLOW PUMP | SUBMERGED CENTRIFUGAL PUMP |
|---|---|---|---|
| 1. Theory of Water Lifting | Pump and shaft of electric motor are installed horizontally. Water is lifted by the centrifugal force of an impeller. | Main axis is installed vertically. Water is lifted by lifting force of an impeller. | Pump and motor are united and submerged to lift water. |
| 2. Required space for installation | Larger space is required since pump is installed outside the junction well and special space for pump installation is necessary. | Small | Small since pump and motor are installed in junction well. |
| 3. Difficulty in Installation | Easy | It requires some time and labour. | Easy |
| 4. Civil Structure | Motor and pump facilities are installed in a room next to the pumping well and the room is a bit deep. Lifting height of pump is not high. | A complicated civil structure is required and Lifting height of pump should be high. | A particular pump room is not required. Lifting height of pump is high. |
| 5. Maintenance | Easy. Overhaul of pump and replacement of roatating parts can be done after dismantling the casing. | A motor is installed on the floor and maintenance is easy though a pump is installed below the floor and daily inspection cannot be done. It requires a longer time and labour for dismantling and reassembling due to longer axis and lots of parts. | Daily inspection of pump and motor is difficult since they are submerged. Overhaul of pump can be done after it is lifted above the ground. |
| 6. Experience | Lots of experience as transmission and distribution pump. | Lots of experience as intake pump | Not so many experience as transmission pump. |
| 7. Cost | — | Much (about 2 times) higher than Horizontal Shaft Centrifugal pump. | A bit higher than Horizontal Shaft Centrifugal pump. |
| 8. Judgement | ◎ | ○ | △ |

## Appendix 7-9 Comparison of Booster Pump

| Item \ Type | HORIZONTAL SHAFT CENTRIFUGAL PUMP | IN-LINE PUMP |
|---|---|---|
| 1. Location of Installation | It is installed on a pipeline and boost water pressure. | It is installed on a pipeline and boost water pressure. |
| 2. Required Area for installation | A bit larger space is required compared with in-line pump. | Small |
| 3. Difficulty in Installation | Easy | Easy |
| 4. Maintenance | | |
| 1) Overhaul | Easy | Easy |
| 2) Repair | Main shaft can be replaced. | Main shaft and Motor should be replaced at the same time and cost for replacement becomes high. |
| 3) Availability of Spare-parts | Easy to obtain. | Easy to obtain. |
| 5. Measures to reduce water hammer | Fly-wheel can be installed. | Large scale and expensive measures such as Air chamber are required. |
| 6. Experience | Many | Many |
| 7. Cost | Almost same with In-Line Pump | Almost same with Horizontal Shaft Centrifugal Pump. |
| 8. Judgement | ◎ | ○ |

## Appendix 7-10 Study on Negative Environmental Impacts

### 1. Wastewater Increase Caused by Water Supply System Improvement

At the first step, quantity of wastewater increase caused by water supply system improvement was studied. Record of water production in 1997 and planned water production in 2005 after implementation of the Project are shown below.

| Month | Year 1997 (record) | | Year 2005 (planned) | |
|---|---|---|---|---|
| | Production | Production | Production | Production |
| | $m^3$/month | $m^3$/day | $m^3$/month | $m^3$/day |
| Jan. | 247,566 | 7,986 | 316,200 | 10,200 |
| Feb | 160,188 | 5,721 | 285,600 | 10,200 |
| Mar | 134,137 | 4,327 | 316,200 | 10,200 |
| Apr | 120,930 | 4,031 | 306,000 | 10,200 |
| May | 245,520 | 7,920 | 316,200 | 10,200 |
| Jun | 285,750 | 9,525 | 306,000 | 10,200 |
| Jul | 295,275 | 9,525 | 316,200 | 10,200 |
| Aug | 295,275 | 9,525 | 316,200 | 10,200 |
| Sep | 285,750 | 9,525 | 306,000 | 10,200 |
| Oct | 295,275 | 9,525 | 316,200 | 10,200 |
| Nov | 285,750 | 9,525 | 306,000 | 10,200 |
| Dec | 295,275 | 9,525 | 316,200 | 10,200 |
| **Total** | **2,946,691 $m^3$/year** | | **3,723,000 $m^3$/year** | |

Quantity of wastewater will be calculated by deducting leakage water from total production. To estimate quantity of leakage, leakage ratio 19 % which was identified by the previous JICA Study was introduced.

| | Year 1997 | Year 2005 |
|---|---|---|
| Production（$m^3$/year） | 2,946,691 | 3,723,000 |
| Quantity of Leakage($m^3$/year) | 559,871 | 707,370 |
| Water Consumption（$m^3$/year） | 2,386,820 | 3,015,630 |
| Incremental Water Consumption（$m^3$/year） | | 628,810 |

Water consumption in 2005 will increase from the consumption in 1997, because people can use water in dry season after the project implementation and number of connection will increase. It is considered that the incremental water consumption was substituted by other alternative water sources. Per capita water consumption who has piped water supply and who does not are shown table below, these data were obtained from questionnaire survey.

| | Per Capita Consumption（lpcd） | Ratio |
|---|---|---|
| Connected to water supply | 148 | 100% |
| Not connected to water supply | 113 | 76% |
| Difference | 35 | 24% |

From the table above, water consumption will increase 113 lpcd to 148 lpcd after connecting water supply service. In other words, water consumption will increase 24 % after having water supply connection. Per capita consumption for people not connected to water supply seems to be rather high, this is because topographical condition of Nuwara Eliya. Central area of Nuwara Eliya is low in elevation and this area is commercial and institutional area. Surrounding this low area, hilly area to the higher mountains is mainly residential area. In this hilly residential area, many streams from mountains are observed and people who does not have water use water from these streams.

From the above data, net increase of water consumption will be 148,705 $m^3$/year, 24 % of total water consumption increase 628,810 $m^3$/year. If all of water consumption and consumption increase became wastewater, wastewater increase will become 6 %. Therefore, it is considered that the wastewater increase caused by water supply system improvement will not be significant.

Because of hilly and mountainous topographic condition of Nuwara Eliya, increased wastewater will flow downwards smoothly and will not cause serious unhygienic condition.

## 2. Pollutant Increase Caused by Water Supply System Improvement

At the second step, quantity of pollutant, focusing on BOD, increase caused by water supply system improvement was studied. In the previous JICA Study, BOD concentration of wastewater was calculated as follows.

BOD per capita： 40ｇ/capita/day
Domestic wastewater： 93 litter per day

BOD concentration in domestic wastewater： 40,000 mg/93 l ＝ 430 mg/l
Non-domestic BOD concentration： 215 mg/l（50％ of domestic）
Quantity of domestic wastewater： 642 $m^3$/day
Quantity of non-domestic wastewater： 1,493 $m^3$/day
Groundwater intrusion： 200 $m^3$/day
Total quantity of wastewater： 2,335 $m^3$/day
Average BOD concentration： BOD=
(430 x 642 + 215 x 1,493)/2,335 = 250 mg/l

Wastewater increase caused by water supply system improvement does not include BOD from human excrements, quantity of excrements dose not have any relation with water supply condition. Therefore, BOD from human excrements should be deducted from BOD per capita used in calculation above.

According to the references, breakdown of BOD per capita in developing countries is as shown below.

| **Source** | **BOD（g/capita/day）** |
|---|---|
| Bathing | 5 |
| Kitchen | 8 |
| Washing | 5 |
| Toilet （stool） | 11 |
| Toilet （urine） | 10 |
| Paper | 1 |
| **Total** | **40** |

BOD per capita excluding BOD from excrements (stool 11 and urine 10 g = 21g) will be 19 g/capita/day (40 – 21 = 19 g). Applying this BOD per capita, average concentration of BOD will be calculated as follows.

BOD per capita： 19 g/capita/day
Domestic wastewater： 93 litter per day
BOD concentration in domestic wastewater： 19,000 mg/93 l ＝ 204 mg/l
Non-domestic BOD concentration： 215 mg/l（same as the Previous JICA Study）
Quantity of domestic wastewater： 642 $m^3$/day
Quantity of non-domestic wastewater： 1,493 $m^3$/day
Groundwater intrusion： 200 $m^3$/day
Total quantity of wastewater： 2,335 $m^3$/day

| | |
|---|---|
| Average BOD concentration： | BOD=<br>(204 x 642 + 215 x 1,493)/2,335 = 194 mg/l |

BOD increase will be calculated by this average BOD concentration and wastewater increase calculated in the previous section as follows.

| | |
|---|---|
| Wastewater increase： | 148,705 $m^3$/year |
| Average BOD concentration： | 194 mg/l |
| BOD Load Increase： | 28,849 kg/year |

## 3. Countermeasures to Reduce BOD Loads

### 3.1 Wastewater Treatment Plant at Brewery Factory

Wastewater treatment plant of brewery factory in Nuwara Eliya was completed in the beginning of year 2000. However, because of deteriorated facilities, insufficient capacity, and malfunction of mechanical/electrical equipment, treatment plant has not been operated properly. Quality of treated water from the plant is analyzed by the factory's laboratory in Colombo, not by the third party.

COD of wastewater before treatment plant was 550～1,050 mg/l and COD and BOD after treatment were 80 mg/l and 200 mg/l, respectively according to the factory. According to the regulation of Sri Lanka, "GENERAL STANDARD FOR DISCHARGE OF EFFLUENTS INTO INLAND SURFACE WATERS" as shown below, maximum BOD concentration of effluent is defined as 30 mg/l.

If agencies concerned strongly order the factory to conform effluent quality to the regulation and the treatment system was improved, BOD load to the environment can be reduced 170 mg/l from current 200 mg/l to 30 mg/l. Based on this reduction, 170 mg/l, total reduction of BOD load can be calculated as follows.

| | |
|---|---|
| Reduction of BOD concentration： | 170 mg/l |
| Quantity of wastewater： | 250 $m^3$/day（Information of the factory） |
| Reduction of BOD Load： | 42.5 kg/day<br>15,513 kg/year |

The Gazette of the Democratic Socialist Republic of Sri Laka

Government Notificacion

NATIOANAL ENVIRONMENTAL ACT,No.47 OF 1980

SCHEDULE Ⅰ

GENERAL STANDARD FOR DISCHARGE OF

EFFLUENTS INTO INLAND SURFACE WATERS

| No. | Determinant | Tolerance |
|---|---|---|
| 1. | Total Suspended Solids, mg/l, max | 50 |
| 2. | Particle size of total suspended solids | shall pass sieve of aperture size 850micro m. |
| 3. | pH value at ambient temperature | 6.0 to 8.5 |
| 4. | Biochemical Oxygen Demand-$BOD_5$ in 5 days at 20℃, mg/l, max | 30 |
| 5. | Temperature of discharge | shall not exceed 40℃ in any Section of the Stream within 15m down stream from the effluent outlet. |
| 6. | Oils and greases, mg/l max | 10.0 |
| 7. | Phenolic Compounds (as phenolic OH) mg/l, max | 1.0 |
| 8. | Cyandes as (CN) mg/l, max | 0.2 |
| 9. | Sulfides, mg/l, max | 2.0 |
| 10. | Flourides, mg/l, max | 2.0 |
| 11. | Total residual chlorine mg/l, max | 1.0 |
| 12. | Arsenic, mg/l, max | 0.2 |
| 13. | Cadmium total mg/l max | 0.1 |
| 14. | Chromium total, mg/l, max | 0.1 |
| 15. | Copper total, mg/l, max | 3.0 |
| 16. | Lead, total mg/l, max | 0.1 |
| 17. | Mercury total, mg/l, max | 0.0005 |
| 18. | Nickel total, mg/l, max | 3.0 |
| 19. | Selenium total, mg/l max | 0.05 |
| 20. | Zinc total, mg/l, max | 5.0 |
| 21. | Ammoniacal nitrogen, mg/l max | 50.0 |
| 22. | Pesticides | Undetectable |
| 23. | Radio active material<br>(a) Alpha emitters micro curie/ml<br>(b)Beta-emitters micro curie/ml | <br>$10^{-7}$<br>$10^{-8}$ |
| 24. | Chemical Oxygen Demand (COD), mg/l, max | 250 |

Note1:All efforts should be made to remove colour and unpleasant odour as far as practicable

Note2:These values are based on dilution of effluents by at least 8 volumes of clean receiving water. If the dilution is below 8 times, the permissible limits are multiplied by 1/8 of the actual dilution.

Note3:The above mentioned General Standards shall cease to apply with regard to a particular industry when industry specific standards are notified for that industry.

### 3.2 BOD Load Reduction by New Treatment Plant of the Central Hospital

There is a central public hospital in Nuwara Eliya. Original wastewater treatment system was broken down completely and wastewater from the hospital has been discharged to small river in front of the hospital without any treatment. In year 2001, new treatment system was completed and treatment plant is under operation. By this new plant, reduction of BOD load can be calculated as follows.

| | |
|---|---|
| BOD concentration of wastewater： | 215 mg/l (apply concentration of non-domestic wastewater in the previous JICA Study) |
| BOD concentration of treated water： | 30 mg/l (conforming to the regulation) |
| Reduction of BOD concentration： | 185 mg/l |
| Quantity of wastewater： | 400 $m^3$/day (information from the hospital) |
| Reduction of BOD Load： | 74.0 kg/day<br>27,010 kg/year |

### 3.3 Urban Development and Low Income Housing Project by ADB

ADB sector project had been implemented from 1993 to 1998 financed by ADB with UDA as implementing agency. Under this project, 17 cities were included but Nuwara Eliya was out of the project scope.

As the second phase of the project, Urban Development and Low Income Housing Project was commenced in 1999 and will be completed in 2004. This second phase project is consist of two stages and the first stage will cover 8 cities and the second stage will cover 19 cities including Nuwara Eliya.

During the field investigation in Nuwara Eliya, meeting on scope of project was held among ADB, Nuwara Eliya Municipal Council and UDA. Sri Lanka side requested the ADB to include following scope.

1. Bank protection of the Nanu Oya River
2. Construction of two floor commercial building along the Park Road
3. Improvement of central bus station（including commercial facilities）
4. Improvement of commercial facilities along the St. Andrews Road
5. Improvement of existing eight public toilets

6. Construction of community septic tank for 300 households
7. Construction of septic tanks for labor houses of tea plantation
8. Construction of a part of roads and road bridges
9. Improvement of housing for low income along the Rosen Road
10. Improvement of Moon Plain Housing

Receiving these requests from Sri Lanka side, ADB started investigation of affordability of Nuwara Eliya Municipal council and the scope of the project will be decided based on the results of the investigation. According to the information from the Municipal Council, request Nos. 5 to 7 among listed above are relating to sanitation improvement and 70 % of sanitation improvement project will be financed by ADB as grant. Therefore, possibility of project implementation will be very high.

Since detailed scope of the request No. 7 is not available, evaluation of BOD reduction can not be conducted. Possibility of BOD reduction for request Nos. 5 and 6 is evaluated as follows.

During the field investigation, number of people using the existing eight public toilets were surveyed. The results are shown table below.

**Number of People Using Existing Public Toilets per Day（September 2000）**

| Public Toilets and Hour | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 6:00 - 7:00 | 0 | 18 | 0 | 0 | 0 | 3 | 14 | 0 | 35 |
| 7:00 - 8:00 | 0 | 19 | 14 | 11 | 3 | 7 | 20 | 0 | 74 |
| 8:00 - 9:00 | 6 | 17 | 8 | 13 | 5 | 3 | 21 | 1 | 74 |
| 9:00 - 10:00 | 10 | 19 | 13 | 14 | 6 | 6 | 17 | 4 | 89 |
| 10:00 - 11:00 | 4 | 23 | 8 | 8 | 6 | 3 | 19 | 6 | 77 |
| 11:00 - 12:00 | 9 | 18 | 9 | 12 | 2 | 4 | 21 | 10 | 85 |
| 12:00 - 13:00 | 7 | 24 | 5 | 15 | 7 | 3 | 22 | 3 | 86 |
| 13:00 - 14:00 | 4 | 21 | 11 | 17 | 3 | 5 | 12 | 9 | 82 |
| 14:00 - 15:00 | 5 | 13 | 3 | 9 | 8 | 0 | 8 | 6 | 52 |
| 15:00 - 16:00 | 11 | 16 | 14 | 13 | 2 | 1 | 9 | 4 | 70 |
| 16:00 - 17:00 | 12 | 22 | 2 | 21 | 6 | 7 | 5 | 2 | 77 |
| 17:00 - 18:00 | 9 | 20 | 3 | 13 | 0 | 0 | 3 | 0 | 48 |
| 18:00 - 19:00 | 0 | 23 | 0 | 16 | 0 | 4 | 0 | 0 | 43 |
| **Total** | **77** | **253** | **90** | **162** | **48** | **46** | **171** | **45** | **892** |

Location of Public Toilet
1 Market
2 CTB Bus Station
3 Main Bus Station
4 Private Bus Station
5 Behind Court

6 Mahagastotte Junction
7 Sunday Fair
8 Victria Park (Gents)

As shown on table above, about 900 people use public toilet per day. Usually septic tank is facilitated with the public toilet, adequate treatment has not been conducted because of absence of proper maintenance.

For request No. 6, number of beneficiaries will be 1,950 person (300 households x 6.5 person per family). Therefore, total beneficiaries of ADB's sanitation improvement will be 2,850 person (900 + 1,950).

Supposing 50 % of BOD load from human excrements will be treated at the improved septic tanks, reduction of BOD load can be calculated as follows.

| | |
|---|---|
| BOD per capita (excrements only)： | 21 g/capita/day |
| Treatment ratio： | 50 % |
| BOD reduction (public toilet)： | 5 g/capita/day (50 % defecation at public toilet) |
| BOD reduction (community septic tank)： | 10 g/capita/day |
| Beneficiary (public toilet)： | 900 person |
| Beneficiary (Commurinty septic tank)： | 1,950 person |
| Reduction of BOD： | 24 kg/day |
| | 8,760 kg/year |

## 3.4 BOD Load Reduction by Efforts of Sri Lanka Side

BOD load reduction will be realized by efforts of Sri Lanka side as described in the previous sections are summarized as table below.

| **Measures** | **BOD Reduction** **（BOD kg/year）** |
|---|---|
| Improvement of Wastewater Treatment System of Brewery Factory | 15,513 |
| Completion of Wastewater Treatment System of Central Hospital | 27,010 |
| Implementation of ADB Sanitation Improvement Project | 8,760 |
| Total | 51,283 |

On the other hand, increasing BOD load by the water supply system improvement will be 28,849 kg/year, therefore in the case that above listed measures were implemented by Sri Lanka side and ADB project was implemented, it will be possible that the increasing BOD load will be balanced.
In other words, since it is possible to offset the pollution load generated by this Project to the environment by completing the abovementioned projects, it is important to ascertain that they are implemented.

Increasing BOD will be offset by the Sri Lanka side efforts, however, this does not deny necessity of public sewerage in Nuwara Eliya. As water quality of Gregory Lake shows eutrophication, public sewerage is indispensable to improve environment of Nuwara Eliya.

In summary, to minimize environmental impact, Sri Lanka side should implement the followings.

- For large-scale water users (brewery, general hospital etc.), an arrangement to strictly comply with effluent standards shall be made
- Effluent quality analysis and monitoring by legally entitled institution (i.e. CEA)
- Promotion of the implementation of ADB Project
- Control of fertilizer and pesticide use in agricultural farms(especially in vegetable farms)
- Strengthening of the maintenance of household septic tanks
- Water quality monitoring downstream of solid waste dumping site (Moon Plain)

## Appendix 7-11 Water Tariff Structure

Current water tariff structure of Nuwara Eliya Waterworks is as follows.

### Water Tariff Structure of Nuwara Eliya Waterworks

**(as of 1998.1.1.)**

Water tariff is categorized 10 categories as follows.

**Category 1: Domestic, Local Government, School Officer Housing, and Religious Facilities**

| 1-10m$^3$/month | 11-20m$^3$/month | 21-30m$^3$/month | 31-40m$^3$/month | 41m$^3$- |
|---|---|---|---|---|
| Free | Rs. 2.00/m$^3$ | Rs. 5.00/m$^3$ | Rs. 7.50/m$^3$ | Rs. 19.00/m$^3$ |

1) Meter charge is added based on its diameter
13mm：Rs.5.00/month
20mm：Rs.10.00/month
25mm：Rs.25.00/month
2) 50 % discount will be applied to religious facilities
3) 20 % will be added for houses equipped with private pump.

**Category 2: Commercial**

| 0-30m$^3$/month | 31m$^3$/month- |
|---|---|
| Rs. 7.50/m$^3$ | Rs. 10.00/m$^3$ |

**Category 3: Temporary water supply for housing construction site**
**Rs. 12.50/m$^3$/month**

**Category 4: Factories approved by Investment Departement**
**Rs. 10.00/m$^3$/month**

**Category 5: Hotel**

| 0-30m$^3$/month | 31m$^3$/month- |
|---|---|
| Rs. 10.00/m$^3$ | Rs. 12.00/m$^3$ |

**Category 6: Government Institution**
**Rs. 12.50/m$^3$/month.**

**Category 7: Public Stand Pipe**
**Rs. 3.00/m$^3$/month**
**Note : Actually not invoiced and free**

**Category 8: New House Connection (Temporary tariff until meter installation)**
Domestic (13 mm)：Rs. 100.00
Commercial (13 mm)：Rs. 300.00
〃 (20mm)：Rs. 500.00

**Category 9:** **Public School**

| 0-10m$^3$/month | 11m$^3$/month- |
|---|---|
| Free | Rs.7.50/m$^3$ |

**Category :10** **Others**
**Rs. 15.00/m$^3$/month**

**Deposit for New Connection**
New customer should pay deposit as follows. Deposit will be returned when customer terminated his contract. In the case that the customer can not pay water tariff, this deposit will be used as substitution.

| | |
|---|---|
| Domestic： | Rs. 200.00 |
| Commercial： | Rs.1,000.00 |
| Temporary connection for construction work: | Rs. 5,000.00 |

**Demand Procedure of Unpaid Tariff**
After sending invoice, if customer did not make any payment after 14 days from designated date, demand letter will be issued to the customer. If customer did not make any payment during 15 days from receiving the demand letter, connection will be disconnected.

## Appendix 7-12 Results of Questionnaire Survey

1. Purpose of Survey

The purposes of this survey are as follows:

- To understand current condition of water supply and sanitation
- To understand problems related to water supply and sanitation
- To check willingness to pay for water supply service

2. Description and Procedure of Survey

The household survey was conducted form September 14 to 22,2000. The Survey team visited selected households in Nuwara Eliya with Questionnaire Forms designed by the team (refer to Attachment) and asked the family member questions according to the forms. Two kinds of forms were prepared prior to the survey, one was for the families that already connected to water supply service and another was for families that did not have water supply service. The team also conducted the water pressure measurement and Residual Chlorine test besides the questionnaire survey. The total number of samples (the total number of households visited by the team) was 140, which consisted of 70 households already connected to water supply service and 70 households not connected. Sample households were scattered into each supply block which was defined under the previous JICA Study conforming to the ratio of water demand in each supply block.

The number of samples in each water supply block was as follows.

Number of valid answers in each water supply block

| Name of water supply block | Connected | Not connected |
|---|---|---|
| Piyatisappura | 2 | 2 |
| High Area 1 | 11 | 10 |
| High Area 2 | 9 | 9 |
| Low Area 1 | 28 | 27 |
| Low Area 2 | 12 | 15 |
| Bonavista | 4 | 3 |
| Unique View + Vijithapura | 4 | 4 |
| **Total** | **70** | **70** |

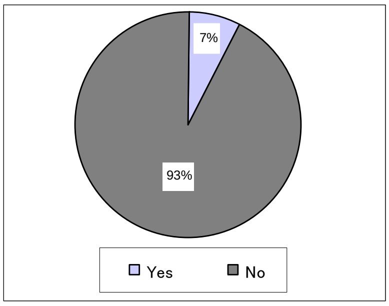
3. Results of Survey

The results of the survey are described below separately, the results of the households connected to water supply service and the results of the households not yet connected. Each part has four categories (Condition of Water/Water Supply, Sanitary Condition, Community, Family Status) and some considerations are given.

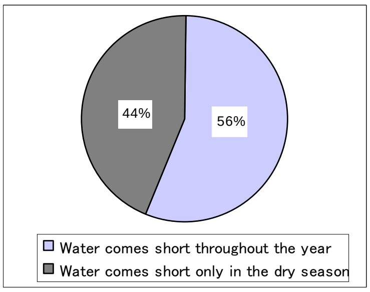
### *3.1 Results form families which already connected to water supply service*

#### *3.1.1 Condition of Water Supply*

1. Is water always available, everyday, 24 hours? （Valid answers 70）

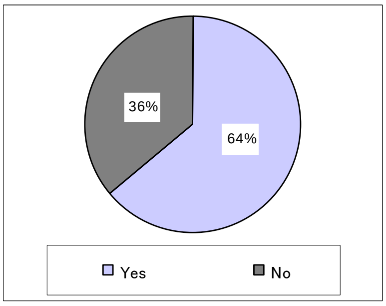



If “No”, when are you short of water?




Concerning the availability of water, more-than-90 % families don’t have continuous water supply. Some of these families are short of water only in the dry season, but more-than-50% families are short of water thorough the year.

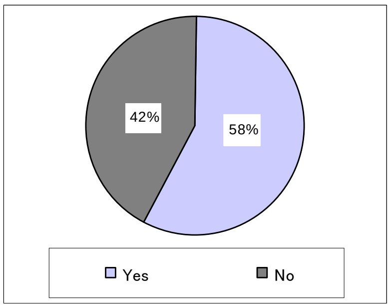
2. Is quantity and pressure enough? （Valid answers 70）




| If ″No″, （Multiple answers are permitted） | |
|---|---|
| Quantity is not enough | 18 |
| Pressure is not enough | 22 |

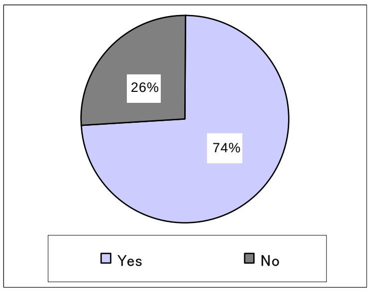
Concerning quantity and pressure of water, 64% families considers they are enough when water supply is available.

3. Do you have any problem concerning water quality? Any smell, turbidity, color? （Valid answers 69）




Concerning quality of water, 42% families don’t have problems, but the rest of the families have problems of smell, turbidity, or color. As for smell, there are many kinds of smell, even though the source of smell could not be identified, such as smell of iron and must. But in this water supply area, it smelled only chlorine odor. As for turbidity, nearly 50% of the families have problems.

4. Do you reserve water in your house? How do you reserve the water? May I see the tank? （Valid answers 70）




Capacity of water tank（m3）

| | |
|---|---|
| Maximum | 8 |
| Minimum | 0.1 |
| Average | 1.2 |

74% families have water storage tanks to reserve water in case of water shortage in the dry season. The sizes of the tanks range from 0.1m3 to 8m3 and the average is 1.2m3.

5. For which purpose do you use the water from public water supply service?
（multiple answers are permitted）　（Valid answers 69）

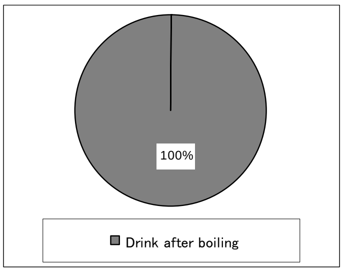
| | |
|---|---|
| Cooking | 66 |
| Washing | 58 |
| Bathing | 57 |
| Toilet | 65 |
| Drinking | 32 |
| Watering plants | 5 |
| others | 9 |

What kind of water do you use except for water from public water supply service?

| | |
|---|---|
| Well | 10 |
| Public tap | 12 |

The water is used mainly for cooking, washing, toilet, and drinking. Besides them, some families use water for gardening and washing car. 31% of families use water from well and public standpipe as alternative source.

6. When you drink water from public supply, do you drink water directly or after boiling or other treatment? （Valid answers 70）




All families have a custom to boil water from water supply service before they dink it. Some families filter the water before boiling.

7. How much water (m3) does your family use per month? （m3/month）
（Valid answers 68）

| | |
|---|---|
| Maximum | 150 |
| Minimum | 10 |
| Average | 30 |

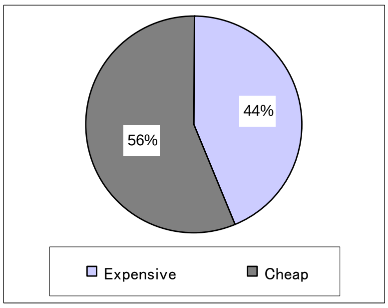
The quantity of water use per month ranges from 10m3 to 150m3 and the average is 30m3.

8. How much do you pay for public water supply per month? （Rs./月）
（Valid answers 69）

| | |
|---|---|
| Maximum | 600 |
| Minimum | 10 |
| Average | 110 |

The water charge per month ranges form Rs.10 to Rs.600 and the average is Rs.110.

9. Do you think the water charge is expensive? （Valid answers 66）



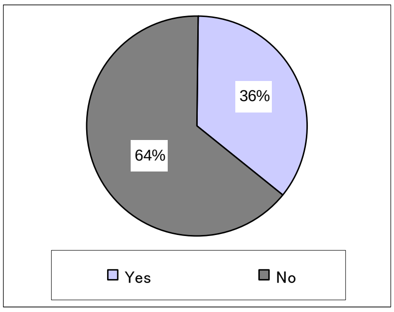

56% families consider the water charge cheap.

10. How much does your family earn per month? （Rs./month）（Valid answers 67）

| | |
|---|---|
| Maximum | 50,000 |
| Minimum | 250 |
| Average | 5,700 |

Household income per month ranges from Rs.250 to Rs.50,000 and the average is Rs.5,700.

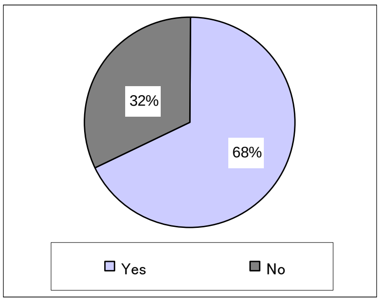
11. Are there any changes on your life style after connecting water supply service?
（Valid answers 70）



| If "Yes", (Multiple answers are permitted) | |
|---|---|
| The high frequency of bathing & washing | 11 |
| The life style became more convinient | 12 |

After connecting the water supply service, 36% families felt the change in their life style. Frequency of bathing and washing became higher and the life style became more convenient.

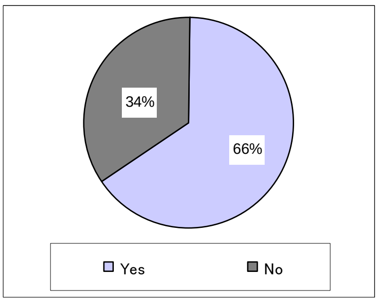
12. Do you have any complain with public water supply services? （Valid answers 69）




| If "Yes", (Multiple answers are permitted) | |
|---|---|
| The service in the dry season is not sufficient | 10 |
| The service throughout the year is not sufficient | 27 |
| Others | 5 |

68% families have some complains with public water supply services because of unstable water supply through the year and specially in dry season.

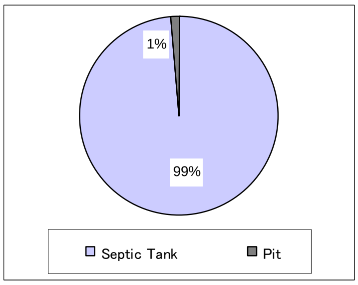
13. Do you have any request for improvement of water supply services?
（Valid answers 70）



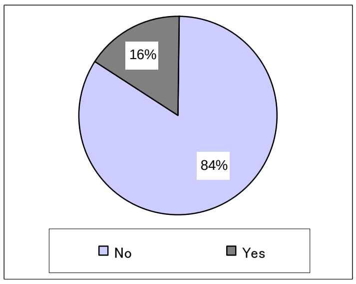

66% families want the improvement of the water supply service and most of the families need the continuous water supply. A few families request the price reduction of the water charge.

***3.1.2 Sanitary Condition***

14. What kind of toilet do you use? Do you have any problem on your toilet?
（Valid answers 70）
Types of the toilet



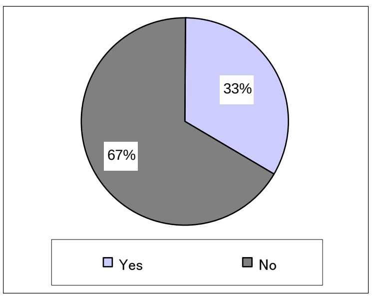

Do you have any problem on your toilet?




| If "Yes", (Multiple answers are permitted) | |
|---|---|
| Smell | 3 |
| The overflow of the sludge | 7 |

Most of the families have Septic Tanks and only 1 family in 70 families has a Pit type toilet that is made by digging the ground. Concerning the problems on toilets, 84% families have no problem, but the rest of the families, 16% families have some problems. They said it smells bad and the toilets are unhygienic because of the overflow of sludge.

15. Do you withdraw sludge from the toilet? （Valid answers 69）



Concerning withdrawal of the sludge from the toilet, 67% families have never withdrawn the sludge.

16. How often do you withdraw the sludge from the toilet? （times/year）（Valid answers 22）

| | |
|---|---|
| Maximum | 5 |
| Minimum | 0.1 |
| Average | 1.1 |

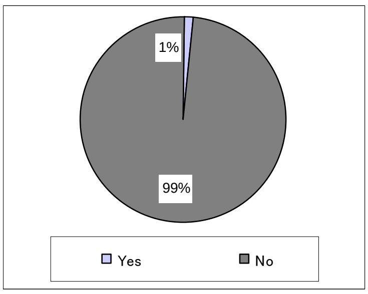
The frequency of withdrawing the sludge ranges from 5 times a year to 1 time a decade. The average is 1 time a year.

17. Who usually does this work? How much do you pay for the withdrawing? (Rs./time)

| | |
|---|---|
| By Municipal Council (Rs./time) <Valid answers 15> | |
| Maximum | 1,700 |
| Minimum | 450 |
| Average | 1,070 |
| | |
| By the private sector (Rs./time) <Valid answers 8> | |
| Maximum | 2,000 |
| Minimum | 500 |
| Average | 1,080 |

Both Municipal Council and the private sector are doing the withdrawal of the sludge. It seems that the system for the withdrawal of the sludge is not established. The average of the charge for the withdrawal by Municipal Council is Rs. 1,070 per time. Maximum is Rs. 1,700 and Minimum is Rs. 450. The reason why maximum and minimum charge is different is that the charge is changeable depend on times to go up and down from each house to landfill. The charge for the withdrawal by private sector ranges from Rs. 2,000 per time to Rs. 500 per time. The average is 1,080 per time.

18. Have you ever tried to reuse the sludge as fertilizer? （Valid answers 69）



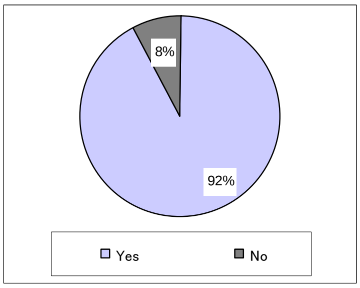

Concerning reuse the sludge as fertilizer, 99 % families don't make use of sludge as fertilizer. In recent years, the spread of agricultural chemicals disable to reuse the sludge as fertilizer.

19. When you get sick, how much does your family spend for medical inspection and medicines per month in average? （Rs./month）（Valid answers 65）

| | |
|---|---|
| Maximum | 3,000 |
| Minimum | 60 |
| Average | 642 |

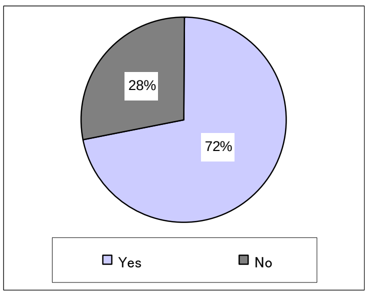
Medical inspection range from Rs. 60 to Rs. 3,000 and the average is Rs. 642.

20. Do your children have hygienic education? （Valid answers 65）




92% children have hygienic education including the customs like washing hands before meals and/or after using the toilet. Most of the children get hygienic education at school.

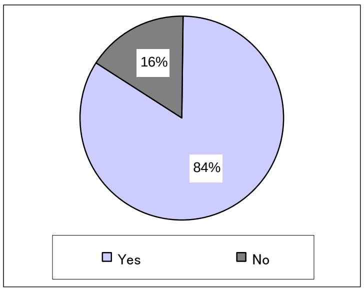
21. Is frequency of diarrhea decreased after having water supply service?
（Valid answers 68）




The frequency of diarrhea decreased after having water supply service in 72% families. It seems that water supply service made the acquisition of water easier and the frequency of washing hands increased and besides, the germ in water was reduced by water supply.

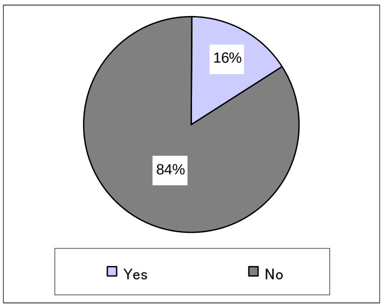
### *3.1.3 社会経済・住民参加について Community*

22. What kind of role do women and children play concerning water?
(Valid answers 70)



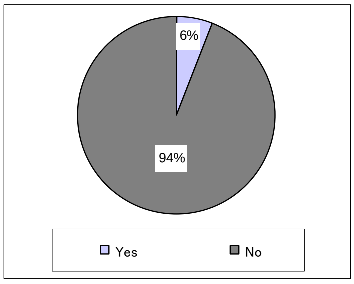

84% women have their role that they reserve water from their tap in a tank and carry water from the well when water comes short. 5% children are doing the same job as women.

23. Are there any comunity organizations concerning water (including water supply service)? (Valid answers 70)




16% families said that community organizations concerning water existed, but the names of the organizations were not confirmed.

24. Are there any private traders selling water?
Have you ever bought water from them? (Valid answers70)
Are there any private traders selling water?




Have you ever bought water from them?

| | |
|---|---|
| Yes | 0 |
| No | 3 |

94% families answered private traders selling water are not exist.

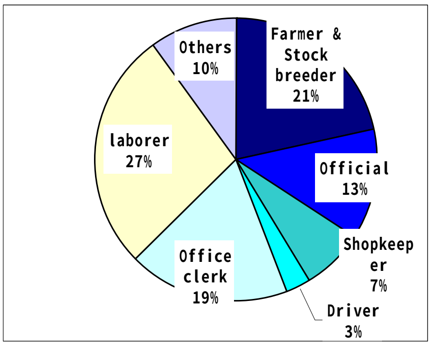
### *3.1.4 Family Status*

25. How many members are there in your family? (Valid answers 70)

| | |
|---|---|
| Maximum | 20 |
| Minimum | 1 |
| Average | 5.8 |

The number of household ranges from 1 to 20 persons and the average is 5.8 persons.

26. What are the occupations of the members earning money? (Valid answers 68)

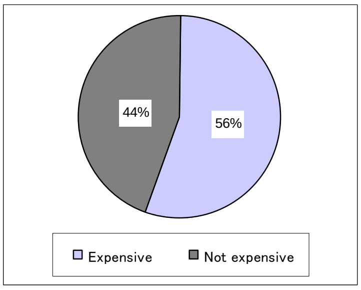



27. How much do you pay for public electronic supply per month? (Rs./month) Do you think it is expensive? (Valid answers 68)

How much do you pay for public electronic supply per month? (Rs./month)

| | |
|---|---|
| Maximum | 1,200 |
| Minimum | 15 |
| Average | 325 |

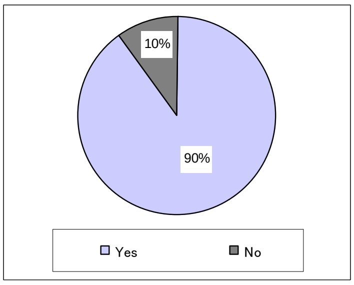
Do you think it is expensive?



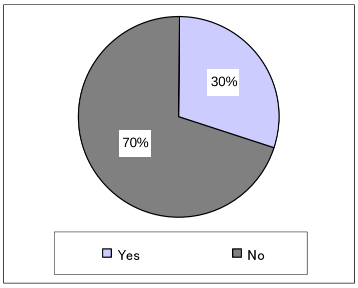

The charge for electricity per month is Rs. 325 in average and this is little expensive compared with Rs. 110 for water charge. 56% families consider the charge for electricity expensive.

28. Do you have a television, a telephone, a motorbike or a car? （Valid answers70）

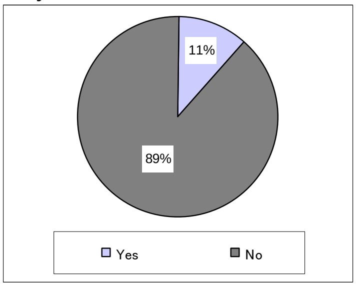
Do you have a television?



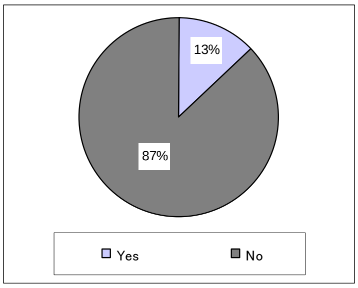

Do you have a telephone?




Do you have a motorbike?




Do you have a car?




To know the living standard, the survey team investigated on the position of televisions, telephones, motorbikes, and cars. 90% families have televisions and only 30% families have telephones. As for motorbike, 11% and cars, 13%. It seems that the position of motorbikes and cars is difficult for average families.

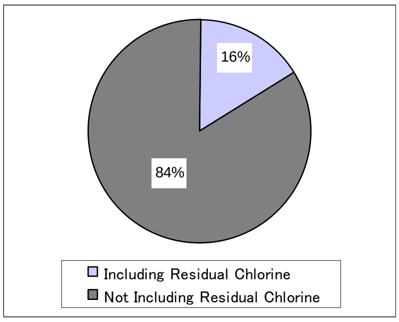
### *3.1.5 Water Pressure and Residual Chlorine*

29. The water pressure （MPa） （Valid answers 46）

| | |
|---|---|
| Maximum | 0.6 |
| Minimum | 0.01 |
| Average | 0.2 |

The survey team conducted the water pressure measurement with pressure gage for water. Valid answers (46 of 70) are few but it could not be measured because water supply cut off when the survey team visited each family. The water pressures range from 0.01 MPa to 0.6 MPa and the average is 0.2 MPa.

30. Residual Chlorine（Valid answers 69）




The Residual Chlorine Test was conducted with the reagent prepared by the survey team. The Residual Chlorine was not found at most of the houses and it means that they are using unhygienic water.

### *3.2 Families not connected to water supply service*

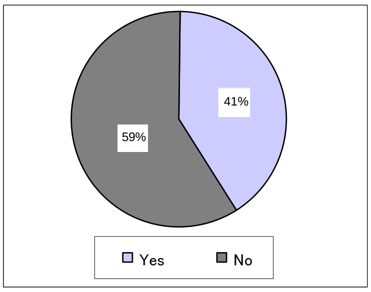
#### *3.2.1 Condition of Water*

1. Where do you get water to use in your house? （Multiple answers are permitted） （Valid answer 70）

| | |
|---|---|
| Falls | 3 |
| Rivers | 11 |
| Springs | 6 |
| Wells | 22 |
| Public taps | 17 |
| Neighbor's house | 25 |

Families that did not have water supply service acquire water from the water sources near their houses. A large number of families answered that they acquired water from neighbors' houses. Some families are using not only one water source but also for example, they are using both wells and Public Taps when they need.

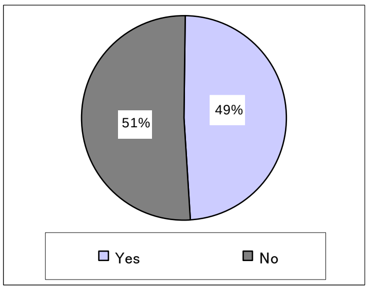
2. Is quantity enough? （Valid answers 67）




| If "No", (Multiple answers are permitted) | |
|---|---|
| It's not enough in the dry season | 13 |
| It's not enough throughout the year | 2 |

Concerning the availability of water, 59% families think that quantity of water is not enough. Specially some of these families are short of water only in the dry season.

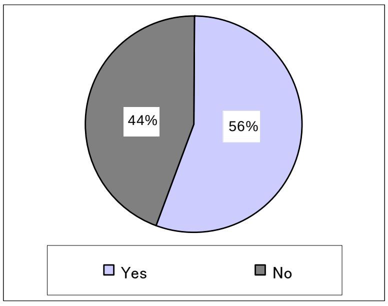
3. Do you have any problem concerning water quality? Any smell, turbidity, color? （Valid answer 67）




| If "Yes", (Multiple answers are permitted) | |
|---|---|
| a problem of smell | 11 |
| a problem of turbidity | 29 |
| a problem of color | 10 |

Concerning quality of water, almost half families don't have problems. Other half families have a problem of smell, turbidity, or color. Among these problems, the most families answered that they had a problem of turbidity.

4. Do you reserve water in your house? How do you reserve the water? May I see the tank? （Valid answers 70）




Capacity of the tank （m3）

| | |
|---|---|
| Maximum | 6 |
| Minimum | 0.05 |
| Average | 0.6 |

56% families have water storage tanks to reserve water in case of water shortage in the dry season. The sizes of the tanks range from 0.05m3 to 6m3 and the average is 0.6m3.

5. How long does it take to carry water to your house? Who is carrying mainly and how many times a day is he/she carrying? （Valid answers 58）

The time required to carry water (minutes)

| | |
|---|---|
| Maximum | 150 |
| Minimum | 0 |
| Average | 20 |

The person who carries water mainly

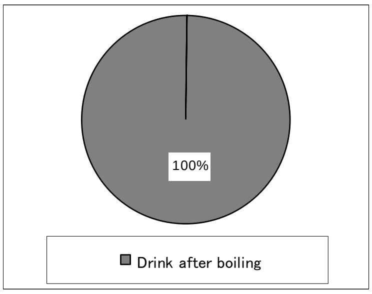
| | |
|---|---|
| Mother | 50 |
| Father | 6 |

How many times a day? (times/day)

| | |
|---|---|
| Maximum | 15 |
| Minimum | 1 |
| Average | 5 |

It takes 20 minutes to bring water from the water source to each house on average. But it takes for some families 150 minutes to go and bring water, that is to say it takes more than 1 hour to reach the water source. Mothers do this work mainly. Concerning the frequency of carrying water, it ranges from 1 time a day to 15 times a day and the average is 5 times a day. From this result, the actual condition is that it takes much time to acquire water.

6. When you drink water from your source, do you drink water directly or after boiling or other treatment? （Valid answers 70）



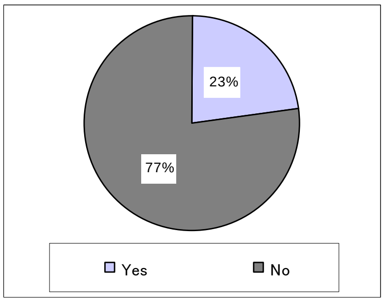

All families have a custom to boil water before they dink it. Some families filter the water before boiling.

7. How much water (m3) does your family use per month? （m3/month） （Valid answers 66）

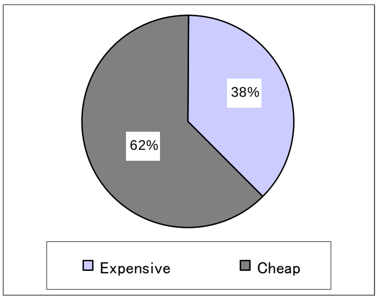
| | |
|---|---|
| Maximum | 50 |
| Minimum | 3 |
| Average | 21 |

The quantity of water use per month ranges from 3m3 to 50m3 and the average is 21m3.

8. Do you pay for water? （Valid answers 70）




If "Yes", do you think it is expensive?




Only 23% families pay for water and among them, 62% families consider its charge cheap.

9. How much does your family earn per month? (Rs./month) （Valid answers 70）

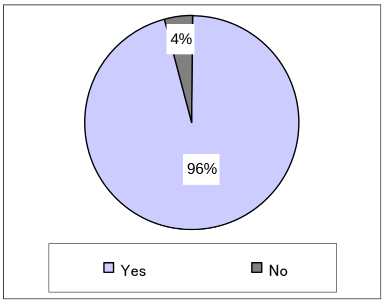
| | |
|---|---|
| Maximum | 25,000 |
| Minimum | 750 |
| Average | 4,400 |

Household income per month ranges from Rs. 750 to Rs. 25,000 and the average is Rs. 4,400.

10. If a water pipe runs near your house, do you want to have water supply service? How much can

| | |
|---|---|
| Maximum | 10,000 |
| Minimum | 100 |
| Average | 2,020 |

you pay for the new connection? If you don't want to, why is it? (Valid answers 70)




How much can you pay for the new connection? (Rs.)

If you don't want to have the service, why is it?

| | |
|---|---|
| Because the income is low | 2 |

96% families wants to have water supply service if water pipes run near their houses. Willingness to pay per connection ranges from Rs. 100/connection to Rs. 10,000/connection and the average is Rs. 2,020/connection. Families that don't want to have water supply service answer that they cannot have because of low income.

11. If you have water supply service, how much can you pay for water tariff per month?
(Rs./month) (Valid answers 62)

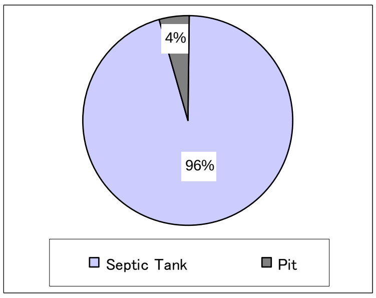
| | |
|---|---|
| Maximum | 500 |
| Minimum | 20 |
| Average | 90 |

After connecting water supply service, willingness to pay of water tariff per month ranges from Rs. 20/month to Rs. 500/month and the average is Rs. 90/month.

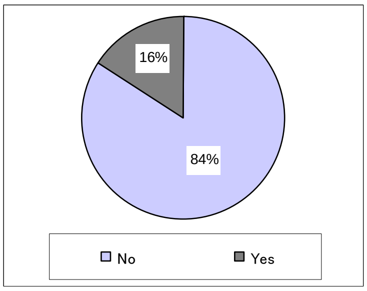
### *3.2.2 Sanitary Condition*

12. What kind of toilet do you use? Do you have any problem on your toilet?
(Valid answers 69)

types of the toilet



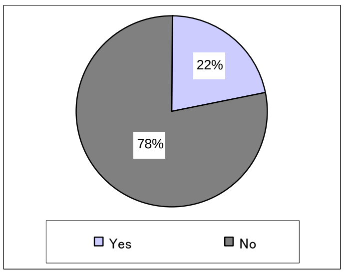

Do you have any problem on your toilet?




| If "Yes", (Multiple answers are permitted) | |
|---|---|
| Smell | 3 |
| The overflow of the sludge | 3 |
| A shortage of tanks | 1 |

Most of the families have Septic Tanks and a part of families have a pit type toilet that is made by digging the ground. Concerning the problems on toilets, 84% families have no problem, but the rest of the families, that is to say 16% families have some problems. They say it smells bad, the toilets are unhygienic because of the overflow of sludge. Besides, some families are sharing a Septic Tank.

13. Do you withdraw sludge from the toilet? (Valid answers 69)



Concerning withdrawal of the sludge from the toilet, 78% families have never withdrawn the sludge.

14. How often do you withdraw sludge from the toilet? (times/year) (Valid answers 15)

| | |
|---|---|
| Maximum | 12 |
| Minimum | 0.08 |
| Average | 2 |

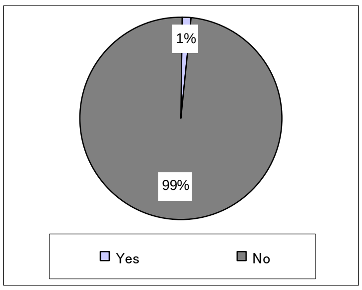
The frequency of withdrawing the sludge ranges from 12 times a year to 1 time in 12 years. The average is 2 times a year.

15. Who usually do this work? How much do you pay for the withdrawing? (Rs./time)

| By Municipal Council (Rs./time) <Valid answers 4> | |
|---|---|
| Maximum | 1,000 |
| Minimum | 0 |
| Average | 330 |
| | |
| By the private sector (Rs./time) <Valid answers 9> | |
| Maximum | 2,000 |
| Minimum | 500 |
| Average | 1,000 |

Both Municipal Council and the private sector are doing the withdrawal of the sludge. It seems that the system for the withdrawal of the sludge is not established. The charge for the withdrawal by Municipal Council ranges from Rs. 330 to Rs. 1,000 per time. The reason why maximum and minimum charge is different is that the charge is changeable depend on times to go up and down from each house to landfill. The charge for the withdrawal by private sector ranges from Rs. 2,000 per time to Rs. 500 per time. The average is 1,000 per time.

16. Have you ever tried to reuse the sludge as fertilizer? (Valid answers 68)



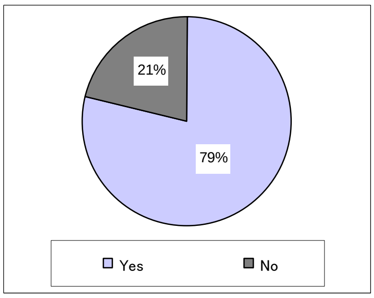

Concerning reuse the sludge as fertilizer, 99 % families don't make use of sludge as fertilizer. In recent years, the spread of agricultural chemicals disable to reuse the sludge as fertilizer.

17. When you get sick, how much does your family spend for medical inspection and medicines per month in average? (Rs./month) (Valid answers 57)

| | |
|---|---|
| Maximum | 2,000 |
| Minimum | 0 |
| Average | 670 |

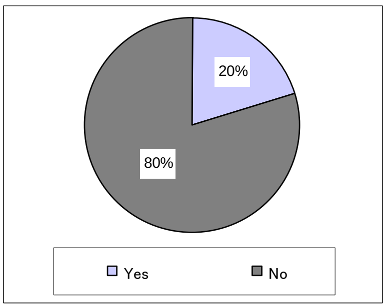
Doctor inspection range from Rs. 0 to Rs. 2,000 and the average is Rs. 670.

18. Do your children have hygienic education? (Valid answers 66)




79% children have hygienic education including the customs like washing hands before meals and/or after using the toilet. Most of the children get hygienic education at school.

19. Do you often have diarrhea? (Valid answers 70)

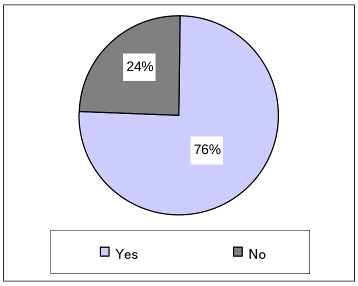


| What do you do to prevent being affected by diarrhea? | |
|---|---|
| Boiling | 11 |
| Washing hands | 3 |

20% families often have diarrhea. Some families answered that they boiled water or washed hands before meals and/or after using the toilet to prevent from being affected by diarrhea.

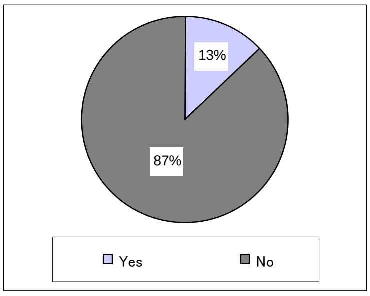
### *3.2.3 Community*

20. What kind of role do women and children play concerning water? （Valid answers 70）



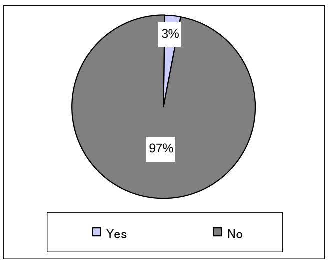

76% women have their routine work concerned with water like carrying water from its source to their houses. 13% children are doing the same job as women.

21. Are there any community organizations concerning water (including water supply service)? （Valid answers 70）




13% families said that residents' organizations concerning water existed, but the names of the organizations were not confirmed.

22. Are there any private traders selling water? （Valid answers 70）




Have you ever bought water from them?

| | |
|---|---|
| Yes | 0 |
| No | 6 |

97% families answered private traders selling water are not exist.

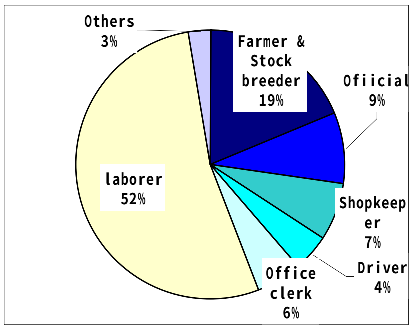
### *3.2.4 Family Status*

23. How many members are there in your family? （Valid answers 70）

| | |
|---|---|
| Maximum | 18 |
| Minimum | 2 |
| Average | 5.1 |

The number of household ranges from 2 persons to 18 persons and the average is 5.1 persons.

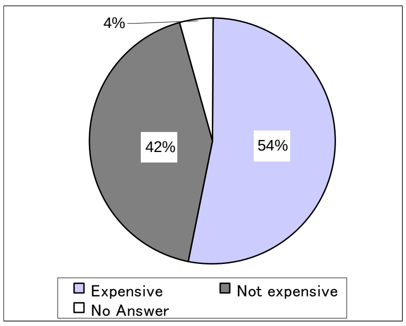
24. What are the occupations of the members earning money? （Valid answers 70）




25. How much do you pay for public electronic supply per month? （Rs./month）（Valid answers 45）

| | |
|---|---|
| Maximum | 1,000 |
| Minimum | 30 |
| Average | 180 |

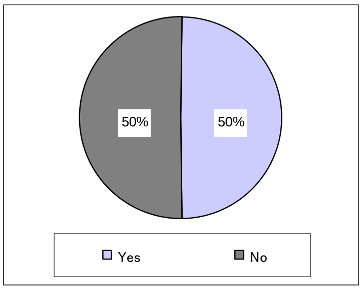
Do you think it is expensive?



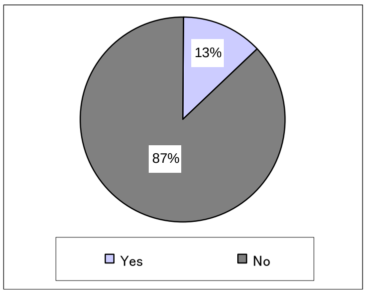
The charge for electricity per month ranges from Rs. 30 to Rs. 1,000 and the average is Rs. 180. As you can see from the number of valid answers, as much as 35% families don't have electricity supply service.

26. Do you have a television, a telephone, a motorbike or a car? (Valid answers 70)

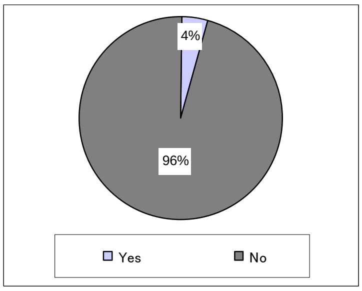
Do you have a television?



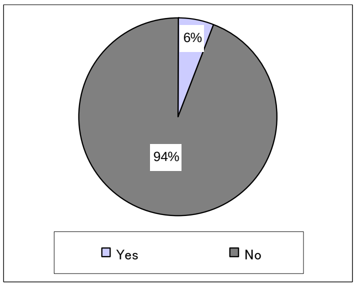

Do you have a telephone?




Do you have a motorbike?




Do you have a car?




To know the living standard, the survey team investigated on the position of televisions, telephones, motorbikes, and cars. 50% families have televisions and only 13% families have telephones. As for motorbike, 4% and cars, 6%. It seems that the position of motorbikes and cars is difficult for average families.

4. Analysis of Relation between Questionnaire Items

In this section, results of analysis the related matters between questions are described.

*4.1 Families that already connected to water supply service*

1. Per Capita Water Consumption

Per Capita Consumption (lpcd)=Consumption (m3/month) / family size (person/household)
=148 (lpcd)

Per capita Consumption was calculated as show above. The average value was calculated by excluding 25% from maximum values and 10% from minimum values to exclude error.

2. The ratio of the charge to household income

| | Rs. /month | (%) |
|---|---|---|
| Water Tariff | 110 | 2 |
| Electricity Charge | 325 | 6 |
| Medical Expense | 642 | 11 |
| Average Income | 5,700 | |

*4.2 Families that do not have water supply service*

1. Per Capita Water Consumption

Per Capita Consumption (lpcd)=Consumption (m3/month) / family size (person/household)
=113 (lpcd)

Per capita Consumption by using above equation was calculated each question. The average value was calculated by excluding 20% from maximum values to exclude error.

2. The ratio of the charge to household income

| | Rs. /month | (%) |
|---|---|---|
| Electricity Charge | 180 | 3 |
| Medical Expense | 670 | 12 |
| Average Income | 4,400 | |

5. Conclusion

1）Condition of water supply
Water shortage in the dry season is serious in Nuwara Eliya. 93% families, that already connected to water supply service and 59% families that did not have water supply service are suffering to get water in dry season. Concerning quality of water, 58%, that already connected to water supply service and 49% families that did not have water supply service have problems of smell, turbidity, or color.

2）Comparisons of families connected and families not yet connected to water supply
Comparison between families that already connected to water supply service and families which do not have water supply service

Concerning major questions, connected families and not connected families are compared. The result is shown on the following table.

| Questions | | Connected | Not connected |
|---|---|---|---|
| Do you have any problems concerning water quality?(%) | Yes | 58 | 49 |
| | No | 42 | 51 |
| What kind of problems? (Number of the answers) | Smell | 6 | 11 |
| | Turbidity | 33 | 29 |
| | Color | 14 | 10 |
| The treatment of the drinking water(%) | Boiling | 100 | 100 |
| Per Capita Consumption (lpcd) | Average | 148 | 113 |
| Household income (Rs./month) | Maximum | 50,000 | 25,000 |
| | Minimum | 250 | 750 |
| | Average | 5,700 | 4,400 |
| The charge for electricity (Rs./month) | Maximum | 1,200 | 1,000 |
| | Minimum | 15 | 30 |
| | Average | 325 | 180 |

Concerning quality of water, 58% of connected families and 49% of not connected families have some problems. As shown on table above, the percentage of connected families is slightly higher than that of not connected families. As for smell, the percentage of not connected families is higher than that of not connected families. Concerning turbidity and color, the percentages of connected families are higher than that of not connected families.

100% of connected and not connected families don't drink water/water from water supply service directly but drink it after boiling.

Per Capita Consumption of connected families is 148 lpcd and that of not connected families is 113 lpcd. It seems that frequency of bathing or washing of not connected families become higher by having water supply service. As a result, per capita consumption is higher about 35 lpcd.

Concerning household income per month, the average of connected families is Rs. 5,700 and that of not connected families is Rs. 4,400. Connected families earn Rs. 1,300 more than not connected families.

Connected families pay Rs. 325 for electricity per month on average and not connected families pay Rs. 180 for electricity per month on average. This means that connected families pay Rs. 145 more than not connected families. It seems that not connected families have tendency to hold down expenses of electricity because their household income is low.

3) Willingness to Pay of families not yet connected to water supply services

(1) Connection Fee

Willingness to pay for new connection of not connected families is Rs. 2,020 on average. But the present charge for a new connection that Nuwara Eliya City set up is Rs. 4,000 and this is almost two times as much as the charge they can pay. To solve the problem, the reduction of the charge or the installment plan for the charge for a new connection should be discussed.

(2) Monthly water tariff

Willingness to pay of monthly tariff of not connected families is Rs. 90 per month on average. This is almost as much as the average water charge of connected families, Rs. 110. Concerning the percentage of water charge to household income, the ratio of water charge Rs. 110 to household income Rs. 4,400 of connected families is 2.5%. The ratio of water charge Rs. 110 to household income Rs. 5,700 of connected families is 1.9%. The ratio of water charge to household income is almost same ratio both connected families and not connected families. Therefore, it considers that not connected families can pay monthly water tariff.

4）Sanitary condition

Only 33% of connected families and 22% of not connected families withdraw the sludge from the toilet. The system of should be established. As for the percentage of expenditure for medical inspection to household income, it is 11% about connected families and 12% about not connected families.

**Questions**
**for**
**Families, which already connected to water supply service**

**Date : September ___, 2000**
**Name of Surveyor ________________________**
**Supply Block**

- ☐ **Piyatisappura**
- ☐ **High Area 1**
- ☐ **High Area 2**
- ☐ **Low Area 1**
- ☐ **Low Area 2**
- ☐ **Bonavista**
- ☐ **Uniqu View + Vijithapura**

**Family Name _________________________________**
**Address ________________________________________________________**

**① Condition of Water Supply**

a. Is water always available, everyday, 24 hours?

Yes No ____________________________________________________________

b. Is quantity and pressure enough?

Yes No (Quantity not enough, Pressure not enough)

c. Do you have any problem concerning water quality? Any smell, turbidity, color?

No Yes (Smell, Turbidity, Color)

d. Do you reserve water in your house? How do you reserve the water? May I see the tank?

Yes No
if "Yes" check capacity of the tank _____________$m^3$

e. For which purpose do you use the water from public water supply service? For other purpose, what kind of water do you use?

Purpose(for public supply)
Cooking, Washing, Bathing, Toilet, Others ____________________
Other water source ________________________________________________

f. When you drink water from public supply, do you drink water directly or after boiling or other treatment?

Yes, drink directly
No, drink after boiling
Other treatment ___________________________________________________

g. How much water ($m^3$) does your family use per month?

________________$m^3$ per month

h. How much do you pay for public water supply per month? Do you think it is expensive?

________________Rs. per month
Expensive Not expensive

i. How much does your family earn per month?

________________Rs. per month

j. Are there any change on your life style after connecting water supply service?

Yes No
If "Yes", how has it changed? ______________________________________
_______________________________________________________________

k. Do you have any complain with public water supply service?

Yes No
If "Yes", what kind of complain? _____________________________________
_______________________________________________________________

l. Do you have any request for improvement of water supply services?

Yes No
If "Yes", what kind of request? _______________________________________
_______________________________________________________________

② **Sanitary Condition**

a. What kind of toilet do you use? Do you have any problem on your toilet? May I see it?

The type of toilet _________________________________________________
No problem, Yes I have problem _____________________________________
Possible to see Not possible to see

b. How often do you withdraw sludge from the toilet? Who usually do this work? How much do you pay for the withdrawing?

______________ times per ______________
The person/the organization/the company doing that work is ________________
I pay Rs. ________________ per time

c. Have you ever tried to reuse the sludge as fertilizer?

Yes No

d. When you get sick, how much does your family spend for doctor inspection and medicines per month in average?

________________ Rs. per month per family in average

e. Do your children have hygienic education?

Yes No

f. Is frequency of diarrhea decreased after having water supply service?

Yes No

③ **Community**

a. What kind of role do women and children play concerning water?

The role of women ____________________________________________________
The role of children ___________________________________________________

b. Are there any residents' organizations concerning water (including water supply service)? If there are, what kind of activities are they doing?

Yes, there are No, there aren't.
If "Yes",
Organizations ___________________________________________________________
Activities _______________________________________________________________

c. Are there any private traders selling water? Have you ever bought water from them?

Yes, there are. No, there aren't.
If "Yes", / You have bought. You have not bought.

④ **Family Status**

a. Please tell us about your family members.
_____ persons,
father, mother, ___children, and other _____________________________________

b. What are the occupations of the members earning money?
_____________________________________________________________________________
_______________________________________________________

c. How much do you pay for public electronic supply per month? Do you think it is expensive?
________________ Rs. per month
Expensive Not expensive

d. Do you have a television, telephone?

| Television | | Telephone | |
|---|---|---|---|
| Yes | No | Yes | No |

e. Do you have a motorbike or a car?

I don't have both of them.
I have a motorbike/motorbikes.
I have a car/cars.
I have both of them.

Residual pressure at tap _______________ Mpa.
Residual chlorine Yes No

**Questions**
**for**
**families, which do not have water supply service**

**Date : September ___, 2000**
**Name of Surveyor ________________________**
**Supply Block**

- ☐ **Piyatisappura**
- ☐ **High Area 1**
- ☐ **High Area 2**
- ☐ **Low Area 1**
- ☐ **Low Area 2**
- ☐ **Bonavista**
- ☐ **Uniqu View + Vijithapura**

**Family Name __________________________________**
**Address ________________________________________________________**

① **Condition of Water**

a. Where do you get water to use in your house?

_________________________________________________________________

b. Is quantity enough?

Yes No

c. Do you have any problem concerning water quality? Any smell, turbidity, color?

No Yes (Smell, Turbidity, Color)

d. Do you reserve water in your house? How do you reserve the water? May I see the tank?

Yes No
if "Yes" check capacity of the tank _____________$m^3$

e. How long does it take to carry water to your house? Who is carrying mainly and how many times a day is he/she carrying?

It takes _____ hours _____ minutes.
_________ is carrying mainly _________ times a day.

f. When you drink water from your source, do you drink water directly or after boiling or other treatment?

Yes, drink directly
No, drink after boiling
Other treatment ___________________________________________________

g. How much water ($m^3$) does your family use per month?

________________$m^3$ per month

h. Do you pay for water? If you do, do you think it is expensive?

Yes No
If "Yes", / Expensive Not expensive

i. How much does your family earn per month?

________________Rs. per month

j. If a water pipe runs near your house, do you want to have water supply service? How much can you pay for the new connection? If you don't want to, why is it?

Yes No
I can pay Rs._________ for new connection.
If "No", why is it? ____________________________________________

k. If you have water supply service, how much can you pay for it per month?

_______________ Rs. per month

② **Sanitary Condition**

a. What kind of toilet do you use? Do you have any problem on your toilet? May I see it?

The type of toilet _________________________________________________
No problem, Yes I have problem _____________________________________
Possible to see Not possible to see

b. How often do you withdraw sludge from the toilet? Who usually do this work? How much do you pay for the withdrawing?

______________ times per ______________
The person/the organization/the company doing that work is ________________
I pay Rs. ________________ per time

c. Have you ever tried to reuse the sludge as fertilizer?

Yes No

d. When you get sick, how much does your family spend for doctor inspection and medicines per month in average?

________________ Rs. per month per family in average

e. Do your children have hygienic education?

Yes No

f. Do you often have diarrhea? What do you do to prevent being affected by diarrhea?

Yes No
Preventive measures ________________________________________________

③ **Community**

a. What kind of role do women and children play concerning water?

The role of women ______________________________________________
The role of children _____________________________________________

b. Are there any residents' organizations concerning water (including water supply service)? If there are, what kind of activities are they doing?

Yes, there are No, there aren't.
If "Yes",
Organizations _______________________________________________
Activities __________________________________________________

c. Are there any private traders selling water? Have you ever bought water from them?

Yes, there are. No, there aren't.
If "Yes", / You have bought. You have not bought.

④ **Family Status**

a. Please tell us about your family members.

_____ persons,
father, mother, ___children, and other ____________________________

b. What are the occupations of the members earning money?

_____________________________________________________________________________
____________________________________________________

c. How much do you pay for public electronic supply per month? Do you think it is expensive?

________________Rs. per month
Expensive Not Expensive

f. Do you have a television, telephone?

Television Yes No
Telephone Yes No

d. Do you have a motorbike or a car?

I don't have both of them.
I have a motorbike/motorbikes.
I have a car/cars.
I have both of them.

Residual pressure at tap _______________ Mpa.
Residual chlorine Yes No

## Appendix 7-13 Study on the Groundwater Development

1. Natural Conditions
   - 1.1 Geography and Topography
   - 1.2 River Basins
   - 1.3 Geology
   - 1.4 Meteorology

2. Groundwater Recharge
   - 2.1 Tank Model
   - 2.2 Groundwater Recharge
   - 2.3 Groundwater Potential in Proposed Area

3. Existing State of Groundwater Use

4. Review of the previous JICA Study

5. Geophysical Survey
   - 5.1 Vertical Electric Sounding
   - 5.2 Electromagnetic Sounding
   - 5.3 Preliminary Selection of Proposed Sites for Well Construction

6. Test Boring
   - 6.1 Location of Boring Sites
   - 6.2 Method of Test Boring
     - 6.2.1 Boring Machine
     - 6.2.2 Method of the Study
   - 6.3 Result of the Study
     - 6.3.1 Boreholes
     - 6.3.2 Geological Structure and Geophysical Logging
     - 6.3.3 Pumping Test
     - 6.3.4 Water Quality

7. Groundwater Development Plan
   - 7.1 Groundwater Basin
   - 7.2 Proposed Location of Wells and Yield
   - 7.3 Proposed Number of Wells and Depth

# 1. Natural Conditions

## 1.1 Geography and Topography

The study area is far about 180 km to the east from Colombo, and is located on the foot of the highest peak named Mt. Pidurtalagala (2,524m) in the central mountain range. The area covers a small basin ranging about 7 km from west to east and 6 km from north to south, which is surrounded by high mountain ridges forming a horseshoe-shaped topography in the north and the west of the area. An average altitude of the area is about 1900 m. **Fig-1.1.1** shows topography of the study area and its surroundings.

Mountainsides are mainly covered by forest of pine trees and eucalyptuses. Gentle slopes are utilized for tee plantation and cultivation. Town areas and residential areas are situated at flat lands and on the gentle slopes in the basin.

## 1.2 River Basins

The study area consists of two drainage basins called as Nanu Oya river basin and Boburella river basin, which is also referred to as Barrack Plain Reservoir basin in some reports. The Nanu Oya river basin occupies approximately two third of the total area of Nuwara Eliya Basin. Both rivers rise from the mountain Pidurtalagala.

River Nanu Oya flows in the direction of southeast while collecting flows of tributary streams, passing Golf Course, town area, Race Course, and Gregory Lake. It changes the direction of flow to the west at the southern border of the basin to discharge out of the basin. Gregory Lake is an artificial reservoir with a constant water level at 1,868m in altitude through a year controlled by a barrage.

River Boburella flows in the direction of east through Hawa Eliya and Barrack Plain Reservoir. Barrack Plain Reservoir is not used for a long period by heavy sand accumulation in the reservoir.
**Table-1.2.1** shows the size of the two river basins and subdivided areas.

A small hill (Upper Lake Hill) situated at almost the center of the Nuwara Eliya basin is the main water divide, which divides the whole basin into two sub-basins, i.e. Boburella river basin in the northeastern side and Nanu Oya river basin in the southwestern side. For convenience, the Nanu Oya river basin is sub-divided into two areas. One is the upstream zone of river Nanu Oya and the other is the downstream zone of river Nanu Oya, i.e. the area of Gregory Lake and its vicinity. The former is referred to Nanu Oya Upstream area and the latter Gregory Lake area in this report.

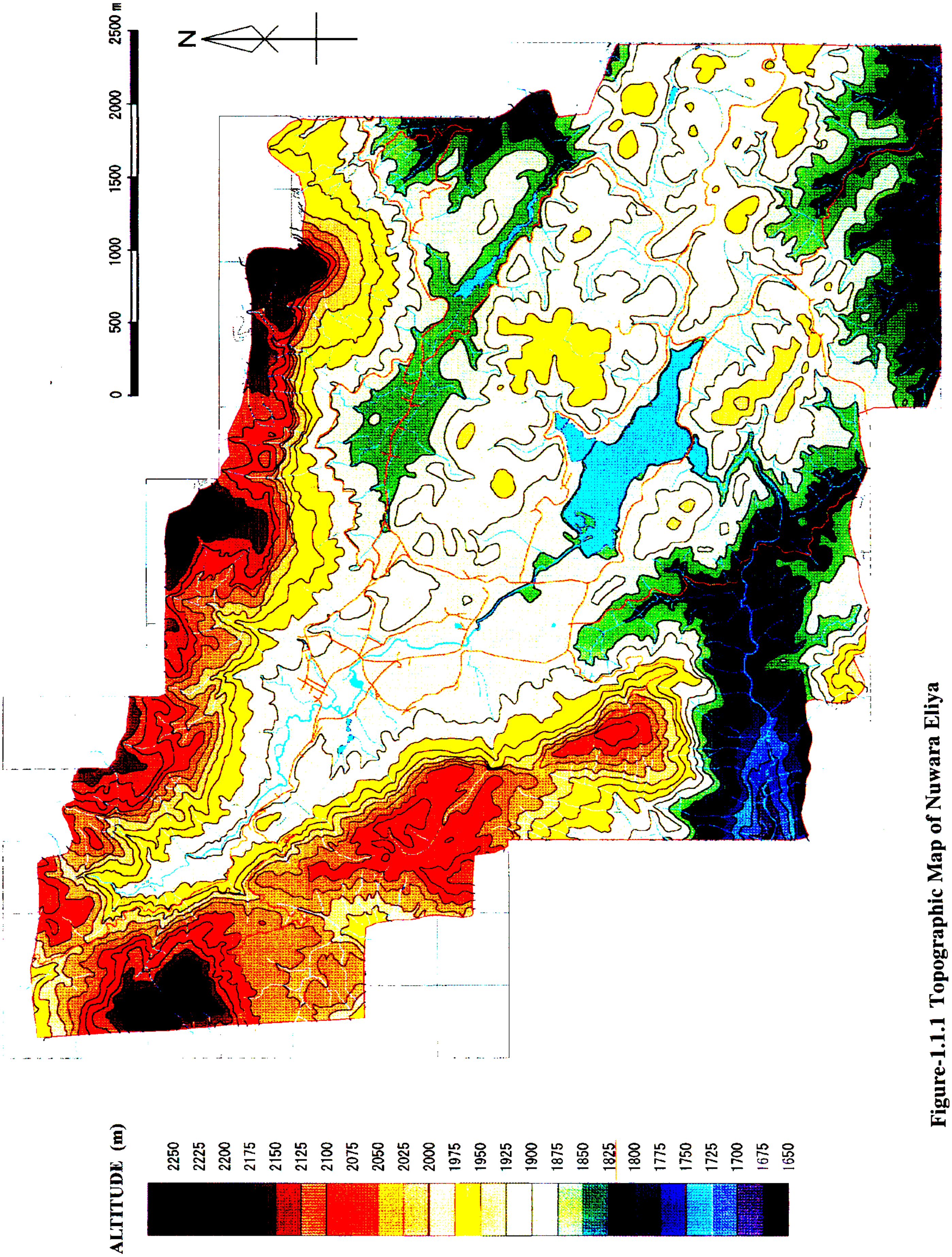



**Figure-1.1.1 Topographic Map of Nuwara Eliya**

The main water intakes for the water supply system of Nuwara Eliya Municipality are located along the foot of the precipice of the mountain Pidurtalagala. These intakes, excluding Brewery Intake, are equipped with flow meters since February in 1998. As the watersheds of tributary streams are small in general, most of the streams are often dried up in the dry season.
**Table-1.2.2** shows the watershed for the main water intakes.

**Table-1.2.1 Area of Basins**

| Basin Name | Area ($km^2$) | Remarks |
|---|---|---|
| Nanu Oya Upstream area | 12.23 | including Golf Course area 4.98 $km^2$ |
| Gregory Lake area | 3.08 | |
| Nanu Oya basin sub-total | 15.31 | |
| Hawa Eliya area | 5.51 | |
| Barrack Plain Reservoir area | 1.68 | |
| Boburella basin sub-total | 7.19 | |
| Total | 22.50 | |

Note: Area of Gregory Lake area includes water surface plain.

**Table-1.2.2 Area of Watershed of main Water Intakes**

| Water intakes | Area ($km^2$) | River Basin |
|---|---|---|
| Bambarakele | 1.80 | Nanu Oya Upstream |
| Piyatissapura | 0.56 | Ditto |
| New Waterfield | 0.24 | Ditto |
| Old Waterfield | 1.11 | Ditto |
| Pedro | 1.80 | Ditto |
| Gamunu Mawatha | 0.34 | Boburella |
| Brewery | 1.14 | Ditto |
| Lover's Leap | 1.75 | Ditto |
| Total | 8.74 | |

## 1.3 Geology

**Fig-1.3.1** shows a geological map of Sri・Lanka As shown on this map, the geology of Nuwara Eliya belongs to the Highland group of Pre-Cambrian age. **Fig-1.3.2** shows a geological map of Nuwara Eliya and its vicinity.

The geology of the Study area is mainly consists of metamorphic rocks of Pre-Cambrian in age such as gneiss and quartzite, which form a major anticlinal fold structure with the axis of NW-SE direction associated with series of minor folds. As the main fold axis has a plunge gently dipping to the northwest in direction, the southeastern part of the anticlinal structure is opened to form a horseshoe shaped mountain ridges.

Several numbers of major faults are running almost in parallel with the axis of the major fold, developing high precipices and steep slopes as shown along the northern and southern flanks of the Upper Lake Hill, the northern side of river Boburella, and the southern side of river Nanu Oya. Some conjugated folds, which obliquely cross the main folds, are also observed in direction of NE-SW.

**Fig-1.3.3** shows the location of the main and conjugated folds observed by the Landsat images.

Cleavage plains, developed in rock of biotite gneiss show a concordant attitude with the anticlinal structure at the flanks of the fold. In general, fractures are well developed in the rocks. However, the attitude of banded gneissic structure and cleavage plains observed in the boring cores of the test boring TB-1, which will be discussed later, are dipping approximately 60 degrees. This is not concordant to the skeleton of the anticlinal structure. From this fact, geological structure of the rocks, which is faulted down inside of the basin, might be complex and discordantly different from that of outside.

According to the results of the test borings carried out in the study area, rocks of gneisses situated near ground surface are strongly weathered and fractured. Decomposed sand and altered white clay are also observed. Although thickness of the weathered zone is slightly different in places, it is estimated to range from 20m to 50m in depth by comparing with the result of electrical soundings.

**Fig-1.3.1 Geological Map of Sri・Lanka**

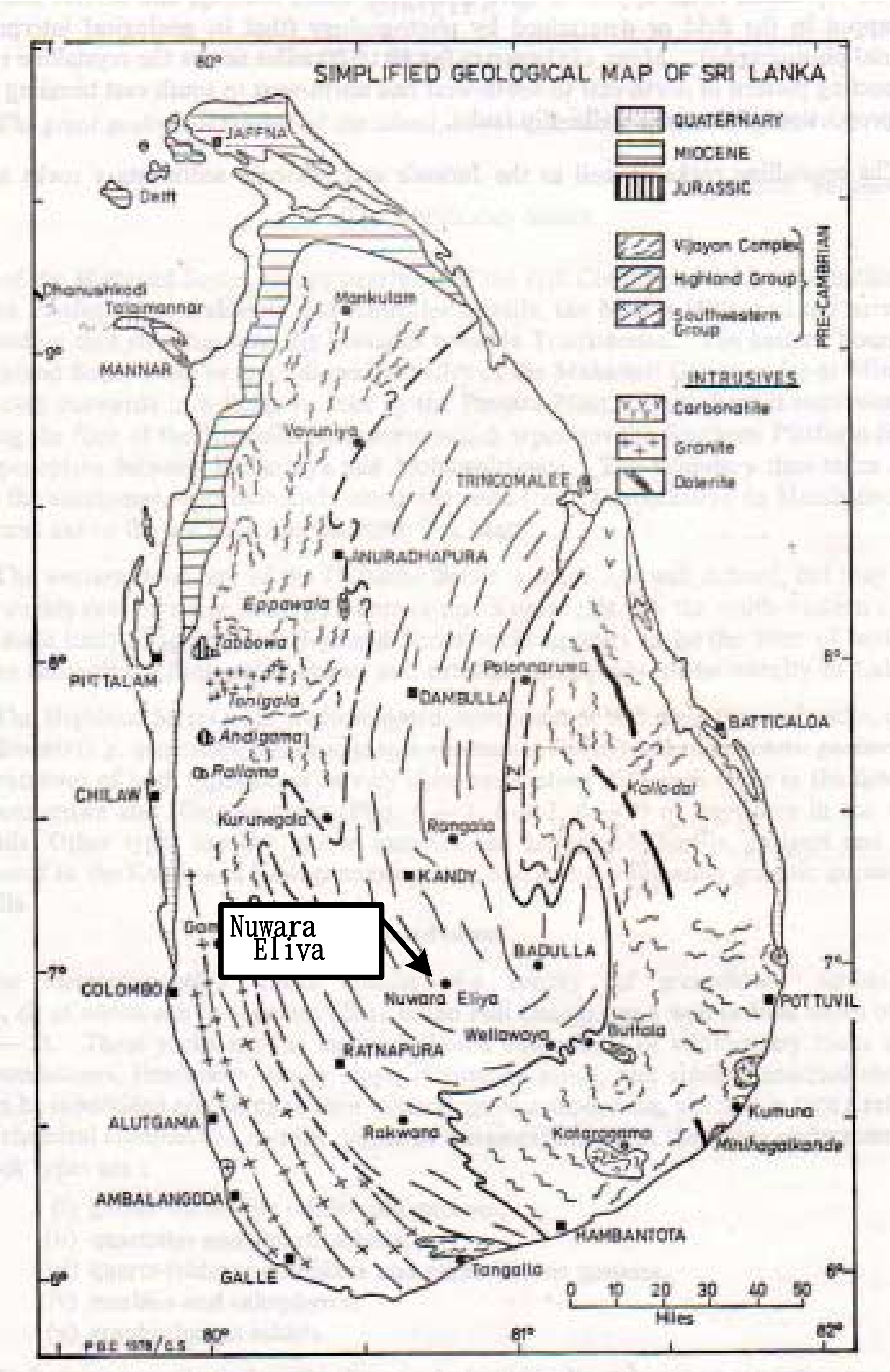
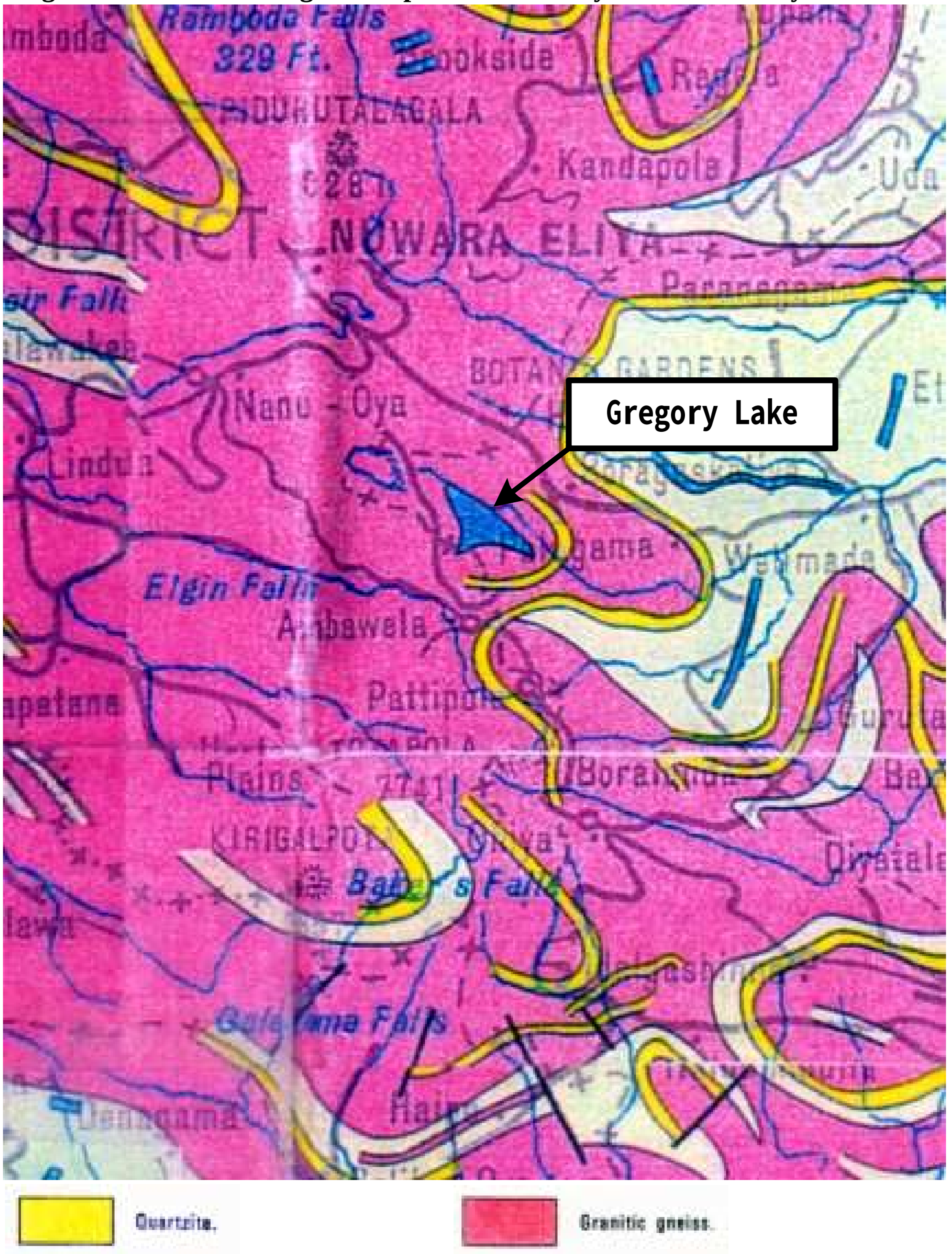


**Fig-1.3.2 Geological Map of Nuwara Eliya and its vicinity**



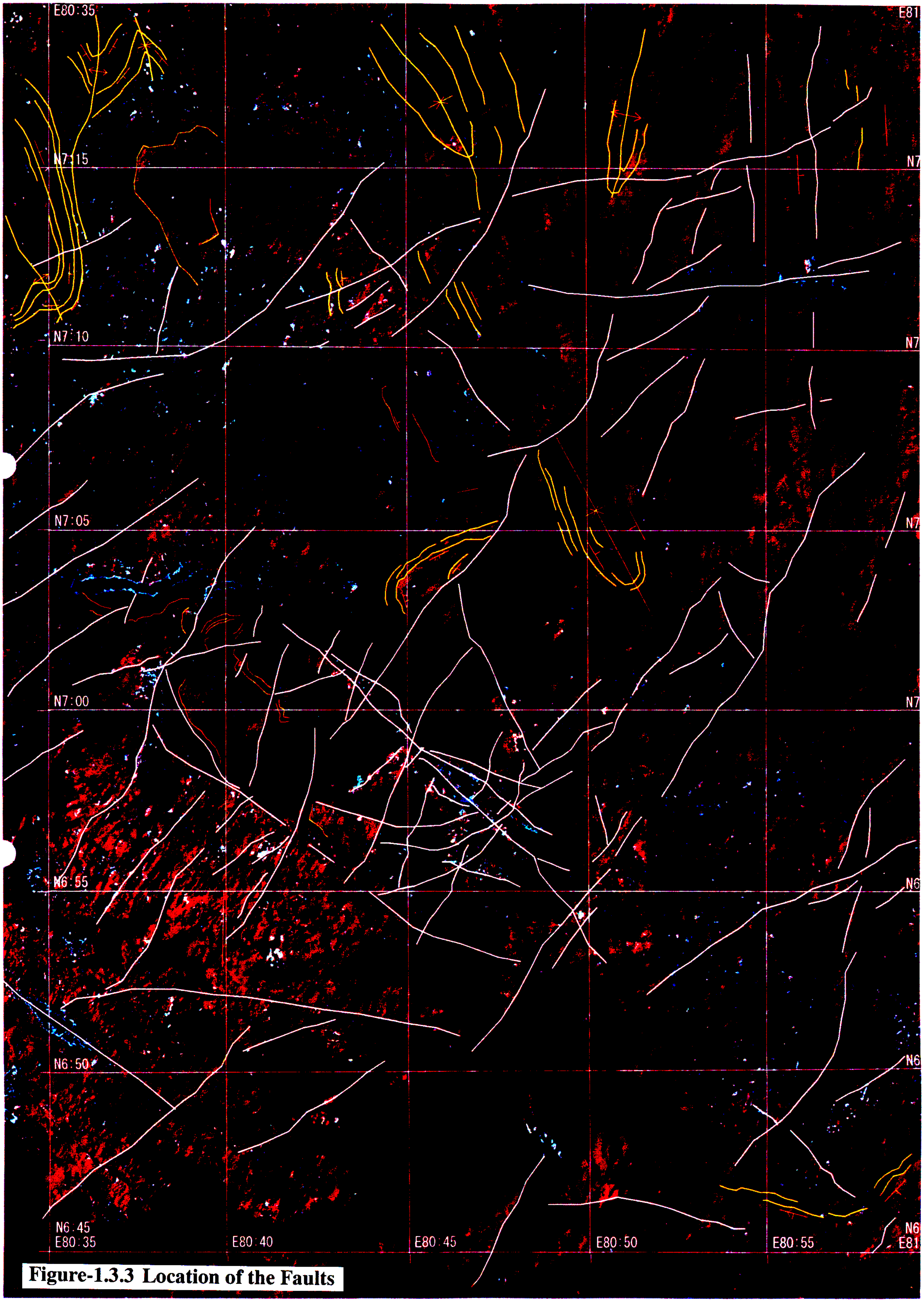



**Figure-1.3.3 Location of the Faults**

## 1.4 Meteorology

The climate of Sri Lanka is categorized in Tropical Rain Forest Climate in most of the area and Savanna Climate in the north. However, the climate at each region is largely different depending on the influence of monsoon and altitude. While the annual mean temperature in the southwestern region (including Colombo) is 25～28 degrees, it become cooler to 14～16 degrees at Nuwara Eliya located in the central high mountain area.

Precipitation is also different largely in each region. Sri Lanka falls into three divisions of precipitation. The southwestern region occupying one fourth of total land area of Sri Lanka has much rain fall. The annual mean precipitation comes to 2,500mm. The other area is classified into a dry region with annual precipitation of 1,200～1,900mm. However, the highland area in the dry region such as Nuwara Eliya, has over 2,000mm of annual precipitation. This is brought by strongly moist wind of Monsoon occurred over the Indian Ocean from June to October. When the moist wind blows against the central high mountains, it is uplifted to form moist cloud. This moist cloud brings heavy rain over the high mountain areas. The second Monsoon from October to November also brings periodical squall and heavy rain. For this reason, the central high mountain area, though it belongs to a dry climate zone, has a unique climate conditions such that this area has much precipitation from June to November but dried up in the other season.

Annually averaged precipitation for 5 years from 1995 through 2000 at the Nanu Oya Upstream basin is 2,247.2 mm, and 2,050.9 mm at Hawa Eliya. Evapotranspiration from wide spread forest and tea field is estimated as 584.3 mm and 600.9 mm respectively. Annually averaged run off is also estimated as 1,112.1 mm and 1,014.4 mm respectively. On the basis of these data, groundwater recharge is estimated to be 17,300 $m^3$/day in the Upper Nanu Oya river basin and 8,520 $m^3$/day in Hawa Eliya.

Meteorological data observed for latest 10 years at the station AGMET（Lat:6.95N Lon:80.80E）, Sita Eliya area in Nuwara Eliya are shown on the following tables. **Table-1.4.1** shows monthly mean of precipitation, **Table-1.4.2** shows monthly mean of potential evapotranspiration, and the other table from **Table-1.4.3** to **Table-1.4.6** show monthly mean of atmospheric temperature, monthly mean of relative humidity, monthly mean of wind velocity, and monthly mean of sunshine hours, respectively.

Potential evapotranspiration value, which is estimated by the Penman's method using daily data, comes to over 1,200mm/year for averaged year. In case that necessary data for the estimation is missing on a certain day, evapotranspiration value on that day is estimated by the Pan evaporation value multiplied by a factor 1.2.

It should be noted that the figures given in parentheses in the following tables are the values calculated without using missing day data.

**Table-1.4.1 Monthly Mean Precipitation**

Unit : mm/month

| Year | Jan. | Feb. | Mar | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | — | — | — | — | — | — | — | — | — | 249.3 | 143.8 | 261.7 | — |
| 1991 | 290.9 | 23.2 | 61.9 | 67.4 | 226.1 | 300.4 | 141.7 | (93.3) | 267.6 | 255.2 | 294.1 | 311.8 | (2333.6) |
| 1992 | 87.0 | 0.0 | 0.0 | 136.7 | 110.3 | 183.5 | 261.0 | 141.2 | 122.8 | 169.4 | 520.3 | 202.7 | 1934.9 |
| 1993 | 55.8 | 32.3 | 72.1 | 38.5 | 219.1 | 319.7 | 224.4 | 38.5 | 210.7 | 389.0 | 347.7 | 321.4 | 2269.2 |
| 1994 | 230.8 | 165.8 | 59.4 | 83.3 | 137.6 | 78.1 | 172.5 | 184.2 | 257.9 | 420.8 | 370.8 | 144.1 | 2305.3 |
| 1995 | 127.0 | 72.5 | 76.8 | 281.3 | (215.4) | 189.6 | 86.5 | 241.0 | 146.2 | 313.6 | 139.5 | 153.6 | (2043.0) |
| 1996 | 185.8 | 102.7 | 16.3 | 236.3 | 62.6 | 175.8 | 285.0 | 183.2 | 236.2 | 208.6 | 203.2 | 73.6 | 1969.3 |
| 1997 | 8.4 | 19.1 | 21.5 | 270.2 | 249.5 | 135.2 | 106.5 | 63.9 | 348.1 | 548.4 | 369.8 | 270.0 | 2410.6 |
| 1998 | 112.6 | 11.6 | 9.1 | 25.1 | 213.9 | 194.8 | 147.1 | 208.1 | 197.8 | 87.3 | 101.8 | 309.5 | 1618.7 |
| 1999 | 322.9 | 185.9 | 17.2 | 85.8 | 210.0 | 275.3 | 67.3 | 82.3 | 167.4 | 335.5 | 123.7 | 127.8 | 2001.1 |
| 2000 | 216.8 | 327.7 | 55.9 | 76.0 | 69.6 | 248.7 | 128.7 | 278.8 | 235.7 | — | — | — | — |
| Average | 163.8 | 94.1 | 39.0 | 130.1 | (171.4) | 210.1 | 162.1 | (151.5) | 219.0 | 297.7 | 261.5 | 217.6 | (2117.9) |

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**Table-1.4.2 Monthly Mean Potential Evapotranspiration**

Unit: mm/day

| Year | Jan. | Feb. | Mar | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | — | — | — | — | — | — | — | — | — | (3.98) | (3.15) | (2.71) | — |
| 1991 | (3.20) | 3.32 | 4.20 | 3.62 | 3.72 | (2.89) | 2.88 | (2.93) | 3.31 | 2.58 | 2.65 | 2.46 | (3.15) |
| 1992 | 2.76 | 5.23 | 6.38 | 5.06 | 3.52 | 3.26 | 3.88 | 3.17 | 2.79 | 3.58 | (2.88) | 2.87 | (3.78) |
| 1993 | 3.88 | 4.96 | 5.31 | 5.95 | 4.38 | 4.08 | 3.09 | 3.41 | 3.24 | 2.83 | 2.47 | (2.98) | (3.88) |
| 1994 | 2.63 | 3.25 | 3.88 | 3.66 | 3.57 | 3.36 | 3.05 | (3.25) | 3.23 | 2.78 | 2.52 | 2.67 | (3.15) |
| 1995 | 2.87 | 3.22 | 4.17 | 3.58 | (3.48) | 2.91 | 3.27 | (3.21) | 3.60 | 3.16 | 3.03 | 2.96 | (3.29) |
| 1996 | 2.76 | 3.28 | 4.15 | 3.44 | 4.13 | 3.50 | 2.87 | 3.09 | 2.72 | 3.25 | 3.00 | 2.74 | 3.24 |
| 1997 | 3.26 | 3.59 | 4.12 | 3.52 | 3.46 | 3.41 | 3.23 | 3.65 | 3.16 | 3.00 | 2.80 | 2.60 | 3.32 |
| 1998 | 3.01 | 3.49 | 4.19 | 4.16 | 3.85 | 3.21 | 3.20 | 3.21 | 3.21 | 3.07 | 3.01 | 2.78 | 3.37 |
| 1999 | 2.89 | 3.25 | 4.06 | 3.62 | 3.27 | 3.25 | 3.41 | 3.45 | 3.29 | 2.50 | 2.81 | 2.65 | 3.20 |
| 2000 | 2.61 | 2.98 | 3.52 | 3.37 | 3.62 | 2.80 | 3.28 | 2.77 | 3.18 | — | — | — | — |
| Average | (2.99) | 3.66 | 4.40 | 4.00 | (3.70) | (3.27) | 3.22 | (3.21) | 3.17 | (3.07) | (2.83) | (2.74) | (3.36) |

**Table-1.4.3 Monthly Mean Atmospheric Temperature**

Unit: ℃

| Year | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | — | — | — | — | — | — | — | — | — | 15.85 | 14.95 | 14.43 | — |
| 1991 | (14.38) | 14.79 | 16.10 | 16.55 | 17.05 | 15.76 | 15.29 | (15.54) | 16.02 | 15.02 | 14.93 | 14.64 | (15.51) |
| 1992 | 13.75 | 14.46 | 16.35 | 17.08 | 16.63 | 15.13 | 14.75 | 15.15 | 15.18 | 14.98 | 15.23 | 13.79 | 15.21 |
| 1993 | 13.50 | 15.01 | 15.43 | 16.56 | 17.15 | 15.63 | 14.68 | 15.46 | 15.68 | 15.55 | 15.66 | 15.35 | 15.47 |
| 1994 | 14.82 | 15.43 | 16.10 | 16.53 | 17.25 | 15.93 | 15.82 | (15.62) | 16.06 | 15.92 | 15.58 | 15.42 | (15.87) |
| 1995 | 15.33 | 15.40 | 16.80 | 17.11 | (17.64) | 16.63 | 16.08 | (16.09) | 18.98 | 16.26 | 16.24 | 14.82 | (16.45) |
| 1996 | 14.50 | 15.11 | 16.27 | 17.22 | 18.06 | 16.49 | 15.42 | 15.61 | 15.58 | 15.86 | 15.98 | 15.28 | 15.95 |
| 1997 | 14.57 | 15.37 | 16.67 | 16.98 | 17.30 | 17.15 | 16.40 | 16.32 | 16.45 | 16.50 | 16.63 | 16.04 | 16.37 |
| 1998 | 16.00 | 16.65 | 17.77 | 18.50 | 18.65 | 16.69 | 16.40 | 16.48 | 15.92 | 16.00 | 16.02 | 16.02 | 16.76 |
| 1999 | 15.14 | 15.98 | 16.57 | 16.70 | 16.53 | 15.95 | 15.60 | 16.01 | 16.17 | 15.55 | 16.15 | 14.97 | 15.94 |
| 2000 | 14.97 | 15.71 | 16.26 | 17.32 | 17.80 | 15.83 | 15.85 | 15.33 | 16.44 | — | — | — | — |
| Average | (14.70) | 15.39 | 16.43 | 17.06 | (17.41) | 16.12 | 15.63 | (15.76) | 16.25 | 15.75 | 15.74 | 15.08 | (15.94) |

Daily Mean=(Daily Max.+Daily Min.)/2

**Table-1.4.4 Monthly Mean Relative Humidity**

Unit: %

| Year | Jan. | Feb. | Mar | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | — | — | — | — | — | — | — | — | — | 90.7 | 88.6 | 92.9 | — |
| 1991 | (85.6) | 75.7 | 71.8 | 78.1 | 84.6 | 94.2 | 90.4 | (91.7) | 85.4 | 91.7 | 87.0 | 86.8 | (85.3) |
| 1992 | 82.4 | 51.1 | 39.7 | 67.0 | 83.0 | 90.8 | 93.5 | 87.9 | 89.2 | 81.3 | 90.3 | 87.0 | 78.6 |
| 1993 | 78.8 | 67.3 | 63.4 | 63.4 | 85.4 | 88.0 | 94.0 | 86.1 | 86.4 | 88.1 | 88.0 | 91.8 | 81.7 |
| 1994 | 84.6 | 73.1 | 62.5 | 75.3 | 79.3 | 88.1 | 90.6 | (88.0) | 84.4 | 88.5 | 90.8 | 86.5 | (82.6) |
| 1995 | 81.8 | 76.9 | 63.8 | 83.5 | (83.7) | 92.3 | 87.5 | (89.1) | 85.8 | 84.1 | 82.3 | 83.5 | (82.9) |
| 1996 | (81.6) | 77.5 | 59.8 | (80.9) | 71.3 | 84.5 | 89.0 | (90.7) | (93.8) | (82.6) | 80.3 | 79.4 | (81.0) |
| 1997 | 70.5 | (63.7) | 57.4 | 75.7 | 81.2 | 79.1 | 88.2 | 85.0 | 85.7 | 86.6 | 86.3 | 89.7 | (79.1) |
| 1998 | 80.7 | 72.0 | 59.3 | 64.0 | 82.5 | 88.0 | 87.3 | 87.2 | 89.3 | 85.3 | (80.8) | (85.5) | (80.2) |
| 1999 | 77.2 | 82.3 | 61.3 | 82.3 | 89.5 | 85.9 | 87.1 | 88.2 | 89.3 | 95.6 | 87.3 | 89.1 | 84.6 |
| 2000 | 86.8 | 84.1 | 73.8 | 80.7 | (86.3) | 94.1 | 88.2 | 94.2 | 91.0 | — | — | — | — |
| Average | (81.0) | (72.4) | 61.3 | (75.1) | (82.7) | 88.5 | 89.6 | (88.8) | (88.0) | (87.5) | (86.2) | (87.2) | (82.4) |

Relative Humidity, Daily Mean=(R.H. at 9pm+R.H. at 6am)/2

**Table-1.4.5 Monthly Mean Wind Velocity**

Unit: km/hr

| Year | Jan. | Feb. | Mar | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | — | — | — | — | — | — | — | — | — | 8.35 | 8.03 | 8.53 | — |
| 1991 | (6.15) | 7.08 | 6.16 | 5.39 | 4.93 | 23.33 | 19.89 | (15.28) | 10.44 | 13.03 | 7.61 | 8.47 | (10.65) |
| 1992 | 7.90 | 5.62 | 6.47 | 5.66 | 10.09 | 23.94 | 19.59 | 17.43 | 11.64 | 11.69 | 8.45 | 8.80 | 11.44 |
| 1993 | 7.98 | 6.57 | 8.05 | 5.86 | 8.06 | 17.65 | 21.95 | 14.65 | 10.69 | 10.72 | 6.30 | 7.25 | 10.48 |
| 1994 | 7.10 | 6.85 | 7.06 | 5.52 | 10.03 | 19.59 | 19.26 | (16.85) | 11.47 | 5.85 | 7.22 | 7.33 | (10.34) |
| 1995 | 5.46 | 7.24 | 7.14 | 5.57 | (10.50) | 18.05 | 16.25 | 16.27 | 13.13 | 9.74 | 6.93 | 7.81 | (10.34) |
| 1996 | 7.33 | 7.58 | 6.06 | 4.30 | 7.63 | 16.64 | 21.70 | 15.77 | 17.89 | 12.39 | 6.25 | 5.93 | 10.79 |
| 1997 | 5.87 | 5.88 | 6.85 | 4.47 | 6.44 | 9.40 | 16.82 | 16.76 | 10.16 | (5.01) | 5.11 | 6.98 | (8.31) |
| 1998 | 7.23 | 5.60 | 5.95 | 5.59 | 9.28 | 21.03 | 16.82 | 12.69 | 17.64 | 12.98 | 7.54 | 7.06 | 10.78 |
| 1999 | 8.09 | 7.50 | 6.96 | 11.50 | 16.41 | 17.09 | 21.00 | 15.74 | 12.54 | 12.70 | 6.23 | 7.06 | 11.90 |
| 2000 | (8.72) | 5.87 | 6.35 | 6.14 | 9.64 | 21.61 | 17.43 | 20.57 | 9.38 | — | — | — | — |
| Average | (7.18) | 6.58 | 6.71 | 6.00 | (9.30) | 18.83 | 19.07 | (16.20) | 12.50 | (10.25) | 6.97 | 7.52 | (10.59) |

**Table-1.4.6 Monthly Mean Sunshine Hours**

Unit: hrs/day

| Year | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | — | — | — | — | — | — | — | — | — | — | (5.67) | (1.66) | — |
| 1991 | (3.91) | (8.42) | (5.86) | (7.49) | (9.65) | — | (3.25) | (3.31) | 5.38 | 2.21 | 4.09 | 3.64 | — |
| 1992 | 5.66 | (8.53) | — | — | — | (1.76) | (2.60) | 4.07 | (0.00) | — | — | — | — |
| 1993 | — | — | — | — | — | — | — | (2.15) | 4.95 | (3.40) | 2.27 | (2.27) | — |
| 1994 | 4.13 | 6.39 | 8.15 | 7.74 | 6.09 | 4.82 | 3.35 | 4.75 | 4.64 | 3.54 | 2.99 | 4.82 | 5.12 |
| 1995 | 5.93 | 6.48 | 8.16 | 6.75 | (5.85) | 2.78 | 5.04 | 4.96 | 4.53 | 4.22 | (5.10) | 5.62 | (5.45) |
| 1996 | 5.17 | 5.87 | 9.01 | 5.63 | 8.44 | 4.85 | 2.00 | 3.33 | (1.89) | 4.69 | 5.50 | 5.07 | (5.12) |
| 1997 | 8.92 | 8.46 | 8.40 | 6.31 | 6.21 | 5.77 | 4.15 | 5.84 | 4.35 | 4.61 | 4.15 | 3.86 | 5.92 |
| 1998 | 5.89 | 7.31 | 8.94 | 8.66 | 6.88 | 3.28 | 3.78 | 4.52 | 3.83 | 3.65 | 5.09 | 4.04 | 5.49 |
| 1999 | 4.56 | 5.36 | 7.89 | 5.15 | 4.18 | 4.67 | 4.36 | 5.19 | 4.64 | 2.05 | 4.51 | 5.16 | 4.81 |
| 2000 | 4.29 | 4.95 | 6.50 | 7.25 | 6.88 | 2.91 | 5.45 | 2.88 | 5.03 | — | — | — | — |
| Average | (5.38) | (6.86) | (7.86) | (6.87) | (6.77) | (3.86) | (3.78) | (4.10) | (3.92) | (3.15) | (4.37) | (4.02) | (5.08) |

# 2. Groundwater Recharge

## 2.1 Tank Model

Daily runoff analysis by Tank Model Method was conducted for estimating groundwater recharge in the watershed Nanu Oya Upstream and Boburella river basin and the water balance composed of precipitation, evapotranspiration, runoff, and groundwater recharge were studied.

The watersheds are subdivided into 15 areas in the Nanu Oya Upstream watershed and 8 areas in the Hawa Eliya watershed respectively, considering drainage system and the flow observation stations. Some of the sub-watersheds, which enclose town area, are further subdivided into two areas in order to separate the area significantly different from the other area in terms of runoff components such as urban runoff and runoff from fissured gneiss.

In order to estimate water demand of crops in each sub-watershed, the major land use and vegetation coverage in each sub-basin are obtained referring the maps prepared by the Nuwara Eliya Environmental Study. The categories of major land use are such as forest, tea plantation, farmland and grassland, public facilities area (including large hotels and official residence), residential area, urban area and industrial area.

As the vegetation coverage pattern is not changed through the year, crop coefficient is estimated to be 0.8 for forest, 0.85 for tea plantation, and 1.0 for the other vegetation (grass, vegetable, crops). An averaged crop coefficient for each basin is estimated to be 0.8 for Nani Oya Upstream basin, and 0.76 for Boburella basin as shown on **Table-2.1.1** and **Table-2.1.2.**

Runoff models for each sub-basin are prepared by try and error until they fit the flow record ( from February, 1998 to September, 2000) observed at each intake weir.Precipitation is multiplied by weighting factor for the mountainous watersheds in Nanu Oya Upstream basin because orographic precipitation is significant in these areas.

Runoff models are tried and calibrated for the watersheds having water intakes simulating the flow record of two and half years (Feb., 1998 - Sep.,2000). The models obtained have four stories of tanks for the watersheds in Nanu Oya Upstream basin and three stories of tanks for those of Boburella basin.

The hydrographs indicate that the watersheds of Bambarakele Intake and Old Waterfield Intake have significant runoff from the areas of fissured gneiss, so that a tank model having two stories of tanks is associated in the respective watershed. The models obtained do not have runoff nozzles with the first tanks, which indicates occurrence of surface runoff. While it is known that surface runoff occurs when rainfall intensity exceeds infiltration capacity of soils, these models indicate that surface runoff does not occur or is negligible under the usual level of rainfall intensity. In the mountainous area, high intensity rainfall in limited area sometimes occurs within short time duration and causes surface runoff. However, the intensity of such a short-tome rainfall is averaged over 24 hours by daily analysis based on the daily flow data. Therefore, it is not possible to simulate such a flash surface runoff by daily analysis.

These models simulate the groundwater runoffs very well by the following at the lower tanks. The second tank simulates intermediate runoff, and the third and the fourth tanks simulate groundwater runoff.

Runoff from the watersheds along the main streams are also modeled and calibrated to simulate the discharge measured at the main streams during the field study. The models obtained are consisted of two stories of tanks. In some watersheds where runoff from urban and residential areas is significant, the models have runoff nozzles with the first tanks. The simulation indicates that the groundwater recharge mainly takes place in the valley floors and surrounding slopes excluding urban and residential areas. The simulation also indicates that the base flow in the river Boburella decreased rapidly within a couple of days after rainfall, and that the flow is largely composed of wastewater from domestic sewage and industrial drainage.

The tank Models applied to the analysis are shown in **Fig-2.1.1**, and the parameters of all the tank models are summarized in **Table-2.1.3** and **Table-2.1.4**.

**Table-2.1.1 Major Land Use and Vegetation Cover in Upper Nanu Oya Basin**

| Watershed | Area | Forest | Tea Plantation | Farmland and Grassland | Public Facilities Area | Residential Area | Urban Area | Industrial Area | Averaged Crop Coefficient | Remarks (Area Name) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1A | 1.38 | 1.38(100) | | | | | | | 0.80 | Bambarakele Intake |
| 1B | 0.42 | 0.42(100) | | | | | | | 0.80 | |
| 2 | 0.56 | 0.56(100) | | | | | | | 0.80 | Piyatissapura Intake |
| 3A | 1.37 | 0.49(100) | 0.71(100) | 0.14(90) | | 0.03(60) | | | 0.83 | Bambarakele |
| 3B | 0.22 | 0.22(100) | | | | | | | 0.80 | |
| 4A | 0.58 | | 0.15(100) | | 0.27(80) | 0.16(50) | | | 0.73 | |
| 4B | 0.19 | 0.19(100) | | | | | | | 0.80 | |
| 5 | 0.24 | 0.24(100) | | | | | | | 0.80 | New Waterfield Intake |
| 6A | 0.90 | 0.90(100) | | | | | | | 0.80 | Old Waterfield Intake |
| 6B | 0.22 | 0.22(100) | | | | | | | 0.80 | |
| 7A | 0.20 | | | | 0.02(90) | 0.14(50) | 0.04(10) | | 0.46 | |
| 7B | 0.08 | 0.08(100) | | | | | | | 0.80 | |
| 8A | 0.20 | | | 0.07(100) | 0.13(90) | | | | 0.82 | |
| 8B | 0.29 | 0.29(100) | | | | | | | 0.80 | |
| 9 | 1.80 | 1.80(100) | | | | | | | 0.80 | Pedro Intake |
| 10A | 0.09 | | | | | 0.06(60) | 0.03(10) | | 0.43 | Town |
| 10B | 0.04 | 0.04(100) | | | | | | | 0.80 | |
| 11A | 0.39 | | | | | 0.27(60) | 0.12(20) | | 0.48 | Town |
| 11B | 0.58 | 0.16(100) | | 0.30(100) | 0.12(80) | | | | 0.90 | Golf Course, Victoria Park |
| 12 | 0.26 | 0.24(100) | 0.02(100) | | | | | | 0.80 | |
| 13A | 0.22 | | | | 0.04(40) | 0.18(60) | | | 0.56 | Unique View |
| 13B | 0.26 | 0.04(100) | | 0.22(95) | | | | | 0.93 | |
| 14 | 0.11 | | | | 0.11(70) | | | | 0.70 | Race Course |
| 15A | 0.45 | 0.10(100) | | 0.35(98) | | | | | 0.94 | Race Course |
| 15B | 0.21 | | | | 0.01(40) | 0.20(60) | | | 0.59 | |
| Total area | 11.26 | 7.37 | 0.88 | 1.08 | 0.70 | 1.04 | 0.19 | 0 | Av.=0.80 | |

Note: Unit of area: $km^2$, Figures in parentheses is vegetation coverage (%).

**Table-2.1.2 Major Land Use and Vegetation Cover in Boburella Basin**

| Watershed | Area | Forest | Tea Plantation | Farmland and Grassland | Public Facilities Area | Residential Area | Urban Area | Industrial Area | Averaged Crop Coefficient | Remarks (Area Name) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.34 | 0.34(100) | | | | | | | 0.80 | Gamunu Mawatha Intake |
| 2 | 1.14 | 1.14(100) | | | | | | | 0.80 | Brewery Intake |
| 3 | 1.75 | 1.75(100) | | | | | | | 0.80 | Lover's Leap Intake |
| 4A | 0.75 | 0.49(100) | 0.26(100) | | | | | | 0.82 | |
| 4B | 0.31 | | | | 0.02(30) | 0.27(50) | | 0.02(20) | 0.47 | |
| 5A | 0.67 | 0.03(100) | | | | 0.60(60) | | 0.04(30) | 0.59 | |
| 5B | 0.05 | 0.05(100) | | | | | | | 0.80 | |
| 6A | 0.06 | | 0.04(100) | | | 0.02(60) | | | 0.77 | |
| 6B | 0.04 | 0.04(100) | | | | | | | 0.80 | Galway Wildlife Bungalow |
| 7 | 0.07 | | 0.03(100) | 0.01(95) | | 0.02(40) | | 0.01(20) | 0.64 | Play Ground |
| 8A | 0.17 | | 0.10(100) | 0.07(95) | | | | | 0.89 | |
| 8B | 0.16 | | | | | 0.16(70) | | | 0.70 | |
| Total Area | 5.51 | 3.84 | 0.43 | 0.08 | 0.02 | 1.07 | | 0.07 | Av.=0.76 | |

Note: Unit of area: $km^2$, Figures in parentheses is vegetation coverage (%).

## Table-2.1.3 Parameters of the Tank Model for Upper Nanu Oya Basin

| Watershed | Precipitation Correction Factor | The First Tank | | The Second Tank | | The third Tank | | The fourth Tank | | Remarks (Major Runoff Source) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Runoff Nozzle | Percolation Nozzle | Runoff Nozzle | Percolation Nozzle | Runoff Nozzle | Percolation Nozzle | Runoff Nozzle | Percolation Nozzle | |
| 1A | 1.2 | - | 0.05 | 0.003(10) | 0.05 | 0.001(40) | 0.0005 | 0.0002(0) | 0.0002 | |
| 1B | 1.3 | - | 0.01 | 0.2(20) | 0 | - | - | - | - | Fractured gneiss |
| 2 | 1.2 | - | 0.05 | 0.003(10) | 0.01 | 0.0005(25) | 0.002 | 0.0002(0) | 0.0007 | |
| 3A | 1.1 | - | 0.1 | 0.005(20) | 0.01 | 0.001(0) | 0 | - | | |
| 3B | 1.2 | - | 0.01 | 0.2(20) | 0 | - | - | - | - | Fractured gneiss |
| 4A | 1.0 | - | 0.08 | 0.001(10) | 0.01 | - | - | - | - | Urban wastewater |
| 4B | 1.1 | 0.2(1) | 0.01 | 0.2(20) | 0 | - | - | - | - | Fractured gneiss |
| 5 | 1.1 | - | 0.05 | 0.005(20) | 0.01 | 0.0005(40) | 0.001 | 0.0002(10) | 0.0007 | |
| 6A | 1.1 | - | 0.05 | 0.001(20) | 0.05 | 0.0005(40) | 0.007 | 0.0002(10) | 0.0006 | |
| 6B | 1.1 | - | 0.01 | 0.2(20) | 0 | - | - | - | - | Fractured gneiss |
| 7A | 1.0 | 0.2(1) | 0.05 | 0.001(10) | 0.01 | - | - | - | - | Urban wastewater |
| 7B | 1.0 | - | 0.05 | 0.001(10) | 0.05 | 0.0005(40) | 0.007 | - | - | |
| 8A | 1.0 | - | 0.09 | 0.001(10) | 0.01 | - | - | - | - | |
| 8B | 1.1 | - | 0.01 | 0.2(20) | 0 | - | - | - | - | |
| 9 | 1.1 | - | 0.05 | 0.01(5) | 0.04 | 0.003(30) | 0.0025 | 0.0005(0) | 0.0005 | |
| 10A | 1.0 | 0.2(1) | 0.04 | 0.001(10) | 0.01 | - | - | - | - | Urban wastewater |
| 10B | 1.0 | - | 0.05 | 0.001(10) | 0.05 | 0.0005(40) | 0.007 | - | - | |
| 11A | 1.0 | 0.2(1) | 0.05 | 0.001(10) | 0.01 | - | - | - | - | Urban wastewater |
| 11B | 1.0 | 0.2(1) | 0.1 | 0.005(10) | 0.01 | - | - | - | - | |
| 12 | 1.1 | - | 0.01 | 0.2(20) | 0 | - | - | - | - | Fractured gneiss |
| 13A | 1.0 | 0.2(1) | 0.06 | 0.005(10) | 0.01 | - | - | - | - | Urban wastewater |
| 13B | 1.0 | - | 0.1 | 0.005(10) | 0.01 | - | - | - | - | |
| 14 | 1.0 | - | 0.07 | 0.001(10) | 0.01 | - | | - | - | |
| 15A | 1.0 | - | 0.1 | 0.005(10) | 0.01 | - | | - | - | |
| 15B | 1.0 | 0.2(1) | 0.06 | 0.005(10) | 0.01 | - | | - | - | Urban wastewater |

Note: Unit of Nozzle size: 1/hr. Figures in parentheses : Height of Runoff Nozzle（mm）.

**Table-2.1.4 Parameters of the Tank Model for Boburella Basin**

| Watershed | Precipitation Correction Factor | The First Tank | | The Second Tank | | The Third Tank | | The Fourth tank | | Remarks (Major Runoff Source)) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Runoff Nozzle | Percolation Nozzle | Runoff Nozzle | Percolation Nozzle | Runoff Nozzle | Percolation Nozzle | Runoff Nozzle | Percolation Nozzle | |
| 1 | 1.0 | - | 0.01 | 0.02(40) | 0.005 | 0.001 | 0.001(0) | - | - | |
| 2 | 1.0 | - | 0.01 | 0.02(40) | 0.005 | 0.001 | 0.001(0) | - | - | |
| 3 | 1.0 | - | 0.04 | 0.05(10) | 0.01 | 0.002 | 0.002(0) | - | - | |
| 4A | 1.0 | - | 0.1 | 0.001(10) | 0.01 | - | - | - | - | |
| 4B | 1.0 | 0.2(1) | 0.05 | 0.001(10) | 0.01 | - | - | - | - | Urban wastewater |
| 5A | 1.0 | 0.2(1) | 0.06 | 0.001(10) | 0.01 | - | - | - | - | Urban wastewater |
| 5B | 1.0 | - | 0.01 | 0.2(20) | 0 | - | - | - | - | Fractured gneiss |
| 6A | 1.0 | 0.2(1) | 0.09 | 0.001(10) | 0.01 | - | - | - | - | Urban wastewater |
| 6B | 1.0 | - | 0.01 | 0.2(20) | 0 | - | - | - | - | Fractured gneiss |
| 7 | 1.0 | 0.2(1) | 0.07 | 0.001(10) | 0.01 | - | - | - | - | Urban wastewater |
| 8A | 1.0 | - | 0.1 | 0.001(10) | 0.01 | - | - | - | - | |
| 8B | 1.0 | 0.2(1) | 0.07 | 0.001(10) | 0.01 | - | - | - | - | Urban wastewater |

Note: Unit of Nozzle size: 1/hr. Figures in parentheses : Height of Runoff Nozzle（mm）.

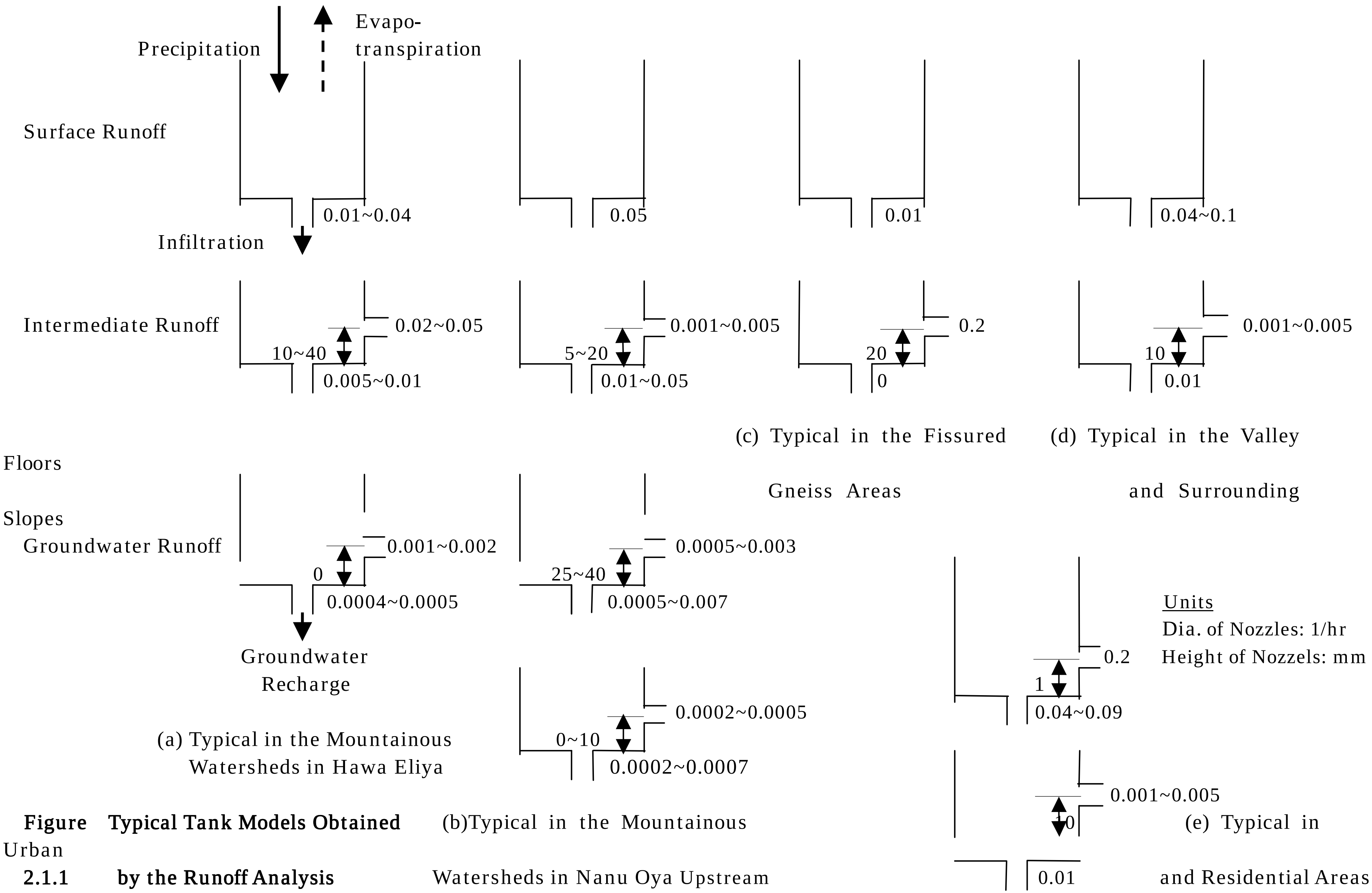



**Figure 2.1.1 Typical Tank Models Obtained by the Runoff Analysis**

## 2.2 Groundwater Recharge

**Table-2.2.1** and **Table-2.2.2** show the water balance in Nanu Oya Upperstream basin and Boburella Basin, obtained by the runoff simulation using above mentioned models for five years ( from October, 1995 to September, 2000 ). **Table-2.2.3** and **Table-2.2.4** show monthly groundwater recharge in each basin.

**Table-2.2.1 Water Balance in Nanu Oya Upstream Basin**

Unit: mm

| Year | Precipitation | Effective Evapotranspiration | Runoff | Groundwater Recharge |
|---|---|---|---|---|
| 1995/96 | 2290.8 | 619.7 | 1033.4 | 473.2 |
| 1996/97 | 1871.3 | 560.3 | 881.6 | 426.5 |
| 1997/98 | 2540.3 | 563.7 | 1379.3 | 625.6 |
| 1998/99 | 2095.8 | 570.8 | 1060.1 | 506.9 |
| 1999/00 | 2437.9 | 607.1 | 1206.1 | 560.9 |
| Average | 2247.2 | 584.3 | 1112.1 | 518.6 |

**Table-2.2.2 Water Balance in Boburella Basin**

Unit: mm

| Year | Precipitation | Effective Evapotranspiration | Runoff | Groundwater Recharge |
|---|---|---|---|---|
| 1995/96 | 2090.6 | 640.9 | 968.7 | 432.4 |
| 1996/97 | 1707.8 | 575.4 | 792.2 | 336.3 |
| 1997/98 | 2318.3 | 572.1 | 1256.6 | 519.6 |
| 1998/99 | 1912.7 | 589.3 | 951.6 | 393.3 |
| 1999/00 | 2224.9 | 627.0 | 1102.8 | 480.9 |
| Average | 2050.9 | 600.9 | 1014.4 | 432.5 |

As shown in **Table-2.2.1** and **Table-2.2.2**, groundwater recharge in the Nanu Oya Upstream basin (12.23km$^2$) and Boburella basin (7.19km$^2$) is estimated to be 518.6mm and 432.5mm, respectively. Consequently, groundwater potential is estimated at 630 Mm$^3$/year (=17,300m$^3$/day) in Nanu Oya Upstream basin, 240Mm$^3$/year ( =6,500m$^3$/day ) in Hawa Eliya (5.51km$^2$ ).

As for the groundwater development plan, the requirements are 4,652m$^3$/day in Nanu Oya Upstream basin, and 1,743m$^3$/day in Hawa Eliya. These requirements are equivalent to 26.9 % and 26.8 % of the groundwater recharge in respective basin.

Although the groundwater development plan is not excessive but feasible, effective groundwater collection should be considered. This subject, relating to the layout of wells and the depth of wells, should be studied further.

**Table-2.2.3 Monthly Groundwater Recharge in Nanu Oya Upstream Basin**

Unit: mm

| Year | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995/96 | 43.8 | 40.5 | 36.0 | 34.5 | 36.5 | 19.7 | 44.2 | 20.1 | 40.6 | 59.0 | 41.3 | 57.4 | 473.2 |
| 1996/97 | 59.6 | 43.8 | 40.6 | 22.0 | 13.0 | 11.6 | 36.1 | 58.2 | 35.0 | 31.8 | 21.3 | 53.3 | 426.5 |
| 1997/98 | 102.9 | 110.1 | 92.3 | 60.9 | 28.8 | 19.7 | 12.3 | 37.7 | 33.5 | 40.9 | 47.2 | 39.4 | 625.6 |
| 1998/99 | 40.3 | 31.2 | 58.8 | 77.1 | 50.8 | 31.7 | 26.5 | 33.3 | 70.7 | 30.9 | 25.9 | 29.9 | 506.9 |
| 1999/00 | 71.8 | 44.0 | 43.0 | 48.3 | 69.7 | 40.0 | 28.7 | 20.6 | 37.2 | 44.5 | 62.5 | 50.8 | 560.9 |
| Average | 63.7 | 53.9 | 54.1 | 48.6 | 39.8 | 24.5 | 29.6 | 34.0 | 43.4 | 41.4 | 39.6 | 46.2 | 518.6 |

**Table-2.2.4 Monthly Groundwater Recharge in Boburella Basin**

Unit: mm

| Year | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995/96 | 57.2 | 40.4 | 30.3 | 27.8 | 30.1 | 6.2 | 44.4 | 7.9 | 38.9 | 60.3 | 32.5 | 56.4 | 432.4 |
| 1996/97 | 54.0 | 31.6 | 26.7 | 5.6 | 2.1 | 3.6 | 40.4 | 61.0 | 24.4 | 21.5 | 8.8 | 56.8 | 336.3 |
| 1997/98 | 112.2 | 106.2 | 74.0 | 36.1 | 5.8 | 2.1 | 1.5 | 38.7 | 30.0 | 37.1 | 44.2 | 31.9 | 519.6 |
| 1998/99 | 30.9 | 20.8 | 58.3 | 76.2 | 37.6 | 10.6 | 12.8 | 26.8 | 72.8 | 11.6 | 11.5 | 23.5 | 393.3 |
| 1999/00 | 78.9 | 33.4 | 32.4 | 41.9 | 69.2 | 23.0 | 13.4 | 6.7 | 34.7 | 39.4 | 63.8 | 44.1 | 480.9 |
| Average | 66.6 | 46.5 | 44.3 | 37.5 | 29.0 | 9.1 | 22.5 | 28.2 | 40.2 | 34.0 | 32.2 | 42.5 | 432.5 |

## 2.3 Groundwater Potential in Proposed Area

1) Nanu Oya Upstream basin

Total area of the basin is approximately 12.23km$^2$. Annual mean values of the climatologic and hydrological components are estimated for the past five years from 1995 to 2000 as followings; precipitation 2247.2mm/year, effective evapotranspiration 584.3mm/year, runoff 1,112.1mm/year. So that, the annual mean of groundwater recharge is estimated at 518.6mm/year. This is equivalent to 17,300 m$^3$/day. Annual mean groundwater recharge in Golf course area ( area 4.98km$^2$ ), which is located in the northwestern sub-basin of the Nanu Oya Upstream basin, is estimated at 7,000 m$^3$/day.

Groundwater basin ranges from the northwest margin of the Golf Course to the northwestern bank of Gregory Lake. Groundwater is reserved in weathered rocks of gneiss origin, located at 20 to 50m in depth, and in fractures developed in fresh rocks of gneiss and quartzite, underlying the weathered rock. In both case, groundwater is confined.

Groundwater development at the shallow weathered aquifer in the vicinity of Gregory Lake is not recommendable because of the high possibility of water pollution caused by domestic wastewater and chemical contamination by fertilizer and agricultural chemicals.

2) Boburella Basin

The area of this basin is approximately 7.19km$^2$. Annual mean of precipitation for five years from 1995 to 2000 is estimated at 2050.9 mm/year, effective evapotranspiration 600.9 mm/year, runoff 1014.4 mm/year. Consequently, annual mean of groundwater recharge is estimated to be 432.5mm/year. This is equivalent to daily recharge at 8,520 m$^3$/day, including daily recharge in Hawa Eliya at 6,500m$^3$/day.

Boburella basin is surrounded in the northeastern margin by a high mountain range, which is the water source of Lover's Leap, and by Upper Lake Hills in the southwestern margin. Groundwater rising from these mountains and hills, percolated down into the weathered rock of gneiss along the slope, recharges aquifer at the bottom of the basin.

Groundwater is mainly reserved in two aquifers. The shallow one consists of weathered gneiss, lying under the ground surface at 20 to 50m in depth, and the deeper one consists of fractured rocks of gneiss and quartzite, underlying the first aquifer as same as in the Nanu Oya Upstream basin. Both aquifers are confined.

3) Magasthota Watershed

The area of this watershed is small and estimated at about 0.6km$^2$ at the mouth of a stream flowing into Gregory Lake. A major fault is running along the valley of watershed. Aquifer is formed in fractured zone developed along the fault. As the aquifer is of low permeability due to weathering, water yield at a existing well is small. The water quality test of the well at Bibile Garment Factory shows low pH and high Iron contents of the groundwater. In case of the groundwater development in this area, groundwater quality and affection from existing wells should be considered.

4) Upper Lake Road area

Upper Lake Road area is located at a flat land along the northeastern bank of Gregory Lake. It lies between Gregory Lake and Upper Lake Hills, and is very small in area. Although a Major fault is running across this area, aquifer zone is weathered and its permeability is low. Quality of groundwater is inferred to be not good because of the similar geological conditions to that of Magasthota area. As the groundwater recharge is small, the groundwater development in this area may involve some risk to draw the water from Gregory Lake into this area.

## 3. Existing State of Groundwater Use

Existing state of groundwater use is described in Main Report, **Section 2-2-2-2**.

## 4. Review of the Previous JICA Study

Review of the Previous JICA Study is described in Main Report, **Section 2-2-2-2**.

## 5. Geophysical Survey

The Basic Design Study carried out extensive geophysical survey (by vertical electric sounding method and electromagnetic sounding method) to investigate the groundwater conditions and related geological structure in the groundwater development area (including Hawa Eliya and Upper Lake Load).

### 5.1 Vertical Electric Sounding

Vertical Electric Sounding by the Schlumberger method was carried out at 39 sites allocated at equal distances in the Nuwara Eliya study area. **Fig-5.1.1** shows the location of the sites.

The maximum sounding depth was less than AB/2=200m. The results of the data analysis showed 3 to 6 layered resistivity structures. On the basis of the general geological information of the study area, high resistivity layers are correlated with crystalline metamorphic rocks, which mainly consist of grayish black colored gneiss, and low resistivity layers are mainly correlated with fractured and jointed metamorphic rocks filled with water, and weathered rocks. **Table-5.1.1** shows the results of data analysis.

The depth of basement of weathered gneiss, shown in **Fig-5.1.2** , illustrates the height of a bottom plain of the low resistivity layer, which is correlated with aquifer and weathered rocks saturated with water, in altitude above sea level. Sub-surface low resistivity layer is excluded from this map, because it is inferred to be strongly weathered rocks.

As shown in **Fig-5.1.2**, the basement of weathered rocks (aquifer) is shallow in the vicinity of Lake Gregory, southeastern side of Gregory Lake, and is deep in Hawa Eliya, Race Course, and Upstream area of Nanu Oya river. The Contour pattern in **Fig-5.1.2** is concordant to the topographic feature. The basement depth ranges approximately from –10m to –130m.

**Fig-5.1.3** shows thickness of the low resistivity layer. In the vicinity of Gregory Lake, the thickness of the low resistivity layer is very thin at 5 to 10m, while it exceeds 30m in the northeastern area (Hawa Eliya), southeastern area (Magasthota), and the Central area (Race Course).

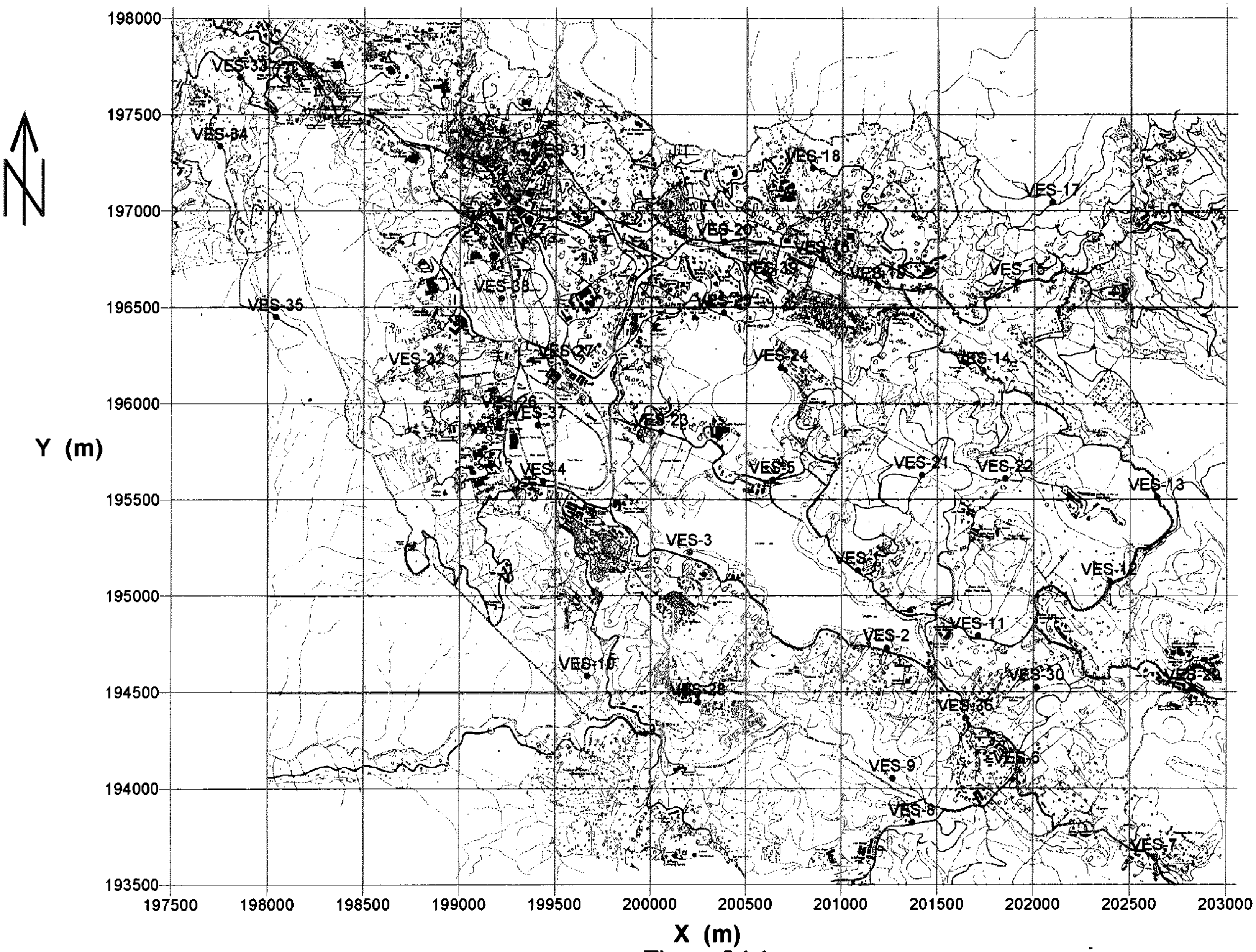



Figure-5.1.1
LOCATION MAP OF THE ELECTRIC SOUNDING SITES

# Table-5.1.1 (1/5)

## RESULTS OF THE ELECTRIC SOUNDING

| No. | COORDINATES | | PROPERTY | LAYERS | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| | Map | GPS | | 1 | 2 | 3 | 4 | 5 | 6 | |
| VES-1 | X=201084 | E80^47'00.9" | Resistivity (Ohm-m) | 253.30 | 58.14 | 720.20 | 1620.70 | 54.85 | 38561.40 | |
| | Y=195132 | N06^57'24.6" | Thickness (m) | 4.40 | 6.11 | 3.25 | 7.32 | 12.54 | - | |
| | ELV=1884 | | Depth (m) | 4.40 | 10.51 | 13.76 | 21.08 | 33.62 | - | |
| | | | Elevation (m) | 1879.6 | 1873.5 | 1870.2 | 1862.9 | 1850.4 | - | |
| VES-2 | X=201237 | E80^47'05.9" | Resistivity (Ohm-m) | 231.20 | 10222.10 | 79.20 | 222.60 | 21807.10 | | |
| | Y=194730 | N06^57'11.5" | Thickness (m) | 3.04 | 0.23 | 5.98 | 103.20 | - | | |
| | ELV=1879 | | Depth (m) | 3.04 | 3.27 | 9.25 | 112.45 | - | | |
| | | | Elevation (m) | 1876.0 | 1875.7 | 1869.8 | 1766.6 | - | | |
| VES-3 | X=200203 | E80^46'32.1" | Resistivity (Ohm-m) | 3647.00 | 34.54 | 4693.00 | 269.00 | | | |
| | Y=195225 | N06^57'27.6" | Thickness (m) | 1.38 | 2.43 | 6.57 | - | | | |
| | ELV=1878 | | Depth (m) | 1.38 | 3.81 | 10.38 | - | | | |
| | | | Elevation (m) | 1876.6 | 1874.2 | 1867.6 | - | | | |
| VES-4 | X=199438 | E80^46'07.1" | Resistivity (Ohm-m) | 607.80 | 76.83 | 296.60 | | | | |
| | Y=195593 | N06^57'39.6" | Thickness (m) | 13.90 | 35.90 | - | | | | |
| | ELV=1881 | | Depth (m) | 13.90 | 49.80 | - | | | | |
| | | | Elevation (m) | 1867.1 | 1831.2 | - | | | | |
| VES-5 | X=200637 | E80^46'46.3" | Resistivity (Ohm-m) | 506.70 | 303.00 | 7982.60 | 137.50 | 15704.50 | | |
| | Y=195602 | N06^57'39.9" | Thickness (m) | 2.67 | 0.28 | 1.04 | 3.17 | - | | |
| | ELV=1887.5 | | Depth (m) | 2.67 | 2.95 | 3.99 | 7.16 | - | | |
| | | | Elevation (m) | 1884.3 | 1884.0 | 1883.0 | 1879.8 | - | | |
| VES-6 | X=201917 | E80^47'28.1" | Resistivity (Ohm-m) | 136.20 | 44.17 | 4068.30 | 270.10 | 1601.20 | | |
| | Y=194095 | N06^56'50.8" | Thickness (m) | 1.89 | 8.14 | 0.35 | 144.60 | - | | |
| | ELV=1901 | | Depth (m) | 1.89 | 10.03 | 10.38 | 154.98 | - | | |
| | | | Elevation (m) | 1899.1 | 1891.0 | 1890.6 | 1746.0 | - | | |
| VES-7 | X=202630 | E80^47'51.4" | Resistivity (Ohm-m) | 101.40 | 1417.70 | 3.26 | 44615.60 | (11.84) | | |
| | Y=193643 | N06^56'36.1" | Thickness (m) | 3.80 | 2.29 | 2.07 | 612.70 | - | | |
| | ELV=1849 | | Depth (m) | 3.80 | 6.09 | 8.16 | 620.86 | - | | |
| | | | Elevation (m) | 1845.2 | 1842.9 | 1840.8 | 1228.1 | - | | |
| VES-8 | X=201372 | E80^47'10.3" | Resistivity (Ohm-m) | 481.00 | 281.00 | 2952.70 | 152.50 | 15006.90 | | |
| | Y=193824 | N06^56'42.0" | Thickness (m) | 2.59 | 3.21 | 25.52 | 64.27 | - | | |
| | ELV=1913 | | Depth (m) | 2.59 | 5.80 | 31.32 | 95.59 | - | | |
| | | | Elevation (m) | 1910.4 | 1907.2 | 1881.7 | 1817.4 | - | | |
| VES-9 | X=201268 | E80^47'06.9" | Resistivity (Ohm-m) | 503.40 | 7767.20 | 1171.60 | 1620.20 | | | |
| | Y=194052 | N06^56'49.4" | Thickness (m) | 1.70 | 3.50 | 14.47 | - | | | |
| | ELV=1915 | | Depth (m) | 1.70 | 5.20 | 19.67 | - | | | |
| | | | Elevation (m) | 1913.3 | 1909.8 | 1895.3 | - | | | |

# Table-5.1.1 (2/5)

## RESULTS OF THE ELECTRIC SOUNDING

| No. | COORDINATES | | PROPERTY | LAYERS | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| | Map | GPS | | 1 | 2 | 3 | 4 | 5 | 6 | |
| VES-10 | X=199670 | E80^46'14.7" | Resistivity (Ohm-m) | 625.20 | 6536.70 | 1585.20 | 469.00 | | | |
| | Y=194583 | N06^57'06.7" | Thickness (m) | 2.80 | 5.56 | 103.30 | - | | | |
| | ELV=1825 | | Depth (m) | 2.80 | 8.36 | 111.66 | - | | | |
| | | | Elevation (m) | 1822.2 | 1816.6 | 1713.3 | - | | | |
| VES-11 | X=201712 | E80^47'21.4" | Resistivity (Ohm-m) | 109.70 | 16.97 | 21935.70 | 12.53 | | | |
| | Y=194792 | N06^57'13.5" | Thickness (m) | 3.45 | 7.69 | 468.20 | - | | | |
| | ELV=1884 | | Depth (m) | 3.45 | 11.14 | 479.34 | - | | | |
| | | | Elevation (m) | 1880.6 | 1872.9 | 1404.7 | - | | | |
| VES-12 | X=202394 | E80^47'43.7" | Resistivity (Ohm-m) | 758.10 | 98.38 | 263.40 | 15321.40 | | | |
| | Y=195074 | N06^57'22.7" | Thickness (m) | 3.22 | 10.51 | 23.91 | - | | | |
| | ELV=1900 | | Depth (m) | 3.22 | 13.73 | 37.64 | - | | | |
| | | | Elevation (m) | 1896.8 | 1886.3 | 1862.4 | - | | | |
| VES-13 | X=202639 | E80^47'51.7" | Resistivity (Ohm-m) | 496.70 | 20317.50 | 159.80 | 9562.50 | 63.12 | | |
| | Y=195510 | N06^57'36.9" | Thickness (m) | 5.23 | 2.99 | 5.74 | 38.00 | - | | |
| | ELV=1890 | | Depth (m) | 5.23 | 8.22 | 13.96 | 51.96 | - | | |
| | | | Elevation (m) | 1884.8 | 1881.8 | 1876.0 | 1838.0 | - | | |
| VES-14 | X=201736 | E80^47'22.2" | Resistivity (Ohm-m) | 344.00 | 4076.90 | 308.40 | 5095.00 | 48.81 | | |
| | Y=196173 | N06^57'58.5" | Thickness (m) | 6.31 | 0.79 | 67.20 | 22.91 | - | | |
| | ELV=1870 | | Depth (m) | 6.31 | 7.10 | 74.30 | 97.21 | - | | |
| | | | Elevation (m) | 1863.7 | 1862.9 | 1795.7 | 1772.8 | - | | |
| VES-15 | X=201914 | E80^47'28.0" | Resistivity (Ohm-m) | 78.98 | 12.79 | 86.05 | 15.08 | | | |
| | Y=196631 | N06^58'13.4" | Thickness (m) | 3.22 | 49.52 | 32.38 | - | | | |
| | ELV=1890 | | Depth (m) | 3.22 | 52.74 | 85.12 | - | | | |
| | | | Elevation (m) | 1886.8 | 1837.3 | 1804.9 | - | | | |
| VES-16 | X=200894 | E80^46'54.7" | Resistivity (Ohm-m) | 35.58 | 2069.00 | 27.34 | 11.29 | 10638.10 | | |
| | Y=196748 | N06^58'17.2" | Thickness (m) | 3.29 | 0.46 | 7.36 | 14.31 | - | | |
| | ELV=1862.0 | | Depth (m) | 3.29 | 3.75 | 11.11 | 25.42 | - | | |
| | | | Elevation (m) | 1858.7 | 1858.3 | 1850.9 | 1836.6 | - | | |
| VES-17 | X=202094 | E80^47'33.9" | Resistivity (Ohm-m) | 204.30 | 4803.30 | 128.20 | 13668.20 | 105.90 | | |
| | Y=197045 | N06^58'26.9" | Thickness (m) | 4.48 | 1.08 | 88.64 | 60.99 | - | | |
| | ELV=1980 | | Depth (m) | 4.48 | 5.56 | 94.20 | 155.19 | - | | |
| | | | Elevation (m) | 1975.5 | 1974.4 | 1885.8 | 1824.8 | - | | |
| VES-18 | X=200845 | E80^46'53.1" | Resistivity (Ohm-m) | 909.80 | 41.90 | 2.80 | 685.90 | | | |
| | Y=197223 | N06^58'32.7" | Thickness (m) | 2.39 | 17.52 | 1.86 | - | | | |
| | ELV=1900 | | Depth (m) | 2.39 | 19.91 | 21.77 | - | | | |
| | | | Elevation (m) | 1897.6 | 1880.1 | 1878.2 | - | | | |

## Table-5.1.1 (3/5)

## RESULTS OF THE ELECTRIC SOUNDING

| No. | COORDINATES | | PROPERTY | LAYERS | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| | Map | GPS | | 1 | 2 | 3 | 4 | 5 | 6 | |
| VES-19 | X=201185 | E80^47'04.2" | Resistivity (Ohm-m) | 241.20 | 68.33 | 18.01 | 55760.20 | (92.32) | | |
| | Y=196612 | N06^58'12.8" | Thickness (m) | 2.97 | 0.26 | 22.54 | 200.70 | - | | |
| | ELV=1863 | | Depth (m) | 2.97 | 3.23 | 25.77 | 226.47 | - | | |
| | | | Elevation (m) | 1860.0 | 1859.8 | 1837.2 | 1636.5 | - | | |
| VES-20 | X=200383 | E80^46'38.0" | Resistivity (Ohm-m) | 220.20 | 151.50 | 17.70 | 30242.50 | | | |
| | Y=196840 | N06^58'20.2" | Thickness (m) | 2.13 | 13.95 | 9.47 | - | | | |
| | ELV=1869 | | Depth (m) | 2.13 | 16.08 | 25.55 | - | | | |
| | | | Elevation (m) | 1866.9 | 1852.9 | 1843.5 | - | | | |
| VES-21 | X=201418 | E80^47'11.8" | Resistivity (Ohm-m) | 787.50 | 6112.10 | 610.90 | | | | |
| | Y=195627 | N06^57'40.7" | Thickness (m) | 4.95 | 25.07 | - | | | | |
| | ELV=1937 | | Depth (m) | 4.95 | 30.02 | - | | | | |
| | | | Elevation (m) | 1932.1 | 1907.0 | - | | | | |
| VES-22 | X=201852 | E80^47'26.0" | Resistivity (Ohm-m) | 703.30 | 382.20 | 136.10 | 361.10 | | | |
| | Y=195608 | N06^57'40.1" | Thickness (m) | 0.86 | 13.78 | 17.36 | - | | | |
| | ELV=1910 | | Depth (m) | 0.86 | 14.64 | 32.00 | - | | | |
| | | | Elevation (m) | 1909.1 | 1895.4 | 1878.0 | - | | | |
| VES-23 | X=200053 | E80^46'27.2" | Resistivity (Ohm-m) | 36.81 | 7426.30 | 18.79 | 10037.10 | 29.19 | | |
| | Y=195851 | N06^57'48.0" | Thickness (m) | 2.70 | 0.28 | 3.74 | 11.73 | - | | |
| | ELV=1879 | | Depth (m) | 2.70 | 2.98 | 6.72 | 18.45 | - | | |
| | | | Elevation (m) | 1876.3 | 1876.0 | 1872.3 | 1860.6 | - | | |
| VES-24 | X=200680 | E80^46'47.7" | Resistivity (Ohm-m) | 70.08 | 7893.60 | 1642.10 | 23.90 | | | |
| | Y=196186 | N06^57'58.9" | Thickness (m) | 3.02 | 2.13 | 81.31 | - | | | |
| | ELV=1906 | | Depth (m) | 3.02 | 5.15 | 86.46 | - | | | |
| | | | Elevation (m) | 1903.0 | 1900.9 | 1819.5 | - | | | |
| VES-25 | X=200380 | E80^46'37.9" | Resistivity (Ohm-m) | 73.65 | 879.30 | 119.10 | 2632.80 | 22.31 | | |
| | Y=196471 | N06^58'08.2 | Thickness (m) | 0.06 | 13.30 | 39.52 | 32.48 | - | | |
| | ELV=1902 | | Depth (m) | 0.06 | 13.36 | 52.88 | 85.36 | - | | |
| | | | Elevation (m) | 1901.9 | 1888.6 | 1849.1 | 1816.6 | - | | |
| VES-26 | X=199260 | E80^46'01.3" | Resistivity (Ohm-m) | 88.34 | 173.10 | 47012.40 | 10.05 | | | |
| | Y=195946 | N06^57'51.1" | Thickness (m) | 6.30 | 36.92 | 23.47 | - | | | |
| | ELV=1887 | | Depth (m) | 6.30 | 43.22 | 66.69 | - | | | |
| | | | Elevation (m) | 1880.7 | 1843.8 | 1820.3 | - | | | |
| VES-27 | X=199554 | E80^46'10.9" | Resistivity (Ohm-m) | 168.00 | 26.74 | 126.00 | 65.22 | 30704.00 | | |
| | Y=196210 | N06^57'59.7" | Thickness (m) | 1.21 | 0.58 | 12.85 | 47.27 | - | | |
| | ELV=1878 | | Depth (m) | 1.21 | 1.79 | 14.64 | 61.91 | - | | |
| | | | Elevation (m) | 1876.8 | 1876.2 | 1863.4 | 1816.1 | - | | |

# Table-5.1.1 (4/5)

## RESULTS OF THE ELECTRIC SOUNDING



| No. | COORDINATES | | PROPERTY | LAYERS | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| | Map | GPS | | 1 | 2 | 3 | 4 | 5 | 6 | |
| VES-28 | X=200249 | E80^46'33.6" | Resistivity (Ohm-m) | 738.70 | 301.50 | 48.70 | 6834.00 | 35.76 | | |
| | Y=194448 | N06^57'02.3" | Thickness (m) | 1.25 | 8.05 | 8.84 | 6.18 | − | | |
| | ELV=1894 | | Depth (m) | 1.25 | 9.30 | 18.14 | 24.32 | − | | |
| | | | Elevation (m) | 1892.8 | 1884.7 | 1875.9 | 1869.7 | − | | |
| VES-29 | X=202826 | E80^47'57.8" | Resistivity (Ohm-m) | 172.60 | 1948.10 | 40454.60 | 145.70 | 6685.20 | | |
| | Y=194525 | N06^57'04.8" | Thickness (m) | 4.76 | 2.75 | 2.33 | 31.65 | − | | |
| | ELV=1917 | | Depth (m) | 4.76 | 7.51 | 9.84 | 41.49 | − | | |
| | | | Elevation (m) | 1912.2 | 1909.5 | 1907.2 | 1875.5 | − | | |
| VES-30 | X=202018 | E80^47'31.4" | Resistivity (Ohm-m) | 397.20 | 797.90 | 127.00 | 14782.30 | | | |
| | Y=194525 | N06^57'04.8" | Thickness (m) | 5.98 | 26.16 | 43.99 | − | | | |
| | ELV=1909 | | Depth (m) | 5.98 | 32.14 | 76.13 | − | | | |
| | | | Elevation (m) | 1903.0 | 1876.9 | 1832.9 | − | | | |
| VES-31 | X=199523 | E80^46'09.9" | Resistivity (Ohm-m) | 524.90 | 1136.40 | 31.30 | 11511.00 | | | |
| | Y=197254 | N06^58'33.7" | Thickness (m) | 2.32 | 3.77 | 14.21 | − | | | |
| | ELV=1900 | | Depth (m) | 2.32 | 6.09 | 20.30 | − | | | |
| | | | Elevation (m) | 1897.7 | 1893.9 | 1879.7 | − | | | |
| VES-32 | X=198777 | E80^45'45.4" | Resistivity (Ohm-m) | 534.10 | 975.60 | 195.60 | 26.25 | | | |
| | Y=196170 | N06^57'58.4" | Thickness (m) | 1.11 | 9.75 | 19.71 | − | | | |
| | ELV=1911 | | Depth (m) | 1.11 | 10.86 | 30.57 | − | | | |
| | | | Elevation (m) | 1909.9 | 1900.1 | 1880.4 | − | | | |
| VES-33 | X=197852 | E80^45'15.3" | Resistivity (Ohm-m) | 464.20 | 231.80 | 86884.40 | 24596.10 | 3093.50 | | |
| | Y=197693 | N06^58'48.0" | Thickness (m) | 3.00 | 5.47 | 7.39 | 64.84 | − | | |
| | ELV=1975 | | Depth (m) | 3.00 | 8.47 | 15.86 | 80.70 | − | | |
| | | | Elevation (m) | 1972.0 | 1966.5 | 1959.1 | 1894.3 | − | | |
| VES-34 | X=197748 | E80^45'11.9" | Resistivity (Ohm-m) | 1109.70 | 4317.90 | 190.00 | 49141.30 | | | |
| | Y=197337 | N06^58'36.4" | Thickness (m) | 4.77 | 9.89 | 31.02 | − | | | |
| | ELV=2055 | | Depth (m) | 4.77 | 14.66 | 45.68 | − | | | |
| | | | Elevation (m) | 2050.2 | 2040.3 | 2009.3 | − | | | |
| VES-35 | X=198042 | E80^45'21.5" | Resistivity (Ohm-m) | 4078.50 | 1955.30 | 306.60 | 1149.70 | | | |
| | Y=196450 | N06^58'07.5" | Thickness (m) | 3.25 | 21.48 | 9.93 | − | | | |
| | ELV=2063 | | Depth (m) | 3.25 | 24.73 | 34.66 | − | | | |
| | | | Elevation (m) | 2059.8 | 2038.3 | 2028.3 | − | | | |
| VES-36 | X=201650 | E80^47'19.4" | Resistivity (Ohm-m) | 115.20 | 1.82 | 7303.10 | 13.80 | 3287.30 | | |
| | Y=194365 | N06^56'59.6" | Thickness (m) | 5.30 | 1.48 | 19.77 | 31.92 | − | | |
| | ELV=1884 | | Depth (m) | 5.30 | 6.78 | 26.55 | 58.47 | − | | |
| | | | Elevation (m) | 1878.7 | 1877.2 | 1857.5 | 1825.5 | − | | |

# Table-5.1.1 (5/5)

## RESULTS OF THE ELECTRIC SOUNDING

| No. | COORDINATES | | PROPERTY | LAYERS | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| | Map | GPS | | 1 | 2 | 3 | 4 | 5 | 6 | |
| VES-37 | X=199410 | E80^46'06.2" | Resistivity (Ohm-m) | 77.65 | 9.67 | 5348.20 | 52.10 | 3901.80 | | |
| | Y=195888 | N06^57'49.2" | Thickness (m) | 1.75 | 0.26 | 9.12 | 8.67 | | | |
| | ELV=1881 | | Depth (m) | 1.75 | 2.01 | 11.13 | 19.80 | | | |
| | | | Elevation (m) | 1879.3 | 1879.0 | 1869.9 | 1861.2 | | | |
| VES-38 | X=199220 | E80^46'00.0" | Resistivity (Ohm-m) | 365.90 | 4384.90 | 101.50 | 3798.00 | 309.30 | | |
| | Y=196545 | N06^58'10.6" | Thickness (m) | 4.94 | 3.37 | 10.17 | 11.11 | | | |
| | ELV=1880 | | Depth (m) | 4.94 | 8.31 | 18.48 | 29.59 | | | |
| | | | Elevation (m) | 1875.1 | 1871.7 | 1861.5 | 1850.4 | | | |
| VES-39 | X=200622 | E80^46'45.8" | Resistivity (Ohm-m) | 443.40 | 21.12 | 2106.30 | 209.00 | 4.44 | 1120.60 | |
| | Y=196640 | N06^58'13.7" | Thickness (m) | 1.71 | 0.31 | 2.89 | 7.21 | 16.57 | | |
| | ELV=1878 | | Depth (m) | 1.71 | 2.02 | 4.91 | 12.12 | 28.69 | | |
| | | | Elevation (m) | 1876.3 | 1876.0 | 1873.1 | 1865.9 | 1849.3 | | |
| VES-40 | | | Resistivity (Ohm-m) | | | | | | | |
| | | | Thickness (m) | | | | | | | |
| | | | Depth (m) | | | | | | | |
| | | | Elevation (m) | | | | | | | |

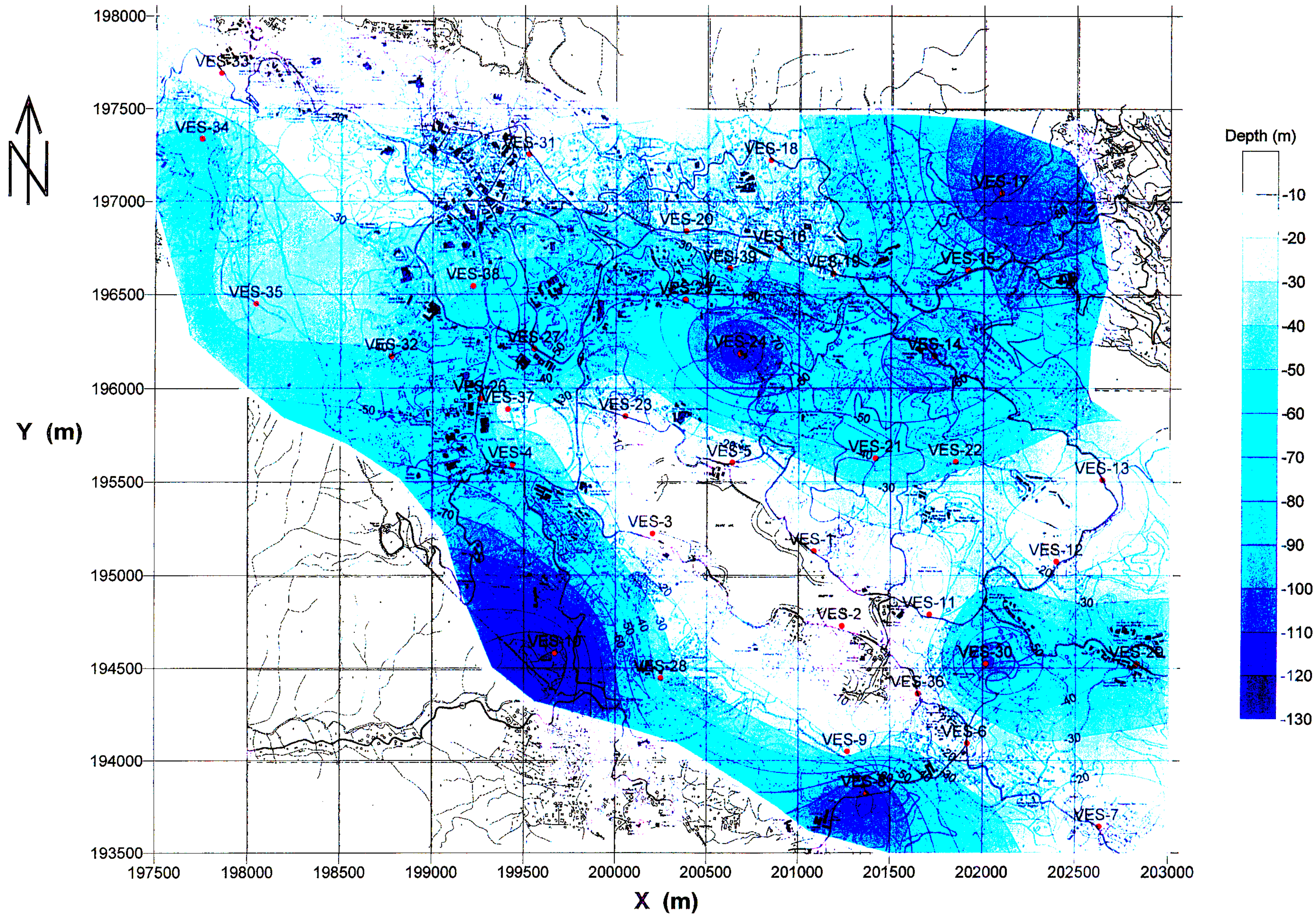



Figure-5.1.2 Estimated Basement Depth of Weathered Gneiss

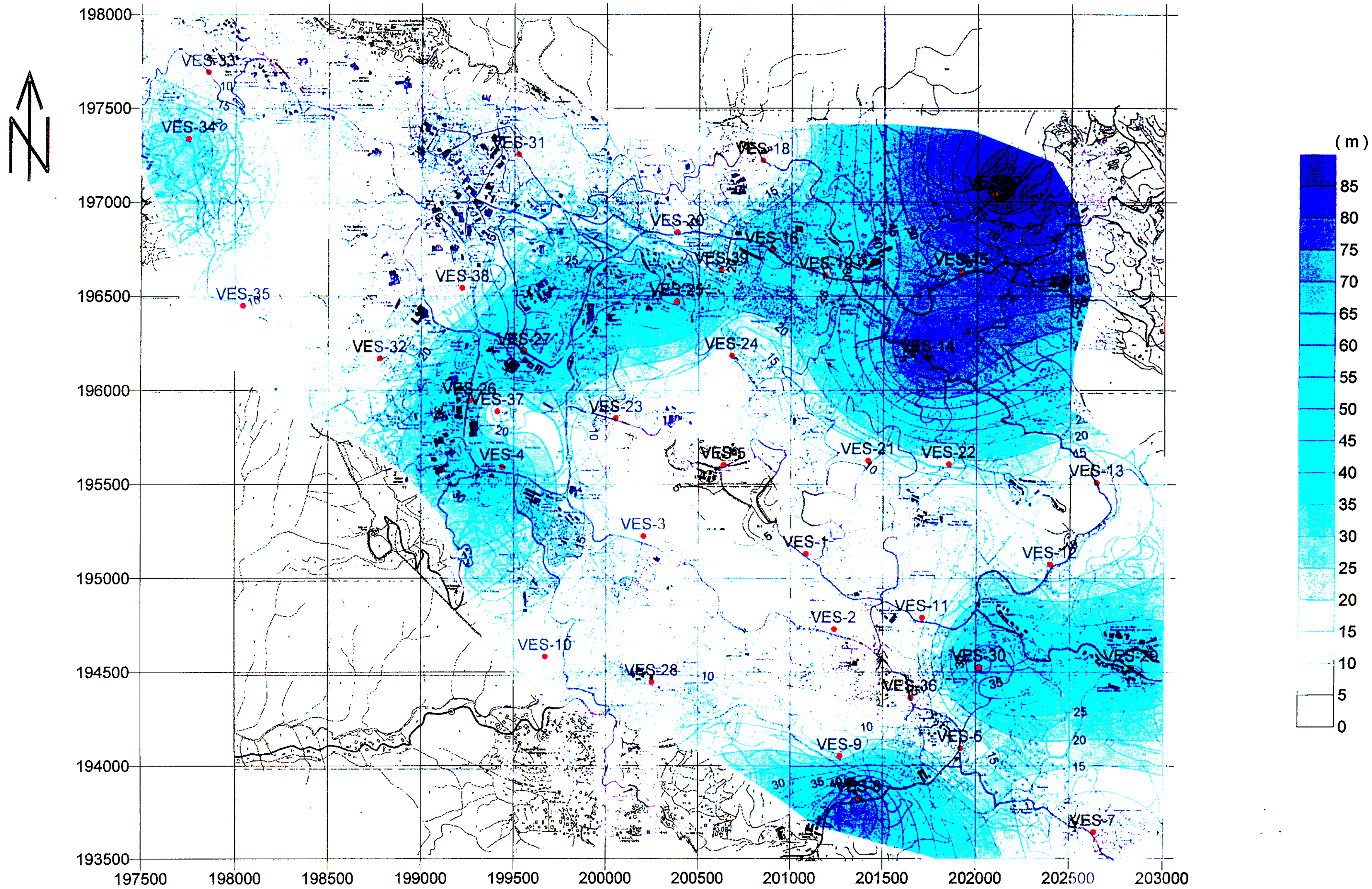



Figure-5.1.3 Estimated Thickness of Weathered Gneiss

## 5.2 Electromagnetic Sounding

Electromagnetic sounding by Loop-Loop method was carried out for the purpose of confirming the location of faults, and investigating the condition of fractured zone associated with the faults. For this purpose, survey lines were laid perpendicularly across a fault, and measuring points were moved horizontally. Total survey sites and survey lines were 64 sites, and 65 lines, respectively. Loop-Loop distances were 30m and 60m.

The locations of major faults were confirmed in many places, as the electromagnetic response was so sensible. This is probably because the major faults contain a lot of water. However, a major fault inferred at Seetha Eliya was not detected. As for the other minor faults, the electromagnetic response was not so clear and detected at few sites. **Fig-5.2.1** shows typical measurement results. In this figure, the intensity of electromagnetic response is converted into apparent resistivity(Ω-m).

The example at the top of **Fig-5.2.1** shows the result of measurement over the fractured zone extended from northern part of town area to Golf Course. The survey line was laid near the test boring site (32/28) drilled by the previous JICA Study. A major fault line passing through Nuwara Eliya Town to Hawa Eliya, which is described in the geological map of Nuwara Eliya, is inferred to pass this area. This graph shows the response of the fault at 80m point on the survey line. Since the graph of depth-30m, fluctuating between 20 to 40 Ω-m, shows low resistivity value at 40m point and 50m point, another fault or fractured zone is inferred at the section between 40 to 50m point. As the resistivity values at a survey depth-60m are very low at all measuring points (7～9Ω-m), the layer underlying subsurface layer is inferred to be weathered rock containing water, but of low permeability. This interpretation matches the record obtained by the test boring. According to the record, weathered rock occurred at shallower depth than 25m, overlying gneiss. The record also describes fractures developed in gneiss at every few meters.

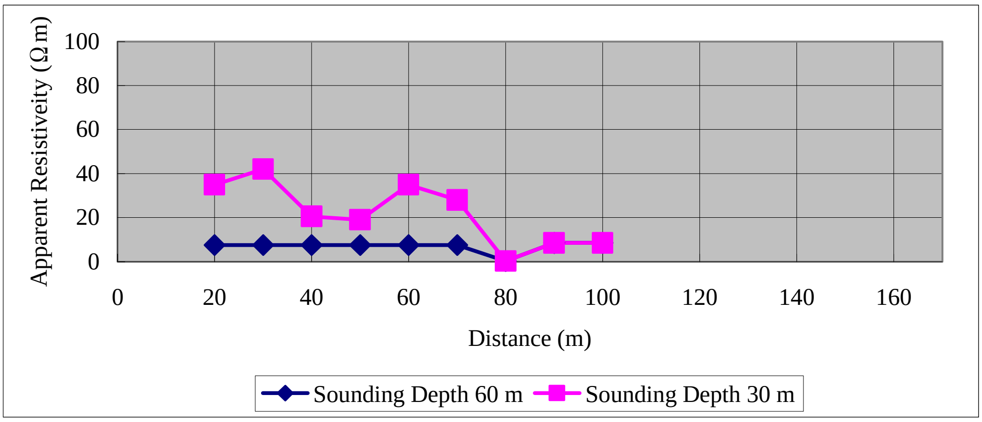
The example at the middle in **Fig-5.2.1** shows the result of measurement over the same fault as mentioned above at Play Ground in Hawa Eliya. The graph of the survey depth 60m shows the location of the fault between 70m to 80m points. As the graph shows almost constant low resistivity at 20Ω-m at both sides out of this section, existence of well developed fractured rocks (aquifer) is inferred at this level.

Resistivity at shallow depth was too low to measure. Although existence of strongly weathered rock saturated with water is inferred, it was not confirmed. The well of INCO neighboring to this site utilizes groundwater at this level.

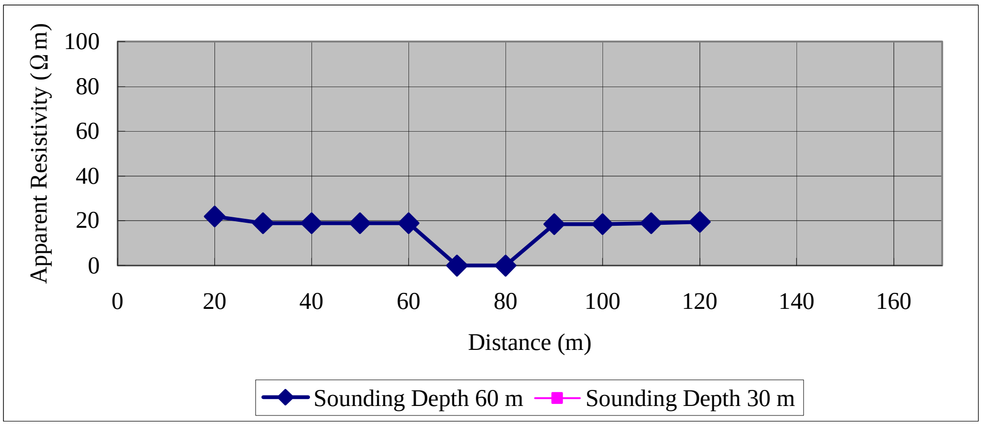
The example at the bottom in **Fig.5.2.1** shows the result of measurement at Bibile Garment Factory located at Magasthota area near Gregory Lake. This site is on the extension of a fault running from Nuwara Eliya Town to Upper Lake. Unfortunately, the valley was too narrow to extend the survey line enough. As the apparent resistivity ranges from 5 to 9 Ω-m, existence of weathered rock saturated with water is inferred. Although the well of this Factory is so deep as 93m, the water yield is little at 346$m^3$/day. This means that large amount of water yield cannot be expected from weathered rocks with low permeability.

**Figure-5.2.1 Typical Measurement Results of Electromagnetic Survey**

Name of Area : Golf Course, Kyandy Road Survey Line : Z
Direction : N15E

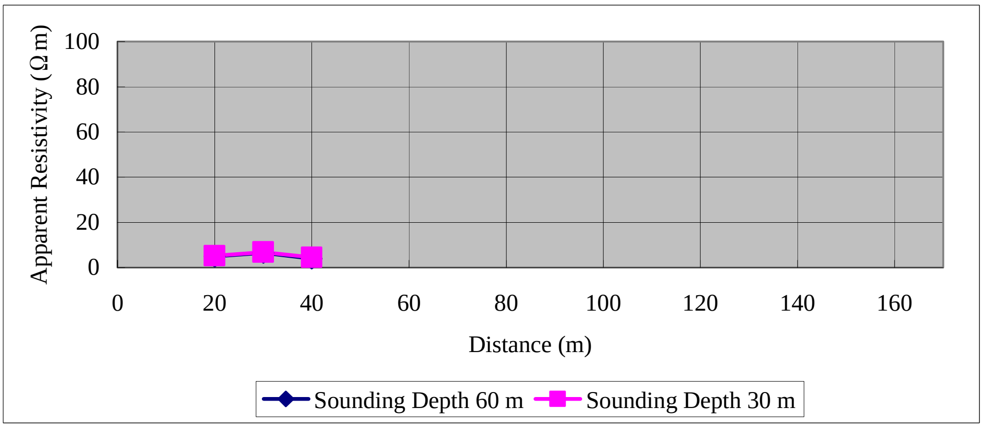



Name of Area : Play ground, Hawa Eliya Survey Line : FFF
Direction : N270E




Note : Sounding depth 30 m observed very low resistivity

Name of Area : Bibile Garment Fac., Magasthota Survey Line : F
Direction : N35E



### 5.3 Preliminary Selection of Proposed Sites for Well Construction

Much of important knowledge for grasping the situation of groundwater basin, such as the basement depth of weathered gneiss, is obtained by the geophysical survey (electric sounding and electromagnetic survey) as mentioned above. As the result, the areas where thick aquifer (more than 30m) is extended are estimated in Haddon Hill, western to northern side of Race Course, Hawa Eliya, and Barrack Plain Reservoir, etc. As for the Hawa Eliya, the previous JICA study also selected it as a promising area. In Gregory Lake area, including Upper Lake Road, which was proposed by the previous JICA Study, it is revealed by geophysical survey that the thickness of aquifer is very thin (less than 5 to 10m). This result would not support the conclusion by Social Development Study.

The reason of the proposal by the previous JICA Study was that the water yield observation from the test well exceeded 1,440 $m^3$/day instantaneously, though the pumping test itself was interrupted. Consequently, the water yield of more than 1,000$m^3$/day was estimated. However, the pumping test was obliged to interrupt because of high drawdown at the first stage of the step test (575$m^3$/day). Nevertheless, safety water yield at 400$m^3$/day was estimated by this pumping test.

The previous JICA Study concluded that the proposal for the sites is a tentative plan, so that it should be confirmed or revised by additional pumping test at the additional test wells constructed in proper measures.

As the propriety of the groundwater development plan in the Upper Lake Road is not verified by the Basic Design Study, this area is excluded from proposed plan. The following two areas are selected preliminary as proposed sites for groundwater development from geophysical, topographical, and geological points of view.

A. Hawa Eliya area（including Barrack Plain Reservoir area）

B. Race Course area（including Haddon Hill area）

In addition to the above-mentioned two areas, Golf Course area, where a pumping test was carried out successfully by the previous JICA Study, was also considered as promising for groundwater development. However, as there was a official information at that time that the expropriation of land would meet some difficulties, the Golf Course area was eliminated.Consequently, the test borings for Test were carried out in the above-mentioned two areas on order to confirm geological conditions and capacity of water yield.

## 6. Test Boring

### 6.1 Location of Boring Sites

Test borings at three sites in all were carried out; one site in Race Course area (Site Name:TB-1, Race Course entrance)、 and two sites in Hawa Eliya area (Site name:TB-2, in front of a school, and TB-3, Play Ground).

## 6.2 Method of Test Boring

### 6.2.1 Boring Machine

（1）TB-１Site：
Rotary Machine
STRATA DRILL 40（EDESCO）
Drilled by Diamond Bit

（2）TB-2 Site：
TOP-150（Tone,1984）
Compressor DSP-540HS
(10.5 kg/cm²)
Down the Hole Hammer Machine

This machine was used at TB-1, but –it could not penetrate collapsed zone.

（3）TB-3 Site：
Unknown Name（U.K.）
Down the Hole Hammer Machine
Compressor（10.5 kg/cm²）

### 6.2.2 Method of the Study

### (1) Drilling Method

TB-1 Site：Down the hole hammer drilling（47.5m）
& Rotary core drilling （47.5m～104.25m）

TB-2 Site：Down the hole hammer drilling（81.0m）
TB-３Site：Down the hole hammer drilling（till 44.2m）

**(2) Geological Observation**

Geological observation was carried out to check rock type, degree of weathering, etc., using boring slime and fragments, which are blown up to the mouth of borehole by compressed air and water. The slime and fragments were collected using a small pan laid on the ground surface. Calcareous fragment ( limestone, calcite vein) was confirmed by dropping a drop of dilute Hydrochloric acid on the fragment. Slime and fragment samples collected at every three meters were put in vinyl sacks. Core samples at TB-1 were put in core boxes. These samples are placed at the NWSDB, KANDY.

**(3) Geophysical Logging**

Geophysical logging (electric logging and temperature logging) was carried out immediately after the completion of drilling at each site. On the basis of the logging data and geological observation, geological column was prepared.

**(4) Pumping Test**

At the pumping test, the following air-water separator and triangle weir were used for measuring water yield, as shown in pictures. During drilling works, water yield was measured using a five-liters bucket and a stopwatch.

**Separator**

**Triangle weir**

**(5) Water Quality Test**

Water quality test was carried out at the end of pumping test at each site using a simple water quality tester (pack-test), EC meter, and pH meter.

## 6.3 Results of the Study

### 6.3.1 Boreholes

**Fig-6.3.1** shows the inner structure of borehole at each site, such as drilling diameter, casing size, and the depth of casing installation.

**TB-1 Site**： Although a down the hole machine, which was used at TB-1 site, was used again at the beginning, it could not penetrate and pass collapsed zone (fractured rocks) between 44.5m to 58m in depth. Inevitably, the machine was changed to another rotary machine, which uses mad water and diamond core bits, and simultaneously drilling diameter was reduced to 75mm in order to install casing pipes in the borehole. The total depth drilled is 104.25m.

**TB-2 Site**： Borehole was drilled using down the hole hammer up to the depth of 81.0 m. When the borehole encountered a fractured zone at the depth of 79.9 m the amount of water yield increased suddenly.

**TB-3 Site**： When the borehole was drilled up to 42.0m by down the hole hammer, it encountered a fractured zone accompanied with much groundwater flashing. Although the borehole was drilled further till 44.2 m, the water pressure was too high for hammering. Consequently, drilling was interrupted at the depth of 44.2 m.

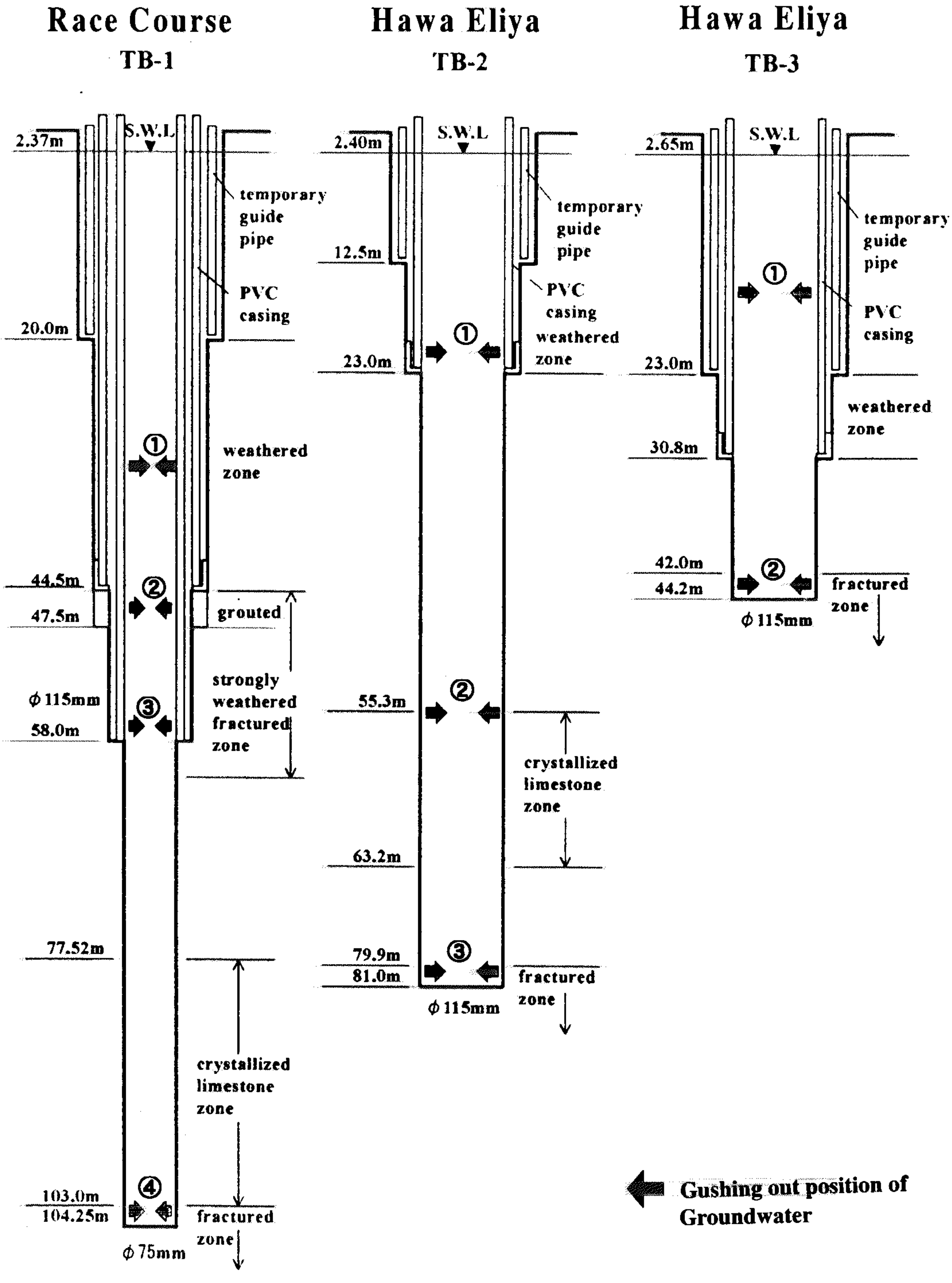



Figure-6.3.1 Structure of Test Boring

### 6.3.2 Result of Geophysical Logging

**Fig-6.3.2**, **Fig-6.3.3**, and **Fig-6.3.4** show the geological column and the results of electric logging at each boring site. These figures show that the fractured zone accompanied with groundwater and low resistivity zone are clearly coincided.

## GEOLOGY

| DEPTH (m) | OBSERVATIONS |
|---|---|
| 8.0 | yellowish brown, clayey soil |
| 20.0 | dark brown soil |
| 38.2 | strongly weathered rocks (biotite gneiss) |
| 44.5 | quartzites (weathered) |
| 47.5 | quartzites (strongly weathered zone) |
| 58.0 | gneiss (strongly weatherd zone) |
| 66.2 | gneiss, garnet rich |
| 73.1 | leucocratic gneiss<br>68.25-69.5m graphite rich |
| 77.52 | biotite, garnet gneiss<br>graphite rich |
| 103.0 | crystallized limestines with quartz veins<br>98.74-98.79m graphite rich |
| 104.4 | quartzites (fractured zone) |

## ELECTRIC LOGGING DATA
## TB-1

25cm: ········ 50cm: ········
100cm: -------- SP : ————

* DEPTH SCALE=1/500 *

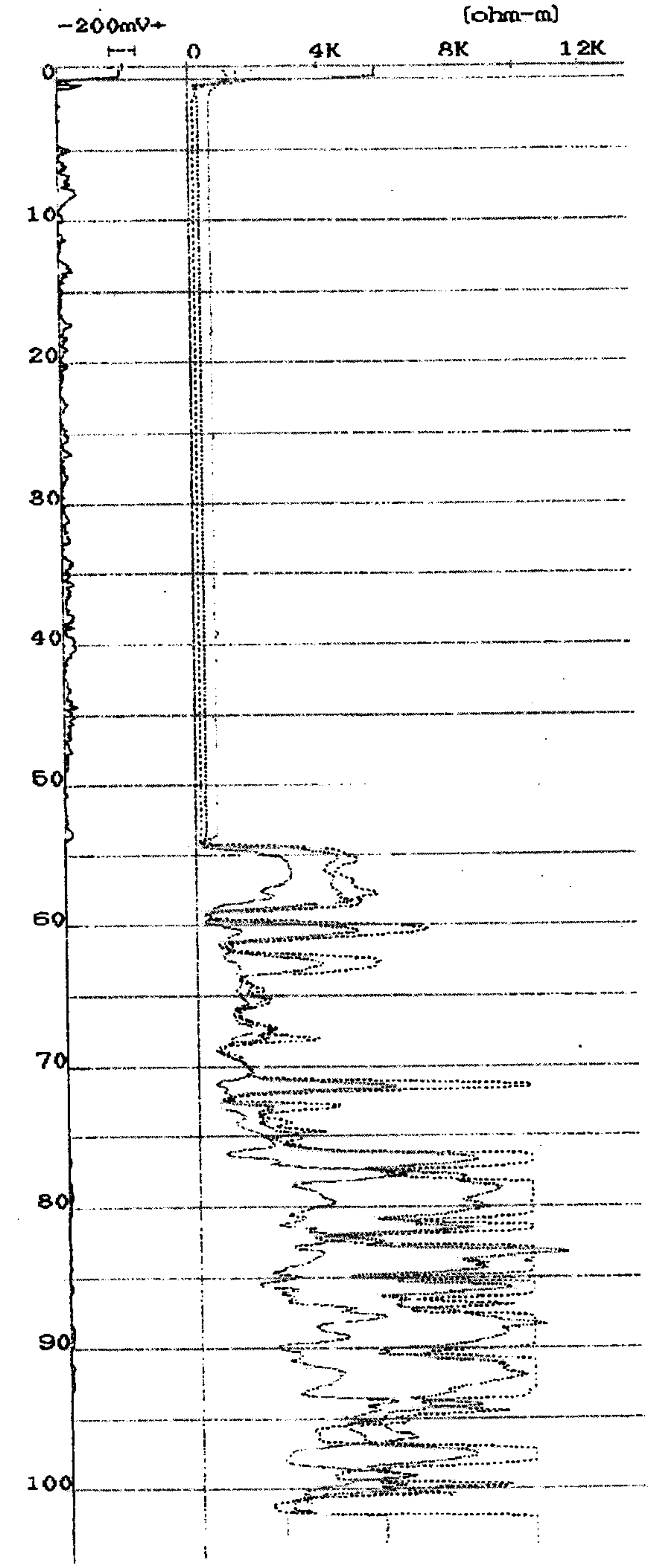



**Figure-6.3.2** Geological and Electrical Logging Data at TB-1

## GEOLOGY

| DEPTH (m) | OBSERVATIONS |
|---|---|
| 3.0 | black soil |
| 21.0 | yellowish brown, clayey soil assosiated with redish brown laterites |
| 32.0 | strongly weathered rocks (biotite gneiss)<br>28.0-28.5m quartzites or quartz veins<br>28.5-29.0m graphite rich biotite gneiss |
| 55.3 | crystallized limestines with quartz veins |
| 63.2 | crystallized limestines with quartz veins (fractured zone/aquifer) |
| 69.5 | biotite, garnet gneiss with quartz vein |
| 72.0 | quartzites |
| 74.4 | biotite, garnet gneiss graphite rich |
| 81.0 | quartzites (fractured zone/aquifer) |

## ELECTRIC LOGGING DATA TB-2

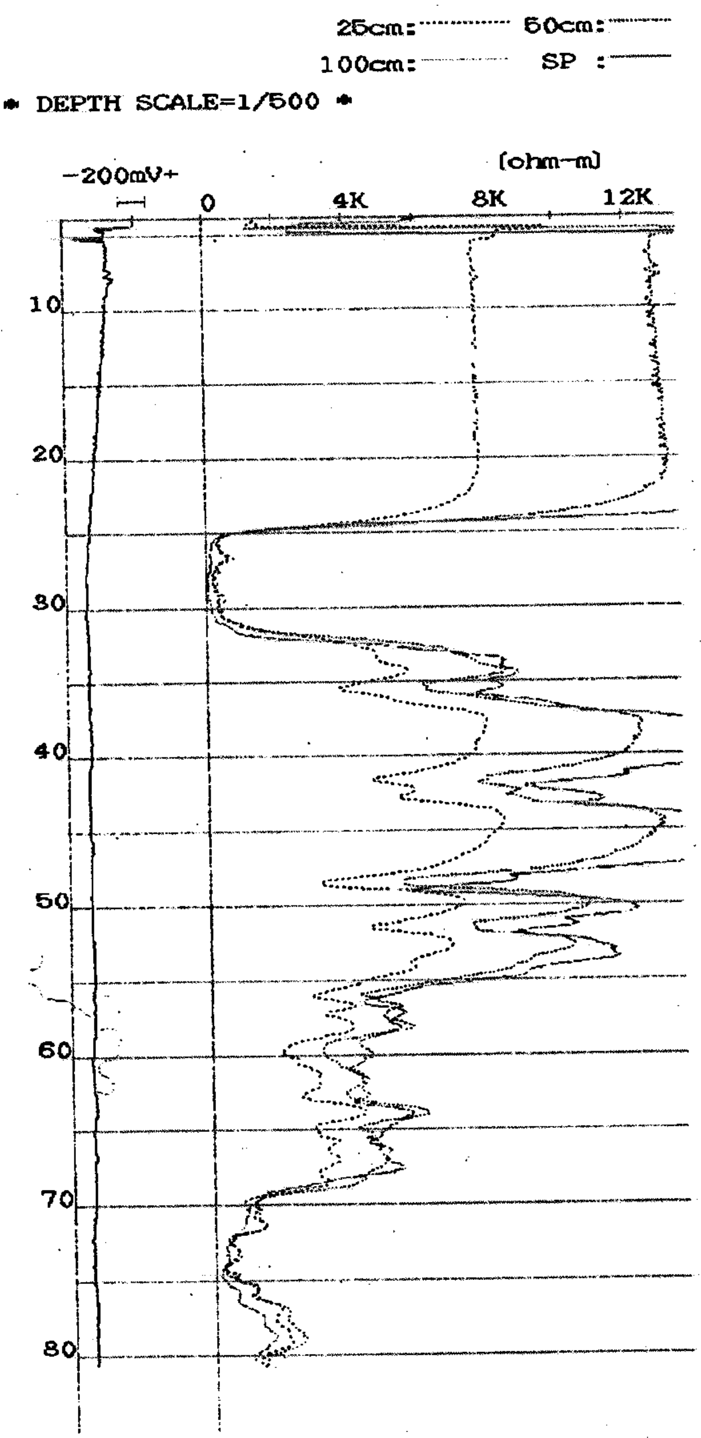



**Figure-6.3.3** Geological and Electrical Logging Data at TB-2

## GEOLOGY

## ELECTRIC LOGGING DATA

### TB-3

| DEPTH (m) | OBSERVATIONS |
|---|---|
| 3.0 | black soil |
| 20.0 | yellowish brown, clayey soil associated with redish brown laterites |
| 30.8 | weathered rocks (biolite gneiss) |
| 42.0 | quartzites (weathered) |
| 44.2 | quartzites (fractured zone) |

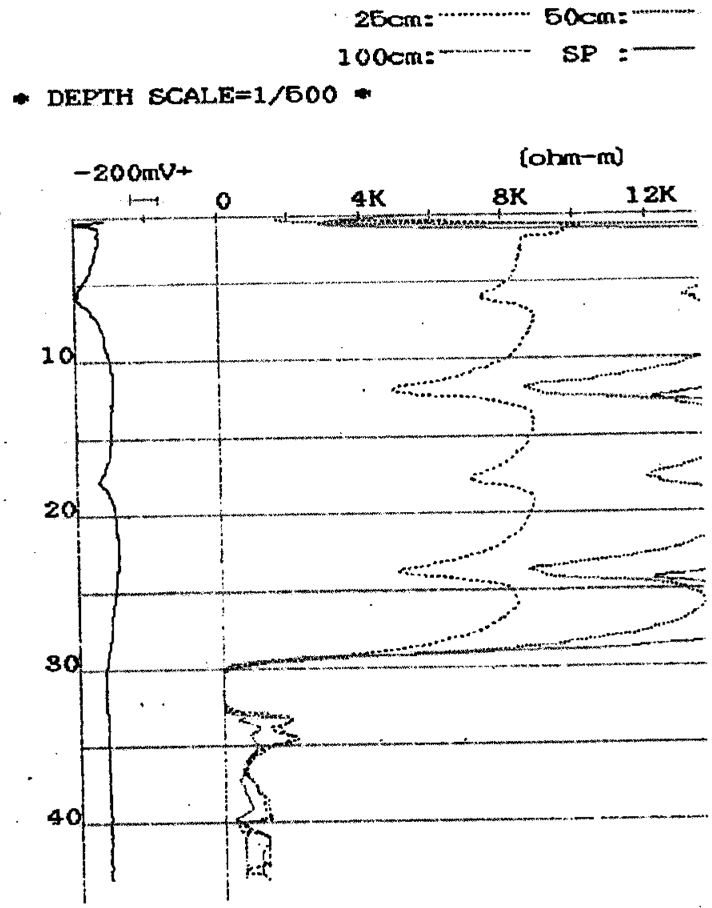



**Figure-6.3.4** Geological and Electrical Logging Data at TB-3

### 6.3.3 Result of Pumping Test

As the borehole diameter is too small to install a submersible pump in the borehole, pumping test was carried out by mean of the airlifting method by using high-pressure compressor. **Table-6.3.1** ~ **Table-6.3.3** show pumping test data. **Fig-6.3.5**～**Fig-6.3.15** show the results of pumping data analysis.

#### (1) TB-1 Site

Heavy collapse of the borehole wall occurred during drilling at the site TB-1. As cementation work for protecting the collapsed wall and borehole size reduction to 75mm were required, the airlifting test was carried out at two times, immediately before the size reduction (at depth of 47.5m) and after completion of drilling (at depth of 104.25m).

After installation of casing pipes for protecting the collapsed zone from 40.25m to 44.5m (where groundwater gushed out), drilling was continued for three meters up to 47.5m. However, the collapsed zone was continued still, so that there was no more means than cementation for the protection of collapsed wall. For this reason, the first airlifting test was conducted.

Although the cementation work at this time had no other choice than cement dropping down to the bottom of the hole, it was failed due to obstacles of collapsed rocks. Hence, the installation of casing pipes was required for further continuation of drilling. Then, the drilling size was reduced inevitably to 75mm. This is the reason of change drilling machine from a down-the-hole-hammer machine to a rotary drilling machine.

As the collapsed zone, which yields groundwater to some extent, continued till 58.0m, casing pipes were installed up to this level. (An alternative measure by screen installation could be taken in the execution stage.)

The second airlifting test was carried out at the time when the drilling was completed at depth of 104.25m. Although a similar fractured zone, which yields groundwater as obtained at the site TB-2, occurred from depth of 103.0m to the bottom of borehole, the further drilling was beyond the capacity of the drilling machine.

Because of such reasons as covering fractured zone by casing pipes, size reduction of borehole, and shortage of borehole depth, the water yield by airlifting test was not enough. The yield was 62～157$m^3$/day（82.5$m^3$/day in average）at the first airlifting test, and 10$m^3$/day at the second airlifting test.

Daily simple observation of groundwater yield, which overflowed out of the mouse of borehole during drilling, recorded 40 to 100 Liters/min. This amount is equivalent to less than a half of the similar observation record of 100 to 250 liters/min at TB-2 and TB-3.

The gushing out position of groundwater at the site TB-1 is in the same geological conditions as at the site TB-2 and TB-3, where sufficient groundwater was obtained. Therefore, it is considered that much more amount of yield could be obtained if the collapsed zone were protected by screen without cementation, and if the borehole could be drilled 10～15m deeper. However, it is also considered that even if such a condition were fulfilled the consequent yield would not exceed more than a half of those at the site TB-2 and TB-3.

**(2) TB-2 Site**

At the site TB-2, the Step Test was carried out in order to investigate the correlation between amount of water airlifted and dynamic water level. At first, groundwater was airlifted continuously at 480 $m^3$/day till dynamic water level became stable. Then, the airlifting was further continued with raised yield at 600 $m^3$/day till dynamic water level became stable at 33 m. After confirming the stable groundwater level, the Recovery Test was started.

Daily observation of yield fluctuation during drilling such as a sudden increase of yield at depth lower than 79.9 m, suggests that much more yield would be obtained by additional drilling more than 10 m.

**(3) TB-3 Site**

The drilling encountered a heavily fractured zone at and below depth of 42m, and a great amount of groundwater started to flash out as if it were an artesian well at that time. As the water pressure was so high that the drilling hammer did not work, the drilling was interrupted inevitably at depth 44.2 m.

The airlifting test was carried out with flashing rate at approximately 700$m^3$/day in average. When the air-pressure was raised a little more, groundwater yield at an amount of more than 1,440 $m^3$/day overflowed a triangular weir for the measurement of water flow. More over, the dynamic water level was less than only two meters. This shows that the fractured zone forms a excellent aquifer. As this fractured zone is estimated to continue further in depth, a deeper well construction is recommended to keep a sufficient thickness of aquifer at this site.

## Table-6.3.1 AIR-LIFTING TEST DATA
## TB-1-1 (58m)

| Time (h:m:s) | Time (sec) | Depth to WL (m) | H (cm) | Discharge (Litre/min) | Remarks |
|---|---|---|---|---|---|
| 9:00:00 | 0 | 2.49 | | | Static W.L=3.90-1.41=2.49m |
| 9:01:40 | 100 | 24.19 | | | Step Test 1 |
| 9:02:00 | 120 | 24.89 | 6.0 | 74 | |
| 9:03:00 | 180 | 26.21 | 7.0 | 109 | |
| 9:04:00 | 240 | 26.59 | 7.0 | 109 | |
| 9:05:00 | 300 | 26.44 | 6.8 | 101 | |
| 9:06:00 | 360 | 26.38 | 6.5 | 90 | |
| 9:07:00 | 420 | 26.74 | 6.0 | 74 | |
| 9:08:00 | 480 | 26.41 | 6.0 | 74 | |
| 9:09:00 | 540 | 26.43 | 6.0 | 74 | |
| 9:10:00 | 600 | 26.50 | 6.0 | 74 | |
| 9:15:00 | 900 | 26.49 | 5.8 | 68 | |
| 9:20:00 | 1200 | 26.65 | 5.8 | 68 | |
| 9:25:00 | 1500 | 26.52 | 5.0 | 47 | |
| 9:30:00 | 1800 | 26.62 | 4.8 | 42 | |
| 9:40:00 | 2400 | 26.59 | 4.6 | 38 | |
| 9:50:00 | 3000 | 26.59 | 4.6 | 38 | |
| 10:00:00 | 3600 | 26.59 | 4.6 | 38 | |
| 10:01:00 | 3660 | 28.59 | 6.2 | 80 | Step Test 2 |
| 10:02:00 | 3720 | 28.76 | 5.8 | 68 | |
| 10:03:00 | 3780 | 29.29 | 5.9 | 71 | |
| 10:05:00 | 3900 | 29.04 | 5.7 | 65 | |
| 10:06:00 | 3960 | 29.15 | 5.6 | 62 | |
| 10:07:00 | 4020 | 29.35 | 5.5 | 60 | |
| 10:08:00 | 4080 | 29.09 | 5.3 | 54 | |
| 10:09:00 | 4140 | 29.25 | 5.2 | 52 | |
| 10:10:00 | 4200 | 29.32 | 5.2 | 52 | |
| 10:15:00 | 4500 | 29.12 | 5.0 | 47 | |
| 10:20:00 | 4800 | 29.32 | 5.0 | 47 | |
| 10:25:00 | 5100 | 29.17 | 5.2 | 52 | |
| 10:30:00 | 5400 | 29.13 | 5.2 | 52 | |
| 10:40:00 | 6000 | 29.18 | 5.0 | 47 | |
| 10:50:00 | 6600 | 29.19 | 5.2 | 52 | |
| 11:00:00 | 7200 | 29.23 | 5.2 | 52 | |
| 11:01:00 | 7260 | 30.49 | | | Step Test 3 |
| 11:01:30 | 7290 | 31.94 | 6.3 | 84 | |
| 11:02:00 | 7320 | 32.21 | 6.3 | 84 | |
| 11:03:00 | 7380 | 32.54 | 6.3 | 84 | |
| 11:04:00 | 7440 | 32.79 | 6.0 | 74 | |
| 11:05:00 | 7500 | 32.85 | 6.0 | 74 | |
| 11:06:00 | 7560 | 32.99 | 6.0 | 74 | |
| 11:07:00 | 7620 | 32.99 | 5.8 | 68 | |
| 11:08:00 | 7680 | 33.08 | 5.6 | 62 | |
| 11:09:00 | 7740 | 33.11 | 5.5 | 60 | |
| 11:10:00 | 7800 | 33.17 | 5.5 | 60 | |
| 11:15:00 | 8100 | 33.15 | 5.4 | 57 | |
| 11:20:00 | 8400 | 33.16 | 5.3 | 54 | |
| 11:25:00 | 8700 | 33.17 | 5.0 | 47 | |
| 11:30:00 | 9000 | 33.21 | 5.0 | 47 | |
| 11:40:00 | 9600 | 33.20 | 5.0 | 47 | |
| 11:50:00 | 10200 | 33.24 | 5.3 | 54 | |
| 12:00:00 | 10800 | 33.29 | 5.3 | 54 | |
| 12:30:00 | 12600 | 33.30 | 6.0 | 74 | |
| 13:00:00 | 14400 | 33.29 | 5.8 | 68 | |
| 13:01:00 | 14460 | 32.84 | | | Recovery Test |
| 13:01:30 | 14490 | 32.16 | | | |
| 13:02:00 | 14520 | 31.59 | | | |

No.

## Table-6.3.1 AIR-LIFTING TEST DATA
## TB-1-1 (58m)

| Time (h:m:s) | Time (sec) | Depth to WL (m) | H (cm) | Discharge (Litre/min) | Remarks |
|---|---|---|---|---|---|
| 13:03:00 | 14580 | 30.45 | | | |
| 13:04:00 | 14640 | 29.31 | | | |
| 13:05:00 | 14700 | 28.25 | | | |
| 13:06:00 | 14760 | 27.21 | | | |
| 13:07:00 | 14820 | 26.21 | | | |
| 13:08:00 | 14880 | 25.30 | | | |
| 13:09:00 | 14940 | 24.36 | | | |
| 13:10:00 | 15000 | 23.49 | | | |
| 13:15:00 | 15300 | 19.76 | | | |
| 13:20:00 | 15600 | 17.46 | | | |
| 13:25:00 | 15900 | 14.79 | | | |
| 13:30:00 | 16200 | 14.03 | | | |
| 13:40:00 | 16800 | 10.24 | | | |
| 13:50:00 | 17400 | 8.31 | | | |
| 14:00:00 | 18000 | 7.06 | | | |
| 14:20:00 | 19200 | 5.39 | | | |
| 14:40:00 | 20400 | 4.39 | | | |
| 15:00:00 | 21600 | 3.84 | | | |
| 15:30:00 | 23400 | 3.33 | | | |
| 16:00:00 | 25200 | 3.14 | | | |
| 16:30:00 | 27000 | 2.99 | | | |
| 17:00:00 | 28800 | 2.89 | | | |
| 17:30:00 | 30600 | 2.79 | | | |
| 18:00:00 | 32400 | 2.74 | | | |
| 18:30:00 | 34200 | 2.69 | | | |
| 19:00:00 | 36000 | 2.64 | | | |
| 20:00:00 | 39600 | 2.61 | | | |
| 21:00:00 | 43200 | 2.57 | | | |
| 22:00:00 | 46800 | 2.56 | | | |
| 23:00:00 | 50400 | 2.55 | | | |
| 0:00:00 | 54000 | 2.55 | | | |
| 2:00:00 | 61200 | 2.52 | | | |
| 4:00:00 | 68400 | 2.50 | | | |
| 6:00:00 | 75600 | 2.49 | | | |
| 7:00:00 | 79200 | 2.49 | | | |
| 9:00:00 | 86400 | 2.49 | | | |

## Table-6.3.1 AIR-LIFTING TEST DATA
## TB-1-2 (104.25m)

| Time (h:m:s) | Time (sec) | Depth to WL (m) | H (cm) | Discharge (Litre/min) | Remarks |
|---|---|---|---|---|---|
| 13:00:00 | 0 | | 2.5 | 8.3 | Static W.L=3.52-1.15=2.37m |
| 14:30:00 | 5400 | ***** | | | Recovery Test |
| 14:32:00 | 5520 | 47.85 | | | |
| 14:33:00 | 5580 | 47.25 | | | |
| 14:34:00 | 5640 | 45.50 | | | |
| 14:35:00 | 5700 | 44.35 | | | |
| 14:36:00 | 5760 | 43.13 | | | |
| 14:37:00 | 5820 | 41.88 | | | |
| 14:38:00 | 5880 | 40.72 | | | |
| 14:39:00 | 5940 | 39.47 | | | |
| 14:40:00 | 6000 | 38.62 | | | |
| 14:45:00 | 6300 | 33.87 | | | |
| 14:50:00 | 6600 | 29.23 | | | |
| 14:55:00 | 6900 | 26.29 | | | |
| 15:00:00 | 7200 | 23.69 | | | |
| 15:05:00 | 7500 | 21.14 | | | |
| 15:10:00 | 7800 | 19.25 | | | |
| 15:15:00 | 8100 | 16.97 | | | |
| 15:20:00 | 8400 | 15.28 | | | |
| 15:25:00 | 8700 | 13.77 | | | |
| 15:30:00 | 9000 | 12.27 | | | |
| 15:40:00 | 9600 | 10.18 | | | |
| 15:50:00 | 10200 | 8.60 | | | |
| 16:00:00 | 10800 | 7.29 | | | |
| 16:10:00 | 11400 | 6.35 | | | |
| 16:30:00 | 12600 | 5.55 | | | |
| 17:00:00 | 14400 | 3.72 | | | |
| 17:30:00 | 16200 | 3.18 | | | |
| 18:00:00 | 18000 | 2.89 | | | |
| 19:00:00 | 21600 | 2.65 | | | |
| 20:00:00 | 25200 | 2.55 | | | |
| 21:00:00 | 28800 | 2.52 | | | |
| 22:00:00 | 32400 | 2.47 | | | |
| 23:00:00 | 36000 | 2.47 | | | |
| 24:00:00 | 39600 | 2.42 | | | |
| 2:00:00 | 46800 | 2.37 | | | |
| 4:00:00 | 54000 | 2.37 | | | |
| 6:00:00 | 61200 | 2.37 | | | |
| 8:00:00 | 68400 | 2.37 | | | |

# Table-6.3.2 AIR-LIFTING TEST DATA
## TB-2 (81m)

| Time (h:m:s) | Time (sec) | Depth to WL (m) | H (cm) | Discharge (Litre/min) | Remarks |
|---|---|---|---|---|---|
| 12:00:00 | 0 | 2.40 | | | Static W.L=3.76-1.36=2.40m |
| 12:00:20 | 20 | 2.90 | | | Step Test 1 |
| 12:00:30 | 30 | 3.25 | | | |
| 12:01:00 | 60 | 3.15 | | | |
| 12:02:00 | 120 | 4.70 | 10.0 | 266 | |
| 12:03:00 | 180 | 6.30 | 10.0 | 266 | |
| 12:04:00 | 240 | 7.95 | 10.0 | 266 | |
| 12:05:00 | 300 | 9.19 | 10.0 | 266 | |
| 12:06:00 | 360 | 10.37 | 10.0 | 266 | |
| 12:07:00 | 420 | 11.42 | 10.0 | 266 | |
| 12:08:00 | 480 | 12.37 | 10.0 | 266 | |
| 12:09:00 | 540 | 13.23 | 10.0 | 266 | |
| 12:10:00 | 600 | 14.05 | 11.0 | 337 | |
| 12:15:00 | 900 | 17.42 | 11.0 | 337 | |
| 12:20:00 | 1200 | 19.81 | 11.0 | 337 | |
| 12:25:00 | 1500 | 21.52 | 11.0 | 337 | |
| 12:30:00 | 1800 | 22.86 | 11.5 | 377 | |
| 12:40:00 | 2400 | 24.75 | 11.5 | 377 | |
| 12:50:00 | 3000 | 25.81 | 11.5 | 377 | |
| 13:00:00 | 3600 | 26.51 | 11.5 | 377 | |
| 13:20:00 | 4800 | 26.80 | 10.0 | 266 | |
| 13:40:00 | 6000 | 26.85 | 10.0 | 266 | |
| 14:00:00 | 7200 | 26.83 | 10.0 | 266 | |
| 14:30:00 | 9000 | 26.85 | 10.0 | 266 | |
| 14:33:00 | 9180 | 27.01 | 10.0 | 266 | Step Test 2 |
| 14:34:00 | 9240 | 27.11 | 12.0 | 419 | |
| 14:35:00 | 9300 | 27.17 | 12.0 | 419 | |
| 14:36:00 | 9360 | 27.25 | 12.0 | 419 | |
| 14:37:00 | 9420 | 27.36 | 12.0 | 419 | |
| 14:38:00 | 9480 | 27.43 | 12.0 | 419 | |
| 14:29:00 | 9540 | 27.50 | 12.0 | 419 | |
| 14:40:00 | 9600 | 27.57 | 12.0 | 419 | |
| 14:42:00 | 9720 | 27.65 | 12.0 | 419 | |
| 14:45:00 | 9900 | 27.90 | 12.0 | 419 | |
| 14:50:00 | 10200 | 28.16 | 12.0 | 419 | |
| 14:55:00 | 10500 | 28.37 | 10.0 | 266 | |
| 15:00:00 | 10800 | 28.52 | 10.0 | 266 | Compressor Stop |
| 15:01:40 | 10900 | 28.35 | | | Recovery Test |
| 15:02:17 | 10937 | 27.05 | | | |
| 15:03:00 | 10980 | 24.33 | | | |
| 15:04:00 | 11040 | 8.65 | | | |
| 15:04:30 | 11070 | 7.99 | | | |
| 15:05:00 | 11100 | 7.65 | | | |
| 15:05:30 | 11130 | 7.48 | | | |
| 15:06:20 | 11180 | 7.27 | | | |
| 15:07:00 | 11220 | 6.84 | | | |
| 15:08:00 | 11280 | 6.44 | | | |
| 15:09:00 | 11340 | 6.03 | | | |
| 15:10:00 | 11400 | 5.71 | | | |
| 15:12:00 | 1520 | 5.17 | | | |
| 15:15:00 | 11700 | 4.69 | | | |
| 15:20:00 | 12000 | 4.21 | | | |
| 15:25:00 | 12300 | 4.02 | | | |
| 15:30:00 | 12600 | 3.88 | | | |
| 15:40:00 | 13200 | 3.69 | | | |
| 15:50:00 | 13800 | 3.60 | | | |
| 16:00:00 | 14400 | 3.52 | | | |

# Table-6.3.2 AIR-LIFTING TEST DATA
## TB-2 (81m)

| Time (h:m:s) | Time (sec) | Depth to WL (m) | H (cm) | Discharge (Litre/min) | Remarks |
|---|---|---|---|---|---|
| 16:10:00 | 15000 | 3.43 | | | |
| 16:30:00 | 16200 | 3.34 | | | |
| 17:00:00 | 18000 | 3.23 | | | |
| 17:30:00 | 19800 | 3.13 | | | |
| 9:00:00 | 95400 | 2.40 | | | |

## Table-6.3.3 AIR-LIFTING TEST DATA
## TB-3 (44.2m)

| Time (h/m/s) | Time (sec) | Depth to WL (m) | H (cm) | Discharge (Litre/min) | Remarks |
|---|---|---|---|---|---|
| 3/13 9:00:00 | 0 | 2.65 | | | Static W.L.=3.88-1.23=2.65m |
| 9:00:30 | 30 | 3.45 | | | Air Lifting Test |
| 9:01:00 | 60 | 3.77 | | | |
| 9:02:00 | 120 | 3.59 | | | |
| 9:03:00 | 180 | 3.57 | 12.5 | 464 | |
| 9:04:00 | 240 | 3.56 | 12.5 | 464 | |
| 9:05:00 | 300 | 3.56 | 12.5 | 464 | |
| 9:06:00 | 360 | 3.56 | 12.5 | 464 | |
| 9:07:00 | 420 | 3.57 | 12.5 | 464 | |
| 9:08:00 | 480 | 3.58 | 12.5 | 464 | |
| 9:09:00 | 540 | 3.60 | 12.5 | 464 | |
| 9:10:00 | 600 | 3.61 | 12.5 | 464 | |
| 9:15:00 | 900 | 3.66 | 12.5 | 464 | |
| 9:20:00 | 1200 | 2.74 | 12.5 | 464 | deleted |
| 9:25:00 | 1500 | 1.16 | 12.5 | 464 | deleted |
| 9:28:20 | 1680 | 3.77 | 12.5 | 464 | deleted |
| 9:30:00 | 1800 | 3.77 | 13.1 | 522 | |
| 9:40:00 | 2400 | 3.83 | 13.3 | 542 | |
| 9:50:00 | 3000 | 3.93 | 12.7 | 483 | |
| 10:00:00 | 3600 | 3.96 | 13.0 | 512 | |
| 10:20:00 | 4800 | 4.08 | 13.0 | 512 | |
| 10:40:00 | 6000 | 4.14 | 13.0 | 512 | |
| 11:00:00 | 7300 | 4.15 | 13.0 | 512 | |
| 11:30:00 | 9000 | 4.17 | 12.8 | 492 | |
| 12:00:00 | 10800 | 4.22 | 12.5 | 464 | |
| 12:30:00 | 12600 | 4.27 | 12.5 | 464 | |
| 13:00:00 | 14400 | 4.33 | 12.5 | 464 | |
| 13:30:00 | 16200 | 4.42 | 12.5 | 464 | |
| 14:00:00 | 18000 | 4.51 | 12.5 | 464 | |
| 14:30:00 | 19800 | 4.51 | 12.5 | 464 | |
| 15:00:00 | 21600 | 4.54 | 12.5 | 464 | |
| 16:00:00 | 25200 | 4.56 | 12.5 | 464 | |
| 16:30:00 | 27000 | 4.55 | 12.5 | 464 | |
| 17:00:00 | 28800 | 4.53 | 12.5 | 464 | |
| 17:01:00 | 28860 | 4.23 | | | Recovery Test |
| 17:01:30 | 28890 | 4.09 | | | |
| 17:02:00 | 28920 | 4.12 | | | |
| 17:03:00 | 28980 | 3.87 | | | |
| 17:04:00 | 29040 | 3.83 | | | |
| 17:05:00 | 29100 | 3.77 | | | |
| 17:06:00 | 29160 | 3.73 | | | |
| 17:07:00 | 29220 | 3.70 | | | |
| 17:08:00 | 29280 | 3.67 | | | |
| 17:09:00 | 29340 | 3.64 | | | |
| 17:10:00 | 29400 | 3.62 | | | |
| 17:12:00 | 29520 | 3.58 | | | |
| 17:15:00 | 29700 | 3.52 | | | |
| 17:20:00 | 30000 | 3.47 | | | |
| 17:25:00 | 30300 | 3.42 | | | |
| 17:30:00 | 30600 | 3.37 | | | |
| 17:35:00 | 30900 | 3.33 | | | |
| 17:40:00 | 31200 | 3.25 | | | |
| 17:45:00 | 31500 | 3.28 | | | |
| 17:50:00 | 31800 | 3.26 | | | |
| 17:55:00 | 32100 | 3.23 | | | |
| 18:00:00 | 32400 | 3.21 | | | |
| 18:10:00 | 33000 | 3.19 | | | |
| 18:20:00 | 33600 | 3.16 | | | |

## Table-6.3.3 AIR-LIFTING TEST DATA
## TB-3 (44.2m)

| Time (h/m/s) | Time (sec) | Depth to WL (m) | H (cm) | Discharge (Litre/min) | Remarks |
|---|---|---|---|---|---|
| 18:30:00 | 34200 | 3.11 | | | |
| 18:40:00 | 34800 | 3.07 | | | |
| 18:50:00 | 35400 | 3.04 | | | |
| 19:00:00 | 36000 | 3.01 | | | |
| 21:00:00 | 43200 | 2.82 | | | |

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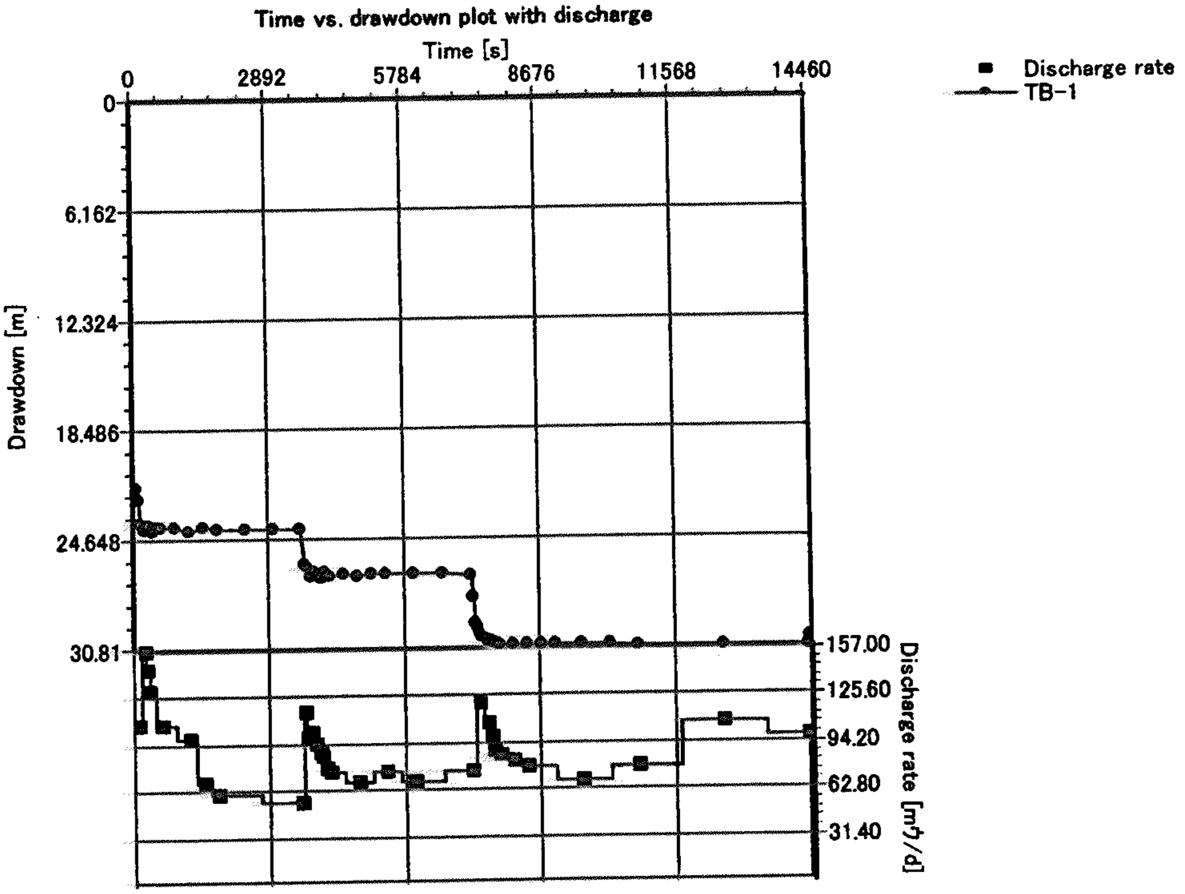
**Pumping test analysis** **Figure-6.3.5**

Project: Basic Design Study on the Project for Improvement of Nuwara Eliya Water Supply

| | | |
|---|---|---|
| Location: TB-1: Race Course | Pumping test: TB-1 air lifting | Pumping well: TB-1 |
| Test performed by: S.KIMURA<br>Test date: 01/03/28 | Evaluated by:<br>Evaluation date: 01/03/29 | |
| Analysis method: Time vs. drawdown plot with discharge | Aquifer thickness: 10.5 [m]<br>Discharge rate: 82.495833 [m³/d] | |



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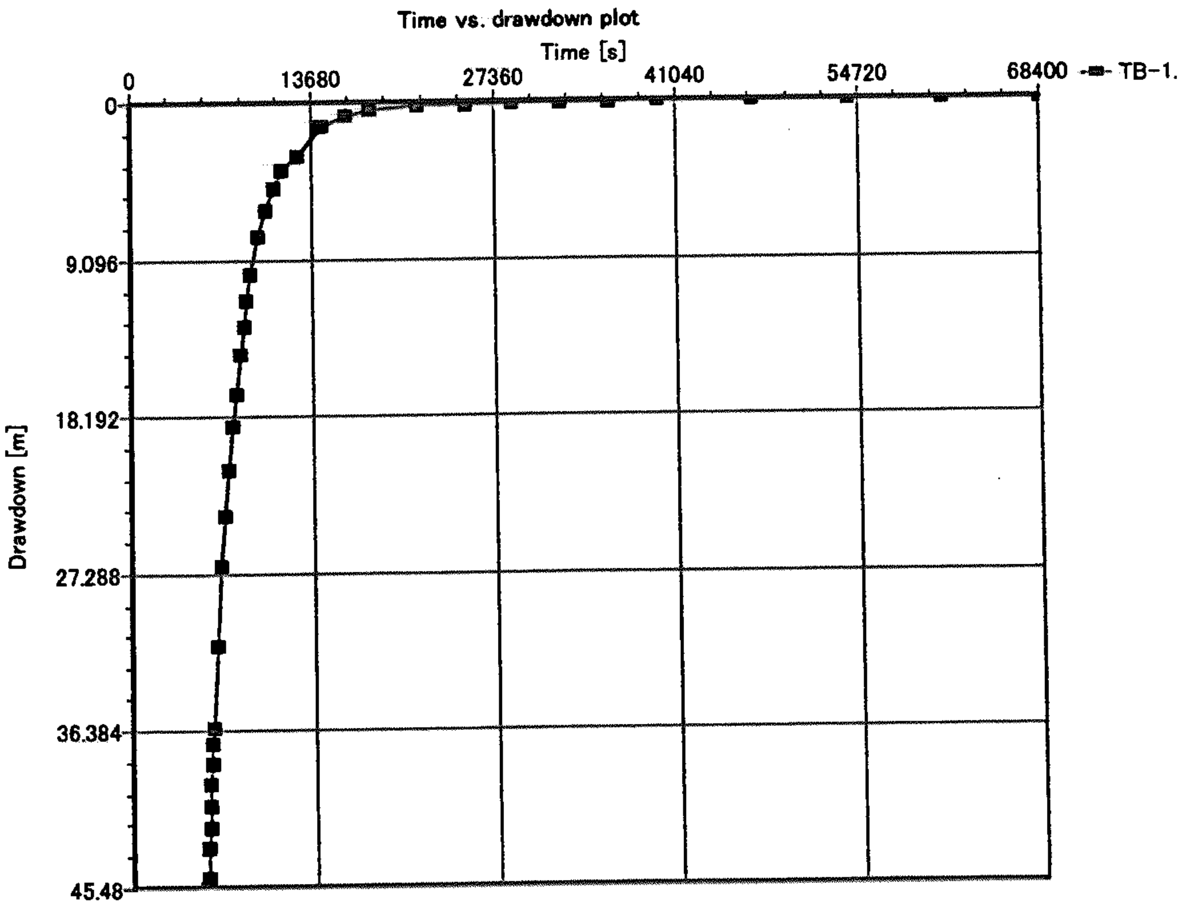
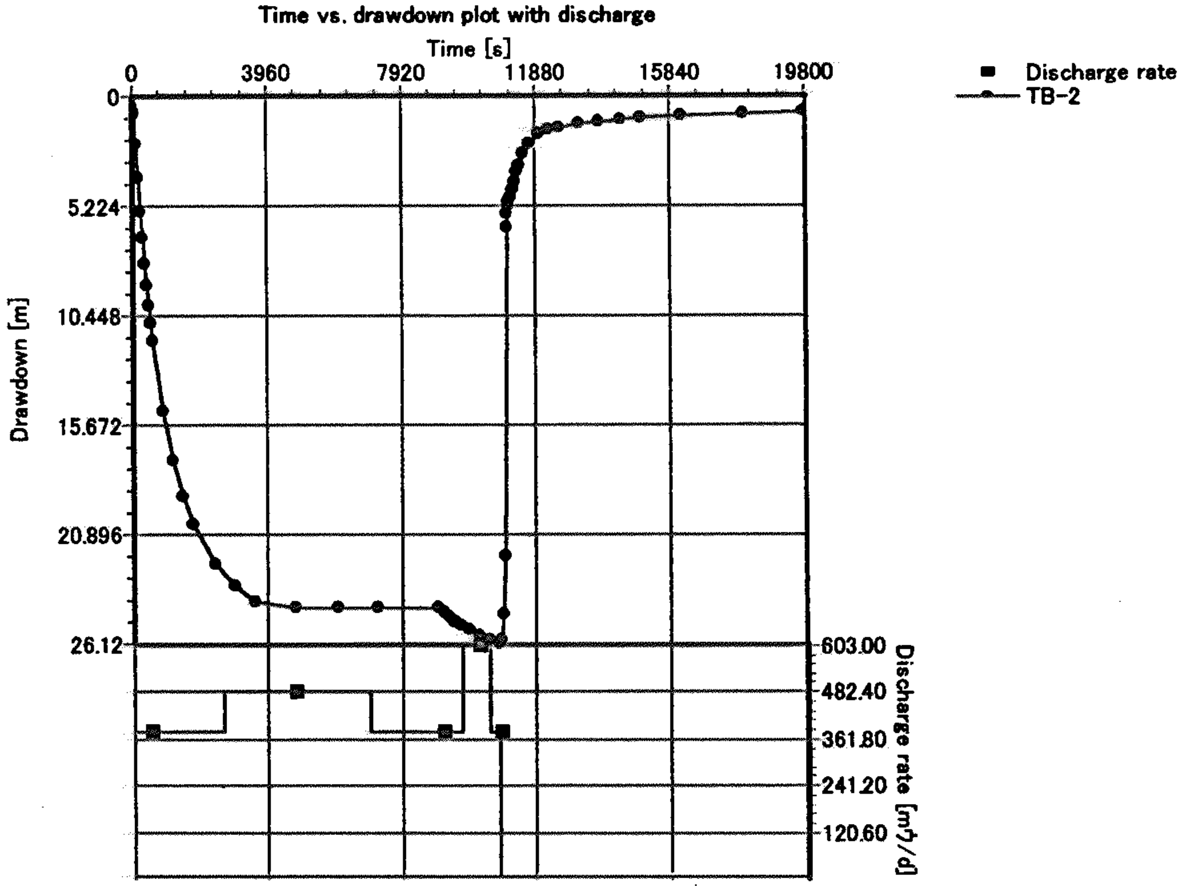
**Pumping test analysis** **Figure-6.3.6**

Project: Basic Design Study on the Project for Improvement of Nuwara Eliya Water Supply

| | | |
|---|---|---|
| Location: TB-1: Race Course | Pumping test: TB-1.air lifting | Pumping well: TB-1. |
| Test performed by: S.KIMURA<br>Test date: 01/04/08 | Evaluated by:<br>Evaluation date: 01/04/08 | |
| Analysis method: Time vs. drawdown plot | Aquifer thickness: 1.25 [m]<br>Discharge rate: 90 [m³/d] | |



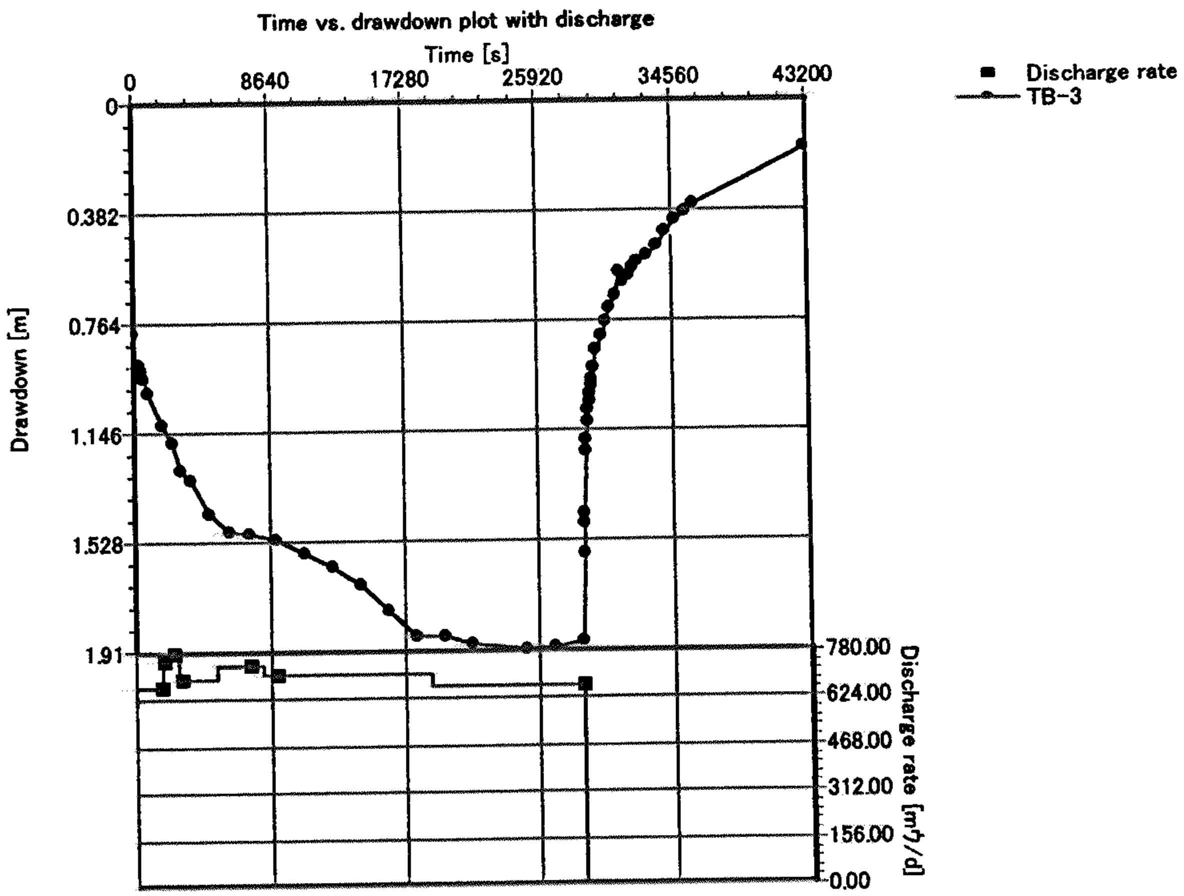
| Nihon Suido Consulltants<br>22-1,Nishi-Shinjyuku 6-Chome<br>Shinjyuku-Ku, Tokyo 163-1122, JAPAN<br>TEL.81-3-5323-6265 FAX.81-3-5323-6487 | Pumping test analysis **Figure-6.3.7**<br>Project: Basic Design Study on the Project for Improvement of Nuwara Eliya Water Supply |
|---|---|
| Location: TB-2 Hawa Eliya | Pumping test: TB-2 air lifting — Pumping well: TB-2 |
| Test performed by: S.KIMURA<br>Test date: 01/03/11 | Evaluated by:<br>Evaluation date: 01/03/30 |
| Analysis method: Time vs. drawdown plot with discharge | Aquifer thickness: 25.7 [m]<br>Discharge rate: 441.31852 [m³/d] |



| Nihon Suido Consulltants<br>22-1,Nishi-Shinjyuku 6-Chome<br>Shinjyuku-Ku, Tokyo 163-1122, JAPAN<br>TEL.81-3-5323-6265 FAX.81-3-5323-6487 | **Pumping test analysis** **Figure-6.3.8**<br>Project: Basic Design Study on the Project for Improvement of Nuwara Eliya Water Supply |
|---|---|

| | | |
|---|---|---|
| Location: TB-3 Hawa Eliya | Pumping test: TB-3 air lifting | Pumping well: TB-3 |

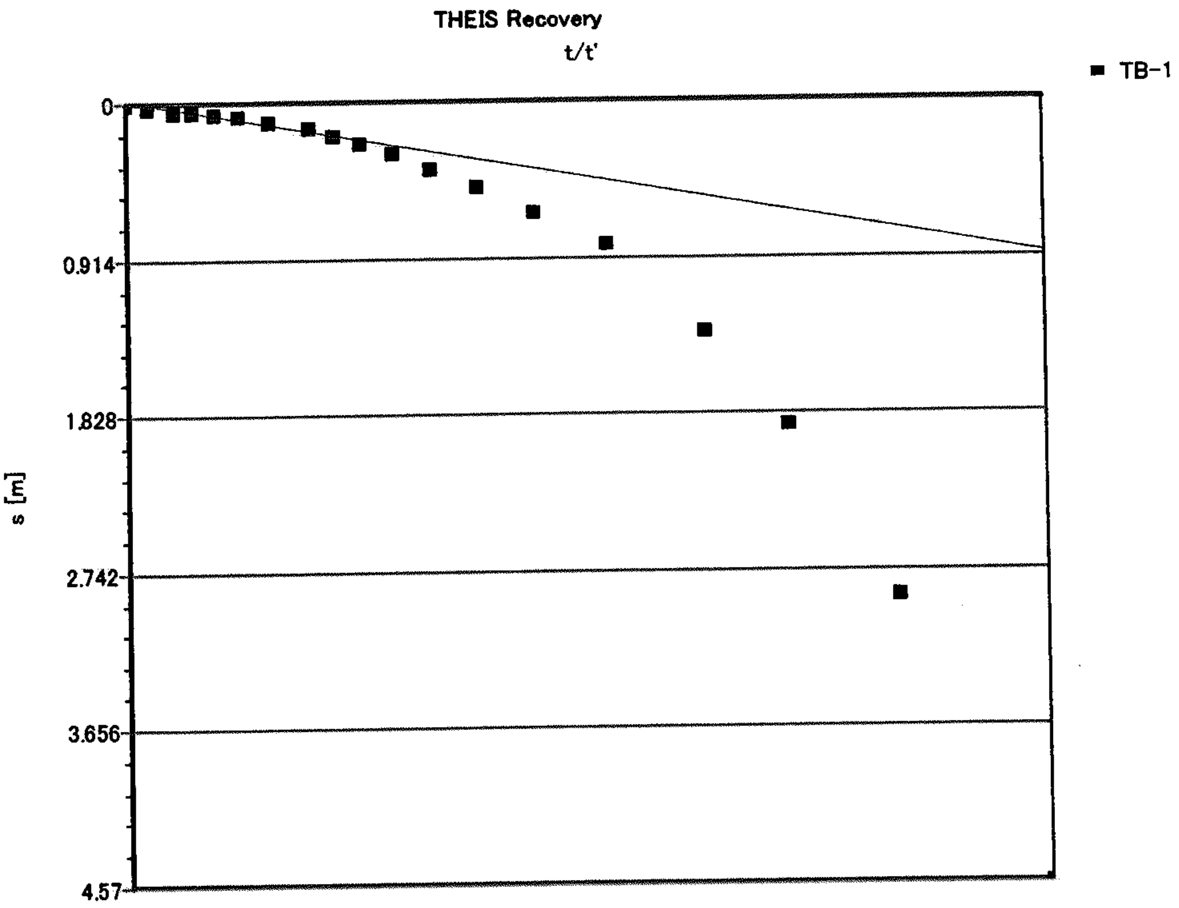
| | |
|---|---|
| Test performed by: S>KIMURA<br>Test date: 01/03/13 | Evaluated by:<br>Evaluation date: 01/03/30 |
| Analysis method: Time vs. drawdown plot with discharge | Aquifer thickness: 13.4 [m]<br>Discharge rate: 695.88333 [m³/d] |



| Nihon Suido Consulltants<br>22-1,Nishi-Shinjyuku 6-Chome<br>Shinjyuku-Ku, Tokyo 163-1122, JAPAN<br>TEL.81-3-5323-6265 FAX.81-3-5323-6487 | Pumping test analysis **Figure-6.3.9**<br>Project: Basic Design Study on the Project for Improvement of Nuwara Eliya Water Supply |
|---|---|

| Location: TB-1: Race Course | Pumping test: TB-1 air lifting | Pumping well: TB-1 |
|---|---|---|

| | |
|---|---|
| Test performed by: S.KIMURA<br>Test date: 01/03/28 | Evaluated by:<br>Evaluation date: 01/03/29 |
| Analysis method: THEIS Recovery | Aquifer thickness: 10.5 [m]<br>Discharge rate: 82.495833 [m³/d] |




Transmissivity: 9.94×10^+0 [m²/d]

Conductivity: 9.47×10^-1 [m/d]

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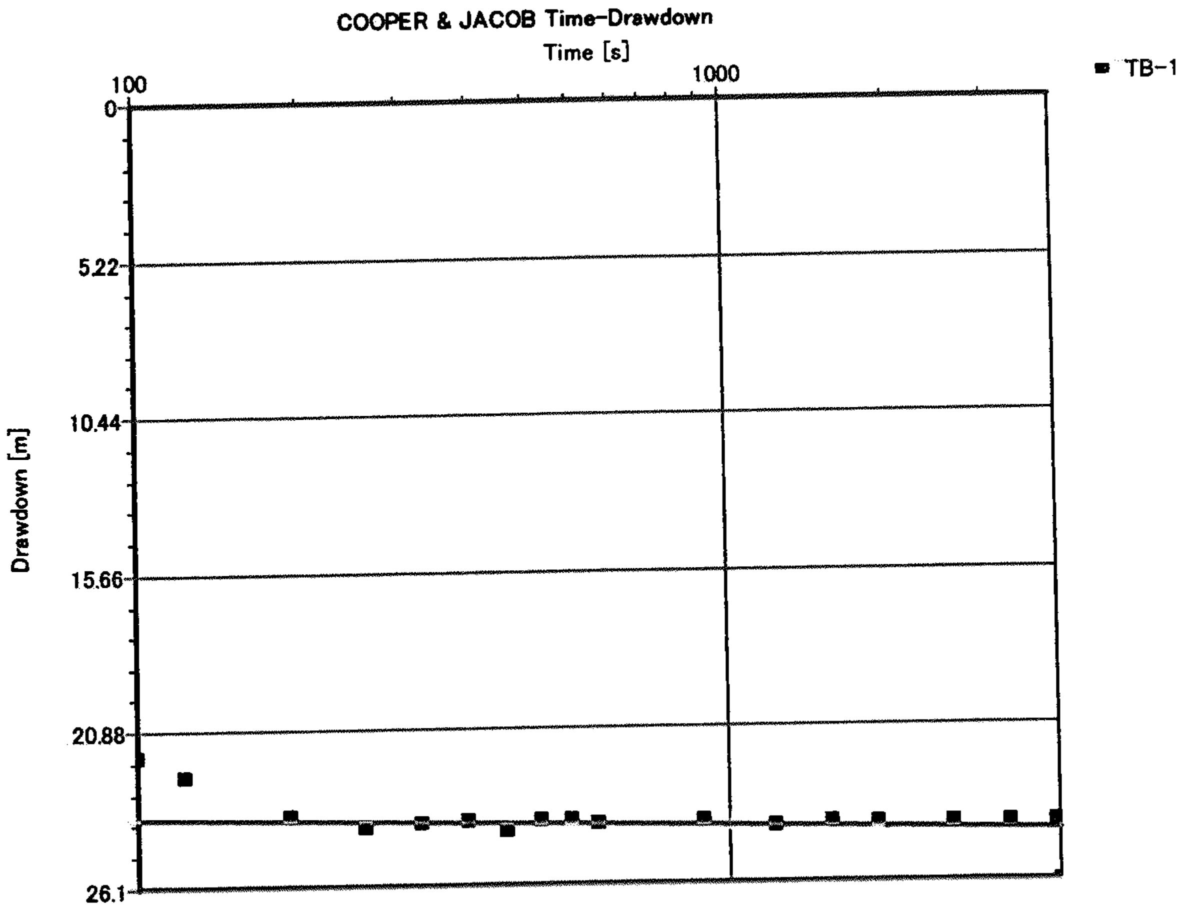
**Pumping test analysis** **Figure-6.3.10**

Project: Basic Design Study on the Project for Improvement of Nuwara Eliya Water Supply

| | | |
|---|---|---|
| Location: TB-1: Race Course | Pumping test: TB-1 air lifting | Pumping well: TB-1 |

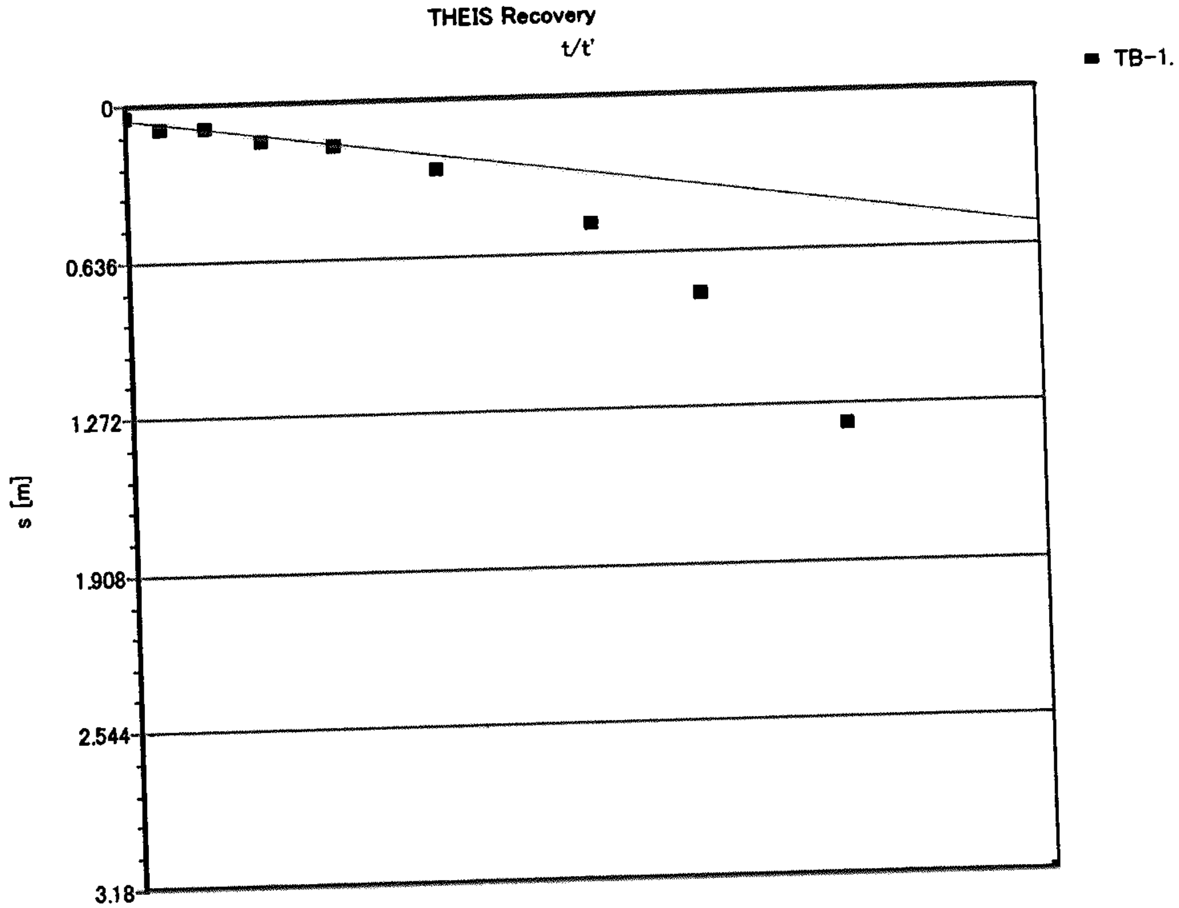
| | |
|---|---|
| Test performed by: S.KIMURA<br>Test date: 01/03/28 | Evaluated by:<br>Evaluation date: 01/03/30 |
| Analysis method: COOPER & JACOB Time-Drawdown | Aquifer thickness: 10.5 [m]<br>Discharge rate: 82.495833 [m³/d] |




Transmissivity: 4.17×10^+1 [m²/d]

Conductivity: 3.97×10^+0 [m/d]

| Nihon Suido Consulltants<br>22-1,Nishi-Shinjyuku 6-Chome<br>Shinjyuku-Ku, Tokyo 163-1122, JAPAN<br>TEL.81-3-5323-6265 FAX.81-3-5323-6487 | Pumping test analysis **Figure-6.3.11**<br>Project: Basic Design Study on the Project for Improvement of Nuwara Eliya Water Supply | |
|---|---|---|
| Location: TB-1: Race Course | Pumping test: TB-1.air lifting | Pumping well: TB-1. |
| Test performed by: S.KIMURA<br>Test date: 01/04/08 | Evaluated by:<br>Evaluation date: 01/04/08 | |
| Analysis method: THEIS Recovery | Aquifer thickness: 1.25 [m]<br>Discharge rate: 90 [m³/d] | |



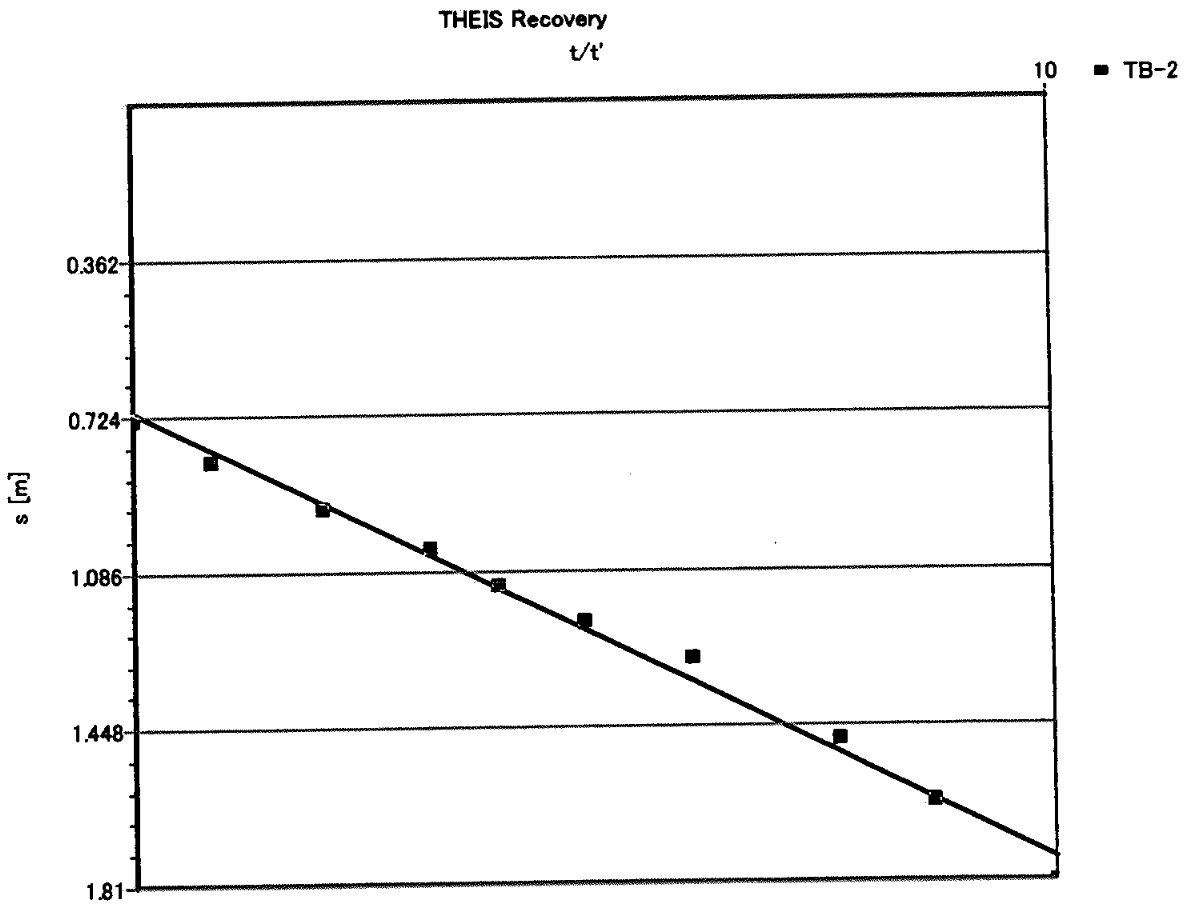

Transmissivity: 5.91×10^+0 [m²/d]

Conductivity: 4.73×10^+0 [m/d]

| Nihon Suido Consulltants<br>22-1,Nishi-Shinjyuku 6-Chome<br>Shinjyuku-Ku, Tokyo 163-1122, JAPAN<br>TEL.81-3-5323-6265 FAX.81-3-5323-6487 | Pumping test analysis **Figure-6.3.12**<br>Project: Basic Design Study on the Project for Improvement of Nuwara Eliya Water Supply |
|---|---|

| Location: TB-2 Hawa Eliya | Pumping test: TB-2 air lifting | Pumping well: TB-2 |
|---|---|---|

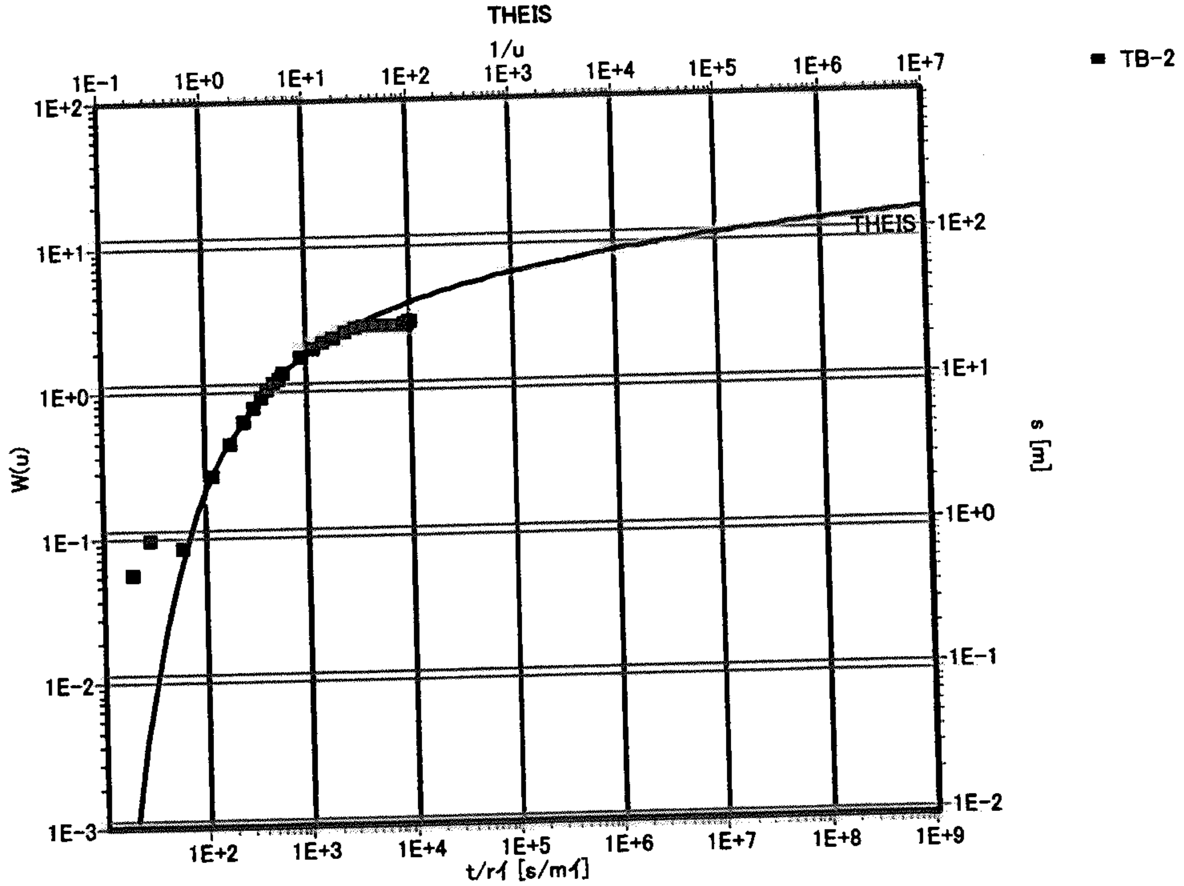
| | |
|---|---|
| Test performed by: S.KIMURA<br>Test date: 01/03/11 | Evaluated by:<br>Evaluation date: 01/03/30 |
| Analysis method: THEIS Recovery | Aquifer thickness: 25.7 [m]<br>Discharge rate: 441.31852 [m³/d] |




Transmissivity: 5.11×10^+1 [m²/d]

Conductivity: 1.99×10^+0 [m/d]

| Nihon Suido Consulltants<br>22-1,Nishi-Shinjyuku 6-Chome<br>Shinjyuku-Ku, Tokyo 163-1122, JAPAN<br>TEL.81-3-5323-6265 FAX.81-3-5323-6487 | Pumping test analysis **Figure-6.3.13**<br>Project: Basic Design Study on the Project for Improvement of Nuwara Eliya Water Supply | |
|---|---|---|
| Location: TB-2 Hawa Eliya | Pumping test: TB-2 air lifting | Pumping well: TB-2 |
| Test performed by: S.KIMURA<br>Test date: 01/03/11 | Evaluated by:<br>Evaluation date: 01/03/30 | |
| Analysis method: THEIS | Aquifer thickness: 25.7 [m]<br>Discharge rate: 441.31852 [m³/d] | |




Transmissivity: 4.00×10^+0 [m²/d]

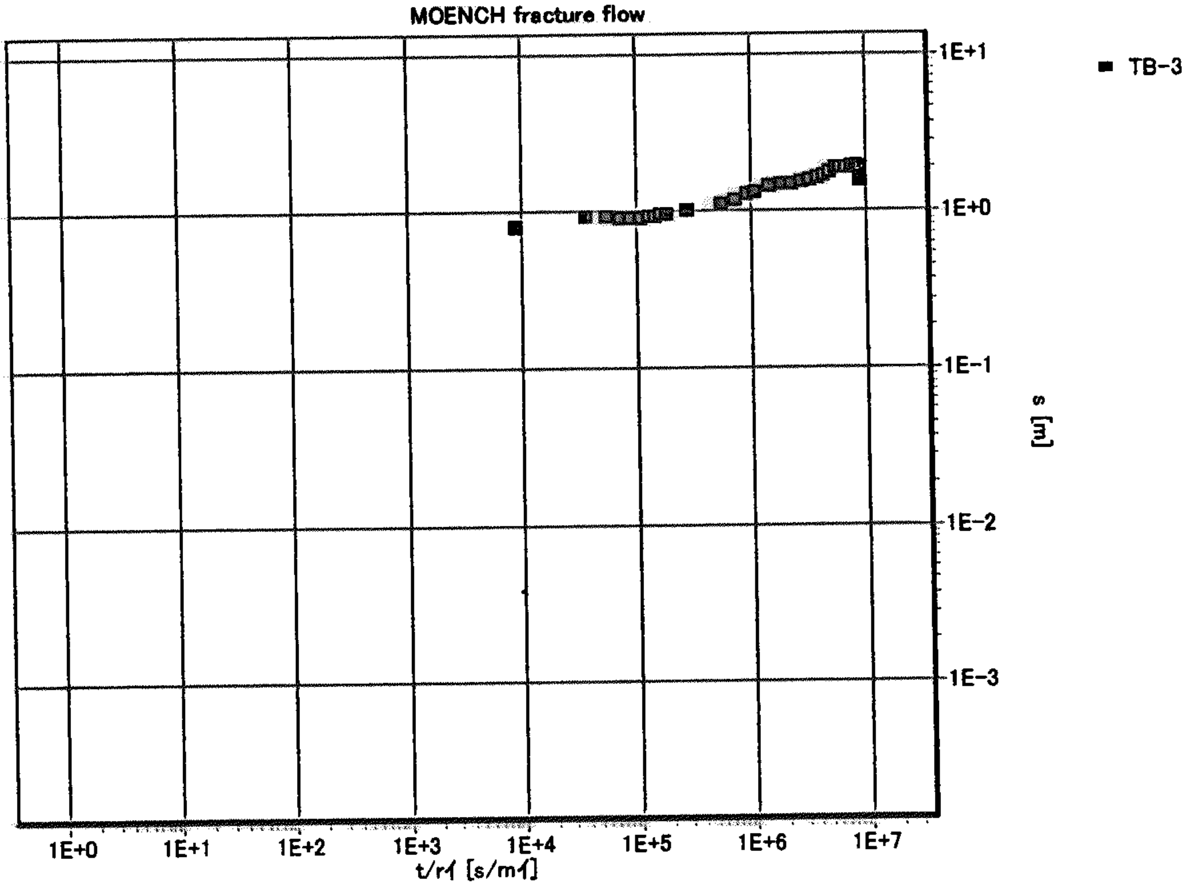
Conductivity: 1.56×10^-1 [m/d]

Storativity: 1.94×10^-2

| Nihon Suido Consulltants<br>22-1,Nishi-Shinjyuku 6-Chome<br>Shinjyuku-Ku, Tokyo 163-1122, JAPAN<br>TEL.81-3-5323-6265 FAX.81-3-5323-6487 | **Pumping test analysis** **Figure-6.3.14**<br>Project: Basic Design Study on the Project for Improvement of Nuwara Eliya Water Supply |
|---|---|

| Location: TB-3 Nuwa Eliya | Pumping test: TB-3 air lifting | Pumping well: TB-3 |
|---|---|---|

| | |
|---|---|
| Test performed by: S>KIMURA<br>Test date: 01/03/13 | Evaluated by:<br>Evaluation date: 01/03/30 |
| Analysis method: MOENCH fracture flow | Aquifer thickness: 13.4 [m]<br>Discharge rate: 695.88333 [m³/d] |




Transmissivity: 4.81×10^-3 [m²/s]

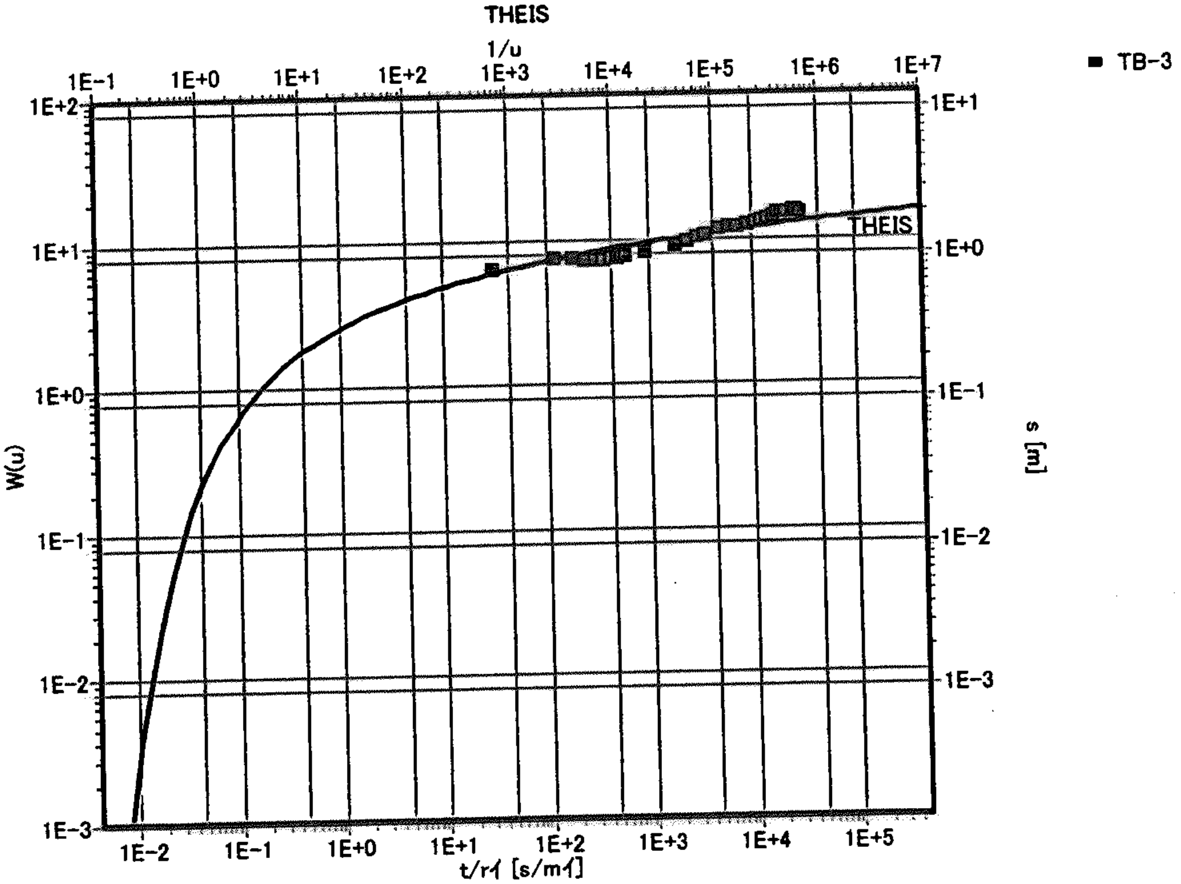
Conductivity: 3.59×10^-4 [m/s]

Storativity: 1.67×10^-1

| Nihon Suido Consulltants<br>22-1,Nishi-Shinjyuku 6-Chome<br>Shinjyuku-Ku, Tokyo 163-1122, JAPAN<br>TEL.81-3-5323-6265 FAX.81-3-5323-6487 | Pumping test analysis **Figure-6.3.15**<br>Project: Basic Design Study on the Project for Improvement of Nuwara Eliya Water Supply |
|---|---|

| Location: TB-3 Hawa Eliya | Pumping test: TB-3 air lifting | Pumping well: TB-3 |
|---|---|---|

| | |
|---|---|
| Test performed by: S>KIMURA<br>Test date: 01/03/13 | Evaluated by:<br>Evaluation date: 01/04/17 |
| Analysis method: THEIS | Aquifer thickness: 13.4 [m]<br>Discharge rate: 695.88333 [m³/d] |




Transmissivity: 5.12×10^-3 [m²/s]

Conductivity: 3.82×10^-4 [m/s]

Storativity: 8.88×10^-4

The result of the Airlifting Test is summarized in **Table-6.3.4.**

**Table-6.3.4 Result of the Airlifting Test of the Test borings**

| Site | Basin／Area | Geology of Aquifer | Depth (m) | Thickness (m) | Critical yield ( $m^3$ /day) | Trans-missibity ( $m^2$ /day) | Permea-bility * (m/day) |
|---|---|---|---|---|---|---|---|
| TB-1 | Nanu Oya Upstram Basin / Race Course | gneiss, quartzite fractured | 104.25 | 10.5 | 300 | 1.26 | 0.12 |
| TB-2 | Boburella basin / Hawa Eliya | gneiss fractured | 81.0 | 25.7 | 800 | 51.1 | 2.0 |
| TB-3 | Boburella basin / Hawa Eliya | gneiss fractured | 44.2 | 13.4 | >1,000 | 230 | 17.2 |

Note: * Permeability is referred to Conductivity in some reports.

### 6.3.4 Water Quality

**Table-6.3.5** shows the result of water quality test.

**Table-6.3.5 Result of Water Quality Test**

| **Chemical Component** | **TB-1 Race Course** | **TB-2 Hawa Eliya** | **TB-3 Hawa Eliya** | **WHO Guide Line** |
|---|---|---|---|---|
| Temperature of water (℃) | 23.8 | 19.8 | 19.0 | - |
| Electric Conductivity (μS/cm) | 325 | 248 | 258 | - |
| PH | 8.9 | 8.5 | 8.2 | - |
| Fe (mg/l) | 0.2 | 0 | 0 | 0.3 |
| F (mg/l) | 0 | 0 | 0 | 1.5 |
| Mg (mg/l) | 1 | 10 | 5 | 300 |
| Mn (mg/l) | 0 | 0 | 0 | 0.5 |
| Ca (mg/l) | 10 | 20 | 20 | 300 |
| Cr (mg/l) | 0 | 0 | 0 | 0.05 |
| NH4 (mg/l) | 0 | 0 | 0 | 1.5 |
| NO2 (mg/l) | 0 | 0 | 0 | 3 |
| NO3 (mg/l) | 0 | 0 | 0 | 50 |
| COD (mgO/l) | 10 | 0 | 0 | - |
| Colon Bacillus | 0 | 0 | 0 | 0 |
| Bacterium | 0 | 0 | 0 | - |

All sample water from the existing wells show slightly acidic pH values, while the water from the survey borings show slightly alkaline pH values and is characterized by high Calcium content.

## 7. Plan of Groundwater Development

### 7.1 Groundwater Basin

On the basis of the field investigations so far executed and the data related with the existing wells, the Test borings sites were selected under the working hypotheses that groundwater basin in Hawa Eliya consists of subsurface unconfined aquifer (less than 10 meters in depth) and confined aquifer lying over the bottom of weathered gneiss. However, the survey boring revealed that another excellent confined aquifer is formed in fresh gneiss, quartzite and limestone layers deeply underlying the layer of weathered gneiss. The amount of yield from fracture zone of these fresh rocks is much more large than from weathered gneiss. In addition to this, the quality of water is also excellent. Consequently, the third aquifer is regarded as the main target aquifer on establishing the groundwater development plan.

### 7.2 Proposed Location of Well Sites and Yield

Although drilling of the survey boring at Race Course (TB-1) was interrupted at the depth of 104m and has not confirmed an aquifer at this depth by a collapse layer and the drilling capability of the machine, measurements of groundwater yield during drilling showed that it was about the half amount of that in Hawa Eliya.

This failure of boring for getting sufficient groundwater at Race Course leaded to the requirement for selecting an alternative-boring site. Then, The Golf Course area, which had been eliminated by the difficulty of land acquisition, came on the table for reconsideration. As the problem of land acquisition, which had been the reason of elimination, was solved by the definite answer from NWSDB, saying that the necessary land acquisiton at Golf Course shall be done by NWSDB, the Golf Course area is adopted to a groundwater development area.

As a result of simulation analysis using the aquifer characteristic value (a permeability coefficient, a transmissivity coefficient, a storage coefficient, layer thickness, diameter of a well) obtained by the Airlifting test, the following values of safety pumping rate are obtained.

| | < Test boring data > | < Planned pumping rate > |
|---|---|---|
| Hawa Eliya area | 600～1,400 ($m^3$/day) | 800 ($m^3$/day) |

| | <Previous JICA Study data > | < Planned pumping rate > |
|---|---|---|
| Golf Course area | 770 ($m^3$/day) | 800 ($m^3$/day) |

The simulation analysis is also applied for the pumping test data obtained at Golf Course by the previous JICA Study.

Since groundwater yield changes greatly with geological conditions and well structures, the safety pumping rate should be decided by the pumping test at each well. On the Basic Design Study, the pumping rate is set a little to the safety side respecting reliability.

The Race Course is eliminated from the proposed well development area, because the critical yield of a well at the Race Course is not expected to exceed more than 300 $m^3$/day, which is not efficient enough in comparison with the yield at Hawa Eliya and Golf Course.

## 7.3 Proposed Number of Wells and Depth

The locations of wells are decided as follows by consideration of hydro-geological conditions and the comparison of alternative plans of water service systems as mentioned above.

Race Course System

Water from the following wells is to be transported to the Junction Well J1 in Race Course.

Golf Course: 4 wells（@800$m^3$/day x 4）

Hawa Eliya: 2 wells（@800$m^3$/day x 2）

Hawa Eliya System

Water from the following wells is to be transported to the Junction Well J2 in Hawa Eliya.

Hawa Eliya 3 wells（@800$m^3$/day x 3)

Consequently, 4 wells in Golf Course, and 5 wells in Hawa Eliya, in total 9 wells are to be constructed.

**Table-7.3.1** and **Table-7.3.2** show proposed well depth at Golf Course and Hawa Eliya, respectively. **Fig-7.3.1** shows the locations of wells. **Fig-7.3.2**, **Fig-7.3.3** and **Fig-7.3.4** show cross sections illustrating topographic profile and basement of weathered rocks along the section lines shown in **Fig-7.3.1**. In consideration of these sections and result of survey boring, the depth for new wells design is proposed as follows.

**Table-7.3.1 Depth of Wells for Race Course System**

| Well | Depth | Remarks |
|---|---|---|
| Golf Course: 4 wells （G1～G4） | 100 m | The Test boring by the previous JICA Study is drilled 88m in depth to get groundwater. |
| Hawa Eliya: H1 | 60 m | Groudwater gushing is confirmed at around 44m in deprh by Test boring. |
| Hawa Eliya: H2 | 100 m | Groundwater gushing is confirmed at around 81m in depth by the Test boring drilled near this site. |

**Table-7.3.2 Depth of Wells for Hawa Eliya System**

| Well | Depth | Remarks |
|---|---|---|
| Hawa Eliya: H3 | 100 m | As this site is located at higher place than other sites in Hawa Eliya, the depth is propose as same as H2. |
| Hawa Eliya: H4 | 60 m | Groudwater gushing is confirmed at around 44m in deprh by Test boring drilled near this site. |
| Hawa Eliya: H5 | 80 m | As there is no reference data of wells near this site, the depth is proposed in average depth in Hawa Eliya. |

Interval of each well is to be more than 150 m in order to minimize the mutual interference. The strainer size is to be 8 inches.

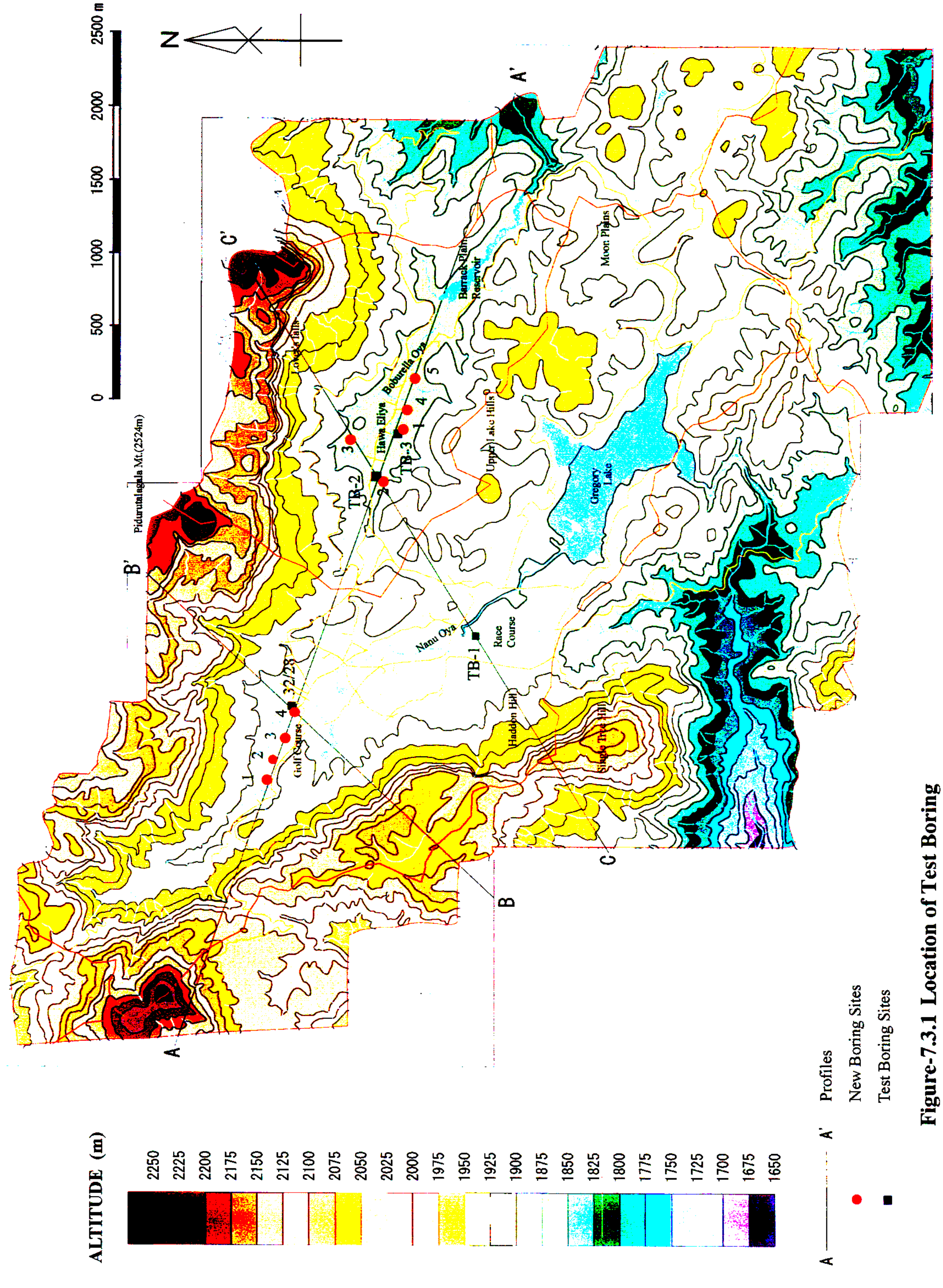



**Figure-7.3.1 Location of Test Boring**

Figure-7.3.2 A-A' Section

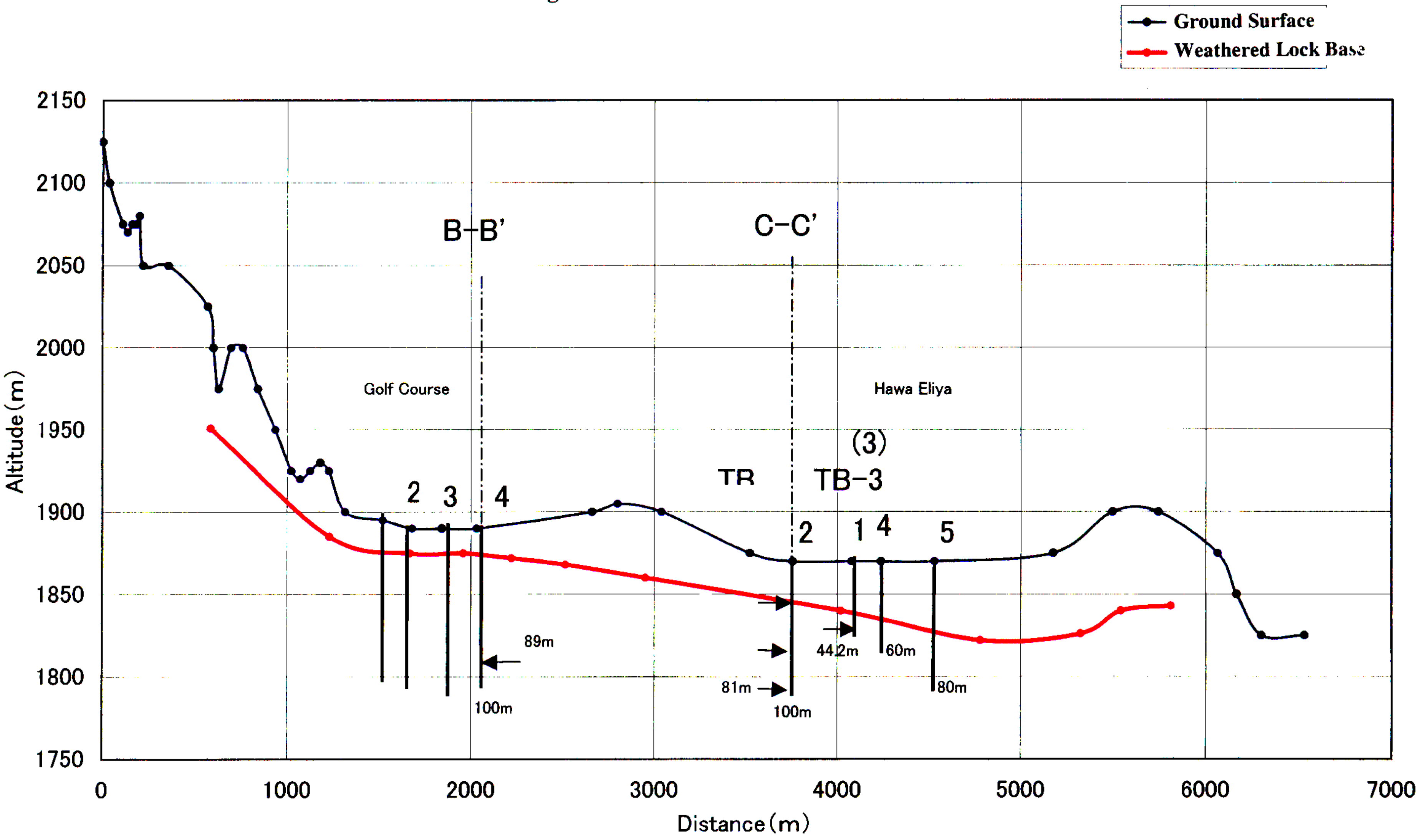
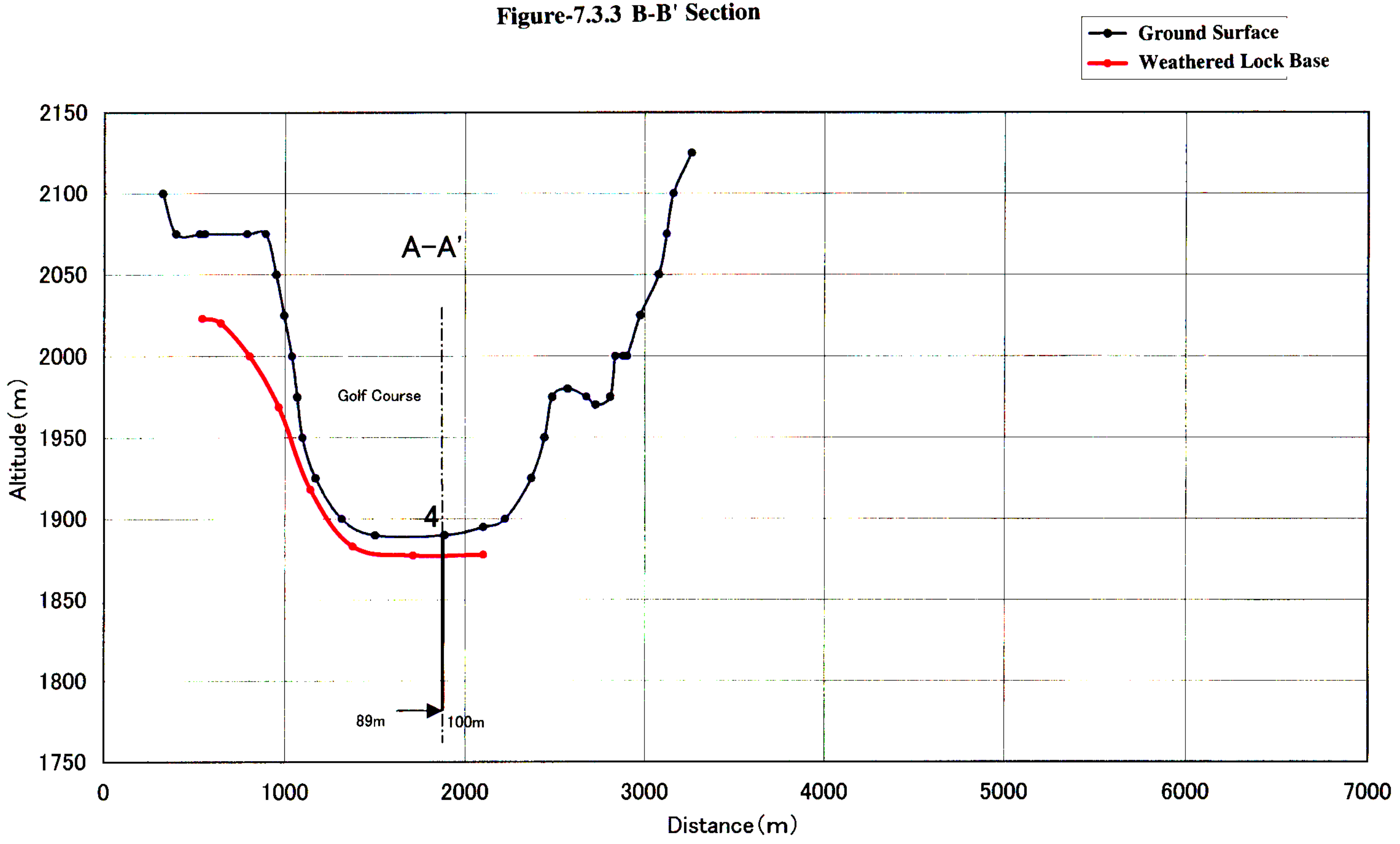
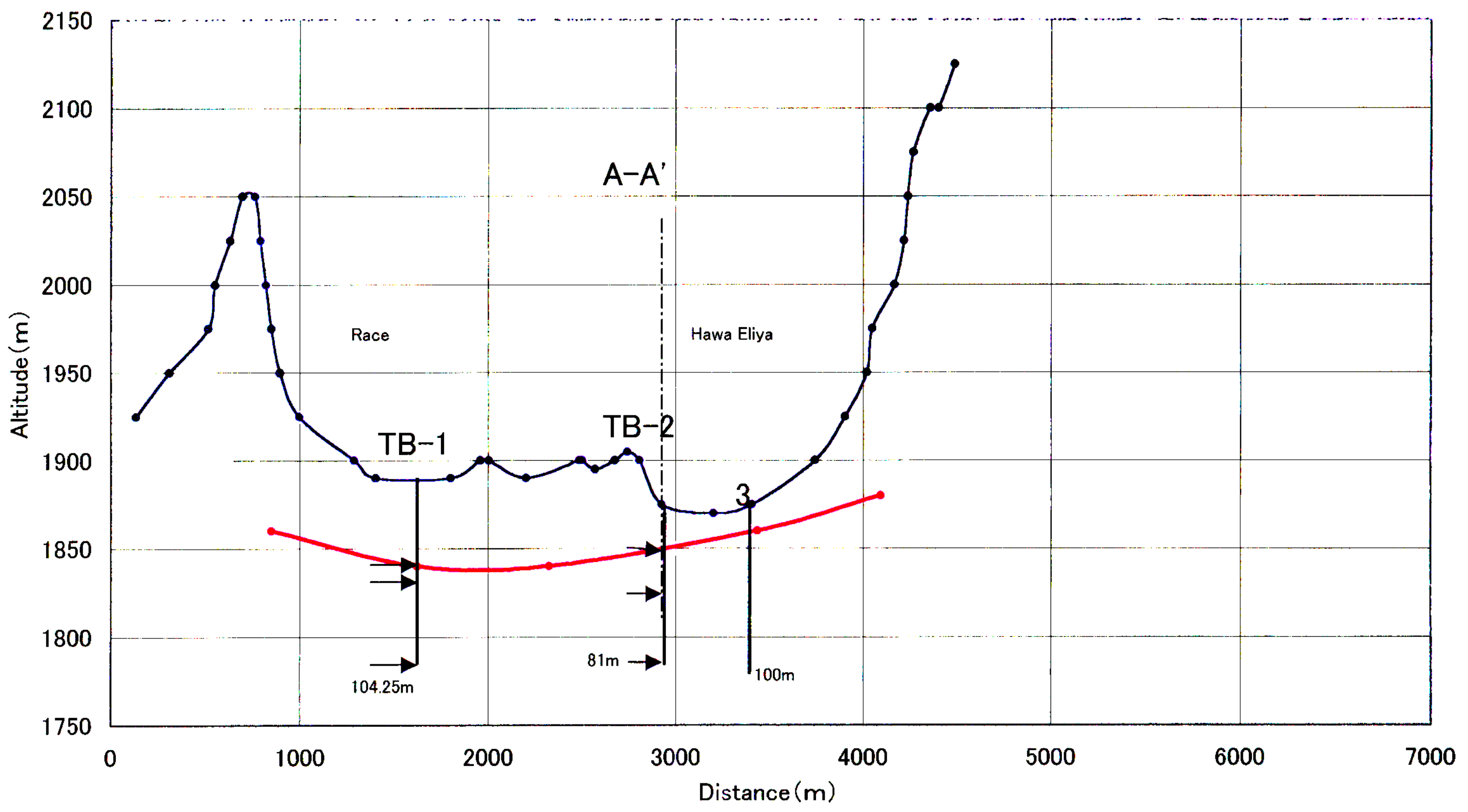


Figure-7.3.3 B-B' Section

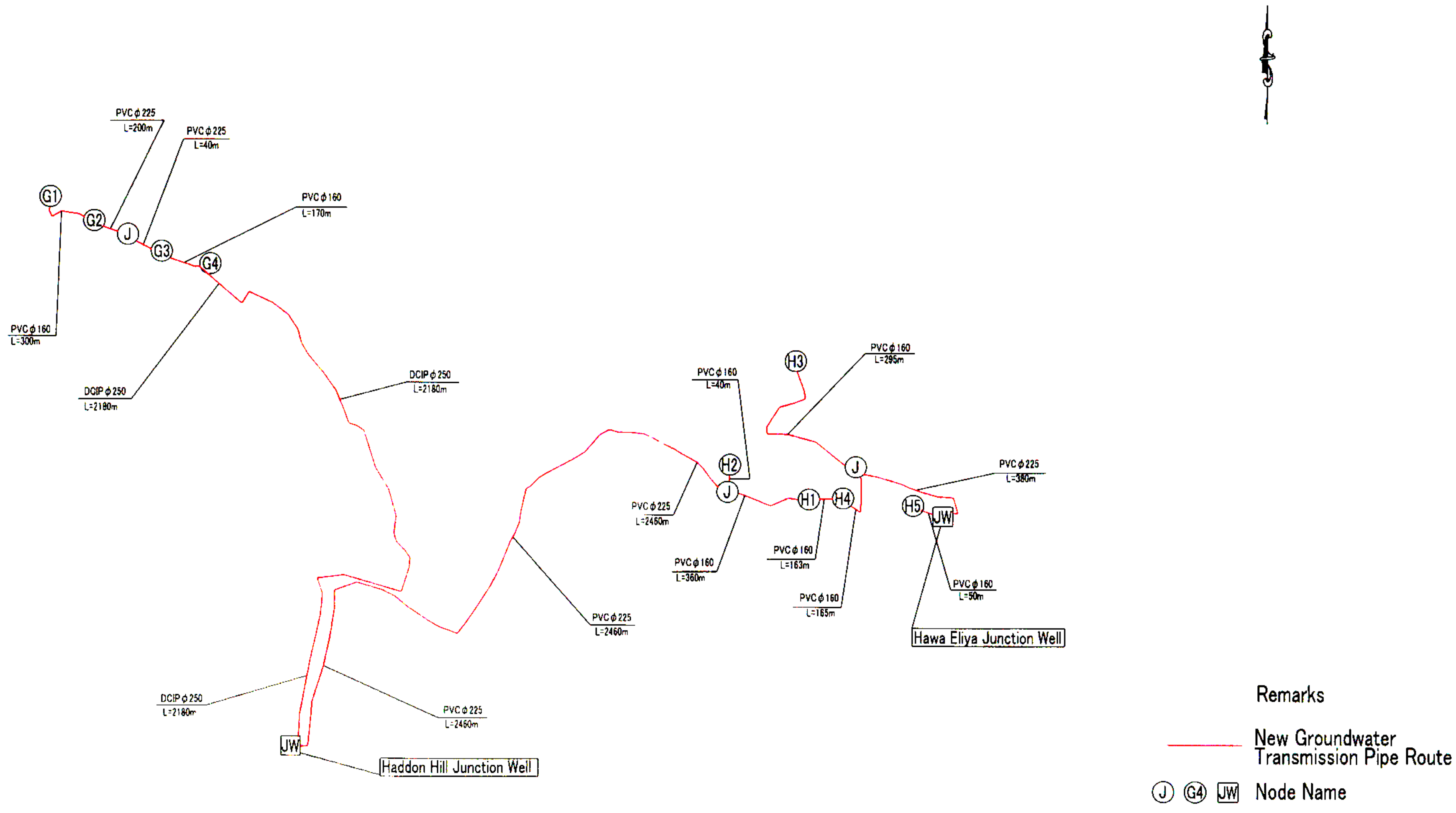


## Figure-7.3.4 C-C' Section



## Appendix 7-14 Results of Hydraulic analysis and Water Hammer

1. Hydraulic analysis of groundwater transmission pipeline
2. Hydraulic analysis of transmission pipeline
3. Hydraulic analysis of distribution pipeline
4. Water hammer analysis




# Groundwater Transmission Pipelines

## Groundwater Transmission (To Junction Well)

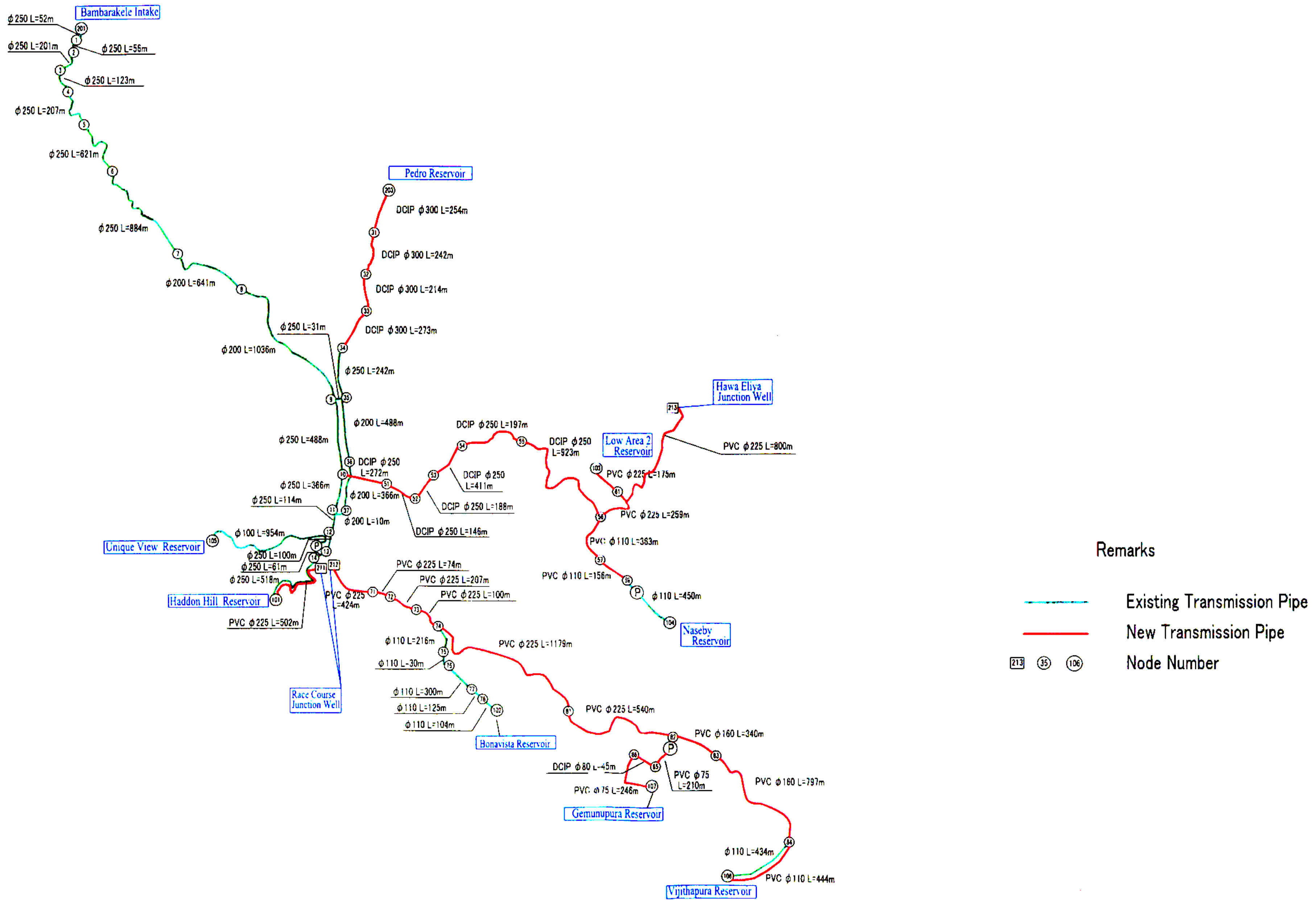
| Location | | D | L | C | Q | | V | I | head loss | GL | WL* | Required | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| To | From | mm | km | | m3/day | m3/sec | m/sec | m/km | m | m | GL-Xm | Head | Well Pump |
| **Hawa Eliya to Junction Well at Race Course** | | | | | | | | | Junction Well | 1880 | | | |
| **J.Well** | **junction** | 198 | 2.460 | 130 | 1,600 | 0.01852 | 0.60 | 2.175 | 5.351 | 1867 | | | |
| **junction** | **H2** | 140 | 0.040 | 130 | 800 | 0.00926 | 0.60 | 3.264 | 0.131 | 1863 | 25 | 52 | 800m3/d x 55m |
| **junction** | **H1** | 140 | 0.360 | 130 | 800 | 0.00926 | 0.60 | 3.264 | 1.175 | 1856 | 10 | 46 | 800m3/d x 50m |
| | | | | | | | | | | | | | |
| **Glof Course to Junction Well at Race Course** | | | | | | | | | Junction Well | 1880 | | | |
| **J.Well** | **G4** | 250 | 2.240 | 120 | 3,200 | 0.03704 | 0.75 | 2.921 | 6.543 | 1875 | 15 | 32 | 800m3/d x 30m |
| **G4** | **G3** | 198 | 0.170 | 130 | 2,400 | 0.02778 | 0.90 | 4.606 | 0.783 | 1880 | 15 | 27 | 800m3/d x 30m |
| **G3** | **G2** | 198 | 0.200 | 130 | 1,600 | 0.01852 | 0.60 | 2.175 | 0.435 | 1880 | 15 | 28 | 800m3/d x 30m |
| **G2** | **G1** | 140 | 0.350 | 130 | 800 | 0.00926 | 0.60 | 3.264 | 1.142 | 1880 | 15 | 29 | 800m3/d x 30m |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **Hawa Eliya to Junction Well at Hawa Eliya** | | | | | | | | | Junction Well | 1853 | | | |
| **J.Well** | **junction** | 198 | 0.380 | 130 | 1,600 | 0.01852 | 0.60 | 2.175 | 0.827 | 1854 | | | |
| **junction** | **H4** | 140 | 0.165 | 130 | 800 | 0.00926 | 0.60 | 3.264 | 0.539 | 1854 | 15 | 21 | 800m3/d x 30m |
| **junction** | **H3** | 140 | 0.295 | 130 | 800 | 0.00926 | 0.60 | 3.264 | 0.963 | 1860 | 25 | 26 | 800m3/d x 30m |
| **J.Well** | **H5** | 140 | 0.050 | 130 | 800 | 0.00926 | 0.60 | 3.264 | 0.163 | 1852 | 20 | 26 | 800m3/d x 30m |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

Note: Approximately 5 m of head loss around the pumps is assumed for Required Head.
*WL : Static Water Level of groudwater (distance from Grond Level)

**[ Reference ] Transmission To Exisiting Reservoir**

| Location | | D | L | C | Q | | V | I | head loss | GL | | Pump | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| To | From | mm | km | | m3/day | m3/sec | m/sec | m/km | m | m | | Head | Well Pump |
| **To Existing Nasbey Reservoir** | | | | | | | | | J.Well | 1880 | | | |
| pump | Resrvoir | 100 | 0.434 | 120 | 561 | 0.00649 | 0.83 | 10.105 | 4.386 | 1,946 | | 75 | OK(<80m) |
| **To Existing Bonaviata Reservoir** | | | | | | | | | J.Well | 1880 | | | |
| pump | Resrvoir | 97 | 0.875 | 130 | 232 | 0.00269 | 0.36 | 1.973 | 1.727 | 1,930 | | 57 | OK(<60m) |

Note: Approximately 5 m of head loss around the pumps is assumed.




# Transmission Pipelines

**TRANSMISSION PIPELINE**
**Phase 1 (2005) RAIN**

| | |
|---|---|
| Nos of nodes | 53 |
| Nos of pipes | 54 |

| | NODE NO | Type | Q l/sec | WL m | GL m | EH m |
|---|---|---|---|---|---|---|
| Bambarakele | 201 | 1 | -56.227 | 1989.00 | 1989.00 | 0.00 |
| Pedro (New) | 203 | 0 | -42.322 | 1946.43 | 1948.00 | -1.57 |
| | 1 | 0 | 0 | 1988.67 | 1,985.0 | 3.67 |
| | 2 | 0 | 0 | 1988.32 | 1,987.0 | 1.32 |
| | 3 | 0 | 0 | 1987.05 | 1,978.0 | 9.05 |
| | 4 | 0 | 0 | 1986.27 | 1,924.0 | 62.27 |
| | 5 | 0 | 0 | 1984.96 | 1,917.0 | 67.96 |
| | 6 | 0 | 0 | 1981.03 | 1,946.0 | 35.03 |
| | 7 | 0 | 0 | 1975.44 | 1,895.0 | 80.44 |
| | 8 | 0 | 0 | 1963.43 | 1,896.0 | 67.43 |
| | 9 | 0 | 0 | 1944.01 | 1,881.0 | 63.01 |
| | 10 | 0 | 0 | 1939.73 | 1,877.0 | 62.73 |
| | 11 | 0 | 0 | 1938.48 | 1,882.0 | 56.48 |
| | 12 | 0 | 0 | 1937.34 | 1,885.0 | 52.34 |
| | 13 | 0 | 0 | 1936.34 | 1,887.0 | 49.34 |
| | 14 | 0 | 0 | 1935.89 | 1,891.0 | 44.89 |
| | 31 | 0 | 0 | 1946.04 | 1,945.0 | 1.04 |
| | 32 | 0 | 0 | 1945.67 | 1,906.0 | 39.67 |
| | 33 | 0 | 0 | 1945.34 | 1,900.0 | 45.34 |
| | 34 | 0 | 0 | 1944.92 | 1,881.0 | 63.92 |
| | 35 | 0 | 0 | 1944.02 | 1,880.0 | 64.02 |
| | 36 | 0 | 0 | 1940.89 | 1,877.0 | 63.89 |
| | 37 | 0 | 0 | 1938.54 | 1,882.0 | 56.54 |
| | 51 | 0 | 0 | 1939.30 | 1,880.7 | 58.60 |
| | 52 | 0 | 0 | 1939.07 | 1,876.5 | 62.57 |
| | 53 | 0 | 0 | 1938.77 | 1,882.0 | 56.77 |
| | 54 | 0 | 0 | 1938.11 | 1,899.4 | 38.71 |
| | 55 | 0 | 0 | 1937.80 | 1,902.8 | 35.00 |
| | 56 | 0 | 0 | 1936.33 | 1,920.0 | 16.33 |
| | 57 | 0 | 0 | 1932.66 | 1,890.2 | 42.46 |
| | 58 | 0 | 0 | 1931.08 | 1,887.0 | 44.08 |
| | 61 | 0 | 0 | 1935.67 | 1,925.0 | 10.67 |
| | 71 | 0 | 0 | 1936.00 | 1,881.8 | 54.20 |
| | 72 | 0 | 0 | 1935.95 | 1,881.3 | 54.65 |
| | 73 | 0 | 0 | 1935.78 | 1,883.7 | 52.08 |
| | 74 | 0 | 0 | 1935.70 | 1,882.3 | 53.40 |
| | 75 | 0 | 0 | 1935.28 | 1,891.4 | 43.88 |
| | 76 | 0 | 0 | 1935.22 | 1,893.9 | 41.32 |
| | 77 | 0 | 0 | 1934.63 | 1,914.9 | 19.73 |
| | 78 | 0 | 0 | 1934.38 | 1,917.5 | 16.88 |
| | 81 | 0 | 0 | 1935.15 | 1,876.0 | 59.15 |
| | 82 | 0 | 0 | 1934.89 | 1,881.3 | 53.59 |
| | 83 | 0 | 0 | 1934.32 | 1,879.2 | 55.12 |
| | 84 | 0 | 0 | 1932.99 | 1,900.0 | 32.99 |
| | 85 | 0 | 0 | 1958.70 | 1,900.0 | 58.70 |
| | 86 | 0 | 0 | 1958.59 | 1,930.0 | 28.59 |
| Haddon Hill | 101 | 0 | 51.13902 | 1933.15 | 1,930.0 | 3.15 |
| Bonavista | 102 | 0 | 2.681075 | 1934.18 | 1,930.0 | 4.18 |
| Low Area 2 (New) | 103 | 0 | 20.16874 | 1935.23 | 1,927.7 | 7.53 |
| Naseby | 104 | 0 | 6.498572 | 1951.52 | 1,946.0 | 5.52 |
| Unique View | 105 | 0 | 9.963006 | 1989.61 | 1,980.2 | 9.41 |
| Gemunupura | 107 | 0 | 1.654984 | 1957.20 | 1,951.1 | 6.15 |
| Vijithapura | 106 | 0 | 6.443406 | 1931.77 | 1,930.8 | 0.97 |

PIPE

| | NO(u) | NO(d) | Dia | Length | C | dH | Q | V | I |
|---|---|---|---|---|---|---|---|---|---|
| | | | mm | m | | m | l/sec | m/sec | o/oo |
| | 1 | 2 | 250.0 | 56.0 | 120.0 | | 56.23 | 1.15 | 6.32 |
| | 2 | 3 | 250.0 | 201.0 | 120.0 | | 56.23 | 1.15 | 6.32 |
| | 3 | 4 | 250.0 | 123.0 | 120.0 | | 56.23 | 1.15 | 6.32 |
| | 4 | 5 | 250.0 | 207.0 | 120.0 | | 56.23 | 1.15 | 6.32 |
| | 5 | 6 | 250.0 | 621.0 | 120.0 | | 56.23 | 1.15 | 6.32 |
| | 6 | 7 | 250.0 | 884.0 | 120.0 | | 56.23 | 1.15 | 6.32 |
| | 7 | 8 | 200.0 | 641.0 | 120.0 | | 56.23 | 1.79 | 18.75 |
| | 8 | 9 | 200.0 | 1036.0 | 120.0 | | 56.23 | 1.79 | 18.75 |
| | 9 | 10 | 250.0 | 488.0 | 120.0 | | 67.06 | 1.37 | 8.76 |
| | 10 | 11 | 250.0 | 366.0 | 120.0 | | 40.40 | 0.82 | 3.43 |
| | 11 | 12 | 250.0 | 114.0 | 120.0 | | 71.88 | 1.46 | 9.96 |
| | 12 | 13 | 250.0 | 100.0 | 120.0 | | 71.88 | 1.46 | 9.96 |
| | 13 | 14 | 250.0 | 61.0 | 120.0 | | 61.10 | 1.24 | 7.37 |
| | 14 | 101 | 250.0 | 518.0 | 120.0 | | 51.14 | 1.04 | 5.31 |
| | 14 | 105 | 100.0 | 954.0 | 120.0 | 75.0 | 9.96 | 1.27 | 22.31 |
| | 34 | 35 | 250.0 | 242.0 | 120.0 | | 42.32 | 0.86 | 3.74 |
| | 35 | 36 | 200.0 | 488.0 | 120.0 | | 31.49 | 1.00 | 6.41 |
| | 36 | 37 | 200.0 | 366.0 | 120.0 | | 31.49 | 1.00 | 6.41 |
| | 37 | 11 | 200.0 | 10.0 | 120.0 | | 31.49 | 1.00 | 6.41 |
| | 9 | 35 | 250.0 | 31.0 | 120.0 | | -10.84 | -0.22 | -0.30 |
| | 1 | 201 | 250.0 | 52.0 | 120.0 | | -56.23 | -1.15 | -6.32 |
| New | 13 | 71 | 198.0 | 424.0 | 130.0 | | 10.78 | 0.35 | 0.80 |
| New | 71 | 72 | 198.0 | 74.0 | 130.0 | | 10.78 | 0.35 | 0.80 |
| New | 72 | 73 | 198.0 | 207.0 | 130.0 | | 10.78 | 0.35 | 0.80 |
| New | 73 | 74 | 198.0 | 100.0 | 130.0 | | 10.78 | 0.35 | 0.80 |
| | 74 | 75 | 97.0 | 216.0 | 130.0 | | 2.68 | 0.36 | 1.97 |
| | 75 | 76 | 97.0 | 30.0 | 130.0 | | 2.68 | 0.36 | 1.97 |
| | 76 | 77 | 97.0 | 300.0 | 130.0 | | 2.68 | 0.36 | 1.97 |
| | 77 | 78 | 97.0 | 125.0 | 130.0 | | 2.68 | 0.36 | 1.97 |
| | 78 | 102 | 97.0 | 104.0 | 130.0 | | 2.68 | 0.36 | 1.97 |
| New | 74 | 81 | 198.0 | 1179.0 | 130.0 | | 8.10 | 0.26 | 0.47 |
| New | 81 | 82 | 198.0 | 540.0 | 130.0 | | 8.10 | 0.26 | 0.47 |
| New | 82 | 85 | 65.0 | 210.0 | 130.0 | 25 | 1.65 | 0.50 | 5.66 |
| New | 85 | 86 | 80.0 | 45.0 | 120.0 | | 1.65 | 0.33 | 2.39 |
| New | 86 | 107 | 65.0 | 246.0 | 130.0 | | 1.65 | 0.50 | 5.66 |
| New | 82 | 83 | 140.0 | 340.0 | 130.0 | | 6.44 | 0.42 | 1.67 |
| New | 83 | 84 | 140.0 | 797.0 | 130.0 | | 6.44 | 0.42 | 1.67 |
| | 84 | 106 | 97.0 | 444.0 | 130.0 | | 3.22 | 0.44 | 2.76 |
| New | 10 | 51 | 250.0 | 272.0 | 120.0 | | 26.67 | 0.54 | 1.59 |
| New | 51 | 52 | 250.0 | 146.0 | 120.0 | | 26.67 | 0.54 | 1.59 |
| New | 52 | 53 | 250.0 | 188.0 | 120.0 | | 26.67 | 0.54 | 1.59 |
| New | 53 | 54 | 250.0 | 411.0 | 120.0 | | 26.67 | 0.54 | 1.59 |
| New | 54 | 55 | 250.0 | 197.0 | 120.0 | | 26.67 | 0.54 | 1.59 |
| New | 55 | 56 | 250.0 | 923.0 | 120.0 | | 26.67 | 0.54 | 1.59 |
| New | 56 | 61 | 198.0 | 259.0 | 130.0 | | 20.17 | 0.66 | 2.55 |
| New | 61 | 103 | 198.0 | 175.0 | 130.0 | | 20.17 | 0.66 | 2.55 |
| New | 56 | 57 | 97.0 | 363.0 | 130.0 | | 6.50 | 0.88 | 10.12 |
| New | 57 | 58 | 97.0 | 156.0 | 130.0 | | 6.50 | 0.88 | 10.12 |
| | 58 | 104 | 97.0 | 450.0 | 130.0 | 25 | 6.50 | 0.88 | 10.12 |
| New | 31 | 32 | 300.0 | 242.0 | 120.0 | | 42.32 | 0.60 | 1.54 |
| New | 32 | 33 | 300.0 | 214.0 | 120.0 | | 42.32 | 0.60 | 1.54 |
| New | 33 | 34 | 300.0 | 273.0 | 120.0 | | 42.32 | 0.60 | 1.54 |
| New | 31 | 203 | 300.0 | 254.0 | 120.0 | | -42.32 | -0.60 | -1.54 |
| New | 84 | 106 | 97.0 | 444.0 | 130.0 | | 3.22 | 0.44 | 2.76 |

End

**TRANSMISSION PIPELINE**
**Phase 1 (2005) DRY**

| | |
|---|---|
| Nos of nodes | 35 |
| Nos of pipes | 32 |

NODE

| | NO | Type | Q l/sec | WL m | GL m | EH m |
|---|---|---|---|---|---|---|
| Bambarakele | 201 | 1 | -15.357 | 1989.00 | 1989.00 | 0.00 |
| J.Well 1 (to H.Hill) | 211 | 1 | -45.741 | 1885.70 | 1885.70 | 0.00 |
| J.Well 1 (to Ge/Vi) | 212 | 1 | -8.098 | 1885.70 | 1885.70 | 0.00 |
| J.Well 2 (ro Low2) | 213 | 1 | -20.169 | 1859.00 | 1859.00 | 0.00 |
| | 1 | 0 | 0 | 1988.97 | 1,985.0 | 3.97 |
| | 2 | 0 | 0 | 1988.94 | 1,987.0 | 1.94 |
| | 3 | 0 | 0 | 1988.82 | 1,978.0 | 10.82 |
| | 4 | 0 | 0 | 1988.75 | 1,924.0 | 64.75 |
| | 5 | 0 | 0 | 1988.63 | 1,917.0 | 71.63 |
| | 6 | 0 | 0 | 1988.28 | 1,946.0 | 42.28 |
| | 7 | 0 | 0 | 1987.77 | 1,895.0 | 92.77 |
| | 8 | 0 | 0 | 1986.68 | 1,896.0 | 90.68 |
| | 9 | 0 | 0 | 1984.92 | 1,881.0 | 103.92 |
| | 10 | 0 | 0 | 1984.64 | 1,877.0 | 107.64 |
| | 11 | 0 | 0 | 1984.43 | 1,882.0 | 102.43 |
| | 12 | 0 | 0 | 1934.37 | 1,885.0 | 49.37 |
| | 13 | 0 | 0 | 1934.36 | 1,887.0 | 47.36 |
| | 14 | 0 | 0 | 1934.35 | 1,891.0 | 43.35 |
| | 61 | 0 | 0 | 1936.96 | 1,925.0 | 11.96 |
| | 71 | 0 | 0 | 1960.49 | 1,881.8 | 78.69 |
| | 72 | 0 | 0 | 1960.46 | 1,881.3 | 79.16 |
| | 73 | 0 | 0 | 1960.36 | 1,883.7 | 76.66 |
| | 74 | 0 | 0 | 1960.31 | 1,882.3 | 78.01 |
| | 81 | 0 | 0 | 1959.76 | 1,876.0 | 83.76 |
| | 82 | 0 | 0 | 1959.50 | 1,881.3 | 78.20 |
| | 83 | 0 | 0 | 1958.94 | 1,879.2 | 79.74 |
| | 84 | 0 | 0 | 1957.61 | 1,900.0 | 57.61 |
| | 85 | 0 | 0 | 1958.31 | 1,900.0 | 58.31 |
| | 86 | 0 | 0 | 1958.21 | 1,930.0 | 28.21 |
| Low Area 2 | 103 | 0 | 20.16874 | 1936.52 | 1,927.7 | 8.82 |
| Haddon Hill (gravty) | 101 | 0 | 5.393519 | 1934.31 | 1,930.0 | 4.31 |
| Haddon Hill (well) | 110 | 0 | 45.74074 | 1939.88 | 1,930.0 | 9.88 |
| Unique View | 105 | 0 | 9.963006 | 1988.08 | 1,980.2 | 7.88 |
| Gemunupura(well) | 107 | 0 | 1.654984 | 1956.81 | 1,951.1 | 5.71 |
| Vijithapura(well) | 106 | 0 | 6.443406 | 1956.38 | 1,930.8 | 25.58 |

PIPE

| | | NO(u) | NO(d) | Dia mm | Length m | C | dH m | Q l/sec | V m/sec | I o/oo |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 250.0 | 56.0 | 120.0 | | 15.36 | 0.31 | 0.57 |
| | | 2 | 3 | 250.0 | 201.0 | 120.0 | | 15.36 | 0.31 | 0.57 |
| | | 3 | 4 | 250.0 | 123.0 | 120.0 | | 15.36 | 0.31 | 0.57 |
| | | 4 | 5 | 250.0 | 207.0 | 120.0 | | 15.36 | 0.31 | 0.57 |
| | | 5 | 6 | 250.0 | 621.0 | 120.0 | | 15.36 | 0.31 | 0.57 |
| | | 6 | 7 | 250.0 | 884.0 | 120.0 | | 15.36 | 0.31 | 0.57 |
| | | 7 | 8 | 200.0 | 641.0 | 120.0 | | 15.36 | 0.49 | 1.70 |
| | | 8 | 9 | 200.0 | 1036.0 | 120.0 | | 15.36 | 0.49 | 1.70 |
| | | 9 | 10 | 250.0 | 488.0 | 120.0 | | 15.36 | 0.31 | 0.57 |
| | | 10 | 11 | 250.0 | 366.0 | 120.0 | | 15.36 | 0.31 | 0.57 |
| | | 11 | 12 | 250.0 | 114.0 | 120.0 | -50 | 15.36 | 0.31 | 0.57 |
| | | 12 | 13 | 250.0 | 100.0 | 120.0 | | 5.39 | 0.11 | 0.08 |
| | | 13 | 14 | 250.0 | 61.0 | 120.0 | | 5.39 | 0.11 | 0.08 |
| | | 14 | 101 | 250.0 | 518.0 | 120.0 | | 5.39 | 0.11 | 0.08 |
| | | 1 | 201 | 250.0 | 52.0 | 120.0 | | -15.36 | -0.31 | -0.57 |
| | | 12 | 105 | 100.0 | 954.0 | 120.0 | 75.0 | 9.96 | 1.27 | 22.31 |
| | well | 211 | 110 | 198.0 | 502.0 | 130.0 | 60.0 | 45.74 | 1.49 | 11.59 |
| | well | 213 | 61 | 198.0 | 800.0 | 130.0 | 80.0 | 20.17 | 0.66 | 2.55 |
| New | | 61 | 103 | 198.0 | 175.0 | 130.0 | | 20.17 | 0.66 | 2.55 |
| New | well | 212 | 71 | 198.0 | 442.0 | 130.0 | 75.0 | 8.10 | 0.26 | 0.47 |
| New | | 71 | 72 | 198.0 | 74.0 | 130.0 | | 8.10 | 0.26 | 0.47 |
| New | | 72 | 73 | 198.0 | 207.0 | 130.0 | | 8.10 | 0.26 | 0.47 |
| New | | 73 | 74 | 198.0 | 100.0 | 130.0 | | 8.10 | 0.26 | 0.47 |
| New | | 74 | 81 | 198.0 | 1179.0 | 130.0 | | 8.10 | 0.26 | 0.47 |
| New | | 81 | 82 | 198.0 | 540.0 | 130.0 | | 8.10 | 0.26 | 0.47 |
| New | | 82 | 85 | 65.0 | 210.0 | 130.0 | | 1.65 | 0.50 | 5.66 |
| New | | 85 | 86 | 80.0 | 45.0 | 120.0 | | 1.65 | 0.33 | 2.39 |
| New | | 86 | 107 | 65.0 | 246.0 | 130.0 | | 1.65 | 0.50 | 5.66 |
| New | | 82 | 83 | 140.0 | 340.0 | 130.0 | | 6.44 | 0.42 | 1.67 |
| New | | 83 | 84 | 140.0 | 797.0 | 130.0 | | 6.44 | 0.42 | 1.67 |
| | | 84 | 106 | 97.0 | 444.0 | 130.0 | | 3.22 | 0.44 | 2.76 |
| New | | 84 | 106 | 97.0 | 444.0 | 130.0 | | 3.22 | 0.44 | 2.76 |

End

**The roles of new Transmission Pipelines**

1) From Pedro Reservoir to Node 34 (DCIPφ300mm)
In rainy season water transmitted from Pedro Reservoir will increase since water should be transmitted to all the reservoirs except for the ones in High Area 1 from Bambarakele Intake and Pedro Intake.

The new transmission pipeline from Pedro Reservoir to Node 34 is to be installed in order to transmit the increased amount of water and to isolate transmission pipeline from distribution pipeline. (At present water is transmitted from Pedro to Haddon Hill reservoir only through distribution pipeline.)

2) From Node 10 to Low Area 2 Reservoir (DCIPφ250mm/PVCφ225mm)
New transmission pipeline from Node 10 to new Low Area 2 Reservoir is required to transmit surface water to the new reservoir in rain season.

3) From Hawa Eliya Junction Well to Node 61 (PVCφ225mm)
New transmission pipeline from new Hawa Eliya junction well to Node 61 is to be installed to transmit groundwater to new Low Area 2 Reservoir in dry season. The pipeline from junction 61 to Low Area 2, which is a part of the pipeline from Node 10 to Low Area 2 reservoir for rain season, will be used in dry season.

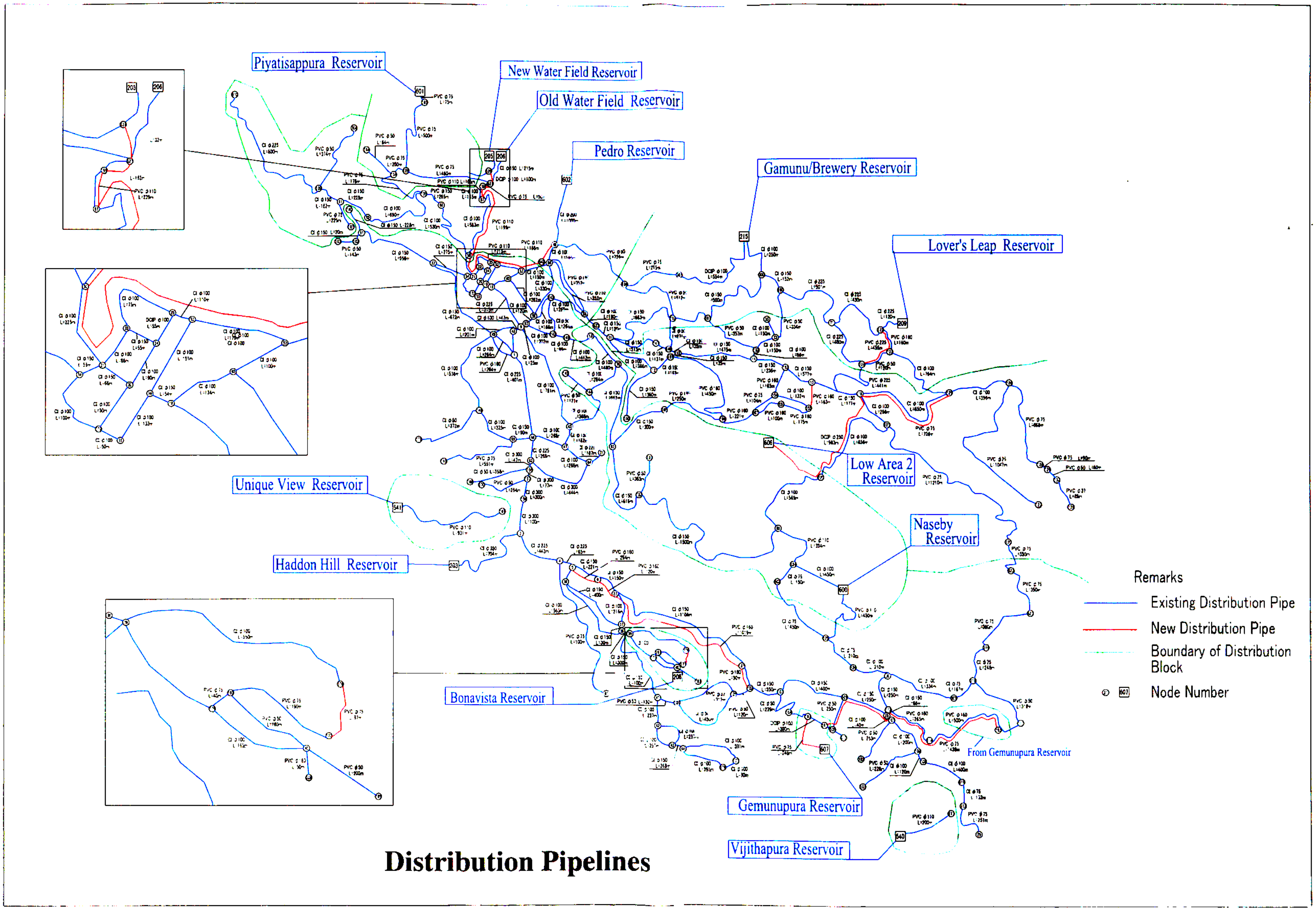
4) From Node 56 to Node 58 (PVCφ110mm)
Surface water is to be transmitted to Naseby reservoir in rain season, where groundwater is transmitted at the moment. For this purpose new transmission pipeline is required to be extended from Node 56 to Node 58. The existing pipeline from Node 58 to Nasbey reservoir will also be used for this purpose.

5) From Race Course Junction Well to Haddon Hill Reservoir (PVCφ225mm)
In dry season groundwater should be transmitted from Race Course Junction Well to Haddon Hill reservoir through the new (additional) transmission pipeline in order to supplement surface water shortage.

6) From Race Course Junction Well/Node 13 to Node 84 (PVCφ225mm/PVCφ160mm)
New independent transmission pipeline is required to transmit water to Bonavista reservoir, Vijithapura reservoir and new Gemunupura reservoir. This pipeline is used in both dry and rain season. Distribution pipeline is used as transmission pipeline at the moment and the reinforcement of distribution pipeline with similar size was planned in Feasibility Study, which is revised.

7) From Node 82 to Gemunupura Reservoir (PVCφ75mm)
New transmission pipeline from Node 82 to new Gemunupura reservoir is to be installed to transmit water to the new reservoir.

8) From Node 84 to Vijithapura Reservoir (PVCφ110mm)
New transmission pipeline is to be installed to reinforce the existing transmission pipeline and surface water will be catered to Vijitahapura reservoir by gravity in rain season.




# Distribution Pipelines

**DISTRIBUTION**
**Phase 1**
**2005 DRY**

High Area 1 : Sub-zoning, Revise boundary of Piyatisappura
Low Area 1 : Separate transmission from distribution
North-east of Lake Gregory : From Haddon Hill and Gemunupura

Nos of nodes 182
Nos of pipes 213

NODE

| | NO | Type | Q | WL | GL | EH | | |
|---|---|---|---|---|---|---|---|---|
| | | | l/sec | m | m | m | | |
| Haddon Hill | 203 | 1 | -85.390 | 1927.00 | 1927.00 | 0.00 | | L1 |
| Bonavista | 208 | 1 | -4.474 | 1927.00 | 1927.00 | 0.00 | | B |
| Lover Leap | 209 | 1 | -6.642516 | 1960.00 | 1960.00 | 0.00 | | 1-3 |
| Nasby | 600 | 1 | -10.863 | 1943.00 | 1943.00 | 0.00 | | H2 |
| Piyatisappura | 601 | 1 | -3.382 | 1991.00 | 1991.00 | 0.00 | | 1-1 |
| Pedro (New) | 602 | 1 | -8.770 | 1948.00 | 1948.00 | 0.00 | | 1-2 |
| Unique View | 603 | 1 | -0.394 | 1976.70 | 1976.70 | 0.00 | | L1 |
| Low Area 2 (New) | 606 | 1 | -30.906 | 1924.70 | 1924.70 | 0.00 | | L2 |
| Gemunupura | 607 | 1 | -1.548 | 1948.50 | 1948.50 | 0.00 | | G |
| | 134 | 0 | 0.966379 | 1986.35 | 1,924.5 | 61.85 | | 1-1 |
| | 164 | 0 | 0.071584 | 1986.34 | 1,919.8 | 66.54 | | 1-1 |
| | 165 | 0 | 1.807486 | 1989.41 | 1,962.5 | 26.91 | | 1-1 |
| | 528 | 0 | 0.536877 | 1986.82 | 1,943.0 | 43.82 | | 1-1 |
| | 50 | 0 | 2.577009 | 1943.23 | 1,886.3 | 56.93 | | 1-2 |
| | 56 | 0 | 0.876899 | 1947.40 | 1,902.7 | 44.70 | | 1-2 |
| | 59 | 0 | 2.1833 | 1947.35 | 1,900.0 | 47.35 | | 1-2 |
| | 66 | 0 | 0.715836 | 1936.96 | 1,910.0 | 26.96 | | 1-2 |
| | 67 | 0 | 0.680044 | 1943.80 | 1,921.5 | 22.30 | | 1-2 |
| | 68 | 0 | 0.751628 | 1946.08 | 1,918.6 | 27.48 | | 1-2 |
| | 91 | 0 | 0 | 1931.57 | 1,899.4 | 32.17 | | 1-2 |
| | 92 | 0 | 0 | 1931.79 | 1,895.4 | 36.39 | | 1-2 |
| | 135 | 0 | 1.037962 | 1936.61 | 1,915.7 | 20.91 | | 1-2 |
| | 139 | 0 | 2.952823 | 1931.43 | 1,905.8 | 25.63 | | 1-2 |
| | 161 | 0 | 0.196855 | 1931.55 | 1,905.3 | 26.25 | | 1-2 |
| | 174 | 0 | 1.861173 | 1944.49 | 1,902.4 | 42.09 | | 1-2 |
| | 188 | 0 | 0.143167 | 1944.62 | 1,931.7 | 12.92 | | 1-2 |
| | 304 | 0 | 1.252713 | 1922.96 | 1,900.4 | 22.56 | | 1-2 |
| | 510 | 0 | 0.912691 | 1931.42 | 1,914.5 | 16.92 | | 1-2 |
| | 527 | 0 | 0.536877 | 1947.04 | 1,931.0 | 16.04 | | 1-2 |
| | 529 | 0 | 0 | 1947.08 | 1,936.0 | 11.08 | | 1-2 |
| | 542 | 0 | 0 | 1945.06 | 1,889.1 | 55.96 | | 1-2 |
| | 11 | 0 | 1.539047 | 1958.98 | 1,902.1 | 56.88 | | 1-3 |
| | 122 | 0 | 1.592735 | 1959.98 | 1,950.0 | 9.98 | | 1-3 |
| | 123 | 0 | 1.163233 | 1959.95 | 1,927.3 | 32.65 | | 1-3 |
| | 136 | 0 | 1.270609 | 1959.67 | 1,944.8 | 14.87 | | 1-3 |
| | 137 | 0 | 2.111716 | 1959.14 | 1,905.0 | 54.14 | | 1-3 |
| | 160 | 0 | 0.340022 | 1959.91 | 1,903.2 | 56.71 | | 1-3 |
| | 187 | 0 | 1.360088 | 1959.36 | 1,903.2 | 56.16 | | 1-3 |
| | 300 | 0 | 0.841107 | 1959.91 | 1,903.6 | 56.31 | | 1-3 |
| | 301 | 0 | 1.360088 | 1960.69 | 1,951.4 | 9.29 | | 1-3 |
| | 523 | 0 | 0.912691 | 1958.98 | 1,903.0 | 55.98 | | 1-3 |
| | 39 | 0 | 0.894795 | 1926.35 | 1,902.4 | 23.95 | | B |
| | 40 | 0 | 0.715836 | 1926.96 | 1,920.0 | 6.96 | | B |
| | 173 | 0 | 0.912691 | 1926.19 | 1,912.0 | 14.19 | | B |
| | 178 | 0 | 0.984274 | 1926.19 | 1,900.0 | 26.19 | | B |
| | 179 | 0 | 0.447397 | 1926.60 | 1,915.0 | 11.60 | | B |
| | 189 | 0 | 0.518981 | 1926.07 | 1,921.8 | 4.27 | | B |
| | 199 | 0 | 0 | 1926.57 | 1,915.0 | 11.57 | | B |
| | 104 | 0 | 0.170011 | 1947.13 | 1,916.3 | 30.83 | | G |
| | 105 | 0 | 0.152115 | 1913.21 | 1,903.9 | 9.31 | | G |
| | 190 | 0 | 0.170011 | 1947.27 | 1,923.0 | 24.27 | | G |
| | 191 | 0 | 0.152115 | 1947.25 | 1,913.0 | 34.25 | | G |
| | 192 | 0 | 1.055858 | 1943.70 | 1,907.5 | 36.20 | for 117 | G |
| | 612 | 0 | 0 | 1913.21 | 1,881.3 | 31.91 | | G |
| | 10 | 0 | 0.447397 | 1922.99 | 1,903.4 | 19.59 | | H2 |
| | 62 | 0 | 1.360088 | 1925.64 | 1,890.2 | 35.44 | | H2 |
| | 70 | 0 | 2.362259 | 1923.00 | 1,904.5 | 18.50 | | H2 |
| | 93 | 0 | 0 | 1923.31 | 1,882.0 | 41.31 | | H2 |
| | 132 | 0 | 0.912691 | 1923.80 | 1,886.8 | 37.00 | | H2 |
| | 133 | 0 | 0.322126 | 1923.14 | 1,898.7 | 24.44 | | H2 |
| | 144 | 0 | 0.69794 | 1922.94 | 1,907.4 | 15.54 | | H2 |
| | 145 | 0 | 0.107375 | 1922.91 | 1,909.3 | 13.61 | | H2 |
| | 185 | 0 | 1.181129 | 1923.29 | 1,902.8 | 20.49 | | H2 |
| | 502 | 0 | 1.431672 | 1930.84 | 1,885.6 | 45.24 | | H2 |
| | 520 | 0 | 1.127442 | 1925.41 | 1,913.6 | 11.81 | | H2 |
| | 524 | 0 | 0.912691 | 1931.22 | 1,887.0 | 44.22 | | H2 |
| | 1 | 0 | 2.1833 | 1920.39 | 1,881.7 | 38.69 | | L1 |
| | 2 | 0 | 1.252713 | 1925.13 | 1,885.1 | 40.03 | | L1 |
| | 4 | 0 | 1.360088 | 1923.68 | 1,881.8 | 41.88 | | L1 |
| | 5 | 0 | 0.715836 | 1923.49 | 1,881.3 | 42.19 | | L1 |
| | 6 | 0 | 1.360088 | 1922.47 | 1,883.7 | 38.77 | | L1 |
| | 9 | 0 | 2.380154 | 1916.80 | 1,881.2 | 35.60 | | L1 |
| | 18 | 0 | 1.914861 | 1916.60 | 1,885.1 | 31.50 | | L1 |
| | 19 | 0 | 1.521151 | 1916.52 | 1,885.8 | 30.72 | | L1 |
| | 20 | 0 | 1.48536 | 1916.27 | 1,885.9 | 30.37 | | L1 |
| | 21 | 0 | 1.735902 | 1916.28 | 1,885.1 | 31.18 | | L1 |
| | 22 | 0 | 1.413776 | 1916.97 | 1,889.4 | 27.57 | | L1 |
| | 23 | 0 | 1.467464 | 1916.16 | 1,887.3 | 28.86 | | L1 |
| | 24 | 0 | 2.09382 | 1916.16 | 1,887.7 | 28.46 | | L1 |
| | 25 | 0 | 0.912691 | 1916.16 | 1,887.0 | 29.16 | | L1 |
| | 27 | 0 | 1.342192 | 1922.10 | 1,882.3 | 39.80 | | L1 |
| | 28 | 0 | 0.465293 | 1912.10 | 1,879.2 | 32.90 | | L1 |
| | 29 | 0 | 0.232647 | 1911.73 | 1,892.4 | 19.33 | | L1 |
| | 30 | 0 | 1.431672 | 1911.43 | 1,882.6 | 28.83 | | L1 |
| | 31 | 0 | 1.664319 | 1923.85 | 1,882.0 | 41.85 | | L1 |
| | 36 | 0 | 0.912691 | 1923.34 | 1,889.3 | 34.04 | | L1 |
| | 37 | 0 | 0.841107 | 1923.06 | 1,891.4 | 31.66 | | L1 |
| | 38 | 0 | 0.751628 | 1923.06 | 1,893.9 | 29.16 | | L1 |
| | 41 | 0 | 0.78742 | 1917.21 | 1,899.2 | 18.01 | | L1 |
| | 42 | 0 | 0.680044 | 1917.17 | 1,896.1 | 21.07 | | L1 |
| | 43 | 0 | 0.715836 | 1917.05 | 1,894.8 | 22.25 | | L1 |
| | 44 | 0 | 0.966379 | 1917.02 | 1,893.4 | 23.62 | | L1 |
| | 45 | 0 | 1.199025 | 1921.71 | 1,884.9 | 36.81 | | L1 |
| | 46 | 0 | 2.272779 | 1922.11 | 1,878.2 | 43.91 | | L1 |
| | 47 | 0 | 0.644252 | 1921.93 | 1,880.7 | 41.23 | | L1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 48 | 0 | 1.807486 | 1919.96 | 1,880.2 | 39.76 | L1 |
| | 49 | 0 | 2.863344 | 1919.92 | 1,881.1 | 38.82 | L1 |
| | 51 | 0 | 0.841107 | 1916.86 | 1,895.4 | 21.46 | L1 |
| | 52 | 0 | 1.735902 | 1916.16 | 1,889.1 | 27.06 | L1 |
| | 53 | 0 | 1.735902 | 1916.12 | 1,895.7 | 20.42 | L1 |
| | 54 | 0 | 0.912691 | 1916.35 | 1,886.0 | 30.35 | L1 |
| | 55 | 0 | 1.592735 | 1916.30 | 1,886.2 | 30.10 | L1 |
| | 57 | 0 | 1.664319 | 1916.40 | 1,884.1 | 32.30 | L1 |
| | 58 | 0 | 2.129612 | 1916.06 | 1,890.9 | 25.16 | L1 |
| | 60 | 0 | 1.78959 | 1916.14 | 1,889.9 | 26.24 | L1 |
| | 61 | 0 | 0.894795 | 1921.91 | 1,885.4 | 36.51 | L1 |
| | 63 | 0 | 0.680044 | 1923.88 | 1,878.7 | 45.18 | L1 |
| | 64 | 0 | 0.78742 | 1923.85 | 1,876.5 | 47.35 | L1 |
| | 69 | 0 | 0.894795 | 1922.03 | 1,879.5 | 42.53 | L1 |
| | 100 | 0 | 0.590565 | 1917.29 | 1,896.6 | 20.69 | L1 |
| | 101 | 0 | 0.447397 | 1917.63 | 1,885.9 | 31.73 | L1 |
| | 102 | 0 | 0.662148 | 1917.74 | 1,876.7 | 41.04 | L1 |
| | 103 | 0 | 0.894795 | 1915.55 | 1,883.1 | 32.45 | L1 |
| | 106 | 0 | 0.769524 | 1913.32 | 1,881.3 | 32.02 | L1 |
| | 107 | 0 | 0.572669 | 1912.03 | 1,880.1 | 31.93 | L1 |
| | 108 | 0 | 0.536877 | 1911.86 | 1,884.1 | 27.76 | L1 |
| | 109 | 0 | 0.357918 | 1911.83 | 1,884.6 | 27.23 | L1 |
| | 112 | 0 | 0 | 1911.77 | 1,900.7 | 11.07 | L1 |
| | 113 | 0 | 0.518981 | 1911.90 | 1,878.5 | 33.40 | L1 |
| | 114 | 0 | 1.020066 | 1910.37 | 1,897.3 | 13.07 | L1 |
| | 117 | 0 | 0 | 1910.36 | 1,907.5 | 2.86 | L1 |
| | 118 | 0 | 0.662148 | 1908.21 | 1,889.0 | 19.21 | L1 |
| | 119 | 0 | 1.145337 | 1905.81 | 1,889.1 | 16.71 | L1 |
| | 140 | 0 | 0.554773 | 1916.86 | 1,899.4 | 17.46 | L1 |
| | 141 | 0 | 1.771694 | 1915.67 | 1,890.2 | 25.47 | L1 |
| | 142 | 0 | 1.843278 | 1915.76 | 1,883.9 | 31.86 | L1 |
| | 143 | 0 | 1.968549 | 1915.84 | 1,888.7 | 27.14 | L1 |
| | 148 | 0 | 1.127442 | 1920.77 | 1,889.6 | 31.17 | L1 |
| | 149 | 0 | 0.501085 | 1921.69 | 1,901.1 | 20.59 | L1 |
| | 156 | 0 | 0.715836 | 1924.88 | 1,884.8 | 40.08 | L1 |
| | 157 | 0 | 0.429502 | 1924.17 | 1,881.9 | 42.27 | L1 |
| | 158 | 0 | 0.429502 | 1923.99 | 1,880.3 | 43.69 | L1 |
| | 162 | 0 | 0.680044 | 1916.86 | 1,891.8 | 25.06 | L1 |
| | 163 | 0 | 0.125271 | 1916.81 | 1,899.3 | 17.51 | L1 |
| | 166 | 0 | 0.322126 | 1923.58 | 1,899.0 | 24.58 | L1 |
| | 169 | 0 | 0.39371 | 1976.70 | 1,917.8 | 58.90 | L1 |
| | 170 | 0 | 0.232647 | 1923.90 | 1,893.3 | 30.60 | L1 |
| | 171 | 0 | 0.340022 | 1920.31 | 1,909.7 | 10.61 | L1 |
| | 172 | 0 | 0.912691 | 1916.29 | 1,886.0 | 30.29 | L1 |
| | 176 | 0 | 0.411606 | 1916.99 | 1,895.0 | 21.99 | L1 |
| | 177 | 0 | 0.411606 | 1916.99 | 1,897.3 | 19.69 | L1 |
| | 181 | 0 | 1.431672 | 1918.06 | 1,881.0 | 37.06 | L1 |
| | 182 | 0 | 0.232647 | 1911.78 | 1,891.9 | 19.88 | L1 |
| | 183 | 0 | 0.214751 | 1911.66 | 1,899.2 | 12.46 | L1 |
| | 503 | 0 | 1.360088 | 1909.83 | 1,884.2 | 25.63 | L1 |
| | 511 | 0 | 0.357918 | 1911.78 | 1,892.1 | 19.68 | L1 |
| | 521 | 0 | 0.912691 | 1903.44 | 1,886.0 | 17.44 | L1 |
| | 522 | 0 | 0.912691 | 1903.34 | 1,880.0 | 23.34 | L1 |
| | 525 | 0 | 0.912691 | 1911.00 | 1,881.0 | 30.00 | L1 |
| | 526 | 0 | 0.912691 | 1911.23 | 1,882.0 | 29.23 | L1 |
| | 12 | 0 | 1.181129 | 1918.82 | 1,880.5 | 38.32 | L2 |
| | 13 | 0 | 0.912691 | 1918.89 | 1,874.2 | 44.69 | L2 |
| | 14 | 0 | 1.181129 | 1919.12 | 1,865.6 | 53.52 | L2 |
| | 15 | 0 | 1.09165 | 1920.77 | 1,860.5 | 60.27 | L2 |
| | 16 | 0 | 1.521151 | 1922.69 | 1,860.5 | 62.19 | L2 |
| | 33 | 0 | 0.912691 | 1918.77 | 1,867.0 | 51.77 | L2 |
| | 35 | 0 | 1.09165 | 1918.71 | 1,870.0 | 48.71 | L2 |
| | 71 | 0 | 1.556943 | 1959.91 | 1,894.5 | 65.41 | L2 |
| | 120 | 0 | 2.022237 | 1920.11 | 1,871.2 | 48.91 | L2 |
| | 121 | 0 | 1.950653 | 1921.52 | 1,862.6 | 58.92 | L2 |
| | 124 | 0 | 1.216921 | 1959.93 | 1,879.6 | 80.33 | L2 |
| | 125 | 0 | 1.932757 | 1918.80 | 1,886.2 | 32.60 | L2 |
| | 126 | 0 | 1.914861 | 1917.24 | 1,894.1 | 23.14 | L2 |
| | 127 | 0 | 0.966379 | 1915.05 | 1,874.9 | 40.15 | L2 |
| | 128 | 0 | 0.680044 | 1915.70 | 1,896.4 | 19.30 | L2 |
| | 129 | 0 | 0.143167 | 1915.67 | 1,896.0 | 19.67 | L2 |
| | 130 | 0 | 0.125271 | 1915.62 | 1,886.4 | 29.22 | L2 |
| | 131 | 0 | 0.071584 | 1915.60 | 1,875.8 | 39.80 | L2 |
| | 146 | 0 | 0.966379 | 1918.88 | 1,876.5 | 42.38 | L2 |
| | 147 | 0 | 1.753798 | 1918.86 | 1,878.9 | 39.96 | L2 |
| | 150 | 0 | 2.111716 | 1918.76 | 1,899.4 | 19.36 | L2 |
| | 151 | 0 | 1.360088 | 1918.89 | 1,874.4 | 44.49 | L2 |
| | 152 | 0 | 1.181129 | 1918.94 | 1,865.9 | 53.04 | L2 |
| | 153 | 0 | 1.270609 | 1919.61 | 1,862.7 | 56.91 | L2 |
| | 154 | 0 | 1.181129 | 1919.71 | 1,864.7 | 55.01 | L2 |
| | 155 | 0 | 0.39371 | 1920.09 | 1,867.6 | 52.49 | L2 |
| | 186 | 0 | 1.181129 | 1919.29 | 1,885.4 | 33.89 | L2 |
| | 500 | 0 | 0.447397 | 1919.76 | 1,892.8 | 26.96 | L2 |
| | 501 | 0 | 1.360088 | 1919.59 | 1,886.6 | 32.99 | L2 |
| New Water F | 205 | 0 | -2.314815 | 1947.31 | 1,960.0 | -12.69 | 1-2 |
| Old Water F (New) | 206 | 0 | -5.594136 | 1947.26 | 1,955.0 | -7.73 | 1-2 |
| Gamunu/Brewery | 215 | 0 | -8.622685 | 1961.93 | 1979.00 | -17.07 | 1-3 |

PIPE

| NO(u) | NO(d) | Dia mm | Length m | C | dH m | Q l/sec | V m/sec | I o/oo |
|---|---|---|---|---|---|---|---|---|
| 139 | 510 | 225.0 | 800.0 | 120.0 | | 0.91 | 0.02 | 0.01 |
| 139 | 304 | 44.0 | 374.0 | 130.0 | | 1.25 | 0.82 | 22.63 |
| 51 | 140 | 150.0 | 228.0 | 120.0 | | 0.55 | 0.03 | 0.01 |
| 162 | 163 | 44.0 | 143.0 | 130.0 | | 0.13 | 0.08 | 0.32 |
| 51 | 162 | 150.0 | 20.0 | 120.0 | | 0.81 | 0.05 | 0.03 |
| 134 | 164 | 44.0 | 84.0 | 130.0 | | 0.07 | 0.05 | 0.11 |
| 66 | 135 | 150.0 | 265.0 | 120.0 | | 6.35 | 0.36 | 1.35 |
| 50 | 66 | 100.0 | 530.0 | 120.0 | | 7.07 | 0.90 | 11.83 |
| 50 | 67 | 100.0 | 199.0 | 120.0 | | -3.27 | -0.42 | -2.85 |
| 67 | 188 | 100.0 | 239.0 | 120.0 | | -3.61 | -0.46 | -3.42 |
| 21 | 54 | 150.0 | 59.0 | 120.0 | | -6.09 | -0.34 | -1.24 |
| 21 | 23 | 100.0 | 88.0 | 120.0 | | 2.16 | 0.27 | 1.32 |
| 23 | 24 | 150.0 | 55.0 | 120.0 | | 0.40 | 0.02 | 0.01 |
| 20 | 24 | 100.0 | 90.0 | 120.0 | | 2.01 | 0.26 | 1.16 |
| 20 | 21 | 150.0 | 66.0 | 120.0 | | -2.19 | -0.12 | -0.19 |
| 25 | 52 | 100.0 | 110.0 | 120.0 | | -0.30 | -0.04 | -0.04 |
| 52 | 53 | 100.0 | 176.0 | 120.0 | | 0.90 | 0.11 | 0.26 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 53 | 60 | 100.0 | 100.0 | 120.0 | -0.84 | -0.11 | -0.23 |
| 18 | 60 | 100.0 | 134.0 | 120.0 | 3.62 | 0.46 | 3.43 |
| 18 | 19 | 150.0 | 54.0 | 120.0 | 6.86 | 0.39 | 1.55 |
| 19 | 52 | 100.0 | 151.0 | 120.0 | 2.94 | 0.37 | 2.33 |
| 19 | 55 | 100.0 | 133.0 | 120.0 | 2.40 | 0.31 | 1.60 |
| 54 | 172 | 100.0 | 100.0 | 120.0 | 1.41 | 0.18 | 0.60 |
| 9 | 18 | 225.0 | 315.0 | 120.0 | 12.40 | 0.31 | 0.64 |
| 9 | 48 | 100.0 | 47.0 | 120.0 | -18.07 | -2.30 | -67.10 |
| 1 | 48 | 225.0 | 265.0 | 120.0 | 20.61 | 0.52 | 1.65 |
| 48 | 49 | 100.0 | 201.0 | 120.0 | 0.74 | 0.09 | 0.18 |
| 22 | 49 | 150.0 | 672.0 | 120.0 | -12.02 | -0.68 | -4.38 |
| 22 | 51 | 150.0 | 596.0 | 120.0 | 2.20 | 0.12 | 0.19 |
| 49 | 148 | 100.0 | 536.0 | 120.0 | -2.39 | -0.30 | -1.59 |
| 148 | 171 | 50.0 | 372.0 | 120.0 | 0.34 | 0.17 | 1.26 |
| 69 | 148 | 100.0 | 325.0 | 120.0 | 3.86 | 0.49 | 3.86 |
| 46 | 69 | 150.0 | 90.0 | 120.0 | 5.26 | 0.30 | 0.95 |
| 69 | 149 | 65.0 | 551.0 | 130.0 | 0.50 | 0.15 | 0.62 |
| 1 | 49 | 100.0 | 264.0 | 120.0 | 2.55 | 0.32 | 1.79 |
| 1 | 46 | 225.0 | 401.0 | 120.0 | -34.55 | -0.87 | -4.29 |
| 46 | 47 | 100.0 | 268.0 | 120.0 | 1.54 | 0.20 | 0.70 |
| 47 | 64 | 100.0 | 268.0 | 120.0 | -5.40 | -0.69 | -7.19 |
| 63 | 64 | 300.0 | 444.0 | 120.0 | 7.85 | 0.11 | 0.07 |
| 46 | 63 | 225.0 | 268.0 | 120.0 | -43.61 | -1.10 | -6.60 |
| 63 | 158 | 300.0 | 47.0 | 120.0 | -52.15 | -0.74 | -2.26 |
| 158 | 166 | 50.0 | 358.0 | 120.0 | 0.32 | 0.16 | 1.14 |
| 157 | 158 | 300.0 | 77.0 | 120.0 | 52.90 | 0.75 | 2.32 |
| 157 | 170 | 44.0 | 264.0 | 130.0 | 0.23 | 0.15 | 1.00 |
| 156 | 157 | 300.0 | 300.0 | 120.0 | 53.56 | 0.76 | 2.38 |
| 2 | 156 | 300.0 | 100.0 | 120.0 | 54.28 | 0.77 | 2.44 |
| 2 | 203 | 350.0 | 704.0 | 120.0 | -85.39 | -0.89 | -2.66 |
| 2 | 4 | 225.0 | 442.0 | 120.0 | 29.86 | 0.75 | 3.28 |
| 4 | 5 | 225.0 | 65.0 | 120.0 | 27.60 | 0.69 | 2.83 |
| 4 | 61 | 65.0 | 972.0 | 130.0 | 0.89 | 0.27 | 1.82 |
| 5 | 6 | 150.0 | 294.0 | 120.0 | 10.63 | 0.60 | 3.49 |
| 6 | 27 | 150.0 | 120.0 | 120.0 | 9.91 | 0.56 | 3.07 |
| 27 | 37 | 100.0 | 216.0 | 120.0 | -4.16 | -0.53 | -4.43 |
| 36 | 37 | 150.0 | 400.0 | 120.0 | 4.47 | 0.25 | 0.70 |
| 36 | 38 | 100.0 | 563.0 | 120.0 | 1.28 | 0.16 | 0.50 |
| 37 | 38 | 150.0 | 30.0 | 120.0 | -0.53 | -0.03 | -0.01 |
| 27 | 181 | 150.0 | 1019.0 | 120.0 | 11.39 | 0.64 | 3.97 |
| 102 | 181 | 150.0 | 90.0 | 120.0 | -10.64 | -0.60 | -3.50 |
| 102 | 103 | 150.0 | 350.0 | 120.0 | 14.58 | 0.82 | 6.26 |
| 101 | 102 | 44.0 | 120.0 | 130.0 | -0.23 | -0.15 | -0.98 |
| 41 | 100 | 44.0 | 120.0 | 130.0 | -0.18 | -0.12 | -0.63 |
| 100 | 101 | 37.0 | 312.0 | 130.0 | -0.15 | -0.14 | -1.09 |
| 42 | 43 | 100.0 | 257.0 | 120.0 | 1.25 | 0.16 | 0.48 |
| 42 | 43 | 100.0 | 257.0 | 120.0 | 1.25 | 0.16 | 0.48 |
| 43 | 44 | 150.0 | 268.0 | 120.0 | 1.79 | 0.10 | 0.13 |
| 44 | 177 | 100.0 | 391.0 | 120.0 | 0.41 | 0.05 | 0.06 |
| 44 | 176 | 100.0 | 391.0 | 120.0 | 0.41 | 0.05 | 0.06 |
| 176 | 177 | 100.0 | 90.0 | 120.0 | 0.00 | 0.00 | 0.00 |
| 29 | 112 | 65.0 | 251.0 | 130.0 | -0.23 | -0.07 | -0.15 |
| 109 | 511 | 100.0 | 400.0 | 120.0 | 0.59 | 0.08 | 0.12 |
| 108 | 109 | 100.0 | 120.0 | 120.0 | 0.95 | 0.12 | 0.29 |
| 108 | 183 | 44.0 | 228.0 | 130.0 | 0.21 | 0.14 | 0.87 |
| 107 | 108 | 100.0 | 200.0 | 120.0 | 1.70 | 0.22 | 0.85 |
| 107 | 182 | 44.0 | 253.0 | 130.0 | 0.23 | 0.15 | 1.00 |
| 28 | 107 | 100.0 | 40.0 | 120.0 | 2.51 | 0.32 | 1.74 |
| 28 | 113 | 150.0 | 66.0 | 120.0 | 9.79 | 0.55 | 3.00 |
| 113 | 114 | 65.0 | 265.0 | 130.0 | 1.67 | 0.50 | 5.77 |
| 114 | 117 | 140.0 | 500.0 | 130.0 | 0.65 | 0.04 | 0.02 |
| 117 | 118 | 44.0 | 318.0 | 130.0 | 0.65 | 0.43 | 6.77 |
| 118 | 119 | 75.0 | 248.0 | 120.0 | 2.97 | 0.67 | 9.66 |
| 28 | 106 | 150.0 | 250.0 | 120.0 | -12.76 | -0.72 | -4.90 |
| 103 | 106 | 150.0 | 400.0 | 120.0 | 13.68 | 0.77 | 5.57 |
| 30 | 526 | 100.0 | 210.0 | 120.0 | 1.83 | 0.23 | 0.97 |
| 62 | 132 | 150.0 | 1,500.0 | 120.0 | 6.03 | 0.34 | 1.22 |
| 155 | 500 | 140.0 | 175.0 | 130.0 | 6.90 | 0.45 | 1.89 |
| 132 | 133 | 44.0 | 363.0 | 130.0 | 0.32 | 0.21 | 1.83 |
| 31 | 64 | 225.0 | 167.0 | 120.0 | -1.66 | -0.04 | -0.02 |
| 70 | 144 | 100.0 | 284.0 | 120.0 | 0.81 | 0.10 | 0.21 |
| 144 | 145 | 44.0 | 121.0 | 130.0 | 0.11 | 0.07 | 0.24 |
| 45 | 47 | 150.0 | 162.0 | 120.0 | -6.29 | -0.36 | -1.32 |
| 9 | 45 | 100.0 | 761.0 | 120.0 | -5.09 | -0.65 | -6.45 |
| 9 | 57 | 100.0 | 25.0 | 120.0 | 8.38 | 1.07 | 16.21 |
| 57 | 58 | 100.0 | 120.0 | 120.0 | 3.26 | 0.42 | 2.83 |
| 58 | 60 | 100.0 | 262.0 | 120.0 | -0.99 | -0.13 | -0.31 |
| 56 | 59 | 97.0 | 352.0 | 130.0 | 0.60 | 0.08 | 0.12 |
| 58 | 143 | 100.0 | 168.0 | 120.0 | 2.13 | 0.27 | 1.28 |
| 142 | 143 | 50.0 | 264.0 | 120.0 | -0.16 | -0.08 | -0.31 |
| 57 | 142 | 100.0 | 202.0 | 120.0 | 3.46 | 0.44 | 3.15 |
| 141 | 142 | 100.0 | 99.0 | 120.0 | -1.77 | -0.23 | -0.91 |
| 12 | 150 | 150.0 | 360.0 | 120.0 | 2.11 | 0.12 | 0.18 |
| 12 | 151 | 150.0 | 163.0 | 120.0 | -3.29 | -0.19 | -0.40 |
| 13 | 151 | 150.0 | 35.0 | 120.0 | 0.05 | 0.00 | 0.00 |
| 151 | 186 | 140.0 | 450.0 | 130.0 | -4.61 | -0.30 | -0.90 |
| 154 | 155 | 100.0 | 132.0 | 120.0 | -3.30 | -0.42 | -2.88 |
| 153 | 154 | 100.0 | 165.0 | 120.0 | -1.42 | -0.18 | -0.61 |
| 14 | 153 | 150.0 | 236.0 | 120.0 | -8.04 | -0.46 | -2.09 |
| 13 | 14 | 150.0 | 475.0 | 120.0 | -3.68 | -0.21 | -0.49 |
| 13 | 146 | 150.0 | 35.0 | 120.0 | 2.72 | 0.15 | 0.28 |
| 146 | 147 | 150.0 | 137.0 | 120.0 | 1.75 | 0.10 | 0.12 |
| 11 | 137 | 150.0 | 663.0 | 120.0 | -2.45 | -0.14 | -0.23 |
| 14 | 152 | 100.0 | 66.0 | 120.0 | 3.19 | 0.41 | 2.71 |
| 33 | 152 | 100.0 | 150.0 | 120.0 | -2.00 | -0.26 | -1.15 |
| 56 | 68 | 100.0 | 165.0 | 120.0 | 5.71 | 0.73 | 7.97 |
| 136 | 137 | 44.0 | 512.0 | 130.0 | 0.24 | 0.16 | 1.04 |
| 137 | 187 | 140.0 | 277.0 | 130.0 | -4.33 | -0.28 | -0.80 |
| 71 | 124 | 225.0 | 400.0 | 120.0 | -2.67 | -0.07 | -0.04 |
| 15 | 16 | 150.0 | 177.0 | 120.0 | -19.58 | -1.11 | -10.81 |
| 16 | 121 | 100.0 | 286.0 | 120.0 | 3.97 | 0.51 | 4.07 |
| 120 | 121 | 97.0 | 1,210.0 | 130.0 | -2.02 | -0.27 | -1.17 |
| 16 | 125 | 100.0 | 850.0 | 120.0 | 4.23 | 0.54 | 4.57 |
| 122 | 209 | 225.0 | 120.0 | 120.0 | -6.64 | -0.17 | -0.20 |
| 125 | 126 | 100.0 | 396.0 | 120.0 | 3.90 | 0.50 | 3.94 |
| 126 | 128 | 65.0 | 668.0 | 130.0 | 1.02 | 0.31 | 2.31 |
| 126 | 127 | 65.0 | 1,047.0 | 130.0 | 0.97 | 0.29 | 2.09 |
| 128 | 129 | 65.0 | 90.0 | 130.0 | 0.34 | 0.10 | 0.30 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 129 | 130 | 44.0 | 60.0 | 130.0 | 0.20 | 0.13 | 0.74 |
| | | 130 | 131 | 37.0 | 88.0 | 130.0 | 0.07 | 0.07 | 0.26 |
| | | 62 | 520 | 100.0 | 569.0 | 120.0 | 1.13 | 0.14 | 0.40 |
| | | 41 | 42 | 100.0 | 237.0 | 120.0 | 0.67 | 0.09 | 0.15 |
| | | 30 | 113 | 150.0 | 250.0 | 120.0 | -7.60 | -0.43 | -1.88 |
| | | 5 | 36 | 150.0 | 105.0 | 120.0 | 6.66 | 0.38 | 1.47 |
| | | 187 | 300 | 150.0 | 500.0 | 120.0 | -5.69 | -0.32 | -1.10 |
| | | 136 | 301 | 65.0 | 215.0 | 130.0 | -1.51 | -0.45 | -4.77 |
| | | 160 | 300 | 150.0 | 152.0 | 120.0 | 0.77 | 0.04 | 0.03 |
| | | 62 | 524 | 97.0 | 334.0 | 130.0 | -8.52 | -1.15 | -16.70 |
| | | 30 | 503 | 100.0 | 334.0 | 120.0 | 4.34 | 0.55 | 4.80 |
| | | 112 | 511 | 75.0 | 132.0 | 120.0 | -0.23 | -0.05 | -0.09 |
| | | 500 | 501 | 140.0 | 100.0 | 130.0 | 6.45 | 0.42 | 1.67 |
| | | 154 | 501 | 65.0 | 104.0 | 130.0 | 0.70 | 0.21 | 1.14 |
| | | 186 | 501 | 140.0 | 221.0 | 130.0 | -5.79 | -0.38 | -1.37 |
| | | 118 | 503 | 75.0 | 167.0 | 120.0 | -2.98 | -0.67 | -9.71 |
| | | 215 | 301 | 100.0 | 554.0 | 120.0 | 2.87 | 0.37 | 2.23 |
| | | 215 | 300 | 100.0 | 250.0 | 120.0 | 5.76 | 0.73 | 8.08 |
| | | 205 | 529 | 100.0 | 150.0 | 120.0 | 2.31 | 0.29 | 1.50 |
| | | 15 | 153 | 150.0 | 577.0 | 120.0 | 7.90 | 0.45 | 2.01 |
| | | 10 | 70 | 150.0 | 480.0 | 120.0 | -0.45 | -0.03 | -0.01 |
| | | 24 | 25 | 100.0 | 55.0 | 120.0 | 0.31 | 0.04 | 0.04 |
| | | 55 | 172 | 100.0 | 50.0 | 120.0 | 0.81 | 0.10 | 0.21 |
| | | 20 | 172 | 100.0 | 50.0 | 120.0 | -1.31 | -0.17 | -0.52 |
| | | 23 | 25 | 100.0 | 75.0 | 120.0 | 0.29 | 0.04 | 0.03 |
| | | 100 | 101 | 44.0 | 450.0 | 130.0 | -0.20 | -0.13 | -0.76 |
| | | 41 | 42 | 150.0 | 150.0 | 120.0 | 2.51 | 0.14 | 0.24 |
| | | 119 | 521 | 65.0 | 350.0 | 130.0 | 1.83 | 0.55 | 6.79 |
| | | 521 | 522 | 97.0 | 350.0 | 130.0 | 0.91 | 0.12 | 0.27 |
| | | 33 | 35 | 100.0 | 150.0 | 120.0 | 1.09 | 0.14 | 0.37 |
| | | 11 | 523 | 150.0 | 120.0 | 120.0 | 0.91 | 0.05 | 0.04 |
| | | 502 | 524 | 75.0 | 150.0 | 120.0 | -1.43 | -0.32 | -2.50 |
| | | 524 | 600 | 100.0 | 450.0 | 120.0 | -10.86 | -1.38 | -26.18 |
| | | 525 | 526 | 75.0 | 210.0 | 120.0 | -0.91 | -0.21 | -1.09 |
| | | 165 | 528 | 65.0 | 500.0 | 130.0 | 1.57 | 0.47 | 5.17 |
| | | 134 | 528 | 65.0 | 200.0 | 130.0 | -1.04 | -0.31 | -2.39 |
| | | 165 | 601 | 65.0 | 75.0 | 130.0 | -3.38 | -1.02 | -21.25 |
| | | 188 | 527 | 65.0 | 150.0 | 130.0 | -2.91 | -0.88 | -16.13 |
| | | 122 | 123 | 140.0 | 160.0 | 130.0 | 1.73 | 0.11 | 0.15 |
| | | 56 | 59 | 140.0 | 352.0 | 130.0 | 1.58 | 0.10 | 0.12 |
| | | 1 | 49 | 158.0 | 264.0 | 130.0 | 9.21 | 0.47 | 1.79 |
| | | 206 | 527 | 150.0 | 215.0 | 120.0 | 5.59 | 0.32 | 1.06 |
| | | 91 | 139 | 150.0 | 162.0 | 120.0 | 5.12 | 0.29 | 0.90 |
| | | 91 | 161 | 65.0 | 225.0 | 130.0 | 0.20 | 0.06 | 0.11 |
| | | 70 | 93 | 150.0 | 662.0 | 120.0 | -3.61 | -0.20 | -0.47 |
| | | 93 | 132 | 150.0 | 616.0 | 120.0 | -4.80 | -0.27 | -0.80 |
| | | 93 | 185 | 150.0 | 300.0 | 120.0 | 1.18 | 0.07 | 0.06 |
| | | 56 | 602 | 200.0 | 1,000.0 | 120.0 | -8.77 | -0.28 | -0.60 |
| | | 22 | 54 | 150.0 | 275.0 | 120.0 | 8.41 | 0.48 | 2.28 |
| | | 71 | 160 | 225.0 | 501.0 | 120.0 | 1.11 | 0.03 | 0.01 |
| | | 91 | 92 | 150.0 | 228.0 | 120.0 | -5.32 | -0.30 | -0.97 |
| | | 92 | 135 | 100.0 | 690.0 | 120.0 | -5.32 | -0.68 | -6.98 |
| | | 105 | 612 | 44.0 | 250.0 | 130.0 | 0.00 | 0.00 | 0.00 |
| | | 174 | 542 | 97.0 | 569.0 | 130.0 | -1.86 | -0.25 | -1.00 |
| | | 169 | 603 | 97.0 | 50.0 | 130.0 | -0.39 | -0.05 | -0.08 |
| | | 208 | 40 | 140.0 | 50.0 | 130.0 | 4.47 | 0.29 | 0.85 |
| | | 40 | 189 | 44.0 | 200.0 | 130.0 | 0.52 | 0.34 | 4.43 |
| | | 40 | 199 | 44.0 | 160.0 | 130.0 | 0.37 | 0.25 | 2.42 |
| | | 40 | 179 | 100.0 | 160.0 | 120.0 | 2.87 | 0.36 | 2.22 |
| | | 179 | 39 | 100.0 | 250.0 | 120.0 | 1.85 | 0.24 | 0.99 |
| | | 179 | 199 | 65.0 | 40.0 | 130.0 | 0.57 | 0.17 | 0.78 |
| | | 199 | 173 | 65.0 | 190.0 | 130.0 | 0.94 | 0.28 | 1.99 |
| | | 39 | 178 | 100.0 | 550.0 | 120.0 | 0.96 | 0.12 | 0.29 |
| New | | 173 | 178 | 65.0 | 97.0 | 130.0 | 0.03 | 0.01 | 0.00 |
| New | | 529 | 527 | 100.0 | 32.0 | 120.0 | 2.31 | 0.29 | 1.50 |
| New | | 527 | 188 | 80.0 | 162.0 | 120.0 | 4.46 | 0.89 | 14.94 |
| New | | 67 | 188 | 97.0 | 239.0 | 130.0 | -3.61 | -0.49 | -3.42 |
| New | | 50 | 67 | 97.0 | 199.0 | 130.0 | -3.27 | -0.44 | -2.85 |
| New | | 5 | 6 | 140.0 | 294.0 | 130.0 | 9.60 | 0.62 | 3.49 |
| New | | 6 | 27 | 140.0 | 120.0 | 130.0 | 8.95 | 0.58 | 3.07 |
| New | | 27 | 181 | 140.0 | 1019.0 | 130.0 | 10.29 | 0.67 | 3.97 |
| New | | 102 | 181 | 140.0 | 90.0 | 130.0 | -9.61 | -0.62 | -3.50 |
| New | R | 16 | 606 | 250.0 | 963.0 | 120.0 | -30.91 | -0.63 | -2.09 |
| New | | 16 | 125 | 65.0 | 727.0 | 130.0 | 1.60 | 0.48 | 5.35 |
| New | | 607 | 190 | 65.0 | 246.0 | 130.0 | 1.55 | 0.47 | 5.00 |
| | | 190 | 191 | 100.0 | 45.0 | 120.0 | 1.21 | 0.15 | 0.45 |
| New | | 191 | 192 | 65.0 | 1,438.0 | 130.0 | 1.06 | 0.32 | 2.47 |
| New | | 50 | 542 | 97.0 | 713.0 | 130.0 | -3.10 | -0.42 | -2.57 |
| New | | 68 | 542 | 97.0 | 166.0 | 130.0 | 4.96 | 0.67 | 6.14 |
| | | 101 | 102 | 140.0 | 120.0 | 130.0 | -4.78 | -0.31 | -0.96 |
| | | 100 | 101 | 140.0 | 450.0 | 130.0 | -4.21 | -0.27 | -0.76 |
| | | 41 | 100 | 140.0 | 120.0 | 130.0 | -3.79 | -0.25 | -0.63 |
| New | R | 15 | 155 | 140.0 | 163.0 | 130.0 | 10.59 | 0.69 | 4.18 |
| | | 123 | 124 | 44.0 | 120.0 | 130.0 | 0.09 | 0.06 | 0.19 |
| New | | 122 | 123 | 198.0 | 260.0 | 130.0 | 3.32 | 0.11 | 0.09 |
| New | | 123 | 124 | 198.0 | 195.0 | 130.0 | 3.79 | 0.12 | 0.12 |
| | | 105 | 106 | 44.0 | 250.0 | 130.0 | -0.15 | -0.10 | -0.46 |
| | | 104 | 190 | 44.0 | 255.0 | 130.0 | -0.17 | -0.11 | -0.56 |

End

**DISTRIBUTION**
**Phase 1**
**2005 RAIN**

High Area 1 : Sub-zoning, Revise boundary of Piyatisappura
Low Area 1 : Separate transmission from distribution
North-east of Lake Gregory : From Haddon Hill and Gemunupura

Nos of nodes 182
Nos of pipes 213

| | NODE NO | Type | Q l/sec | WL m | GL m | EH m | |
|---|---|---|---|---|---|---|---|
| Haddon Hill | 203 | 1 | -85.390 | 1927.00 | 1927.00 | 0.00 | L1 |
| Bonavista | 208 | 1 | -4.474 | 1927.00 | 1927.00 | 0.00 | B |
| Lover Leap | 209 | 1 | -6.642516 | 1960.00 | 1960.00 | 0.00 | 1-3 |
| Nasby | 600 | 1 | -10.863 | 1943.00 | 1943.00 | 0.00 | H2 |
| Piyatisappura | 601 | 1 | -3.382 | 1991.00 | 1991.00 | 0.00 | 1-1 |
| Pedro (New) | 602 | 1 | -3.118 | 1948.00 | 1948.00 | 0.00 | 1-2 |
| Unique View | 603 | 1 | -0.394 | 1976.70 | 1976.70 | 0.00 | L1 |
| Low Area 2 (New) | 606 | 1 | -30.906 | 1924.70 | 1924.70 | 0.00 | L2 |
| Gemunupura | 607 | 1 | -1.548 | 1948.50 | 1948.50 | 0.00 | G |
| | 134 | 0 | 0.966379 | 1986.35 | 1,924.5 | 61.85 | 1-1 |
| | 164 | 0 | 0.071584 | 1986.34 | 1,919.8 | 66.54 | 1-1 |
| | 165 | 0 | 1.807486 | 1989.41 | 1,962.5 | 26.91 | 1-1 |
| | 528 | 0 | 0.536877 | 1986.82 | 1,943.0 | 43.82 | 1-1 |
| | 50 | 0 | 2.577009 | 1949.22 | 1,886.3 | 62.92 | 1-2 |
| | 56 | 0 | 0.876899 | 1947.91 | 1,902.7 | 45.21 | 1-2 |
| | 59 | 0 | 2.1833 | 1947.87 | 1,900.0 | 47.87 | 1-2 |
| | 66 | 0 | 0.715836 | 1942.95 | 1,910.0 | 32.95 | 1-2 |
| | 67 | 0 | 0.680044 | 1952.06 | 1,921.5 | 30.56 | 1-2 |
| | 68 | 0 | 0.751628 | 1947.91 | 1,918.6 | 29.31 | 1-2 |
| | 91 | 0 | 0 | 1937.56 | 1,899.4 | 38.16 | 1-2 |
| | 92 | 0 | 0 | 1937.78 | 1,895.4 | 42.38 | 1-2 |
| | 135 | 0 | 1.037962 | 1942.60 | 1,915.7 | 26.90 | 1-2 |
| | 139 | 0 | 2.952823 | 1937.41 | 1,905.8 | 31.61 | 1-2 |
| | 161 | 0 | 0.196855 | 1937.54 | 1,905.3 | 32.24 | 1-2 |
| | 174 | 0 | 1.861173 | 1947.37 | 1,902.4 | 44.97 | 1-2 |
| | 188 | 0 | 0.143167 | 1954.02 | 1,931.7 | 22.32 | 1-2 |
| | 304 | 0 | 1.252713 | 1928.95 | 1,900.4 | 28.55 | 1-2 |
| | 510 | 0 | 0.912691 | 1937.41 | 1,914.5 | 22.91 | 1-2 |
| | 527 | 0 | 0.536877 | 1960.96 | 1,931.0 | 29.96 | 1-2 |
| | 529 | 0 | 0 | 1961.19 | 1,936.0 | 25.19 | 1-2 |
| | 542 | 0 | 0 | 1947.94 | 1,889.1 | 58.84 | 1-2 |
| | 11 | 0 | 1.539047 | 1958.98 | 1,902.1 | 56.88 | 1-3 |
| | 122 | 0 | 1.592735 | 1959.98 | 1,950.0 | 9.98 | 1-3 |
| | 123 | 0 | 1.163233 | 1959.95 | 1,927.3 | 32.65 | 1-3 |
| | 136 | 0 | 1.270609 | 1959.67 | 1,944.8 | 14.87 | 1-3 |
| | 137 | 0 | 2.111716 | 1959.14 | 1,905.0 | 54.14 | 1-3 |
| | 160 | 0 | 0.340022 | 1959.91 | 1,903.2 | 56.71 | 1-3 |
| | 187 | 0 | 1.360088 | 1959.36 | 1,903.2 | 56.16 | 1-3 |
| | 300 | 0 | 0.841107 | 1959.91 | 1,903.6 | 56.31 | 1-3 |
| | 301 | 0 | 1.360088 | 1960.69 | 1,951.4 | 9.29 | 1-3 |
| | 523 | 0 | 0.912691 | 1958.98 | 1,903.0 | 55.98 | 1-3 |
| | 39 | 0 | 0.894795 | 1926.35 | 1,902.4 | 23.95 | B |
| | 40 | 0 | 0.715836 | 1926.96 | 1,920.0 | 6.96 | B |
| | 173 | 0 | 0.912691 | 1926.19 | 1,912.0 | 14.19 | B |
| | 178 | 0 | 0.984274 | 1926.19 | 1,900.0 | 26.19 | B |
| | 179 | 0 | 0.447397 | 1926.60 | 1,915.0 | 11.60 | B |
| | 189 | 0 | 0.518981 | 1926.07 | 1,921.8 | 4.27 | B |
| | 199 | 0 | 0 | 1926.57 | 1,915.0 | 11.57 | B |
| | 104 | 0 | 0.170011 | 1947.13 | 1,916.3 | 30.83 | G |
| | 105 | 0 | 0.152115 | 1913.11 | 1,903.9 | 9.21 | G |
| | 190 | 0 | 0.170011 | 1947.27 | 1,923.0 | 24.27 | G |
| | 191 | 0 | 0.152115 | 1947.25 | 1,913.0 | 34.25 | G |
| | 192 | 0 | 1.055858 | 1943.70 | 1,907.5 | 36.20 for 117 | G |
| | 612 | 0 | 0 | 1913.11 | 1,881.3 | 31.81 | G |
| | 10 | 0 | 0.447397 | 1922.99 | 1,903.4 | 19.59 | H2 |
| | 62 | 0 | 1.360088 | 1925.64 | 1,890.2 | 35.44 | H2 |
| | 70 | 0 | 2.362259 | 1923.00 | 1,904.5 | 18.50 | H2 |
| | 93 | 0 | 0 | 1923.31 | 1,882.0 | 41.31 | H2 |
| | 132 | 0 | 0.912691 | 1923.80 | 1,886.8 | 37.00 | H2 |
| | 133 | 0 | 0.322126 | 1923.14 | 1,898.7 | 24.44 | H2 |
| | 144 | 0 | 0.69794 | 1922.94 | 1,907.4 | 15.54 | H2 |
| | 145 | 0 | 0.107375 | 1922.91 | 1,909.3 | 13.61 | H2 |
| | 185 | 0 | 1.181129 | 1923.29 | 1,902.8 | 20.49 | H2 |
| | 502 | 0 | 1.431672 | 1930.84 | 1,885.6 | 45.24 | H2 |
| | 520 | 0 | 1.127442 | 1925.41 | 1,913.6 | 11.81 | H2 |
| | 524 | 0 | 0.912691 | 1931.22 | 1,887.0 | 44.22 | H2 |
| | 1 | 0 | 2.1833 | 1920.39 | 1,881.7 | 38.69 | L1 |
| | 2 | 0 | 1.252713 | 1925.13 | 1,885.1 | 40.03 | L1 |
| | 4 | 0 | 1.360088 | 1923.68 | 1,881.8 | 41.88 | L1 |
| | 5 | 0 | 0.715836 | 1923.49 | 1,881.3 | 42.19 | L1 |
| | 6 | 0 | 1.360088 | 1922.60 | 1,883.7 | 38.90 | L1 |
| | 9 | 0 | 2.380154 | 1916.80 | 1,881.2 | 35.60 | L1 |
| | 18 | 0 | 1.914861 | 1916.60 | 1,885.1 | 31.50 | L1 |
| | 19 | 0 | 1.521151 | 1916.52 | 1,885.8 | 30.72 | L1 |
| | 20 | 0 | 1.48536 | 1916.27 | 1,885.9 | 30.37 | L1 |
| | 21 | 0 | 1.735902 | 1916.28 | 1,885.1 | 31.18 | L1 |
| | 22 | 0 | 1.413776 | 1916.97 | 1,889.4 | 27.57 | L1 |
| | 23 | 0 | 1.467464 | 1916.16 | 1,887.3 | 28.86 | L1 |
| | 24 | 0 | 2.09382 | 1916.16 | 1,887.7 | 28.46 | L1 |
| | 25 | 0 | 0.912691 | 1916.16 | 1,887.0 | 29.16 | L1 |
| | 27 | 0 | 1.342192 | 1922.19 | 1,882.3 | 39.89 | L1 |
| | 28 | 0 | 0.465293 | 1912.01 | 1,879.2 | 32.81 | L1 |
| | 29 | 0 | 0.232647 | 1911.63 | 1,892.4 | 19.23 | L1 |
| | 30 | 0 | 1.431672 | 1911.34 | 1,882.6 | 28.74 | L1 |
| | 31 | 0 | 1.664319 | 1923.85 | 1,882.0 | 41.85 | L1 |
| | 36 | 0 | 0.912691 | 1923.35 | 1,889.3 | 34.05 | L1 |
| | 37 | 0 | 0.841107 | 1923.08 | 1,891.4 | 31.68 | L1 |
| | 38 | 0 | 0.751628 | 1923.08 | 1,893.9 | 29.18 | L1 |
| | 41 | 0 | 0.78742 | 1917.12 | 1,899.2 | 17.92 | L1 |
| | 42 | 0 | 0.680044 | 1917.08 | 1,896.1 | 20.98 | L1 |
| | 43 | 0 | 0.715836 | 1916.96 | 1,894.8 | 22.16 | L1 |
| | 44 | 0 | 0.966379 | 1916.92 | 1,893.4 | 23.52 | L1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 45 | 0 | 1.199025 | 1921.71 | 1,884.9 | 36.81 | L1 |
| | 46 | 0 | 2.272779 | 1922.11 | 1,878.2 | 43.91 | L1 |
| | 47 | 0 | 0.644252 | 1921.93 | 1,880.7 | 41.23 | L1 |
| | 48 | 0 | 1.807486 | 1919.96 | 1,880.2 | 39.76 | L1 |
| | 49 | 0 | 2.863344 | 1919.92 | 1,881.1 | 38.82 | L1 |
| | 51 | 0 | 0.841107 | 1916.86 | 1,895.4 | 21.46 | L1 |
| | 52 | 0 | 1.735902 | 1916.16 | 1,889.1 | 27.06 | L1 |
| | 53 | 0 | 1.735902 | 1916.12 | 1,895.7 | 20.42 | L1 |
| | 54 | 0 | 0.912691 | 1916.35 | 1,886.0 | 30.35 | L1 |
| | 55 | 0 | 1.592735 | 1916.30 | 1,886.2 | 30.10 | L1 |
| | 57 | 0 | 1.664319 | 1916.40 | 1,884.1 | 32.30 | L1 |
| | 58 | 0 | 2.129612 | 1916.06 | 1,890.9 | 25.16 | L1 |
| | 60 | 0 | 1.78959 | 1916.14 | 1,889.9 | 26.24 | L1 |
| | 61 | 0 | 0.894795 | 1921.91 | 1,885.4 | 36.51 | L1 |
| | 63 | 0 | 0.680044 | 1923.88 | 1,878.7 | 45.18 | L1 |
| | 64 | 0 | 0.78742 | 1923.85 | 1,876.5 | 47.35 | L1 |
| | 69 | 0 | 0.894795 | 1922.03 | 1,879.5 | 42.53 | L1 |
| | 100 | 0 | 0.590565 | 1917.19 | 1,896.6 | 20.59 | L1 |
| | 101 | 0 | 0.447397 | 1917.53 | 1,885.9 | 31.63 | L1 |
| | 102 | 0 | 0.662148 | 1917.65 | 1,876.7 | 40.95 | L1 |
| | 103 | 0 | 0.894795 | 1915.46 | 1,883.1 | 32.36 | L1 |
| | 106 | 0 | 0.769524 | 1913.23 | 1,881.3 | 31.93 | L1 |
| | 107 | 0 | 0.572669 | 1911.94 | 1,880.1 | 31.84 | L1 |
| | 108 | 0 | 0.536877 | 1911.77 | 1,884.1 | 27.67 | L1 |
| | 109 | 0 | 0.357918 | 1911.73 | 1,884.6 | 27.13 | L1 |
| | 112 | 0 | 0 | 1911.67 | 1,900.7 | 10.97 | L1 |
| | 113 | 0 | 0.518981 | 1911.81 | 1,878.5 | 33.31 | L1 |
| | 114 | 0 | 1.020066 | 1910.28 | 1,897.3 | 12.98 | L1 |
| | 117 | 0 | 0 | 1910.27 | 1,907.5 | 2.77 | L1 |
| | 118 | 0 | 0.662148 | 1908.11 | 1,889.0 | 19.11 | L1 |
| | 119 | 0 | 1.145337 | 1905.72 | 1,889.1 | 16.62 | L1 |
| | 140 | 0 | 0.554773 | 1916.86 | 1,899.4 | 17.46 | L1 |
| | 141 | 0 | 1.771694 | 1915.67 | 1,890.2 | 25.47 | L1 |
| | 142 | 0 | 1.843278 | 1915.76 | 1,883.9 | 31.86 | L1 |
| | 143 | 0 | 1.968549 | 1915.84 | 1,888.7 | 27.14 | L1 |
| | 148 | 0 | 1.127442 | 1920.77 | 1,889.6 | 31.17 | L1 |
| | 149 | 0 | 0.501085 | 1921.69 | 1,901.1 | 20.59 | L1 |
| | 156 | 0 | 0.715836 | 1924.88 | 1,884.8 | 40.08 | L1 |
| | 157 | 0 | 0.429502 | 1924.17 | 1,881.9 | 42.27 | L1 |
| | 158 | 0 | 0.429502 | 1923.99 | 1,880.3 | 43.69 | L1 |
| | 162 | 0 | 0.680044 | 1916.86 | 1,891.8 | 25.06 | L1 |
| | 163 | 0 | 0.125271 | 1916.81 | 1,899.3 | 17.51 | L1 |
| | 166 | 0 | 0.322126 | 1923.58 | 1,899.0 | 24.58 | L1 |
| | 169 | 0 | 0.39371 | 1976.70 | 1,917.8 | 58.90 | L1 |
| | 170 | 0 | 0.232647 | 1923.90 | 1,893.3 | 30.60 | L1 |
| | 171 | 0 | 0.340022 | 1920.31 | 1,909.7 | 10.61 | L1 |
| | 172 | 0 | 0.912691 | 1916.29 | 1,886.0 | 30.29 | L1 |
| | 176 | 0 | 0.411606 | 1916.90 | 1,895.0 | 21.90 | L1 |
| | 177 | 0 | 0.411606 | 1916.90 | 1,897.3 | 19.60 | L1 |
| | 181 | 0 | 1.431672 | 1917.97 | 1,881.0 | 36.97 | L1 |
| | 182 | 0 | 0.232647 | 1911.68 | 1,891.9 | 19.78 | L1 |
| | 183 | 0 | 0.214751 | 1911.57 | 1,899.2 | 12.37 | L1 |
| | 503 | 0 | 1.360088 | 1909.74 | 1,884.2 | 25.54 | L1 |
| | 511 | 0 | 0.357918 | 1911.68 | 1,892.1 | 19.58 | L1 |
| | 521 | 0 | 0.912691 | 1903.34 | 1,886.0 | 17.34 | L1 |
| | 522 | 0 | 0.912691 | 1903.25 | 1,880.0 | 23.25 | L1 |
| | 525 | 0 | 0.912691 | 1910.91 | 1,881.0 | 29.91 | L1 |
| | 526 | 0 | 0.912691 | 1911.14 | 1,882.0 | 29.14 | L1 |
| | 12 | 0 | 1.181129 | 1918.82 | 1,880.5 | 38.32 | L2 |
| | 13 | 0 | 0.912691 | 1918.89 | 1,874.2 | 44.69 | L2 |
| | 14 | 0 | 1.181129 | 1919.12 | 1,865.6 | 53.52 | L2 |
| | 15 | 0 | 1.09165 | 1920.77 | 1,860.5 | 60.27 | L2 |
| | 16 | 0 | 1.521151 | 1922.69 | 1,860.5 | 62.19 | L2 |
| | 33 | 0 | 0.912691 | 1918.77 | 1,867.0 | 51.77 | L2 |
| | 35 | 0 | 1.09165 | 1918.71 | 1,870.0 | 48.71 | L2 |
| | 71 | 0 | 1.556943 | 1959.91 | 1,894.5 | 65.41 | L2 |
| | 120 | 0 | 2.022237 | 1920.11 | 1,871.2 | 48.91 | L2 |
| | 121 | 0 | 1.950653 | 1921.52 | 1,862.6 | 58.92 | L2 |
| | 124 | 0 | 1.216921 | 1959.93 | 1,879.6 | 80.33 | L2 |
| | 125 | 0 | 1.932757 | 1918.80 | 1,886.2 | 32.60 | L2 |
| | 126 | 0 | 1.914861 | 1917.24 | 1,894.1 | 23.14 | L2 |
| | 127 | 0 | 0.966379 | 1915.05 | 1,874.9 | 40.15 | L2 |
| | 128 | 0 | 0.680044 | 1915.70 | 1,896.4 | 19.30 | L2 |
| | 129 | 0 | 0.143167 | 1915.67 | 1,896.0 | 19.67 | L2 |
| | 130 | 0 | 0.125271 | 1915.62 | 1,886.4 | 29.22 | L2 |
| | 131 | 0 | 0.071584 | 1915.60 | 1,875.8 | 39.80 | L2 |
| | 146 | 0 | 0.966379 | 1918.88 | 1,876.5 | 42.38 | L2 |
| | 147 | 0 | 1.753798 | 1918.86 | 1,878.9 | 39.96 | L2 |
| | 150 | 0 | 2.111716 | 1918.76 | 1,899.4 | 19.36 | L2 |
| | 151 | 0 | 1.360088 | 1918.89 | 1,874.4 | 44.49 | L2 |
| | 152 | 0 | 1.181129 | 1918.94 | 1,865.9 | 53.04 | L2 |
| | 153 | 0 | 1.270609 | 1919.61 | 1,862.7 | 56.91 | L2 |
| | 154 | 0 | 1.181129 | 1919.71 | 1,864.7 | 55.01 | L2 |
| | 155 | 0 | 0.39371 | 1920.09 | 1,867.6 | 52.49 | L2 |
| | 186 | 0 | 1.181129 | 1919.29 | 1,885.4 | 33.89 | L2 |
| | 500 | 0 | 0.447397 | 1919.76 | 1,892.8 | 26.96 | L2 |
| | 501 | 0 | 1.360088 | 1919.59 | 1,886.6 | 32.99 | L2 |
| New Water F | 205 | 0 | -5.401235 | 1962.26 | 1,960.0 | 2.26 | 1-2 |
| Old Water F (New) | 206 | 0 | -8.159722 | 1961.42 | 1,955.0 | 6.42 | 1-2 |
| Gamunu/Brewery | 215 | 0 | -8.622685 | 1961.93 | 1979.00 | -17.07 | 1-3 |

PIPE

| NO(u) | NO(d) | Dia mm | Length m | C | dH m | Q l/sec | V m/sec | I o/oo |
|---|---|---|---|---|---|---|---|---|
| 139 | 510 | 225.0 | 800.0 | 120.0 | | 0.91 | 0.02 | 0.01 |
| 139 | 304 | 44.0 | 374.0 | 130.0 | | 1.25 | 0.82 | 22.63 |
| 51 | 140 | 150.0 | 228.0 | 120.0 | | 0.55 | 0.03 | 0.01 |
| 162 | 163 | 44.0 | 143.0 | 130.0 | | 0.13 | 0.08 | 0.32 |
| 51 | 162 | 150.0 | 20.0 | 120.0 | | 0.81 | 0.05 | 0.03 |
| 134 | 164 | 44.0 | 84.0 | 130.0 | | 0.07 | 0.05 | 0.11 |
| 66 | 135 | 150.0 | 265.0 | 120.0 | | 6.35 | 0.36 | 1.35 |
| 50 | 66 | 100.0 | 530.0 | 120.0 | | 7.07 | 0.90 | 11.83 |
| 50 | 67 | 100.0 | 583.0 | 120.0 | | -4.38 | -0.56 | -4.87 |
| 67 | 188 | 100.0 | 165.0 | 120.0 | | -7.08 | -0.90 | -11.87 |
| 21 | 54 | 150.0 | 59.0 | 120.0 | | -6.09 | -0.34 | -1.24 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 21 | 23 | 100.0 | 88.0 | 120.0 | 2.16 | 0.27 | 1.32 |
| 23 | 24 | 150.0 | 55.0 | 120.0 | 0.40 | 0.02 | 0.01 |
| 20 | 24 | 100.0 | 90.0 | 120.0 | 2.01 | 0.26 | 1.16 |
| 20 | 21 | 150.0 | 66.0 | 120.0 | -2.19 | -0.12 | -0.19 |
| 25 | 52 | 100.0 | 110.0 | 120.0 | -0.30 | -0.04 | -0.04 |
| 52 | 53 | 100.0 | 176.0 | 120.0 | 0.90 | 0.11 | 0.26 |
| 53 | 60 | 100.0 | 100.0 | 120.0 | -0.84 | -0.11 | -0.23 |
| 18 | 60 | 100.0 | 134.0 | 120.0 | 3.62 | 0.46 | 3.43 |
| 18 | 19 | 150.0 | 54.0 | 120.0 | 6.86 | 0.39 | 1.55 |
| 19 | 52 | 100.0 | 151.0 | 120.0 | 2.94 | 0.37 | 2.33 |
| 19 | 55 | 100.0 | 133.0 | 120.0 | 2.40 | 0.31 | 1.60 |
| 54 | 172 | 100.0 | 100.0 | 120.0 | 1.41 | 0.18 | 0.60 |
| 9 | 18 | 225.0 | 315.0 | 120.0 | 12.40 | 0.31 | 0.64 |
| 9 | 48 | 100.0 | 47.0 | 120.0 | -18.07 | -2.30 | -67.10 |
| 1 | 48 | 225.0 | 265.0 | 120.0 | 20.61 | 0.52 | 1.65 |
| 48 | 49 | 100.0 | 201.0 | 120.0 | 0.74 | 0.09 | 0.18 |
| 22 | 49 | 150.0 | 672.0 | 120.0 | -12.02 | -0.68 | -4.38 |
| 22 | 51 | 150.0 | 596.0 | 120.0 | 2.20 | 0.12 | 0.19 |
| 49 | 148 | 100.0 | 536.0 | 120.0 | -2.39 | -0.30 | -1.59 |
| 148 | 171 | 50.0 | 372.0 | 120.0 | 0.34 | 0.17 | 1.26 |
| 69 | 148 | 100.0 | 325.0 | 120.0 | 3.86 | 0.49 | 3.86 |
| 46 | 69 | 150.0 | 90.0 | 120.0 | 5.26 | 0.30 | 0.95 |
| 69 | 149 | 65.0 | 551.0 | 130.0 | 0.50 | 0.15 | 0.62 |
| 1 | 49 | 100.0 | 264.0 | 120.0 | 2.55 | 0.32 | 1.79 |
| 1 | 46 | 225.0 | 401.0 | 120.0 | -34.55 | -0.87 | -4.29 |
| 46 | 47 | 100.0 | 268.0 | 120.0 | 1.54 | 0.20 | 0.70 |
| 47 | 64 | 100.0 | 268.0 | 120.0 | -5.40 | -0.69 | -7.19 |
| 63 | 64 | 300.0 | 444.0 | 120.0 | 7.85 | 0.11 | 0.07 |
| 46 | 63 | 225.0 | 268.0 | 120.0 | -43.61 | -1.10 | -6.60 |
| 63 | 158 | 300.0 | 47.0 | 120.0 | -52.15 | -0.74 | -2.26 |
| 158 | 166 | 50.0 | 358.0 | 120.0 | 0.32 | 0.16 | 1.14 |
| 157 | 158 | 300.0 | 77.0 | 120.0 | 52.90 | 0.75 | 2.32 |
| 157 | 170 | 44.0 | 264.0 | 130.0 | 0.23 | 0.15 | 1.00 |
| 156 | 157 | 300.0 | 300.0 | 120.0 | 53.56 | 0.76 | 2.38 |
| 2 | 156 | 300.0 | 100.0 | 120.0 | 54.28 | 0.77 | 2.44 |
| 2 | 203 | 350.0 | 704.0 | 120.0 | -85.39 | -0.89 | -2.66 |
| 2 | 4 | 225.0 | 442.0 | 120.0 | 29.86 | 0.75 | 3.28 |
| 4 | 5 | 225.0 | 65.0 | 120.0 | 27.60 | 0.69 | 2.83 |
| 4 | 61 | 65.0 | 972.0 | 130.0 | 0.89 | 0.27 | 1.82 |
| 5 | 6 | 150.0 | 221.0 | 120.0 | 11.49 | 0.65 | 4.03 |
| 6 | 27 | 150.0 | 150.0 | 120.0 | 9.42 | 0.53 | 2.79 |
| 27 | 37 | 100.0 | 216.0 | 120.0 | -4.01 | -0.51 | -4.13 |
| 36 | 37 | 150.0 | 400.0 | 120.0 | 4.35 | 0.25 | 0.67 |
| 36 | 38 | 100.0 | 563.0 | 120.0 | 1.24 | 0.16 | 0.48 |
| 37 | 38 | 150.0 | 30.0 | 120.0 | -0.49 | -0.03 | -0.01 |
| 27 | 181 | 150.0 | 1106.0 | 120.0 | 11.15 | 0.63 | 3.81 |
| 102 | 181 | 150.0 | 92.0 | 120.0 | -10.58 | -0.60 | -3.46 |
| 102 | 103 | 150.0 | 350.0 | 120.0 | 14.58 | 0.82 | 6.26 |
| 101 | 102 | 44.0 | 120.0 | 130.0 | -0.23 | -0.15 | -0.96 |
| 41 | 100 | 44.0 | 120.0 | 130.0 | -0.18 | -0.12 | -0.63 |
| 100 | 101 | 37.0 | 312.0 | 130.0 | -0.15 | -0.14 | -1.09 |
| 42 | 43 | 100.0 | 257.0 | 120.0 | 1.25 | 0.16 | 0.48 |
| 42 | 43 | 100.0 | 257.0 | 120.0 | 1.25 | 0.16 | 0.48 |
| 43 | 44 | 150.0 | 268.0 | 120.0 | 1.79 | 0.10 | 0.13 |
| 44 | 177 | 100.0 | 391.0 | 120.0 | 0.41 | 0.05 | 0.06 |
| 44 | 176 | 100.0 | 391.0 | 120.0 | 0.41 | 0.05 | 0.06 |
| 176 | 177 | 100.0 | 90.0 | 120.0 | 0.00 | 0.00 | 0.00 |
| 29 | 112 | 65.0 | 251.0 | 130.0 | -0.23 | -0.07 | -0.15 |
| 109 | 511 | 100.0 | 400.0 | 120.0 | 0.59 | 0.08 | 0.12 |
| 108 | 109 | 100.0 | 120.0 | 120.0 | 0.95 | 0.12 | 0.29 |
| 108 | 183 | 44.0 | 228.0 | 130.0 | 0.21 | 0.14 | 0.87 |
| 107 | 108 | 100.0 | 200.0 | 120.0 | 1.70 | 0.22 | 0.85 |
| 107 | 182 | 44.0 | 253.0 | 130.0 | 0.23 | 0.15 | 1.00 |
| 28 | 107 | 100.0 | 40.0 | 120.0 | 2.51 | 0.32 | 1.74 |
| 28 | 113 | 150.0 | 66.0 | 120.0 | 9.79 | 0.55 | 3.00 |
| 113 | 114 | 65.0 | 265.0 | 130.0 | 1.67 | 0.50 | 5.77 |
| 114 | 117 | 140.0 | 500.0 | 130.0 | 0.65 | 0.04 | 0.02 |
| 117 | 118 | 44.0 | 318.0 | 130.0 | 0.65 | 0.43 | 6.77 |
| 118 | 119 | 75.0 | 248.0 | 120.0 | 2.97 | 0.67 | 9.66 |
| 28 | 106 | 150.0 | 250.0 | 120.0 | -12.76 | -0.72 | -4.90 |
| 103 | 106 | 150.0 | 400.0 | 120.0 | 13.68 | 0.77 | 5.57 |
| 104 | 190 | 44.0 | 255.0 | 130.0 | -0.17 | -0.11 | -0.56 |
| 105 | 106 | 44.0 | 250.0 | 130.0 | -0.15 | -0.10 | -0.46 |
| 30 | 526 | 100.0 | 210.0 | 120.0 | 1.83 | 0.23 | 0.97 |
| 62 | 132 | 150.0 | 1,500.0 | 120.0 | 6.03 | 0.34 | 1.22 |
| 155 | 500 | 140.0 | 175.0 | 130.0 | 6.90 | 0.45 | 1.89 |
| 132 | 133 | 44.0 | 363.0 | 130.0 | 0.32 | 0.21 | 1.83 |
| 31 | 64 | 225.0 | 167.0 | 120.0 | -1.66 | -0.04 | -0.02 |
| 70 | 144 | 100.0 | 284.0 | 120.0 | 0.81 | 0.10 | 0.21 |
| 144 | 145 | 44.0 | 121.0 | 130.0 | 0.11 | 0.07 | 0.24 |
| 45 | 47 | 150.0 | 162.0 | 120.0 | -6.29 | -0.36 | -1.32 |
| 9 | 45 | 100.0 | 761.0 | 120.0 | -5.09 | -0.65 | -6.45 |
| 9 | 57 | 100.0 | 25.0 | 120.0 | 8.38 | 1.07 | 16.21 |
| 57 | 58 | 100.0 | 120.0 | 120.0 | 3.26 | 0.42 | 2.83 |
| 58 | 60 | 100.0 | 262.0 | 120.0 | -0.99 | -0.13 | -0.31 |
| 56 | 59 | 97.0 | 352.0 | 130.0 | 0.60 | 0.08 | 0.12 |
| 58 | 143 | 100.0 | 168.0 | 120.0 | 2.13 | 0.27 | 1.28 |
| 142 | 143 | 50.0 | 264.0 | 120.0 | -0.16 | -0.08 | -0.31 |
| 57 | 142 | 100.0 | 202.0 | 120.0 | 3.46 | 0.44 | 3.15 |
| 141 | 142 | 100.0 | 99.0 | 120.0 | -1.77 | -0.23 | -0.91 |
| 12 | 150 | 150.0 | 360.0 | 120.0 | 2.11 | 0.12 | 0.18 |
| 12 | 151 | 150.0 | 163.0 | 120.0 | -3.29 | -0.19 | -0.40 |
| 13 | 151 | 150.0 | 35.0 | 120.0 | 0.05 | 0.00 | 0.00 |
| 151 | 186 | 140.0 | 450.0 | 130.0 | -4.61 | -0.30 | -0.90 |
| 154 | 155 | 100.0 | 132.0 | 120.0 | -3.30 | -0.42 | -2.88 |
| 153 | 154 | 100.0 | 165.0 | 120.0 | -1.42 | -0.18 | -0.61 |
| 14 | 153 | 150.0 | 236.0 | 120.0 | -8.04 | -0.46 | -2.09 |
| 13 | 14 | 150.0 | 475.0 | 120.0 | -3.68 | -0.21 | -0.49 |
| 13 | 146 | 150.0 | 35.0 | 120.0 | 2.72 | 0.15 | 0.28 |
| 146 | 147 | 150.0 | 137.0 | 120.0 | 1.75 | 0.10 | 0.12 |
| 11 | 137 | 150.0 | 663.0 | 120.0 | -2.45 | -0.14 | -0.23 |
| 14 | 152 | 100.0 | 66.0 | 120.0 | 3.19 | 0.41 | 2.71 |
| 33 | 152 | 100.0 | 150.0 | 120.0 | -2.00 | -0.26 | -1.15 |
| 56 | 68 | 100.0 | 165.0 | 120.0 | 0.06 | 0.01 | 0.00 |
| 136 | 137 | 44.0 | 512.0 | 130.0 | 0.24 | 0.16 | 1.04 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 137 | 187 | 140.0 | 277.0 | 130.0 | -4.33 | -0.28 | -0.80 |
| | | 71 | 124 | 225.0 | 400.0 | 120.0 | -2.67 | -0.07 | -0.04 |
| | | 15 | 16 | 150.0 | 177.0 | 120.0 | -19.58 | -1.11 | -10.81 |
| | | 16 | 121 | 100.0 | 286.0 | 120.0 | 3.97 | 0.51 | 4.07 |
| | | 120 | 121 | 97.0 | 1,210.0 | 130.0 | -2.02 | -0.27 | -1.17 |
| | | 16 | 125 | 100.0 | 850.0 | 120.0 | 4.23 | 0.54 | 4.57 |
| | | 122 | 209 | 225.0 | 120.0 | 120.0 | -6.64 | -0.17 | -0.20 |
| | | 125 | 126 | 100.0 | 396.0 | 120.0 | 3.90 | 0.50 | 3.94 |
| | | 126 | 128 | 65.0 | 668.0 | 130.0 | 1.02 | 0.31 | 2.31 |
| | | 126 | 127 | 65.0 | 1,047.0 | 130.0 | 0.97 | 0.29 | 2.09 |
| | | 128 | 129 | 65.0 | 90.0 | 130.0 | 0.34 | 0.10 | 0.30 |
| | | 129 | 130 | 44.0 | 60.0 | 130.0 | 0.20 | 0.13 | 0.74 |
| | | 130 | 131 | 37.0 | 88.0 | 130.0 | 0.07 | 0.07 | 0.26 |
| | | 62 | 520 | 100.0 | 569.0 | 120.0 | 1.13 | 0.14 | 0.40 |
| | | 41 | 42 | 100.0 | 237.0 | 120.0 | 0.67 | 0.09 | 0.15 |
| | | 30 | 113 | 150.0 | 250.0 | 120.0 | -7.60 | -0.43 | -1.88 |
| | | 5 | 36 | 150.0 | 105.0 | 120.0 | 6.51 | 0.37 | 1.41 |
| | | 187 | 300 | 150.0 | 500.0 | 120.0 | -5.69 | -0.32 | -1.10 |
| | | 136 | 301 | 65.0 | 215.0 | 130.0 | -1.51 | -0.45 | -4.77 |
| | | 160 | 300 | 150.0 | 152.0 | 120.0 | 0.77 | 0.04 | 0.03 |
| | | 62 | 524 | 97.0 | 334.0 | 130.0 | -8.52 | -1.15 | -16.70 |
| | | 30 | 503 | 100.0 | 334.0 | 120.0 | 4.34 | 0.55 | 4.80 |
| | | 112 | 511 | 75.0 | 132.0 | 120.0 | -0.23 | -0.05 | -0.09 |
| | | 500 | 501 | 140.0 | 100.0 | 130.0 | 6.45 | 0.42 | 1.67 |
| | | 154 | 501 | 65.0 | 104.0 | 130.0 | 0.70 | 0.21 | 1.14 |
| | | 186 | 501 | 140.0 | 221.0 | 130.0 | -5.79 | -0.38 | -1.37 |
| | | 118 | 503 | 75.0 | 167.0 | 120.0 | -2.98 | -0.67 | -9.71 |
| | | 215 | 301 | 100.0 | 554.0 | 120.0 | 2.87 | 0.37 | 2.23 |
| | | 215 | 300 | 100.0 | 250.0 | 120.0 | 5.76 | 0.73 | 8.08 |
| | | 205 | 529 | 100.0 | 150.0 | 120.0 | 5.40 | 0.69 | 7.19 |
| | | 15 | 153 | 150.0 | 577.0 | 120.0 | 7.90 | 0.45 | 2.01 |
| | | 10 | 70 | 150.0 | 480.0 | 120.0 | -0.45 | -0.03 | -0.01 |
| | | 24 | 25 | 100.0 | 55.0 | 120.0 | 0.31 | 0.04 | 0.04 |
| | | 55 | 172 | 100.0 | 50.0 | 120.0 | 0.81 | 0.10 | 0.21 |
| | | 20 | 172 | 100.0 | 50.0 | 120.0 | -1.31 | -0.17 | -0.52 |
| | | 23 | 25 | 100.0 | 75.0 | 120.0 | 0.29 | 0.04 | 0.03 |
| | | 100 | 101 | 44.0 | 450.0 | 130.0 | -0.20 | -0.13 | -0.76 |
| | | 41 | 42 | 150.0 | 150.0 | 120.0 | 2.51 | 0.14 | 0.24 |
| | | 119 | 521 | 65.0 | 350.0 | 130.0 | 1.83 | 0.55 | 6.79 |
| | | 521 | 522 | 97.0 | 350.0 | 130.0 | 0.91 | 0.12 | 0.27 |
| | | 33 | 35 | 100.0 | 150.0 | 120.0 | 1.09 | 0.14 | 0.37 |
| | | 11 | 523 | 150.0 | 120.0 | 120.0 | 0.91 | 0.05 | 0.04 |
| | | 502 | 524 | 75.0 | 150.0 | 120.0 | -1.43 | -0.32 | -2.50 |
| | | 524 | 600 | 100.0 | 450.0 | 120.0 | -10.86 | -1.38 | -26.18 |
| | | 525 | 526 | 75.0 | 210.0 | 120.0 | -0.91 | -0.21 | -1.09 |
| | | 165 | 528 | 65.0 | 500.0 | 130.0 | 1.57 | 0.47 | 5.17 |
| | | 134 | 528 | 65.0 | 200.0 | 130.0 | -1.04 | -0.31 | -2.39 |
| | | 165 | 601 | 65.0 | 75.0 | 130.0 | -3.38 | -1.02 | -21.25 |
| | | 188 | 527 | 65.0 | 150.0 | 130.0 | -5.15 | -1.55 | -46.24 |
| | | 122 | 123 | 140.0 | 160.0 | 130.0 | 1.73 | 0.11 | 0.15 |
| | | 56 | 59 | 140.0 | 352.0 | 130.0 | 1.58 | 0.10 | 0.12 |
| | | 1 | 49 | 158.0 | 264.0 | 130.0 | 9.21 | 0.47 | 1.79 |
| | | 206 | 527 | 150.0 | 215.0 | 120.0 | 8.16 | 0.46 | 2.14 |
| | | 91 | 139 | 150.0 | 162.0 | 120.0 | 5.12 | 0.29 | 0.90 |
| | | 91 | 161 | 65.0 | 225.0 | 130.0 | 0.20 | 0.06 | 0.11 |
| | | 70 | 93 | 150.0 | 662.0 | 120.0 | -3.61 | -0.20 | -0.47 |
| | | 93 | 132 | 150.0 | 616.0 | 120.0 | -4.80 | -0.27 | -0.80 |
| | | 93 | 185 | 150.0 | 300.0 | 120.0 | 1.18 | 0.07 | 0.06 |
| | | 56 | 602 | 200.0 | 1,000.0 | 120.0 | -3.12 | -0.10 | -0.09 |
| | | 22 | 54 | 150.0 | 275.0 | 120.0 | 8.41 | 0.48 | 2.26 |
| | | 71 | 160 | 225.0 | 501.0 | 120.0 | 1.11 | 0.03 | 0.01 |
| | | 91 | 92 | 150.0 | 228.0 | 120.0 | -5.32 | -0.30 | -0.97 |
| | | 92 | 135 | 100.0 | 690.0 | 120.0 | -5.32 | -0.68 | -6.98 |
| | | 105 | 612 | 44.0 | 250.0 | 130.0 | 0.00 | 0.00 | 0.00 |
| | | 174 | 542 | 97.0 | 569.0 | 130.0 | -1.86 | -0.25 | -1.00 |
| | | 169 | 603 | 97.0 | 50.0 | 130.0 | -0.39 | -0.05 | -0.06 |
| | | 208 | 40 | 140.0 | 50.0 | 130.0 | 4.47 | 0.29 | 0.85 |
| | | 40 | 189 | 44.0 | 200.0 | 130.0 | 0.52 | 0.34 | 4.43 |
| | | 40 | 199 | 44.0 | 160.0 | 130.0 | 0.37 | 0.25 | 2.42 |
| | | 40 | 179 | 100.0 | 160.0 | 120.0 | 2.87 | 0.36 | 2.22 |
| | | 179 | 39 | 100.0 | 250.0 | 120.0 | 1.85 | 0.24 | 0.99 |
| | | 179 | 199 | 65.0 | 40.0 | 130.0 | 0.57 | 0.17 | 0.78 |
| | | 199 | 173 | 65.0 | 190.0 | 130.0 | 0.94 | 0.28 | 1.99 |
| | | 39 | 178 | 100.0 | 550.0 | 120.0 | 0.96 | 0.12 | 0.29 |
| New | | 173 | 178 | 65.0 | 97.0 | 130.0 | 0.03 | 0.01 | 0.00 |
| New | | 529 | 527 | 100.0 | 32.0 | 120.0 | 5.40 | 0.69 | 7.19 |
| New | | 527 | 188 | 80.0 | 162.0 | 120.0 | 7.88 | 1.57 | 42.81 |
| New | | 67 | 188 | 97.0 | 239.0 | 130.0 | -5.80 | -0.78 | -8.20 |
| New | | 50 | 67 | 97.0 | 199.0 | 130.0 | -7.82 | -1.06 | -14.27 |
| New | | 5 | 6 | 140.0 | 294.0 | 130.0 | 8.89 | 0.58 | 3.03 |
| New | | 6 | 27 | 140.0 | 120.0 | 130.0 | 9.60 | 0.62 | 3.49 |
| New | | 27 | 181 | 140.0 | 1019.0 | 130.0 | 10.53 | 0.68 | 4.14 |
| New | | 102 | 181 | 140.0 | 90.0 | 130.0 | -9.67 | -0.63 | -3.54 |
| New | R | 16 | 606 | 250.0 | 963.0 | 120.0 | -30.91 | -0.63 | -2.09 |
| New | | 16 | 125 | 65.0 | 727.0 | 130.0 | 1.60 | 0.48 | 5.35 |
| New | | 607 | 190 | 65.0 | 246.0 | 130.0 | 1.55 | 0.47 | 5.00 |
| | | 190 | 191 | 100.0 | 45.0 | 120.0 | 1.21 | 0.15 | 0.45 |
| New | | 191 | 192 | 65.0 | 1,438.0 | 130.0 | 1.06 | 0.32 | 2.47 |
| New | | 50 | 542 | 97.0 | 713.0 | 130.0 | 2.55 | 0.35 | 1.80 |
| New | | 68 | 542 | 97.0 | 166.0 | 130.0 | -0.69 | -0.09 | -0.16 |
| | | 101 | 102 | 140.0 | 120.0 | 130.0 | -4.78 | -0.31 | -0.96 |
| | | 100 | 101 | 140.0 | 450.0 | 130.0 | -4.21 | -0.27 | -0.76 |
| | | 41 | 100 | 140.0 | 120.0 | 130.0 | -3.79 | -0.25 | -0.63 |
| New | R | 15 | 155 | 140.0 | 163.0 | 130.0 | 10.59 | 0.69 | 4.18 |
| | | 123 | 124 | 44.0 | 120.0 | 130.0 | 0.09 | 0.06 | 0.19 |
| New | | 122 | 123 | 198.0 | 260.0 | 130.0 | 3.32 | 0.11 | 0.09 |
| New | | 123 | 124 | 198.0 | 195.0 | 130.0 | 3.79 | 0.12 | 0.12 |

End

**2. The roles of new Distribution Pipelines**

1) From Node 529 to Node 88 through Node 50 (DCIPφ100mm/PVCφ110mm)
The pipeline is to be installed to reinforce the existing distribution line from Old/New Water Field and to supply water from Pedro Reservoir to High Area 1-2 after block separation. After installation of this pipeline sufficient amount of water can be distributed in High Area 1-2 with adequate pressure by eliminating negative pressure.

2) From Low Area 2 Reservoir to Node 16 to Node 125 (DCIPφ250mm/PVCφ75mm)
The distribution pipe up to Node 16 is required to distribute water from new Low Area 2 reservoir to Low Area 2 area. Pipe should be reinforced from Node 16 to Node 125 in order to improve poor condition of water supply.

3) From Node 15 to Node 155 (PVCφ160mm)
Reinforcement of a distribution pipeline was planed in the Feasibility Study to supply sufficient water to a area in Low Area 2 where water demand is expanding. The proposed road was too narrow to install pipes and the route was revised to the one from Node 15 to Node 155.

4) From Node 122 to Node 124 (PVCφ225mm)
The waterworks of Nuwara Eliya is suffering from frequent leakage from the distribution main near Lover's Leap reservoir due to land movement. The pipeline from Node 122 to Node 124 is planned to reroute this distribution main.

5) From Node 5 to Node 102 (PVCφ160mm)
The distribution pipe from Node 5 to Node 102 is planned to reinforce the exiting small size pipe (CI φ150mm) and to eliminate negative pressure and distribute sufficient water to the western part of Low Area 1, where water is distributed from Haddon Hill reservoir.

6) From Node 173 to Node 178 (PVCφ75mm)
About 97 meter of PVCφ75mm pipe is planned to distribute sufficient water to Node 178 and improve stability of water distribution system in Bonavista area.

7) Gemunupura Reservoir to Node 192 (PVCφ75mm)
A pipeline from Gemunupura reservoir to Node 192 with a few connections on the way is planned to convey water to the high area where water supply condition is very poor. The location and number of connection on the way should be strictly controlled in order to distribute sufficient water in the high area.

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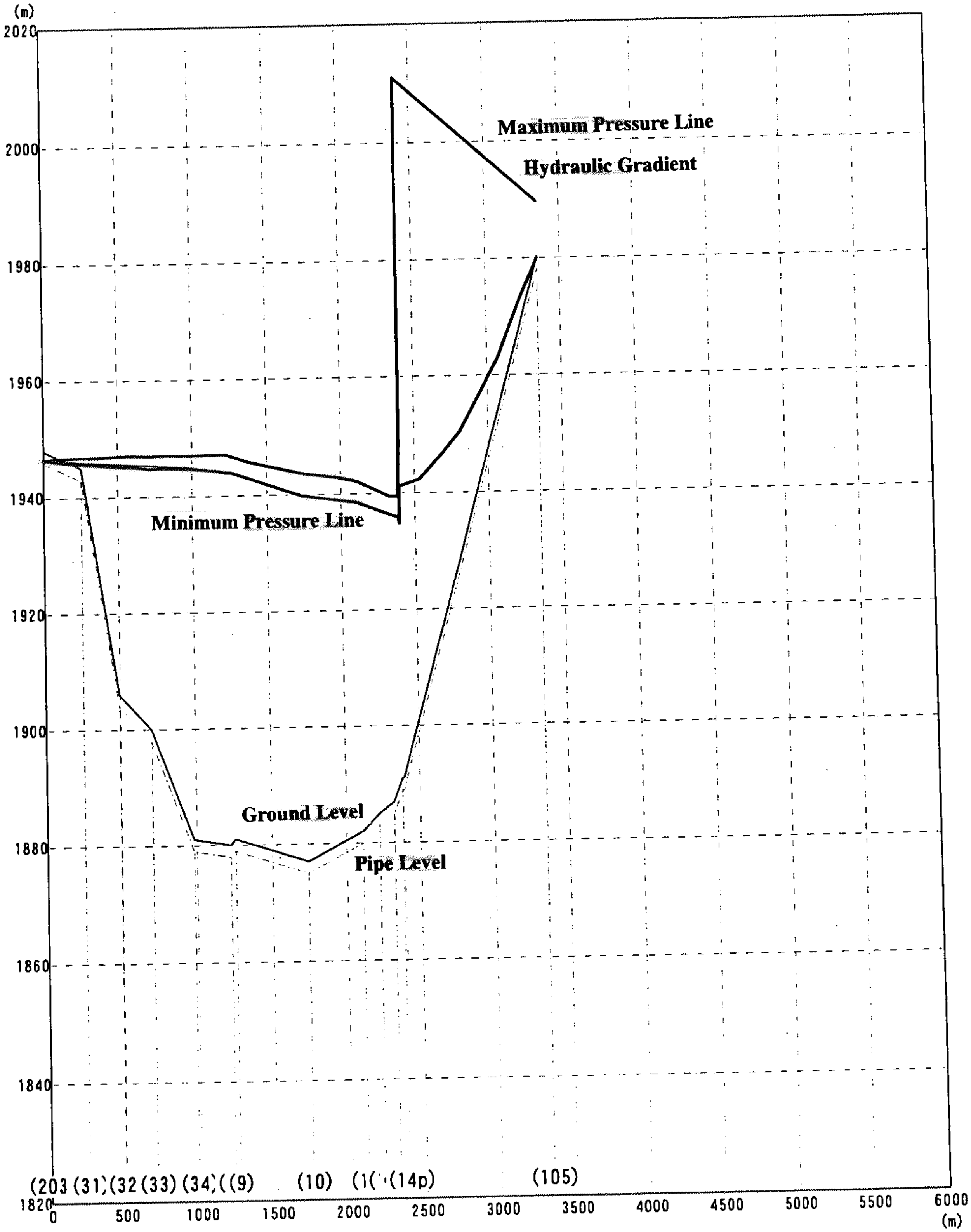

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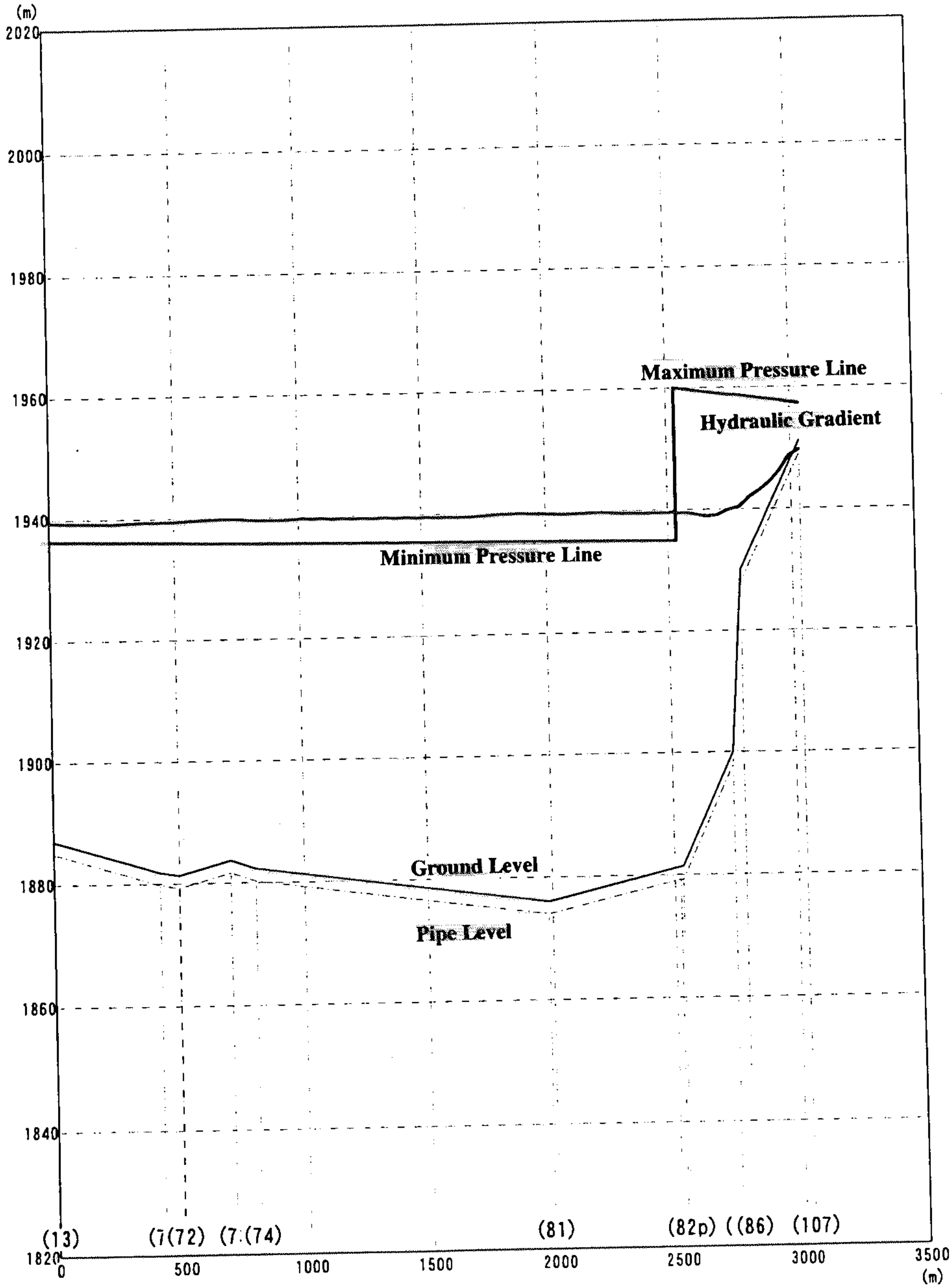

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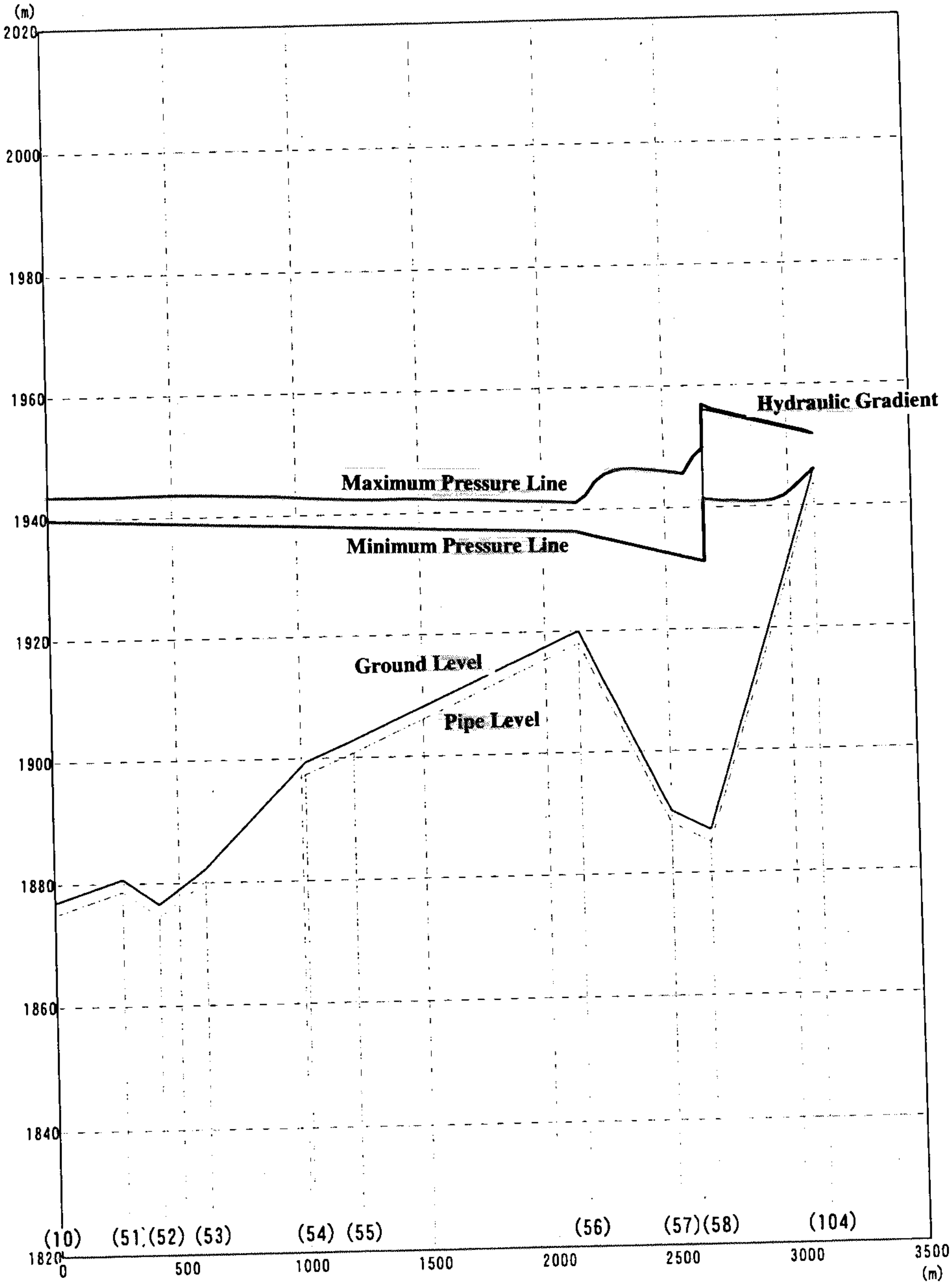

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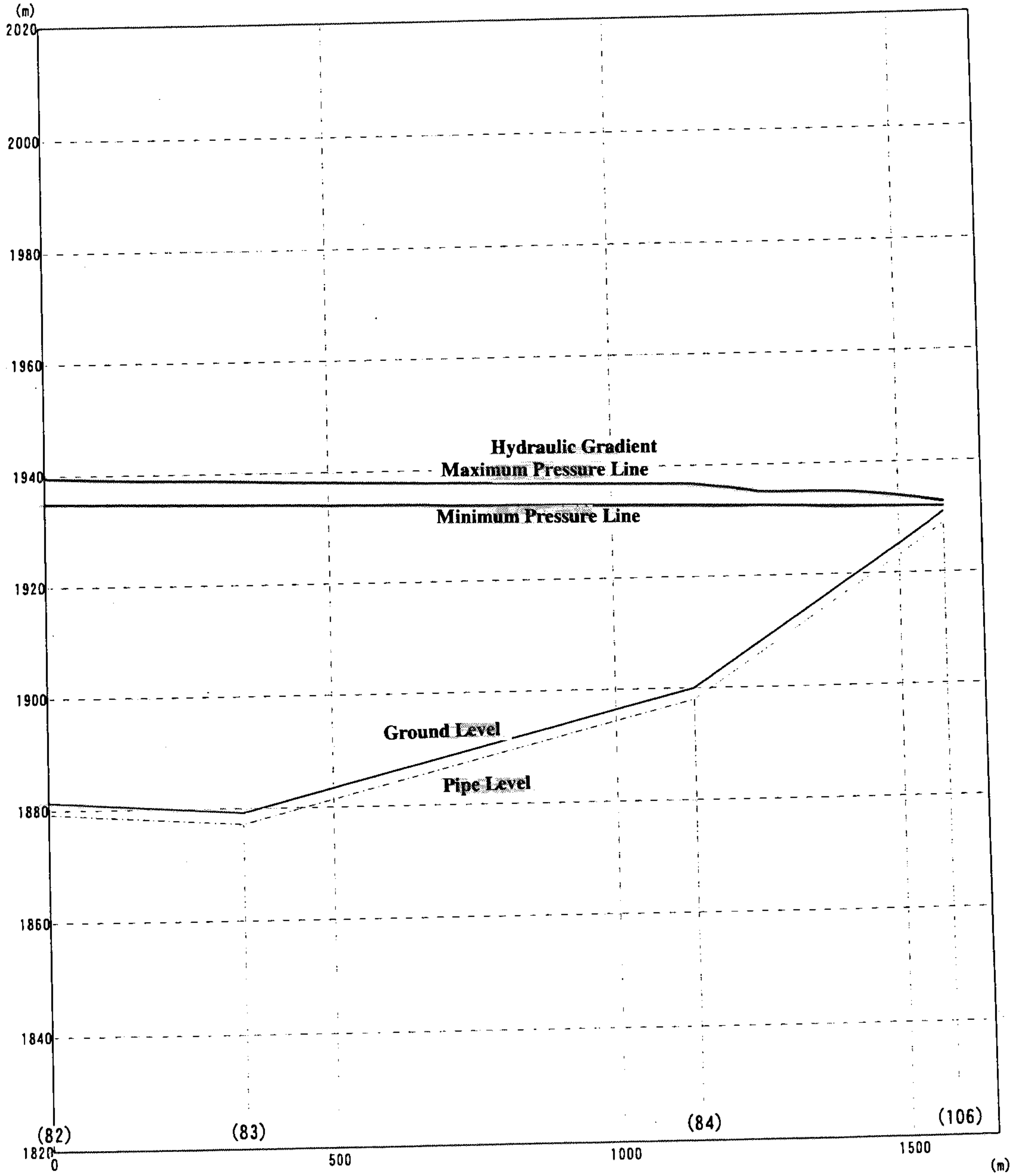

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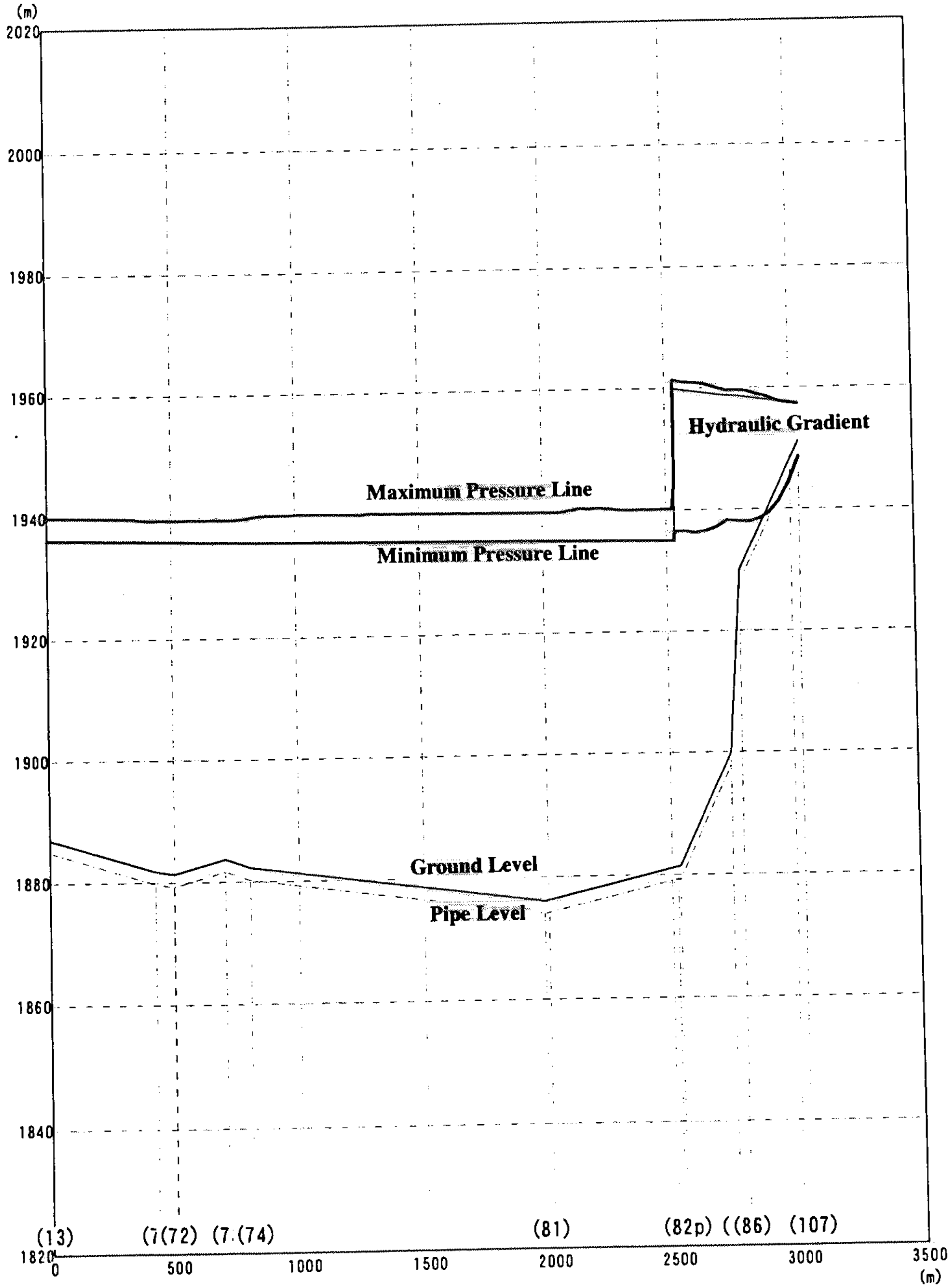

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