6.5 PILOT PLAN

6.5.1 WATER SUPPLY SYSTEM PLAN

The water supply system plans were allocated by comparing the demand estimated and groundwater development potential of each GND. This allocation was made based on the coverage plans of NWSDB. Measure of the conveyance facilities plan (that is, the levels of water supply scheme) were determined in accordance with the future water demand estimated and groundwater potential both of quality and quantity. The following are the determined water supply system plans for the groundwater resources development plans.

(1) Combination System of Level 3 (Direct Connection) and 2 (Yard Tap)

This system plan is the combination system of yard tap and direct connection. Water is pumped up by submersible pump(s) in the well(s) to an elevated tank and sent to both yard taps (level 2) and houses (level 3).

Future water demand for most of GNDs was estimated based on this system. The designed allocation of the coverage plan by Level 2 and Level 3 differs depending on the GND. This allocation depends on the existence of the water supply scheme within the GND. In a GND partly covered by an existing scheme, the level 3 system is allocated 90% of the total water demand and level 2 system is allocated the remaining 10% of the demand. On the other hand, in the GND without existing scheme, level 3 system is allocated 80% of the total water demand and level 2 system is allocated the remaining 20% of the demand. The consumption rates of 45 litre/capita/day and 140 litre/capita/day are adopted for level 2 and 3 respectively.

The conceptual diagram of the combination system of level 3 and 2 is shown in *Figure 6.8*.

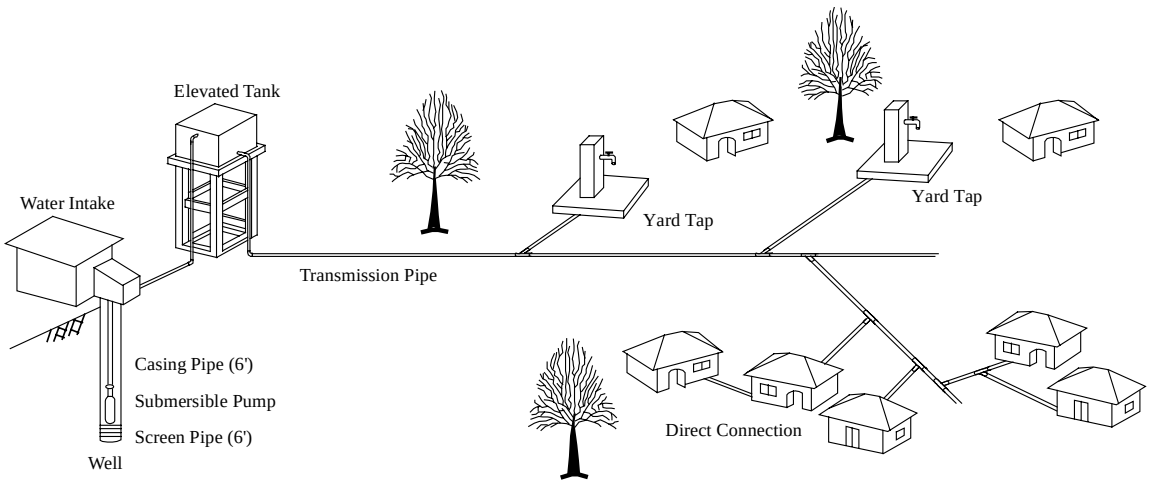

Figure 6.8 Conceptual Diagram of the Combination System of Level 3 and 2

(2) Level 3 (Direct Connection) System

This system plan is water distribution through the direct connection only. Water is pumped up by submersible pump(s) in the well(s) to an elevated tank and sent to each house.

This system plan was adapted to GND that are already covered by an existing scheme. The consumption rate of 140 litre/capita/day is adopted for the system.

The conceptual diagram of the level 3 is shown in *Figure 6.9*.

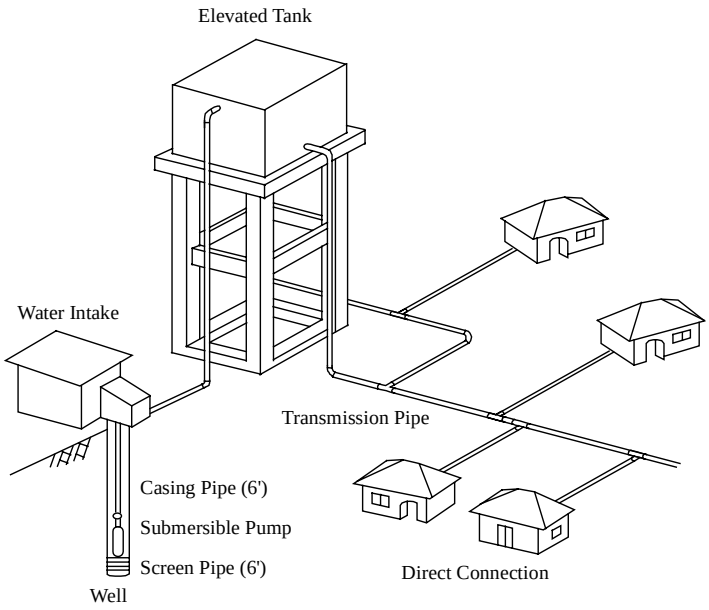

Figure 6.9 Conceptual Diagram Level 3 System

(3) Level 2 (Yard Tap) System

This system plan is water distribution through yard tap only. Water is pumped up by submersible pump(s) in the well(s) to an elevated tank and sent to several yard taps.

In the original system plan made by NWSDB, the system with 100% coverage by level 2 was not adopted. However, if the source capacity does not cover the water demand for the combination system of level 3 and 2, or the system of level 3 only, the system plan of the water supply levels must be altered to the level 2 system. The consumption rate of 45 litre/capita/day is adopted for the system.

The conceptual diagram of the level 2 is shown in *Figure 6.10*.

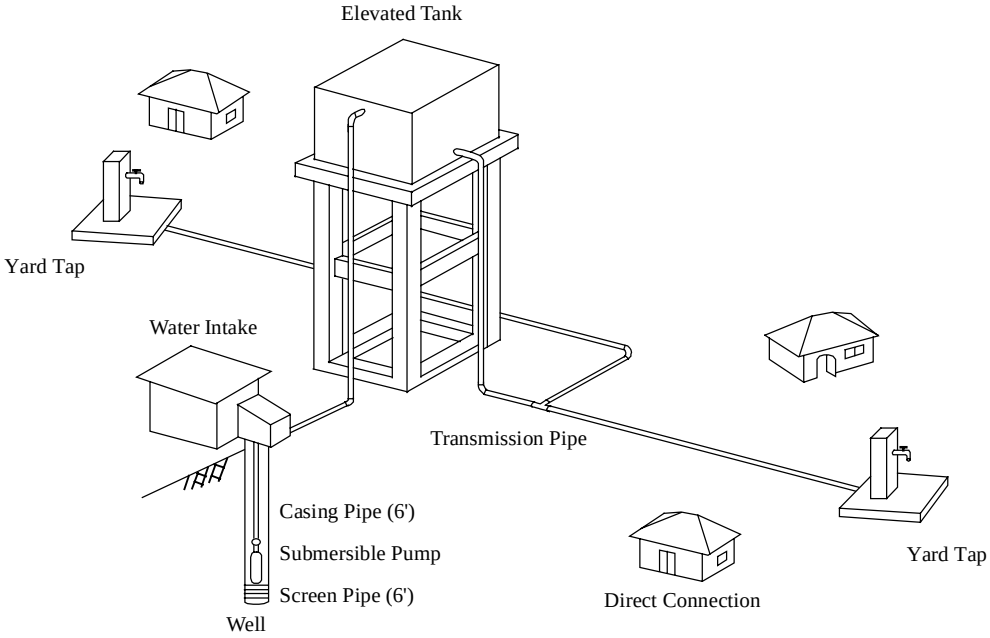

Figure 6.10 Conceptual Diagram Level 2 System

(4) Level 1 (Hand Pump) System

This system is water distribution through a single public hydrant with hand pump.

In the original system plan made by NWSDB, the level 1 system of hand pump is not adopted. However, if the groundwater potential is not enough to supply the domestic water in terms of both yield and water quality, or if the level 3 and level 2 plan is stated as unfeasible by the feasibility study, the coverage plan must be altered to level 1 system. The consumption rate of 45 litre/capita/day is adopted for the system.

The conceptual drawing of the hand pump (level 1 system) is shown in *Figure 6.11*.

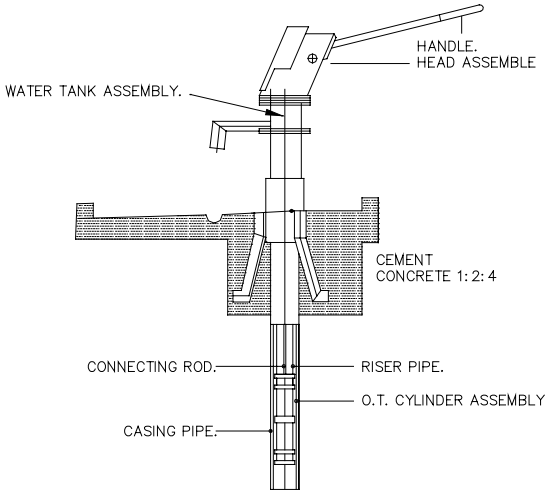

Figure 6.11 Conceptual Drawing of Hand Pump (Level 1 System)

6.5.2 GROUNDWATER DEVELOPMENT PLAN

Based on the future water demand estimated by section 6.3, and groundwater potential evaluation by Chapter 5, the groundwater resources development plans for the Pilot GNDs are formulated as shown in *Table 6.6*.

In the GNDs where the test wells were drilled, the source capacities were estimated by the results of pumping test. Such GNDs are the four GNDs of Bodagama, Yalabowa, Badalkumbura and Sevanagala in Monaragala district, and six GNDs of Keliyapra, Talunna, Wediwewa, Tammennawewa, Pahala Mattala and Siyambalagasvila North in Hambantota district. For other GNDs (namely, Hambegamuwa, Hulandawa Left and Unawatuna in Monaragala district, and Vitarandeniya and Ranna west in Hambantota district) estimated capacities by the groundwater evaluation were adopted.

As a result, the combination system of level 3 and 2 with the original coverage plan was adopted for the five GNDs of Bodagama, Yalabowa, Badalkumbura, Talunna and Tammennawewa. For the other GNDs, the coverage plan was altered due to the limitation of source capacity. In the Hambantota district, the three GNDs (Keliyapura, Wediwewa and Siyambalagasvila North), it is difficult to make the plan by both upper and lower/deep groundwater resources due to the inappropriate water quality and low source capacity. In these GNDs, however, expansion of existing system will be the feasible option because the GNDs are situated close to the main scheme of Hambantota and amount of the demand is comparatively small.

In Bodagama and Tammennawewa, a considerable amount of the source capacity to cover the future water demand was confirmed. However, due to the inappropriate water quality, an uneconomical water treatment plant by osmosis process for the rural water supply is required. Water supply for miscellaneous use is one of the feasible options.

Table 6.6 Groundwater Resources Development Plan in Pilot GNDs (2010)

GN Division Name	Plan (by NWSDB)						Project Water		Source Capacity						Development Plan			
	Population 2010		Cover -ed	Total Dem.	level 2 (Y.T.)	level 3 (D.C.)	Demand 2010		Well	Test Well			Evaluated yield[1]	Water	level 2 (Y.T.)	level 3 (D.C.)	**Supply Amoount**	No. of
	No.	Density Nos/km^2	No.	m^3/day	%	%	Popula -tion No.	**Dem. m^3/day**	Depth m	Rate m^3/h	Oper. Hrs.	Capacity m^3/day	m^3/day	Quality[2]	%	%	**m^3/day**	well.
MONARAGALA																		
M1 Hambegamuwa	2,170	13.7	0	469	20	80	2,170	**469**	*70*	*6*	*12*	N.A.	***72.00***	*good*	100	0	**174**	3
M2 Bodagama	1,801	86.0	0	389	20	80	1,801	**389**	100.00	26.40	12	**316.80**	N.A.	**Alkalinity & F$^-$**	45	55	**316**	1
M3 Hulandawa L	2,270	312.9	0	491	20	80	2,270	**491**	*70*	*6*	*12*	N.A.	***72.00***	*good*	100	0	**182**	3
M4 Unawatuna	2,427	285.4	503	633	10	90	1,924	**563**	*70*	*6*	*12*	N.A.	***72.00***	*good*	100	0	**148**	2
M5 Yalabowa	1,980	412.4	1,194	480	10	90	786	**313**	100.00	36.60	12	**439.20**	N.A.	**Alkalinity**	10	90	**313 plus 1GND**	1
M6 Badalkumbura	1,380	709.7	1,119	334	10	90	261	**178**	88.32	57.00	12	**684.00**	N.A.	**Fe^{3+}**	10	90	**178 plus 2GND**	1
M7 Sevanagala	6,085	368.3	0	1,315	20	80	6,085	**1,315**	40.8	5.10	12	**61.20**	N.A.	**PH & Pb**	100	0	**174**	3
HAMBANTOTA																		
H1 Keliyapura	668	26.6	1,070	160	0	100	(402)	**11**	200.20	0.36	2	**0.72**	N.A.	**Inappropriate**	0	100	**E.S[3]**	**N.A**
H2 Vitarandeniya	1,633	249.7	2,240	380	10	90	(607)	**66**	*100*	*3*	*12*	N.A.	***36.00***	*Fair*	35	65	**36**	1
H3 Talunna	1,224	276.2	485	274	10	90	739	**206**	194.00	24.90	12	**298.80**	N.A.	**Hardness & Ca^{2+}**	10	90	**206 plus**	1
H4 Wediwewa	1,699	84.7	0	352	20	80	1,699	**352**	200.40	1.08	1	**1.08**	N.A.	**Inappropriate**	20	80	**E.S**	**N.A**
H5 Tammennawewa	1,754	88.3	2,132	523	0	100	(377)	**225**	110.40	25.92	12	**311.04**	N.A.	**Inappropriate**	0	100	**225 plus**	1
H6 Pahala Mattala	424	36.9	241	118	10	90	183	**84**	52.50	6.36	12	**76.32**	N.A.	**Desirable**	20	80	**76**	1
H7 Siyambalagasvila N	1,049	576.5	1,180	252	0	100	(131)	**87**	200.40	0.25	3	**0.75**	N.A.	**Inappropriate**	0	100	**E.S**	**N.A**
H8 Ranna West	1,792	643.5	790	395	10	90	1,001	**284**	*100*	*6*	*12*	N.A.	***72.00***	*Fair*	84	16	**71**	1

Remarks
1) Estimated yield by the hydrogeological evaluation.
2) Water quality,
Good: EC value is less than750 µS/cm.
Fair: EC value is between 750 to 3,500µS/cm.
3) Expansion of "Existing Scheme" is recommended.
N.A. Not applicable.

Dem. : Demand
Oper. Hrs : Operation hours

The details of the groundwater development plans formulated by the Study are described below.

(1) Monaragala District

1) Hambegamuwa (Thabanalwila DS Division) M1

The water demand is estimated as 469 m^3/day with the projected population of 2,170 at the year 2010. The original coverage plan is a combination system of level 3 (80%) and level 2 (20%). No test well was drilled in this GND, so that estimated capacity of 72 m^3/day based on the groundwater evaluation was adopted for planning.

Estimated source capacity is not enough to cover the demand. The coverage rate of the demand, therefore, was reviewed to reach the amount that can be covered by a reasonable number of the wells. The demand was altered as 174 m^3/day for the coverage rate of 100% of level 2. As a result, the plan was formulated as level 2 system from three wells.

For water quality, the area is ranked as "good" with less than 750 ms/cm of EC value by the provided hydrogeological map. Considering this evaluation, the system plan may be made without treatment system. However, since the parameters of Iron (Fe^{3+}) and Fluoride (F^-) will not affect the EC value, water quality must be examined from the obtained water samples from drilled wells.

The conceptual diagram of the plan for Hambegamuwa is shown in *Figure 6.12.*

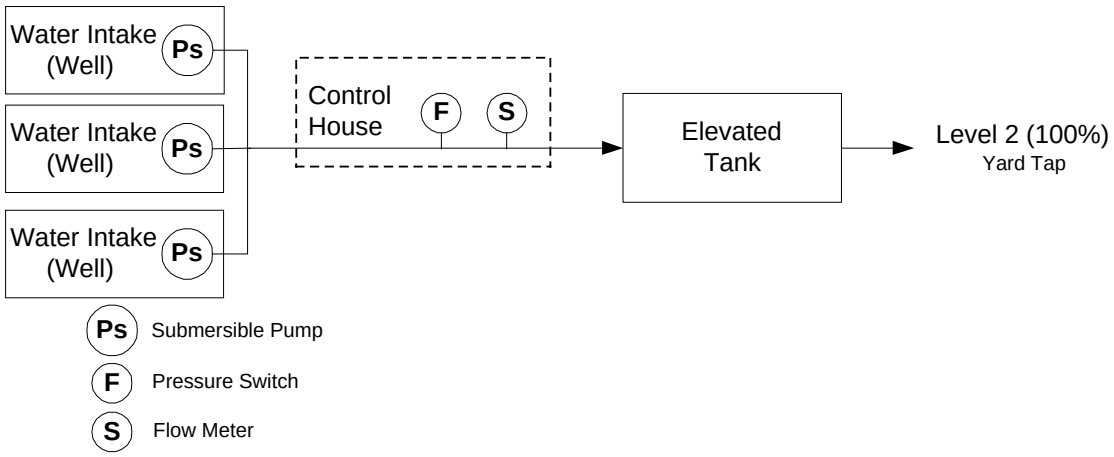

Figure 6.12 Conceptual Diagram of Hambegamuwa Scheme

2) Bodagama (Thabanalwila DS Division) M2

The water demand is estimated as 389 m^3/day with the projected population of 1,801 at the year 2010. The original coverage plan is a combination system of level 3 (80%) and level 2 (20%). A test well was drilled in this GND. The source capacity was determined as 316 m^3/day by the 12 hours pumping operation.

This capacity is not enough to cover the estimated demand of 389 m^3/day. The coverage rate of the demand, therefore, shall be reviewed. An altered coverage rate of 45% of level 2 and 55% of level 3 was adopted to cover the source capacity of 316 m^3/day.

The result of water quality analysis indicates that the water is inappropriate for the drinking purpose due to the high concentration of total alkalinity and fluoride. Therefore, water treatment plant by the reverse osmosis process is required.

The conceptual diagram of the plan for Bodagama is shown in *Figure 6.13.*

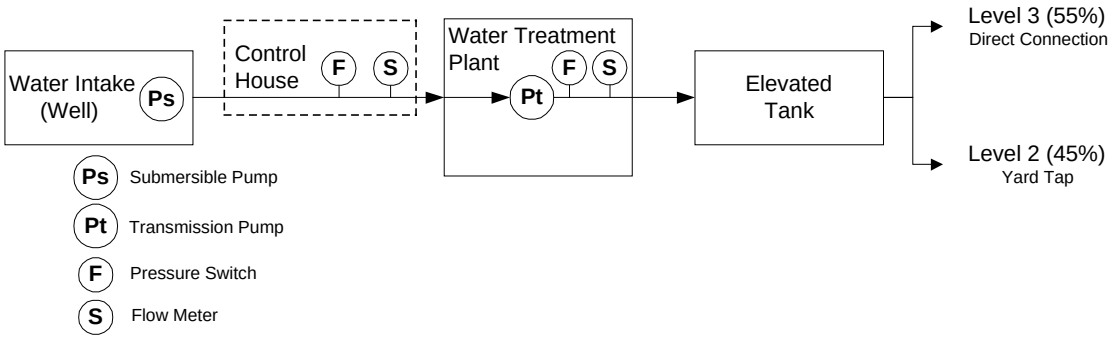

Figure 6.13 Conceptual Diagram of the Bodagama Scheme

The results of quality analysis indicate that concentrations of total alkalinity and fluoride exceed the criteria (Maximum Permissible Level) for drinking water.

Total alkalinity could be improved by addition of pH control chemicals. While, there are two major methods for defluoride, which are the coagulation-sedimentation and filtration method by alum and the ion exchange method by activated alumina. From viewpoints of operation cost, simplified facilities /maintenance and generation of sludge, it is recommended that the ion exchange method by activated alumina to be applied as the defluoride method. A schematic of this system is shown below *Figure 6.14.*

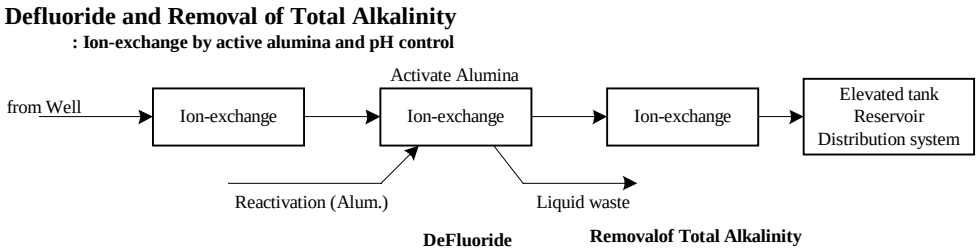

Figure 6.14 System Flow of Water Treatment Plant for the Bodagama Scheme

3) Hulandawa Left (Monaragala DS Division) M3

The water demand is estimated as 491 m^3/day with the projected population of 2,270 at the year 2010. The original coverage plan is a combination system of level 3 (80%) and level 2 (20%). No test well was drilled in this GND, so that estimated capacity of 72 m^3/day based on the groundwater evaluation was adopted for planning.

Estimated source capacity is not enough to cover the demand. The coverage rate of the demand, therefore, was reviewed to reach the amount that can be covered by a reasonable number of the wells. The demand was altered as 182 m^3/day for the coverage rate of 100% of level 2. As a result, the plan was formulated as level 2 system from three wells.

For water quality, the area is ranked as "good" with less than 750 ms/cm of EC value by the provided hydrogeological map. Considering this evaluation, the system plan may be made without treatment system. However, since the parameters of Iron (Fe^{3+}) and Fluoride (F^-) will not affect the EC value, water quality must be examined from the obtained water samples from drilled wells.

The conceptual diagram of the plan for Hulandawa Left is shown in *Figure 6.15.*

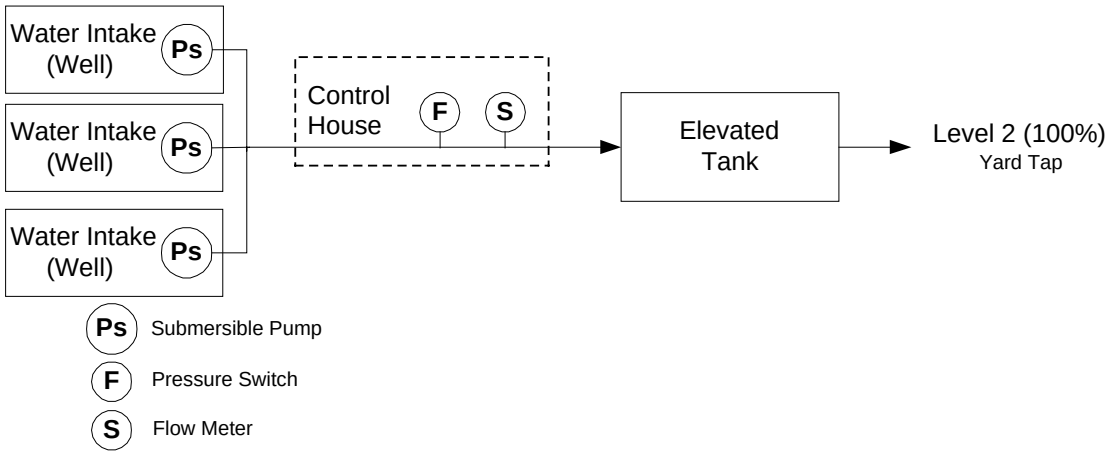

Figure 6.15 Conceptual Diagram of Hulandawa Left Scheme

4) Unawatuna (Buttala DS Division) M4

A population of 1,924 out of the total projected population of 2,424 is to be covered by this project, along with other population of 503 which has the plan to be covered by the expansion of existing schemes. Therefore, the water demand is estimated as 563 m^3/day at the year 2010. The original coverage plan is a combination system of level 3 (90%) and level 2 (10%). No test well was drilled in this GND, so that estimated capacity of 72 m^3/day based on the groundwater evaluation was adopted for planning.

Estimated source capacity is not enough to cover the demand. The coverage rate of the demand, therefore, was reviewed to reach the amount that can be covered by a reasonable number of the wells. The demand was altered as 142 m^3/day for the coverage rate of 100% of level 2. As a result, the plan was formulated as level 2 system from two wells.

For water quality, the area is ranked as "good" as less than 750 ms/cm of EC value by the provided hydrogeological map. Considering this evaluation, the system plan may be made without treatment system. However, since the parameters of Iron (Fe^{3+}) and Fluoride (F^-) will not affect the EC value, water quality must be examined from the obtained water samples from drilled wells.

The conceptual diagram of the plan for Unawatuna Left is shown in *Figure 6.16.*

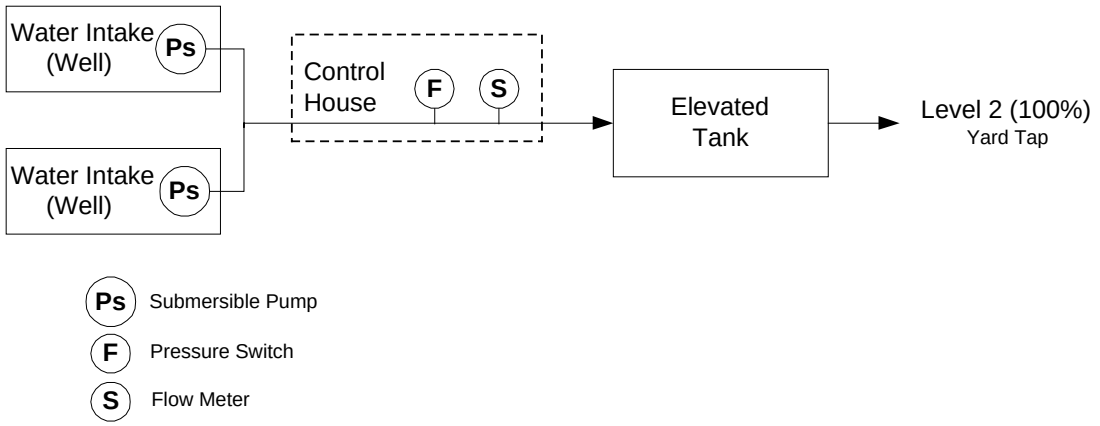

Figure 6.16 Conceptual Diagram of Unawatuna Scheme

5) Yalabowa (Wellawaya DS Division) M5

A population of 786 out of the total projected population of 1,980 is to be covered by this project. Other population of 1,194 will be covered by the expansion of existing schemes, before the target year. Therefore, the water demand is estimated as 313 m^3/day at the year

2010 for the population of 786. The original coverage plan is a combination system of level 3 (90%) and level 2 (10%). The source capacity was determined as 439 m^3/day by the 12 hours pumping operation. This capacity is larger than the demand of 2010. Therefore, the plan to cover the neighboring GNDs is proposed.

A total of two GNDs adjoin to Yalabowa. These are Wellawaya and Nugayaya (see *Figure 17*). The future water demand and coverage plan of these GNDs are summarized as follows:

GND name	Demand in 2010 (m^3/day)	Coverage Rate (%) Level 2	Level 3
Wellawaya	276	10	90
Nugayaya	346	20	80

The remaining water amount of 126.2 m^3/day from the Yalabowa Scheme can be utilized for the water supply for neighboring GNDs. This amount is not enough to cover the demand of either Wellawaya (276 m^3/day) or Nugayaya (276 m^3/day). However, part of the demand to the either neighboring GND can be cover. To cover the all demand of neighboring GND of Nugayaya, it is necessary to increase the number of production wells to two or more. Considering the 440 m influence radius of the water table drawdown and the planned pumping rate of 36 m^3/h of a well, such plan may also be made after the feasibility study.

The result of water quality analysis indicates that the concentration of total alkalinity (476 mg/l) slightly exceeds the criteria of drinking water standard (400 mg/l). On the other hand, the results of water quality analysis of the deep fracture aquifer satisfies all parameter including total alkalinity drinking water standard. Since the excess value of 76 mg/l is minor, the system plan may be made without treatment system. However, since the removal of total alkalinity has neither costly nor a complicated operation and maintenance, to assure the safety of drinking use, the system plan with treatment system is recommended.

The conceptual diagram of the plan for Yalabowa and surroundings is shown in *Figure 6.18.*

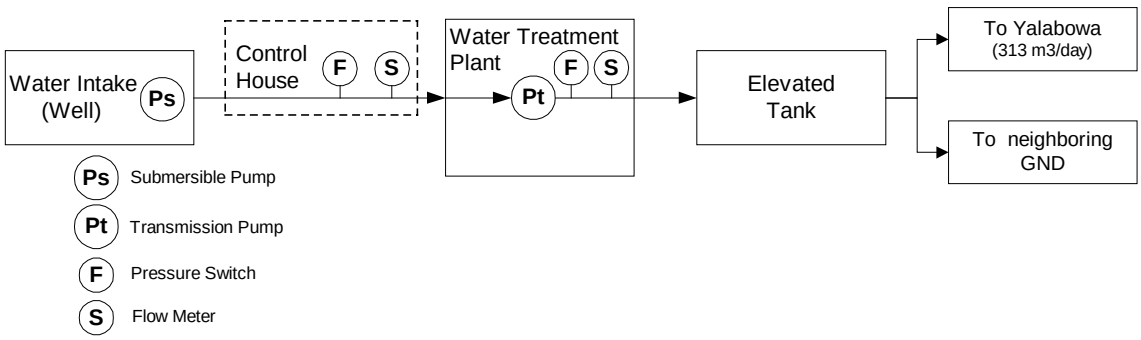

Figure 6.18 Conceptual Diagram of the Yalabowa Scheme

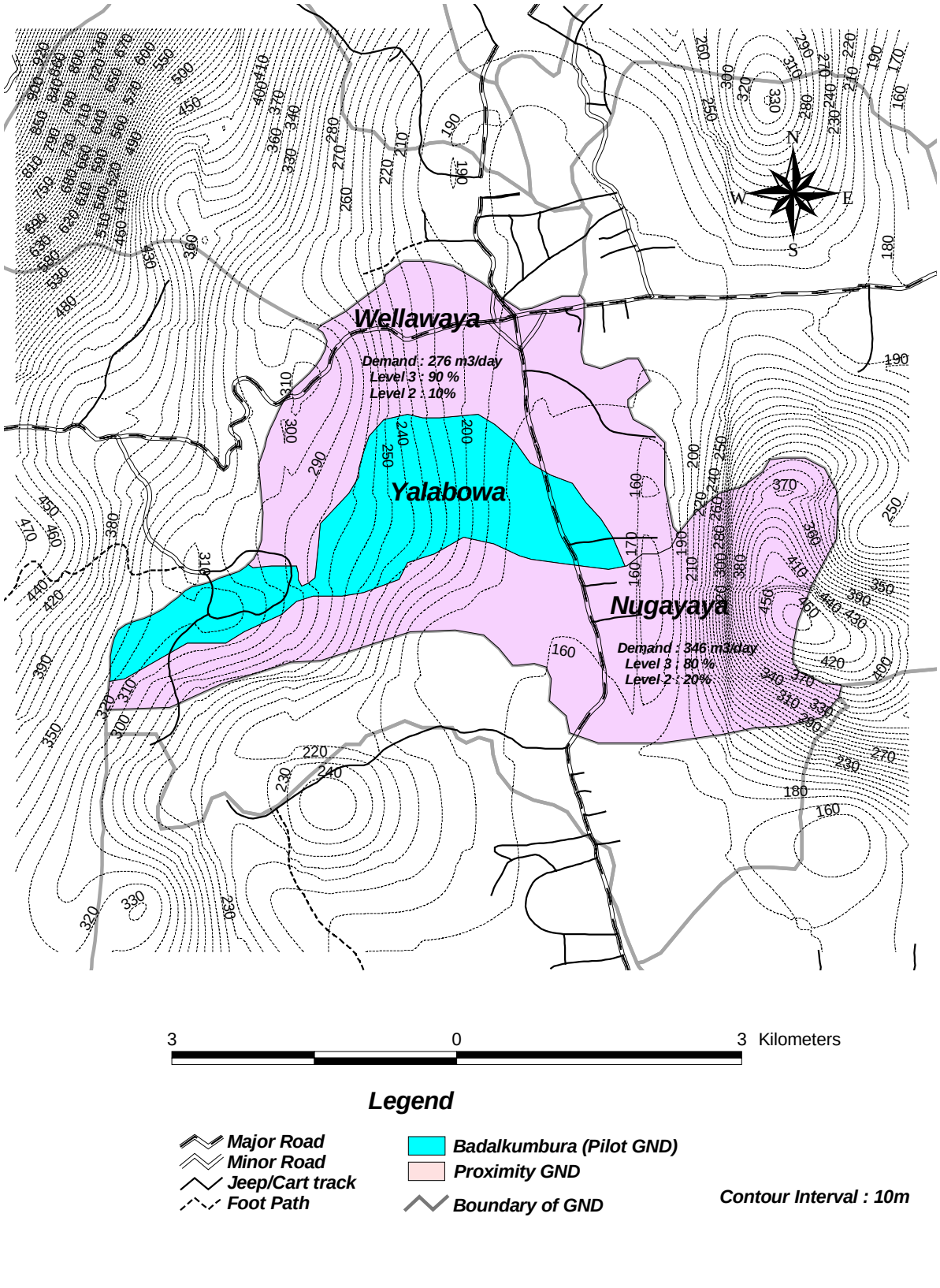

FIGURE 6.17 LOCATIONS AND THE PLANS FOR YALABOWA AND NEIGHBOURING GNDS

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The total alkalinity could be improved by addition of pH control chemicals. The required treatment facilities are flow meter, flush mixing tank, chemical-feeding facilities and pH meter. A schematic of this system is shown *Figure 6.19*.

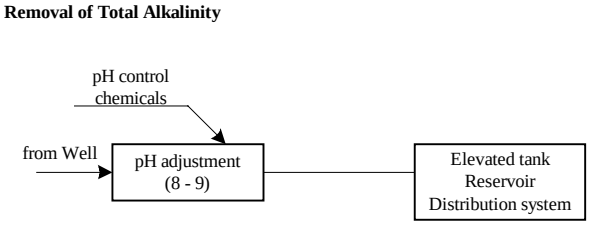

Figure 6.19 System Flow of Water Treatment Plant for the Yalabowa Scheme

6) Badalkumbura (Badalkumbura DS Division) M6

The population of 261 out of the total projected population of 1,380 is to be covered by this project. Other population of 1,119 will be covered by the expansion of existing schemes before 2010. Therefore, water demand is estimated as 178 m^3/day at the target year 2010. The original coverage plan is a combination system of level 3 (90%) and level 2 (10%). The source capacity was determined as 684 m^3/day by 12 hours pumping operation of a well. This capacity is far larger than the demand of 2010. Therefore, the plan to cover the neighboring GNDs is proposed.

A total of six GNDs adjoin to Badalkumbura. These are Wekumbura, Maligathenna, Pussellawa, Madugahapattiya, Kalagaha Kivula and Wasipotha. The future water demand and coverage plan of these GNDs are summarized as follows:

GND name	Demand in 2010 (m^3/day)	Coverage Rate (%) Level 2	Level 3
Wekumbura	185	20	80
Maligathenna	265	10	90
Pussellawa	320	10	90
Madugahapattiya	285	10	90
Kalagaha Kivula	145	20	80
Wasipotha	302	10	90

The remaining water amount of 506 m^3/day from the Badalkumbra Scheme can be utilized for the water supply for neighboring GNDs. The most feasible option for the plan is to distribute to the two GNDs of Pussellawa (320 m^3/day demand) and Kalagaha Kivula (145 m^3/day demand), considering the elevation and existence of the road (see *Figure 6.20*).

The plan can be formulated as a combination system with original coverage to the three GNDs of Badalkumbura, and Pussellawa (320 m^3/day demand) and Kalagaha Kivula (145 m^3/day demand) by a well. The conceptual diagram of the plan for Badalkumbura and surroundings is shown in *Figure 6.21*.

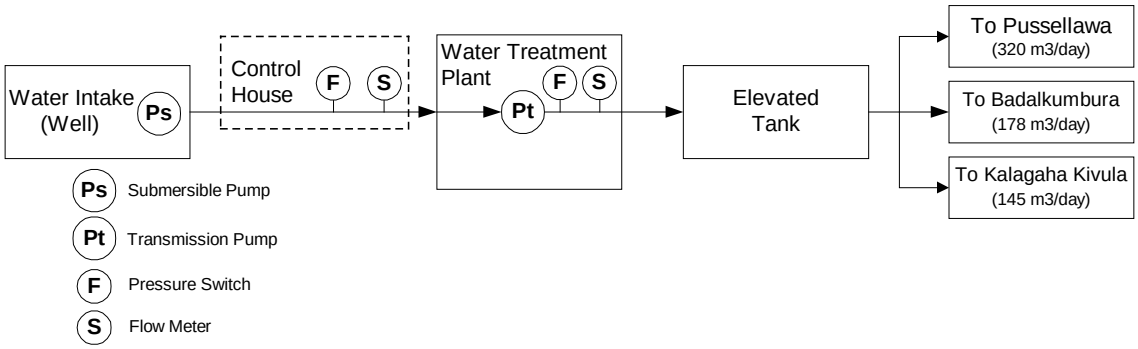

Figure 6.21 Conceptual Diagram of Badalkumbura Scheme

The results of groundwater quality analysis indicate that concentration of total iron exceeds the criteria for the drinking water standard.

The typical removal process of iron in water consists of two stages: the first stage is oxidation by chlorination or aeration from the dissoluble ferrous compound to the non-dissoluble ferric compound, and the second stage is coagulation-sedimentation and filtration process or filtration process only.

A schematic of this system is shown in *Figure 6.22*.

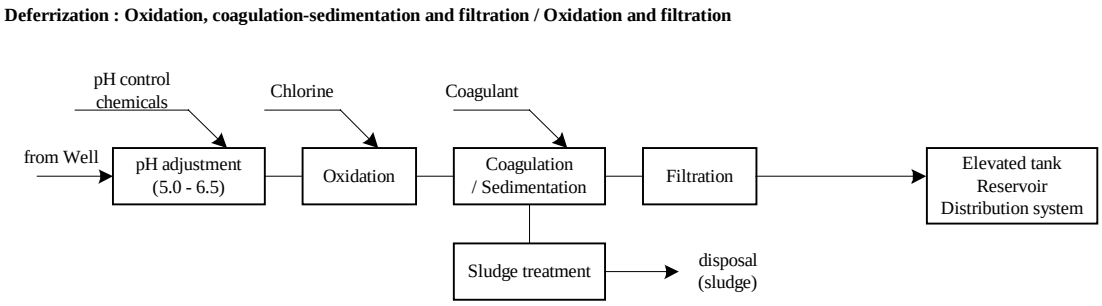

Figure 6.22 System Flow of Water Treatment Plant for the Badalkumbura Scheme

For the reason that the concentration of total iron is not significantly high, oxidation by aeration and filtration without coagulation processes are recommended for the rural water supply system in Badalkumbura. However, it is necessary to confirm treatment efficiency by the treatment demonstration test.

7) Sevanagala (Sevanagala DS Division) M7

Water demand is estimated as 1,315 m^3/day for the projected population of 6,085 at the year 2010. The original coverage plan is a combination system of level 3 (80%) and level 2 (20%). A test well was drilled in this GND. The source capacity was determined as 61.2 m^3/day by 12 hours pumping operation. Therefore, the capacity is not sufficient to cover the estimated demand of 1,315 m^3/day.

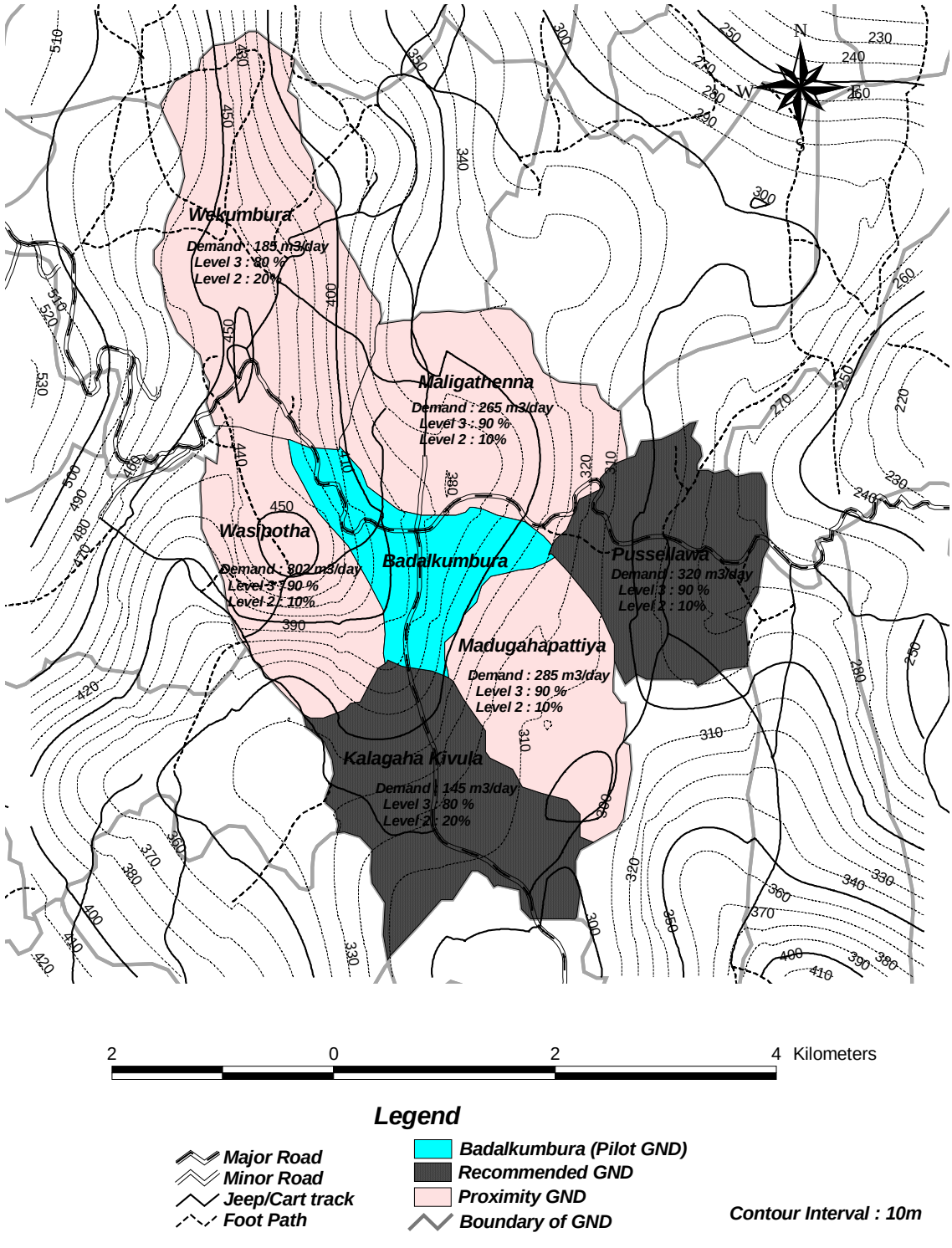

FIGURE 6.20 LOCATIONS AND THE PLANS OF BADALKUMBURA AND NEIGHBOURING GNDS

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Since the pumping rate of a single well is small (61.2 m^3/day), more than 20 wells are required to cover the demand. Considering the hydrogeological conditions of the area, it is not feasible to construct such a large number of wells within the GND. The coverage rate of the demand, therefore, was reviewed. The demand was adjusted to reach the amount that can be covered by a reasonable number of the wells. The demand was estimated as 174 m^3/day by altering the coverage rate to 100% of level 2. Three wells are required to cover this demand. Considering the 870 m influence radius of the water table drawdown and the planned pumping rate of 5 m^3/h of a well, construction of the three wells is possible.

As a result, the plan was formulated as level 2 system from three wells. The conceptual diagram of the plan for Sevanagala is shown in *Figure 6.23.*

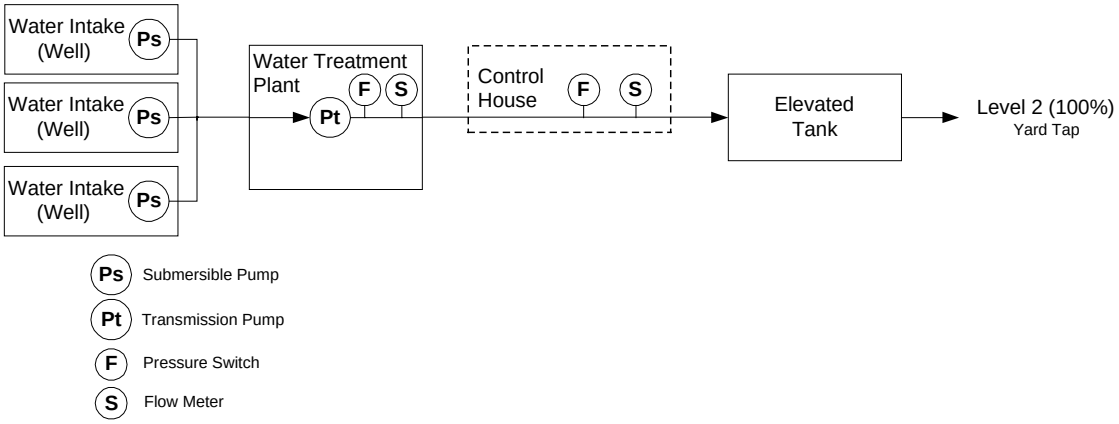


Figure 6.23 Conceptual Diagram of Sevanagala Scheme

The results of groundwater quality analysis indicate that pH and concentration of lead exceed the criteria for drinking water standard. Especially, lead is one of the health-related items in the criteria for drinking water.

Lead could be removed from water by coagulation-sedimentation and filtration. Coagulation and filtration process as a common purification process for water supply system is recommended for removal of lead and pH control. From this process, one expects more than 95 percent of removal efficiency with accurate operation and maintenance. A schematic of this system is shown *Figure 6.24.*

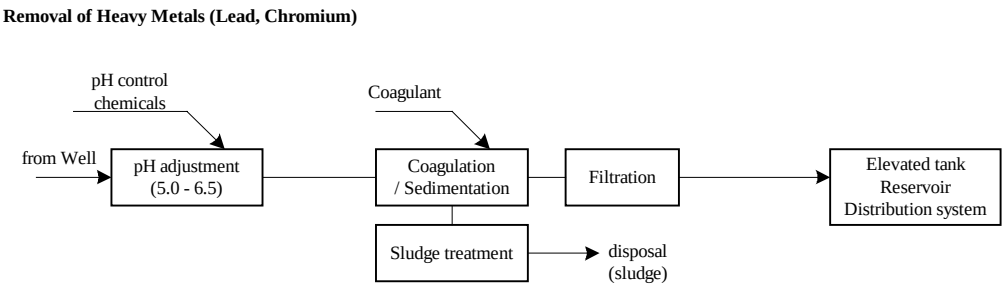


Figure 6.24 System Flow of Water Treatment Plant for the Sevanagala Scheme

However, considering the economical feasibility of the practical operation and maintenance of the scheme, it is difficult to introduce purification processes for removal of heavy metals as the rural water supply system.

As above mentioned, the source capacity of groundwater in this area is limited and its groundwater quality is inapplicable for drinking water. Further detail feasibility study is required, since a considerable amount of the source capacity to cover the future water demand was confirmed.

(2) Hambantota District

1) Keriyapura (Hambantota DS Division) H1

The present plan of expansion of the existing scheme will cover more than the estimated population of 2010. However, since this existing plan does not include non-domestic and non-revenue water demand, the GND still has demand of 11 m^3/day at the year 2010. The demand estimation is based on the coverage rate of level 3 only. The source capacity is small, 0.72 m^3/day. This low yield is confirmed by the extremely low specific capacity of 0.21 l/min/m of the test well. Furthermore, due to the very high drawdown rate of water level, the daily operation hours of the submersible pump is restricted to two hours.

Additionally, the groundwater quality is inappropriate for drinking purpose since the water quality parameters do not satisfy the criteria for drinking water. These are parameters of pH, EC, Total Hardness, Total Alkalinity, TDS, Calcium, Total Iron and Chromium. Improvement of such water quality condition for drinking purpose could be achieved by reverse osmosis, which is widely utilized as the desalination treatment of sea water and brine water.

Meanwhile, the reverse osmosis process has disadvantages as listed below.

- High construction and operation/maintenance costs.
- Large energy consumption.
- Need for pretreatment or turbid raw water treatment with acid and other chemicals to prevent fouling of the membranes by slimes, suspended solids, iron, manganese, and precipitates of calcium carbonate and magnesium hydroxide.
- Need to stabilize finished water with lime or other chemicals to prevent corrosion in distribution systems.
- Disposal of the reject wastewater from reverse osmosis units.

Therefore, considering the economical feasibility of the practical operation and maintenance of the scheme, it is not recommended that the reverse osmosis method be applied for the rural water supply system.

The hydrogeological map presented in Chapter 5 shows low yielding of 20 to 50 l/min and high electric conductivity value of more than 3,500 μs/cm in this area. It is suggested therefore, the development of a shallow aquifer by hand pump well is not feasible in terms of both water quality and quantity. It is recommended therefore, the water supply plan be made by the further expansion of the existing scheme.

2) Vitarandeniya (Tangalle DS Division) H2

The present plan of expansion of the existing scheme will cover more than the estimated population of 2010. However, since this existing plan does not include non-domestic and non-revenue water demand, the GND still has demand of 66 m^3/day at the year 2010. The demand estimation is based on the coverage rate of level 3 (90%) and level 2 (10%). No test well was drilled in this GND, so that estimated capacity of 36 m^3/day based on the groundwater evaluation was adopted for the planning.

Estimated source capacity is not sufficient to cover the demand. The coverage rate of the demand, therefore, was reviewed to reach the amount that can be covered by a reasonable number of the wells. The demand was altered to 36 m^3/day by the coverage rate of level 3 (65%) and level 2 (35%). As a result, the plan was formulated as a combination system of level 3 and 2 by a well.

For water quality, the area is ranked as “fair” with the range between 750 to 3,500 ms/cm of EC value by the provided hydrogeological map. Considering this evaluation, water

treatment plant may necessary for the system. For the details of the treatment, water quality must be examined from the obtained water samples from drilled wells.

The conceptual diagram of the plan for Hambegamuwa is shown in *Figure 6.25.*

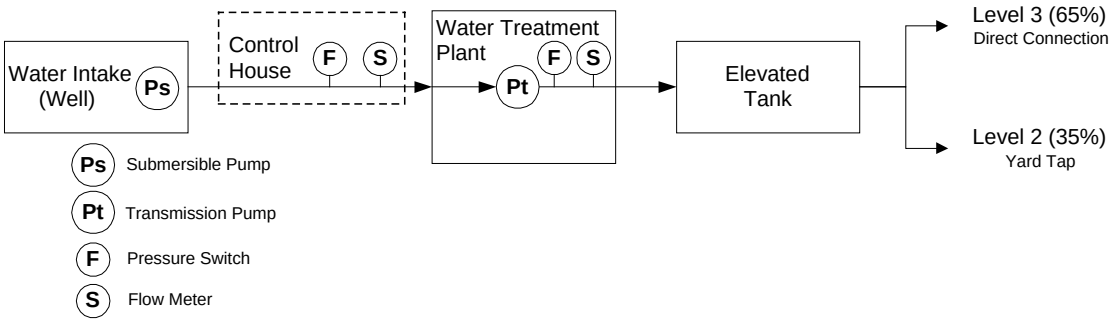


Figure 6.25 Conceptual Diagram of Vitarandeniya Scheme

3) Talunna (Tangalle DS Division) H3

The population of 739 out of the total projected population of 1,224 is to be covered by this project. Other population of 485 will be covered by the expansion of existing schemes, before the target year 2010. Therefore, the water demand is estimated as 206 m^3/day at the year 2010 for the population of 739. The original coverage plan is a combination system of level 3 (90%) and level 2 (10%). The source capacity was determined as 298.8 m^3/day by 12 hours pumping operation. Therefore, the plan can be formulated as a combination system with the original coverage plan from a well.

The source capacity covers the total amount of future water demand. The conceptual diagram of the plan for Bodagama is shown in *Figure 6.26.*

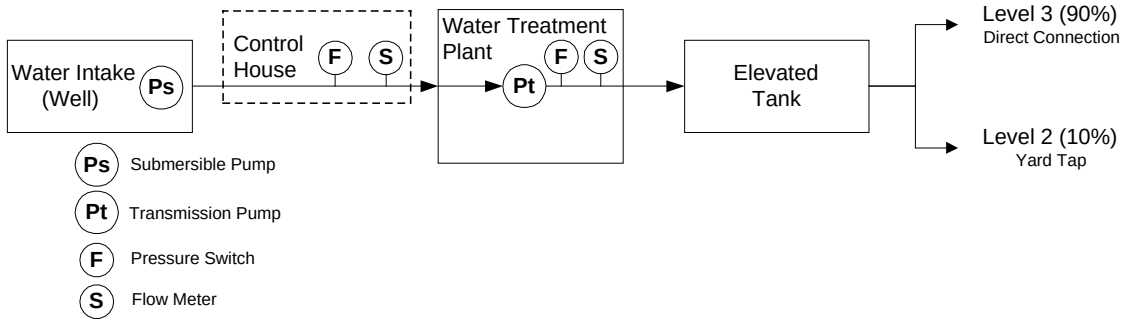


Figure 6.26 Conceptual Diagram of Talunna Scheme

On the other hand, in terms of the water quality, raw water is not eligible for drinking purpose. Hardness is expressed in terms of the sum of the concentration of polyvalent ions, the principal ones being calcium and magnesium. Therefore, removal of calcium and magnesium is required as treatment method. There are presently several major types of softening processes: lime softening/lime-soda ash softening, crystallization process for calcium removal. The details of these softening processes are mentioned in Supporting Chapter 7.

According to the following advantages/disadvantages of the softening method, it is recommended that the crystallization process for calcium removal be applied as the softening method for Talunna.

- Sufficient treatment efficiency (The standards for drinking water (Maximum Permissible Level: Total Hardness is 600 mg/l as $CaCO_3$) could be satisfied by removal of approximately 75% of calcium.)
- Simplified operation/maintenance
- Application of a small-scale plant
- No required sludge treatment

A schematic of this system is shown *Figure 6.27*.

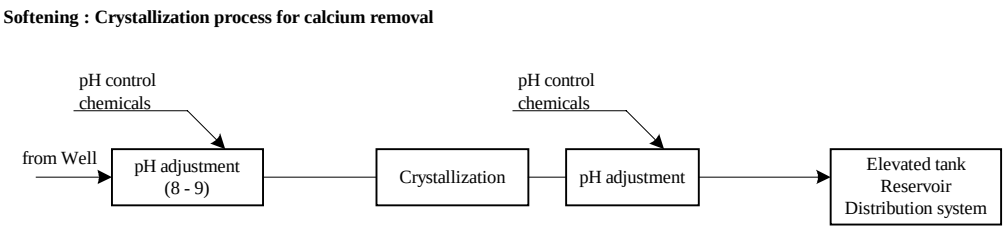


Figure 6.27 System Flow of Water Treatment Plant for the Talunna Scheme

4) Wediwewa (Hambantota DS Division) H4

The water demand is estimated as 352 m^3/day with the projected population of 1,699 at the year 2010. The original coverage plan is a combination system of level 3 (80%) and level 2 (20%). A test well was drilled in this GND. The determined source capacity is small, 1.08 m^3/day. This low yield is confirmed by the extremely low specific capacity of 0.65 l/min/m of the test well. Furthermore, due to the very high drawdown rate of water level, the daily operation hours of the submersible pump is restricted to only one hour.

The groundwater quality of the test well shows inappropriate level for the drinking purpose. In the items of pH, EC, Total-Hardness, Total Alkalinity, TDS, Sulphate and Chromium, observed the values exceed the drinking water standards. Therefore, the reverse osmosis is an appropriate method for the treatment plant for the system.

However, considering the economical feasibility of the practical operation and maintenance of the scheme, it is not recommended that the reverse osmosis method be applied for the rural water supply system. It is suggested that consideration of comprehensive development plan for water resource be pursued.

The hydrogeological map presented in Chapter 5 shows low yielding of 20 to 50 l/min and high electric conductivity value of more than 3,500 μs/cm in this area. It is concluded therefore, the development of the shallow aquifer by hand pump well is not feasible in terms of both water quality and quantity. It is recommended, therefore, that the water supply plan be made by the further expansion of the existing scheme.

5) Tammennawewa (Hambantota DS Division) H5

The present plan of expansion of the existing scheme will cover more than the estimated population of 2010. However, since this existing plan does not include non-domestic and non-revenue water demand, the GND still has demand of 225 m^3/day at the year 2010. The demand estimation is based on the coverage rate of level 3 only. A test well was drilled in this GND. The source capacity was determined as 311.04 m^3/day by 12 hours pumping operation. Therefore, the plan can be formulated as a combination system with the original coverage plan by a well.

The source capacity covers the total amount of future water demand. The conceptual

diagram of the plan for Tammennawewa is shown in *Figure 6.28.*

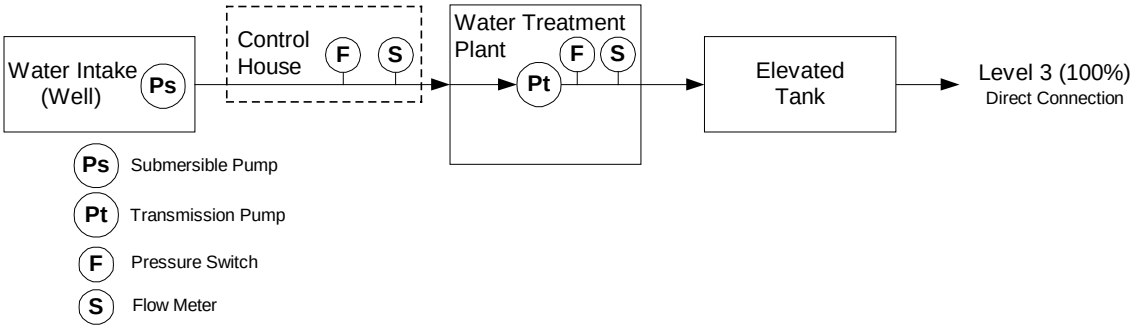


Figure 6.28 Conceptual Diagram of Tammennawewa Scheme

On the other hand, in terms of the water quality, raw water is not eligible for drinking purpose. High concentrations of Calcium, Magnesium and Sulphate were detected by the water quality test. The reverse osmosis is a required method for the treatment plant for the system.

The recommendable system flow for the treatment plant is shown in *Figure 6.29.*

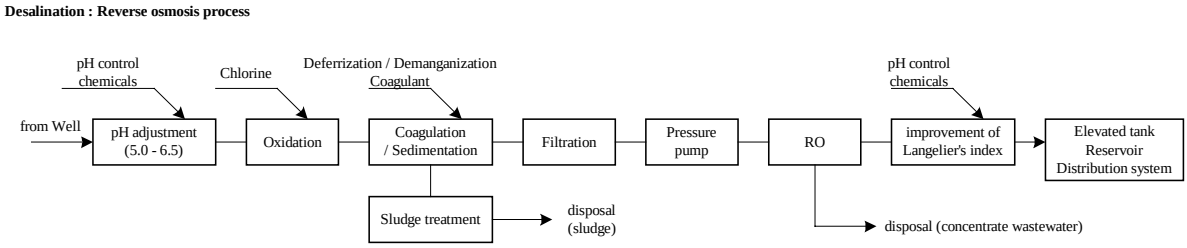


Figure 6.29 System Flow of Water Treatment Plant for the Tammennawewa Scheme

However, considering the economical feasibility of the practical operation and maintenance of the scheme, it is not recommended to introduce the method as the rural water supply system.

Water supply for miscellaneous use by this scheme is one of the feasible options, since a considerable amount of the source capacity to cover the future water demand was confirmed. However, further detailed feasibility study is required, to examine the water use.

6) Pahala Mattala (Lunugamwehera DS Division) H6

The population of 183 among the total projected population of 424 is the population to be covered by this project. The other population of 241 will be covered by the expansion of existing schemes, before the target year. Therefore, the water demand is estimated as 84 m^3/day at the year of 2010, for the population of 183. The original coverage plan is combination system of level 3 (90%) and level 2 (10%). The source capacity was determined as 76.32 m^3/day by the 12 hours pumping operation. Therefore, the source capacity does not cover the total demand of 84 m^3/day.

The coverage rate of the demand was reviewed to obtain the feasible amount which can be supplied by the source capacity. As the results, the revised amount of the demand of 76 m^3/day by alters the coverage rate of level 3 (80%) and level 2 (20%). The source capacity of 76.32 m^3/day covers the revised demand by a well. The result of water quality analysis indicates that all the parameter satisfy the drinking water standards.

The conceptual diagram of the plan for Sevanagala is shown in *Figure 6.27.*

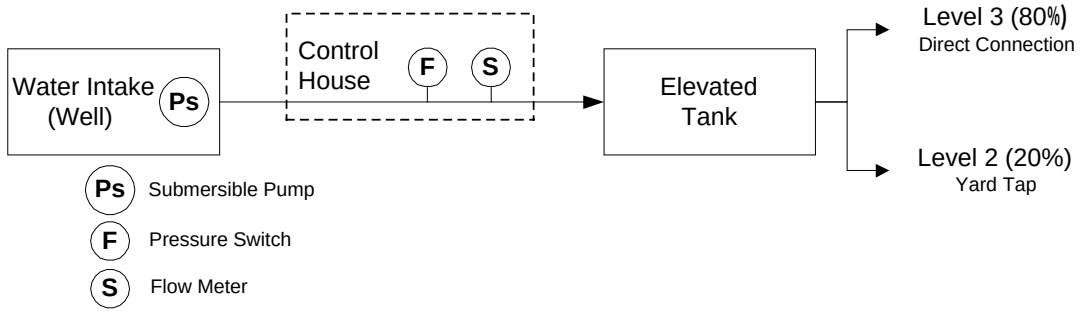


Figure 6.30 Conceptual Diagram of Pahala Mattala Scheme

7) Siyambalagasvila North (Hambantota DS Division) H7

The present plan of expansion of the existing scheme will cover more than the estimated population of 2010. However, since this existing plan does not include non-domestic and non-revenue water demand, the GND still has demand of 87 m^3/day at the year 2010. The demand estimation is based on the coverage rate of level 3 only. The source capacity is small, 0.75 m^3/day. This low yielding is confirmed by the extremely low specific capacity of 0.75 l/min/m of the test well. Furthermore, due to the very high drawdown rate of water level, the daily operation hours of the submersible pump is restricted to three hours.

Additionally, the water quality is inappropriate for domestic purpose due to high Calcium, Magnesium, Chloride and Sulphate, Calcium, and Total Hardness. Reverse osmosis is a required method for the treatment plant for the system. However, considering the economical feasibility of the practical operation and maintenance of the scheme, it is not recommended to introduce the method as the rural water supply system.

The hydrogeological map presented in Chapter 5 shows low yielding of 0 to 20 l/min and high electric conductivity value of more than 3,500 μs/cm in this area. It is concluded, therefore, that the development of a shallow aquifer by hand pump well is not feasible in terms of both water quality and quantity. It is recommended therefore, the water supply plan be made by the further expansion of the existing scheme.

8) Ranna West (Tangalle DS Division) H8

The population of 1,001 out of the total projected population of 1792 is to be covered by this project, along with other population of 790 which has the plan to be covered by the expansion of existing schemes. Therefore, the water demand is estimated as 284 m^3/day at the year 2010. The original coverage plan is a combination system of level 3 (90%) and level 2 (10%). No test well was drilled in this GND, so that estimated capacity of 72 m^3/day based on the groundwater evaluation was adopted for the planning.

Estimated source capacity is not sufficient to cover the demand. The coverage rate of the demand, therefore, was reviewed to reach the amount that can be covered by a reasonable number of the wells. The demand was altered to 71 m^3/day with the coverage rate of level 3 (84%) and level 2 (16%). As a result, the plan was formulated as a combination system of level 3 and 2 by a well.

For water quality, the area is ranked as “fair” as the range between 750 to 3,500 ms/cm of EC value by the provided hydrogeological map. Considering this evaluation, water treatment plant may necessary for the system. For the details of the treatment, water quality must be examined from the obtained water samples from drilled wells.

The conceptual diagram of the plan for Ranna West is shown in *Figure 6.31*.

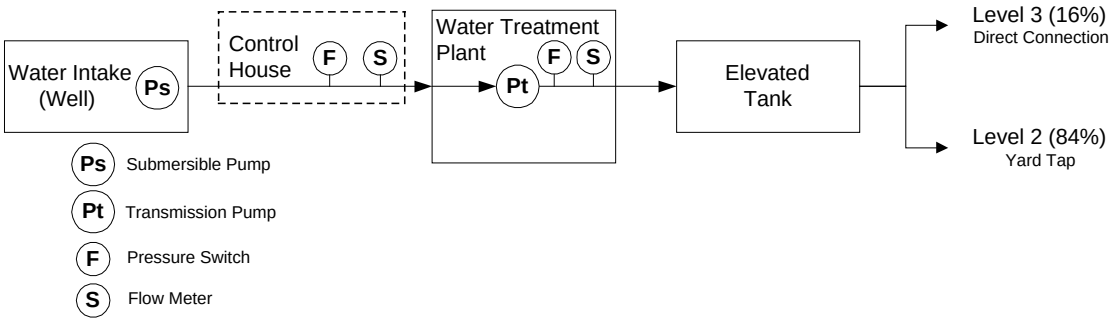


Figure 6.31 Conceptual Diagram of Ranna West Scheme

6.6 GROUNDWATER MONITORING PLAN

Purposes of groundwater monitoring are: (i) to utilize the groundwater datat for future hydrological studies and execution groundwater development plans and (ii) to ensure the proper and sustainable operation of the groundwater utilization by obtaining the fluctuation of groundwater flow, quality and level.

(1) Proposed Monitoring Items and Frequency

In this Study, the monitoring of water level and water quality was conducted once in one and a half months in 10 test wells and 30 selected existing wells.

To make the data collected in this Study more beneficial and utilize it for planning and operation in future, it is desirable to give the test wells the status of monitoring well and continue the monitoring of groundwater by the same method (number of wells and frequency) as well as selected existing wells. However, if it is difficult to continue the monitoring of all the wells of this Study due to shortage of budget and human resources of WRB, at least monitoring of 10 test wells should be continued. The drilled depth of these test wells is first case in Sri Lanka, so that this data will be quite valuable in future groundwater study.

Proposed monitoring items and frequency of monitoring are as follows:

1) 10 test wells (for deep fractured aquifer)

- Monitoring items: water level and water quality.
- Frequency of Monitoring: once every two months.

2) 30 selected exiting wells (for shallow fractured aquifer)

- Monitoring items: water level and water quality.
- Frequency of Monitoring: once every two months (If it is difficult, at least twice a year in each rainy and dry season is recommended).

(2) Engineering Practice for the Measurement

1) Specification of the Data Logger Installed

The main features of specification are summarized as follows;

- memory	:	32KByte for at least 32x484 = 15,488 measuring values (without time marks)
- communication	:	via M-Bus with communication interface at RS232 with 2400Baud
	:	increase by read data up to 4800 Baud values
- clock	:	real time clock ±15ppm
- operating temperature	:	-20 to +70℃ (exception: glaciation)
- power supply conditions	:	average temperature <25℃
	:	max. pluses 500/day
	:	measuring cycle times >=15min
	:	interface operation max. 5min/month
- operating life	:	15 years
- expected runtime	:	20 years

As described above, manufacturer guarantees 15 years for battery life, accordingly, data-logger must be sent to the manufacturer to change the battery 15 years after.

The memory capacity of the data logger is only 15,488. Time interval for data recording was set every 1 hour for monitoring purpose. If data capturing is carried out once a year, number of data becomes 8,760. The data logger can be left about 1.5 years.

2) Proposed Practice for the Measurement

As mentioned above, maximum number of the data can be memorized is only 15,488. If the number of data exceeds the capacity, new data will be overwritten automatically. In order to avoid such data missing, it is recommended that data capturing should be executed at least once a year. The well head facility consists of not only the data-logger, but also a lot of device was installed to maintain proper function of the data-logger. Inspection of these devices also required. From this point of view, it is considered that visit to the wells for data capturing at least once a year is appropriate.

For the 30 selected existing wells, the monitoring of at least twice a year is recommended. Therefore, the data capturing of from the data logger installed on 10 test well is recommended to carried out at once when the monitoring of existing wells are carried out.

(3) Proposed Organization in Charge of Monitoring

As described in Supporting 10, WRB conducts periodic monitoring in several wells. Therefore, it is not necessary to formulate a new organization and system for such work. Monitoring work is usually conducted by the WRB geologist of hydrogeology division in Colombo. However, WRB has a regional office in Monaragala; hence, it is proposed that Monaragala regional office should have responsibility of the monitoring (i.e., for direct measurement and sample collecting). Since the office doesn't have laboratory, water quality analysis should be conducted in the laboratory in Colombo.

Regarding the test wells, automatic water level recorders are installed. For collecting the data, some technique and dedicated equipment is necessary. The Geologist in Monaragala regional office has already acquired how to operate this equipment through technical transfer during this Study.

(4) Monitoring of New Production Wells

In case new wells and water supply facility will be constructed based on the result of this Study, the following monitoring is recommended to examine the appropriate pumping rate for the operation and to gain further hydrogeological data.

Monitoring Item	Frequency	Remarks
Water level	Everyday	O & M person of facility checks by using water measurement pipe installed inside of well.
Water quality	Once every two months	By WRB geologists

6.7 OPERATION, MAINTENANCE AND MANAGEMENT PLAN

6.7.1 OPERATION AND MAINTENANCE PLAN FOR PROPOSED WATER SUPPLY SCHEMES

NWSDB is proceeding with preparing various manuals and guidelines for more efficient and sustainable water supply and already starting to act along the lines mentioned in them. In reality, human resources and organization of rural water supply level is not adequate to fully follow these guidelines. However, the policy and contents of these guidelines are quite substantial and useful. In this Study, operation and maintenance is planned according to these guidelines assuming that NWSDB will follow them.

According to NWSDB guidelines, water supply scheme that is a population of not more than 6,000, a limit of 1,000 connections or 1,000 m^3/day capacity is categorized as rural water supply scheme and should be managed and operated by Pradeshiya Sabha or CBO (Community Based Organization). In case that schemes of tube wells with hand pumps are recommended because of shortage of water quantity as a result of this Study, operation and management should be conducted by Consumer Society.

The categorization for organization in charge of operation and management of water supply scheme is shown in *Table 6.7*. As for rural water supply scheme of which water supply area stretches over several GNDs, it is proposed that PS is appointed as the management organization.

Table 6.7 Categorization for Operation & Management Organization

	Pradeshiya Sahba	Community Based Organization	Consumer Society
Scale of Scheme	Less than 6,000 population, Less than 1,000 connectoins, or Less than 1,000 m3/day capacity Water supply area stretches over several GNDs	Less than 6,000 population, Less than 1,000 connectoins, or Less than 1,000 m3/day capacity Water supply area limits to only one GND	Tube Well with Hand Pump

The proposed organization in charge of operation and management in 15 Pilot GNDs is shown in *Table 6.8*. Basically, CBO is appointed as organization in charge because the groundwater development plan described in section 5.2 is planned at the GND level. If water capacity is so large as to be able to distribute to other GNDs, PS is to be appointed as the management organization.

Table 6.8 Proposed Operation & Management Organization

PS	CBO	CS	Others*
Yalabowa Badalkumbura	Hambegamuwa Bodagama Hulandawa Left Unawatuna Sevanagala Vitarandeniya Talunna Tammennawewa Pahala Mattala Ranna West	non	Keliyapura Wediwewa Siyambalagasvila North

Remarks: *: Expansion of existing scheme is recommended in these GND.

Details of each management and operation system are shown in Supporting 10. The recommended personnel for each organization is shown in *Table 6.9*.

Table 6.9 Recommended Personnel Organization

Pradeshiya Sabha Water Supply Unit	**CBO**	**Consumer Society**
- Technical officer (on full time basis) - Community development officer (on part-time basis) - Subject clerk (on part-time basis) And, where necessary - Water supply mechanics - Hand pump mechanics/technicians - Scheme caretakers/operators/plumbers	- President - Vice president - Secretary - Assistant Secretary - Treasurer - Voluntary Health Worker (Male/Female) - 10-12 Committee Members - Checking Officer of Accounts - Caretakers (Number is depending on facilities)	- President - Vice president - Secretary - Assistant Secretary - Treasurer - Voluntary Health Worker (Male/Female) - 2 Committee Members - Checking Officer of Accounts - 2 Caretakers (combine the above roles in some cases)

Human resources requirement for operation and maintenance of facility plan is shown in *Table 6.10*.

Table 6.10 Human Resources Requirement of Each Facility Plan

Type	Facility	O & M person	Type of Treatment Plant
1	Treatment Plant (elaborate) Elevated Tank Submersible Pump Transmission Pump Transmission Pipe Distribution Pipe	Technical Officer (PT*) 1 Treatment Plant Caretaker 4 Pump Opretor 1 Watcher 1 Plumber 1	・pH control, oxidation, coagulation-sedimentation, filtration, reverse osmosis process
2	Treatment Plant (simple) Elevated Tank Submersible Pump Transmission Pump Transmission Pipe Distribution Pipe	Technical Officer (PT) 1 Treatment Plant Caretaker 2 Pump Opretor 1 Watcher 1 Plumber 1	・pH control, Oxidation, coagulation-sedimentation and filtration ・pH control, coagulation-secimentation, and filtration
3	Treatment Plant (very simple) Elevated Tank Submersible Pump Transmission Pump Transmission Pipe Distribution Pipe	Technical Officer (PT) 1 Treatment Plant Caretaker 1 Pump Opretor 1 Watcher 1 Plumber 1	・Cristallization process and pH control ・Ion-exchange and pH control ・pH control
4	Elevated Tank Submersible Pump Transmission Pump Transmission Pipe Distribution Pipe	Technical Officer (PT) 1 Pump Opretor 1 Watcher 1 Plumber 1	non
5	Hand Pump	Caretaker 2	non

Remarks: *: Part-time basis

On the basis of the above, Pilot GNDs is categorized as shown in *Table 6.11*.

Table 6.11 Human Resources Requirement of Each Facility Plan of Pilot GNDs

Type	1	2	3	4	5
Name of GND	Tammennawewa	Badalkumbura Sevanagala	Bodagama Yalabowa Vitarandeniya Talunna Ranna West	Hambegamuwa Hulandawa Left Unawatuna Pahala Mattala	Non

This proposal is only general; therefore, it is recommended that after finishing feasibility study, NWSDB, committee and user itself hold substantial discussions from primary planning stage and determine proper facility plan and achievable management, operation and maintenance plan through discussion.

6.7.2 Proposed Plan for Operation and Maintenance of Drilling Machines to be Donated

Drilling machines used in this Study are recommended to be utilized for the further groundwater study in the country where development of deeper fractured aquifer is required. In Sri Lanka the study of deeper fractured aquifer has not been conducted yet except in this Study.

It is an area which needs study in a large number of sites, such as eastern area of Monaragala, Kurunegala, and Matara and so on.

Although there are no remarkable problems of WRB's management, operation and maintenance systems for drilling machines and equipment, the following is recommended for improving effective drilling activity, as became apparent through this Study.

Although minor repair can be done by drilling staff themselves in the regional office, major repair is impossible. In addition, neither WRB nor regional office have a mobile workshop-like container car; hence, they cannot repair at site except for minor repairs, and they have to come back all the way to the office for major repairing. To introduce the mobile workshop is recommended for efficient work.

6.8 ORGANIZATION, INSTITUTION AND HUMAN RESOURCES DEVELOPMENT PLAN

Although organization, institution and human resources related to groundwater development have no significant problem at present, the following is proposed as the items to be strengthened and improved.

6.8.1 STRENGTHENING OF WRB DRILLING DIVISION

(1) New Establishing of Drilling Division in Monaragala

In order to conduct drilling of lower/deeper aquifer according to drilling program of groundwater development plan in the Study area, one drilling rig with necessary equipment capable of drilling to 200 m depth with 8 inches hole diameter will be needed.

WRB has their regional office in Monaragala district. Although Monaragala regional office has drilling unit, it doesn't have any own drilling rig and equipment. The office includes enough yard and storehouse space to maintain a complete set of drilling equipment. Therefore, it is recommended to organize a drilling division possessed of a complete set in Monaragala regional office to complete the program.

The necessary equipment to organize the drilling division in Monaragala for the program is listed in *Table 6.12*.

In this Study, drilling staff of Monaragala regional office conducted drilling of test wells with 200m depth. This drilling unit has sufficient technical capability and has acquired further skill to operate drilling machines through technical transfer by actual drilling works in this Study.

Table 6.12 Necessary Equipment for Monaragala Drilling Division for the Program

Item No.	Sub-Item	Description
I		DRILLING EQUIPMENT
	I.1	Drilling Rig and Standard Accessories Type: Top head drive type applicable for mud rotary and DTH hammer drilling Specification: Truck mounted type, 6 X 6 all wheels drive, with the drilling capacity of 200 m depth with 4-3/4" drill pipe, or the Truck mounted type, 4 X 4 all wheels drive, with the drilling capacity 200 m depth with 4-1/2" drill pipe.
	I.2	Drilling Tools Consisting of: General tools, Tools for Down-The-Hole-Hammer (DTH) Drilling, Tools for direct mud circulation drilling, Casing Tools, Air Lifting Tools, Miscellaneous Tools, Tools for drilling works.
	I.3	High Pressure Air Compressor Type: Truck mounted type, 4 X 4 all wheels drive, 900 CFM with 20.5 Kgf/cm^2 operating pressure.
	I.4	Hydro Fracturing Equipment Type: Truck mounted type, 4 X 4 all wheels drive, Specification: 3,600 kg winch pulling capacity, 245 l/min. at 190 kg/cm^2 high pressure pump, 700 kg/cm^2 working pressure of packer hose reel.
II		SUPPORTING VEHICLES
	II.1	Cargo Truck with Six-ton Cab Back Crane with Long Body Type: 6 X 6 all wheels drive, 6 m (inside) length cargo, with 6 ton crane.
	II.2	2.2 Cargo Truck with Three-ton Cab Back Crane with Long Body Type: 4 X 4 all wheels drive, 4 m (inside) length cargo, with 3 ton crane.
	II.3	Water Tank lorry Type: 4 X 4 all wheels drive, SPHC water tank, 8,000 liters capacity.
	II.4	Station wagon type light vehicle
	II.5	Pick up type light vehicle
III		BOREHOLE TESTING EQUIPMENT
	III.1	Borehole Logging Instrument Measuring Items: Normal receptivity, Spontaneous potential (SP), Natural gamma, temperature (intervals, min. 5 cm, measuring depth, max. 200 m)
	III.2	Pumping Test Equipment • Submersible motor pumps of 200 l/min × 150mTDH and 500 l/min × 80mTDH. • Generator for submersible pump, 30 KVA, 400 V/50 Hz • Water level detector
IV		MAINTENANCE EQUIPMENT AND FACILITY Equipment for workshop: Engine welding machine and equipment, Hand tools kit, Test and Inspection tools kit, Power tools kit, Hydraulic ram and pump kit, Lubricating kit, Electric & Air supply kit, Engine service kit、Chassis service kit, container type workshop facility
V		FACILITY FOR THE CONSTRUCTION SITE
	V.1	Camping trailer and equipment
	V.2	Submersible pump for the production wells

(2) Appropriate Budget Allocation for Maintenance & Repairs of Drilling Machines

Haploid number of drilling machines that WRB possesses is malfunction condition at present. As for drilling rigs, WRB has 14 rigs and most of them has used from the beginning of 1980's. Presently, seven rigs are malfunction condition and four rigs of them have been under malfunction condition for more than five years.

Most malfunctioned drilling rigs have many broken parts to need replacement, mainly hydraulic pump. For complete repair, it cost Rs.1.5 to 2 million per one drilling rig. Work Shop of WRB has enough technical capabilities to repair them, however, it is difficult to get necessary spare parts for repairing. Although an agency of the rig company exists in Sri Lanka and route to get the spare parts is secured, finance is not enough to procure them.

Actual budget of WRB in 2000 for maintenance and repairs of machinery is around Rs.4.6 million. Among that, the expenditure for new spare parts is around Rs.2 million. It is for not only drilling rig but also other machine such as air compressor, water tank, etc.

In 2000, 160 tube wells with average 40m-60m depths were constructed. However, this 160 is far less than 500, which is annual demand for the tube well drilling to WRB. It is due to not only shortage of fund of both of central and local government to request the construction of tube well to the WRB but also shortage of budget of WRB for maintenance and repairs.

For effective drilling activity using existing machines and equipments to satisfy the annual demand to WRB, it is recommended to increase budget allocation for maintenance and repairs of drilling machines.

6.8.2 CAPACITY BUILDING OF PRADESHIYA SABHA

Pradeshiya Sabha has a responsibility to not only managing the water supply scheme which are directly operated and maintained by PS but also assisting and providing backup support to the CBOs managing water supply schemes within PS area. Therefore, capacity building of PS is absolutely essential for stable and sustainable management operation, maintenance and management of rural water supply schemes.

At present, PS is in a more weakened state among the organizations managing water supply schemes judging from site visits and comparison with other organizations. It is mainly due to deficiency of technical capability of PS staffs, such as technical officer or mechanics, therefore, training program to them should be conducted.

It is proposed that the training program according to the following concept;

- Suitable training curriculum depending on target person
  e.g. Technical officer: Management, O&M planning, overall monitoring, etc.
  Mechanics: O&M activity, monitoring, etc.

- Adequate training period depending on target person

- Proper and sufficient training staff depending on target person and training program

NWSDB is sequentially conducting training program to PS taken along the above-mentioned concept at present; therefore, it is recommended that NWSDB continues and proceeds with this plan further.

In addition, human resources and number of personnel are not adequate either in PS. For example, almost all of Technical Officers can't work on full time basis because they have other work, such as

road construction, environment, etc. It is one of the reasons why quality of operation and maintenance by PS come down.

If training program for PS staff will be conducted, shortage of human resources will still cause inadequate situation of capacity of operation and management.

It is necessary that measures be improved for securing human resources; for example, by improving labour conditions and/or creating an attractive work environment in the area.

6.9 EVALUATION OF GROUNDWATER RESOURCES DEVELOPMENT PLAN

6.9.1 GENERAL

The proposed groundwater development plan for pilot GNDs was evaluated from the aspects listed below. The overall evaluation of the development plan is made by integrating all the aspects of the evaluation.

(1) Socio-economic Aspect

Social effects of the plan to each pilot GND were discussed qualitatively. Economic benefits were qualitatively evaluated in connection with decrease of water-born diseases, release from water drawing labor, and so on expected benefits from clean water supply.

(2) Financial Aspect

Financial aspects were discussed by focussing on possible financial sources of the groundwater development. Financial analysis was carried out to determine tariff level that will cover operation costs.

(3) Environment

Problems due to excessive pumping, such as land subsidence and seawater intrusion, were discussed in the evaluation of the groundwater development potential. Environmental evaluation mainly focuses on potential effects of decline of groundwater level on the vegetation and agriculture in surrounding areas.

6.9.2 SOCIO-ECONOMIC ASPECT

Basically, a water supply project in a rural area will bear extensive benefits which will normally be evaluated not only by the quantitative factors, but also by various qualitative factors. In this section, therefore, the following qualitatively factors are evaluated as the socio-economic benefits of the project.

(1) Remedy Social Inequality

The lack of availability of existing water source restricts the improvement of the water supply system under present operation of NWSDB. In the Study area, 84% of population in Monaragala, and 77% of population of Hambantota are living in areas where water supply improvement plans were precluded. From this point of view, it can be judged that social inequality is generated by the lack of availability of existing water source.

Development of groundwater, therefore, has significant merit to remedy the social inequality by providing safe drinking water to such unserved inhabitants in the pilot GNDs.

(2) Mitigation of Labor to Obtain Water

Labor to obtain water is heavy physical labor; therefore it will considerably impact the socio-economic activities of the rural inhabitants. The distances to the present water sources at each pilot GND were obtained by the result of questionnaire survey. The time differences between the present water source and development plan that is Level 3 (direct connection) and Level 2 (yard tap) are estimated. The Study assumes such differences are indices of socio-economic impact.

For the calculation of estimated time to draw water, an average rate of 50 m a minute was adopted to obtain the travel time. In case of present water sources and Level 2, 15 and 5 minutes to draw water at site were added. Estimated time to draw water in case of Level 3 (direct connection) was assumed as nil.

Under the above assumptions, socio-economic impact of labor to obtain water is examined as shown in *Table 6.13*.

Table 6.13 Socio-economic Impacts by the Time to Obtain Water

GND	Distance[1] to the present water source RT (m)	Estimated time to draw water			**Socio-economic Impact**	
		to the present water source[2] (average) (min)	in case of Level 3 (D.C) (assumption) (min)	in case of Level 2 (Y.T)[3] (average) (min)	Time difference between the present water source and:	
					Level 3 (D.C) (min)	Level 2 (Y.T) (min)
MONARAGALA						
Hambegamuwa	176	19	0	14	**19**	**5**
Bodagama	298	21	0	14	**21**	**7**
Hulandawa	392	23	0	14	**23**	**9**
Unawatuna	84	17	0	14	**17**	**3**
Yalabowa	148	18	0	14	**18**	**4**
Badalkumbura	514	25	0	14	**25**	**11**
Sevanagala	426	24	0	14	**24**	**10**
HAMBANTOTA						
Keliyapura	600	27	0	19	**27**	**8**
Vitarandeniya	1234	40	0	19	**40**	**21**
Talunna	1160	38	0	19	**38**	**19**
Wediwewa	3546	86	0	19	**86**	**67**
Tammennawewa	658	28	0	19	**28**	**9**
Pahala Mattala	690	29	0	19	**29**	**10**
Siyambalagaswila	918	33	0	19	**33**	**14**
Ranna West	120	17	0	19	**17**	**-2**

[1] Results of questionaire survey

[2] Estimated by the average rate of 50 m/min plus 15 minutes to draw water from present water source site.

[3] Estimated by the average rate of 50 m/min plus 5 minutes to draw water at a stand post.

The results suggest that there are significant impacts to mitigate the labor in case of the Level 3 plan. The range of time difference between the present water source and the plan shows 17 to 86 minutes. Considerable impacts are observed even in Level 2 plan. The range of time difference between the present water source and the plan shows 3 to 67 minutes, except the GND Ranna.

It is therefore, concluded that the development plan will contribute a big socio-economic benefit to the inhabitants by the mitigation of the labor to obtain water.

(3) Health Care

In the Hanbantota and Monaragala districts, there are actual and substantive problems in the health sector. The Study area shows a high water-borne disease rate (See, *Table 6.14*). As indicated by annual health bulletin 2000, especially in Monaragala district, water-borne diseases of “Typhoid Fever”, “Malaria” and “Shigellosis” are considerably higher than the country average. In

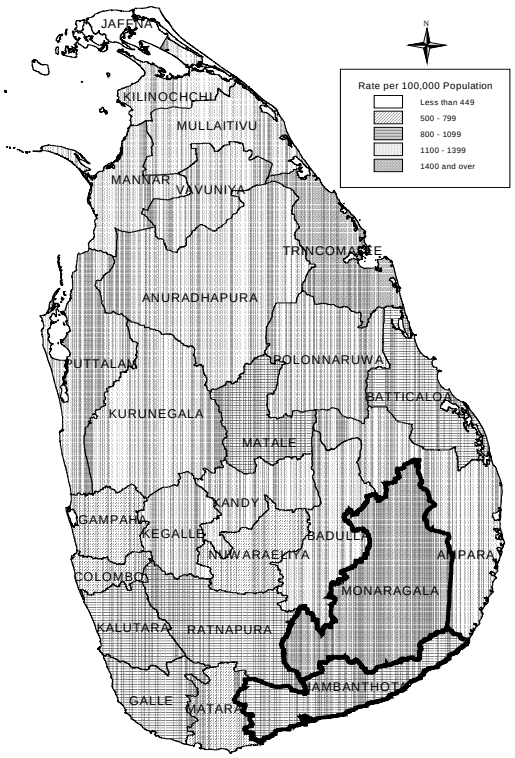
Hambantota, the ratio of Typhoid Fever is relatively low; however, "Malaria" and "Shigellosis" shows higher ratios than the national average or Colombo.

Table 6.14 Distribution of Water-Bone Diseases rate per 100,000 population (number of cases per district, 2000)

District	Typhoid Fever	Malaria	Shigellosis
Hambantota	13.1	199.5	**68.7**
Monaragala	**149.2**	**311.8**	**143.9**
Colombo	29.0	50.5	45.6
National Average	45.7	314.2	55.2

Source: Medical Statistical Unit, Department of Health Services 2000

According to the Health Bulleting 1998, Monaragala district was ranked as having the highest incidence of diarrhoeal disease: more than 1,400 cases rate per 100,000 persons (See, *Figure 6.32*). Hambantota shows a better ratio, but still relatively higher than the national level. The national programme for the control of diarrhoeal diseases, especially water born diarrhoeas is mainly managed with the use of intravenous fluid therapy for dehydration. As a result, although the mortality rate due to the diarrhoeal diseases has come down dramatically, the morbidity rate has not decreased comparably (MOH 1998). This fact reveals that there is a limit to eradicating diarrhoeal diseases by medical practice. Social environmental factors, especially in rural areas play a major role in keeping the morbidity rate high.



Source: Annual Health Bulleting, Ministry of Health (1988)

Figure 6.32 Distribution of Cases of Diarrhoeal Diseases by District 1998

Therefore, the contribution to health of safe water supply by the groundwater development is estimated to be large for the both Monaragala and Hambantota districts.

(4) Other Benefits

The other benefits related to the socio-economic aspect are: 1) improvement of living standard, 2) stabilization of the people's livelihood in rural area, 3) contribution to tourism promotion and 4) hiking land value.

6.9.3 FINANCIAL ASPECT

Financial aspects are discussed by assuming that NWSDB's tariff level is applied to the proposed development plan.

(1) Income Level

Table 6.15 shows the mean household income per month by sector (1995/1996) and average monthly water tariff in both Level 3 (house connection system) and Level 2 (yard tap) water supply system.

Table 6.15 Mean Household Income per Month by Sector 1995/96 and Average Monthly Water Tariff

Sector	Mean Income	House Connection		Yard tap	
		Average Monthly Water Tariff	Ratio of Water Tariff to Mean Income	Average Monthly Water Tariff	Ratio of Water Tariff to Mean Income
	Rs.	Rs.	%	Rs.	%
All Island*	6476	154.27	2.4	-	-
Urban	11240	196.42 [1)]	1.7	-	-
Rural	5852	113.02 [2)]	1.9	-	-
Estate	4059	-	-	-	-
Uva Province	3888	-	-	-	-
Monaragala District	**4231**	**108** [4)]	**2.6**	**30** [3)]	**0.7**
Southern Province	5540	-	-	-	-
Hambantota District	**4397**	**108** [4)]	**2.5**	**50** [5)]	**1.1**

Source: Household Income and Expenditure Survey 1995/1996, Department of Census and Statistics, Ministry of Finance and Planning
Annual Report 2000, NWSDB

1) Value of "Greater Colombo" in Annual Report 2000, NWSDB
2) Value of "Regions" of Annual Report 2000, NWSDB
3) Data Source: Hearing from NWSDB District Manager's office in Monaragala
4) Data Source: Hearing from NWSDB Regional Manager's office in Hambantota
5) CBO, namely Small Fisherman's Organization, of the Village near Tammennawewa in Hambantota

According to the *Table 6.15*, in Monaragala district, the ratio of water tariff to mean income of the house connection water supply system is 2.6%, and that for the yard tap system is 0.7%. In Hambantota, the ratio of water tariff to mean income of the house connection water supply system is 2.5%, and that for the yard tap system is 1.1%.

(2) Affordability of Pilot GNDs

Using the actual average monthly water tariffs of Hambantota and Monaragala in *Table 6.15*, ratio of water tariff to mean income of both level 3 and 2 are estimated for the Pilot GNDs as shown as *Table 6.16*. In all the GNDs except Talunna in Hanbantota, the ratios for Level 3 exceed 2.5%, which is considered the maximum affordable level due to the lower income level; thus indicating Level 3 service not affordable in those GNDs. Moreover, high ratios of Level 2 suggest that even Level 2 is not affordable in some GNDs.

Table 6.16 Estimated Ratio of Water Tariff to Mean Income

GN Division Name	Average Income* (Rs.)	Level 3 (House Connection)		Level 2 (Yard Tap)	
		Average Monthly Water Tariff	Ratio of Water Tariff to Mean Income	Average Monthly Water Tariff	Ratio of Water Tariff to Mean Income
Monaragala					
Hambegamuwa	2179	108	5.0%	30	1.4%
Bodagama	2840	108	3.8%	30	1.1%
Hulandawa Left	2267	108	4.8%	30	1.3%
Unawatuna	1711	108	6.3%	30	1.8%
Yalabowa	2533	108	4.3%	30	1.2%
Badalkumbura	3733	108	2.9%	30	0.8%
Sevanagala	1769	108	6.1%	30	1.7%
Hambantota					
Keliyapura	2733	108	4.0%	50	1.8%
Vitarandeniya	4200	108	2.6%	50	1.2%
Talunna	5200	108	**2.1%**	50	**1.0%**
Wediwewa	2733	108	4.0%	50	1.8%
Tammennawewa	3414	108	3.2%	50	1.5%
Pahala Mattala	3400	108	3.2%	50	1.5%
Siyambalagasvila	2400	108	4.5%	50	2.1%
Ranna West	3629	108	3.0%	50	1.4%

*: Result of questionnaire survey

On the other hand, most World Bank's projects recommend to make a tariff of water supply and sanitation services in rural development less than 4% of a monthly household income in consideration of affordability. Therefore, it is suggested that the ratios of water tariff to mean income presented in section 1) (2.5 to 2.6%) are regarded as affordable level because Development Plan proposed covers water supply service only.

(3) Willingness to Pay

Willingness to pay for the water supply system was analysed by questionnaire survey. The self-financing possibility of the development plan is also reviewed by the willingness to pay. *Table 6.17* shows the possible coverage rate of water supply system level determined by the willingness of the inhabitants to pay.

Table 6.17 Possible Coverage Rate by the Willingness to Pay

GND	Average monthly triff		Range of willingness to pay for the water triff (%)						Possible coverage rate by the willingness to pay			Development Plan	
	Level 3 D.C. (Rs.)	Level 2 Y.T. (Rs.)	less than 20Rs.	between 21-40Rs.	between 41-80Rs.	between 81-120Rs.	more than 121Rs	Average (Rs.)	low ability (%)	Level 2 Y.T. (%)	Level 3 D.C. (%)	Level 2 Y.T. (%)	Level 3 D.C. (%)
MONARAGALA													
Hambegamuwa	108	30	41	33	21	5	0	32	**41**	**59**	**5**	100	0
Bodagama	108	30	100	0	0	0	0	7	**100**	**0**	**0**	45	55
Hulandawa	108	30	13	10	23	31	23	91	**13**	**87**	**54**	100	0
Unawatuna	108	30	93	7	0	0	0	8	**93**	**7**	**0**	100	0
Yalabowa	108	30	17	80	3	0	0	29	**17**	**83**	**0**	10	90
Badalkumbura	108	30	60	10	10	10	10	47	**60**	**40**	**20**	10	90
Sevanagala	108	30	68	22	10	0	0	20	**68**	**32**	**0**	100	0
		Average	**56**	**23**	**10**	**7**	**5**	**33**	**56**	**44**	**11**		
HAMBANTOTA													
Keliyapura	108	50	7	21	14	37	21	91	**28**	**72**	**58**	0	100
Vitarandeniya	108	50	14	14	29	43	0	66	**28**	**72**	**43**	35	65
Talunna	108	50	0	0	5	37	58	154	**0**	**100**	**95**	10	90
Wediwewa	108	50	3	33	20	34	10	74	**36**	**64**	**44**	20	80
Tammennawewa	108	50	8	18	48	11	15	76	**26**	**74**	**26**	0	100
Pahala Mattala	108	50	20	60	10	10	0	37	**80**	**20**	**10**	20	80
Siyambalagaswila	108	50	64	5	0	21	10	52	**69**	**31**	**31**	0	100
Ranna West	108	50	51	29	17	0	3	30	**80**	**20**	**3**	84	16
		Average	**21**	**23**	**18**	**24**	**15**	**73**	**43**	**57**	**39**		

According to the table, the willingness to pay that meets the development plan is only in Talunna of Hambantota district. This has been expected from its affordability as discussed above. On the other hand, it should be mentioned that in other GNDs, which seem not-affordable from their low income levels, some portion of the population that can afford it revealed the willingness to pay for the development plan.

The average water tariffs of existing water supply system of level 2 are 30 Rs in Monaragala, 50 Rs in Hambantota district. An average water tariff of existing water supply system of level 3 is 108 Rs in both districts.

In Monaragala district, average amount of willingness to pay is 33 Rs that over the average water tariffs of existing water supply system of level 2. Additionally, 11% of population has the willingness to pay for level 3. In Hambantota district, average amount of willingness to pay is 73 Rs that over the average water tariffs of existing water supply system of level 2. Additionally, 39% of population has the willingness to pay for level 3.

The result suggests that there is willingness to pay that afford at least water tariff of level 2 plan, although their income level is low. Furthermore, considerable portion of the population revealed the willingness to pay that afford the level 3 plan.

6.9.4 ENVIRONMENT ASPECT

According to IEE (Initial Environmental Examination) procedure guidelines from JICA, groundwater resources development plans for 15 pilot GNDs are to be evaluated from viewpoint of environmental considerations. This section presents the conclusion of IEE. Details of IEE are mentioned in Supporting Chapter 9 of the Supporting Report.

(1) Characteristics of the Development Plans and Project Areas

The groundwater resources development plans for 15 pilot GNDs in this Study are formulated as conceptual master plans. The plans prescribe the water supply level, coverage rate, required number of wells, and conceptual diagram of required water supply facilities for 12 pilot GNDs (excluding Keliyapura, Wediwewa and Siyambalagaswila North).

The characteristics of the groundwater resources development plans and its project area is shown in *Table 6.18*.

Table 6.18 Characteristics of the Groundwater Resources Development Plans and its Project Area (15 pilot GNDs)

	Groundwater Resources Development Plan						Net Population density [4] (person/ha)	Number of existing tube well	Groundwater quality
	Level 1 (hand pump)	Level 2 (yard tap)	Level 3 (direct connection)	Amount of water supply m^3/day	Number of production wells	Required purification facilities			
Hambegamuwa (M-1)	0%	100%	0%	174	3	No required	4.8	11	good [5]
Bodagama (M-2)	0%	45%	55%	316	1	RO [1]	4.5	13	inappropriate [6]
Hulandawa Left (M-3)	0%	100%	0%	182	3	No required	7.0	0	good [5]
Unawatuna (M-4)	0%	100%	0%	148	2	No required	7.0	0	good [5]
Yalabowa (M-5)	0%	10%	90%	313	1	Alkalinity [2]	5.3	0	treatment [6]
Badalkumbura (M-6)	0%	10%	90%	178	1	Deferrization	28.2	0	treatment [6]
Sevanagala (M-7)	0%	100%	0%	174	3	H-Metal [3]	3.6	8	treatment [6]
Keliyapura (H-1)	No proposed scheme in this Study.						2.9	0	inappropriate [6]
Vitarandeniya (H-2)	0%	35%	65%	36	1	No required	1.5	12	fair [5]
Talunna (H-3)	0%	10%	90%	206	1	Softening	3.7	0	treatment [6]
Wediwewa (H-4)	No proposed scheme in this Study.						35.6	5	inappropriate [6]
Tammennawewa (H-5)	0%	0%	100%	225	1	RO [1]	7.8	1	inappropriate [6]
Pahala Mattala (H-6)	0%	20%	80%	76	1	No required	8.1	17	good [6]
Siyambalagaswila N. (H-7)	No proposed scheme in this Study.						14.4	1	inappropriate [6]
Ranna West (H-8)	0%	84%	16%	71	1	No required	8.8	0	fair [5]

1) RO: Reverse osmosis

2) Alkalinity: Removal of total alkalinity

3) H-metal: Removal of heavy metals

4) Net population density: divide population by build up and homestead area

5) Based on the hydrogeological map, this is estimated by EC value as below.

good : less than 750 micro-S/cm as EC

fair : from 750 to 3,500 micro-S/cm as EC

6) According to the results of groundwater quality analysis, this groundwater quality is evaluated.

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1) Water supply systems

Proposed water supply systems are mainly the combination system of level 2 (yard tap) and level 3 (direct connection). Amount of water supply is the range of 36 to 316 m3/day. From such amount, the plans can be categorised as small-scale rural water supply systems. Three GNDs (Keliyapura, Wediwewa and Siyambalagaswila North) have no proposed water supply system by groundwater development.

2) Components of water supply facilities

The conceptual diagram of these water supply systems consists of intake, water treatment, transmission, elevated tank and distribution facilities, which do not cause significant environmental impact.

3) Population density

Net population density of 13 pilot GNDs range from 1.5 to 28 persons/ha with average 7 persons/ha. This low population density will make it easy to acquire a project site for water supply system without resettlement, loss of production base or change of economic structure.

4) Existing tube wells

Number of existing tube wells in 13 pilot GNDs ranges from 0 to 17. Therefore, establishment of monitoring system must include the existing wells.

5) Groundwater quality

According to the results of groundwater quality analysis of test wells, two wells satisfy the criteria for drinking water without treatment out of the 12 test wells.

(2) Initial Environmental Examination (IEE)

The potential environmental impacts by the project implementation are evaluated from 23 viewpoints covering social, natural and pollution aspects.

No practical difference in the evaluation of potential environmental impacts of the each GNDs was found, because the actual project sites for the facilities in GNDs have not been declared by the Study. Concerning land acquisition, it is not difficult to acquire project site without any potential environmental impact from viewpoint of the low net population density.

From the above evaluation of conditions, the potential environmental impacts in the all pilot GNDs by the project implementation are identified and evaluated by IEE (See, *Table 6.19*). The results of the IEE are summarised below.

- Environmental Impact Assessment (EIA) for these plans will be not required.
- Basically, the implementation of the plans will not cause significant negative impact to environment in the area. The groundwater problems caused by the decline of the groundwater level due to overdraft pumping operation will rarely occur.
- However, proposed groundwater monitoring plan for groundwater level and groundwater quality will help avoid groundwater problems.
- Detailed field survey is required to obtain information of determined construction site and its surrounding conditions.
- Detailed field survey is required to prepare proper operation programs for proper yield of production well and for water quality management of supplied water.

Table 6.19 Identification of Potential Environmental Impacts and Overall Evaluation

Identification of Potential Environmental Impacts						Overall Evaluation	
Environmental Items			Construction stage	Operation stage	Remarks (Reason)	Evaluation	Additional Survey and Study for Next Planning Stage
Social Environment	1	**Resettlement**	**P**	**-**	Potentially expected for the sites of production well, treatment facilities and reservoir tank / elevated Tank.	**C**	Detail field survey for planning site
	2	**Economic Activities**	**P**	**-**	Potentially expected. The same reason with '1-Resettlement'	**C**	Detail field survey for planning site
	3	**Traffic and Public Facilities**	**E**	**-**	Expected. The construction vehicles and machinery can affect traffic on the local roads.	**C**	Traffic survey and detail field survey for planning site
	4	**Division of Communities**	**-**	**-**	Not expected.	**N**	
	5	**Historical or cultural site**	**P**	**-**	Potentially expected. The same reason with '1-Resettlement'	**C**	Detail field survey for planning site
	6	**Water Rights and Rights of Common**	**-**	**-**	Not expected.	**N**	
	7	**Public Health Condition**	**-**	**P**	Potentially expected. Water-bone disease might be caused by supplied water. Potentially expected. Stagnation of wastewater from stand post.	**C**	Enforcement of monitoring (groundwater quality) Detail field survey for planning site (stand post)
	8	**Waste**	**-**	**E**	Expected. Chemical sludge and liquid waste are generated from purification facilities, if purification method of RO, removal of heavy metals and deferrization with coagulation are introduced.	**C**	Preparation of sludge and liquid waste disposal scheme. (Subject GNDs: Bodagama (M-2), Badalkumbura (M-6), Sevanagala (M-7) and Tammennawewa (H-5))
	9	**Risk of disaster**	**-**	**-**	Not expected.	**N**	
Natural Environment	10	**Topography and Geology**	**-**	**-**	Not expected.	**N**	
	11	**Soil Erosion**	**P**	**-**	Potentially expected for the construction sites of transmission pipe and other facilities.	**N**	
	12	**Groundwater**	**-**	**P**	Potentially expected.	**C**	Enforcement of monitoring (groundwater table)
	13	**Hydrological Situation**	**-**	**-**	Not expected.	**N**	
	14	**Coastal Zone**	**-**	**-**	Not expected.	**N**	
	15	**Fauna and Flora**	**P**	**-**	Potentially expected for the construction sites of well/pump facilities, reservoir tank and transmission pipe.	**C**	Detail field survey for planning site
	16	**Meteorology**	**-**	**-**	Not expected.	**N**	
	17	**Landscape**	**-**	**-**	Not expected.	**N**	
Pollution	18	**Air Pollution**	**-**	**-**	Not expected.	**N**	
	19	**Water Pollution**	**-**	**-**	Not expected.	**N**	
	20	**Soil Contamination**	**-**	**-**	Not expected.	**N**	
	21	**Noise and Vibration**	**E**	**-**	Expected mainly during construction works	**C**	Detail field survey for construction site
	22	**Land Subsidence**	**-**	**P**	Potentially expected for the overdraft of groundwater.	**C**	Enforcement of monitoring (groundwater table)
	23	**Offensive Odor**	**-**	**-**	Not expected.	**N**	

Identification of Potential Environmental Impacts

E : The potential environmental impacts are **E**xpected.
P : It is not clear that potential environmental impacts are **P**otentially expected or not.
- : There are no environmental impacts.

Overall Evaluation

A : Serious impact is expected.
B : Some impact is expected.
C : Extent of impact is unknown and examination is needed.
N : No impact is expected. IEE/EIA is not necessary.

6.9.5 OVERALL EVALUATION

The results of socio-economic evaluation indicate that the development plan will contribute to economic activities and the improvement of public health conditions. As an overall evaluation, it is concluded that the development plan is an effective measure to: 1) mitigate the labor to obtain water, 2) supply the growing water demand, 3) solve health problems caused by the water born diseases and 4) cover the seasonal or annual deficit as well as future shortage of water to sustain the welfare of the people and the development of the country.

The results of environmental evaluation indicate that the implementation of the development plan will not cause significant negative impacts to the environment in the Study area. The groundwater problems caused by the decline of the groundwater level due to overdraft pumping operation will rarely occur. However, the proposed groundwater monitoring plan will help avoid groundwater problems. For the evaluation, it is concluded that the natural environment in the Study area will not be affected by the development plan. Thus, environmental impact assessment (EIA) for the development plan will not be required.

The results of financial evaluation indicate that the development plan is not necessarily affordable in GNDs other than Talunna of Hambantota judging from the ratio of water supply service charge to income. However, on the other hand, the result suggests that there is willingness to pay that afford at least water tariff of level 2 plan, although their income level is low. Furthermore, considerable portion of the population revealed the willingness to pay that afford the level 3 plan.

Overall results of the project evaluation are shown in *Table 6.20.*

Table 6.20 Overall Result of the Evaluation of the Development Plan

GND	Development Plan		Socio-economic Aspect			Financial Aspect			Environment Aspect
	Level 2 Y.T. (%)	Level 3 D.C. (%)	mitigation of labor to obtain water	growth of water demand	contribution to **health care** and others	income level to cover the average tariff	viable to maintain Level 2	viable to maintain Level 3	environmental impact
MONARAGALA									
Hambegamuwa	100	0	effective	Low	benefit	Not satisfy	59%	5%	no impact
Bodagama	45	55	effective	**High**	benefit	Not satisfy	0%	0%	no impact
Hulandawa	100	0	effective	**High**	benefit	Not satisfy	89%	54%	no impact
Unawatuna	100	0	effective	Moderate	benefit	Not satisfy	7%	0%	no impact
Yalabowa	10	90	effective	Moderate	benefit	Not satisfy	83%	0%	no impact
Badalkumbura	10	90	effective	Moderate	benefit	Not satisfy	40%	20%	no impact
Sevanagala	100	0	effective	Moderate	benefit	Not satisfy	32%	0%	no impact
HAMBANTOTA									
Keliyapura	0	100*	effective	Moderate	benefit	Not satisfy	72%	58%	no impact
Vitarandeniya	35	65	highly effective	Moderate	benefit	Not satisfy	72%	43%	no impact
Talunna	10	90	**highly effective**	Moderate	benefit	**Satisfy**	**100%**	**95%**	no impact
Wediwewa	20*	80*	**highly effective**	Moderate	benefit	Not satisfy	64%	44%	no impact
Tammennawewa	0	100	effective	Moderate	benefit	Not satisfy	74%	26%	no impact
Pahala Mattala	20	80	effective	Moderate	benefit	Not satisfy	20%	10%	no impact
Siyambalagaswila	0	100*	**highly effective**	Moderate	benefit	Not satisfy	31%	31%	no impact
Ranna West	84	16	effective	Moderate	benefit	Not satisfy	20%	3%	no impact

* by the expansion of existing water supply scheme

6.9.6 RECOMMENDATION

The development Plan proposed is found to greatly benefit the people by supplying safe water, wiping out the fear of drought and releasing people from water obtaining labour without hardly any negative impact to the environment.

On the other hand, the financial analysis indicates a concern about people's affordability of the tariff level that would be applied to receive water supply service of the development plan. At same time the people showed a higher willingness to pay compared to their income level, which may be a sign of their strong eagerness to receive water.

Considering the expected benefits and concerns above, it is recommended that to start water supply service with Level 2 and gradually convert to Level 3 in accordance with an increase of people's income level. This option may encourage the financial independence of the water supply service.

CHAPTER 7 CONCLUSION AND RECOMENDATION

7.1 CONCLUSION

"The Study of Comprehensive Groundwater Resources Development for Hambantota and Monaragala Districts in the Democratic Socialist Republic of Sri Lanka" has been completed. There are three purposes of the Study: namely, evaluation of the groundwater potential, formulation of the groundwater development plan and the technology transfer.

(1) Hydrogeology

On the basis of hydrogeological study, the fractured aquifer in the area was categorized into three parts: namely, the upper fractured aquifer, the lower fractured aquifer, and the deeper fractured aquifer. This was the first groundwater study that confirmed the occurrence of a productive aquifer below 100 m. The test well drilling confirmed the occurrence of the productive lower fractured aquifer in three test wells: No.M-2 Bodagama, No.M-3 Badalkumbura, No.M-4 Yalabowa. A productive deeper fractured aquifer was confirmed by the drilling of test well No.H-2 Talunna. Pumping test and water level fluctuation suggest that the deeper fractured aquifer is connected with the upper fracture in the area.

(2) Groundwater Evaluation

Based on the results of the hydrogeological study, two hydrogeological maps covering the Hambantota and Monaragala districts have been prepared: namely, the hydrogeological map for the upper fractured aquifer and the hydrogeological map for the lower and deeper fractured aquifer. These maps will be revised with the further accumulation of hydrogeological data. In addition, groundwater resources evaluation maps have been provided based on the hydrogeological maps to contribute to the development plan. The groundwater resources evaluation map shows promising areas for groundwater development. The promising area is fairly large in Monaragala. The coastal side of the central area in Hambantota is mostly evaluated as poor due to water quality. These maps were first prepared in Sri Lanka, and most important achievement by the Study since they serve as the basis for future groundwater development and insure the efficient use of investment of two districts.

(3) Groundwater Resources Development Plan

The promising areas for the groundwater resources development were detected by the study, through the preparing the groundwater evaluation maps. The amount of the water demand, and the area that are covered by the promising area of the groundwater development were extracted. The total demand amount covered by the promising areas in two districts was estimated as 154,165 m^3/day. This amount is the total water demand of year 2010 for 647 GNDs covering an area of 5,909 km^2. In Hambantota district, the demand amount was estimated as 65,651 m^3/day for 351 GNDs covering an area of 1,290 km^2, while Monaragala district was estimated as 88,514 m^3/day for 296 GNDs covering an area of 4,618.97 km^2.

(4) Drilling Program for the Development Plan

Drilling programs for the production wells was examined based on the groundwater development plan. A total of 468 wells for the Upper Aquifer and a total of 193 wells for the Lower/Deeper Aquifer are estimated. Since the number of production wells was estimated by the average yield of existing and test wells, the estimated number is not an absolute number. However, to cover the

demand, it is estimated that 600 to 700 wells will be required to be newly drilled in both Upper and Lower/Deeper Aquifers.

(5) Pilot Plan

Groundwater development plans for 15 pilot GNDs are proposed. Proposed water supply schemes differ with the GND, since the hydrogeological properties such as extractable yield and water quality differ in area. The combination system of level 3 (direct connection) and 2 (yard tap) is the major scheme proposed for the seven GNDs of Bodagama, Yalabowa, Badalkumbura, Talunna, Pahala Mattala and Ranna West, although the coverage ratio of level 3 and 2 vary according to the water demand and source capacity (extractable yield). Level 3 schemes are adapted to the Tammennawewa GND. Level 2 schemes are adapted to the four GNDs of Hambegamuwa, Hulandawa Left, Unawatuna and Sevanagala that the source capacity is not enough to cover the demand. For the three GNDs of Keliyapura, Wediwewa and Siyambalagasvilla, expansion of the existing scheme is recommended since the groundwater potential of both Upper and Lower/Deeper Aquifer are very low. Level 1 (hand pump) scheme is not adapted to any pilot GNDs.

(6) Evaluation of Groundwater Development Plan

The results of socio-economic evaluation of proposed development plan of 15 pilot GNDs indicate that the development plan will contribute to the economic activities and improvement of public health condition. As the overall evaluation, it is concluded that the development plan includes effective measures to: 1) mitigate the labour required to obtain water, 2) cover the growing water demand, 3) help solve the health problems caused by the water born diseases and 4) cover the seasonal or annual deficit as well as future shortage of water to sustain the welfare of the people and the development of the country.

(7) Operation and Management Plan

Concerning each proposed water supply scheme level, organizations in charge of operation, maintenance and management were proposed and personnel organization of them was also proposed. Basically, Community Based Organization is appointed as management organization. As for water supply scheme of which water supply area stretches over several GNDs, it is proposed that Pradeshiya Sabha is appointed as the management organization. In case of scheme of tube wells with hand pumps, operation and management should be conducted by Consumer Society.

In addition, personnel plan for operation and maintenance of each facility plan was proposed.

(8) Organization, Institution and Human Resources Development Plan

The following is proposed as the items to be strengthened and improved.

- To organize a drilling division possessed of a complete set of drilling machines and equipments in Monaragala regional office of WRB.
- To increase budget allocation of WRB for maintenance and repairs of drilling machines.
- To conduct training program to Pradeshiya Sabha staffs.
- To implement the measures for securing human resources of Pradeshiya Sabha.

(9) Drilling Technique Transferred

Through the study, drilling method and equipment for the deep well (depth to 200m) were first introduced in Sri Lanka. Furthermore, the necessary techniques for the deep drilling for the various types of geological formations and hole wall conditions were transferred. Considering the capacity of the organization and technical ability of the drillers in WRB, transferred technology and equipments is adequately available for the extending hydrogeological studies to the areas where deep groundwater development is required as well as groundwater development of the Study area.

7.2 RECOMMENDATION

(1) Further Hydrological Study

For the estimation of groundwater recharge, hydrological data such as rainfall, evaporation and surface water runoff is essential to verify the water balance. It is recommended therefore, to conduct further hydrological study based on the additional measurements of river discharges and rainfalls, especially in the upstream basin of discharge measurement point. It is also recommended to measure the hydrological data in small catchments with land use of forest and agriculture. These data will help for the understanding of the groundwater potential in a sustainable manner of the development.

(2) Further Hydrogeological Study

In the Study, 5 of 10 test wells yielded more than 400 litre/min and two other test wells yielded from 85 to 100 litre/min. These are high productive results compared with the data in the past. The locations of test wells were selected based on the geological study, especially geophysical survey. Because fractured aquifer in hard rock is unevenly distributed even in the promising area, geophysical survey is essential to select a well location. The relation between geological structure and groundwater also helps to decide the geophysical survey line. The hydrogeological map will be revised when these data collected in the future.

(3) Priority Area for the Future Groundwater Study

The result of groundwater evaluation shows the central area of Monalagara, namely Buttala and its surroundings, has a good potential for groundwater development. There are mountainous highlands with lots of rainfall to the northwest of the area and large geological structure lines run from northwest to southeast in the area. Analysis using GIS made known that geological lineaments with the direction have superiority of groundwater yield. While not so many tube wells have been drilled, this is a considerable area to be given priority for the future groundwater study of the Lower/Deeper aquifer.

(4) Drilling of Wells with the Depth of more than 70 metres

As part of the above study, it is recommended to drill more test and production wells to explore the lower and deeper fractured aquifer below 70 m. The JICA Study proved the practicability to obtain water with the volume of hundreds litres per minute or more from an aquifer below 70 m in some areas. This amount is both quantitatively and economically sufficient to be exploited for regional water supply use. The study area, however, has been studded with only nine test wells drilled to deeper aquifer at the present. The further drilling of wells with the depth of more than 70 m is valuable for planning a development. It will provide the additional hydrogeological information in the area and confirm the feasibility of the future development. The appropriate drilling sites shall be determined as described in the next section.

(5) Determination of the Drilling site

On the implementation stage of the development plan, to determine the promising drilling sites, it is recommended that a geophysical survey will be carried out by the following procedure.

- Preliminary geological study shall be conducted to decide effectively the number and location of survey stations and survey lines in a target area. It will pay attention especially to geological structure such as lineaments.

- A main survey line is set to be orthogonal to geological structure extracted by the preliminary geological study. In addition the setting of some other survey lines, especially grid survey lines, is preferable to analyse more accurately. Besides, an interval between survey stations is 50 to 100 m.

- A well location shall be selected in the areas showing low resistivity anomalies by the result of geophysical survey. The areas with the resistivity of less than 400 ohm-m are recommended as a drilling point of a production well in Monaragala, while the areas with the resistivity between 100 to 400 ohm-m are recommendable in Hambantota.

(6) Drilling Program

The following drilling programs are recommended:

- For the Upper Aquifer, two rigs owned by WRB or NWSDB are proposed to assign for the program. Approximately 7.8 years period will be required for drilling a total of 468 wells for the Upper Aquifer. The proposed candidate areas of Bibule- Madula Brock, Monaragala-Syyambanduwa Block, Thanamalwila Sub-block and Katumana-Weeraketiya Sub-block are the major recommended areas to assign the rigs.

- For the Lower/Deeper Aquifer, one drilling rig with necessary equipment capable of drilling to 200 m depth with 8 inches hole diameter is proposed to assign for the program. Approximately 7.5 years period will be required for drilling a total of 193 wells for the Lower/Deeper Aquifer. The proposed candidate areas of Badalkumbura-Wellawaya Brock and Wellawaya-Lunugamwera Block are the recommended areas to assign the rig.

(7) Water Supply Plans for Unpromising Areas

Promising areas for the groundwater development are identified by the groundwater evaluation, accordingly groundwater development plan was made. On the other hand, the areas other than promising areas could be categorized as low potential areas for the groundwater development. In such areas, water supply shall be planned in combination with the surface water and groundwater. In central to northern part of Monaragala low potential areas due to low yield are distributed. In these areas, conventional groundwater development by hand pump wells or the surface water development are the manners left.

In southern part of Monaragala and most of area of Hambantota, low potential areas due to inadequate water quality are widely distributed. The combination with expansion of existing scheme and surface water development is the recommendable manner for these areas. For Hambantota district, Walawe Ganga would have potential resources to supply the area where the groundwater potential is low. A groundwater development block of “Badalkumbura-Wellawaya Block” situated in western part of Monaragala where highest groundwater yield is confirmed would have potential resources to the Hambantota district, though it will require feasibility study.

However, the groundwater development is not absolutely impossible for such low groundwater development potential areas. The groundwater evaluation maps were prepared on the basis of limited regional data; thus it is anticipated that the extractable groundwater yield will vary from place to place. However, even in such areas, groundwater development would be required due to social factors. In such cases, careful geological and geophysical investigation is required to select the location of wells.Promising areas for the groundwater development are identified by the groundwater evaluation, accordingly groundwater development plan was made. On the other hand, the areas other than promising areas could be categorized as low potential areas for the groundwater development. In such areas, water supply shall be planned in combination with the surface water and groundwater. In central to northern part of Monaragala low potential areas due to low yield are distributed. In these areas, conventional groundwater development by hand pump wells or the surface water development are the manners left

(8) Implementation of the Plan

Considering the expected socio-economic benefits, it is recommended that to start the water supply service with Level 2 and gradually convert to Level 3 in accordance with an increase of people's income level. This option may encourage the financial independence of the water supply service.

(9) Operation, Maintenance and Management

The operation and maintenance plan proposed by the Study is a fundamental principle; therefore, it is recommended that after finishing the feasibility study, NWSDB, committee and users will discuss from the primary planning stage and determine the proper facility plan and achievable management, operation and maintenance plan.

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