CHAPTER 6 PRIORITY PROJECT OF WATER SUPPLY SYSTEM PLAN

CHAPTER 6 PRIORITY PROJECT OF WATER SUPPLY SYSTEM PLAN

6.1 Identification of the Priority Project

The first phase project of the long-term development plan was selected as the priority project, for which the Feasibility Study was conducted.

Water sources to be developed for the year 2005 will meet approximately 90 percent of the requirement for the year 2015 as shown in Table 6.1. The sizes of the facilities to be constructed are too small to introduce phased construction when considering the expected cost increases that phased construction would incur. Therefore, wells and their accompanying conveyance pipelines will be constructed to meet the demand in 2015.

Table 6.1 Required Water Source Development

	Target Years	
	2005	2015
Required Quantity (m^3/d)	5,840	6,500
Ratio	90%	100%

Transmission pipelines from surface water sources will also be constructed for the effective use of water during the rainy season. The target year of the feasibility study is 2005, however the difference in water demand between the target years of 2005 and 2015 is only 7 percent. Transmission and distribution pipelines are therefore designed to meet water demand in the target year 2015.

Water demand by sub-service area and corresponding water source capacity as well as required capacity of distribution reservoirs is shown in Table 6.2.

6.2 Preliminary Design of Water Supply System

6.2.1 Design Conditions

(1) Topographic condition

The water supply service area of Nuwara Eliya is situated at an elevation of approximately 1,890 m AMSL ranging from 1,860 m to 1,990 m. Within this service area, five new distribution reservoirs are planned:

Table 6.2 Demand and Capacity of Sources and Reservoirs by Service Block (2005, Dry Season)

No.	Block		2005 Avg. Daily Demand (m^3/d)	2005 Max. Daily Demand A (m3/d)	Water Source Name	Water Source Yield B (m^3/d)	Water Source Balance C=B-A (m^3/d)	Water Source New Facility	Reserver	Reserver Name	Required Capacity D=6/24*A (m^3)	Existing Capacity E (m^3)	Existing Capacity F (hours)	Balance G=E-D (m^3)	New Facility
1	Shanthipura		-	-	Shanthipura	-	-			Shantipura	-	-	-	-	
2	Piyatisappura		78	94	Piyatisappura	255	161			Piyatisappura	23	190	48.7	166.6	
3	High Area 1	Old Water Field	303	363	Old Water Field	290	-73		New	Old Water Field	91	0	0.0	-90.9	To be constructed 100 m^3
		New Water Field	53	63	New Water Field	120	57			New Water Field	16	70	26.6	54.2	
		Gamunu	15	18	Gamunu	19	1			Gamunu/Brewery	62	190	18.4	128.1	
		Brewery	192	230	Brewery	428	198								
		Pedro	680	815	Pedro	651	-164		New	Pedro	204	0	0.0	-203.8	To be constructed 220 m^3
		Lovers Leap	86	103	Lovers Leap	255	152			Lovers Leap	26	900	209.9	874.3	
	Sub Total		1,328	1,592		1,763	171					1,160			
4	Low Area 1	Haddon Hill	3,731	4,474	Bambarakele	1,327	-4,651			Haddon Hill	1,119	1,800	9.7	681.5	
		Unique View	718	861						Unique View	215	40	1.1	-175.1	To be augmented 200 m^3
		Vijithapura	537	644						Vijithapura	161	40	1.5	-120.9	To be augmented 140 m^3
	Sub Total		4,985	5,978		1,327	-4,651	New Borehole × 5 units				1,880			
5	Low Area 2		1,453	1,742		0	-1,742	New Borehole × 2 units	New	Low Area 2	436	0	0.0	-435.6	To be constructed 470 m^3
6	High Area 2		469	562	Upper Lake Road Borehole	600	38			Naseby	140	190	8.1	49.5	
7	Bonavista		193	232	Race Course Borehole	300	68			Bonavista	58	190	19.7	132.0	
	Total		8,506	10,200		4,245	-5,955					3,610	8.5		

- Old Water Field reservoir and Pedro reservoir are located near the new water intake (dam) site.
- Unique View and Vijithapura reservoirs are located as expansion facilities beside the existing ones.
- Low Area 2 reservoir is planned as a new facility to serve Low Area 2.
- Old Water Field and Low Area 2 reservoirs are to be located on the slopes.
- Vijithapura reservoir is planned to be constructed after raising the original ground elevation by 2.5 m in order to attain the same ground elevation as the existing reservoir.

Site elevations for each reservoir are summarized in Table 6.3.

Table 6.3 Site Elevation of Proposed Reservoirs

Name of Reservoir	Ground Elevation (m amsl)
Old Water Field	1,965 to 1,955
Pedro	1,933 to 1,934
Unique View	1,982 to 1,980
Vijithapura	1,923.5 to 1,925.5
Low Area 2	1,920

(2) Geological condition

The proposed site of Pedro reservoir has surface soil consisting of clay or sandy clay up to a depth of about 3 m and will be subject to soil replacement. Unique View reservoir site requires about 2 m depth of soil excavation to lie at the same elevation as the existing reservoir. Other reservoirs are to be constructed at the existing ground elevation.

(3) Reliability of power supply

No particular measures are considered necessary. The water will be distributed by gravity flow for which any power interruption will have minimal effect occurrence on the continuous operation of the water supply system.

6.2.2 Intake Facility

(1) Water intake method

As mentioned above, the future water demand (daily maximum basis) is estimated to reach 10,200 m^3/day in 2005 and 10,700 m^3/day in 2015, respectively. On the other hand, the existing surface water and groundwater sources have a total supply capacity of about

4,200 m^3/day in the dry season. The water supply deficit of about 6,500 m^3/day is planned to be provided by groundwater development.

Groundwater development potential was evaluated through test wells from which it was determined that approximately 1,000 m^3/day is available from one well. In this regard, seven wells are planned to be constructed as the priority project. Five wells with a total discharge of 5,000 m^3/day are planned at Low Area 1, while two wells with a total discharge of 1,879 m^3/day are planned to be located at Low Area 2, respectively.

1) Capacity of new groundwater source

The required pump capacity was verified with the water demand in 2005 and concluded that the same capacity would be required both for 2005 and 2015.

a. Facility requirement of a new well for Haddon Hill block

Planned intake amount per well:	Q = 1,000 m^3/day = 0.70 m^3/min
Suction pipe:	PVC 160 mm dia., L = 1,110 m
Head loss:	h = 2.2 m
Actual pumping head:	H_1 = 50 m
Total pumping head:	H = H_1 + h + Allowance (5 m) = 58 m
Well pump capacity:	0.70 m^3/min x 58 m x 15 kW x 5 units
Transmission line:	PVC 160 mm dia.
	L = 10 + 110 + 220 + 330 + 440 = 1,110 m

b. Facility requirement of a new well for Low Area 2 block

Planned intake amount per well:	Q = 1,000 m^3/day = 0.70 m^3/min
Suction pipe:	PVC 160 mm dia., L = 130 m
Head loss:	h = 0.6 m
Actual pumping head:	H_1 = 50 m
Total pumping head:	H = H_1 + h + Allowance (5 m) = 56 m
Well pump capacity:	0.70 m^3/min x 56 m x 15 kW x 2 units
Transmission line:	PVC 160 mm dia., L = 10 + 120 = 130 m

2) Booster pump

Groundwater exploited from wells is collected in a pump pit and transmitted to respective reservoirs via booster pump.

The required pump capacity was verified with the water demand in 2005 and concluded that the same capacity would be required both for 2005 and 2015.

a. Facility requirement of booster pump for Haddon Hill block

Planned transmission volume in 2015: Q = 5,000 m^3/day = 3.47 m^3/min

Transmission line:	DI 300 mm dia., L = 4,320 m,
Head loss:	h = 10.3 m,
Actual pumping head:	H_1 = 1,927 - 1,875 = 52 m
Total pumping head:	H = H_1 + h + Allowance (5 m) = 68 m
Booster pump capacity:	3.47 m^3/min x 68 m x 75 kW x 2 units (including 1 standby)

b. Facility requirement of booster pump for Low Area 2 block

Planned transmission volume in 2015: Q = 1,879 m^3/day = 1.30 m^3/min

Transmission line:	PVC 225 mm dia., L = 700 m,
Head loss:	h = 2.4 m,
Actual pumping head:	H_1 = 1,920 - 1,865 = 55 m
Total pumping head:	H = H_1 + h + Allowance (5 m) = 63 m
Booster pump capacity:	1.30 m^3/min x 63 m x 30 kW x 2 units (including 1 standby)

Transmission lines and booster pumps are summarized as follows:

Table 6.4 Required Transmission Line for Groundwater

Type	Diameter (mm)	Length (m)	Remarks
PVC	160	1,240	Intake 1,110 + 130
PVC	225	700	
DI	300	4,320	
Total		6,260	

Table 6.5 Required Booster Pumps

Haddon Hill Block	Low Area 2 Block
3.47 m^3/min × 68 m × 75 kW × 2 units (including 1 standby)	1.30 m^3/min × 63 m × 30 kW × 2 units (including 1 standby)

The proposed layout of the wells and transmission lines are shown in Figure 5.6, section 5.4.3)

(2) Evaluation of existing well pump facility

The existing well pumps at Upper Lake Road and Race Course are pumping uphill and transmitting groundwater to the Naseby reservoir and Bonavista tank respectively. The capacity of those pumps was evaluated with regard to the rearrangement of water supply service blocks and water demand as follows:

1) Well pump at Upper Lake Road for Naseby Reservoir

Present pump capacity:	0.39 m^3/min x 82 m x 11 kW x 1 unit
Planned transmission volume in 2015:	Q = 600 m^3/day = 0.42 m^3/min
Transmission line:	100 mm dia., L = 410 m,
Head loss:	h = 4.7 m
Actual pumping head:	H_1 = 1,946 - 1,872 = 74 m
Total pumping head:	H = H_1 + h + Allowance (5 m) = 84 m

It was concluded that the existing pump can be utilized in the future based on the above evaluation referring to the pump performance curve (H-Q curve).

2) Well pump at Race Course for Bonavista Tank

Present pump capacity:	0.42 m^3/min x 80 m x 11 kW x 2 units (including 1 standby)
Planned transmission volume in 2015:	Q = 250 m^3/day = 0.17 m^3/min < 0.42 m^3/min

It was concluded that the existing pump can be utilized in the future based on the above evaluation.

6.2.3 Transmission Facility

The required sizes, lengths and pipe materials for the transmission lines to supply water from the existing water treatment plant were determined based on the hydraulic analysis for the target year 2015. The analysis result was verified with the water demand in 2005 so as to minimize the initial investment in the priority project and confirmed that a part of transmission line (Node Nos. 9 to 50) having a diameter of 250 mm for a length of 488 m could be omitted. The configuration of transmission lines to be augmented during the priority project is summarized in Table 6.6 (refer to Figure 5.9 and Appendix 5.4).

Table 6.6 Length of Transmission Lines for Surface Water Supply

Pipe Material	Diameter (mm)	Length (m)
PVC	110	2,867
DI	250	3,545
Total		6,412

The capacity requirement of the transmission pump was also verified for its ability to supply water from the existing water treatment plant to the Naseby Block. The pump specification was determined to be same for both the priority project (562 m^3/day in 2005) and the Master Plan (606 m^3/day in 2015).

Table 6.7 Required Transmission Pump to Serve for Naseby Block

Type of Pump	Required Equipment
Inline Booster Pump	0.42 m^3/min x 25 m x 3.7 kW x 1 unit

6.2.4 Distribution Facility

(1) Distribution network

The required sizes, lengths and pipe materials for the distribution network were determined based on the hydraulic analysis for the target year 2015. The analysis result was verified with the water demand in 2005 so as to minimize the initial investment in the priority project. The configuration of the distribution network to be augmented during the priority project is summarized in Table 6.8 (refer to Figure 5.10 and Appendix 5.4).

Table 6.8 Distribution Network to be Augmented in Priority Project

Pipe Material	Diameter (mm)	Length (m)
PVC	63	50
	75	1,460
	110	1,839
	160	1,828
	225	1,760
DCI	250	2,069
Total Length		9,006

(2) Booster pump

Booster pumps are required to serve the Vijithapura reservoir area and Unique View Hill reservoir area. Because the difference in water demand between 2005 and 2015 is small, as shown in Table 6.9, the pump capacity for both areas were determined to be same in 2005 and 2015.

Table 6.9 Water Demand of Vijithapura and Unique View Hill Reservoir Areas

Service Area	Water Demand (m^3/day)	
	2005	2015
Vijithapura Reservoir Area	644	694
Unique View Hill Reservoir Area	861	928

1) Booster pump capacity to serve for Vijithapura distribution reservoir

   0.48 m^3/min x 19 m x 3.7 kW x 1 unit

2) Booster pump capacity to serve for Unique View Hill distribution reservoir

   0.64 m^3/min x 85 m x 18 kW x 1 unit

(3) Distribution reservoir and disinfection facility

Based on the water demand projection for the priority project, the following distribution reservoirs are planned to be newly constructed or expanded. Disinfection facilities will also be provided for every reservoir (refer to Figure 5.11, section 5.4.6).

Table 6.10 Distribution Reservoirs to be Constructed or Expanded

Proposed Location of Reservoir	Required Capacity (m^3)	Dimension and Required Number of Unit	Design Capacity (m^3)	Remarks
Old Water Field	98.1	4.5mW x 3.7mL x 3.0mD x 2 units	100	
Pedro	219.7	6.0mW x 6.2mL x 3.0mD x 2 units	220	Elevated Tank
Low Area 2	469.8	10.0mW x 7.9mL x 3.0mD x 2units	470	
Unique View Hill	192.0	8.6mW x 8.6mL x 3.0mD x 1 unit	200	The existing reservoir shall be utilized.
Vijithapura	133.5	8.5mW x 5.5mL x 3.0mD x 1 unit	140	The existing reservoir shall be utilized.

6.2.5 Other Facilities

(1) Flow measurement of distribution amount

Flow measurement is indispensable in assessing NRW as a balance between bulk flow from reservoirs and amounts supplied to consumers.

There are several types of flow measurement devices, such as mechanical flow meters and electromagnetic flow meters. From the cost effectiveness view point, mechanical flow meters, which costs only 1/3 to 1/8 of electromagnetic, are suitable for installation in the priority project as shown in Table 6.11. Variation of flow meter sizes will be minimized for ease of O&M by the application of common consumables.

Table 6.11 Flow Meters to be Installed at Reservoirs

Reservoir	Outflow Pipe Size (mm)	Max. Daily Flow (m^3/day)	Meter Size (mm)
Piyatisappura	75	101	75
New Water Field	100	68	75
Gamunu/Brewery 1		83	
Gamunu/Brewery 2		184	
Lovers Leap	225	111	
Bonavista	75	250	
Old Water Field	150	392	
Pedro	200	879	100
Low Area 2	250	1,879	200
Haddon Hill	350	4,825	300

(2) Water quality analysis equipment

The Nuwara Eliya water supply system consists of both surface water treatment and well water. In this regard laboratory facilities and equipment are considered necessary to perform general examinations of water quality, as described in Chapter 7.

For the time being, the water quality analysis may be limited to: turbidity; residual chlorine; and odor in consideration of available manpower resources.

(3) Protection of surface water intake site

Local residents are utilizing the raw water intake site as a place for washing of their clothes. From the viewpoint of water quality conservation at the water intake a public washing place should be provided downstream of the intake facility.

(4) Investigation of the existing Race Course well

Operation of the existing Race Course well has been suspended due to high sand content in the groundwater.

The cause of high sand content will be investigated to determine the possibility for rehabilitation. Appropriate rehabilitation methods will be determined by means of submersible TV observation. Major reasons for this particular problem are:

1) Inappropriate slot size of well screen to the water bearing formation.
2) Corrosion/disconnection of casing pipes, if steel casing is applied.
3) Disconnection/damage of casing pipe, if PVC casing pipe is applied.

The following countermeasures are available for the above cases:

1) Smaller size of new casing pipe can be inserted into the existing casing pipe, if the existing casing pipe has enough diameter. However, the discharge amount will be subsequently decreased.
2) Sand trap pit can be applied near to the existing well and booster pump used to transmit sand-free water.

The former measure is not applicable to the existing well. The latter measure depends on the survey result, because large amounts of sand discharge may cause land-subsidence at the well site. If these two measures are not applicable, the existing well will be abandoned and a new well will be constructed.

6.3 NRW Reduction Program

In the priority project, the costs for a leakage detection survey for 70 percent of the total length of the distribution network, and for leakage repair will constitute five percent of the current total construction cost of the existing distribution network.

As a result of these project inputs, the current 56 percent of NRW are expected to be reduced to 40 percent by the target year of 2005 and to 25 percent by the Master Plan target year of 2015.

6.4 Project Cost

The total cost of the proposed project is estimated at approximately Sri Lankan Rs 549 million as shown in Table 6.12. (refer to Appendix 5.5 for details).

Table 6.12 Estimated Project Cost

Unit: Thousand Sri Lankan Rs.

(1) Construction cost		
1) Intake Facilities		112,499
Well / Well Pump		
2) Transmission Pipe		93,024
3) Water Treatment Plant		3,150
Chlorination		
4) Distribution Facilities		108,496
Reservoir	64,513	
Pipe Facilities	42,983	
House Connection Replacement	1,000	
5) NRW Reduction Program (Leak detection)		2,500
6) Rehabilitation of NRW Reduction		17,000
7) Administration cost		17,331
Sub-Total		**354,000**
(2) Procurement of maintenance equipment		25,000
(3) Engineering cost		
1) Detailed design	19,000	
2) Construction supervision	16,000	
Sub-Total		**35,000**
(4) Common expenses		
1) General and administration expenses	4,000	
2) Land acquisition	6,000	
Sub-Total		**10,000**
(5) Contingency		**64,000**
(6) GST (12.5%)		**61,000**
Total		**549,000**

Note: Exchange rate: SL Rs 1.00 = Japanese Yen 1.80 (as of Nov., 1998)

6.5 Implementation Program

6.5.1 Implementation Schedule

With regard to the target year for this Study (2005), the Phase 1 or priority project is expected to be completed by the end of 2003.

Priority Project (1999 to 2003)

1999-2000	Preparation of project
2001-02	Detailed design and bidding
2002	Commencement of construction & procurement of equipment
2002-03	Construction
2004	Commencement of operation

The project implementation and disbursement schedule with estimated annual disbursements of project cost is presented in Table 5.18 in section 5.7.1. The required project activities are described below:

6.5.2 Activities in Project Implementation

The required project activities are described below:

(1) Preparation of Project

Preparatory work for the project implementation includes:

- Budgetary arrangements within the Sri Lankan Government for land acquisition and institutional development,
- Negotiation of grant/loan with foreign lending institution/s, and
- Selection of consultants in accordance with the agreement executed between the foreign lending institution and the executing agency of the Sri Lankan Government

This preparatory work will be commenced by the middle of 1999 and completed by the end of the same year.

It should be noted that the institutional development of the executing agency and staffing as required for project implementation are a prerequisite not only to ensure the successful achievement of the project objectives, but also to secure the firm commitment of financial assistance from the foreign lending institution/s. Appraisal missions by the institution will focus on the preparedness and maturity of the proposed project as well as the implementing capability of the executing agency, both financially and institutionally.

(2) Pre-construction stage

The majority of project activities will be undertaken by the consultants hired by the executing agency. Those activities to be carried out by the consultants include, but are not limited to, detailed field investigations, detailed engineering design, and preparation of tender documents for bidding. These activities will be carried out in the year 2001.

After preparation of the tender documents, bidding for procurement of maintenance equipment and for construction of the proposed project will be executed in the year 2002.

In parallel with the above project activities, the executing agency will, in accordance with the detailed design, negotiate with respective landowners and acquire the required land for construction. Other important subjects, such as a tariff system for water supply service cost recovery, shall also be carried out by the executing agency.

(3) Construction

The major scope of construction work is as follows:

1) Intake Facilities
   - Wells / Well Pumps
2) Transmission Pipelines
   - Civil Work
3) Distribution Facilities
   - Distribution Reservoirs
   - Distribution Pipelines

Construction periods for the major works are estimated in months, as follows:

1) Intake Facilities	
- Mobilization	1.0
- Wells/Well Pumps	20.0
2) Transmission Facilities	
- Mobilization	1.0
- Civil work	20.0
Total	21.0
3) Distribution Facilities	
- Mobilization	1.0
- Civil work	20.0
Total	21.0

(4) Procurement of maintenance equipment

Preparation of bid documents and specifications for the maintenance equipment, such as water quality analysis equipment, leakage detection equipment, trucks with loading cranes, etc. will be prepared by the consultant during the detailed design of the water facilities and procured within 2003 by international bidding.

6.5.3 Construction Equipment and Materials

Most of the construction materials are imported from adjacent countries, except sand, gravel, concrete pipe etc. The imported materials, however, are available in the local market in Sri

Lanka. Mechanical and electrical equipment must however, be imported from foreign countries.

Local products and imported materials and equipment are listed below. However, the imported materials for civil work are considered to be procured through sales agents and suppliers in Sri Lanka.

(1) Local material

Cement, stone, aggregate, sand, timber, plywood, steel reinforcement bars, structural steel, small PVC Pipe, concrete pipe, steel pipe, road curb, concrete block, brick, AC roof and tiles, pre-cast built wall, fence, road/pedestrian gates, wire nails, gabion mesh, gasoline, diesel, lubricants, admixtures, waterstop, scaffolding, metal forms, guardrail, asphalt, emulsion and other small items.

(2) Imported material

Construction equipment, valves, fittings, ductile iron pipe, truck cranes, vehicles, motorcycles, computers, pumps, motors, transformers, switchgears, disinfection facilities, laboratory equipment, flow meters, and other mechanical and electrical equipment.

CHAPTER 7 OPERATION AND MAINTENANCE PROGRAM FOR WATER SUPPLY SYTEM

CHAPTER 7 OPERATION AND MAINTENANCE PROGRAM FOR WATER SUPPLY SYSTEM

7.1 General

The water supply facilities must be maintained to ensure that the required supply of sufficient quantities of safe and potable water at the required pressure are available at all times.

Any omission or neglect of proper operation and maintenance functions may result in unexpected failures to the water supply facility and which will require additional cost and time for repair.

Regular activities to maintain facilities and equipment mainly comprise patrol/inspection and maintenance works. Patrol/inspection is commonly carried out to check operating status of respective facilities/equipment, while maintenance is to be performed to insure normal operating conditions are maintained.

7 .2 Work Program for Operation and Maintenance

7.2.1 Intake Facility and Disinfection Facility

Water supply system in Nuwara Eliya adopts only disinfection for both surface water and groundwater and disinfection facility is designed to be located at each reservoir.

The Operation and Maintenance (O&M) activities for the intake facility and disinfection facility are classified into two categories, - daily and periodical functions. The work categories by O&M type are shown in Table 7.1.

Table 7.1 Work Categories for Water Intake and Disinfection Facility by O&M Type

O&M Category	Work Category
Daily Inspection	-Flow rate of water intake and distribution, -Inspection to water sources, -Operating conditions of disinfection facility, -Operating conditions of mechanical/electrical facilities -Water quality examination
Periodical Work	-Cleaning of water source facility (monthly/seasonal) -Removal of sediments at reservoir (monthly/seasonal) -Inspection/repair of mechanical/electrical facilities (annually) -Overhaul of mechanical/electrical facilities (at 5 to 10 year interval)

The O&M activities for the intake facility and distribution facility should be carried out in accordance with the working program as shown below.

(1) Daily work program

Measurements of intake and treated water quantities are the principal activities in order to supply water to meet demand fluctuations.

The washing of clothes upstream of the water intake should be discouraged on a regular basis. The population should be urged to carry out this downstream of the intake.

To insure that the required quality of water is produced, inspection of the operating conditions of the disinfection facility and examination of raw water quality are prerequisites. Regular and periodical water quality examination at water sources and reservoir should be carried out as shown in Table 7.2. Examinations for major characteristics except turbidity, residual chlorine and odor shall be contracted out to local contractors/laboratories to obviate the purchase of expensive equipment for infrequent use.

Table 7.2 Laboratory Tests and Frequency

Characteristics	Raw Water	Tap Water
Water Temp.	once a month	
Turbidity	once a day	once a month
Color	once a month	once a month
pH Value	once a month	once a month
Odor	once a day	once a month
Taste	once a month	once a month
Ammonia	once a month	
Nitrite	once a month	once a month
Nitrate	once a month	once a month
$KMnO_4$	once a month	once a month
Chloride	once a month	
T-Hardness	once a month	
Total solids	twice a year	
E. Conductivity	once a month	
Sulphate	twice a year	
T-Iron	once a month	
T-Manganese	once a month	
Zinc	once a month	
Copper	once a month	
Lead	once a month	
H-Chromium	twice a year	
Cadmium	twice a year	
T-Mercury	twice a year	
Arsenic	twice a year	
Fluoride	twice a year	
Selen	twice a year	

A-Surfactant	once a month	
Cyanide	twice a year	
Organic-Phosphate	twice a year	
Phenol	twice a year	
Bacteria	once a month	
E. Coli.	once a month	once a month
Res. Chlorine		once a day
Tri-methanes		twice a year
Pesticide	twice a year	

T : total H : hexa Res. : residual Tri : trihalo

(2) Periodical work program

Periodical O&M items mainly focus on mechanical/electrical facilities. Reservoirs shall be periodically cleaned and sediments shall be removed and disposed of to landfill.

7.2.2 Transmission and Distribution Facilities

O&M activities include daily inspection, site investigation, rehabilitation of damaged pipes, etc. as shown in Table 7.3.

Table 7.3 Work Categories for Distribution Facilities by O&M Type

O&M Type	Work Items
Daily Inspection	-Operation of pumping facilities -Operation of electrical facilities
Site Investigation	-Confirmation of transmission/distribution facilities and their surrounding environment.
Rehabilitation	-Replacement/repair of damaged pipes
Water Quality Examination	-Periodical water quality examination of respective reservoirs and distribution lines.

The O&M for the transmission and distribution facilities should be conducted in accordance with the program below:

(1) Daily inspection

Pumping facilities are designed to operate automatically based on the change of water level in the reservoirs. Daily inspection of pump stations is required to monitor the operating conditions of pumps and associated electrical system.

(2) Site investigation

The transmission and distribution lines, reservoirs and surrounding environment should be surveyed regularly for damages caused by land-subsidence, erosion of slopes by rainfall, etc.

(3) Rehabilitation

Leakage repair of transmission/distribution lines and replacement of wearing parts for pumping equipment is the usual rehabilitation works.

Replacement of damaged pipes is usually sub-let to local contractors based on the annual rehabilitation plan or based on regular inspection reports. Water Board officials in charge of such repair work should prepare reports on situation and cause of damages, and countermeasures taken up for rehabilitation, as future reference for preventive O&M work.

(4) Water quality examination

Periodical sampling and water quality examination should be carried out at reservoirs, distribution lines and taps (end points of distribution lines) to confirm conformity to drinking water quality standards.

7.3 Organization for Operation and Maintenance

The proposed staffing for operation and maintenance is shown below and is 7 persons for Phase 1 and Phase 2.

Table 7.4 Required Number of Staff for O & M of Water Supply System

unit: persons

Field & Position		Phase 1	Phase 2	Assignment
Manager		1	1	Responsible for overall management/ supervision of waterworks
Maintenance	Technician	1	1	Responsible for site works
	Worker	5	5	Responsible for site works
Water Quality Examination**	Chemist	-	-	Water quality examination and control
Total		7	7	

* Vehicle maintenance shall be done by the municipal workshop.

** To be carried out by contract

7.4 Operation and Maintenance Cost

Annual costs for transmission/distribution facilities and water treatment plant operation and maintenance programs as described in the preceding sections are as shown in Table 7.5. The detailed cost is shown in Appendix 7.1.

Table 7.5 Operation and Maintenance Cost

Unit: Thousand Rs./year

Item	Phase 1	Phase 2
Personal Expenses	2,160	2,160
Electricity Cost	2,495	2,733
Chemical Cost	9	10
Repair Cost	6,181	6,181
Total	10,845	11,084

CHAPTER 8 GROUNDWATER RESOUCES

CHAPTER 8 GROUNDWATER RESOURCES

8.1 Physiography

8.1.1 Geographic Setting

The NESA (Nuwara Eliya Study Area) is located in a 12.6 km^2 mountain valley in the rugged and steep mountains of the highest peneplain with elevations in the NESA ranging from about 1850m to 2000m above MSL. The valley is structurally controlled, oriented along a major shear zone in a NW - SE direction. The valley is narrow near the top, expanding into a relatively flat valley with the Nanu Oya meandering through the NESA. About one-third of the way down the valley, the valley narrows briefly, leaving only a gap for the Nanu Oya and road to pass through. This constriction is also structurally controlled. The lower two thirds of the valley is relatively flat with some low hills leading up to the steep mountains on either side. The headwaters of the Nanu Oya originate in the NESA, draining the valley into Lake Gregory, before leaving the area to the west.

The area is subject to precipitation during both monsoon seasons, with rain falling for nine to ten months of the year. The temperature is significantly cooler at this higher elevation, ranging from 0°C to 20°C. The cool temperatures, high elevation, and rugged topography combine to create cold, wet, windy, and misty conditions during much of the wet season. The short dry season and other occasional dry periods provide a very pleasant climate that attracts tourists seasonally. Tea is commonly grown in the NESA and is some of the highest quality in the world. The steepest areas of the mountains generally are not suitable for growing crops and are either forested or bare rock.

8.1.2 Geology

Underlying the NESA is the HC (Highland Complex) consisting of high-grade multi-phase metamorphic Precambrian rocks. Meter scale layering and an internal fabric characteristic of ductile deformation, with extreme flattening and stretching dominates the HC structure. Probably up to six phases, including minor phases, of deformation have contributed to the complex internal structure and layering. The repeated and intense metamorphism of these Precambrian rocks has resulted in strong folding (antiforms, synforms, and overturns), shearing along the fold axes, and lithological changes due to melting. Subsequent episodes of uplift and submergence have caused extensive regional faults and fault zones. In addition to the fault and shear fracture zones, shallow fractures due to the effects of weathering and erosion can also be found.

Predominant lithologies in the NESA are garnet-sillimanite-biotite gneiss, with less dominant quartzites, marble, and charnockitic gneiss. These lithologies are an important source of road metal, sand, and gemstones in Sri Lanka.

8.2 Geophysical Surveys

A total of 14 single dimension electrical resistivity soundings were conducted in the NESA to identify the contact of the fresh rock and search for deep fractures. The locations are shown in Figure 8.1 and given in Table 8.1. Sounding locations were based on prior sounding locations, and geologic and topographic information. Exploration depths up to 200m were used. The survey equipment consisted of a "Sting R1" (AGI Inc.) instrument with accessories. Analysis was conducted with the assistance of a commercial software package and interpreted by a hydrogeologist.

Table 8.1 Electrical Resistivity Soundings

Sounding No.	Date	Site Name	Location X	Location Y
1	13 Jul 98	Westward Ho	197.91	198.23
2	13 Jul 98	Victoria Park	199.41	196.54
3	14 Jul 98	Upper Lake Rd	200.60	195.50
4	14 Jul 98	Badulla Road	201.16	194.84
5	14 Jul 98	Boat house	200.27	195.22
6	14 Jul 98	Playground	199.41	195.86
7	14 Jul 98	Race course 3	199.61	195.92
8	15 Jul 98	Galway's bungalow	200.44	196.18
9	15 Jul 98	Upper Lake Rd 2	201.00	195.13
10	15 Jul 98	Golf Links 1	199.17	196.55
11	15 Jul 98	Golf Links 3	198.71	197.01
12	15 Jul 98	Golf Links 5	198.73	197.41
13	16 Jul 98	Golf Links 4	199.04	197.19
14	16 Jul 98	Race course 2	199.78	195.71

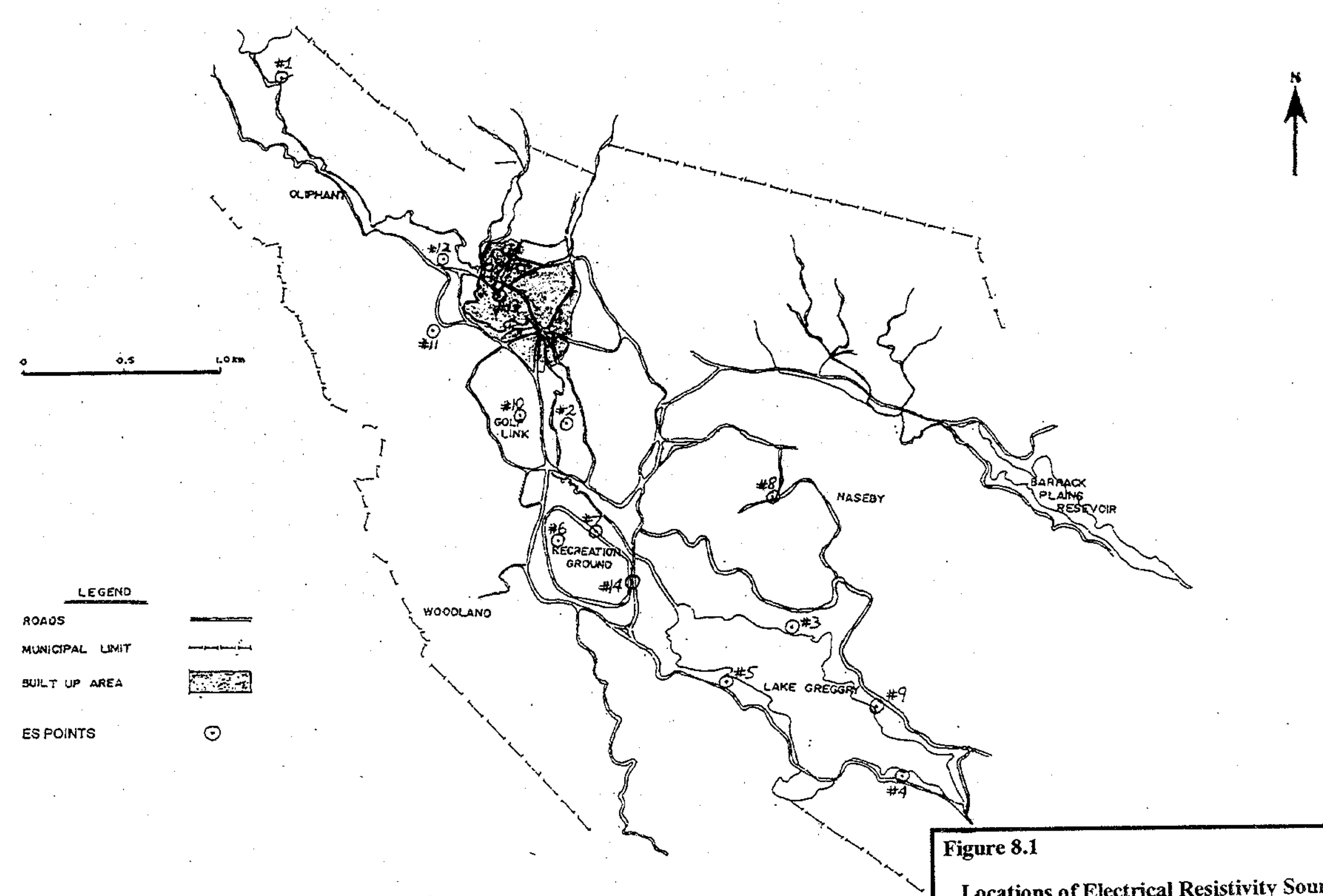


Figure 8.1

Locations of Electrical Resistivity Soundings

Initial low-resistivity zones generally indicate alluvial deposits and weathered rock, usually ranging from a depth of five to 60m. Below this is a higher-resistivity zone, indicating a layer of clay or hard rock. Deeper, very thin, very low-resistivity zones usually indicate fractures in the hard rock or a saturated contact between formations. Deeper and thicker low-resistivity zones generally indicate a saturated permeable formation such as quartzite or limestone.

8.3 Test Wells

A total of eight test wells was drilled during August 1998 and is summarized in Table 8.2. Additional details of well drilling and construction are given in the photocopies of the drilling logs and pump test records.

About one week was required for the construction of each well. Typically, each site experienced at least one delay due to any number of mechanical or supply reasons. In addition, none of the work crews was prepared for the constant adverse weather conditions (wind, rain, and cool temperatures) which caused numerous illnesses. Mechanical breakdowns, unreliable water sources, insufficient and incorrect construction materials, and illnesses contributed significantly to delays and construction failures.

Site selection was determined after the preliminary phase of fieldwork and analysis, and did not benefit from later geophysical surveys and geological mapping. This had a direct impact on the production success of the test wells. Locations of the test wells are shown in Figure 8.2. Since there are many shear zones extending through the valley, most of the well locations correspond closely to them.

Pump tests (well tests) were conducted or attempted on the completed wells. Pump tests also experienced problems and delays due to insufficient supplies, mechanical problems, and antiquated equipment. Initially, a step drawdown test was conducted to get a preliminary evaluation of the aquifer and to set the pumping rate for the 48-hour test. All pump tests are single well tests, without an observation well.

Table 8.2 Summary of Test Wells

Test Well Number	Date Finished	Site Name	Location X	Location Y	Final Depth (m.)	Construction Status	Pump Test Status
33/46A	31 Jul 98	Victoria Park 1	199.30	196.56	62.0	Abandoned	N/A
32/27	4 Aug 98	Upper Lake Rd. 1	200.94	195.17	75.0	Completed	Failed
33/46	8 Aug 98	Galway Wildlife Bungalow	200.48	196.24	76.8	Completed	Completed
32/28A	11 Aug 98	Golf Course 1	198.92	197.31	18.7	Abandoned	N/A
32/28	16 Aug 98	Golf Course 2	198.93	197.32	88.0	Completed	Completed
33/47	17 Aug 98	Victoria Park 2	199.31	196.56	87.5	Abandoned	N/A
32/29	27 Aug 98	Upper Lake Rd. 2	201.12	195.01	75.0	Completed	Incomplete
33/48	27 Aug 98	Upper Lake Rd. 3	201.15	194.99	68.0	Completed	Failed

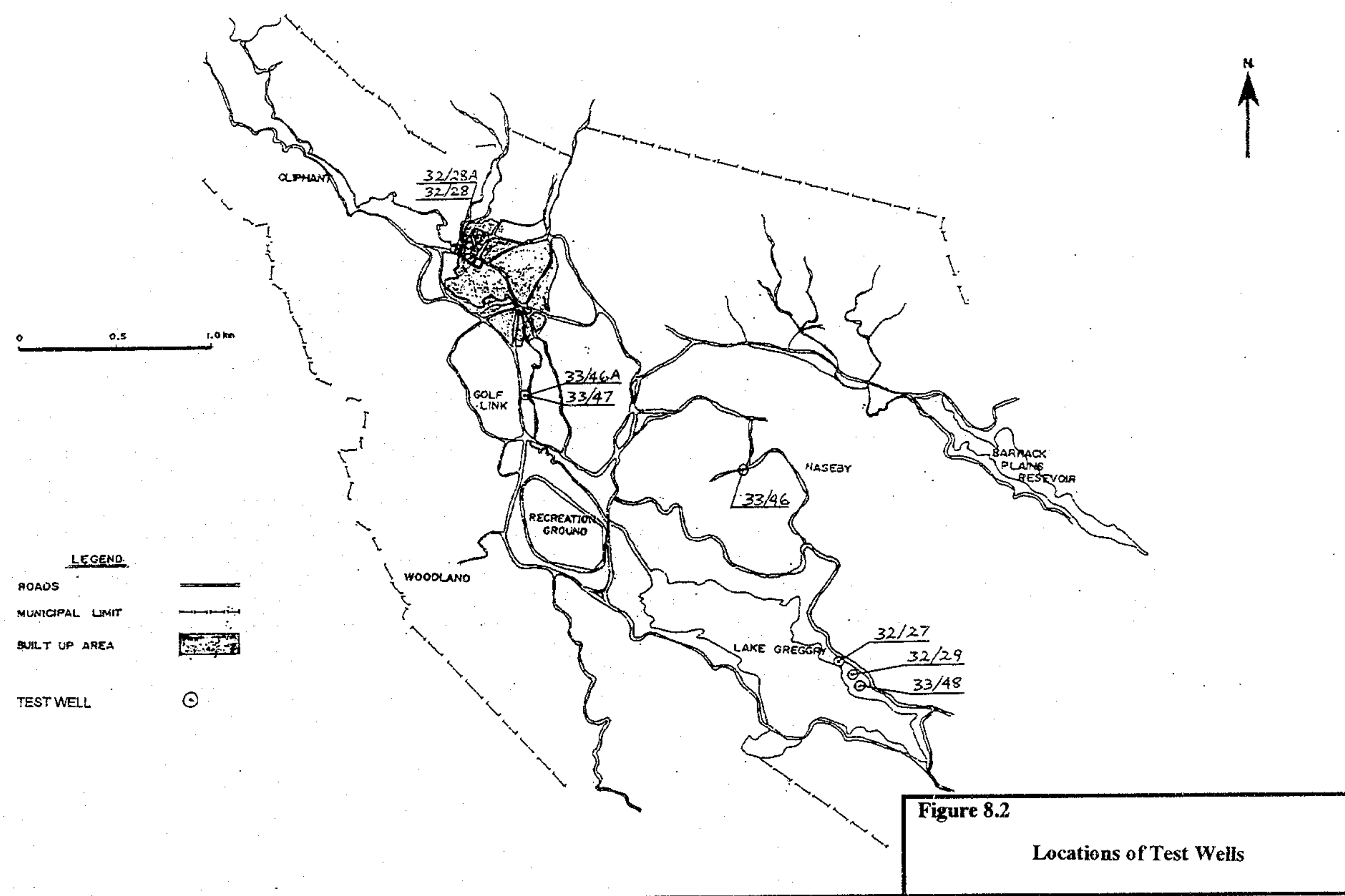


Figure 8.2

Locations of Test Wells

In both cases where the pump tests failed, the failure was due to excessive silt and sand in the water. This was most likely due to inadequate development, no screen, and no gravel pack, all problems of well construction.

Figures 8.3 through 8.10 show the drawdown and recovery data for the completed pump tests. From these data, preliminary hydraulic parameters were calculated. However, in most cases the recovery data was used for the final calculations. For a detailed explanation of the terms and theories behind the parameters and calculations, the reader should consult a reference book on hydrogeology and/or well hydraulics. Below are the formulas used for the calculations.

Transmissivity is given as:

$$\mathbf{T = 0.183 \times Q / \Delta s}$$

where,

T is the coefficient of Transmissivity, in m^2/day
Q is the pumping rate, in m^3/day, and
Δs is the change in drawdown over one log cycle, expressed as a slope.

Specific Capacity is given as:

$$\mathbf{S_c = Q / s}$$

where,

$\mathbf{S_c}$ is the Specific Capacity of the well, in m^3/day/m
Q is the pumping rate, in m^3/day, and
s is drawdown, in meters.

Safe Yield is 67 percent of the maximum drawdown, defined by the pump/intake depth or S_c as given in standard T-S_c tables.

Figure 8.3 shows a graph of the step drawdown in well 33/46, located at the Galway Wildlife Bungalow. The 3 steps are clearly defined for the pumping rates of 430, 850, and 1037 m^3/day. During the first 20 minutes of pumping the rate was unstable while it was being adjusted. The initial rate has very little impact on the water level, but the latter rates show a more significant impact on the water level as it decreases to almost 2.8 meters below the SWL (Standing Water Level). Still, this is a relatively small drawdown.

Based on the results of the step test, a 48-hour pump test was conducted at a rate of 1037 m^3/day. Normally the water level will stabilize after a time but as shown in Figure 8.4, the water level further decreased instead of stabilizing. This indicates that a boundary condition was encountered after about 30 minutes of pumping. Most likely the water bearing fractures are shallow and not continuous, which effectively reduces the amount of water available to the well.

The recovery data shown in Figure 8.5 more accurately reflect the hydraulic conditions in the aquifer and were used for the final calculations. Based on these data, this well has a transmissivity of about 41.7 m^2/day and an S_c of 23 m^3/day/m. Using these numbers and 12 meters of drawdown in 10 days leads to a conservatively estimated Safe Yield of 276 m^3/day.

Figure 8.6 shows a graph of the step drawdown in well 32/28, located at the Golf Course, near hole number ten. The three steps are clearly defined for the pumping rates of 720, 1010, and 1300 m^3/day. The initial response to pumping shows that the water level drops about two meters in the first minute followed by a nearly perfect drawdown curve. This initial drawdown is typical where casing storage influences the test. After a short delay, the aquifer is stressed and begins to recharge the well, producing a normal drawdown curve. The latter steps show similar responses but the relative drawdown is still very small. At the higher pumping rates, the curve appears to deflect downward after pumping more than an hour, indicating a possible boundary condition.

Based on the results of the step test, a 48-hour pump test was conducted at a rate of 1440 m^3/day. Figure 8.7 shows the drawdown data for this pump test. Again, the effects of casing storage can be seen in the first minute of pumping. Drawdown is steady until about 80 minutes into the test, when it is deflected downward. It continues to hold a steady drawdown rate but fluctuations are observed later in the test. Most likely the water bearing fractures are interconnected and the pumping stress encounters the various fractures, each showing as a boundary disturbance. None of these boundary disturbances is strong enough to severely limit the flow of water to the well and most likely, the water level would stabilize after prolonged pumping.

The recovery data shown in Figure 8.8 also reflect the boundary conditions in the aquifer. Initial recharge was unstable, showing the effects of the various fractures, but stabilized as the recovery progressed. Both pumping and recovery data were considered stable enough for calculations but the recovery data was favored to eliminate effects of pumping bias. Based on these data, this well has a transmissivity of about 117 m^2/day and an S_c of 70 m^3/day/m. Using these numbers and 11 meters of drawdown in 10 days leads to a conservatively estimated Safe Yield of 770 m^3/day. This well clearly has more potential but the shallow depth of the large diameter bore (21m) is the obvious limiting factor.

Figure 8.9 shows a graph of the step drawdown in well 32/29, located at Upper Lake Rd., near Lake Gregory. Based on the flushing rates (at least 1440 m^3/day) the initial pumping rate was set to 575 m^3/day for the first step. However, the water level did not stabilize and the water was not clear. The pumping test was discontinued before completion of the first step because the drawdown (36m) had reached the pump and the water was too turbid. Invariably this problem might be interpreted as a boundary condition, but the dirty water indicates that problems with the well construction are largely to blame. The flushing rate clearly indicates that the well has a much higher potential yield but the silt and sand in the water clearly indicate either the need for further development, a screen, and gravel packing, or damaged casing.

The recovery data shown in Figure 8.10 also reflect the problems with the well. Recharge was slow and at the end of the measuring period, the water level had only recovered halfway. The sediments in the fractures and well are effectively clogging the well. Both pumping and recovery data were considered inadequate for calculations but the recovery data was used to calculate a preliminary estimate of hydraulic parameters. Based on these data, this well has a transmissivity of about 25 m^2/day and an S_c of 16 m^3/day/m. Using these numbers and 24 meters of drawdown in 10 days leads to a conservatively estimated Safe Yield of 400 m^3/day. This well clearly has more but the outlined problems will need to be addressed before this well can be fully utilized.

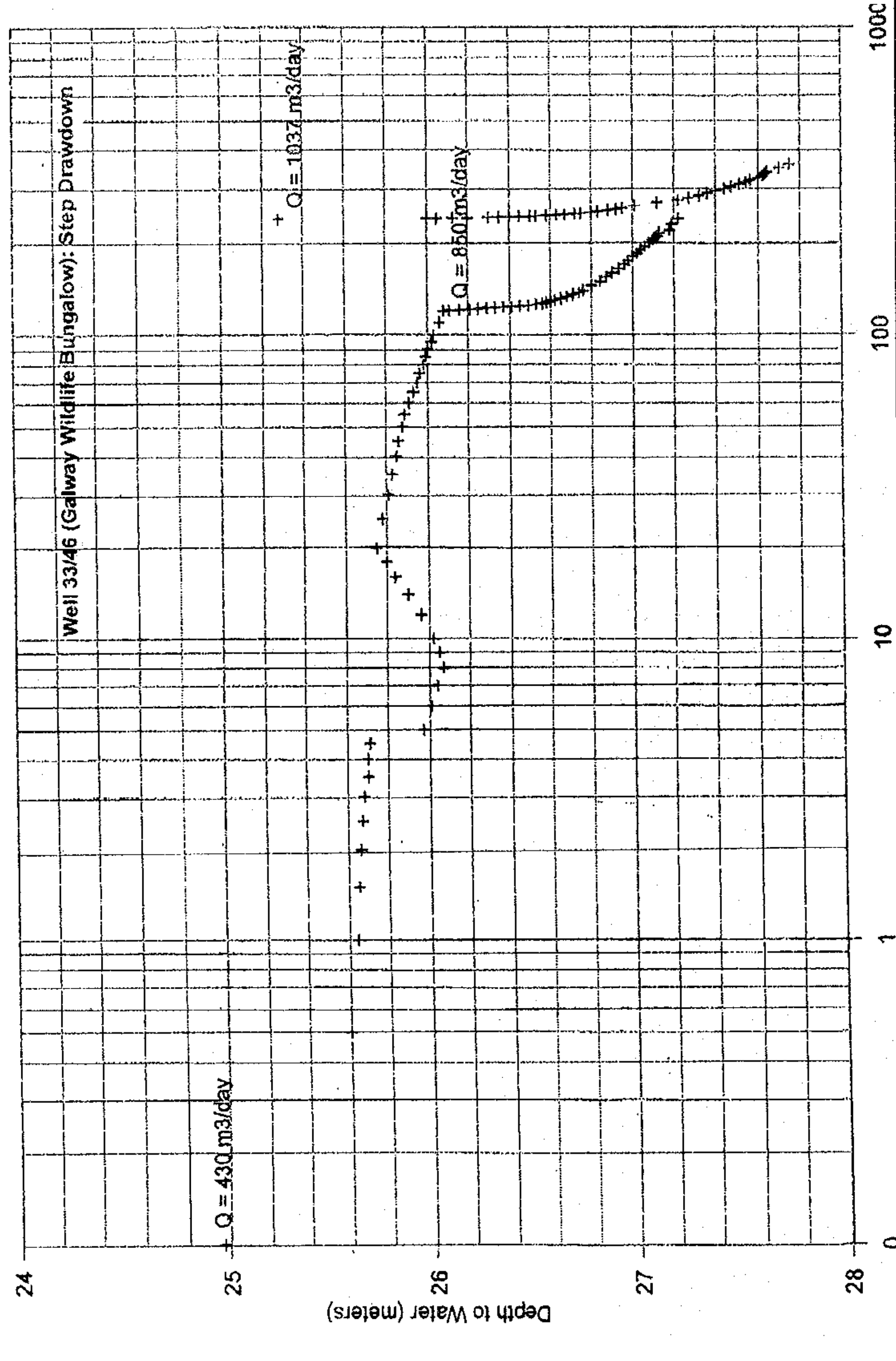


Figure 8.3

Well 33/46 (Galway Wildlife Bungalow)
Step Drawdown

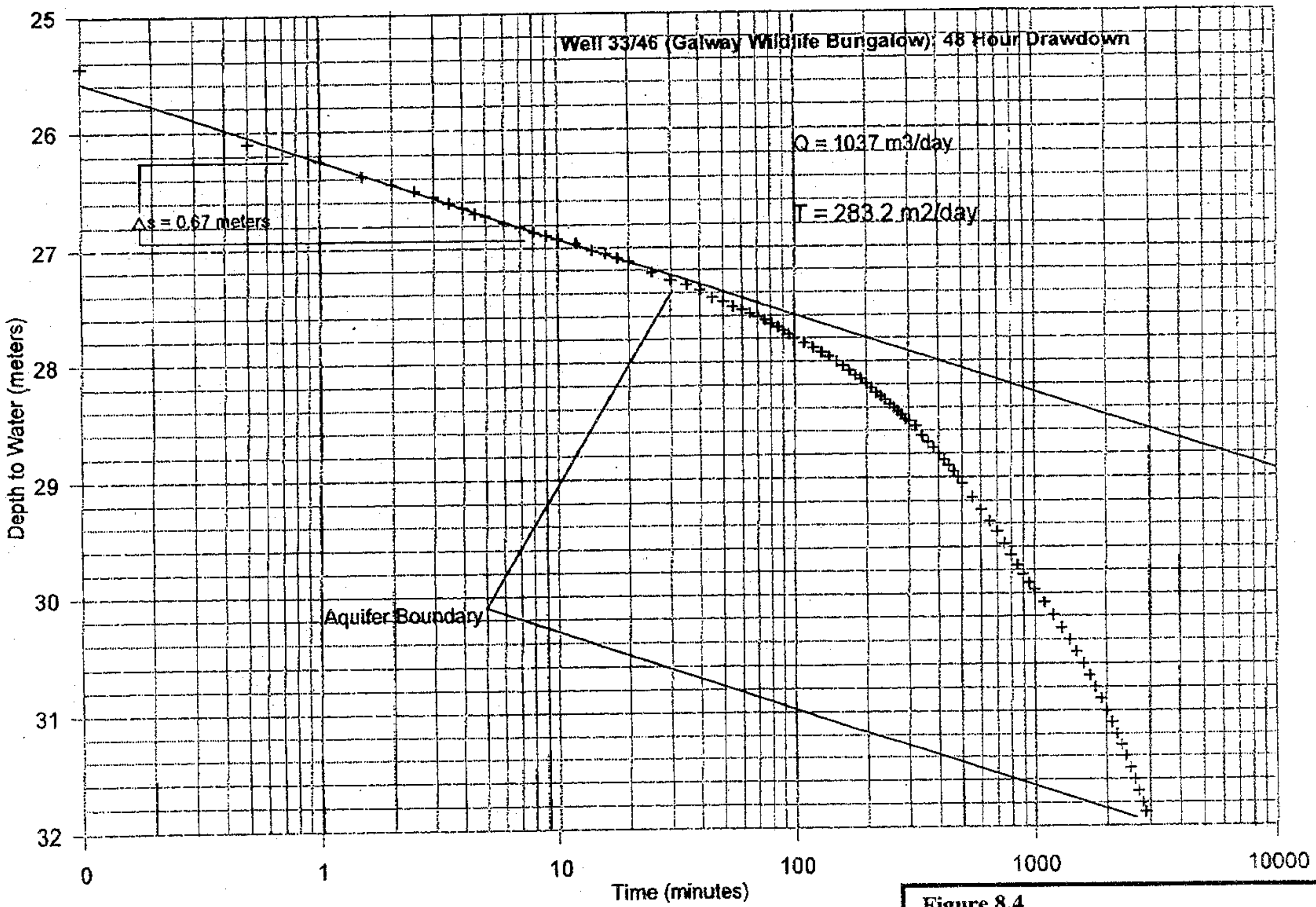


Figure 8.4
Well 33/46 (Galway Wildlife Bungalow)
48-Hour Drawdown

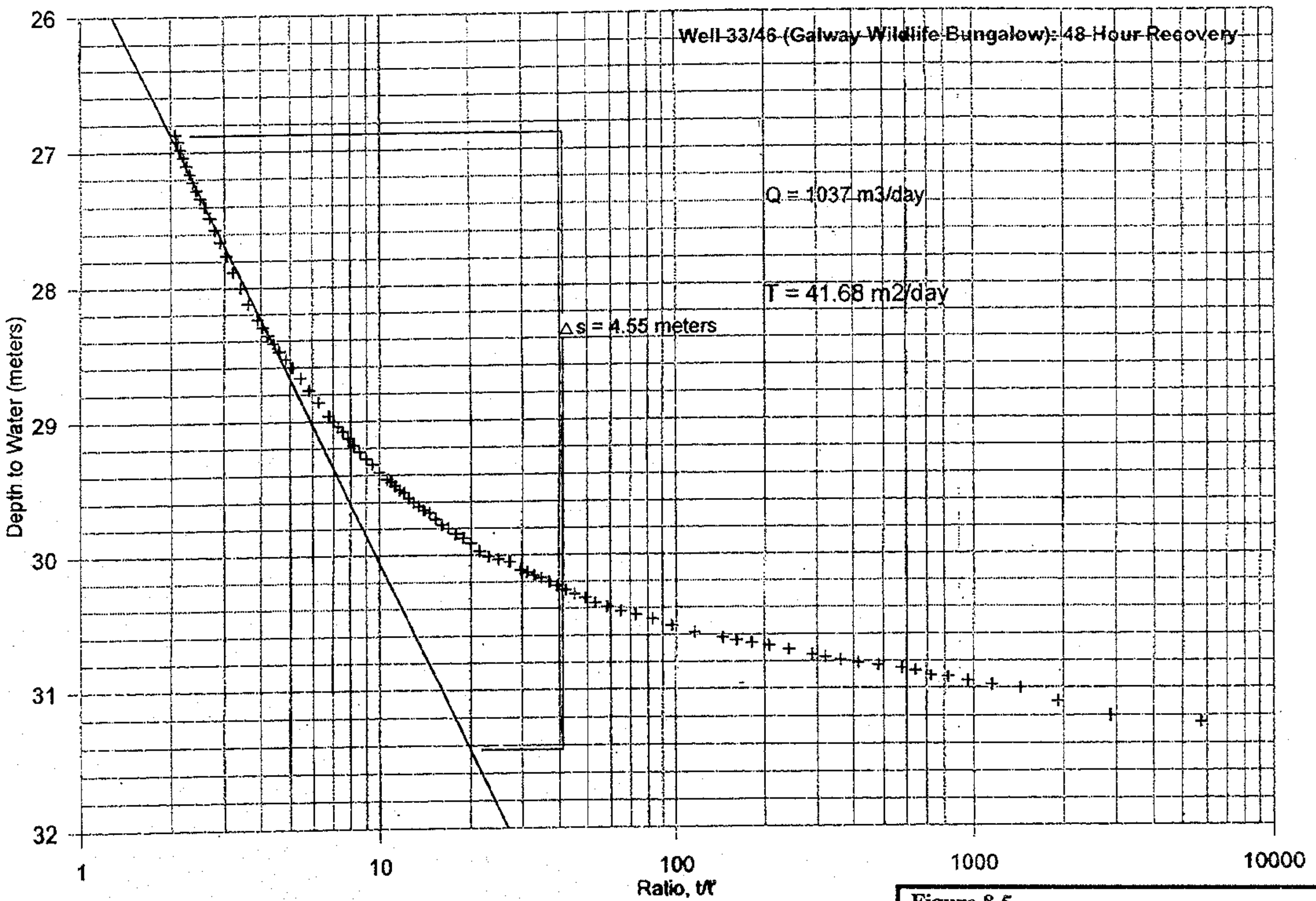


Figure 8.5

Well 33/46 (Galway Wildlife Bungalow)
48-Hour Recovery

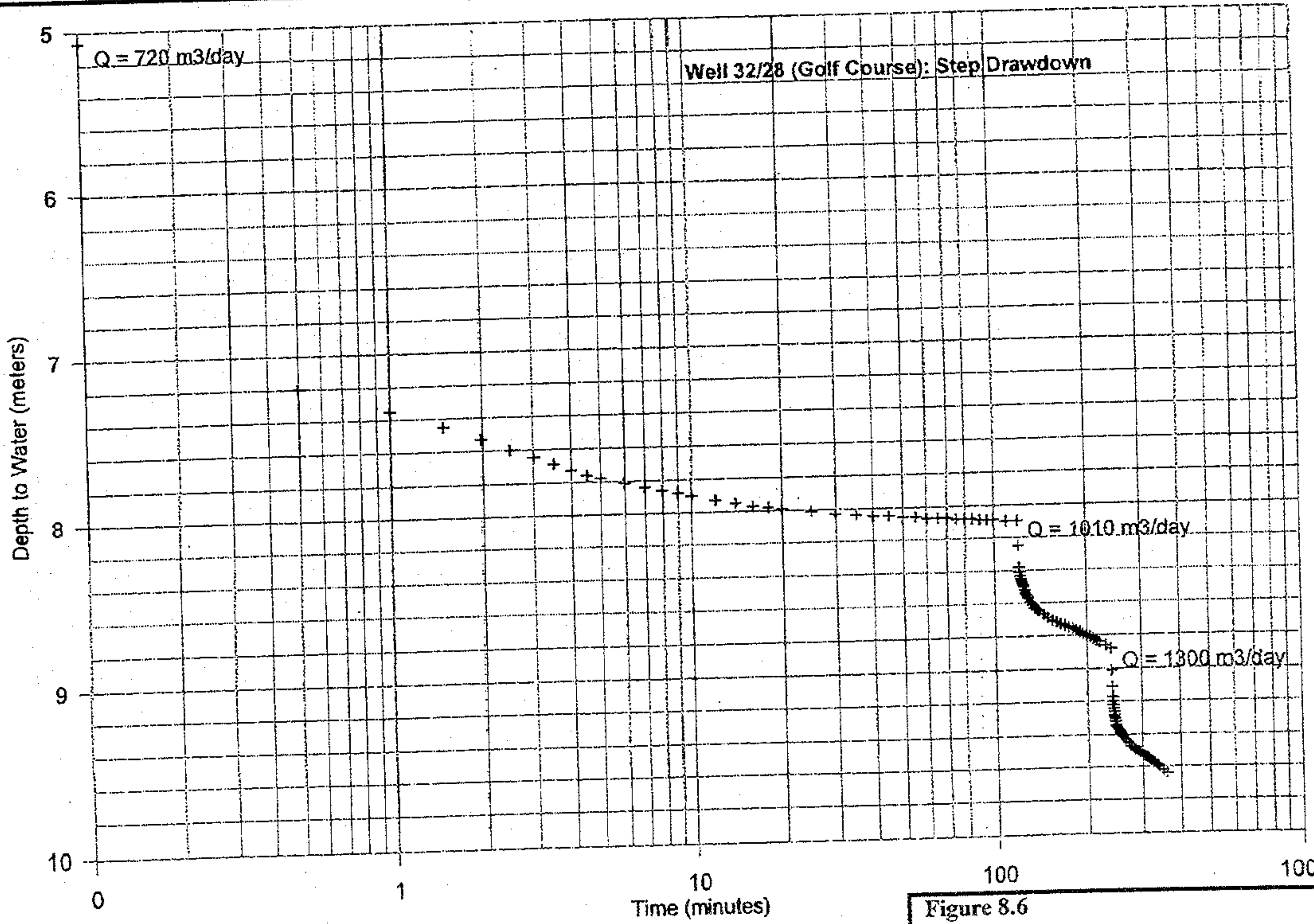


Figure 8.6

Well 32/28 (Golf Course) Step Drawdown

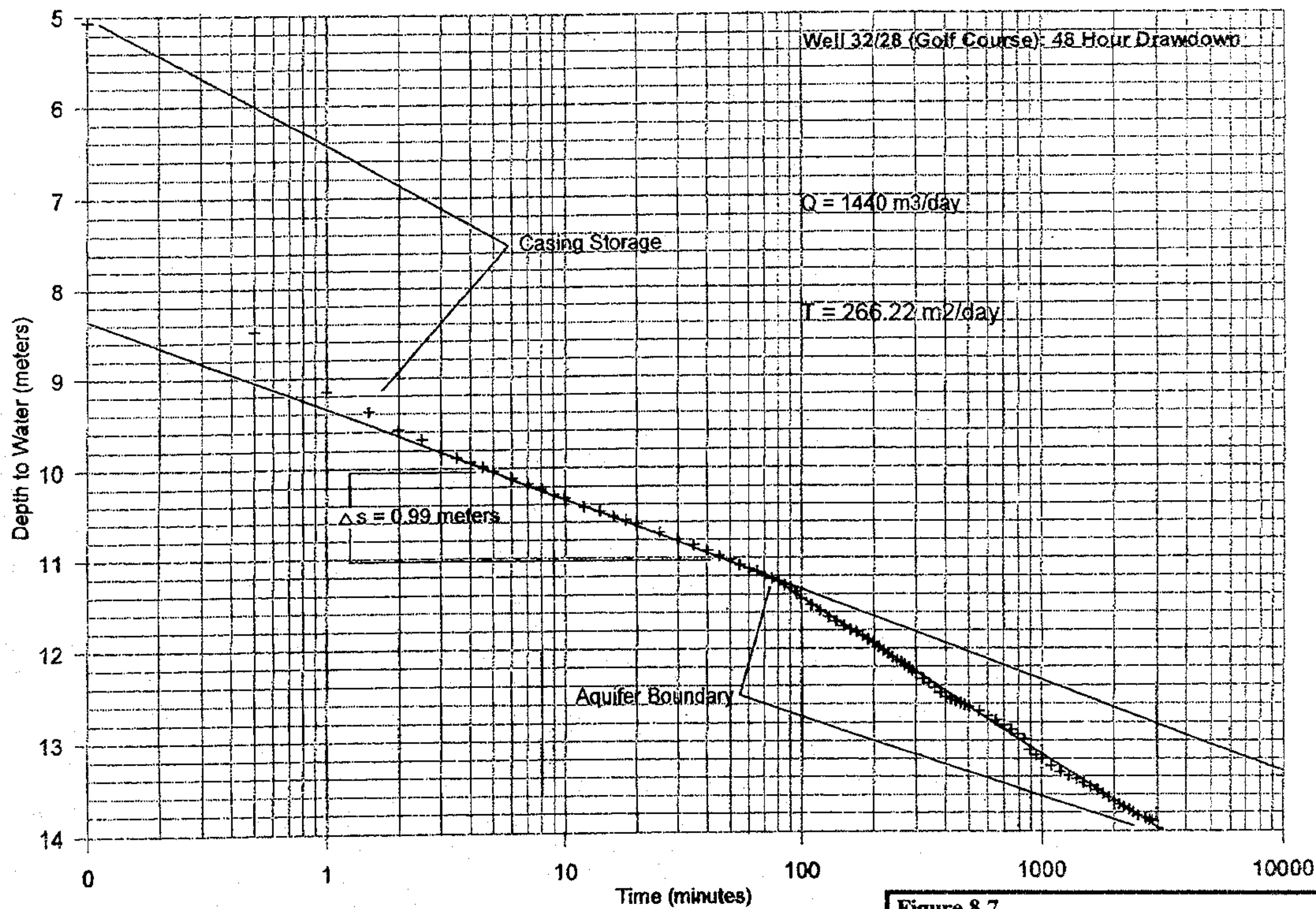


Figure 8.7

Well 32/28 (Golf Course) 48-Hour Drawdown

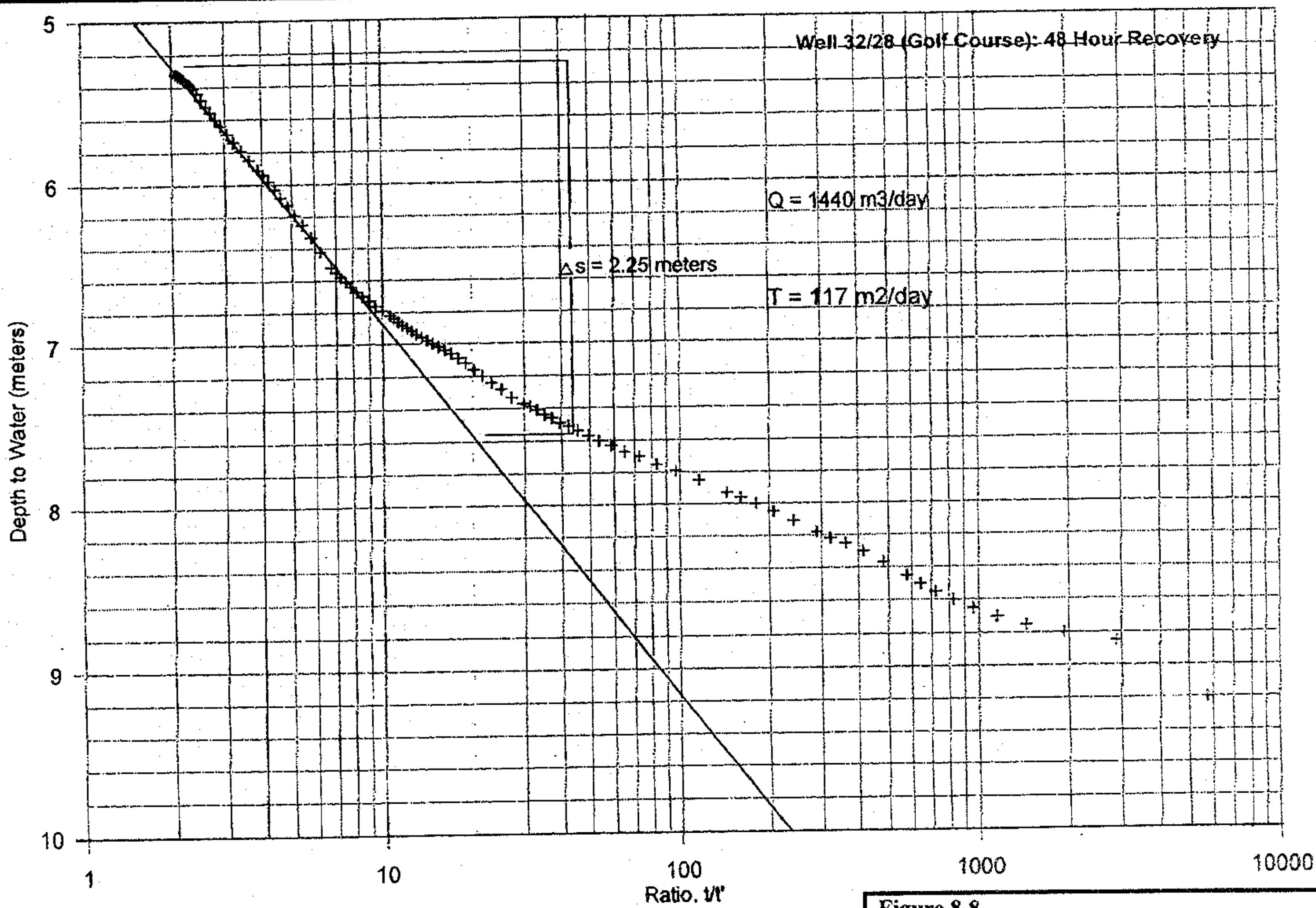


Figure 8.8

Well 32/28 (Golf Course) 48-Hour Recovery

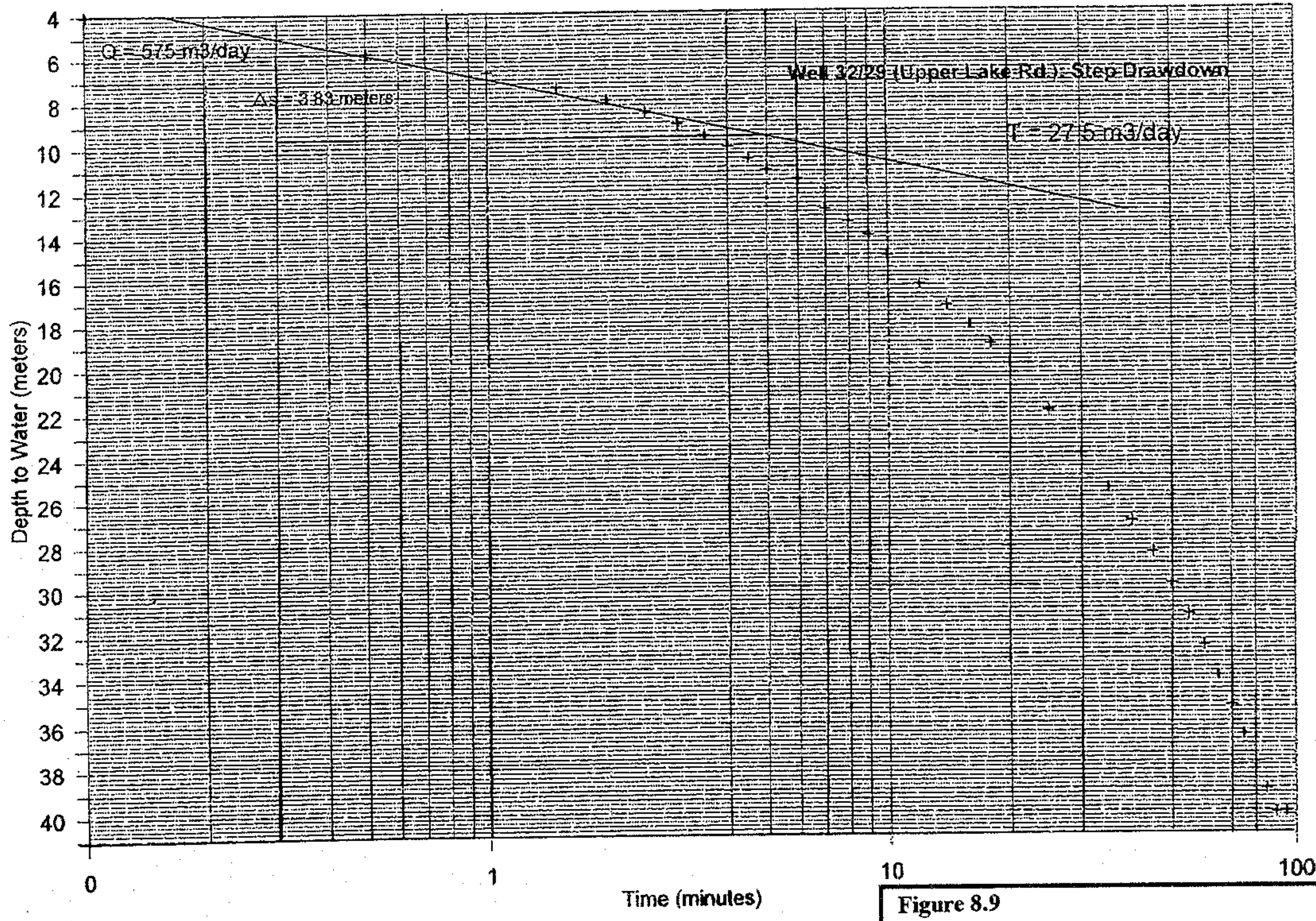


Figure 8.9

Well 32/29 (Upper Lake Rd.) Step Drawdown

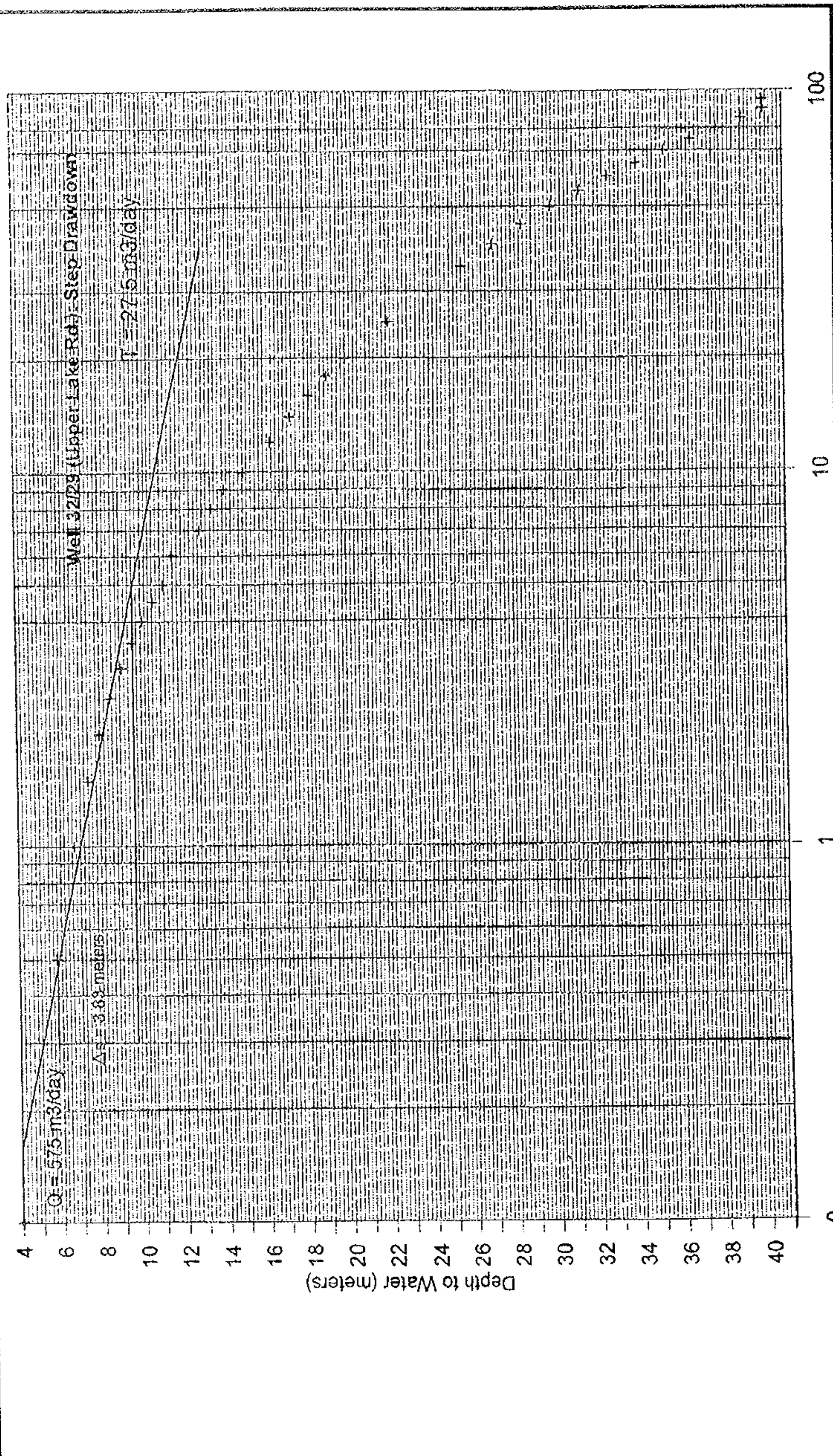


Figure 8.9

Well 32/29 (Upper Lake Rd.) Step Drawdown

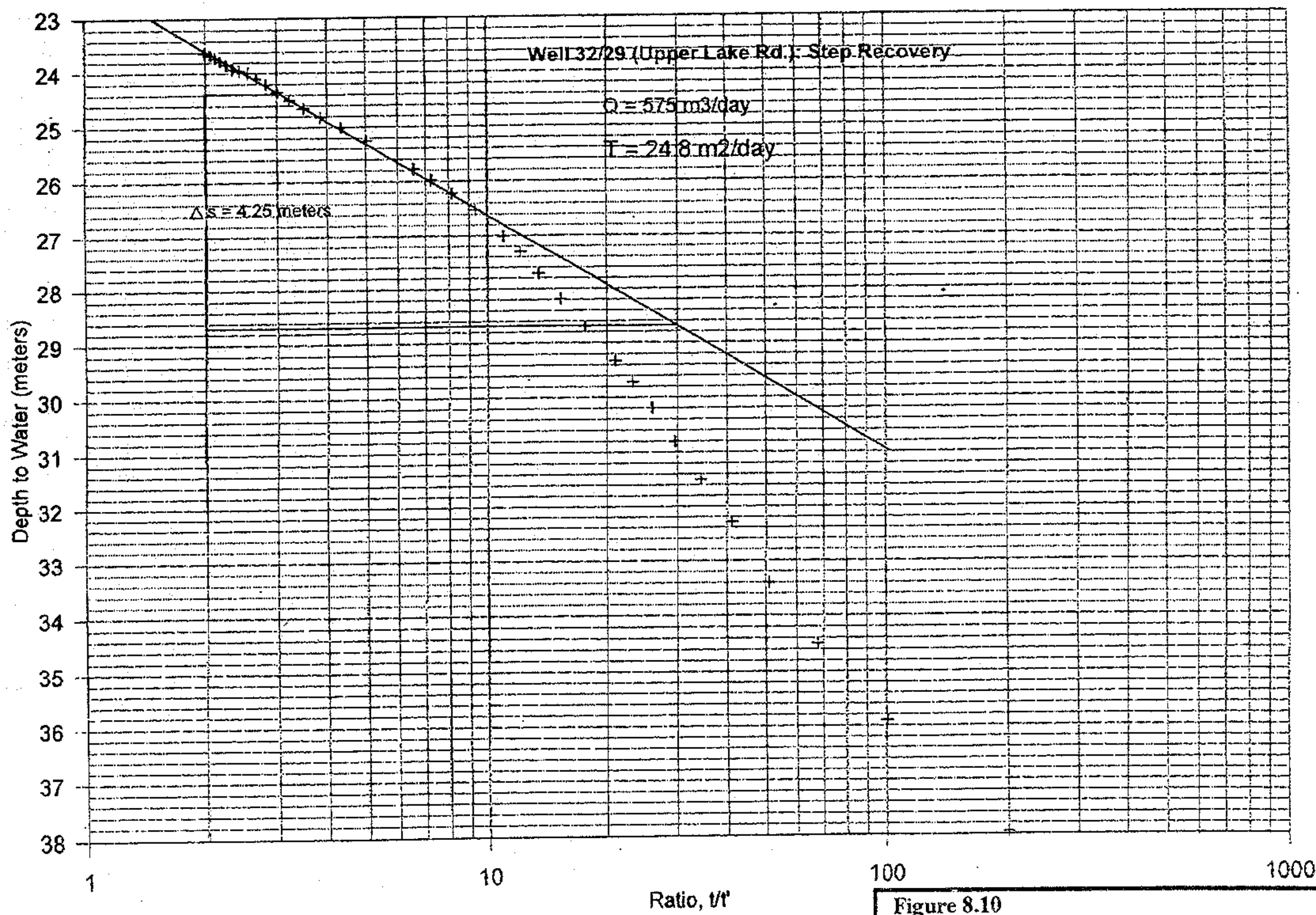


Figure 8.10

Well 32/29 (Upper Lake Rd.) Step Recovery

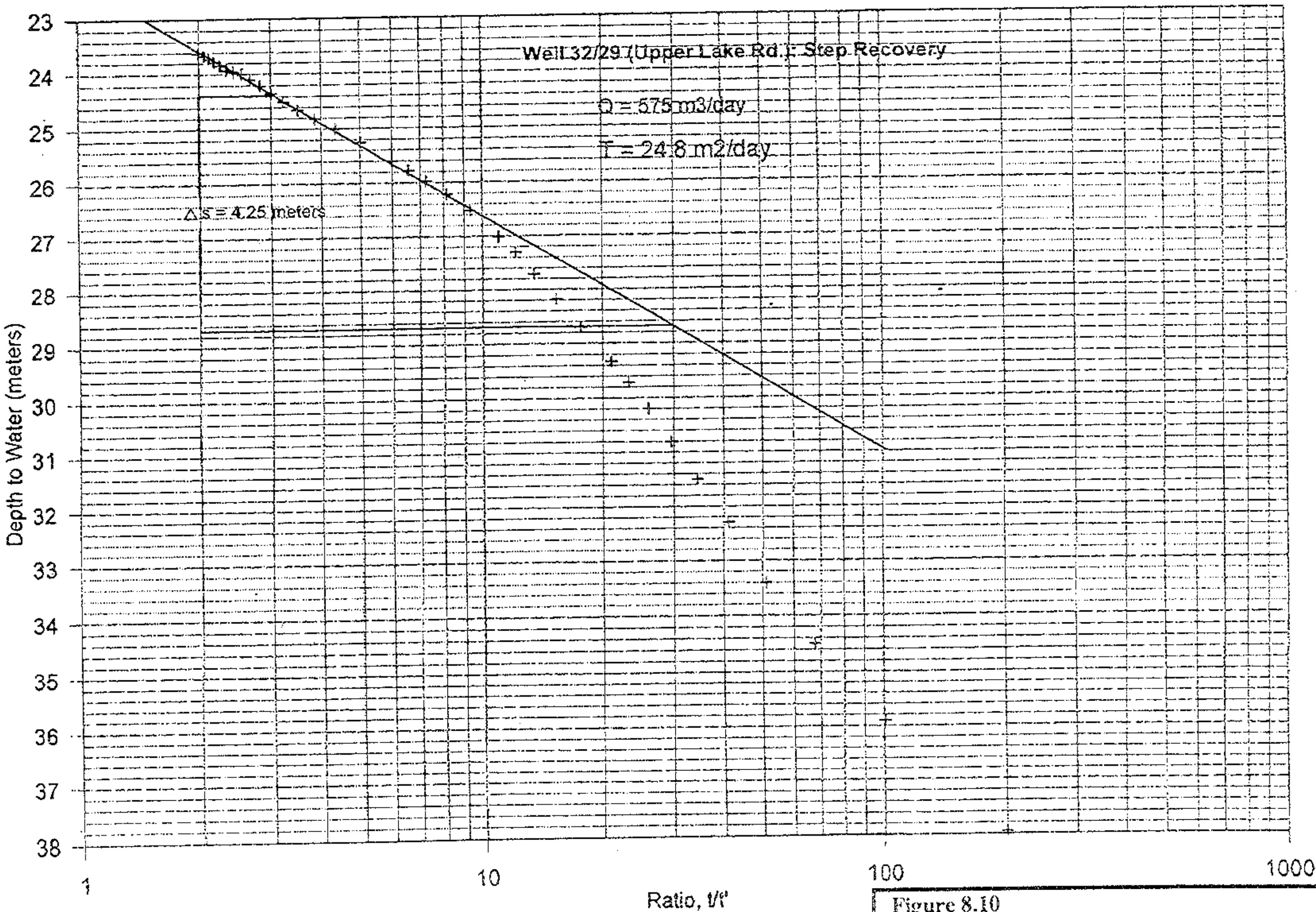


Figure 8.10

Well 32/29 (Upper Lake Rd.) Step Recovery

8.4 Hydrogeology

The geography of the NESA strongly suggests a lack of groundwater resources, with the valley situated among the highest mountains of Sri Lanka. However, the structural geology of the area suggests potential resources to be explored and developed.

Analyses of existing wells, geology, and geophysical data indicate that several distinct hydrogeologic zones exist. Test wells that were drilled yielded additional valuable hydrogeologic data. Typically, a groundwater system of 2 to 4 zones (aquifers, aquitards) is defined by the hydrogeology within the first 200m. These zones, which may or may not occur at various locations, are described below.

Overburden consists primarily of weathered gneisses, and commonly has a thickness of two to 50m. However, this weathered zone extends down as far as 75m or more below the surface in some valley locations. The overburden is stratified with lenses of clay and quartz, and is usually permeable. Groundwater in the overburden is classified as a local flow regime with recharge and discharge generally taking place within the limits of the NESA.

In areas of deep overburden a two to three meter zone of clay and freshly weathered rock can be found just above the contact with hard rock. In this zone, the clay is an aquitard, or confining layer, thus preventing any significant water seepage from reaching the layers below. In addition, the clay particles tend to adsorb petroleum chemicals and contaminants, effectively creating an environmental filter and barrier.

The hard rock typically has a shallow zone of fractures associated with weathering processes and is usually saturated. This zone is probably connected hydraulically with the overlying freshly weathered rock and can be considered a thin (2-10m) confined aquifer.

The remaining hydrogeologic zone is structurally controlled. A series of faults and shears result in regional-scale deep fracture zones. The shear zones are oriented primarily in a NW-SE direction and typically extend from ten to over 100km, generally following the axial orientation of the major structural folds. The fault zones are oriented primarily in a NE-SW direction, which is generally perpendicular to the shear zones, and typically extend from ten to over 100km. Headwaters of the Nanu Oya originate in a fault zone at the head of the valley, indicating a discharge zone, and suggesting that the fault zones are saturated.

Figure 8.11 shows the locations of the major fracture zones in the NESA. These zones generally correspond to areas where more groundwater is available, with the fault zones having the most potential as a resource (1000 to 2000 m^3/day). The figure shows that two significant faults pass through the valley, one at the head of the valley and another passing through the town area. Another one crosses the south end of the valley but is poorly mapped and needs further mapping to verify it. Several extensive shear zones penetrate the NESA, extending along the axis of the valley. These shear zones also have a strong potential as a groundwater resource but generally do not penetrate as deep; therefore, the yields are not as high as in the fault zones (500 to 1000 m^3/day).

Marble generally has joints that transmit water and springs are commonly found in low-lying zones. There is a marble formation near the south end of the valley, near the poorly mapped fault in the same area. Wells completed in this zone can be expected to have a good yield and are suitable for households and small farms, although water from the marble is usually hard due to higher concentrations of dissolved calcium and magnesium.

Quartzite strata dip to the north and cross the valley near the head of the valley. However, field inspection indicates that it is relatively thin and shallow. It is generally unsuitable as a community water source but functions as an important conduit for water circulation in the valley.

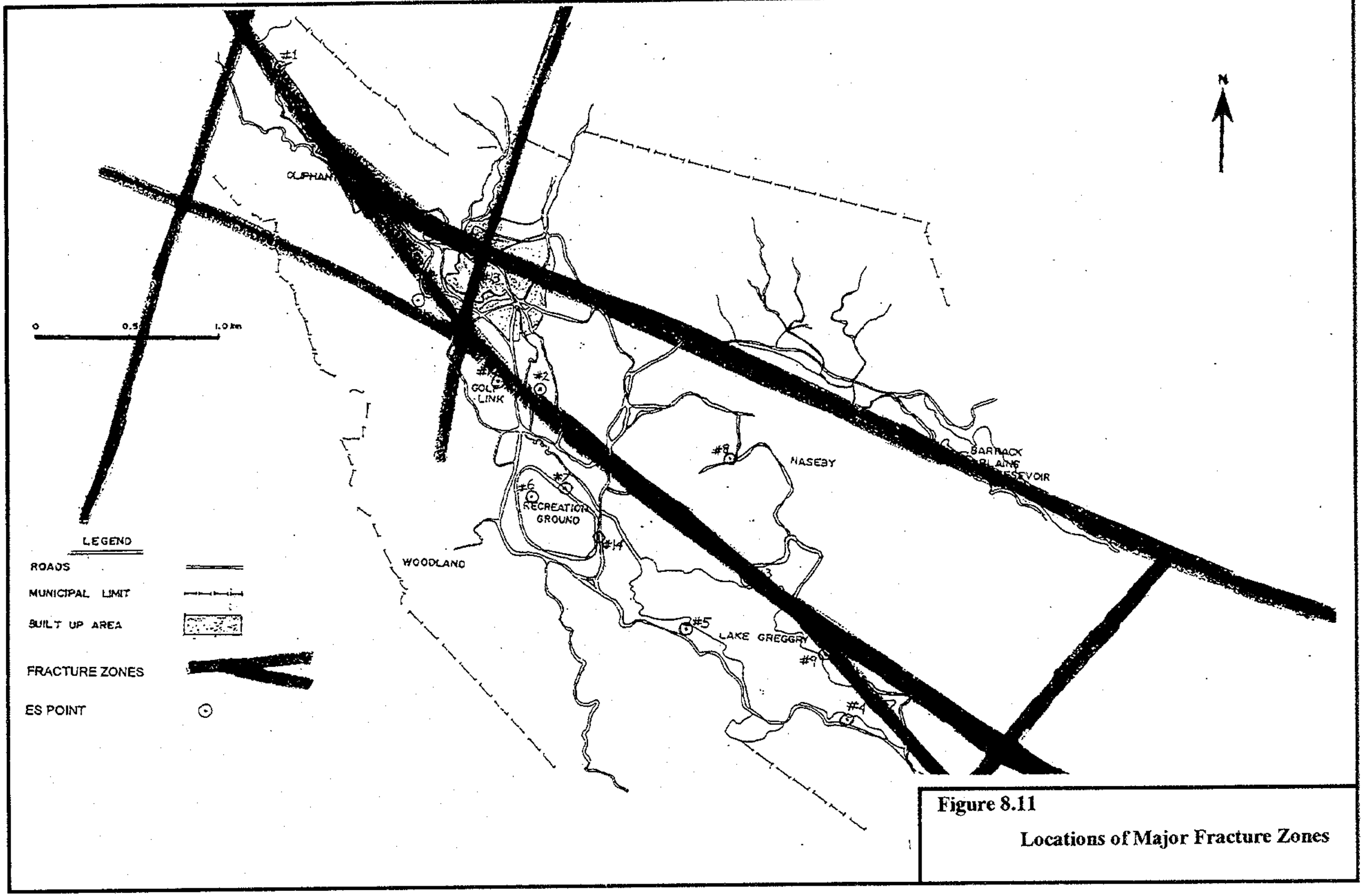


Figure 8.11

Locations of Major Fracture Zones

8.5 Conclusions and Recommendations

The geographic setting combined with the hydrogeology as described above, result in an environment that is challenging to find and develop a suitable community water source based on groundwater. Most of the existing wells in the valley are shallow and do not penetrate the underlying hard rocks. In addition, very little effort has been made to explore deeper zones for groundwater resources due to a lack of understanding and equipment.

Several shear zones extend through the long axis of the valley, and two prominent faults intersect perpendicular to the shear zone. The combination of these features, field survey data, and test well results indicate that groundwater resources are available but are localized and are difficult to locate in substantial quantity. Data collected during the well drilling and subsequent pumping tests have been analyzed and estimates of groundwater and development recommendations have been made.

Among the test wells that have failed or incomplete pump test results, it is recommended to determine the nature of the problem and either recover or abandon the test well. In the cases of wells 32/27, 32/29, and 33/48, all located at Upper Lake Rd., they all suffered from excessive mud and silt in the wells. The mud and silt in the wells needs to be flushed out, the fractures should be further developed, and screens with gravel packs should be installed. Then the wells should be pump tested. Based on the flushing rates of these wells during construction and the results of the incomplete pump test, they should be capable of producing around 1000 m^3/day each.

The pump test conducted at test well 33/46, at the Galway Wildlife Bungalow, clearly shows that the yield is somewhat limited and conservatively estimated at 276 m^3/day. However, another series of pump tests would allow a better estimation of the safe yield. This should include a step test at 200, 400, and 600 m^3/day, with each step lasting four hours, and a 120 hour long duration test at an appropriate rate.

The pump test conducted at test well 32/28, at the Golf Course, clearly shows that the safe yield of 770 m^3/day can be improved. The primary limiting factor in this case is the depth of the large diameter bore. The completed depth is 88 m, indicating that the large diameter bore can be extended deeper, allowing the pump to be set lower. This would allow a higher pumping rate. This well would also benefit from a 120 hour long duration test to determine the stable pumping water level.

All future pump tests would greatly benefit from having at least one observation well within 20 m of the pumping well. The observation well should be of small diameter (5-10 cm) and should penetrate to the same depth as the water bearing zone in the pumped well. This kind of aquifer test would allow a much more detailed analysis of the aquifer instead of just the well.

Future groundwater exploration should include very site specific geophysical surveys such as electrical resistivity, or seismic, to identify more precisely the water bearing fracture zones. The locations for future consideration should be focused where the faults are located, near the fishery center at the head of the valley, and across the center of town. Test wells should be located in these areas.

Other areas for future consideration are at Lake Gregory, where a lineament appears to cross the lake, and to the south of the lake where the other fault is mapped, near the marble formation.

It is important to note that drilling boreholes in fractured rocks can present problems with well construction and development, such as collapsing formations, fracture debris, and hydraulic connections to the surface. Drilling operations should be prepared to handle a variety of drilling conditions. Generally, the most desirable fracture zone will have a substantial layer of solid rock above it; therefore, it may be necessary to continue drilling beyond the point where the first water and fractures were found. The nature of fracture zones usually make it necessary to put a screen and gravel pack in the water bearing zone to prevent fracture debris from entering and clogging the plumbing. Additionally, it will be necessary to develop the wells sufficiently to ensure maximum yield and clear, clean water. To correctly evaluate the well and aquifer, it is necessary to conduct a pumping test using one or more properly constructed and spaced observation wells.

However, problems that are more fundamental still exist which will certainly prevent the successful development of groundwater resources in the NESA. The correct construction materials are either in short supply or not available, such as blank steel casing (10", 12", 14", 16", 18", at least 80m per well), high quality PVC casing (straight, type 1000 or thicker), commercially made screens (i.e. Johnson Screens). There is a lack of certain equipment and existing equipment is in need of repair. For example, drill bits are worn, size and type selections are inadequate, and there aren't any portable mud pits. Before undertaking any additional exploratory or production drilling, a complete inventory should be taken to facilitate repairs to existing equipment and acquire materials and supplies. It is clear that fracture zone hydrology in Sri Lanka is poorly understood and that the NWSDB would benefit from assistance and training from experienced and qualified hydrogeologists and groundwater engineers.

It can be seen that there is a very high potential to locate further groundwater resources in the NESA. However, this will be difficult, if not impossible, without international assistance. It is strongly recommended that the Sri Lankan Government seeks and utilizes international assistance to resolve water supply problems in the NESA, as well as improve their ability and equipment resources for future groundwater projects.

CHAPTER 9 NON-REVENUE WATER REDUCTION PROGRAM

CHAPTER 9 NON-REVENUE WATER REDUCTION PROGRAM

9.1 General

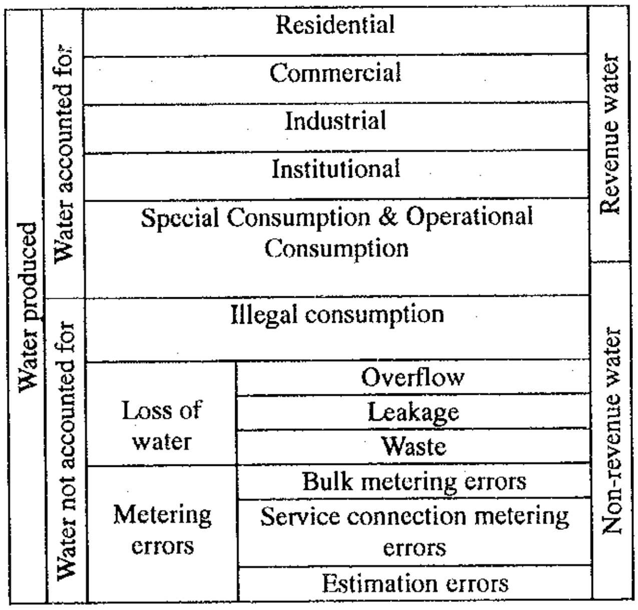
For the purposes of this investigation, NRW is defined as the difference between the quantity of water produced and the quantity for which the water utility receives revenue. NRW is not the same as unaccounted for water (UFW), as illustrated in Figure 9.1. The difference between UFW and NRW consists of water use by legal connections that are provided with water at no charge. The subject of billed water versus revenues actually received is discussed in Chapter 4.

It is strongly recommended that any proposed plans to augment water supplies be accompanied by a vigorous non-revenue water (NRW) reduction program. NRW can be due to a number of causes:

- Transmission main and distribution system leakage
- Reservoir leakage/overflow
- Unbilled legal connections
- Illegal connections
- Service connection meters
- Distribution system pressure
- Production metering
- Administrative errors

Figure 9.1

Non-revenue and Unaccounted for Water[1]



Some of these components, unbilled legal connections such as public standposts, for example, are known but not billed for social or economic reasons and constitute no problem other than financial for the water utility. Other components, such as leakage, can only be estimated and reduced by relatively expensive methods. The cost of efforts to reduce NRW should not be greater than the value of the water saved by those efforts. It is therefore important to make as accurate as possible an estimate of the various components of NRW in order to provide a basis for designing a cost effective NRW reduction program. Estimates of the magnitude of the

[1] Adapted from: Operation and Maintenance of Water supply and Sanitation Systems, A Guide for Managers, World Health Organization, 1994.

various NRW components and a recommended NRW reduction program are presented in the following sections.

The Nuwara Eliya M.C. water system has 3,936 service connections and 12 standposts. The present NRW in Nuwara Eliya is 56 percent.

9.2 Transmission Main and Distribution System Leakage

Most of the commercially available leak detection equipment relies primarily on the detection of noise resulting from pipes leaking under high pressure. Large sections of the study area distribution system does not operate at sufficient pressure to produce detectable leakage sounds, thus limiting the effectiveness of conventional leak detection equipment. There is no practical method for directly measuring the present level of leakage. It is, however, possible to make some estimate of the other components of NRW. By subtracting the estimated values for these other components from the total NRW, we can arrive at an approximation of current leakage levels. The magnitude of the leakage component relative to other NRW components will provide an indication of how much of the NRW reduction program effort should be expended on leak detection and repair. The range of pressures in any given distribution system will dictate what types of leak detection equipment and methods would be appropriate.

A summary of the lengths, materials and diameters of existing pipelines in the Nuwara Eliya transmission mains and distribution system is given in Table 9.1. The cast iron pipe has rigid joints (poured lead) and could be a source of leaks, although most of this type of pipe is above ground transmission pipe in open country that can be easily inspected for leakage. Those portions of the rigid joint pipes that are installed below ground and subject to traffic loads have a high potential for leakage due to joint movement. All valves in the system are either working properly or will be repaired under the ongoing ADB project (Scheduled for completion in 1999).

Table 9.1 Nuwara Eliya Pipe Lengths

Material	Diameter (mm)	Length (km)
Old Mains		
Cast iron	75 to 350	40.4
Galvanized iron	40 to 100	3.6
PVC	40 to 100	20.1
Asbestos cement	250	0.1
Subtotal		64.2
New Mains (ADB Project)		
Ductile iron	100 to 200	4.9
PVC	90 to 225	13.0
Subtotal		17.9
Total		82.1

The actual length of distribution piping is substantially greater than this figure. A significant proportion of the existing service meter installations have very long, small diameter service connection lines extending from the nearest available distribution main to the service meter inside the consumer property line. Distribution system pipelines are primarily confined to major roads and have not been extended to many secondary streets and lanes due to insufficient funds. Applicants for service connections are required to pay for the connecting lines, and the municipality has been honoring requests for service connections by installing individual connecting lines for new customers. This has resulted in "bundles" of small diameter service (mostly 12 to 25 mm) connection lines in many secondary streets. These "bundles" often consist of up to a dozen pipes in a single street with little or no cover.

Water utility staff have recently initiated a survey of streets with "bundled" service connection lines, and have identified some 1,000 meters of streets with this condition after covering about ten percent of the service area. Field observations suggest that there are an average of five service connections lines on these streets, which would suggest that there could be as much as 25 kilometers of service connection pipes involved. This would increase the effective pipeline length in the distribution system by about 30 percent.

A characteristic of water distribution systems is that the amount of leakage per kilometer is essentially independent of pipeline diameter. The expansion of the effective length of pipelines in the distribution system that has been caused by past service connection practices has undoubtedly contributed significantly to the amount of leakage. Most of the service connection pipes are not buried deep enough to offer protection against pedestrian or vehicular traffic. This suggests that leakage rates per kilometer from service connection pipes could well be even higher than from the larger transmission and distribution pipes, which for the most part are buried at much greater depths under paved streets. Because there is inadequate data to support this supposition, estimated leakage has been allocated between major pipelines and service connection lines solely on the basis of pipeline length.

Water utility maintenance staff indicates that they repair an average of four to five service connection related leaks per day. Repairs of leaks and pipe bursts on transmission mains and distribution pipes average only two to four per month. The past practice of installing service connection meters at the end of long small diameter service lines to individual households has resulted in "bundles" of small diameter service lines along a number of secondary streets.

9.3 Reservoir Leakage/ Overflow

Existing reservoirs and appurtenances in the Nuwara Eliya water system have been upgraded and repaired under an ongoing ADB improvement project that is scheduled for completion in

1999. Reservoir leakage/overflow has therefore been assumed to be zero for the purposes of this investigation.

9.4 Unbilled Legal Connections

It is common practice in many water utilities not to bill certain categories of legally connected water users. Such categories can include municipal parks and buildings, religious institutions, government institutions, schools or low-income groups. Although it is certainly within the purview of water utility management to make essentially social decisions of this type, such selective favoring of one group of customers over another will affect the financial viability of the utility. The quantities of water resulting from such decisions and the cost to the utility should be clearly identified.

The Nuwara Eliya water utility has five customer categories that are provided with water without charge.

- Schools
- City park
- Municipal Council offices
- Standposts
- Public toilet (one)

Although these customers are not presently metered, the water utility is now implementing a program to install meters on all of these service connections. Schools are to be subject to a unit charge that will initially be based on estimated water use and on metered quantities after the meter installation work has been completed.

The estimated amount of water being used by these categories is presented in Table 9.2. School use has been estimated 10 liters per day per student, and standpost use at 10 m^3/d per standpost. Estimated water use for the remaining unbilled legal connection categories were developed by water utility staff on the basis of comparisons with other comparable metered customers. This amounts to ten percent of the current water production during a year with

Table 9.2

Unbilled Legal Connections in Nuwara Eliya

Customer Category	Average Water Use (m^3/d)
Schools	70
City Park	300
Municipal council offices	100
Standposts	150
Public toilet	20
Total	640

plentiful rainfall.

9.5 Illegal connections

The Nuwara Eliya M.C. has formed a special task force to check for illegal connections in their system. This group has located 10 illegal connections during the first seven months of 1998. Maintenance staff believes that there are relatively few illegal connections, but nonetheless estimate that about three percent of the total is illegal, which represents about two percent of total production. Although it is suspected that the large number of home gardens in the Nuwara Eliya distribution system service area may be responsible for a significant amount of illegal water use, surveys carried out under the present investigation have found no reliable data to support this suspicion.

9.6 Service Meters

The present policy of the Nuwara Eliya water utility is to provide five meters of service line with the meter installed adjacent to the distribution pipe, irregardless of where the customer property line is located. Until recently (1998), the policy was similar to that of the NWSDB wherein the meter is installed within the customer's property no matter how long a service connection line was required. Most buildings that are connected to the water system have roof tanks, but these are needed only during the dry season when pressures are low. Although existing service connection lines appear to be a mix of PVC and GI pipes, the water utility has opted to use only GI pipes for service connections since early 1998. That portion of the service line between the meter and the house plumbing is the responsibility of the customer, and it was observed that a wide range of pipe materials and workmanship were used for these pipes.

Eighty percent of the existing meters are very old and have no built in reverse flow protection devices. All of the new meters currently being installed have built in non-return valves.

Service meters are repaired or replaced based on consumer complaints and meter reader reports. The water utility has a workshop that is used for storage of meters and meter parts and repair work. The workshop has no meter test bench or calibration equipment. Meters brought in for repairs are checked for accuracy by comparison with new meter performance on a water tap. No record is kept of the accuracy of meters that have been brought into the workshop for repair. On the average, about sixty meters per month are repaired, or about 20 percent of the total number of installed meters. The most common defect is some type of blockage from rust or sand particles.

Based on the above, an over all under registration equal to 10 percent of production has been assumed.

9.7 Distribution System Pressure

During the rainy season, when supplies from the surface water sources are more than adequate to meet demand, pressures are adequate throughout the distribution system. Some low-lying areas even have problems with high leakage and pipe bursts during the rainy season due to excessive pressure. During the dry period, pressures are much lower, with some ten percent of the service area experiencing negative pressures at some point in the day as supplies are switched from one area to another in attempts to satisfy as much demand as possible. Although detailed data on system pressures is not available, maintenance staff indicate that during the wet season most of the system pressures are 20 meters or higher. Given the relatively high pressures and good condition of the system valves, there may be significant portions of the Nuwara Eliya system where leak detection equipment could be used to good effect.

9.8 Production Metering

Measurement of production from the surface water sources serving Nuwara Eliya is accomplished by means of V-notch weirs located at the sources. These weirs are so located that when all flow is directed into the transmission system, as is the case during the dry season, the weir measurement equals the entire production. Although the available flow data is somewhat limited, most of it has been collected during the dry season and is believed to provide an adequate estimate of dry season production (January-May).

During the wet season (June-December), flow is in excess of the transmission system capacity and actual flow into the transmission system cannot be measured with the weirs. For the purposes of this investigation, production during the wet season has been taken as equal to the estimated capacity of the transmission mains. Transmission main capacities were estimated[2] based on theoretical hydraulic calculations and water utility operational experience and thus may contain a considerable margin of error. A comparison of previous billing records with rainfall and flow measurement records suggests that this error may result in too high an estimate of wet season production. The basic assumption contained in this estimate is that demand exceeds supply even during the wet season and that the total capacity of the

[2] ADB Project Design Report, 1998

transmission mains will be utilized whenever enough water is available. That this assumption is not always true is suggested by the fact that, during very wet years, billed water use is higher during some portions of the dry season than during the wet season. It is not possible to determine the magnitude of this error without installing bulk meters on the transmission mains. Pending the availability of more accurate flow measurement data, a value of ten percent of production has been assigned to this NRW component.

9.9 Administrative Errors

For the purposes of this investigation, administrative errors have been taken to include the following:

- Estimated Meter Reading (for defective meters)
- Errors in estimating unmetered Consumption

The Nuwara Eliya water utility reads meters on a monthly basis and estimate billing quantities for service connections with defective meters by comparison with the last three months metered consumption. Where no metered record is available, consumption is estimated by comparison with metered consumption for similar dwellings. Only six percent of the Nuwara Eliya service connections are estimated. Based on the above, administrative error is judged to be negligible.

It should perhaps be noted that current practice (since August 1998) in Nuwara Eliya is to estimate unmetered connections high to encourage applications for metered connections. This is a recent innovation and would not affect the estimate of NRW used in this report, which was based on 1997 data.

9.10 Summary of Estimated NRW Components

A summary of the estimated NRW components discussed above is presented in Table 9.3.

In Nuwara Eliya, the major components appear to be transmission main and distribution pipeline leakage, unbilled legal connections and production metering error. The relatively large component of major pipeline leakage could simply be a result of the backhanded method that must be used to estimate leakage. Namely, that leakage is assumed to be equal to the remainder of NRW after the best available estimate of all other components has been subtracted. Given the serious questions that exist regarding the accuracy of the estimated production metering error (See discussion in previous section), the leakage component could also be greatly in error.

Table 9.3 Estimated NRW Components in Nuwara Eliya

Item	NRW (% of Production)
Transmission Main and Distribution System Leakage	11
Service Connection Line Leakage	8
Reservoir Leakage/Overflow	0
Unbilled Legal Connections	10
Illegal connections	2
Low Service Connection Meter Registration	10
Production Metering	15
Administrative Errors	0
Total	56

As noted in previous sections, estimates of most of the other NRW components are in themselves only very general approximations. The resultant estimate of the leakage component can thus only provide an approximate range within which the true leakage amount will fall.

9.11 The Cost of Non Revenue Water

Water saved due to implementation of a NRW reduction program is immediately reflected either in a reduction of projected demand or an increase in water utility revenues. The reduction of some NRW components, such as leakage, where the loss is not being put to a useful purpose, will result in a reduction in projected demand. Elimination of other components, such as illegal connections, where the water is being put to some beneficial use, will result in greater water utility income.

The increase in utility income may not, however, be equal to the value of the entire quantity used by illegal connections because this water is no longer being provided to the customer free of charge. The net effect of a successful NRW reduction program will be to increase water utility revenue and thus the ability to pay for water supply augmentation projects, and savings in construction and operation and maintenance costs for projects that can be delayed or reduced in size.

Because existing supplies in Nuwara Eliya are woefully inadequate to meet present demands, the question of project postponement does not arise. The cost of NRW can therefore be taken as equal to the present day costs to augment existing supplies to a given service area. For convenience in comparing water supply augmentation costs to NRW reduction program costs, both have been presented in terms of Rs./m^3.

For Nuwara Eliya, water supply augmentation costs have been assumed to be equal to the cost to extract and deliver additional groundwater to the distribution system. It should be noted that, in the event that groundwater resources should not be adequate to meet all of the projected demand, some new supplies must be derived from surface water sources. This would cause the average unit water supply augmentation cost to increase dramatically due to the very high costs associated with surface water development in Nuwara Eliya.

It has been assumed that groundwater pumping will be required for only an average of eight months per year. This assumption is based on the limited and sporadic flow measurement records that are currently available for the existing Nuwara Eliya surface water sources. These records, taken together with the available rainfall data, indicate that the existing surface water sources are capable of meeting all of the projected demand during the rainy season, which persists for about half of the year, and a substantial portion of the demand during the dry season. When the groundwater extraction facilities have been placed in operation, it may well be possible to operate these facilities for an even shorter period, but for the purposes of this investigation a conservative estimate of the required well field operating period has been adopted. As shown in Table 9.4, the value of water saved due to NRW reduction efforts in Nuwara Eliya would be Rs. 9.54/m^3.

Table 9.4 Unit NRW Costs for Nuwara Eliya

Item	
Capacity (m^3/d)	5,070
Annual O&M cost (1,000 Rs./year)	6,689
Capital cost (1,000 Rs.)	156,818
Amortized capital cost (1,000 Rs./year)	10,970
Average annual cost (1,000 Rs./year)	17,659
Unit NRW cost (Rs./m^3)	9.54

9.12 Recommended NRW Reduction Program

The recommendations given in the following sections to reduce NRW have been based on the limited data available at the time of preparation of this report. As implementation of the NRW reduction program proceeds, better information will become available and more accurate estimates of the relative importance of the various NRW components can be made. The form and emphasis of the NRW reduction program presented below should therefore be periodically reviewed and updated to ensure that program efforts are cost effective.

9.12.1 Waste Management Districts

The location of areas where there are high concentrations of leaking pipes or illegal connection activity is best accomplished by dividing the distribution system into waste management districts. Waste management districts are areas that can be isolated from the rest of the distribution system by means of appropriately placed valves. Water supply to the district can then be measured by one or two specialized waste meters and the results compared to billing record data. Measurements are usually carried out during minimum water use periods during the early morning hours.

Experience on NRW reduction programs in Colombo indicates that waste meters cannot be effectively employed where the following conditions exist:

- Low distribution system pressures
- Consumers have tanks that are filled at night when pressures are highest
- High system connectivity
- Valves in poor condition, insufficient in number or not properly located to facilitate waste district isolation

Because all of these conditions exist to a significant degree in the Nuwara Eliya water supply system, the classical approach to estimation of leakage quantities by comparing minimum night flows to service meter records cannot be employed until these conditions have been removed. Visual inspection and sounding methods are the only practical means of leak detection that can be utilized until conditions have been improved.

9.12.2 Leak Detection and Repair

Increases in the number and severity of leaks that usually accompany the addition of new water supplies to an existing system can overwhelm the leak repair capacity of existing maintenance staff and increase NRW. Unless steps are taken to minimize the negative impact of higher system pressures, the planned benefits of the additional water supplies may not be fully realized. When the new water supplies that will be part of the proposed water system improvement project come on line, system pressures are expected to increase dramatically. Leakage rates and the number of pipe bursts can also be expected to increase substantially, which will create a major problem for the already overburdened maintenance staff. This increase in maintenance workload should be a relatively short-term phenomenon. Given sufficient resources to find and repair the new leaks, the number and severity of leaks in a distribution system will tend to reach a steady state at some point where additional expenditures for leakage reduction would no longer be cost effective.

Consideration should be given to the use of private contractors to augment the leak detection and repair capabilities of regular maintenance staff until such a steady state condition can be achieved. Increases in permanent water utility maintenance staff should be limited to that required to maintain a cost effective leakage level status quo.

Implementation of the NRW reduction program should be carefully coordinated with the schedule of improvements to the water systems to allow maintenance staff time to deal with the higher leakage repair work load and minimize increases in leakage and waste by customers. This can best be accomplished by identifying areas in advance of connection of new supplies where distribution system piping can be isolated from surrounding areas. Leakage repair resources should be focused on each of these areas in turn as new supplies are connected.

9.12.3 Unbilled Legal Connections

Although most unbilled legal connections are for worthy social causes (public standposts, schools, religious institutions, the Town Hall, etc.) the cost of such connections should not necessarily be borne by the water utility and its customers. Most of these uses are of benefit to the population at large and their costs should more appropriately be shouldered by some more broadly based financing mechanism (e.g. property tax). In most cases in the study area this is already being done or policy decisions have been made which will eventually result in shifting the burden of these costs away from the water utility. Nuwara Eliya is currently providing a significant amount of water to various legally connected users at no charge, but has recently embarked on a program to meter all of these uses and bill for that use wherever possible.

9.12.4 Illegal Connections

Although it is widely believed that illegal connections exist, their detection is no easy matter. All of the water utilities already have some procedures in place to detect illegal water users, but there are many factors that limit the effectiveness of these procedures. Nuwara Eliya has a special team charged with locating illegal connections.

The presence of numerous long service connection lines before the service meter provides ample opportunity for additional illegal connections to be made before the meter. The existence of service connections without meters, unreadable meters or meters that will register flow when installed in a reverse direction all contribute to the difficulty of identifying illegal connections. All of these conditions should be corrected to minimize the probability that illegal connections will remain undetected.

9.12.5 Service Connections

Based on the data available to date, it appears that the major causes of NRW in the Nuwara Eliya water system are related to the service connections. Although it is not clear whether the greatest impact is due to the extensive "bundles" of service connection pipes or under registration of the meters, it is apparent that their collective impact is large. Over 98 percent of the leaks repaired by the maintenance staff are associated with service connection leakage and service meters brought in for repairs have major under registration problems.

Consideration should be given to using polyethylene pipe (PE) for small diameter distribution main extensions and service connection lines instead of the PVC currently used by most water utilities in the study area. PE pipe offers a number of advantages over PVC, including a reduced number of joints (and thus less potential for leakage) and greater flexibility and resistance to damage. This type of pipe comes in rolls in the smaller diameters and is relatively easy to transport and install. It is understood that PE pipe has been manufactured in Sri Lanka for some time and is competitive with PVC in price.

The high rate of clogging that has been observed in many service meters is undoubtedly due in large measure to the surging effect on pipe flow rates that is a natural result of being forced to operate with inadequate supplies and widely varying distribution system pressures. As supplies increase with implementation of the proposed water system improvements, meter clogging should eventually diminish, but in the mean time attention to keeping repaired or newly installed pipes free from debris and periodic flushing of mains should help to minimize the problem.

Correction of the service meter flow reversal problem will involve a number of actions.

- Provide enough additional water supply to ensure adequate 24 hour pressures in the distribution system. This is a major objective of the proposed water supply improvement project, but it is also a precondition for solving the meter registration reversal problem.
- Provide existing service meters that do not have reverse flow prevention capability with effective reverse flow prevention devices.
- Ensure that the reverse flow prevention devices on existing service meters are operational by periodic inspection or provision of suitable backup equipment.
- Install all new service connections in accordance with appropriate back flow prevention plumbing regulations.

Nuwara Eliya appears to be coping with their service meter repair needs with existing meter workshop facilities and equipment, but they lack meter calibration equipment.

9.12.6 Distribution System Pressure

Although some areas do exist in the Nuwara Eliya water system where excessive pressures aggravate the leakage problem, these areas are not extensive. The analysis of the Nuwara Eliya transmission system that was carried out under the current investigation delineated pressure control zones where valves will be provided under the proposed improvement project to eliminate existing areas of excessive system pressure. Although no requirement has been identified during the feasibility level analysis of the study area transmission systems, it is still possible that some requirement for pressure reducing valves may be identified during the detailed design phase.

9.12.7 Production Metering

It is understood that bulk meters were installed on the Nuwara Eliya transmission mains in the past, but they caused a major reduction in supply to the distribution system and were removed before any useful flow measurement data could be acquired. It is recommended that suitable (Electromagnetic or other type suitable for metering a raw water source) bulk flow meters be installed on the transmission mains to provide an accurate means of measuring production in the future.

9.12.8 Customer Leakage and Waste

The service connection pipes between the meter and the building plumbing in the study area are, in many cases, of poor quality materials and workmanship and subject to high levels of leakage and waste. As the additional supplies that will be developed under the proposed water system improvement project come on line, leakage and wastage on the consumer side of the meter is expected to escalate in tandem with the increases that will undoubtedly occur in the distribution systems. Although leakage and waste on the customer side of the service meter are generally not considered to be the problem of the water utility, there is an indirect negative impact on the utility. Excessive water use by water utility customers, even though they pay for it, ultimately increases the quantity of new water supplies that must be financed and developed by the utility in order to satisfy demand. Given the relatively high cost of new water supplies in the study area, it is a benefit to the water utility to minimize future demand and postpone the development of new water sources for as long as possible.

There are a number of tools available that can be used to raise public awareness of this problem and enlist their support in the conservation of water. The NWSDB has had extensive experience with public education programs that included use of TV spots, newspaper articles, radio commercials, posters, leaflets, public meetings and school competitions. All of these methods have been used successfully in previous projects, and should be applied to a conservation oriented public awareness campaign.

A recommended adjunct to the public education methods noted above is to provide assistance to the customer in identifying sources of leakage and waste. Although a customer may be thoroughly convinced by the public education campaign that water conservation is a worthy goal, he does not necessarily have the expertise to do anything about it. One technique that has met with success elsewhere is to pinpoint customers that could potentially have a leakage and waste problem. Computer searches of the billing records can be used to identify customers where usage has increased dramatically from the same month the previous year, or even to a level more than some percentage above their average use for the last few months. Notification to customers with a potential problem can be included with their monthly bill, or, in cases where exceptionally large increases are noted, direct contact may be warranted. Assistance to the customer in identifying and repairing sources of leakage and waste can be provided by the water utility in the form of lists of plumbers certified to possess the skills and equipment required for the detection and rectification of leakage and waste problems. Local plumbers are often lacking in such skills, so it is advisable that one of the requirements for certification by the water utility be completion of a training course in detection and repair of leakage and waste sources in buildings.

9.12.9 Technical Assistance and Training

The establishment of an effective NRW reduction capability will require a substantial upgrading of study area water utility staff capabilities in a number of areas. Technical assistance will be required to train maintenance staff in the skills that will be needed to implement the proposed NRW reduction program and to assist them in establishing appropriate procedures to accomplish the various program objectives. Areas where it is believed that technical assistance and training are needed are as follows:

- Leak detection methods and equipment
- Bulk meter repair and calibration
- Service meter calibration
- Service connection installation and repair

- Leak repair methods and equipment
- Pipe installation methods

9.12.10 Data Collection

One important observation that can be made as a result of this analysis is that there are many areas where data that is essential to planning and implementation of an effective NRW reduction program is either not available or inadequate. A list of the types of information that should be collected and recorded in support of the NRW reduction program is given below.

- Distribution system pressures
- Leak repairs (leakage rate, type of pipe, reason for leak)
- Valves (type, last date inspected, repaired, operated, condition)
- Bulk meter flow measurements
- Service meter records (accuracy when pulled for repair, accuracy of meters in place, reasons for repair)
- Waste meter flow measurements

9.12.11 Estimated Costs

A number of defects in the Nuwara Eliya water system are either responsible for the excessive NRW rates or make it difficult to identify the causes of NRW, the most important of which have been discussed above. A listing of the actions needed to correct them is given below:

- Replace "bundles" of service connection lines with appropriately sized distribution main extension pipes
- Provide adequately calibrated bulk meters on all sources of supply
- Repair or replace gate valves to drop tight condition
- Repair or replace ball valves on reservoirs to prevent overflow losses
- Install air valves as required to minimize service meter reversal
- Replace old pipes with excessive leakage
- Relay pipes that have not been buried to an adequate depth
- Repair or replace leaking service connection valves
- Repair or replace under registering service meters
- Install meters on all service connections
- Provide additional leak detection equipment
- Provide adequate leak repair equipment and materials
- Provide additional meter repair and calibration equipment

- Provide waste metering equipment

It is arguable as to which of these items of system rehabilitation should be attributed to the cost of NRW reduction and which are simply standard maintenance responsibilities for a properly operated water system. No matter what the costs are charged against, all of these system improvements will be required to support an NRW reduction program. In any case, the cost of any NRW reduction activity should be compared to the value of the water expected to be saved (See previous discussion on the cost of NRW in Section 9.11).

Though the required cost for the NRW reduction program will be determined based on intensive field investigation work, it was estimated as follows for planning purposes in the study:

- Leakage detection by sounding (for 70 percent of all existing distribution pipeline by foreign specialist)
- Repair of leaks (estimated to be 5 percent of potential construction cost of the existing distribution pipeline)

9.12.12 Implementation

The estimated magnitude of the various components of NRW presented in the preceding sections are necessarily very approximate due to the limited amount of data currently available. A more accurate estimate is beyond the scope of the present study, but is required to provide a more reliable basis for development of a detailed NRW reduction program. The recommended NRW reduction program that is based upon the current estimate should consequently be regarded as only a starting point for the development of a more detailed program.

Refinement of the present estimate of the magnitude of individual NRW components will require the collection of additional data (see previous discussion on data collection needs in Section 9.12.10) that was not available during the course of the current investigation. Development of reasonably accurate estimates of the cost of system improvements required in support of the NRW reduction program will involve a detailed analysis of the existing water systems.

Implementation of the NRW reduction program should proceed in stages. An initial data gathering stage should be carried out to provide an adequate basis for a refined estimate of NRW components and the costs to upgrade existing facilities to the point where conventional leakage and loss detection methods can be applied. Once this information is available, development of a detailed short term and long term action plan can proceed, followed by full-scale implementation of the recommended NRW reduction program. It is suggested that technical assistance in planning, coordination and implementation of the NRW reduction program be provided to study area water utilities.